Fish fauna of the lower course of the Parnaíba river, northeastern Brazil

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RESUMO: **(Ictiofauna do baixo curso do rio Parnaíba, nordeste do Brasil).** A ictiofauna do baixo curso do rio Parnaíba foi investigada através de coletas periódicas. Trinta e duas amostragens georeferenciadas foram realizadas: 11 no curso principal do rio Parnaíba, duas no rio Poti, 14 no rio Longá, duas no rio Piracuruca e três no rio Igaraçu. As amostragens foram realizadas durante os anos de 2012 a 2014 com o uso de rede de arrasto, tarrafa, rede de emalhar e puçá, capturando-se 2.732 espécimes pertencentes a 65 espécies distribuídas em 24 famílias e 11 ordens. O estudo demonstrou grande similaridade ictiofaunística entre o baixo rio Parnaíba e a Bacia Amazônica. Uma espécie não descrita, três endêmicas e uma introduzida foram registradas na área de estudo. As ordens predominantes foram Characiformes (34 espécies), Siluriformes (13) e Cichliformes (7). Characidae foi a família com maior número de espécies (18), seguida de Cichlidae (7) e Loricariidae (7). Oito espécies tiveram grande abundância e representaram 62,7% do material coletado (*Astyanax lacustris, Curimatella immaculata, Hemigrammus rodwayi*, *Hyphessobrycon* sp., *Jupiaba polylepis*, *Psellogrammus kennedyi*, *Serrapinnus piaba* e *Tetragonopterus argenteus*). *Astyanax lacustris* e *Hemigrammus rodwayi* tiveram sua área de distribuição conhecida ampliada para bacia do rio Parnaíba. Foram registradas cinco espécies de ambiente estuarino: *Anchovia surinamensis*, *Anchoviella guianensis*, *Awaous tajasica*, *Lycengraulis batesii* e *Microphis lineatus*.

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Palavras-chave: Região Neotropical**,** ictiofauna, Região Hidrográfica Maranhão-Piauí, taxonomia, distribuição geográfica.

ABSTRACT: The fish fauna of the lower Parnaíba river was investigated through periodic sampling. Thirty-two geo-referenced samples were performed: 11 in the main course of Parnaíba river, two in the Poti river, 14 in the Longá river, three in Igaraçu river, and two in Piracuruca river. Sampling was performed during the years 2012 to 2014, using beach seine, cast net, gillnet, and hand net, resulting in 2,732 captured specimens belonging to 65 species in 24 families and 11 orders. The study demonstrated great ichthyofaunistic similarity between the lower Parnaíba and the Amazon basin. One undescribed, three endemic, and one introduced species were recorded in the area. The predominant orders were Characiformes (34 species), Siluriformes (13), and Cichliformes (7). Characidae was the family with the greatest number of species (15), followed by Cichlidae (7), and Loricariidae (6). Eight species had high abundance and represented 62.7% of captured specimens (*Astyanax lacustris, Curimatella immaculata, Hemigrammus rodwayi*, *Hyphessobrycon* sp, *Jupiaba polylepis*, *Psellogrammus kennedyi*, *Serrapinnus piaba*, and *Tetragonopterus argenteus*). *Astyanax lacustris* and *Hemigrammus rodwayi* had their known geographic ranges expanded to the Parnaíba river. We report five species from estuarine environments: *Anchovia surinamensis*, *Anchoviella guianensis*, *Lycengraulis batesii*, *Microphis lineatus*, and *Awaous tajasica*.
Key words: Neotropical Region, ichthyofauna, Maranhão-Piauí Hydrographic Region, taxonomy, geographic distribution.

Introduction

The Parnaíba river is 1,400 km long and drains 275 municipalities of the Brazilian states of Piauí, Maranhão, and Ceará (MMA, 2006). This perennial river lies in a transition area known as Middle North Region, between the semi-arid and poorly vegetated Northeast Region, and the Amazon Rainforest (Farias *et al*., 2015). It is the second largest river drainage of northeastern Brazil and flows through the Cerrado and the Caatinga biomes (Rosa *et al*., 2003, MMA, 2006, Chellappa *et al*., 2009). Its headwaters are located in the Serra da Ibiapaba and Serra Geral do Piauí, in southern Piauí. The semiarid region is marked with considerable seasonality, with distinct rain and dry seasons, contrasting with the humid Amazonian rainforest. The rainy season in the lower Parnaíba lasts from December to May, and the dry season goes from June to November (MMA, 2016). The lower stretch of the Parnaíba, downstream of the mouth

of the Poti river, forms a large river delta as it flows into the Atlantic Ocean, encompassing an archipelago of 2,700 km^2 made up of over 70 islands (Farias *et al*., 2015). The Parnaíba river basin was recognized as a freshwater ecoregion in a global assessment of aquatic diversity based mostly on fish diversity (Abell *et al*., 2008, Albert *et al*., 2011).

The earliest contributions to the knowledge of fish species of the Parnaíba river were derived from the Thayer expedition in the 19th Century, which collected fish in 157 stations in northern, northeastern and eastern Brazil (Higuchi, 1996; Rosa *et al*., 2003). Fish species collected in the Parnaíba basin during the expedition lead by Louis Agassiz were described by Steindachner (1877), Eigenmann & Eigenmann (1889), Garman (1890a, b), Eigenmann (1917), and Borodin (1931). Oliveira (1974) listed 66 teleostean species collected in the estuary of the Parnaíba river, including 11 species of freshwater fishes. The knowledge about the diversity of fish of the basin increased considerably after the end of the 20th Century. Rosa *et al*. (2003) summarized the information about species richness of Caatinga and recognized four hydrographic ecoregions in this biome: Maranhão-Piauí, Middle East Northeast, São Francisco, and East ecoregions. The Maranhão-Piauí Ecoregion comprises the Munin basin flowing into the Golfão Maranhense, small coastal basins located east of the Munin river, and the Parnaíba river basin. Rosa *et al*. (2003) recorded 86 fish species from the Maranhão-Piauí Ecoregion. Additional species have since been described and recorded from the lower portion of Parnaíba basin, including *Melanorivulus parnaibensis* Costa (2003), *Roeboides margareteae* Lucena (2003), *Geophagus parnaibae* Staeck & Shindler (2006), *Roeboides sazimai* Lucena (2007), *Pituna schindleri* Costa (2007), *Platydoras brachylecis* Piorski *et al*. (2008), *Cynolebias parnaibensis* Costa *et al*. (2010), and *Poecilia sarrafae* Bragança & Costa (2011). More recently, Ramos *et al*. (2014), in a new summary of the ichthyological exploration of the Parnaíba basin, recorded 146 fish species, including 54 endemics, and highlighted the need for more inventories. Silva *et al*. (2015) recorded six additional species in the Gurgueia sub basin: *Hasemania nana* (Lütken, 1875), *Hemigrammus brevis* Ellis (1911), *H. guyanensis* Géry (1959), *H. ora* Zarske, Le Bail & Géry (2006), and two undescribed species (*Corydoras* sp., and *Cetopsorhamdia* sp.). These records increased the total number of species of the Parnaíba basin to 152.

The current patterns of fish distribution in freshwater ecosystems of the Caatinga are the result of historical processes that involve geologic factors, eustatic sea level changes, climatic changes, vicariance events, as well as anthropic activities (Rosa *et al*., 2003). Aquaculture, agriculture, and urban pollution have grown substantially in northeastern Brazil, and it is likely that these activities are causing considerable loss of biodiversity. Therefore,

detailed distributional data are required to establish conservation strategies for fish species.

The aim of this investigation is to describe the composition and spatial distribution of fish species present in the lower portion of the Parnaíba river in order to improve the knowledge of freshwater biodiversity of this poorly known area, and provide baseline data for future biodiversity conservation efforts. The species checklist is linked to distribution records, abundance data, and voucher specimens in scientific collections.

Material and Methods

Fieldwork was carried out from May 2012 to February 2014, in the lower course of the Parnaíba river and some of its tributaries (Igaraçu, Longá, Poti, and Piracuruca rivers; Table 1, Figures 1, 2, and 3). Thirty-two field campaigns were conducted in the municipalities of Araioses in the State of Maranhão, and Barras, Boa Hora, Buriti dos Lopes, Ilha Grande, Parnaíba, Teresina, and Porto in the State of Piauí: eight in the rainy season, and 24 in the dry season (Table 1). The study included 11 samples in the Parnaíba river, two in the Poti river, 14 in the Longá river, three in the Igaraçu river, and two in the Piracuruca river. Each sampling site was photographed and georeferenced by Global Positioning System (GPS).

The fish were captured under SISBIO license #34869-1 from Instituto Chico Mendes de Conservação da Biodiversidade (ICMBio). Fish were sampled with gillnet, beach seine, cast net, and hand net during 60 min at each site (Table 1). Some sites were sampled repeatedly. Sampling was performed four times in the Pirangi (samples 7, 9, 23 and 25), twice in the Bolão's Dam in the Longá drainage (samples 10 and 20), and near the harbor of the municipality of Porto (17 and 26). The samples were preserved in the field in 10% formalin and later transferred to 70% ethanol for permanent storage. The specimens were sorted and identified at the Laboratório de Ciências Biológicas, Universidade Estadual do Piauí, *Campus* Alexandre Alves de Oliveira (UESPI). Voucher specimens were deposited in MBML (Museu de Biologia Melo Leitão, Instituto Nacional da Mata Atlântica), MPEG (Museu Paraense Emílio Goeldi), UESPIPHB (Coleção Ictiológica UESPI Campus Parnaíba), and MNRJ (Museu Nacional, Universidade Federal do Rio de Janeiro). The voucher material is listed in the appendix, including the number of individuals.

Species identification was based on dichotomic keys, original descriptions, identification manuals, and taxonomic reviews (Garman, 1890a,b; Eigenmann, 1915; Borodin, 1931;.Géry, 1977; Dawson, 1982; Kullander, 1980; Kullander, 1983; Britski *et al*., 1988; Reis, 1989; Vari, 1989a,b; Ploeg, 1991;

Table 1. Sampling sites in the lower course of Parnaíba River basin. dry (d), rain (r), casting net (c), beach seine net (b), hand net (h), gil net (g), sludge (sld), clay (cl), sand (s), rock (rc), stone (st), Igaraçu (i), Longá (l), Parnaíba (p), Piracuruca (pi), Poti (po).

Sample	State	Municipality	Locality	Coordinates	Richness	Drainage	Season	Sampling date	Collecting gear	Substratum
1	PI	Ilha Grande	Tatus river.	02°50'08.1"S 41°49'46.6"W	8	p	r	05/27/12	c	csld
2	PI	Parnaíba	Lake near Igaraçu river.	02°53'54.0"S 41°45'33.0"W	13	i	r	06/16/12	c, h	cl
3	PI	Parnaíba	Dam, near Igaraçu river and Lagoa da Prata.	02°55'01.4"S 41°47'3.5"W	5	i	r	06/09/12	c, h	sld
4	PI	Buriti dos Lopes	Small affluent on the right margin of Longá river in its mouth near Buriti lake.	03°12'56.1"S 41°53'59.9"W	17	l	d	07/03/12	h, b, g	s
5	PI	Buriti dos Lopes	Buriti lake.	03°10'22.5"S 41°52'23.4"W	6	l	d	07/03/12	c, h, b	s
6	PI	Buriti dos Lopes	Right margin of the Parnaíba river, in the farm of Mr. Bodó.	03°05'26.3"S 41°53'27.6"W	2	p	d	08/10/12	c	s
7	MA	Araioses	Left margin of Parnaíba river at Pirangi.	03°05'47.1"S 41°54'34.2"W	1	p	d	08/10/12	c, h, b, g	rc
8	PI	Parnaíba	Small pond near Igaraçu river.	02°53'46.6"S 41°45'35.0"W	6	i	d	08/28/12	c, h	cl
9	MA	Araioses	Left margin of Parnaíba river at Pirangi .	03°05'47.1"S 41°54'34.2"W	15	p	d	09/27/12	c, h, b, g	rc
10	PI	Buriti dos Lopes	Bolão's Dam in the right margin of Longá river near its mouth.	03°13'28.1"S 41°54'1.3"W	15	l	d	09/28/12	c, h, b, g	s/cl

Table 1 (cont.)

Sample	State	Municipality	Locality	Coordinates	Richness	Drainage	Season	Sampling date	Collecting gear	Substratum
11	PI	Buriti dos Lopes	Right margin of Longá river near its mouth.	03°12'55.4"S 41°54'1.8"W	22	l	d	09/28/12	c, h, b, g	s
12	PI	Teresina	Mouth of Poti river with Parnaíba river.	05 °02'05.7"S 42°50'21.2"W	7	po	d	11/08/12	c, h, b, g	sld
13	PI	Teresina	Left margin of Poti river.	05°02'04.8"S 42°49'47.2"W	1	po	d	11/08/12	c	sld
14	PI	Teresina	Right margin of Parnaíba river near Maranhão avenue.	05°04'50.5"S 42°49'43.1"W	3	p	d	11/08/12	c, h, b, g	sld/s
15	PI	Teresina	Right margin of Parnaíba river near Maranhão avenue.	05°08'29.7"S 42°48'32.3"W	1	p	d	11/08/12	c, h	sld/s
16	PI	Teresina	North Teresina, in its rural area, Iedas´s locality.	05°00'05.6"S 42°51'06.0"W	7	p	d	11/09/12	c, h, b, g	s
17	PI	Porto	Near to the harbor of the municipality of Porto.	03°53'41.5"S 42°43'15.0"W	17	p	d	11/09/12	c, h, b, g	rc/s
18	PI	Barra	Left margin of Longá river.	04°23'40.0"S 42°10'57.1"W	13	l	d	11/23/12	c, h, b, g	rc/s
19	PI	Barra	Left margin of Longá river at “Cospe Fogo”.	04°23'09.3"S 42°11'35.0"W	14	l	d	11/23/12	c, h, b, g	cl/s
20	PI	Buriti dos Lopes	Right margin of Longá river in Bolão’s Dam.	03°13'29.0"S 41°54'33.5"W	22	l	d	12/06/12	c, h, b, g	s/cl
21	PI	Buriti dos Lopes	Right margin of Longá river, very near to its mouth.	03°12'55.4"S 41°54'01.0"W	19	l	d	12/06/12	c, h, g	s

Table 1 (cont.)

Sample	State	Municipality	Locality	Coordinates	Richness	Drainage	Season	Sampling date	Collecting gear	Substratum
22	PI	Buriti dos Lopes	Right margin of Longá river.	03°13'19.6"S 41°54'41.4"W	5	l	d	12/06/12	c, h, b	s/cl
23	MA	Araioses	Left margin of Parnaíba river at of Pirangi.	03°05'49.3"S 41°54'33.0"W	8	p	d	12/06/12	c, h, b, g	rc
24	PI	Buriti dos Lopes	Northeastern margin of Buriti lake.	03°12'21.7"S 41°52'46.5"W	13	l	r	04/19/13	c, h, b, g	s/cl
25	MA	Araioses	Left margin of Parnaíba river at Pirangi.	03°05'47.1"S 41°54'34.2"W	1	p	r	05/16/13	c	rc
26	PI	Porto	Near to the harbor of the municipality of Porto.	03°53'41.5"S 42°43'15.0"W	20	p	r	05/17/13	c, h, b, g	rc/s
27	PI	Barra	Left margin of Longá river.	04°23'34.0"S 43°11'03.0"W	12	l	d	08/05/13	h	rc
28	PI	Boa Hora	Right margin of Longá river.	04°23'38.0"S 42°10'57.0"W	6	l	d	08/05/13	c, h, b	s
29	PI	Piracuruca	Near to water intake station.	03°57'13.0"S 41°41'46.0"W	4	pi	d	11/28/13	c, h, b	cl
30	PI	Piracuruca	Fish farmers association dam in Piracuruca river in the locality of Cantinho.	03°59'24.0"S 41°39'59.1"W	13	pi	d	11/28/13	c, h, b, g	st
31	PI	Boa Hora	Pond at right margin of Longá river.	04°23'28.1"S 42°11'00.0"W	9	l	r	02/24/14	h, b	s
32	PI	Boa Hora	Right margin of Longá river.	04°23'38.0"S 42°10'56.1"W	5	l	r	02/24/14	c	s

Vari, 1991; Vari, 1992; Vari *et al*., 1995; Planquette *et al*., 1996; Watson, 1996; Ferreira *et al*., 1998; Malabarba, 1998; Buckup & Hahn, 2000; Carpenter, 2002; Castro *et al*., 2004; Armbruster & Page, 2006; Staeck & Schindler, 2006; Covain & Fisch-Muller, 2007; Lucena, 2007; Netto-Ferreira *et al*., 2009; Lucena &

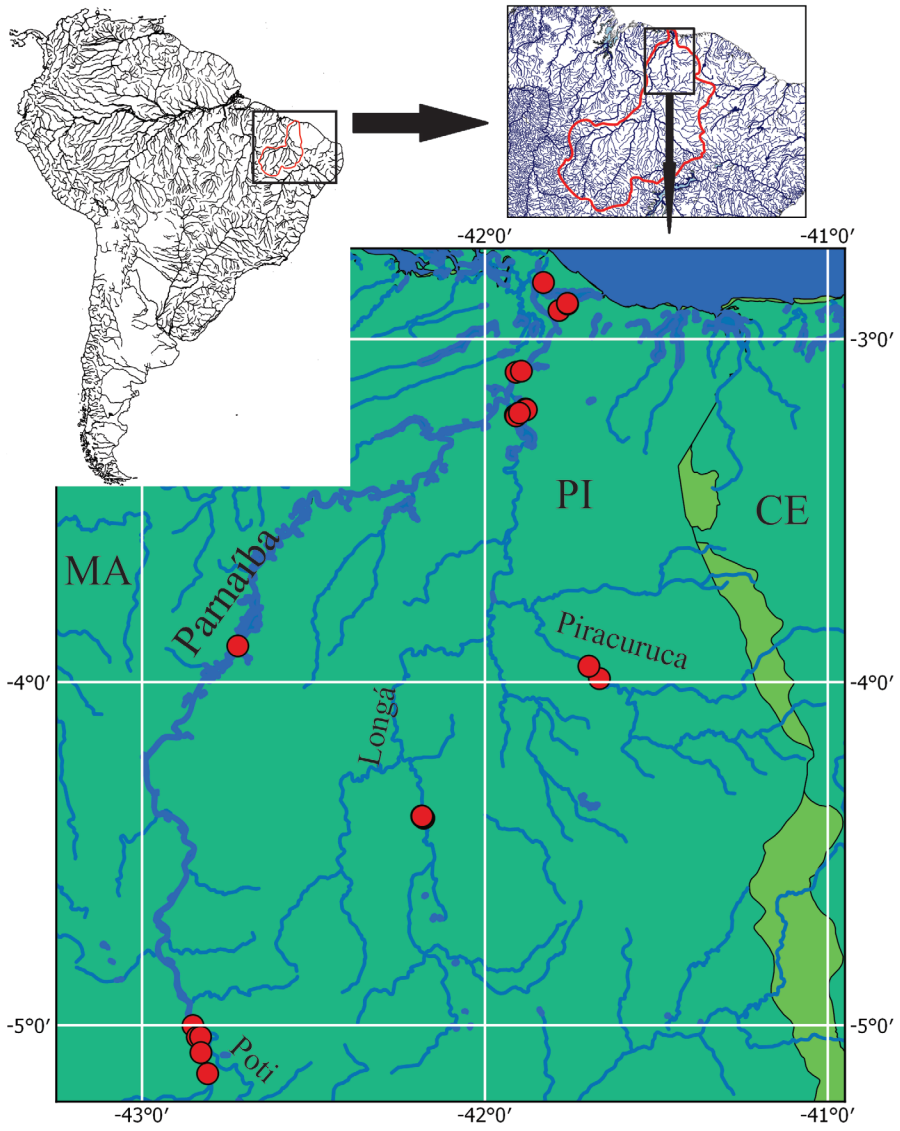

Figure 1. Study area in the lower Parnaíba. Some circles represent more than one locality. Collecting sites are listed in Table 1.

Malabarba, 2010; Birindeli *et al*., 2011; Bragança & Costa, 2011; Piorsky *et al*., 2008; Lucena & Soares, 2016). The species list follows the taxonomic classification used by Reis *et al*. (2003) as updated by Nelson *et al*. (2016), with genera and species listed alphabetically.

Species richness and abundance were recorded for each locality. Species representativeness was calculated as the number of captured individuals of a species in relation to the total number of specimens, and represented by percentages. The index of species constancy, C (Dajoz, 1978), was calculated using the formula C = n/N * 100, where n is the number of samples in which the species was captured, and N is the total number of sampling events carried out in the study. Constancy values were categorized following Dajoz (1978) as constant (C > 50%), accessory (25% < C < 50%), and accidental (C < 25%).

Results

A total of 2,732 specimens were captured, belonging to 65 species, 24 families and 11 orders (Table 2, Figures 4 to 10). Average abundance was 82.6 specimens per sample. The ichthyofauna included 34 species of Characiformes (52.3%), 13 Siluriformes (20.0%), seven Cichliformes (10.8%), three Clupeiformes (4.6%), two Cyprinodontiformes (3.1%), one Gobiiformes (1.5%), one Gymnotiformes (1.5%), one Myliobatiformes (1.5 %), one Acanthuriformes (1.5%), one Synbranchiformes (1.5%), and one Syngnathiformes (1.5%). Characiformes (2,142 specimens, 78.4%) was the most abundant group, followed by Cichliformes (216 specimens, 7.9%), Siluriformes (146 specimens, 5.3%), Clupeiformes (130 specimens, 4.8%), Cyprinodontiformes (75 specimens, 2.7%), Acanthuriformes (14 specimens, 0.5%), Gymnotiformes (three specimens, 0.1%), Gobiiformes (two specimens, 0.07%), Syngnathiformes (two specimens, 0.07%), Synbranchiformes (one specimen, 0.04%), and Myliobatiformes (one specimen, 0.04%) (Table 2). Eight species had high abundance and comprised 62.7% of all collected specimens: *Hemigrammus rodwayi* (17.1%), *Hyphessobrycon* sp. (13.9%), *Serrapinnus piaba* (9.8 %), *Psellogrammus kennedyi* (6.4%), *Astyanax lacustris* (3.7%), *Tetragonopterus argenteus* (4.5%), *Jupiaba polylepis* (3.8%), and *Curimatella immaculata* (3.5%) (Figure 11).

The fish community in the sampled area includes estuarine species. *Lycengraulis batesii*, *Anchovia surinamensis,* and *Anchovia guianensis* belong to the Engraulidae, which include estuarine species that migrate into rivers to spawn (Nizinski & Munroe, 2002). *Lycengraulis batesii*, and *Anchovia surinamensis* were captured on both the rain and the dry seasons.

Anchovia guianensis was captured just once on the dry season. Occurrence of the estuarine *Microphis lineatus* and *Awaous tajasica* was also restricted to the dry season.

There was great variation in fish community composition, with

Figure 2. Site locations for samples 2, 4, 7, 8, 9, 11, 12, 13, 15, 16, 17, 19, 20, 25 and 27 in the lower Parnaíba basin.

none of the species found in more than 50% of the sampled sites. *Astyanax lacustris*, *Curimatella immaculata* and *Serrapinnus piaba* occurred in 15 samples; *Geophagus parnaibae*, in 14; two species, *Cichlasoma orientale* and *Hyphessobrycon* sp., in 12; and two species, *Moenkhausia dichroura*, *Serrasalmus rhombeus*, were collected in 11 samples (Table 2). Most species were categorized as accessory, with 52 species (67%) recorded in only one or two localities. *Characidium* cf. *zebra*, *Corydoras treitlii, Eigenmannia virescens*, *Hemigrammus rodwayi*, *Hemiodus parnaguae, Knodus victoriae*, *Metynnis lippincottianus*, *Phenacogaster calverti*, *Plagioscion squamosissimus*, and *Schizodon dissimilis* were captured only in the Longá and Piracuruca rivers.

Species richness in the sites ranged from one to 22 (9.1&% ± 6.6 sd). The highest number of species was found in the lower course of the Longá river in two localities (samples 12 and 21, Table 1). The lowest values of species richness (1 - 3 species) were recorded in the urban area of the city of Teresina (samples 13, 14 and 15) under severe anthropic impact. Only two species were collected in the Bodó's Farm (sample 6), and a site in Pirangi (sample 25), where only the cast net was used to collect fishes.

Figure 3. Site locations for samples 28, 29, 31 and 32 in the lower Parnaíba basin.

Table 2. List of species collected in the lower Parnaíba river basin, Piauí State, Brazil.

Taxon	Sites	Constancy
MYLIOBATIFORMES		
Potamotrygonidae		
Potamotrygon orbignyi (Castelnau, 1855)	25	accidental
CLUPEIFORMES		
Engraulidae		
Anchovia surinamensis (Bleeker, 1865)	6, 20, 21, 26	accidental
Anchoviella guianensis (Eigenmann, 1912)	21	accidental
Lycengraulis batesii (Gunther, 1868)	10, 11, 21, 22, 24, 26	accidental
GYMNOTIFORMES		
Sternopygidae		
Eigenmannia virescens (Valenciennes, 1836)	18, 19	accidental
CHARACIFORMES		
Crenuchidae		
Characidium cf. *zebra* Eigenmann, 1909	19, 28	accidental
Erythrinidae		
Hoplias malabaricus (Bloch, 1794)	2, 3, 9, 10, 11, 16, 23, 31	accidental
Serrasalmidae		
Colossoma macropomum (Cuvier, 1816)	24	accidental
Metynnis lippincottianus (Cope, 1870)	4, 18	accidental
Myleus asterias (Muller & Troschel, 1844)	4	accidental
Serrasalmus rhombeus (Linnaeus, 1766)	1, 4, 9, 11, 16, 18, 26, 28, 29, 30, 31	accessory
Pygocentrus nattereri Kner, 1858	2, 21, 24	accidental
Hemiodontidae		
Hemiodus parnaguae Eigenmann & Henn, 1916	1, 19, 21, 30	accidental
Anostomidae		
Leporinus friderici (Bloch, 1794)	9, 14, 17, 19, 20, 21, 26, 28, 30, 32	accessory
Leporinus obtusidens (Vallenciennes, 1836)	26	accidental

Table 2 (cont.)

Taxon	Sites	Constancy
Schizodon aff. *dissimilis* (Garman, 1890)	20	accidental
Schizodon sp.	17	accidental
Chilodontidae		
Caenotropus labyrinthicus (Kner, 1858)	14, 26	accidental
Curimatidae		
Curimata macrops (Eigenmann & Eigenmann, 1889)	1, 10, 21, 24, 26, 28	accidental
Curimatella immaculata (Fernández-Yépez, 1948)	4, 9, 10, 11, 17, 18, 19, 20, 21, 22, 24, 26, 30, 31, 32	accessory
Psectrogaster rhomboides Eigenmann & Eigenmann, 1889	9, 11, 12	accidental
Steindachnerina notonota (Miranda Ribeiro, 1937)	9, 11, 12, 24, 28	accidental
Prochilodontidae		
Prochilodus lacustris Steindachner, 1907	1, 11, 12, 24, 26, 28	accessory
Characidae		
Genera incertae sedis		
Astyanax fasciatus (Cuvier, 1819)	11, 19, 27, 28, 30	accidental
Astyanax lacustris (Lütken, 1875)	1, 2, 4, 5, 7, 8, 9, 10, 11, 17, 20, 25, 26, 30, 31	accessory
Hemigrammus rodwayi Durbin, 1909	2, 4, 10, 11, 30, 31	accidental
Hyphessobrycon sp.	4, 5, 8, 9, 10, 11, 17, 18, 19, 27, 29, 31	accessory
Jupiaba polylepis (Gunther, 1864)	4, 9, 10, 18, 20, 23, 26, 27, 28, 29	accessory
Moenkhausia dichroura (Kner, 1858)	4, 5, 10, 12, 17, 18, 20, 21, 24, 26, 31, 32	accessory
Psellogrammus kennedyi (Eigenmann, 1903)	2, 4, 5, 9, 11, 17, 20, 21, 24	accessory
Subfamly Stethaprioninae		
Brachychalcinus parnaibae Reis, 1989	4, 9, 11, 18, 19, 21, 22, 23, 24, 26	accessory
Subfamily Characinae		
Phenacogaster calverti (Fowler, 1941)	18, 20	accidental
Roeboides sazimai Lucena, 2007	4, 9, 19, 20, 21, 25	accidental
Roeboides margareteae Lucena, 2003	11, 20	accidental

Table 2 (cont.)

Taxon	Sites	Constancy
Subfamily Tetragonopterinae		
Tetragonopterus argenteus Cuvier, 1816	1, 4 ,11, 17, 23, 26, 28, 30, 32	accessory
Subfamily Cheirodontinae		
Serrapinnus heterodon (Eigenmann 1915)	2, 4, 5, 9, 18, 19, 29	accidental
Serrapinnus piaba (Lütken, 1875)	2, 4, 5, 8, 9, 10, 17, 18, 20, 21, 23, 27, 28, 30, 31	accessory
Subfamily Stevardiinae		
Knodus victoriae (Steindachner, 1907)	19	accidental
Triportheidae		
Triportheus signatus (Garman, 1890)	4, 11, 12, 24, 26	accidental
SILURIFORMES		
Callichthyidae		
Corydoras treitlii Steindachner, 1906	19	accidental
Hoplosternum littorale (Hancock, 1828)	8	accidental
Loricariidae		
Hypostomus sp.1	1, 10, 17, 20, 21, 22	accidental
Hypostomus sp.2	10, 17	accidental
Loricaria parnahybae Steindachner, 1907	14	accidental
Loricariichthys derbyi Fowler, 1915	10, 11, 20, 21	accidental
Pterygoplichthys parnaibae (Weber 1991)	2, 3, 11, 20	accidental
Rineloricaria sp.	20, 21	accidental
Heptapteridae		
Pimelodella parnahybae Fowler, 1941	4, 6, 10, 11, 17, 18, 19, 20, 21, 26	accidental
Pimelodidae		
Pimelodus blochii Valenciennes, 1840	1, 12, 17, 26	accidental
Doradidae		
Hassar affinis (Steindachner, 1881)	11, 12	accidental
Platydoras brachylecis Piorski, Garavello, Arce H. & Sabaj Pérez, 2008	11, 21	accidental

Table 2 (cont.)

Taxon	Sites	Constancy
Auchenipteridae		
Trachelyopterus galeatus (Linnaeus, 1766)	23	accidental
GOBIIFORMES		
Gobiidae		
Awaous tajasica (Lichtenstein, 1822)	17, 23	accidental
SYNGNATHIFORMES		
Syngnathidae		
Microphis lineatus (Kaup 1856)	9	accidental
SYNBRANCHIFORMES		
Synbranchidae		
Synbranchus marmoratus Bloch, 1795	2	accidental
CICHLIFORMES		
Cichlidae		
Apistogramma piauiensis Kullander, 1980	4, 10, 11	accidental
Cichla monoculus Spix & Agassiz, 1831	12, 13, 16, 17, 18, 20, 28, 29, 32	accessory
Cichlasoma orientale Kullander 1983	2, 3, 4, 8, 9, 11, 16, 17, 24, 28, 30, 31	accessory
Crenicichla menezesi Ploeg 1991	2, 4, 9, 10, 16, 17, 20, 21, 23, 26, 32	accessory
Crenicichla sp.	23	accidental
Geophagus parnaibae Staeck & Schindler, 2006	2, 4, 8, 10, 16, 17, 18, 19, 20, 21, 26, 28, 30, 32	accessory
Oreochromis niloticus (Linnaeus, 1785)	2, 3	accidental
CYPRINODONTIFORMES		
Poeciliidae		
Pamphorichthys hollandi (Henn, 1916)	2, 3, 4, 8, 9, 10, 11, 16, 30	accessory
Poecilia sarrafae Bragança & Costa, 2011	2, 8, 9, 27, 30	accidental
ACANTHURIFORMES		
Sciaenidae		
Plagioscion squamosissimus (Heckel, 1840)	19, 21	accidental

Among the species collected in the present study, *Astyanax lacustris* belongs to a group of species characterized by the presence of a horizontally elongate oval black spot in the humeral region, two dark vertical bars in the humeral region, and a black spot in the caudal peduncle extending up to the tips of the median caudal rays. Within this group, *A. lacustris* is distinguished from *A. bimaculatus* by the absence of maxillary teeth and by the absence of a conspicuous midlateral black stripe extending above the lateral line from the humeral spot or just behind it to the caudal peduncle, continuing along the median rays of the caudal fin (Garutti & Britski 2000; Garutti & Langeani 2009; Peres *et al*., 2012; Lucena & Soares 2016). Lucena & Soares (2016) also diagnosed the species by the absence of horizontal lines forming a zigzag pattern on the body (*vs*. presence), the markedly concave external surface of the second tooth of the internal series of the premaxilla, and misaligned cusps in this tooth (*vs*. teeth having slightly concave surfaces with cusps almost aligned and on the same plane), and by a small number (30-39) of perforated scales on the lateral line. Specimens of *A. lacustris* from the Parnaíba river basin have 31-37 perforated lateral-line scales (mean 34.6 ± 1.4 sd, n=37), 22-35 branched anal-fin rays (mean 25.1 ± 2.3 sd, n=40), 14-15 scales around the caudal peduncle (mean 14.2 ± 0.4 sd, n=34), 6-7 rows of scales between the dorsal-fin and the lateral line (mean 6.9 ± 0.3, n=39), 5-7 rows of scales between the pelvic fin and the lateral line (mean 6.1 ± 0.3 sd, n=39), 8-11 gill rakers on the upper branch of the first gill arch (mean 9.1 ± 0.7 ±, n=40). Just one specimen (UESPIPHB 158) has one tricuspid maxillary tooth. All these meristic data fit in the morphological redescription of *A. lacustris* by Lucena & Soares (2016).

One specimen of *Awaous tajasica* was previously collected in mangrove near the town of Parnaíba (MCZ 61812; Watson, 1996). The specimens recorded in the present study as *A. tajasica* represent the second record of the species in the Parnaíba river. They have Pore F (*sensu* Iwata & Jeon, 1995) singular, a postorbital portion of infraorbital canal with a short branch running postero-ventrally, 69 lateral line scales, 18 transverse series of scales, and 19 predorsal scales.

Six taxa (*Hyphessobrycon* sp., *Hypostomus* sp. 1, *Hypostomus* sp. 2, *Crenicichla* sp., *Rineloricaria* sp., and *Schizodon* sp.) could not be identified to the species level due to lack of taxonomic revisions and small size of the specimens. The second most abundant species, *Hyphessobrycon* sp., is characterized by the presence of iii-iv, 20-21 anal-fin rays, 8-13 perforated scales in the lateral line, outer row of premaxillary theeth with 1-3 teeth bearing 3 cusps, inner row with 5 teeth bearing 3-5 cusps, dentary with 4 large teeth, somewhat anteriorly projected and arranged in a nearly straight line, with 3-4

cusps, followed by 5-7 minute teeth with 1-3 cusps, maxilla with 1-2 teeth, bearing 1-3 cusps. It is included in a putative group, which includes H. *brumado* Zanata & Camelier (2010), H. *negodagua* Lima & Gerhard (2001) and *H.*

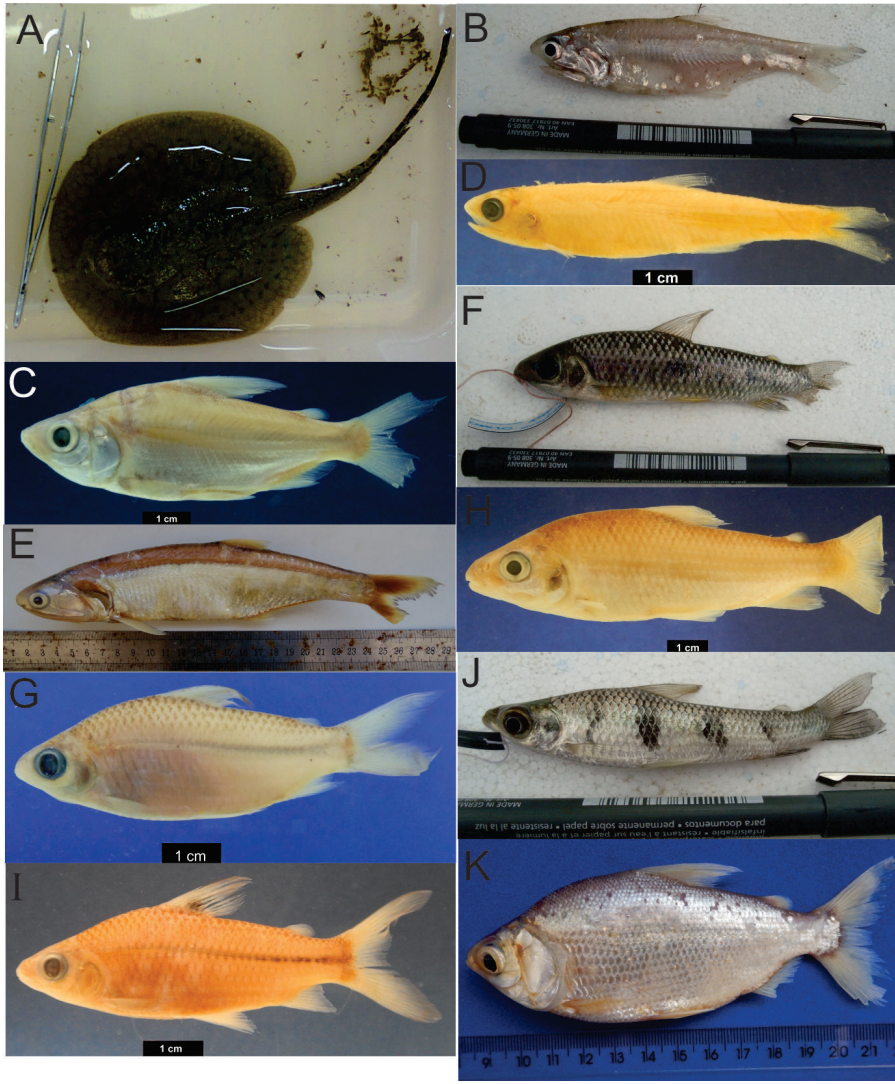

Figure 4. Fish species collected in lower Parnaíba: **A** – *Potamotrygon orbignyi*, **B** – *Anchovia surinamensis*, **C** – *Curimata macrops*, **D** – *Anchoviella guianensis*, **E** – *Lycengraulis batesii,* **F** – *Leporinus friderici*, **G** – *Curimatella immaculata*, **H** – *Leporinus obtusidens*, **I** – *Steindachnerina notonota*, **J** – *Schizodon dissimilis,* **K** – *Psectrogaster rhomboides*.

parvellus Ellis (2011). These species share a reduced layer of musculature between first and second ribs, absence of humeral spot (Zanata & Camelier, 2010). Because the distribution of these species beyond the neighborhood of their type localities is poorly known, identification of populations from the Parnaíba cannot be accomplished at the present time. *Hypostomus* sp. 1 differs from *Hypostomus* sp. 2 by the presence of small platelets on the abdomen (versus naked abdomen). Ramos *et al*. (2014) recognized four undescribed species of *Hypostomus*, and *Hypostomus johnii* (Steindachner, 1877) in the Parnaíba

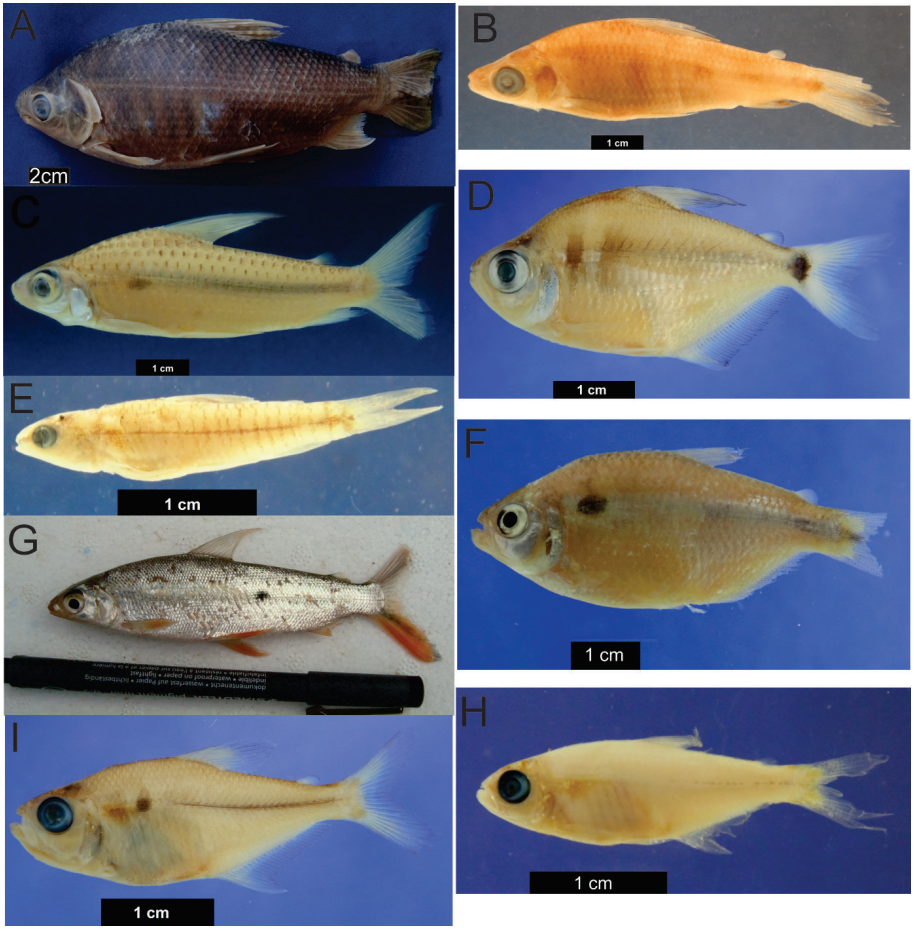

Figure 5. Fish species collected in lower Parnaíba: **A** – *Prochilodus lacustris*, **B** – *Schizodon* sp., **C** – *Caenotropus labyrinthicus*, **D** – *Tetragonopterus argenteus,* **E** – *Characidium* cf. *zebra*, **F** – *Astyanax lacustris*, **G** – *Hemiodus parnaguae*, **H** – *Hyphessobrycon* sp., **I** – *Jupiaba polylepis*.

basin. *Hypostomus* sp. 1, and *Hypostomus* sp.2 differ from *H. johnii*, an endemic species of the Parnaíba basin, by the lower number (up to 40) of premaxillary teeth (*versus* 140 to 197). The genus *Rineloricaria* comprises more than 60 valid species that can be found in a great variety of freshwater habitats (Reis *et al*., 2003; Ferraris, 2007; Fichberg & Chamon, 2008; Ghazzi, 2008; Ingenito *et al*., 2008; Rapp Py-Daniel & Fichberg, 2008; Rodriguez & Miquelarena, 2008; Rodriguez & Reis, 2008). The genus was recorded for the first time in the Parnaíba river by Ramos *et al.* (2014), but there are still no taxonomic revision of species of *Rineloricaria* from the Parnaíba basin. Ramos *et al*. (2014) recorded *Crenicichla menezesi* Ploeg (1991) from the Parnaíba basin. Here we report a small specimen, 2.9 cm of standard length, which belongs to a second species of *Crenicichla*. *Crenicichla menezesi* differs from this second species of *Crenicichla* sp. by the presence of a darker and distinct humeral blotch in the lateral stripe (*vs.* absence of blotches on lateral side). Ramos *et al*. (2014) also recorded the occurrence of three species of *Schizodon* in the Parnaíba basin: *Schizodon knerii* (Steindachner, 1875), *S. rostratus* (Borodin, 1931), *S. dissimilis* (Garman, 1890). The comparison of our specimens with photographs of the types of *S. rostratus* and *S. dissimilis* allowed us to confirm that *Schizodon* sp. and *S. dissimilis* are very similar, respectively, to those type specimens. *Schizodon dissimilis* has four vertical lateral blotches and no spot at the base of caudal fin. The specimen of *Schizodon* sp. is a young with 70.0 mm standard length, and does not have vertical lateral stripes and caudal spot. However, the specimens of *Schizodon* sp. and *S. dissimilis* can be distinguished from *S. rostratus* by the possession of 16 scales around the caudal peduncle (*versus* 20 in *S. rostratus*, Heraldo A. Britski, personal communication).

Discussion

The predominance of Characiformes, followed by Siluriformes, observed in the present study is consistent with the general pattern found in tropical areas of the Neotropical Region (Lowe-McConnell, 1987; Reis *et al*., 2003; Buckup *et al*., 2007; Barros *et al*., 2011). However, the composition of the fish community at lower taxonomic levels seems to be significantly different from other areas of the Parnaíba watershed. The species collected in the present study represent only 43.0% of those listened by Rosa *et al*. (2003) for the Maranhão-Piauí portion of the northeastern ecoregions 323 and 325 of Abell *et al*. (2008), and 38.4% of those recorded in the Parnaíba basin by Ramos *et al*. (2014). These low values of similarity are indicative of significant differences in fish community structure between the lower Parnaíba basin and

the remainder of the basin.

Four categories were recognized according to the geographical distribution patterns: endemic species, species shared with coastal basins in

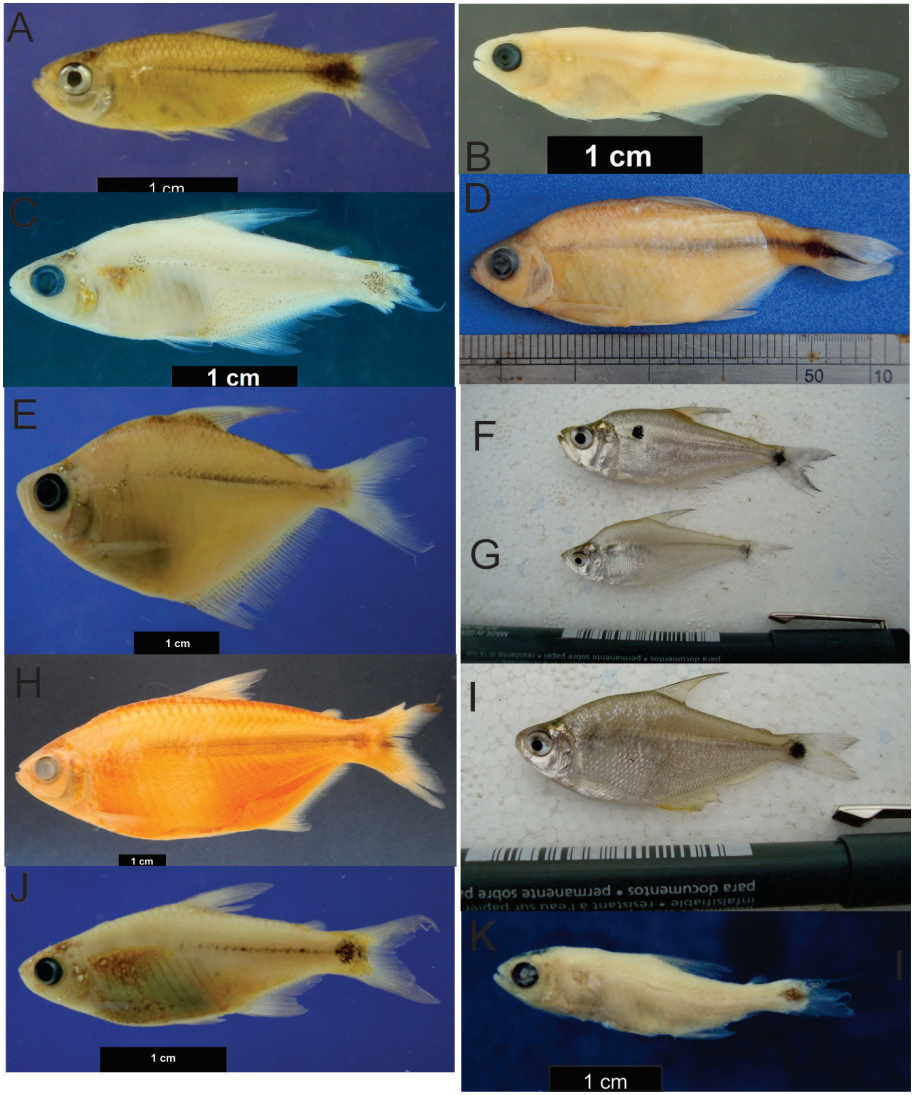

Figure 6. Fish species collected in lower Parnaíba: **A** – *Hemigrammus rodwayi*, **B** – *Knodus victoriae*, **C** – *Phenacogaster calverti*, **D** – *Astyanax fasciatus*, **E** – *Brachychalcinus parnaibae,* **F**– *Roeboides margareteae*, **G** – *Roeboides sazimai,* **H** – *Moenkhausia dichroura,* **I** – *Psellogrammus kennedyi*, **J** – *Serrapinnus piaba*, **K** – *Serrapinnus heterodon*.

the Northeastern Region, species shared with the Amazon and Guianas basins, and widespread species, which occur in two or more of these hydrographic basins. *Ancistrus damasceni, Apistogramma piauiensis, Aspidoras raimundi, Auchenipterus menezesi, Brachychalcinus parnaibae, Curimata macrops,*

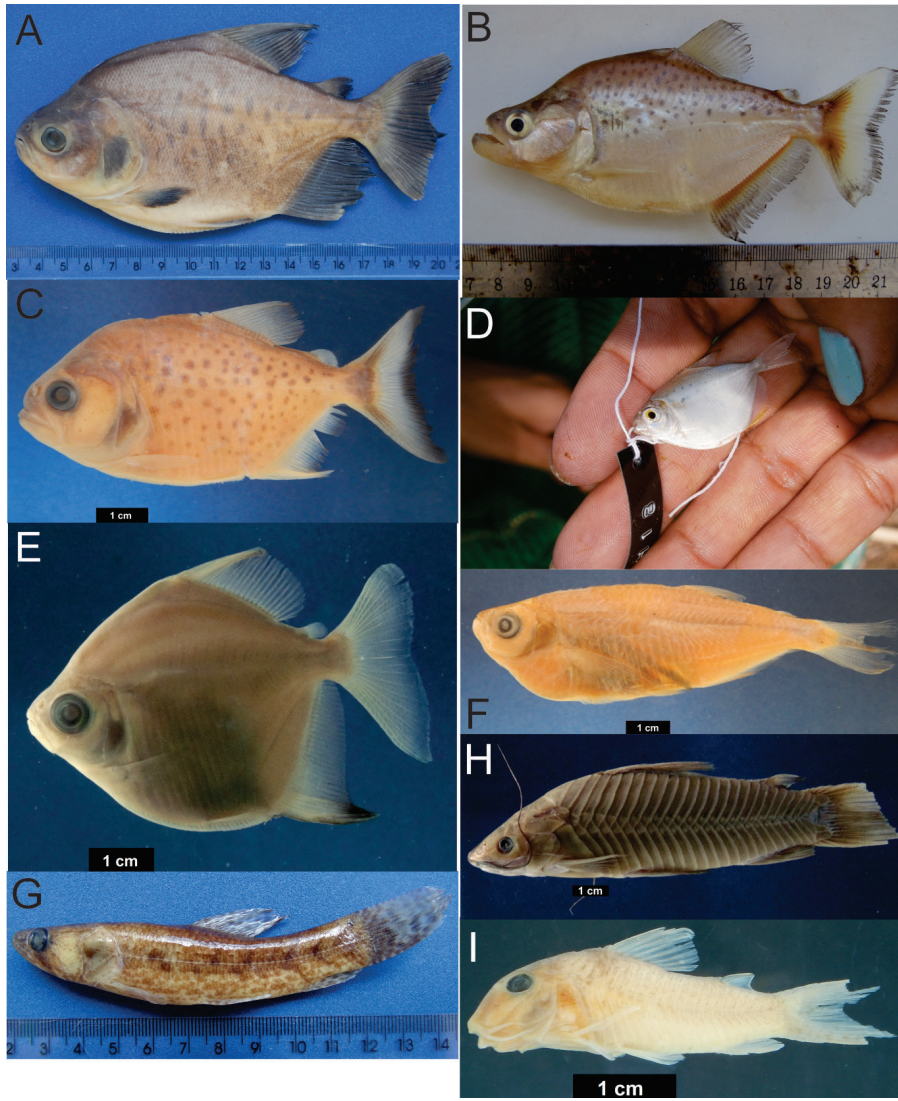

Figure 7. Fish species collected in lower Parnaíba: **A** – *Colossoma macropomum*, **B** – *Serrasalmus rhombeus*, **C** – *Pygocentrus nattereri*, **D** – *Metynnis lippincottianus*, **E** –*Myleus asterias*, **F** – *Triportheus signatus*, **G** – *Hoplias malabaricus*, **H** – *Hoplosternum litorale*, **I** – *Corydoras treitlii*.

Corydoras treitlii, Cynolebias parnaibensis, Geophagus parnaibae, Hassar affinis, Hemiodus parnaguae, Hypsolebias coamazonicus, Knodus victoriae, Melanorivulus parnaibensis, Parotocinclus haroldoi, Pimelodella parnahybae, Pituna schindleri, Platydoras brachylecis, Poecilia sarrafae, Potamotrygon signata, Prochilodus lacustris, Pterygoplichthys parnaibae, Roeboides margareteae, R. sazimai, Schizodon dissimilis, and *S. rostratus* are endemic to the Maranhão-Piauí region, which includes the Parnaíba river (Rosa *et al*., 2003; Barros *et al*., 2011; Ramos *et al*., 2014). Among six species described from the lower Parnaíba river, four (*Apistogramma piauiensis*, *Poecilia sarrafae*, *Roeboides sazimai*, and *R. margareteae*) were collected in this study. The remaining species, *Hypsolebias coamazonicus* and *Pituna schindleri*, are rivulid fishes known to occur in temporary pools, which are unlikely to occur in the main course of rivers sampled in our study. *Pterygoplichthys parnaibae* was described from the Lagoa Parnaguá, in the upper Parnaíba basin, with paratypes collected in the Poti river, and the Parnaíba river around Teresina (Weber, 1991; Reis *et al*., 2003; Rosa *et al*., 2003). The current study represents the first record of this species in the low course of the Parnaíba river (samples 2, 3, 12 and 21).

Among species that occur outside the Maranhão-Piauí Ecoregion, only six, *Steindachnerina notonota*, *Cichlasoma orientale*, *Crenicichla menezesi*, *Triportheus signatus*, *Phenacogaster calverti*, and *Psectrogaster rhomboides* are restricted to northeastern Brazil, while 15 species (*Anchovia surinamensis*, *Anchoviella guianensis*, *Caenotropus labyrinthicus*, *Characidium* cf. *zebra*, *Curimatella immaculata*, *Hemigrammus rodwayi*, *Jupiaba polylepis*, *Leporinus friderici*, *Lycengraulis batesii*, *Myleus asterias*, *Metynnis lippincottianus*, *Pimelodus blochii*, *Plagioscion squamosissimus, Pygocentrus nattereri*, and *Serrasalmus rhombeus*) are known from the Orinoco, Amazon, and Guianean basins. Agassiz & Agassiz (1869) were the first to comment about the similarity of the fish faunas of the Amazon and Parnaíba rivers and to suggest that such similarity is related to an ancient geological connection. Although the small number of species shared between the Parnaíba and the northeastern basins may be due to the low diversity of the northeastern fish fauna, some phylogenies corroborate a close and complex biogeographic history uniting the Parnaíba and the Amazonian basins. Vari (1989b) reconstructed the most parsimonious hypothesis of phylogenetic relationships within *Psectrogaster*, and recognized a clade uniting *P. rhomboides* with two Amazonian species. Similar patterns are present in other taxa. *Roeboides margareteae* and *R. microlepis* are closely related to *R. myersi* and *R. araguaito*, from the Amazon and Orinoco basins, respectively (Lucena, 2003). Román-Valencia *et al*. (2013) recorded *Knodus victoriae* from Peru

and Bolivia, although we are unable to confirm those records, and it has been recorded elsewhere as an endemic species of Parnaiba river basin (Lima *et al*., 2003; Buckup *et al*., 2007). The occurrence of *K. victoriae* in Peru and Bolivia would be a remarkable case of disjunct geographic distribution, and

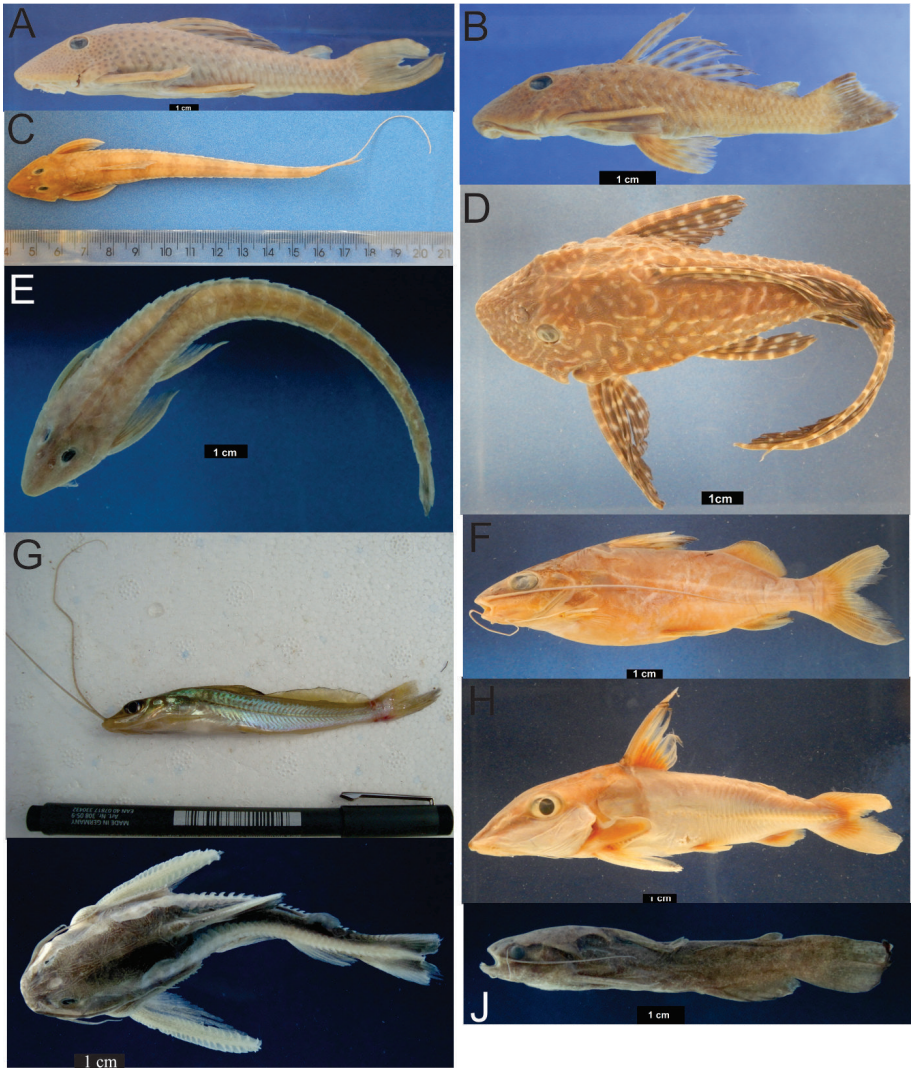

Figure 8. Fish species collected in lower Parnaíba: **A** – *Hypostomus* sp. 1, **B** – *Hypostomus* sp. 2. **C** – *Loricaria parnahybae,* **D** – *Pterygoplichthys parnaibae,* **E** – *Rineloricaria* sp., **F** – *Pimelodus blochii*, **G** – *Pimelodella parnahybae*, **H** – *Hassar affinis*, **I** – *Platydoras brachylecis*, **J** –*Trachelyopterus galeatus*.

such record suggests the need for additional taxonomic studies of this species. *Hemigrammus rodwayi* is distributed in rivers of the Guyana, Suriname, French Guiana, and Amazon Basin rivers (Lima *et al*., 2003; Planquete *et*

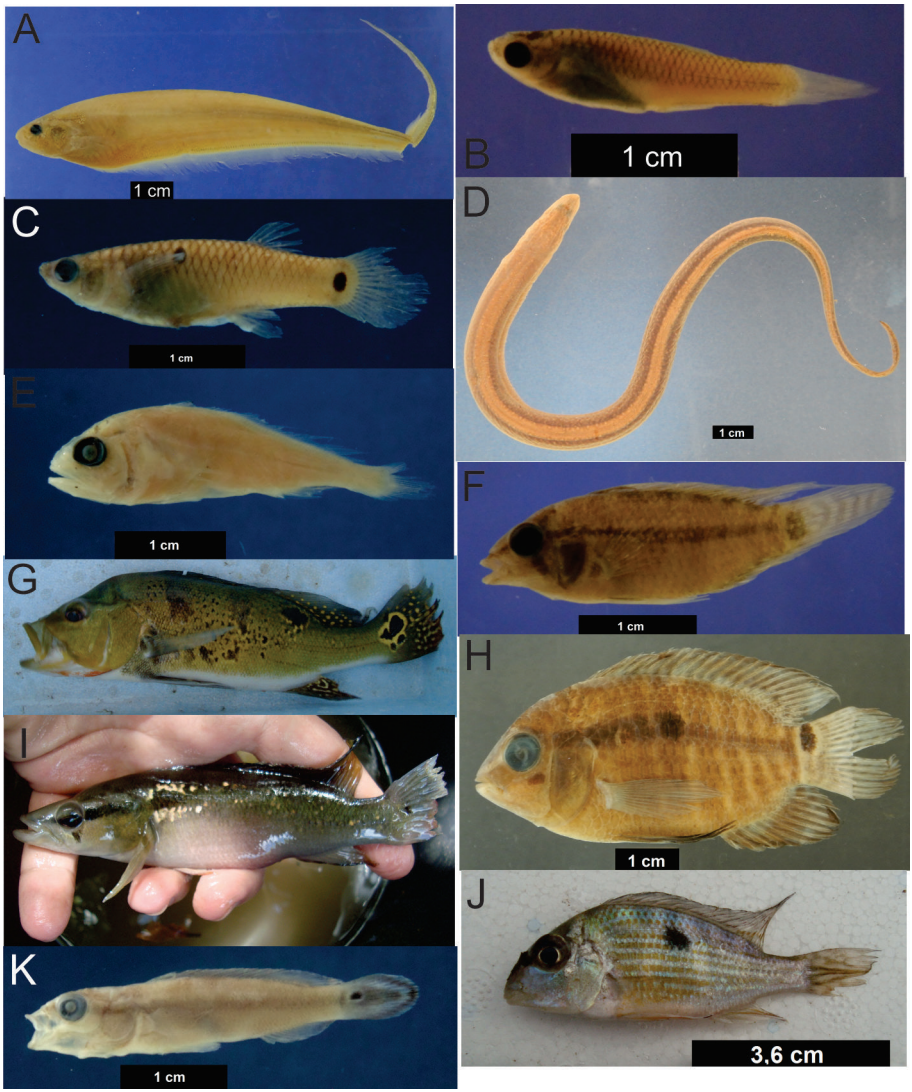

Figure 9. Fish species collected in lower Parnaíba: **A** – *Eigenmannia virescens,* **B** – *Pamphorichthys hollandi,* **C** – *Poecilia sarrafae*, **D** – *Synbranchus marmoratus*, **E** – *Plagioscion squamosissimus*, **F** – *Apistogramma piauiensis*, **G** – *Cichla monoculus*, **H** – *Cichlasoma orientale*, **I** – *Crenicichla menezesi*, **J** – *Geophagus parnaibae*; **K** – *Crenicichla* sp.

al., 1996), and this study is the first record of the occurrence of this species in the Parnaiba River basin. There are no records of *H. rodwayi* between the Guianas and the Parnaíba river, and the lack of records in the lower Amazon should be further investigated.

A few species are often reported as geographically widespread, occurring in several South American river basins: *Synbranchus marmoratus*, *Eigenmannia virescens*, *Hoplosternum littorale*, *Trachelyopterus galeatus*, *Hoplias malabaricus*. Except for *H. littorale*, and *T. galeatus*, these taxa are likely to represent species complexes, rather than distinct taxa, and are in need of taxonomic revision (Hauser & Benedito, 2012; Utsunomia *et al*., 2014; Torres *et al*., 2005). We are currently unaware of taxonomic problems affecting *H. littorale*, and *T. galeatus*, and their widespread occurrence deserves future investigation. *Tetragonopterus argenteus* occurs in the Amazon and the La Plata river basins. The known distribution of *Astyanax lacustris* was recently expanded to the La Plata, São Francisco, Laguna dos Patos, Tramandaí, and Araguaia river drainages by Lucena & Soares (2016). *Astyanax lacustris* was

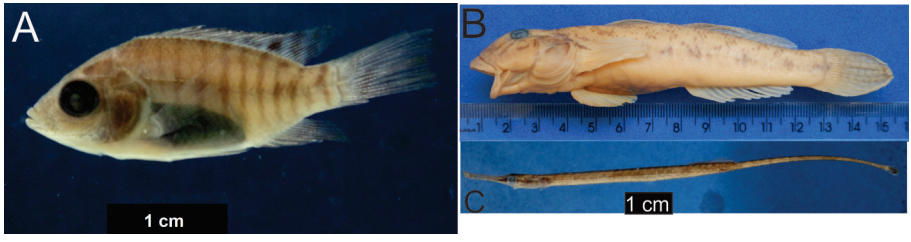

Figure 10. Fish species collected in lower Parnaíba: **A** – *Oreochromis niloticus*, **B** – *Awaous tajasica*, **C** – *Microphis lineatus*.

described from the São Francisco basin and is here recorded for the first time in the Parnaíba basin. Previous studies about the Parnaíba river fish fauna (Ramos *et al*., 2014, Melo *et al*., 2014, and Silva *et al*., 2015) recorded *A. lacustris* as *Astyanax* aff. *bimaculatus*. *Astyanax fasciatus* has been reported from many rivers in the Neotropical Region, but Melo (2005) and Melo & Buckup (2006) concluded that the name *A. fasciatus* should only be applied to specimens from the São Francisco river drainage, although no *Astyanax* from the Parnaíba river had been examined in those studies. The specimens identified in the present study as *Astyanax fasciatus* fit in the morphological redescription and diagnose of *A. fasciatus* by Melo (2005) and Melo & Buckup (2006). In a similar pattern of distribution, *Leporinus obtusidens* occurs in the Paraná, La Plata, and São Francisco river basins.

Oreochromis niloticus and *Colossoma macropomum* are introduced species registered in the study area. *Oreochromis niloticus*, an African cichlid now present in several South American river basins, was captured in two localities and has been previously registered in the Parnaíba river, in three temporary lakes inside a wind farm in northern Piauí (Ramos 2012; Melo *et al*., 2014). Non-native species represent a serious threat to aquatic environments and native fish species in South America (Vitule, 2009). The introduction of exotic species in aquatic environments can cause irreversible damage to biodiversity, because they may compete for food resources with native wildlife, spread parasites, and modify the habitat in ways that are harmful to

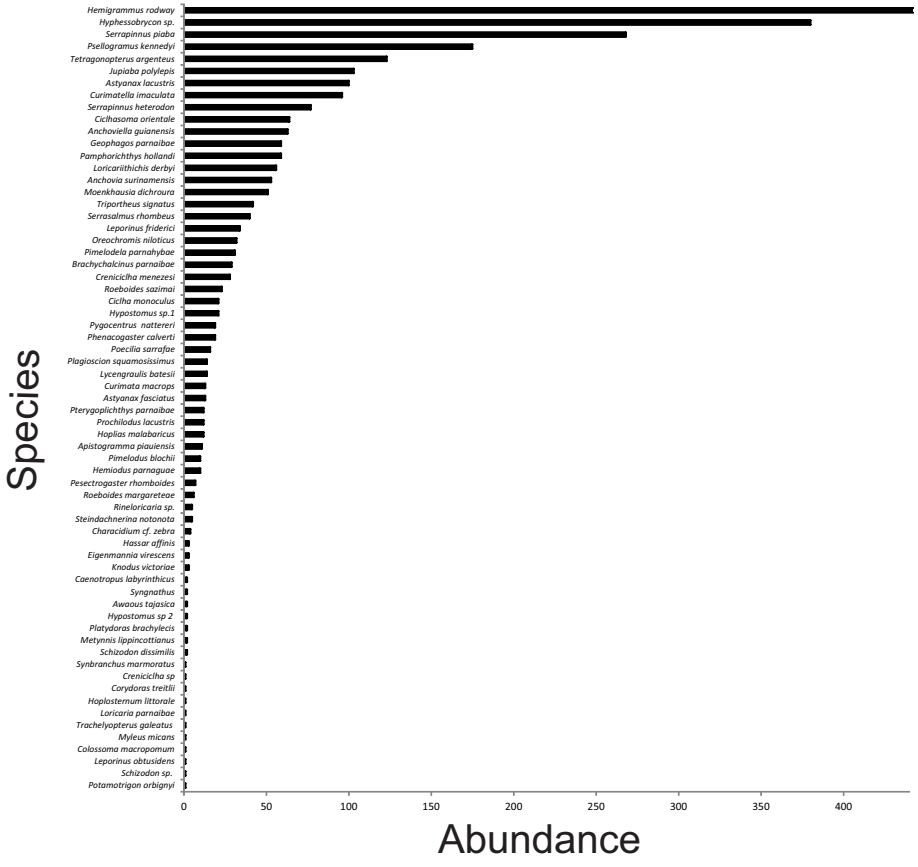

Figure 11. Total abundance (number of specimens) of fish species collected in the lower Parnaíba.

other species (Lima-Júnior, 2012). *Oreochromis niloticus* was also observed in a fish-culture dam at Associação dos Piscicultores de Cantinho in the municipality of Piracuruca (Table 1, Sample 30), although not captured. The greatest number of specimens was captured in the adjacent site (Sample 30, n=510, 19.0% of total specimens). The high number of fish collected near the fish cages, mainly *Hemigrammus rodwayi* with 431 specimens, seems to be the result of proliferation of the fish population caused by the artificial input of food. The fish cage culture is a source of organic matter and phosphorus for the aquatic environment (Alencar Araripe *et al*., 2006). Unfortunately, there is no previous inventory of the fish community in this locality prior to the establishment of the fish culture facility.

Anchovia surinamensis, *Anchoviella guianensis, Awaous tajasica*, *Lycengraulis batesii*, and *Microphis lineatus* occur in both fresh and brackish water, but only the first two occurred in both the rain and dry seasons. Such pattern suggests that the distribution of estuarine species is influenced by seasonal variation in pluviosity in the Parnaíba basin.

Physical habitat alteration, habitat loss, water usage, pollution, and introduction of non-native species are human activities that have severely affected freshwater ecosystems worldwide (Revenga *et al.,* 2005; Dudgeon *et al*., 2006). This also holds true for the Parnaíba river basin, and all of these activities threaten its fish fauna. The margins of the Longá river have been destroyed and modified into agricultural areas (samples 4, 12). The studied area also suffers anthropic effects due to urban pollution, especially in the municipality of Teresina, and destruction of riparian vegetation (samples 13, 14, 15, 16, and 17). Despite the prevalence of these treats to the fish community, there are no published studies about the conservation status of the ichthyofauna of the Parnaíba river. The data about the diversity and distribution of fish species produced in the present study are likely to inform future conservation and management strategies in the area.

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Natural History Stuttgart) for taxonomic information about Syngnathidae. We also thank Carlos A. Figueiredo (Universidade Federal do Estado do Rio de Janeiro, UNIRIO), and an anonymous referee for the critical review and improvements of an earlier version of the manuscript. Field work was done under permit 20088-3/2009 MMA/ICMBio/SISBIO from Sistema de Autorização e Informação em Biodiversidade, Ministério do Meio Ambiente. We thank PIBIC (Programa Institucional de Bolsas de Iniciação Científica) for financial support to A.K.N. Souza, T.C. Costa, and C.M.A. Silva. This study was supported by FAPEPI (Fundação de Amparo à Pesquisa no Estado do Piauí). Research by P.A.Buckup is supported by grants from CNPq (307610/2013-6, 564940/2010-0, 476822/2012-2), FAPERJ (E-26/111.404/2012, E-26/200.697/2014), and CAPES.

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APPENDIX

Voucher Material. Quantities of specimens are indicated in parentheses; lots with photographed specimens are indicated with an asterisk.
Potamotrygon orbignyi*:** UESPIPHB 367* (1). ***Anchovia surinamensis*:** UESPIPHB 101 (1), UESPIPHB 260 (56), UESPIPHB 308 (1), UESPIPHB 235* (38). ***Anchoviella guianensis*:** UESPIPHB 259* (57), MBML 9953 (6). ***Lycengraulis batesii*:** UESPIPHB 129 (1), UESPIPHB 166* (1), UESPIPHB 280 (1), UESPIPHB 360 (1), MBML 9955 (6), MNRJ 43196 (4). ***Eigenmannia virescens*:** UESPIPHB 217* (1), UESPIPHB 229 (2). ***Characidium* cf. *zebra*:** UESPIPHB 323* (1), MNRJ 42558 (3). ***Hoplias malabaricus*:** UESPIPHB 47 (2), UESPIPHB 61 (2), UESPIPHB 125* (1), UESPIPHB 131 (1), UESPIPHB 160 (1), UESPIPHB 183 (1), UESPIPHB 276 (1), UESPIPHB 288 (1), UESPIPHB 354 (2). ***Colossoma macropomum*:** UESPIPHB 310* (1). ***Metynnis lippincottianus*:** UESPIPHB 78 (1), UESPIPHB 212* (1). ***Myleus asterias*:** UESPIPHB 95* (1). ***Pygocentrus nattereri*:** MNRJ 43205 (9), UESPIPHB 53* (9), UESPIPHB 267 (1). ***Serrasalmus rhombeus*:** UESPIPHB 44 (1), UESPIPHB 77 (1), UESPIPHB 121 (1), MBML 9970 (6), UESPIPHB 154* (1), UESPIPHB 187 (1), UESPIPHB 213 (8), UESPIPHB 318 (1), UESPIPHB 328 (2), UESPIPHB 336 (1), UESPIPHB 346 (15). ***Hemiodus parnaguae*:** UESPIPHB 39 (1), UESPIPHB 222 (4), UESPIPHB 238* (1), UESPIPHB 338 (4). ***Leporinus friderici*:** UESPIPHB 127 (1), UESPIPHB 178 (2), UESPIPHB 201 (2), UESPIPHB 215 (1), UESPIPHB 221 (1), UESPIPHB 236* (5), UESPIPHB 261 (1), UESPIPHB 294 (13), UESPIPHB 237 (1), UESPIPHB 337 (6), UESPIPHB 356 (1). ***Leporinus obtusidens*:** UESPIPHB 295* (1). ***Schizodon* aff. *dissimilis*:** UESPIPHB 237 (2)*. ***Schizodon* sp.:** UESPIPHB 200 * (1). ***Caenotropus labyrinthicus*:** UESPIPHB 180*(1), UESPIPHB 306 (1). ***Curimata macrops UESPIPHB 41 (1), UESPIPHB 130* (1), UESPIPHB 257 (1), MNRJ43197 (1), UESPIPHB 291 (4), UESPIPHB 235 (5). ***Curimatella immaculata*:** UESPIPHB 67 (8), UESPIPHB 116 (10), UESPIPHB 135 (15), UESPIPHB 149 (4), UESPIPHB 196 (7), UESPIPHB 206 (4), UESPIPHB 220

(3), UESPIPHB 234 (7), UESPIPHB 258 (4), UESPIPHB 281 (1), UESPIPHB 292 (3), UESPIPHB 292 (3), UESPIPHB 332 (13), UESPIPHB 353 (6), UESPIPHB 355* (19), MBML 9959 (6), MNRJ 43198 (7). ***Psectrogaster rhomboides*****:** UESPIPHB 117 (1), UESPIPHB 157* (1), UESPIPHB 171 (5). ***Steindachnerina notonota*****:** UESPIPHB 118 (1), UESPIPHB 165* (1), UESPIPHB170 (1), MNRJ43199 (1), UESPIPHB 320 (1). ***Prochilodus lacustris*****:** UESPIPHB 40 (1), UESPIPHB 167 (1), UESPIPHB 256* (1), MNRJ43200 (5), UESPIPHB 293 (1), UESPIPHB 322 (3). ***Astyanax fasciatus*****:** UESPIPHB 145 (1), UESPIPHB 189* (1), UESPIPHB 223 (1), UESPIPHB 311 (3), UESPIPHB 317 (7), UESPIPHB 340 (1). ***Astyanax lacustris*** UESPIPHB 42 (1), UESPIPHB 48 (10), UESPIPHB 68 (2), UESPIPHB 84 (6), UESPIPHB 90 (1), UESPIPHB 103 (4), UESPIPHB 108 (5), UESPIPHB 110 (6), MBML 9950 (6), UESPIPHB 158* (1), UESPIPHB 190 (1), UESPIPHB 239 (1) UESPIPHB 296 (1), UESPIPHB 398 (10), UESPIPHB 399 (15), UESPIPHB 499 (4),UESPIPHB 350 (26). ***Brachychalcinus parnaibae*****:** MNRJ 43201 (5), UESPIPHB 91* (5), UESPIPHB 99 (2), UESPIPHB 126 (1), UESPIPHB 148 (1), UESPIPHB 207 (2), UESPIPHB 224 (1), UESPIPHB 265 (1), UESPIPHB 282 (1), UESPIPHB 289 (1), UESPIPHB 309 (9). ***Hemigrammus rodwayi*****:** UESPIPHB 49 (19), UESPIPHB 92 (1), UESPIPHB 132 (5), UESPIPHB 146 (5), UESPIPHB 344* (394), UESPIPHB 345 (37), UESPIPHB 347 (1), MBML 9949 (6), MBML 9969 (10). ***Hyphessobrycon* sp.:** UESPIPHB 69 (21), UESPIPHB 87 (2), UESPIPHB 107 (2), UESPIPHB 113 (9), UESPIPHB 133 (1), UESPIPHB 147 (5), UESPIPHB 192 (19), UESPIPHB 208* (211), UESPIPHB 225 (32), UESPIPHB 312 (14), UESPIPHB 313 (10), UESPIPHB 329 (3), UESPIPHB 349 (44), UESPIPHB 361 (5), MBML 9960 (10), MBML 9966 (6). ***Jupiaba polylepis*****:** UESPIPHB 70 (7), UESPIPHB 98 (1), UESPIPHB 115* (11), UESPIPHB 134 (5), UESPIPHB 191 (1), UESPIPHB 209 (1), UESPIPHB 245 (2), UESPIPHB 285 (1), UESPIPHB 286 (1), UESPIPHB 307 (3), UESPIPHB 313 (10), UESPIPHB 316 (49), UESPIPHB 330 (7), MBML 9958 (6). ***Knodus victoriae*****:** UESPIPHB 233* (1). ***Moenkhausia dichroura*****:** MNRJ 43202 (1), UESPIPHB 71 (1), UESPIPHB 86 (2), UESPIPHB 93 (1), UESPIPHB 136 (7), UESPIPHB 172* (18), UESPIPHB 193 (4), UESPIPHB 210 (4), UESPIPHB 240 (3), UESPIPHB 266 (2), UESPIPHB 297 (6), UESPIPHB 351 (1). ***Psellogrammus kennedyi*****:** UESPIPHB 50 (14), UESPIPHB 72 (9), UESPIPHB 85 (2), UESPIPH 96 (3), UESPIPHB 114 (10), UESPIPHB 151 (103). UESPIPHB 194 (1), UESPIPHB 241* (1), UESPIPHB 264 (9), MBML 9951 (6), MBML 9954 (6), MNRJ 43207 (11). ***Phenacogaster calverti*****:** UESPIPHB 211* (12), MBML 9961 (6), UESPIPHB 247 (1). ***Roeboides sazimai*****:** UESPIPHB 73 (3), UESPIPHB 94 (1), UESPIPHB 128 (1), UESPIPHB 243* (5), UESPIPHB 263 (8), UESPIPHB 279 (4), UESPIPHB

299 (1). ***Roeboides margareteae*:** UESPIPHB 153 (5), UESPIPHB 242* (1), ***Serrapinnus heterodon*:** UESPIPHB 51 (2), UESPIPHB 74 (3), UESPIPHB 88 (6), MBML 9964 (20), UESPIPHB 112 (2), UESPIPHB 226 (35), UESPIPHB 245 (1), UESPIPHB 342* (7), UESPIPHB 362 (1). ***Serrapinnus piaba*:** UESPIPHB 52 (22), MBML 9952 (6), MBML 9962 (6), MBML 9967 (6), MBML 9968 (6), UESPIPHB 75 (1), UESPIPHB 89 (4), UESPIPHB 106 (1), UESPIPHB 111 (32), UESPIPHB 137 (4), UESPIPHB 169 (1), UESPIPHB 195 (64), UESPIPHB 214 (9), UESPIPHB 244 (3), UESPIPHB 262 (1), UESÍPHB 314 (50), UESPIPHB 319 (20), UESPIPHB 341* (40), UESPIPHB 348 (3), UESPIPHB 363 (1). ***Tetragonopterus argenteus*:** UESPIPHB 100 (1), UESPIPHB 150 (1), UESPIPHB 284 (2), UESPIPHB 298* (101), UESPIPHB 326 (1), UESPIPHB 333 (4), UESPIPHB 357 (1), UESPIPHB 534 (1), UESPIPHB 545 (9). ***Triportheus signatus*:** MNRJ 43204 (8), UESPIPHB 76 (7), UESPIPHB 162 (1), UESPIPHB 173 (1), UESPIPHB 300 (24), UESPIPHB 536 (1). . ***Corydoras treitlii*:** UESPIPHB 227* (1). ***Hoplosternum littorale*:** UESPIPHB 366* (1). ***Hypostomus* sp. 1:** UESPIPHB 46 (1), UESPIPHB 248 *(10), UESPIPHB 140 (3), UESPIPHB 202 (2), UESPIPHB 268 (1), UESPIPHB 278 (1). ***Hypostomus* sp. 2:** UESPIPHB 255* (1), UESPIPHB 301(1) ***Loricaria parnahybae*:** UESPIPHB 179* (1), UESPIPHB 250 (4), UESPIPHB 270 (1). ***Loricariichthys derbyi*:** UESPIPHB 54(1), UESPIPHB 139 (6), UESPIPHB 163 (2), UESPIPHB 249 (1), UESPIPHB 269 (24), MPEG 28102 (10), MBML 9956 (6), MBML 9963 (6). ***Pterygoplichthys parnaibae*:** UESPIPHB 62* (9), UESPIPHB 63 (1), UESPIPHB 168 (1). ***Rineloricaria* sp.:** UESPIPHB 250 (4), UESPIPHB 270* (1). ***Pimelodella parnahybae*:** UESPIPHB 79 (3), UESPIPHB 102 (1), UESPIPHB 138 (5), UESPIPHB 161 (1), UESPIPHB 204 (1), UESPIPHB 216 (1), UESPIPHB 228 (4), UESPIPHB 251* (3), UESPIPHB 271 (11), UESPIPHB 302 (1) ***Pimelodus blochii*:** UESPIPHB 45 (1), UESPIPHB 174 (1), UESPIPHB 181 (1), UESPIPHB 303* (7). *Hassar affinis* UESPIPHB 155* (1), UESPIPHB 175 (2). ***Platydoras brachylecis*:** UESPIPHB 156* (1), UESPIPHB 275 (1). ***Tracheliopterus galeatus*:** UESPIPHB 287* (1). ***Awaous tajasica*:** UESPIPHB 205* (1), UESPIPHB 286 (1). ***Microphis lineatus*:** UESPIPHB 124 (2). ***Synbranchus marmoratus*:** UESPIPHB 60* (1). ***Apistogramma piauiensis*:** UESPIPHB 80 (1), UESPIPHB 141* (5), UESPIPHB 152 (5). ***Cichla monoculus*:** UESPIPHB 277* (2). ***Cichlasoma orientale*:** MNRJ 43206 (1), UESPIPHB 57* (7), UESPIPHB 64 (2), UESPIPHB 81 (3), UESPIPHB 105 (12), UESPIPHB 119 (2), UESPIPHB 159 (4), UESPIPHB 184 (5), UESPIPHB 197 (21), UESPIPHB 322 (4), UESPIPHB 335 (1), UESPIPHB 352 (2). ***Crenicichla menezesi*:** UESPIPHB 56 (2), UESPIPHB 82 (3), UESPIPHB 120 (10), UESPIPHB 143 (1), UESPIPHB 185 (5), UESPIPHB 198 (6), UESPIPHB 253 (1),

UESPIPHB 272 (1), UESPIPHB 283 (1), UESPIPHB 304* (1). ***Crenicichla* sp.:** UESPIPHB 290* (1). ***Geophagus parnaibae*:** UESPIPHB 55 (1), UESPIPHB 97 (1), UESPIPHB 109 (1), UESPIPHB 142(2), UESPIPHB 186 (2), UESPIPHB 199 (2), UESPIPHB 218 (2), UESPIPHB 230 (8), UESPIPHB 254* (4), UESPIPHB 255 (1), UESPIPHB 274 (1), UESPIPHB 304 (1), UESPIPHB 323 (4), UESPIPHB 334 (14), UESPIPHB 358 (9), MBML 9965 (6). ***Oreochromis niloticus*:** MBML 9948 (6), UESPIPHB 58* (3), UESPIPHB 65 (29). ***Pamphorichthys hollandi*:** UESPIPHB 66 (3), UESPIPHB 83(11), UESPIPHB 123(3), UESPIPHB 144 (1), UESPIPHB 164 (2), UESPIPHB 188 (5), UESPIPHB 343* (8), UESPIPHB 364 (12), UESPIPHB 315 (1), MBML 9957 (6). ***Poecilia sarrafae*:** UESPIPHB 59 (6), UESPIPHB 104* (13), UESPIPHB 122 (2), UESPIPHB 339 (2). ***Plagioscion squamosissimus*:** UESPIPHB 230* (8), UESPIPHB 272 (6).