Biota Neotropica 16(3): e20150151, 2016
www.scielo.br/bn

biotaneotropica
ISSN 1676-0611 (online edition)
inventory

Inventory of the fish fauna from Ivaí River basin, Paraná State, Brazil

Augusto Frota[1,2,4], Gabriel de Carvalho Deprá[1,2], Letícia Machado Petenucci[1] & Weferson Júnio da Graça[1,3]

[1]*Universidade Estadual de Maringá, Coleção Ictiológica do Núcleo de Pesquisas em Limnologia, Ictiologia e Aquicultura, Av. Colombo, 5790. CEP 87020-900. Maringá, PR, Brasil.*
[2]*Universidade Estadual de Maringá, Programa de Pós-Graduação em Ecologia de Ambientes Aquáticos Continentais, Av. Colombo, 5790. CEP 87020-900. Maringá, PR, Brasil.*
[3]*Universidade Estadual de Maringá, Centro de Ciências Biológicas, Departamento de Biologia e Núcleo de Pesquisas em Limnologia, Ictiologia e Aquicultura, Av. Colombo, 5790. CEP 87020-900. Maringá, PR, Brasil.*
[4]*Corresponding author: Augusto Frota, e-mail: frota.augusto@gmail.com*

FROTA, A., DEPRÁ, G.C., PETENUCCI, L.M., GRAÇA, W.J. **Inventory of the fish fauna from Ivaí River basin, Paraná State, Brazil**. Biota Neotropica. 16(3): e20150151. http://dx.doi.org/10.1590/1676-0611-BN-2015-0151

Abstract: We compiled data on fish fauna of the Ivaí River basin from recent specialised literature, standardised sampling and records of species deposited in fish collections. There were 118 fish species of eight orders and 29 families. Of these, 100 species are autochthonous (84.8%), 13, allochthonous (11.0%) and five, exotic (4.2%). The main causes for the occurrence of non-native species are escapes from aquaculture, introduction for fishing purposes and the construction of the Itaipu hydroelectric plant. The predominance of small and medium-sized Characiformes and Siluriformes, including 13 species new to science, accounts for approximately 11.0% of all species and 13.0% of all native species. About 10.2% of all species and 12.0% of all native species are endemic to the upper stretch of the Ivaí River, isolated by numerous waterfalls in tributary rivers and streams. The Ivaí River basin is subjected to various anthropogenic interferences such as pollution, eutrophication, siltation, construction of dams, flood control, fisheries, species introduction and release of fingerlings. These activities raise concerns about biodiversity of Brazilian inland waters especially regarding the fish fauna; the basin of the Ivaí River already has species classified in categories of extinction risk: *Brycon nattereri* and *Apareiodon vladii* (Vulnerable) and *Characidium heirmostigmata* and *Steindachneridion scriptum* (Endangered). The high species richness of native fish, endemism of some, high environmental heterogeneity, high risk of extinction and lack of knowledge of several other species along with the eminent human activities raise the need to enrich the scientific knowledge for future conservation efforts for the studied basin.
Keywords: *ichthyofauna, upper Paraná River, checklist, biogeographic barriers, conservation.*

FROTA, A., DEPRÁ, G.C., PETENUCCI, L.M., GRAÇA, W.J. **Inventário da ictiofauna da bacia do rio Ivaí, Paraná, Brasil**. Biota Neotropica. 16(3): e20150151. http://dx.doi.org/10.1590/1676-0611-BN-2015-0151

Resumo: Nós compilamos dados sobre a diversidade da ictiofauna da bacia do rio Ivaí proveniente de recentes informações contidas em estudos divulgados na literatura especializada, coletas padronizadas e registros das espécies depositadas em coleções ictiológicas. Foram registradas 118 espécies de peixes pertencentes a oito ordens e 29 famílias. Dessas, 100 são autóctones, (84.8%), 13 são alóctones (11.0%) e cinco são exóticas (4.2%). As principais causas da ocorrência de espécies não nativas são escapes da piscicultura, introduções para pesca e a construção da usina hidrelétrica de Itaipu. Ocorre o predomínio de espécies de Characiformes e Siluriformes com porte pequeno e médio, sendo que 13 espécies são novas, o que representa aproximadamente 11.0% do total de espécies e 13.0% do total de espécies nativas. Ainda, aproximadamente 10.2% do total de espécies e 12.0% do total de espécies nativas correspondem a espécies endêmicas, isoladas pela presença de inúmeras cachoeiras em rios e riachos afluentes no trecho superior do rio Ivaí. A bacia do rio Ivaí está sujeita a uma variedade de interferências antrópicas como poluição, eutrofização, assoreamento, construção de represas, controle do regime de cheias, pesca, introduções de espécies e soltura de alevinos. Tais atividades apontam alarmantes preocupações com a biodiversidade das águas continentais brasileiras sobretudo para a ictiofauna, sendo que a bacia do rio Ivaí já apresenta espécies listadas em categorias de ameaças de extinção como *Brycon nattereri* e *Apareiodon vladii* (Vulneráveis) e *Characidium heirmostigmata* e *Steindachneridion scriptum* (Em Perigo). Devido à alta riqueza de espécies de peixes nativos, endemismo de algumas, alta heterogeneidade ambiental, sérios riscos de extinções e desconhecimento de várias outras espécies somados às eminentes ações antrópicas deve-se enriquecer o aporte científico de futuros apelos conservacionistas para a bacia aqui inventariada.
Palavras-chave: *peixes, alto rio Paraná, lista de espécies, barreiras biogeográficas, conservação.*

Introduction

Of the Brazilian basins, the Paraná River basin is the second largest drainage area after the Amazon basin (Stevaux et al. 1997, Galves et al. 2009). According to Agostinho et al. (2007), the upper section of the Paraná River is the most investigated with regards to Brazilian freshwater fish. This stretch covers water systems that cross the states of Goiás, Minas Gerais, São Paulo, Mato Grosso do Sul and Paraná. In the latter, it extends to the upstream region of the city of Guaíra, formerly Sete Quedas, now submerged by the Itaipu lake.

Studies on fish of the upper Paraná River basin have increased in recent years but are still mainly concentrated in basins of the São Paulo State (Langeani et al. 2007). Although these authors have surveyed the number of species with records in the upper Paraná River basin and totaled 310 valid species and 50 likely new species, a study performed by Galves et al. (2009) on the fish fauna surveys of the main tributaries of the upper Paraná River basin indicated a gap of these studies in relation to the Ivaí River basin, which is an important left bank tributary of the Paraná River, in the Paraná State.

There are only few surveys on fish fauna in the Ivaí River basin, especially for the tributaries, Barra Bonita River (Maier et al. 2008), Bonito River (Viana et al. 2013), some streams located in the Perobas Biological Reserve (Delariva & Silva 2013) and a first-order stream in the municipality of Marialva (Araújo et al. 2011); and there are few genetic studies with some species of Loricariidae (Zawadzki et al. 2004, Portela-Castro et al. 2007, Paiva et al. 2013) or ecological studies (Luiz et al. 2003, Luiz et al. 2005) and description of new species (Graça & Pavanelli 2008, Roxo et al. 2014, Tencatt et al. 2014, Zawadzki et al. 2016) with fish of this basin.

This study aims to provide a compilation of data on the diversity of the fish fauna of the Ivaí River basin from recent specialised literature, standardised sampling and records of species deposited in fish collections. In addition, endemism and threats to the species are discussed.

Material and Methods

1. Study area

A dense drainage network with many tributaries composes the watershed of the Ivaí River, the second largest in the Paraná State, located at the geographical coordinates 22º56'17'' – 25º35'27'' S and 50º44'17'' – 53º41'43'' W (Destefani 2005). The Ivaí River is a left bank tributary of the Paraná River in the Paraná State and has 35,845 km^2 drainage area, which is approximately 685 km in length (Maack 1981). This river is formed in the municipality of Ivaí by the confluence of the rivers Patos and São João (Santos et al. 2008), both in the State Park of Serra da Esperança, on the border between the second and third plateau of the Paraná State (Maack 1981).

The Ivaí River basin has different geological and geomorphological characteristics, since it runs through different lithologies and drains distinct morphological and topographical environments (Destefani 2005). In this way, this author has defined three sections for the basin considering the geology, geomorphology, topography and slope: upper, middle and lower stretches (Figure 1).

The upper section is the longest with about 440 km and has the highest slopes of the whole basin, especially from the source of the Patos River until its confluence with the São João River; also there are rapids and waterfalls due to the type of geological substrate formed by sedimentary rocks, which, according to Maack (1981), promote a stepped relief formed by ridges. By crossing the slope of the Serra da Esperança, the Ivaí River enters the third plateau and flows upon basaltic rocks, giving rise to the middle section, which is approximately 170 km. In this section, the slope is much smaller, with a less energetic relief; there are small and shallow waterfalls as well as important rapids as the Ferro and Índio rapids, intercalated by backwaters of gentle slope (Destefani 2005). The lower section is the floodplain and is approximately 164 km in length. Therein, the river flows over sandstones of the Caiuá formation and of alluvial sediments, with a very small slope of 20 meters until flowing into the Paraná River (Destefani 2005).

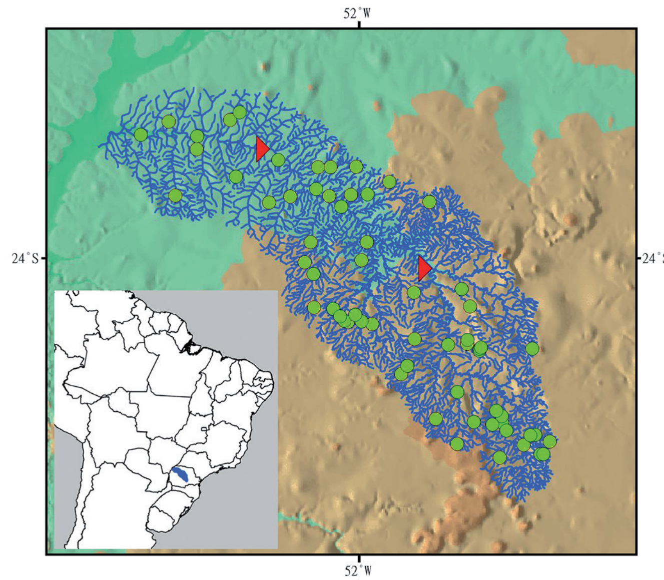

Figure 1. Map of the Ivaí River basin, showing the most thoroughly sampled sites (green dots). Each dot may correspond to more than one collection site. Limits between upper, medium and lower sections are represented by red triangles.

Other studies show some physical characteristics of each part of the Ivaí River basin, such as altitude, temperature and rainfall. Paiva (2008) stated that the altitude in the upper section of this basin has, on average, 800 m, but it can reach up to 1,250 m, in the middle stretch, the average altitude is 500 meters, and in the lower reaches, 250 m, on average. Ichiba (2006) reports the average annual temperatures for each section of the basin: 18°C for the upper reaches, 20ºC in the middle and 22ºC in the lower reaches. The research of Sousa (2006) determined the average annual rainfall for the same sections: 1,800 mm for the upper reaches, 1,600 mm in the middle and 1,400 mm for the lower reaches.

2. Database

The list of species for the Ivaí River basin was developed by consulting the material deposited in the fish collections of the Universidade Estadual de Londrina, Londrina (MZUEL); Museu de Zoologia da Universidade de São Paulo, São Paulo (MZUSP); Museu de História Natural Capão da Imbuia, Curitiba (MHNCI), Museu de Ciências e Tecnologia da PUCRS, Porto Alegre (MCP) and the Coleção Ictiológica do Nupélia, Maringá (NUP), which are available at http://splink.cria.org.br. This list was compared with the species listed for the

 http://dx.doi.org/10.1590/1676-0611-BN-2015-0151

upper Paraná River basin in Langeani et al. (2007). Species with doubtful occurrence or identification were reviewed by experts.

To complement the information, recent collections were conducted under the permission #14028-1 (Sistema de Informação e Autorização em Biodiversidade - Sisbio, Instituto Chico Mendes de Conservação da Biodiversidade) in 21 streams of the upper reaches of the basin, the region with the lowest number of samples. The origin of each species was determined according to by Langeani et al. (2007), in which autochthonous species are native to the upper Paraná River basin, the allochthonous species were introduced from other basins belonging to the Neotropical region and the exotic were introduced from other continents. The origin of each species were obtained from Reis et al. (2003), Langeani et al. (2007), Graça & Pavanelli (2007) and Julio Júnior et al. (2009), which compile data of several long-term studies carried out by the Nupélia – Universidade Estadual de Maringá.

Threat level was determined in accordance with the Portaria do Ministério do Meio Ambiente Nº 445, of December 17th, 2014 and changed by Nº 98, of April 28th, 2015, which recognize species of fish and aquatic invertebrates of Brazilian fauna threatened with extinction classified in the following categories: Extinct in the Wild (EW), Critically Endangered (CR), Endangered (EN) and Vulnerable (VU). For endemism determinations, some species were considered as restricted to the basin by Graça & Pavanelli (2008), Roxo et al. (2014), Tencatt et al. (2014), Zawadzki et al. (2016) and personal communications from Cláudio H. Zawadzki (UEM); other species were considered endemic by means of analysis and comparison of data obtained with comparative material from adjacent basins.

3. *Fish identification*

Identification follows Graça & Pavanelli (2007), Graça & Pavanelli (2008), Tencatt et al. (2014) and Roxo et al. (2014). Some individuals of *Trichomycterus* identified as *Trichomycterus* sp., *Trichomycterus* sp. 1 *Trichomycterus* sp. 2 and *Trichomycterus* sp. 3 in the studies of Maier et al. (2008), Araújo et al. (2011), Delariva & Silva (2013) and Viana et al. (2013), which are deposited in the fish collection of Nupélia, were re-examined and identified as *Trichomycterus davisi* (Haseman, 1911). In addition, some species recorded in the collections analysed were re-examined and identifications were rectified, namely: *Hypostomus aspilogaster* (Cope, 1894) is *Hypostomus ancistroides* (Ihering, 1911); *Hypostomus* sp. is *Hypostomus* sp. 1; *Hypostomus* sp. 1 is *Hypostomus* sp. 2; *Hypostomus* sp. 3 is *Hypostomus hermanni* (Ihering, 1905); *Corumbataia* sp. is *Hisonotus pachysarkos* Zawadzki, Roxo & Graça, 2016; *Bryconamericus exodon* (Eigenmann, 1907) is *Piabarchus* aff. *stramineus* (Eigenmann, 1908); *Creagrutus* sp. is *Bryconamericus* sp.; *Hyphessobrycon* sp. is *Diapoma guarani* (Mahnert & Géry, 1987); *Hyphessobrycon* aff. *guarani* Mahnert & Géry, 1987 is *Planaltina* sp.; *Mimagoniates microlepis* (Steindachner, 1877) is *Piabarchus* aff. *stramineus; Oligosarcus* sp. is *Oligosarcus paranensis* Menezes & Géry, 1983; *Piabina* sp. is *Piabina argentea* Reinhardt, 1867; *Serrasalmus spilopleura* Kner, 1858 is *Serrasalmus maculatus* Kner, 1858; *Phalloceros* aff. *caudimaculatus* (Hensel, 1868) is *Phalloceros harpagos* Lucinda, 2008; *Gymnotus* aff. *carapo* (Linnaeus, 1758) is *Gymnotus inaequilabiatus* (Valenciennes, 1839), *Crenicichla niederleinii* (Holmberg, 1891) and *Crenicichla haroldoi* Luengo & Britski, 1974 are *Crenicichla jaguarensis* Haseman, 1911. Five species have had taxonomic changes recently: *Astyanax altiparanae* Garutti & Britski, 2000 considered a junior synonym of *A. lacustris* (Lütken, 1875) by Lucena and Soares (2016); three new genus changes of *Bryconamericus stramineus* to *Piabarchus*, *Hyphessobrycon guarani* to *Diapoma* by Thomaz et al. (2015) and *Hisonotus insperatus* Britski & Garavello, 2003 and *H. oliveirai* to *Curculionichthys* by Roxo et al. (2015).

Results

There were 118 fish species registered in the Ivaí River basin (Table 1) belonging to eight orders and 29 families (Table 2). The most species-rich orders are Siluriformes and Characiformes (Table 1), with 51 and 48 species, respectively (Table 2). Together, they represent 83.9% of all species registered. The richest families are Loricariidae and Characidae with, respectively, 24 and 20 species (Table 2), representing approximately 37.2% of the species.

The Ivaí River basin has 13 new species to science (species marked with an asterisk are endemic to the Ivaí River basin; Figure 2, Table 1): *Ancistrus* sp., *Apareiodon* sp.*, *Aphyocharax* sp., *Bryconamericus* sp.*, *Cnesterodon* sp.*, *Hoplias* sp. 2, *Hoplias* sp. 3, *Hypostomus* sp. 1*, *Hypostomus* sp. 2*, *Hypostomus* sp. 3*, *Neoplecostomus* sp.*, *Odontostilbe* sp. and *Planaltina* sp.*, representing 11.0% of all species and 13.0% of native species. Eight of the new species plus *Characidium heirmostigmata* Graça & Pavanelli, 2008, *Corydoras lacrimostigmata* Tencatt, Britto & Pavanelli, 2014, *Curculionichthys oliveirai* (Roxo, Zawadzki & Troy, 2014) and *Hisonotus pachysarkos* Zawadzki, Roxo & Graça, 2016 make a total of twelve endemic species (Figure 2, Table 1), corresponding to 10.2% of all species and 12.0% of all native species. Fish species of the Ivaí River basin listed in the Portaria do Ministério do Meio Ambiente Nº 445 and changed by Nº 98 fall into the conservation status categories Endangered (EN) and Vulnerable (VU) (Table 1). The following species are considered to be the most threatened: *Apareiodon vladii* Pavanelli, 2006; *Brycon nattereri* Günther, 1864; *Characidium heirmostigmata* Graça & Pavanelli, 2008; and *Steindachneridion scriptum* (Miranda-Ribeiro, 1918).

Five exotic species were captured (Figure 3). Of these, the carp, *Cyprinus carpio* (Linnaeus, 1758), and the tilapias, *Oreochromis niloticus* (Linnaeus, 1758) and *Tilapia rendalli* (Boulenger, 1897), probably colonised the basin by escaping from fish farms. This also explains the presence of the other two exotic species, the channel catfish, *Ictalurus punctatus* (Rafinesque, 1818), and the black bass, *Micropterus salmoides* (La Cépède, 1802), along with introduction for sport-fishing purposes. From the 13 allochthonous species (Figure 2, Table 1), nine invaded the upper Paraná River and the Ivaí River from the lower Paraná basin through the spawning channel of the Itaipu Reservoir (Canal da Piracema), opened December 2002. Those species are: *Apteronotus* aff. *albifrons* (Linnaeus, 1766), *Hemiodus orthonops* Eigenmann & Kennedy, 1903, *Hypostomus commersoni* Valenciennes, 1836, *Pimelodus ornatus* Kner, 1858, *Porotergus ellisi* Arámburu, 1957, *Potamotrygon falkneri* Castex & Maciel, 1963, *Roeboides descalvadensis* Fowler, 1932, *Steindachnerina brevipinna* (Eigenmann & Eigenmann, 1889) and *Trachydoras paraguayensis* (Eigenmann & Ward, 1907). Two other allochthonous species, *Erythrinus erythrinus* (Bloch & Schneider, 1801) and *Hoplerythrinus unitaeniatus* (Agassiz, 1829), were introduced by sport fishers; one species, *Plagioscion squamosissimus* (Heckel, 1840), was introduced by escape from fish farming; and another species, *Poecilia reticulata* Peters, 1859, was introduced for mosquito control.

Table 1. Ichthyofauna from the Ivaí River basin: species, voucher specimens, origin of each species, threat level and endemism. The symbol # refers to species added to the list due to personal observation. The asterisk (*) represents endemic species.

Species	Voucher	Origin/Threat level
ELASMOBRANCHII		
Myliobatiformes		
Potamotrygonidae		
1 *Potamotrygon falkneri* Castex & Maciel, 1963	NUP10918	Allochthonous
ACTINOPTERYGII		
Characiformes		
Acestrorhynchidae		
2 *Acestrorhynchus lacustris* (Lütken, 1875)	NUP5541	Autochthonous
Anostomidae		
3 *Leporinus amblyrhynchus* Garavello & Britski, 1987	NUP5554	Autochthonous
4 *Leporinus friderici* (Bloch, 1794)	#	Autochthonous
5 *Leporinus octofasciatus* Steindachner, 1915	NUP10636	Autochthonous
6 *Schizodon nasutus* Kner, 1858	NUP1440	Autochthonous
Bryconidae		
Bryconinae		
7 *Brycon nattereri* Günther, 1864	NUP8534	Autochthonous/(VU)
Salmininae		
8 *Salminus brasiliensis* (Cuvier, 1816)	#	Autochthonous
Characidae		
9 *Astyanax bockmanni* Vari & Castro, 2007	NUP5487	Autochthonous
10 *Astyanax lacustris* (Lütken, 1875)	NUP3941	Autochthonous
11 *Astyanax* aff. *fasciatus* (Cuvier, 1819)	NUP11538	Autochthonous
12 *Astyanax* aff. *paranae* Eigenmann, 1914	NUP11794	Autochthonous
13 *Hemigrammus* cf. *marginatus* Ellis, 1911	NUP1498	Autochthonous
14 *Moenkhausia* aff. *gracilima* Eigenmann, 1908	NUP9746	Autochthonous
15 *Oligosarcus pintoi* Campos, 1945	NUP16388	Autochthonous
16 *Oligosarcus paranensis* Menezes & Géry, 1983	NUP16381	Autochthonous
Aphyocharacinae		
17 *Aphyocharax* sp.	NUP5550	Autochthonous
Characinae		
18 *Galeocharax knerii* (Steindachner, 1879)	NUP10737	Autochthonous
19 *Roeboides descalvadensis* Fowler, 1932	NUP5531	Allochthonous
Cheirodontinae		
20 *Odontostilbe* sp.	NUP5533	Autochthonous
21 *Serrapinnus notomelas* (Eigenmann, 1915)	NUP17827	Autochthonous
Stevardiinae		
22 *Bryconamerius* aff. *iheringii* (Boulenger, 1887)	NUP16083	Autochthonous
23 *Bryconamericus turiuba* Langeani, Lucena, Pedrini & Tarelho-Pereira, 2005	NUP16369	Autochthonous
24 *Bryconamericus* sp.	NUP17150	Autochthonous*
25 *Diapoma guarani* (Mahnert & Géry, 1987)	NUP5066	Autochthonous
26 *Piabarchus* aff. *stramineus* (Eigenmann, 1908)	NUP16385	Autochthonous
27 *Piabina argentea* Reinhardt, 1867	NUP5010	Autochthonous
28 *Planaltina* sp.	NUP17152	Autochthonous*
Curimatidae		
29 *Cyphocharax modestus* (Fernández-Yépez, 1948)	NUP11730	Autochthonous

http://dx.doi.org/10.1590/1676-0611-BN-2015-0151

Continued Table 1.

30 *Cyphocharax nagelii* (Steindachner, 1881)	NUP5530	Autochthonous
31 *Steindachnerina brevipinna* (Eigenmann & Eigenmann, 1889)	NUP5538	Allochthonous
32 *Steindachnerina* cf. *corumbae* Pavanelli & Britski, 1999	NUP16396	Autochthonous
33 *Steindachnerina insculpta* (Fernández-Yépez, 1948)	NUP5529	Autochthonous
Crenuchidae		
34 *Characidium* aff. *zebra* Eigenmann, 1909	NUP1383	Autochthonous
35 *Characidium gomesi* Travassos, 1956	NUP11718	Autochthonous
36 *Characidium heirmostigmata* Graça & Pavanelli, 2008	NUP17136	Autochthonous*/(EN)
Erythrinidae		
37 *Erythrinus erythrinus* (Bloch & Schneider, 1801)	NUP11729	Allochthonous
38 *Hoplerythrinus unitaeniatus* (Spix & Agassiz, 1829)	NUP1499	Allochthonous
39 *Hoplias intermedius* (Günther, 1864)	NUP10020	Autochthonous
40 *Hoplias* sp. 2	NUP14323	Autochthonous
41 *Hoplias* sp. 3	NUP15907	Autochthonous
Hemiodontidae		
42 *Hemiodus orthonops* Eigenmann & Kennedy, 1903	#	Allochthonous
Parodontidae		
43 *Apareiodon affinis* (Steindachner, 1879)	NUP5539	Autochthonous
44 *Apareiodon piracicabae* (Eigenmann, 1907)	NUP4548	Autochthonous
45 *Apareiodon vladii* Pavanelli, 2006	NUP16081	Autochthonous/(VU)
46 *Apareiodon* sp.	NUP1501	Autochthonous*
47 *Parodon nasus* Kner, 1859	NUP9857	Autochthonous
Prochilodontidae		
48 *Prochilodus lineatus* (Valenciennes, 1850)	NUP6064	Autochthonous
Serrasalmidae		
49 *Serrasalmus maculatus* Kner, 1858	#	Autochthonous
Cypriniformes		
Cyprinidae		
50 *Cyprinus carpio* Linnaeus, 1758	NUP860	Exotic
Cyprinodontiformes		
Poeciliidae		
51 *Cnesterodon* sp.	NUP5475	Autochthonous*
52 *Phalloceros harpagos* Lucinda, 2008	NUP5551	Autochthonous
53 *Poecilia reticulata* Peters, 1859	NUP11792	Allochthonous
Gymnotiformes		
Apteronotidae		
54 *Apteronotus* aff. *albifrons* (Linnaeus, 1766)	NUP3058	Allochthonous
55 *Apteronotus caudimaculosus* Santana, 2003	NUP10613	Autochthonous
56 *Porotergus ellisi* Arámburu, 1957	NUP3057	Allochthonous
Gymnotidae		
57 *Gymnotus inaequilabiatus* (Valenciennes, 1839)	NUP15364	Autochthonous
58 *Gymnotus sylvius* Albert & Fernandes-Matioli, 1999	NUP11281	Autochthonous
Perciformes		
Centrarchidae		
59 *Micropterus salmoides* (La Cepède, 1802)	NUP2672	Exotic

Continued Table 1.

Cichlidae		
60 *Cichlasoma paranaense* Kullander, 1983	NUP11728	Autochthonous
61 *Crenicichla britskii* Kullander, 1982	NUP3575	Autochthonous
62 *Crenicichla jaguarensis* Haseman, 1911	NUP10797	Autochthonous
63 *Geophagus brasiliensis* (Quoy & Gaimard, 1824)	NUP5524	Autochthonous
64 *Oreochromis niloticus* (Linnaeus, 1758)	NUP15900	Exotic
65 *Tilapia rendalli* (Boulenger, 1897)	NUP858	Exotic
Sciaenidae		
66 *Plagioscion squamosissimus* (Heckel, 1840)	#	Allochthonous
Siluriformes		
Auchenipteridae		
67 *Glanidium* cf. *cesarpintoi* Ihering, 1928	NUP5543	Autochthonous
68 *Tatia neivai* (Ihering, 1930)	NUP11045	Autochthonous
69 *Parauchenipterus galeatus* (Linnaeus, 1766)	#	Autochthonous
Callichthyidae		
70 *Callichthys callichthys* (Linnaeus, 1758)	NUP6122	Autochthonous
71 *Corydoras* aff. *aeneus* (Gill, 1858)	NUP11736	Autochthonous
72 *Corydoras ehrhardti* Steindachner, 1910	NUP15899	Autochthonous
73 *Corydoras lacrimostigmata* Tencatt, Britto & Pavanelli, 2014	NUP1446	Autochthonous*
Cetopsidae		
74 *Cetopsis gobioides* Kner, 1858	NUP11673	Autochthonous
Doradidae		
75 *Trachydoras paraguayensis* (Eigenmann & Ward, 1907)	NUP2084	Allochthonous
Loricariidae		
Hypoptopomatinae		
76 *Curculionichthys insperatus* (Britski & Garavello, 2003)	NUP3578	Autochthonous
77 Curculionichthys oliveirai (Roxo, Zawadzki & Troy, 2014)	NUP16070	Autochthonous*
78 *Hisonotus francirochai* (Ihering, 1928)	NUP16379	Autochthonous
79 *Hisonotus pachysarkos* Zawadzki, Roxo & Graça, 2016	NUP16258	Autochthonous*
Hypostominae		
80 *Ancistrus* sp.	NUP15978	Autochthonous
81 *Hypostomus ancistroides* (Ihering, 1911)	NUP16080	Autochthonous
82 *Hypostomus albopunctatus* (Regan, 1908)	NUP10109	Autochthonous
83 *Hypostomus commersoni* Valenciennes, 1836	NUP856	Allochthonous
84 *Hypostomus hermanni* (Ihering, 1905)	NUP9806	Autochthonous
85 *Hypostomus iheringii* (Regan, 1908)	NUP 4837	Autochthonous
86 *Hypostomus margaritifer* (Regan, 1908)	NUP4921	Autochthonous
87 *Hypostomus* aff. *paulinus* (Ihering, 1905)	NUP15329	Autochthonous
88 *Hypostomus strigaticeps* (Regan, 1908)	NUP4530	Autochthonous
89 *Hypostomus regani* (Ihering, 1905)	NUP4979	Autochthonous
90 *Hypostomus* cf. *topavae* (Godoy, 1969)	NUP4529	Autochthonous
91 *Hypostomus* sp. 1	NUP 2597	Autochthonous*
92 *Hypostomus* sp. 2	NUP10917	Autochthonous*
93 *Hypostomus* sp. 3	NUP 4745	Autochthonous*
94 *Megalancistrus parananus* (Peters, 1881)	NUP4466	Autochthonous

Continued Table 1.

Loricariinae		
95 *Farlowella amazonum* (Günther, 1864)	NUP1450	Autochthonous
96 *Loricaria prolixa* Isbrücker & Nijssen, 1978	NUP3359	Autochthonous
97 *Rineloricaria pentamaculata* Langeani & Araújo, 1994	NUP16079	Autochthonous
98 *Rineloricaria* cf. *latirostris* (Boulenger, 1900)	NUP5527	Autochthonous
Neoplecostominae		
99 *Neoplecostomus* sp.	NUP10113	Autochthonous*
Heptapteridae		
100 *Cetopsorhamdia iheringi* Schubart & Gomes, 1959	NUP5483	Autochthonous
101 *Heptapterus mustelinus* (Vallenciennes, 1835)	NUP11667	Autochthonous
102 *Imparfinis borodini* Mees & Cala, 1989	NUP4549	Autochthonous
103 *Imparfinis mirini* Haseman, 1911	NUP3582	Autochthonous
104 *Imparfinis schubarti* (Gomes, 1956)	NUP11809	Autochthonous
105 *Pimelodella avanhandavae* Eigenmann, 1917	NUP5553	Autochthonous
106 *Pimelodella gracilis* (Valenciennes, 1835)	NUP1783	Autochthonous
107 *Rhamdia quelen* (Quoy & Gaimard, 1824)	NUP16090	Autochthonous
108 *Phenacorhamdia tenebrosa* (Schubart, 1964)	NUP16072	Autochthonous
Ictaluridae		
109 *Ictalurus punctatus* (Rafinesque, 1818)	NUP757	Exotic
Pimelodidae		
110 *Iheringichthys labrosus* (Lütken, 1874)	NUP5544	Autochthonous
111 *Pimelodus microstoma* Steindachner, 1877	NUP5534	Autochthonous
112 *Pimelodus ornatus* Kner, 1858	NUP10747	Allochthonous
113 *Pimelodus paranaensis* Britski & Langeani, 1988	NUP9143	Autochthonous
114 *Pseudoplatystoma corruscans* (Spix & Agassiz, 1829)	#	Autochthonous
115 *Steindachneridion scriptum* (Miranda-Ribeiro, 1918)	NUP2511	Autochthonous/(EN)
Trichomycteridae		
116 *Trichomycterus davisi* (Haseman, 1911)	NUP16071	Autochthonous
117 *Trichomycterus diabolus* Bockmann, Casatti & de Pinna, 2004	NUP5482	Autochthonous
Synbranchiformes		
Synbranchidae		
118 *Synbranchus marmoratus* Bloch, 1795	NUP5552	Autochthonous

Discussion

The ichthyofauna of the Ivaí River basin, comprised of 118 species, has an alpha diversity superior to that of all other river systems confined to the Paraná State. There are 110 species in the Tibagi River basin (Shibatta et al. 2002), 76 in the Pirapó River basin (Pagotto et al. 2012), 62 in the Piquiri River basin (Gubiani et al. 2006), 54 in the Jordão River basin (Frota et al. in prep.) and 48 in the Areia river basin (Frota et al. in prep.). The Iguaçu River basin, another important system in the Paraná State, although not completely comprised in it, lacks a complete inventory, but Baumgartner et al. (2012) found in its lower stretch 106 species, an amount similar to that of the Ivaí River as a whole. Other comparable systems within the upper Paraná River basin for which inventories are available show similar species richness. The Mogi Guaçu River has about 135 species (Meschiatti & Arcifa 2009, Oliveira et al. 2009), and the Corumbá Reservoir and its influence area, 119 (Pavanelli et al. 2007). The upper Paraná floodplain harbors 182 fish species, a number considerably higher than that observed in the Ivaí River basin, but that region also presents a higher habitat diversity (Graça & Pavanelli 2007).

In the headwaters of the Ivaí River, there is a predominance of small and medium-sized (15 cm or less in length) Characiformes and Siluriformes. As already highlighted by Viana et al. (2013) in their study of the Bonito River, backwaters separated by rapids typically bear a wide variety of microhabitats. Those environments favour species with greater ability to stay in the water column (*e.g.*, *Astyanax* and *Bryconamericus*), as well as benthic species equipped with spines that

Table 2. Number of species in the Ivaí River basin, sorted by Order and Family.

Order	Family	Number of species	%
1. Characiformes		48	40.7
	1. Acestrorhynchidae	1	0.8
	2. Anostomidae	4	3.4
	3. Bryconidae	2	1.7
	4. Characidae	20	16.9
	5. Curimatidae	5	4.2
	6. Crenuchidae	3	2.5
	7. Erythrinidae	5	4.2
	8. Hemiodontidae	1	0.8
	9. Parodontidae	5	4.2
	10. Prochilodontidae	1	0.8
	11. Serrasalmidae	1	0.8
2. Cypriniformes		1	0.8
	12. Cyprinidae	1	0.8
3. Cyprinodontiformes		3	2.5
	13. Poeciliidae	3	2.5
4. Gymnotiformes		5	4.2
	14. Apteronotidae	3	2.5
	15. Gymnotidae	2	1.7
5. Perciformes		8	6.8
	16. Centrarchidae	1	0.8
	17. Cichlidae	6	5.1
	18. Sciaenidae	1	0.8
6. Siluriformes		51	43.2
	19. Auchenipteridae	3	2.5
	20. Callichthyidae	4	3.4
	21. Cetopsidae	1	0.8
	22. Doradidae	1	0.8
	23. Loricariidae	24	20.3
	24. Heptapteridae	9	7.6
	25. Ictaluridae	1	0.8
	26. Pimelodidae	6	5.1
	27. Trichomycteridae	2	1.7
7. Synbranchiformes		1	0.8
	28. Synbranchidae	1	0.8
8. Myliobatiformes		1	0.8
	29. Potamotrygonidae	1	0.8

allow them to attach to rocks and resist the water flow (*e.g.*, loricariids and *Trichomycterus*). On the other hand, higher-order waterbodies have greater water volume and light incidence, which result in increased primary production and greater availability of resources (Ferreira et al. 2010). Thus, the lower reaches of the Ivaí River basin bear large-sized pelagic (*e.g.*, the characiforms *Salminus* and *Leporinus*) and benthic (*e.g.*, the siluriforms *Pseudoplatystoma* and *Steindachneridion*) species. In addition, higher-order streams offer a wider array of food items, which allows the coexistence of several trophic guilds ranging from detritivores and planktivores to piscivores, also contributing to their species richness (Ferreira et al. 2010).

The proportion of new species in relation to the total observed in the Ivaí River basin (11.0%) is close to the 14.4% reported by Langeani et al. (2007) for the entire upper Paraná River. Of the new species from the Ivaí River, only five are not endemic, and have already been recognized as so in previous studies performed in other river systems (*e.g.*, Graça & Pavanelli 2007). That shows how poorly known the Ivaí River basin is and that the sampling of low-order streams can reveal unknown species even in a relatively well-sampled river basin such as that of the upper Paraná River. The identification of areas of endemism is extremely important considering that they compose basic geographic units that allow understanding of the evolution of complex regional biota (Morrone 1994) and that should be prioritised for biodiversity conservation (Löwenberg-Neto & Carvalho 2004). Historical biogeography may explain this endemism as a result of speciation processes caused by the emergence of geographic barriers mainly in the upper reaches of the basin, located on the Serra da Esperança. Maack (1981) stated that this mountain range is part of the Triassic-Jurassic relief and corresponds, among other basins, to areas draining the headwaters of the Ivaí River. The sandy and clayey rocks of the geological formations that underlie the Serra da Esperança, combined with the dense drainage network, allow the development of a very uneven relief, with altitudes up to 1,200 m (Maack 1981). Thus, tectonism imposed deformations to the basis, forming some local inflections on the ground, as the Ponta Grossa Arch, and had close relationship with the basaltic effusion in the Mesozoic. Because of these orogenetic features, in that region there are numerous waterfalls, some over 50 meters high, such as Saltos São João and São Francisco (Maack 1981). According to Ribeiro (2006), the formation of some of the Paraná State river basins was strongly affected by the origin of the Ponta Grossa Arch, which may have had an influence on speciation processes.

According to IUCN (2012), the categories Vulnerable and Endangered contain species to which the best available evidence indicates they are at, respectively, high and very high risk of extinction in the wild. Environments with species listed in these categories should be prioritized in terms of conservation. It is therefore important to create more Conservation Units and National Plans that focus the full protection of these sites, such as stretches of the upper Ivaí River basin where most records of *Characidium heirmostigmata* (Endangered), *Apareiodon vladii* and *Brycon nattereri* (vulnerable) were made. Additionally, for many species there is no adequate information to assess, directly or indirectly, the risk of extinction, therefore more studies are necessary to determine a more appropriate threat classification.

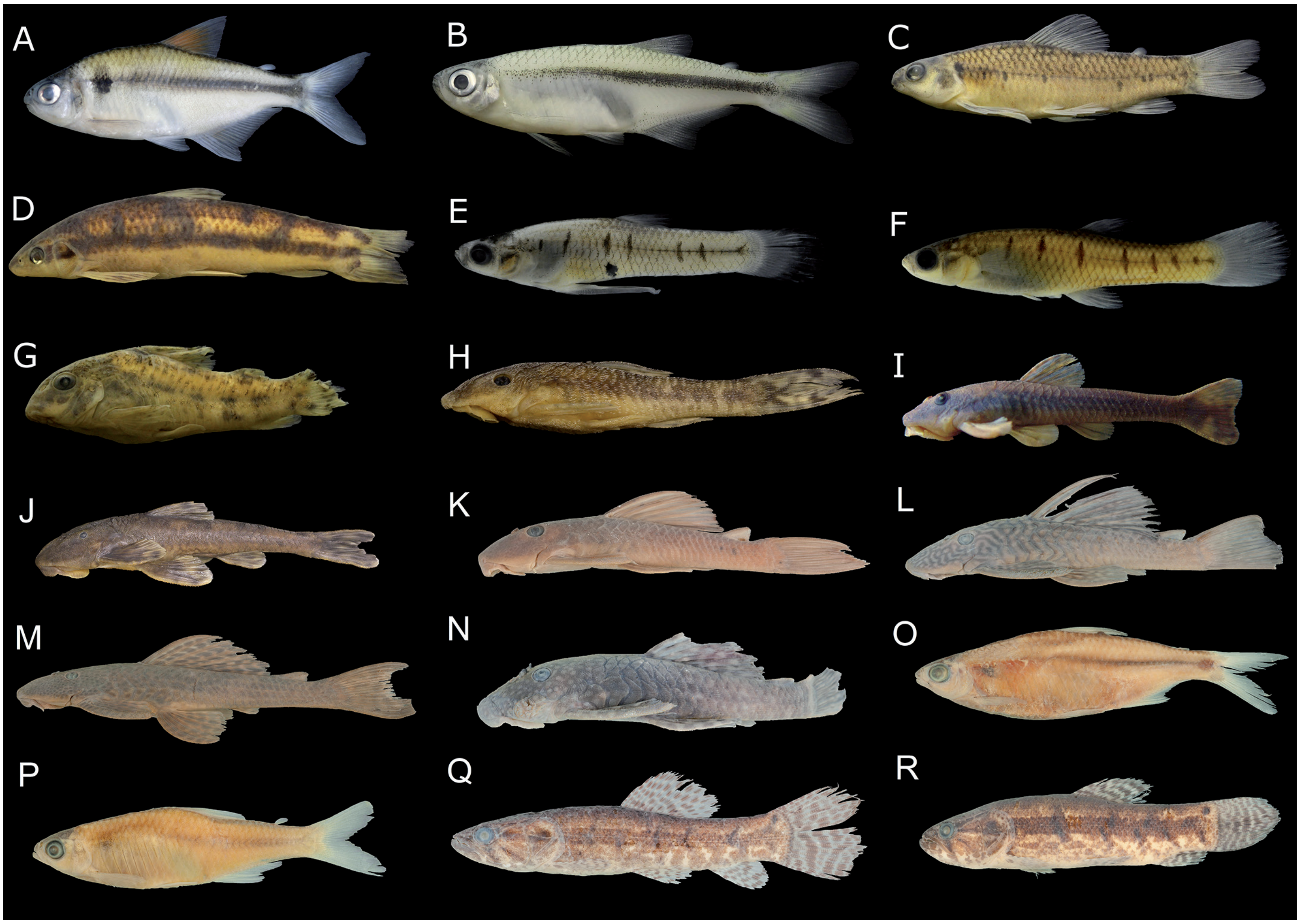

Figure 2. Representative specimens of endemic and new fish species to the Ivaí River basin. Their catalogue numbers in the Coleção Ictiológica do Nupélia (NUP) and standard lengths are presented after the names of species. A) *Bryconamericus* sp., NUP 17150, 66.7 mm; B) *Planaltina* sp., NUP 17152, 39.6 mm; C) *Characidium heirmostigmata*, NUP 17136, 46.6 mm; D) *Apareiodon* sp., NUP 1501, 89.7 mm; E) *Cnesterodon* sp. (male), NUP 4167, 19.2 mm; F) *Cnesterodon* sp. (female), NUP 5475, 30.3 mm; G) *Corydoras lacrimostigmata*, NUP 1446, 33.6 mm; H) *Curculionichthys oliveirai* - NUP 16070, 28.7 mm; I) *Hisonotus pachysarkos*, NUP 16258, 35.8 mm; J) *Neoplecostomus* sp., NUP 10113, 81.1 mm; K) *Hypostomus* sp. 1, NUP 2597, 86.8 mm; L) *Hypostomus* sp. 2; NUP 10917, 141.1 mm; M) *Hypostomus* sp. 3; NUP 4745, 139.97 mm; N) *Ancistrus* sp., NUP 15978, 101.7 mm; O) *Odontostilbe* sp., NUP 5553, 70.3 mm; P) *Aphyocharax* sp., NUP 5550, 39.1 mm; Q) *Hoplias* sp. 2, NUP 14323, 94.2 mm; R) *Hoplias* sp. 3, NUP 15907, 101.7 mm.

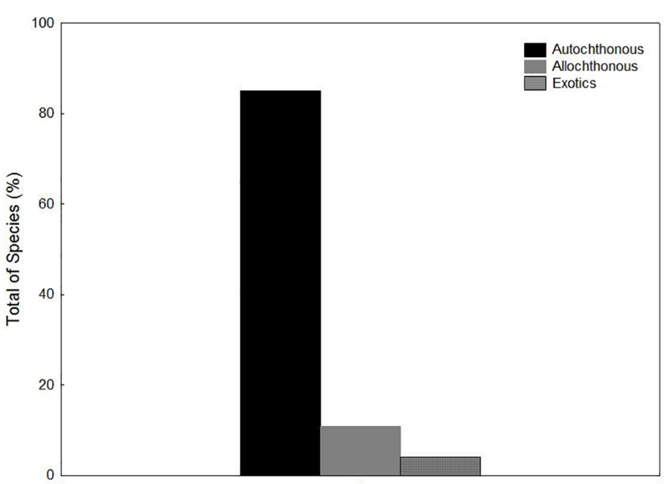

Figure 3. Graphic showing the percentages of the origins of species in the Ivaí River basin.

Agostinho et al. (2005) provided alarming data on the habitat conditions of Brazilian freshwater species and listed the main causes of biodiversity loss: pollution, eutrophication, siltation, construction of dams, flood control, fisheries and species introduction. This is also true for the Ivaí River basin (Affonso et al. 2015). In its drainage area, there are nearly one million inhabitants, of which only 36% have domestic sewage treatment (Paraná 2010). Also contributing to the pollution of its waters, the area comprises virtually no conservation units and little riparian vegetation due to the intensive use of the soil for agriculture and cattle raising (Paraná 2010). These activities greatly contribute to the siltation of the waterbodies, which was observed in the sites sampled herein and by Viana et al. (2013), and lead to destruction of native vegetation that provide important food items in the diet of some species.

Hydropower enterprises threaten fish biodiversity by controlling the hydrological regime and changing the longitudinal distribution of the species (Petry et al. 2011). This affects the reproductive success of the migratory species by influencing the timing, duration and intensity of floods and droughts (Pelicice et al. 2015). In the last few years, several projects for building hydroelectric plants of different proportions in the Ivaí River basin have been put forward. Those projects were received with apprehension not only by ecologists (Affonso et al. 2015), but also by communities that would be directly affected by their implantation. By demonstrating that the number of new, endemic and threatened species in the Ivaí River is greater than previously imagined, the present paper reinforces the need to promote popular manifestations against those dams.

Although overfishing is not a major problem in the Ivaí River basin, sport fishing contributes to the accidental or intentional introduction of species. In that basin, escapes from fish farms and invasion from the lower Paraná River basin also contribute to the presence of non-native species. Among the ones observed in the Ivaí River basin, few have been studied for their potential of invasion and possible antagonistic interactions with native species. That is the case of *Plagioscion squamosissimus*, which has been demonstrated to consume the same food items as other piscivores in the upper Paraná flodplain and thus, to be a probable competitor (Pereira et al. 2015). Similar studies are not available for *Micropterus salmoides*, but the fact that this species is also a piscivore indicate that it also has a potential to affect negatively native species from the Ivaí River. This calls for a close observation upon invasive species, as in the study of Pelicice & Agostinho (2009), who reported on the relationship between the expansion of *Cichla kelberi* Kullander & Ferreira in the Rosana Reservoir and the decline of fish communities associated with macrophyte stands. Although this species is absent from the Ivaí River Basin, a similar threat may be posed by *M. salmoides* and *P. squamosissimus*.

An activity that has become quite common in the Ivaí River is the careless release of thousands of fingerlings of the species of sport fishes, *e.g. Leporinus* spp., *Piaractus mesopotamicus*, *Pseudoplatystoma* spp., *Prochilodus* spp. and *Salminus* spp. Although welcomed by the population, this practice is stated by Agostinho et al. (2007) as frequently inefficient (because the river was devoid of its ancestral capacity of supporting large fish populations) or even harmful to the natural populations. It potentially causes loss of genetic diversity and of important alleles selected along many years by their advantages to the survival of the species in that particular habitat, as well as introduction of new pathogens and parasites (Agostinho et al. 2010). Thus, until those actions are carried out based on a large body of knowledge on the life history and population genetics of the species that are being reintroduced, they will continue to be no more than a waste of public money and an additional threat to the native species, as well as a deceiving electoral strategy.

From the results obtained, it becomes evident the need for efforts to preserve the Ivaí River basin, given its high environmental heterogeneity, high species richness, endemism and high risk of extinction of some species. In addition, the lack of information on biology and ecology of various species and the eminent human activities that affect much of the waterbodies in the basin, raise the need for continuity of studies on fish fauna in this basin.

Acknowledgements

We are deeply grateful to Steven Grant for English review; to Francisco Alves Teixeira (Nupélia), Wladimir Marques Domingues (Nupélia) and Rodrigo Júnio da Graça (PGB and Nupélia) for the aid in the field trip; to Claudimar dos Santos by cataloging the vouchers; to Cláudio Zawadzki (UEM) and Angélica Corrêa Dias for Loricariidae identification, Luiz Fernando Caserta Tencatt for *Corydoras* identification, Luiz Roberto Malabarba and Fernando Camargo Jerep for *Hyphessobrycon* identification; Ricardo Vicari (UEPG) for material donations, and Vinícius Abilhoa (MHNCI), Francisco Langeani (DZSJRP), Osvaldo Oyakawa (MZUSP) and Carlos Lucena (MCP) for loans of comparative material; to Guilherme Okuda Landgraf and Luiz Fernando Pesenti Junior for taking some of the pictures; to Fundação Araucária (SETI-PR) for financial support and Nupélia and PEA from logistical support. AF and GCD has been suppoted by scholarship from Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) and WJG has been supported by personal grants from Fundação Araucária (Seti-PR).

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Received: 14/12/2015
Revised: 21/06/2016
Accepted: 27/06/2016