Ichthyofauna of lotic environments in the Ivinhema river basin, upper Paraná river, Mato Grosso do Sul state, Brazil

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Abstract: In order to inventory the species richness and fish fauna composition along the Ivinhema river basin, 232 stretches of rivers and streams were sampled from 2000 to 2018, using a rectangular sieve, trawls, gillnets, cast nets, and electrofishing. A total of 141 species was caught in the basin, including seven orders and 35 families. For the recorded species, 42 are from the upper Paraná river, 51 from lower Paraná river, 27 from other basins, two from other continents, and the origin for 19 species are unknown/not reported. Six species are registered for the first time in the upper Paraná river basin: Astyanax abramis, Moenkhausia oligolepis, Serrapinnus kriegi, Curimatopsis myersi, Pyxiloricaria menezesi, and Cichlasoma dimerus. This is the first complete survey of the ichthyofauna in lotic environments along the whole Ivinhema river basin, containing relevant information for comparing studies and serving as reference data that can contribute to the management and implementation of policies for conservation of the basin. This survey also increases 24 species on the list of the most complete inventory in the upper Paraná river published in 2007.

Keywords: Fish communities, freshwater, survey.

Ictiofauna de ambientes lóticos na bacia do rio Ivinhema, alto rio Paraná, Mato Grosso do Sul, Brasil

Resumo: Com o objetivo de inventariar a riqueza de espécies e a composição da ictiofauna ao longo da bacia do rio Ivinhema, 232 trechos de rios e riachos foram amostrados de 2000 a 2018, utilizando uma peneira retangular, rede de arrasto, rede de espera, tarrafas e pesca elétrica. Ao todo 141 espécies foram amostradas na bacia, incluindo oito ordens e 35 famílias. Para as espécies registradas, 42 são do alto rio Paraná, 51 do baixo rio Paraná, 27 de outras bacias, duas de outros continentes e para 19 espécies as origens são desconhecidas ou não reportadas. Seis espécies são registradas pela primeira vez na bacia alto rio Paraná: Astyanax abramis, Moenkhausia oligolepis, Serrapinnus kriegi, Curimatopsis myersi, Pyxiloricaria menezesi e Cichlasoma dimerus. Este é o primeiro levantamento da ictiofauna em ambientes lóticos para toda a bacia do rio Ivinhema, contendo informação relevante para estudos comparativos e servindo como dados de referência que podem contribuir para gerenciamento e implementação de políticas para conservação da bacia. Este levantamento também acrescenta 24 espécies na lista do inventário mais completo realizado no alto rio Paraná publicado em 2007.

Palavras-chave: Comunidades de peixes, água doce, inventário.
Introduction

The upper Paraná river basin, with 367 fish species, being 317 described and 50 not formally described (Langeani et al. 2007), is located entirely within the territory of Brazil and extends from the municipalities of Guaira and Mundo Novo, upstream to the ancient waterfall known as Sete Quedas, which is currently submerged by the Itaipu Reservoir, and encompasses 891,000 km² or 10.5% of the area of Brazil (Agostinho et al. 2003). This portion of the Paraná river basin is the most studied regarding Brazilian freshwater fish (Agostinho et al. 2007), but for some regions the knowledge is still insufficient. Most of those studies were performed in the Brazilian Southeast (Paraná and São Paulo states) and despite of increasing researches, there have been only a few studies in the Midwest Brazilian region where upper Paraná is inserted, including Mato Grosso do Sul and Goiás states and Federal District (Aquino et al. 2009).

In the particular case of the Ivinhema river basin, a tributary practically free of impoundments and located in the western portion of upper Paraná river basin, some studies have been conducted to determine the environmental features that influence fish species in some few headwater streams (Súarez et al. 2007, Súarez & Lima-Junior, 2009), that influence spacial and temporal variation of fish in streams of lower Ivinhema (Súarez 2008a) or the fish richness in streams of the whole Ivinhema basin (Súarez et al. 2011). Fish eggs and larvae distribution related to environmental factors were also studied in the upper Ivinhema and its river tributaries (Nascimento & Nakatani 2006) and fishfauna associated to macrophyte mats were described in the lower Ivinhema (Bulla et al. 2011). In the latter, in Súarez (2008b) and in Súarez & Lima-Junior (2009) a small list of 28, 46 and 64 fish species is presented, respectively, and restricted to the lower Ivinhema river. The richness of 111 fish species was reported in Súarez et al. (2011), but no list of fish species was presented. In the current study, more streams and rivers stretches were sampled and then we described a larger fish richness and composition along the whole Ivinhema river basin, including streams and the main river tributaries.

Given that the upper Paraná river basin is located in a densely populated area that is also one of the most industrialized regions in Brazil (Thomaz et al. 2004), it is not surprising that this area has experienced continuous environmental alteration, that may have a substantial influence on fish communities and their habitats (Bryce et al. 1999, Holt et al. 2006). Therefore, studies describing fish community composition and occurrence in the western part of the upper Paraná river basin are needed, where lotic environments, free from impoundment, still exist. This is particularly important in the state of Mato Grosso do Sul, which has experienced over the last decade great expansion of sugar-cane cultivation and alcohol production (Domingues & Thomaz Junior 2012). Studies, like the present work, would be very important in obtain information useful in the minimization and mitigation of the impacts of anthropic alteration and facilitate management policies for conservation, specifically for the fish fauna.

It is in this context that the present study was conducted, using data from field sampling, with the aim of inventorying the richness and composition of fish species in the Ivinhema river basin.

Material and Methods

The Ivinhema river is the main tributary of the Paraná river in the western portion of the state of Mato Grosso do Sul. The mouth of this river is in the stretch of the Paraná river below Engenheiro Sérgio Motta dam but above Itaipu hydroelectric dam, which is the only stretch of the Paraná free of impoundments (Agostinho et al. 2000), including the Ivinhema river basin. The headwater is the Dourados river (area = 9,900 km²) at 700 m of altitude, with the contribution of other subbasins including Santa Maria river (area = 2,700 km²), Brilhante river (area = 8,878 km²), Vacaria river (area = 6,500 km²), and the Ivinhema river (18,045 km²), forming the Ivinhema river basin, with a total area of 46,023 km². Samplings were performed along 232 stretches of rivers and streams, throughout the Ivinhema river basin from January 2000 to June 2018, being that seven stretches were sampled in Súarez (2008b), seven in Súarez & Lima-Junior (2009), 186 in Súarez (2011) and 32 in the current study (Figure 1).

Fish were sampled from an approximately 100 m extension of each stream: 40 throws of a 1.2 x 0.8 m (2 mm mesh size) rectangular sieve; 10 trawlings (1.5 x 5 m; 2 mm mesh size); 12 hours of exposition to a sequence of 14 gillnets (10 x 1.5 m, with mesh sizes between adjacent knots: 1.5, 2.0, 3.0 4.0, 5.0, 6.0, 7.0, 8.0, 9.0, 10.0 cm) and three cast nets (height 1.5 to 3 m, diameter 3 to 6 m, and mesh sizes between adjacent knots: 1.5, 3.0, 6.0 cm). Also, electrofishing was employed in small streams, with approximately 100-m-long hauls. In rivers, fish were also captured with a series of 14 gillnets and cast nets in each stretch, whereas along the banks of the rivers the rectangular sieve and trawls were used mainly to sample small sized fish.

Fish were anesthetized with Eugenol solution, euthanized and, in the sequence, fixed in 10% formalin and preserved in 70% ethanol. The euthanasia followed all the ethic criterion established by the Universidade Estadual de Mato Grosso do Sul, along the accomplishment of all the projects that originated the current data. The collections of specimens were authorized by the Brazilian Environment Institute (IBAMA), through special license number # 13458-115900-1, issued by SISBIO. Taxonomic identifications followed Graça & Pavanelli (2007) and current taxonomic reviews. Some specimens were deposited in zoological collections: Núcleo de Pesquisas em Limnologia, Ictiologia e Aquicultura da Universidade Estadual de Maringá (NUP/UEM), Museu de Zoologia da Universidade de São Paulo (MZUSP), Museu da Universidade Federal do Rio Grande do Sul (UFRGS), Museu de Zoologia da Universidade Estadual de Londrina (MZUEL) and Coleção de Peixes da Universidade estadual de Mato Grosso do Sul (CPUEMS).

For those species that we were not able to present voucher specimens, we inserted the information of other references that had already reported the occurrence of the species in the Ivinhema river basin or upper Paraná river basin.

After the list was compiled, in order to confirm species names, possible synonyms and their basin of occurrence, we confronted it with information available on ‘Check List of the Freshwater Fishes of South and Central America’ (Reis et al. 2003), ‘Catálogo das Espécies de Peixes de Água Doce do Brasil’ (Buckup et al. 2007), ‘Catalog of Fishes’ (Eschmeyer et al. 2018) and ‘Fishbase’ (Froese & Pauly 2018).
The geographic origin for fish species followed Langeani et al. (2007) as autochthonous (native), natural species from the upper Paraná; allochthonous, species from other Neotropical regions and introduced in the upper Paraná; and exotic, species from other continents. For some species not reported in Langeani et al. (2007), the origin was defined according to reviews for the species or the remarks of Ota et al. (2018).

The fish fauna composition based in size was analyzed through the maximum size of each species (standard length for fish that has caudal fin, total length for fish that has only this information available and for Gymnotiformes or Synbranchiformes, and the total disc length for stingrays). This information were gathered from FishBase or directly measured on the specimen in the case of species is not described, not inserted in the database or the sampled specimen was longer than the reported in the FishBase. The size classes were obtained by Sturges formula ($K = 1 + 3.32 \log n$, where $K =$ number of classes; and, $n =$ the size sample), which furnishes the number of classes for the total sampling, based on the range of total fish size divided by the number of classes.

Results

A total of 141 species was caught in this study. From this, eight species are without voucher numbers, but we inserted references that already reported these species in the Ivinhema river basin, and only one species we did not find any reference reporting its occurrence in the basin (Table 1). All species are distributed in 7 orders and 35 families. Characiformes and Siluriformes were the most representative orders with 65 (46.1%) and 50 species (35.5%), respectively, and Characidae and Loricariidae were the most abundant families with 28 (19.8%) and 17 species (12%), respectively. Althought four species were identified at genus level, they were considered different species from those that are already described and reported for the upper Paraná basin.

After verification for synonymies and species that were redescribed, our study also contributed to increase the fish inventory furnished by Langeani et al. (2007), since 24 species were not reported on that list, and six of these species are the first reporting (species with asterisk) in the upper Paraná river: \textit{Phalloceros harpagos},
Table 1. Fish species caught between January 2000 and June 2018 in the Ivinhema river basin and its sub-basins (Santa Maria river – S; Dourados river – D; Vacaria river – V; Brilhante river – B; Ivinhema river – I), upper Paraná river basin. Voucher numbers, size (standard length, total length*, or total disc length** in centimeters) and species origin.

| Species | Voucher or Reference | Size (cm) | sub-basin | origin       |
|---------|---------------------|-----------|-----------|--------------|
| **MYLIOBATIFORMES** |                     |           |           |              |
| Potamotrygonidae |                     |           |           |              |
| Potamotrygon falkneri Castex & Maciel, 1963 | Agostinho et al. 1997, Lonardoni et al. 2006, Lacerda et al. 2008 | 78**      | B,I       | allochthonous |
| Potamotrygon motoro (Müller & Henle, 1841) | Agostinho et al. 1997, Lonardoni et al. 2006, Lacerda et al. 2008 | 50**      | B         | allochthonous |
| **CHARACIFORMES** |                     |           |           |              |
| Acestrorhynchidae |                     |           |           |              |
| Acestrorhynchus lacustris (Lütken, 1875) | CPUEMS118 | 27        | S,D,V,B,I | autochthonous* |
| Anostomidae |                     |           |           |              |
| Leporellus vittatus (Valenciennes, 1850) | #         | 30        | S,V       | autochthonous |
| Leporinus amblyrhynchus Garavello & Britski, 1987 | CPUEMS18 | 27.4      | I         | autochthonous |
| Leporinus friderici (Bloch, 1794) | NUP9375 | 40        | S,D,V,B,I | autochthonous* |
| Leporinus lacustris Campos, 1945 | NUP9387 | 20.3      | D,B,I     | autochthonous |
| Leporinus octofasciatus Steinbach, 1915 | CPUEMS424 | 31.2      | S,I       | autochthonous* |
| Leporinus striatus Kner, 1859 | CPUEMS290 | 25        | S,D,V,B   | autochthonous |
| Megaleporinus macrocephalus (Garavello & Britski, 1988)* | CPUEMS754 | 60        | S,V,B,I   | allochthonous |
| Megaleporinus piavussu Britski, Birindelli & Garavello, 2012* | NUP9371 | 40        | D,I       | autochthonous* |
| Megaleporinus obtusidens (Valenciennes, 1837)* | CPUEMS301 | 39.8      | I         | autochthonous* |
| Schizodon borellii (Boulenger, 1900) | CPUEMS705 | 30        | S,D,V,I   | autochthonous* |
| **Bryconidae** |                     |           |           |              |
| Salminus brasiliensis (Cuvier, 1816) | CPUEMS707 | 100       | S,D,V,B,I | autochthonous* |
| Salminus hilarii Valenciennes, 1850 | NUP9374 | 50        | S,D,V,B,I | autochthonous* |
| **Characidae** |                     |           |           |              |
| Aphyocharax anisitsi Eigenmann & Kennedy, 1903 | CPUEMS261 | 5.5       | I         | allochthonous |
| Aphyocharax dentatus Eigenmann & Kennedy 1903 | NUP9944 | 7.2       | S,V,I     | autochthonous* |
| Aphyocharax sp. | NUP9361 | 5.3       | S,D,V,B,I | unknown     |
| Astyanax abramis (Jenyns, 1842) | MZUEL14444 | 14       | I         | autochthonous |
| Astyanax biotae Castro & Vari, 2004 | CPUEMS537 | 5.2       | ---       | autochthonous |
| Astyanax bockmanni Vari & Castro, 2007 | Súarez 2008b | 6.7 | S,D,I     | autochthonous* |
| Astyanax fasciatus (Cuvier, 1819) | CPUEMS116 | 12        | S,D,V,B,I | autochthonous* |
| Astyanax lacustris (Lütken, 1875)* | NUP9378 | 10.6      | S,D,V,B,I | autochthonous |
| Astyanax paranae Eigenmann, 1914 | CPUEMS523 | 11.3      | D,V,B,I   | autochthonous |
| Galeocharax kneri (Steindachner, 1879) | CPUEMS280 | 33.1      | D,V,B,I   | autochthonous |
| Hyphessobrycon anisitsi (Eigenmann, 1907) | CPUEMS170 | 6        | D,B,I     | autochthonous* |
| Hyphessobrycon eques (Steindachner, 1882) | NUP9314 | 4        | S,D,I     | autochthonous* |
| Knodus moenkhassii (Eigenmann & Kennedy, 1903) | CPUEMS522 | 4.8       | ---       | allochthonous |
| Moenkhausia bonita Benine, Castro & Sabino, 2004 | NUP9317 | 4.4       | D,I       | unknown     |
| Moenkhausia forestii Benine, Mariguela & Oliveira, 2009 | NUP9318 | 3.8       | S,D,V,B,I | autochthonous* |
| Moenkhausia intermedia Eigenmann, 1908 | CPUEMS232 | 8        | S,D,B,I   | autochthonous* |
| Moenkhausia oligolepis (Günther, 1864) Glass tetra | CPUEMS531 | 10       | ---       | unknown     |
| Moenkhausia sanctaeilomenae (Steindachner, 1907) | NUP9936 | 7        | S,D,V,B,I | autochthonous* |
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Continuation Table 1.

| Species | Voucher or Reference | Size (cm) | sub-basin | origin          |
|---------|----------------------|-----------|-----------|----------------|
| Oligosarcus pintoi Campos, 1945 | NUP9315 | 8.4 | S,D,V,B,I | autochthonous   |
| Piabarchus stramineus Eigenmann, 1908* | CPUEMS119 | 5.6 | S,D,V,B,I | autochthonous   |
| Piabina argentea Reinhardt, 1867 | NUP9323 | 7.3 | S,D,V,B,I | autochthonous   |
| Psellogrammus kennedyi (Eigenmann, 1903) | NUP9321 | 5.9 | S,D,V,B,I | autochthonous   |
| Roeboides descalvadensis Fowler, 1932 | NUP9363 | 8.9 | S,D,V,B,I | allochthonous   |
| Serrapinnus calliurus (Boulenger, 1900) | MZUELI4483 | 4.4 | I | autochthonous   |
| Serrapinnus heterodon (Eigenmann, 1915) | CPUEMS208 | 4.1 | V,B | autochthonous   |
| Serrapinnus kriegi (Schindler, 1937) | MZUELI4348 | 2.4 | I | unknown         |
| Serrapinnus notomelas (Eigenmann, 1915) | NUP9937 | 3.6 | S,D,V,B,I | autochthonous   |
| Serrapinnus sp. | CPUEMS16 | 3.2 | D,V,B,I | unknown         |

Crenuchidae

| Species | Voucher or Reference | Size (cm) | sub-basin | origin |
|---------|----------------------|-----------|-----------|--------|
| Characidium gomesi Travassos, 1956 | CPUEMS248 | 6.5 | D,V,B,I | autochthonous |
| Characidium lagosantense Travassos, 1947 | CPUEMS257 | 4.1 | I | unknown |
| Characidium laterale (Boulenger, 1845) | MZUELI4344 | 3.5 | I | autochthonous |
| Characidium zebra Eigenmann, 1909 | NUP9353 | 7.4 | S,D,V,B,I | autochthonous* |

Curimatidae

| Species | Voucher or Reference | Size (cm) | sub-basin | origin |
|---------|----------------------|-----------|-----------|--------|
| Curimatopsis myersi Vari, 1982 | MZUELI4516 | 4.4 | I | unknown |
| Cyphocharax modestus (Fernández-Yépez, 1948) | NUP9327 | 16.2 | S,D,V,B,I | autochthonous |
| Cyphocharax vanderi (Britski, 1980) | MZUELI4496 | 6.8 | I | autochthonous |
| Steindachnerina brevipinna (Eigenmann & Eigenmann, 1889) | NUP9365 | 10.9 | S,D,V,B,I | allochthonous |
| Steindachnerina insculpta (Fernández-Yépez, 1948) | NUP9358 | 10.6 | D,V,B,I | autochthonous |

Cynodontidae

| Species | Voucher or Reference | Size (cm) | sub-basin | origin |
|---------|----------------------|-----------|-----------|--------|
| Rhaphiodon vulpinus Spix & Agassiz, 1829 | Agostinho et al. 1997, Reynalte-Tataje et al. 2011 | 80 | B,I | autochthonous* |

Erythrinidae

| Species | Voucher or Reference | Size (cm) | sub-basin | origin |
|---------|----------------------|-----------|-----------|--------|
| Erythrinus erythrinus (Bloch & Schneider, 1801) | CPUEMS542 | 20 | I | allochthonous |
| Hoplerythrinus unitaeniatus (Agassiz, 1829) | NUP9376 | 25 | D,V,B,I | allochthonous |
| Hoplias misionera Rosso, Mabraga, Gonzalez-Castro Delpiani, Avigliano, Schenone, Dias de Astarloa, 2016* | MUZELI4495 | 49 | S,D,V,B,I | autochthonous* |

Hemiodontidae

| Species | Voucher or Reference | Size (cm) | sub-basin | origin |
|---------|----------------------|-----------|-----------|--------|
| Hemiodus orthonops Eigenmann & Kennedy, 1903 | CPUEMS275 | 25 | S,I | allochthonous |

Lebiasinidae

| Species | Voucher or Reference | Size (cm) | sub-basin | origin |
|---------|----------------------|-----------|-----------|--------|
| Pyrrhulina australis Eigenmann & Kennedy, 1903 | NUP9356 | 5 | S,D,V,B,I | autochthonous* |

Parodontidae

| Species | Voucher or Reference | Size (cm) | sub-basin | origin |
|---------|----------------------|-----------|-----------|--------|
| Apareiodon affinis (Steindacher, 1879) | Agostinho et al. 1997 | 17 | D | autochthonous* |
| Apareiodon ibitiensis Campos, 1944 | MZUSP5418 | 11.3 | S,D,B,I | autochthonous |
| Apareiodon piracicabae (Eigenmann, 1907) | NUP9934 | 12 | S,D | autochthonous |
| Parodon nasus Kner, 1859 | CPUEMS138 | 12.7 | S,D,V,B,I | autochthonous* |

Prochilodontidae

| Species | Voucher or Reference | Size (cm) | sub-basin | origin |
|---------|----------------------|-----------|-----------|--------|
| Prochilodus lineatus (Valenciennes, 1836) | CPUEMS595 | 59.2 | S,D,V,B,I | autochthonous* |

Serrasalmidae

| Species | Voucher or Reference | Size (cm) | sub-basin | origin |
|---------|----------------------|-----------|-----------|--------|
| Metynnis lippincottianus (Cope, 1870) | NUP9380 | 14.9 | I | unknown |
| Myloplus tiete (Eigenmann & Norris, 1900)* | NUP9364 | 16.3 | I | autochthonous |
| Serrasalmus maculatus Kner, 1858 | CPUEMS521 | 20.2 | S,D,V,B,I | autochthonous* |
| Serrasalmus marginatus Valenciennes, 1837 | CPUEMS708 | 27 | S,D,B,I | autochthonous |

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## Continuation Table 1.

| Species                  | Voucher or Reference | Size (cm) | sub-basin | origin            |
|--------------------------|----------------------|-----------|-----------|-------------------|
| **GYMNOTIFORMES**        |                       |           |           |                   |
| Apteronotidae            |                      |           |           |                   |
| *Apterodonotus albifrons* (Linnaeus, 1766) | NUP9386           | 50*       | D,I       | allochthonous     |
| Gymnotidae               |                      |           |           |                   |
| *Gymnotus inaequilabiatus* (Valenciennes, 1839) | CPUEMS697        | 60*       | D,V,I     | allochthonous     |
| *Gymnotus omarorum* Richer-de-Forges, Crampton & Albert, 2009 | MUZEL14328       | 25.4*     | I         | unknown           |
| *Gymnotus pantanal* Fernandes, Albert, Daniel-Silva, Lopes, Crampton & Almeida-Toledo, 2005 | MUZEL14486       | 25.1*     | I         | autochthonous     |
| *Gymnotus paraguensis* Albert & Crampton, 2003 | CPUEMS179        | 24*       | D,I       | allochthonous     |
| *Gymnotus sylvius* Albert & Fernandes-Matioli, 1999 | NUP9389           | 36*       | S,D,V,B,I | autochthonous     |
| **Hypopomidae**          |                      |           |           |                   |
| *Brachyhypopomus gauderio* Giora & Malabarba, 2009* | NUP9390           | 18.6*     | B,I       | allochthonous     |
| **Rhamphichthyidae**     |                      |           |           |                   |
| *Gymnorhamphichthys britskii* Carvalho, Ramos & Albert, 2011* | NUP9384           | 11.5      | I         | autochthonous     |
| **Sternopygidae**        |                      |           |           |                   |
| *Eigenmannia trilineata* López & Castello, 1966 | NUP9381           | 25*       | S,D,B,I   | autochthonous     |
| *Eigenmannia virescens* (Valenciennes, 1847) | CPUEMS284         | 35.8*     | S,B,I     | autochthonous     |
| *Sternopygus maacurus* (Bloch & Schneider, 1801) | NUP9388           | 141*      | S,D,B,I   | autochthonous     |
| **SILURIFORMES**         |                      |           |           |                   |
| **Aspredinidae**         |                      |           |           |                   |
| *Bunocephalus larai* Ihering, 1930 | NUP9352           | 5.6       | S,B,I     | autochthonous     |
| **Auchenipteridae**      |                      |           |           |                   |
| *Auchenipterus osteomystax* (Miranda Ribeiro, 1918) | CPUEMS709        | 27        | B,I       | autochthonous     |
| *Tatia neivai* (Ihering, 1930) | NUP9313           | 8.2       | D,B,I     | autochthonous     |
| *Trachelyopterus coriaceus* Valenciennes, 1840 | MZUEL14503       | 18*       | I         | unknown           |
| *Trachelyopterus galeatus* (Linnaeus, 1766) | NUP9377           | 22        | D,V,B,I   | autochthonous     |
| **Callichthyidae**       |                      |           |           |                   |
| *Callichthys callichthys* (Linnaeus, 1758) | NUP9359           | 17        | V,B,I     | autochthonous     |
| *Corydoras aeneus* (Gill, 1858) | NUP9362           | 7.5       | S,D,V,B,I | autochthonous     |
| *Hoplosternum litorale* (Hancock, 1828) | NUP9368           | 15.8      | B,I       | autochthonous     |
| *Lepthoplosternum pectorale* (Boulenger, 1895) | MUZEL14322       | 6         | I         | unknown           |
| **Cetopsidae**           |                      |           |           |                   |
| *Cetopsis gobioides* Kner, 1858 | NUP9367           | 10.9      | B,I       | autochthonous     |
| **Clariidae**            |                      |           |           |                   |
| *Clarias gariepinus* (Burchell, 1822) | CPUEMS594        | 32.9      | D,V       | exotic            |
| **Doradidae**            |                      |           |           |                   |
| *Ossancora eigenmannii* (Boulenger, 1895) | CPUEMS704        | 15.2      | S,I       | allochthonous     |
| *Platydoras armatulus* (Valenciennes, 1840) | Agostinho et al. 1997 | 43   | B         | unknown           |
| *Pterodoras granulosus* (Valenciennes, 1821) | CPUEMS273        | 60        | B,I       | allochthonous     |
| *Trachydoras paraguayensis* (Eigenmann & Ward, 1907) | CPUEMS224        | 19.2      | D,B,I     | allochthonous     |
| **Heptapteridae**        |                      |           |           |                   |
| *Cetopsoharhamida iheringi* Schubart & Gomes, 1959 | NUP9348           | 11.1      | D,V,J     | autochthonous     |
| *Imparfinis borodinii* Mees & Cala, 1989 | CPUEMS701        | 15.7      | B         | autochthonous     |
| *Imparfinis mirini* Haseman, 1911 | NUP9355           | 8.5       | D,B,I     | autochthonous     |
| *Imparfinis schubarti* (Gomes, 1956) | NUP9348           | 10.6      | D,V,J     | autochthonous     |
Continuation Table 1.

| Species | Voucher or Reference | Size (cm) | sub-basin | origin |
|---------|----------------------|-----------|-----------|--------|
| Phenacorhamdia tenebrosa (Schubart, 1964) | MZUSP85419 | 6.7 | S,D,V,B,I | autochthonous |
| Pimelodella avanhandavae Eigenmann, 1917 | NU9372 | 12.5 | S,D,V,B,I | autochthonous |
| Pimelodella gracilis (Valenciennes, 1835) | NUP9346 | 18 | S,D,V,B,I | autochthonous* |
| Pimelodella taenioptera Miranda-Ribeiro, 1914 | CPUEMS820 | 12.1 | D,V,B | allochthonous |
| Rhamdia quelen (Quoy & Gaimard, 1824) | MZUEL14499 | 38.7 | D,V,B,I | autochthonous* |

**Loricariidae**

| Species | Voucher or Reference | Size (cm) | sub-basin | origin |
|---------|----------------------|-----------|-----------|--------|
| Ancistrus sp. | NUP9328 | 11 | V,B | unknown |
| Curculionichthys insperatus Britski & Garavello, 2003* | MZUSP85735 | 3 | S,D,V,B,I | autochthonous |
| Farlowella hahni Meinken, 1937* | NUP9396 | 22.5 | D,B,I | autochthonous* |
| Hisonotus francirochai (Ihering, 1928) | MUZEL14355 | 3.6 | I | autochthonous |
| Hypostomus albopunctatus (Regan, 1908) | CPUEMS268 | 40 | S,V,B | autochthonous |
| Hypostomus ancistroides (Ihering, 1911) | MUZEL14450 | 21 | S,D,V,B,I | autochthonous |
| Hypostomus cochlodon Kner, 1854 | CPUEMS228 | 23 | S,D,V,B,I | allochthonous |
| Hypostomus iheringii (Regan, 1908) | NUP9354 | 11.6 | S,D,V,B,I | autochthonous |
| Hypostomus regani (Ihering, 1905) | CPUEMS712 | 41 | S,D,I | autochthonous |
| Hypostomus strigaticeps (Regan, 1908) | NUP9340 | 16 | S,D,V,B,I | autochthonous |
| Loricariichthys platymetopon Isbrücker & Nijssen, 1979 | NUP9338 | 30 | S,D,V,B,I | allochthonous |
| Otothyropsis marapoama Ribeiro, Carvalho & Melo, 2005 | NUP9395 | 3.6 | S,D,I | autochthonous |
| Otothyropsis polyodon Caleagri, Lehmann A. & Reis, 2013 | NUP9392 | 4.2 | S,D,V,B,I | unknown |
| Pyxiloricaria menezesi Isbrücker & Nijssen, 1984 | NUP9382 | 14 | S,D,V,B,I | unknown |
| Rineloricaria lanceolata (Günther, 1868) | NUP9336 | 9.5 | S,D,B,I | unknown |
| Rineloricaria sp. | NUP9342 | 8.6 | S,D,I | unknown |

**Pimelodidae**

| Species | Voucher or Reference | Size (cm) | sub-basin | origin |
|---------|----------------------|-----------|-----------|--------|
| Hemisorubim platyrhynchos (Valenciennes, 1840) | CPUEMS272 | 52.5 | D,V,B,I | autochthonous* |
| Pimelodus maculatus La Cepède, 1803 | CPUEMS281 | 36 | S,D,B,I | autochthonous* |
| Pimelodus ornatus Kner, 1858 | CPUEMS235 | 38.5 | D | allochthonous |
| Pseudoplatystoma corrucans (Spix & Agassiz, 1829) | Agostinho et al. 1997, Sáurez & Lima-Junior 2009, Reynalte-Tataje et al. 2011, Vaini et al. 2016 | 114 | D,V,B,I | autochthonous* |
| Sorubim lima (Bloch & Schneider, 1801) | CPUEMS713 | 50.5 | B,J | allochthonous |

**Pseudopimelodidae**

| Species | Voucher or Reference | Size (cm) | sub-basin | origin |
|---------|----------------------|-----------|-----------|--------|
| Pseudopimelodus mangurus (Valenciennes, 1835) | Sáurez 2008b, Sáurez & Lima-Junior 2009 | 34.5 | I | autochthonous* |

**Scoloplacidae**

| Species | Voucher or Reference | Size (cm) | sub-basin | origin |
|---------|----------------------|-----------|-----------|--------|
| Scoloplax empousa Schaefer, Weitzman & Britski, 1989 | NUP9347 | 2 | I | unknown |

**Trichomycteridae**

| Species | Voucher or Reference | Size (cm) | sub-basin | origin |
|---------|----------------------|-----------|-----------|--------|
| Paravandellia oxyptera Miranda Ribeiro, 1912 | CPUEMS66 | 2.8 | D | autochthonous* |
| Trichomycterus davisi (Haseman, 1911)* | UFRGS11158 | 8 | D | autochthonous |

**Cynolebiidae**

| Species | Voucher or Reference | Size (cm) | sub-basin | origin |
|---------|----------------------|-----------|-----------|--------|
| Melanorivulus ivinhemensis Volcan, Severo-Neto & Lanes, 2018* | NUP9350 | 3 | D,I | autochthonous |

**CYPRIINODONTIFORMES**

**Poeciliidae**

| Species | Voucher or Reference | Size (cm) | sub-basin | origin |
|---------|----------------------|-----------|-----------|--------|
| Phalloceros harpagos Lucinda, 2008 | NUP9360 | 3.4 | D,B,I | autochthonous* |
| Poecilia reticulata Peters, 1859 | NUP9379 | 5 | D,V,B | allochthonous |
Continuation Table 1.

| Species | Voucher or Reference | Size (cm) | sub-basin | origin |
|---------|----------------------|-----------|-----------|--------|
| SYNBRANCHIFORMES | | | | |
| Synbranchidae | | | | |
| Synbranchus marmoratus Bloch, 1795 | NUP9357 | 150* | S,D,V,B,I | autochthonous* |
| CICHLIFORMES | | | | |
| Cichlidae | | | | |
| Apistogramma commbrae (Regan, 1906) | CPUEMS133 | 3.3 | I | allochthonous |
| Astronotus crassipinnis Heckel, 1840 | CPUEMS541 | 24 | V,B | allochthonous |
| Chaetobranchopsis australis Eigenmann & Ward, 1907 | NUP9366 | 12 | I | allochthonous |
| Cichlasoma dimerus (Heckel, 1840) | MZUEL14512 | 11.7 | I | unknown |
| Cichlasoma paranaense Kulander, 1983 | NUP9385 | 7.8 | S,D,V,B,I | autochthonous |
| Coptodon rendalli (Boulenger, 1897)* | NUP9316 | 16.6 | D,B,I | exotic |
| Crenicichla britskii Kulander, 1982 | MUZEL14324 | | | |
| Gymnogeophagus setequedas Reis; Malabarba & Pavanelli, 1992 | CPUEMS598 | 9.8 | D | autochthonous* |
| Laetacara araguaiae Ottoni & Costa 2009* | MUZEL14324 | 6 | I | allochthonous |

1 Species name with asterisk indicates that the deposit was made with the synonym species and it changed according to the new identification.
2 Acronym refers to the following collections: Universidade Estadual de Maringá (NUP), Coleção de Peixes - Universidade Estadual Paulista/Campus de São José do Rio Preto (DZSIRP), Museu de Zoologia da Universidade de São Paulo (MZUSP), Museu de Ciências e Tecnologia da PUCRS (MCP), Universidade Federal do Rio Grande do Sul (UFRGS) and Museu de Zoologia da Universidade de Londrina (MZUEL), Coleção de Peixes da Universidade estadual de Mato Grosso do Sul (CPUEMS).
3 Autochthonous: species from upper Paraná, asterisk indicates the type locality outside upper Paraná; Allochthonous: species from other Neotropical basins; Exotic: species from other continents and Unknown species no information about the origin.
4 Voucher number indicates species deposited by this work; References were used when it was not possible to deposit voucher specimens, but the species was already reported in the Ivinhema river basin; hastag, the only species without deposited specimens in the Ivinhema river basin, but reported by Langeani et al. (2007) in the upper Paraná river basin.

SÚAREZ, Y.R. & LIMA-JÚNIOR, S.E. 2009 Spatial and temporal variation in stream fish assemblages of Guiraí River Basin, Upper Paraná Basin. Biota Neotrop., 9(1):101-111 http://www.biotaneotropica.org.br/v9n1/en/ abstract?article+bn01709012009 (ultimo acesso em 21/01/2019)

VAINI, J.O., CRISPIM, B.A., SILVA, D.B.S., BENITES, C., RUSSO, M. R. & GRISOLIA, A. B. 2016. Genetic variability of pure Pseudoplatystoma corruscans and Pseudoplatystoma reticulatum individuals in the Paraná and Paraguay River basins. Fish. Sci. 82:605-611.

Moenkhausia forestii, Brachyhypopus gauderio, Lactacara araguaiae, Gymnotus omarorum, Gymnorhamphichthys britskii, Otothryopsis polyleon, Melanorivulus ivinhenensis, Astyanax abramis*, Moenkhausia oligolepis*, Serrapinnus kriegi*, Curimatopsis myersi*, Pyxilorichia menezesi*, Cichlasoma dimerus*, Characidium lagosantense, Rineloricaria lanceolata, Moenkhausia bonia, Metynnis lippincottianus, Farlowella hahni, Trichomycterus tavisi, Apistogramma commbrae, Chaetobranchopsis australis, Pseilogrammus kumii, and Serrapinnus callius. Some species may be visualized in Figure 2.

Regarding geographic origin, 93 species were autochthonous from the Paraná river (42 from upper Paraná and 51 from lower Paraná), 27 were allochthonous and two were exotics (Table 1). It was not possible to define the origin of 19 species, mainly because nothing is reported about them or because the species are yet to be described.

The length of fish species varied from two to 150 cm. Small-sized fish were mostly common (63.8%, 90 species) in size class until 20.7 cm (Figure 3), fish of medium size were in the second size class 39.4 cm (19.9%, 28 species) and the other 16 species (16.3%) were considered large size, above 39.5 cm and until 150 cm.

Discussion

For the upper Paraná river basin it was reported 317 described fish species by Langeani et al. (2007). Although, since it was published this list may be increased, in function of the new descriptions, our study has 117 identified species (35.6%) in common, it can be said that the Ivinhema river basin, covering only 5% of the total area of the upper Paraná, possesses an expressive fish fauna, one third of the species.

From 24 species not reported on the inventory of Langeani et al. (2007), eight were described after the publication: References were used when it was not possible to deposit voucher specimens, but the species was already reported in the Ivinhema river basin; hastag, the only species without deposited specimens in the Ivinhema river basin, but reported by Langeani et al. (2007) in the upper Paraná river basin.

SÜAREZ, Y.R. & LIMA-JÚNIOR, S.E. 2009 Spatial and temporal variation in stream fish assemblages of Guiraí River Basin, Upper Paraná Basin. Biota Neotrop., 9(1):101-111 http://www.biotaneotropica.org.br/v9n1/en/ abstract?article+bn01709012009 (ultimo acesso em 21/01/2019)

VAINI, J.O., CRISPIM, B.A., SILVA, D.B.S., BENITES, C., RUSSO, M. R. & GRISOLIA, A. B. 2016. Genetic variability of pure Pseudoplatystoma corruscans and Pseudoplatystoma reticulatum individuals in the Paraná and Paraguay River basins. Fish. Sci. 82:605-611.
Figure 2. Representative specimens for some fish species reported in the Ivinhema river basin, in the upper Paraná river basin, Mato Grosso do Sul State, Brazil. A) Astyanas lacustris; B) Hemigrammus marginatus; C) (Female and male) Poecilia reticulata; D) Steindacherina brevipinna; E) Corydoras aeneus; F) Pyrrhulina australis; G) Myloplus tiete; H) Erythrinus erythrinus; I) Knodus moenkhausii; J) Hoplerythrinus unitaeniatus; K) Scoloplax empousa; L) Leporinus octofasciatus; M) Otothyropsis polyodon; N) Leporinus striatus; O) Paradon nasus.
Paraguay and Uruguay basins and Brazilian southeastern coast (Giora & Malabarba 2009), but according to Ota et al. (2018) this species was identified as *B. cf. pinnicaudatus* (Graça & Pavanelli 2007) and its occurrence in the upper Paraná might be associated to introduction as a live bait by anglers. *Laetacara araguaianae* was described from the Verde and Araguaia rivers (Ottoni & Costa 2009), but as a non-native species, it was reported the upper Paraná floodplain, probably introduced by the aquarium trade (Ota et al. 2018), and now we expanded its occurrence to the river Ivinhema.

For six species, the current study had extended their occurrence to the upper Paraná river: *Astrayna bimaculatus* subgroup was revised by Lucena & Soares (2016) and they re-described *A. abramis* as a valid species from Paraguay, Lower Paraná and La Plata river basin. *Moenkhausia oligolepis* was reported originally only in the Guianas and Amazon river basins, but Benine et al (2009) with a detailed revision of this species reported its occurrence in Paraguay river. For *S. kriegi*, *C. myersi*, *P. menezesi* and *C. dimerus* and the other above-mentioned species, there was not found any report for these six species in the upper Paraná, thus these are the first reports.

Ten species not reported in Langeani et al. (2007) had their taxonomic status revised or occurrence extended. *Characidium lagosantense* was re-described and reported in the Mogi-Guaçu river by Silveira (2008). The taxonomic revision of *Rineloricaria* species was carried out in the Paraguay river (Vera-Alcaráz et al. 2012), but *R. lanceolata* occurrence was also recorded in the Ivinhema river in 2011 and reported by Froehlich et al. (2017). *Moenkhausia bonita* was described in 2004 in the Paraguay river (Benine et al. 2004), but its occurrence in the Ivinhema river was registered in 2006 and reported by Froehlich et al. (2017) and Ota et al. (2018). *Mystynis lippincottianus* was reported in the Ivinhema river by Suárez (2011) and Froehlich et al. (2017). It is interesting to point out that *M. lippincottianus* was not reported by Langeani et al. (2007) and it was adverted that it had been identified in the upper Paraná as *M. maculatus* (Graça & Pavanelli 2007). However, as an original Amazonian fish, two populations of this species were reported in two tributary streams of Ilha Solteira dam, suggesting these populations were installed locally (Froehlich et al. 2017) and now our study reported this species in many streams in the Ivinhema river. Its occurrence can be associated with the releasing of specimens for restocking or with the aquarium trade (Ota 2015).

*Farlowella hahni,* despite not being reported by Langeani et al. (2007), it was reported in the upper Paraná by Graça & Pavanelli (2007) as *F. amazonum,* but Ota et al. (2018) comparing the characters, described for the genus by Retzer & Page (1996), decided that the species would match more with the description of *F. hahni.* This species was reported before in the lower Paraná river and its occurrence in the upper portion can be associated to the inundation of the Sete Quedas Falls after the filling of Itaipu Reservoir (Ota et al. 2018). *Trichomycterus davisi,* first identified as *Trichomycterus sp.* (Graça & Pavanelli 2007), has now been assigned as *T. davisi* belonging to a species complex (Ota et al. 2018). *Apistogramma commbrae* and *C. australis* may have been introduced accidentally by aquarists or even after the construction of the Itaipu dam, since these species originally occurred only in the lower Paraná river and were firstly reported in the upper Paraná (Ivinhema river) by Suárez et al. (2011). *Psellogrammus kennedyi,* also reported for this latest author, and *S. calliurus* are considered a not-native species in the upper Paraná and had their occurrence associated with the function of a fish ladder that connects downstream portion (lower Paraná) to upstream portion (upper Paraná) in the Itaipu Dam (Ota et al. 2018).

Whereas Langeani et al. (2007) estimated at least 50 more species to be described, our inventory shows that the true richness of the Ivinhema river basin may be even greater insofar as specific identification was not possible for four species (four species at genus level). According to taxonomists, we probably have four new species: *Serrapinnus* sp., *Ancistrus* sp., and *Rineloricaria* sp. (personal communication). Thus, even without considering other species with uncertain taxonomic definitions, 2.8% of the sampled species are poorly or completely unknown to science.

The greater representation of the orders Characiformes and Siluriformes is a frequent pattern in Neotropical waters (Castro et al. 2004). Both orders accounted for 81.6% of the sampled species, which is consistent with that found by Langeani et al. (2007). This pattern is not surprising since both orders are the most representative of South America freshwater fish (Lowe-Mcconnell 1999). On the other hand, the greater representation of the families Characidae and Loricariidae reflects a recurrent pattern in Brazilian continental waters (Reis et al. 2003, Buckup et al. 2007).

Although the majority of fish reported in the Ivinhema river basin was autochthonous (29.8%) in the upper Paraná and autochthonous in the lower Paraná (36.2%), summing 66%, there was a substantial occurrence of allochthonous species (20%). The two exotic species recorded (1.4%), *Clarias gariepinus* and *Coptodon rendalli,* were clearly introduced into the basin through pisciculture (Langeani et al. 2007). This is the first report of *C. gariepinus* in the Dourados and Vacaria rivers, expanding the knowledge about their occurrence in tributaries of upper Paraná, which is considered to be highly adaptable and capable of negatively affecting the native fish fauna (Alves et al. 1999). During sampling, local fishermen and riverine communities reported that this species is frequently caught in these sub-basins and in abundance in the Dourados river.

Even though we do not have knowledge about the origin of 13.5% of the species, a point that is very concerning in this inventory is that only 29.8% of species may be considered native from the upper Paraná, the remaining fishes (56.7%) are from the lower Paraná, other basins or other continents. When the subject is homogenization and species
invasion, it is important to consider not only allochthonous and exotic species. Introduced species from different parts of the basin may be more problematic than species from other basins or continents (Vitule 2009). In Paraná river, even the species that overcame the barrier from the lower to the upper parts, because of the impoundment caused by Itaipu Dam, may cause some troubles for upper communities, such as pointed by Taylor et al. (1984): hybridization, genetic losses, trophic alterations, parasites or diseases introduction. Those alterations in local communities may result in extinction of native species, biodiversity losses or biota homogenization (Vitule 2009).

The streams of the present study exhibited greater species richness (112) than streams of other works in upper Paraná, such as Castro et al. (2003, 2004), Gubiani et al. (2006) e Gomiero & Braga (2006), which reported 52, 64, 62 and 48 species, respectively. In spite of these researches have used different methodologies and our samples were carried out in more stretches and in a greater area, consequently reflecting on difference catch effort and species richness, the rivers of the Paraná river basin in the state of São Paulo have experienced the influence of a series of impoundments for hydroelectric reservoirs, a process that affects sub-basin connections, thereby preventing recolonization and, thus, influencing species richness. On the other hand, the Ivinhema river basin, in the western portion of the upper Paraná, does not contain significant impoundments, with only two small hydropower plants in the upper portion of the Dourados river (São João I and II), or any other barriers, thus maintaining the potential for greater connectivity among streams, facilitating species flux and even recolonization by species from the Paraná river floodplain.

The most common species sampled were *Astyanax lacustris*, *Serrapinnus notomelas*, *Piabarchus stramineus*, and *Hypostomus ancistroides*. These small-sized species have great feeding plasticity and are known for their capacity to adapt to and colonize different water bodies. These species were reported throughout the Ivinhema river basin and are widely distributed in the upper Paraná river (Castro et al. 2004, Gubiani et al. 2006, Teresa & Casatti 2010, Viana et al. 2013).

A wide range of standard length was registered for the sampled fish (2 to 150 cm), however, it was evidenced that the fish fauna of Ivinhema river basin is composed basically of small-sized species, about 63.8% smaller than 20.7 cm. Despite of a greater number of samples in streams, and this may influence in a higher richness of small-sized fish (Castro 1999, Castro et al. 2003, 2004, Couto & Aquino 2011), this may be considered a pattern for the basin, because the large-sized species were sampled mainly below the intermediate altitude (430m) and in larger rivers, in areas located in tributaries such as Dourados, Brilhante and Ivinhema rivers. Moreover, 65% of 310 species analyzed in the upper Paraná river were small-sized (≤ 20.8 cm) (Langeagni et al., 2007) and 50% of South-American freshwater fish are small-sized (Castro 1999). According to this last work, this pattern may be a result of the high hydrological variability in streams; we believe that this pattern act more intensively structuring fish assemblages locally, where the water levels may vary between rainy and dry periods until five meters (personal observation), selecting generalist and resilient small-sized fish that are more prone to establish in these areas.

In conclusion, the current study is particularly significant because it helps reduce the lack of information on fish communities of an ecosystem that has been kept relatively free from dams and impoundments, from its headwaters to its confluence with the Paraná river basin. These data are also important for understanding the distribution of fish among sub-basins, adding new species records for the Ivinhema river basin, and the upper Paraná basin as a whole, serving as reference data for each region and contributing to the management, decision-making, and implementation of politics to conserve the basin as a whole. Furthermore, these data should prove useful as a reference for monitoring the fish fauna of the basin, which has experienced great alterations to its landscapes over the last decade due to the expansion of sugarcane crops and also may be suffering some pressure by a high percentage of non-native species in the upper Paraná.

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**Author Contributions**

Wagner Vicentin: Substantial contribution in the concept and design of the study; contribution to data collection; Contribution to data analysis and interpretation; Contribution to manuscript preparation; Contribution to critical revision, adding intellectual content.

Fabiane Silva Ferreira: Substantial contribution in the concept and design of the study; contribution to data collection; Contribution to data analysis and interpretation; Contribution to manuscript preparation; Contribution to critical revision, adding intellectual content.

Yzel Rondon Súarez: Substantial contribution in the concept and design of the study; contribution to data collection; Contribution to data analysis and interpretation; Contribution to manuscript preparation; Contribution to critical revision, adding intellectual content.

**Conflicts of interest**

The authors declare that they have no conflict of interest related to the publication of this manuscript.
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