Biota Neotropica 17(3): e20170344, 2017
www.scielo.br/bn

biotaneotropica
ISSN 1676-0611 (online edition)

Inventory

Survey of fish species from plateau streams of the Miranda River Basin in the Upper Paraguay River Region, Brazil

*Fabiane Silva Ferreira[1], Gabriela Serra do Vale Duarte[1], Francisco Severo-Neto[2], Otávio Froehlich[3] & Yzel Rondon Súarez[4]**

[1]*Universidade Estadual de Mato Grosso do Sul, Centro de Estudos em Recursos Naturais, Dourados, MS, Brazil*
[2]*Universidade Federal de Mato Grosso do Sul, Laboratório de Zoologia, Campo Grande, CG, Brazil*
[3]*Universidade Federal de Mato Grosso do Sul, Departamento de Zoologia, Campo Grande, CG, Brazil*
[4]*Universidade Estadual de Mato Grosso do Sul, Centro de Estudos em Recursos Naturais, Lab. Ecologia, Dourados, MS, Brazil*
**Corresponding author: Yzel Rondon Súarez, e-mail: yzel@uems.br*

FERREIRA, F. S., DUARTE, G. S. V., SEVERO-NETO, F., FROEHLICH O., SÚAREZ, Y. R. **Survey of fish species from plateau streams of the Miranda River Basin in the Upper Paraguay River Region, Brazil.** Biota Neotropica. 17(3): e20170344. http://dx.doi.org/10.1590/1676-0611-BN-2017-0344

Abstract: The objective of this study was to provide a comprehensive list of the fish fauna of headwater streams of the Miranda River in the Upper Paraguay River Basin. Our primary data set was constructed from sampling of fish using a rectangular sieve, trawl, and gill nets from 2004 to 2015. Our secondary data were derived from published reports conducted in the Miranda River Basin, in addition to taxonomic and distribution data from other studies conducted in the basin. All data were compiled, which in the end encompassed a period from 1999 to 2015. The datasets yielded a total of 143 species, 104 from the primary data (72.7%) and 39 from the secondary data (27.3%). Species were distributed among seven orders and 30 families were found in the Miranda River Basin. Characiformes and Siluriformes were the predominant orders, and the families Characidae and Loricariidae had the greatest number of species. Our results indicate a greater number of species compared to other studies of the Upper Paraguay Basin headwaters, likely due to the longer time frame covered by our primary and secondary datasets.

Keywords: *Species List, Pantanal, streams ichthyofauna, plateau, Paraguay basin.*

Levantamento das espécies de peixes da bacia do Rio Miranda em riachos do planalto, Alto Rio Paraguai, Brasil

Resumo: O objetivo deste trabalho é o de prover uma listagem da ictiofauna de riachos de cabeceira da bacia do Rio Miranda, Alto Rio Paraguai. Os peixes foram amostrados utilizando uma peneira retangular, rede de arrasto e rede de espera no período de 2004 a 2015, além disso, outros trabalhos realizados na bacia do Rio Miranda foram compilados e adicionados na listagem total, assim como, artigos de descrição e distribuição de espécies amostradas na bacia compreendendo o período de 1999 a 2015. A bacia do Rio Miranda apresentou um total de 143 espécies, 104 espécies oriundas de dados primários (72,7%) e 39 de dados secundários (27,3%). As espécies estão distribuídas em sete ordens e 30 famílias. Characiformes e Siluriformes foram as ordens predominantes e as famílias Characidae e Loricariidae apresentaram maior número de espécies. Os resultados obtidos neste estudo demonstram um maior número de espécies quando comparados com outros estudos realizados em cabeceiras na bacia do Alto Rio Paraguai decorrente ao longo período de estudo.

Palavras-chave: *Lista de espécies, Pantanal, ictiofauna de riachos, planalto, bacia do Paraguai.*

Introduction

The Paraguay River Basin is an important drainage of the La Plata River Basin (Lowe-McConnell 1999), and occupies a total area of about 496,000 km^2 (Junk et al. 2006). The Brazilian Pantanal has a total area of approximately 361,700 km^2, with 72.7% of the total territory lying in Brazil and the remainder in Bolivia and Paraguay. The upper Paraguay basin in Brazilian divided into two distinct regions: a floodplain known as the 'Pantanal', which at approximately 138,200 km^2 constitutes one of the largest wetland areas in the world; and a plateau comprised of areas with altitudes greater than 200 m encompassing approximately 223,500 km^2 (Silva & Abdon 1998). These two regions are distinguished by geological and geomorphological characteristics, however they are also interdependent since the headwaters of the most important rivers

draining into the Pantanal are in the plateau region, resulting in strong hydrologic connectivity (Willink et al. 2000, Teresa et al. 2010).

Approximately 270 fish species have been identified in the Paraguay River Basin (Britski et al. 2007). However, the total number of species would likely be higher if the plateau streams had been included (Alho & Sabino 2012). Numerous studies have been carried out in the basin over the past two decades, including the floodplain region (Catella & Petrere-Jr 1996, Willink et al. 2000, Junk et al. 2006, Baginski et al. 2007, Pacheco & Silva 2009, Pains-Silva et al. 2010, Tondato et al. 2013, Súarez et al. 2013, Pains-Silva et al. 2014, Polaz et al. 2014, Botini et al. 2015 and Severo-Neto et al. 2015) and plateau waters (Súarez et al. 2007, Terra & Sabino 2007, Teresa et al. 2010, Casatti et al. 2010, Teresa & Romero 2010, Castro & Vizzotto 2013, Krinski et al. 2015 and Oliveira et al. 2015). In studies of the plateau portion of the basin, analyses at small spatial scales were the predominant.

Compared to Brazilian hydrographic basins (e.g. the Upper Paraná River system), the fish fauna of central Brazil is poorly described (Casatti et al. 2010). Despite being a hotspot for endemic fauna (Willink et al. 2000) the main Pantanal headwater streams are understudied. The goal of this study was thus to describe the ichthyofauna of plateau region streams of the Miranda River Basin by combining primary and secondary data compiled from previous studies on the basin.

Materials and Methods

1. Study site

The Miranda River Basin is entirely within the limits of the Brazilian region, in Mato Grosso do Sul State. The total basin area is 42,993.83 km^2, with Serra da Bodoquena as the western boundary and the Paraguay River as the northwestern boundary (Plano de Recursos Hídricos da Bacia Hidrográfica do Rio Miranda 2014). The main tributaries are the Miranda and Aquidauana Rivers. The rivers and streams of the Aquidauana and Miranda Rivers flow into the Brazilian Cerrado (savanna), which is composed of patches of deciduous, semi-deciduous, and riparian forest that vary in density depending on the ecological drainage system in which they lie (Jesus 2003, Junk et al. 2006).

Surveys were conducted at 42 sites in the Miranda River Basin from January 2004 to January 2015 (primary data). Additional secondary data were compiled from 16 collection sites from published work on stream fish assemblages in the Miranda River Basin (Willink et al. 2000, Casatti et al. 2010, Teresa et al. 2010, Teresa & Romero 2010). These 58 sampling sites are distributed among streams from first to third order in 18 municipalities in Mato Grosso do Sul, Brazil (Figure 1). Taxonomic and distribution data from additional studies were also added to the final species list (Sabino & Trajano 1997, Willink et al. 2000, Ribeiro et al. 2007, Terra & Sabino 2007, Zawadzki et al. 2014, Shibatta 2016).

2. Sampling

For the primary data set, fish were sampled predominantly using a 0.8 x 1.2 m rectangular sieve and 5 x 1.5 m trawl nets, both with 2 mm mesh. In streams with a higher volume, sampling was supplemented with 10 x 1.5 m gill nets with mesh sizes of 15, 25, 30, 40, and 50 mm between adjacent knots. Sampled fish were anesthetized with Eugenol solution and subsequently fixed by immersion in 4% formaldehyde solution for at least 48 hours. Specimens were then washed and transferred to 70% ethanol.

Fish identification was performed mainly using the Pantanal fish identification key of Britski et al. (2007), and specific keys were used when necessary. Voucher specimens were deposited in the fish collection at the Universidade Federal de Mato Grosso do Sul (ZUFMS/UFMS) and the Núcleo de Pesquisa em Limnologia, Ictiologia e Aquicultura at the Universidade Estadual de Maringá (Nupelia/UEM). For the secondary data set, obtained by published articles and fish collection, voucher specimens were deposited in the fish collection of the Departamento de Zoologia e Botânica at the Universidade Estadual Paulista, São José do Rio Preto (DZSJRP/UNESP), Fish collection of Laboratório de Ictiologia de Ribeirão Preto (LIRP/USP) and Fish collection of Museu de Zoologia of University of Londrina (MZUEL/UEL). Collections were authorized by IBAMA (collection permit number SISBIO; process number 13458-1). Fish classification follows Eschmeyer et al. (2017).

3. Data analysis

To evaluate sampling efficiency, the total richness in the basin was estimated using a species accumulation curve with the bootstrap method (Smith & Van Belle 1984), as well as standard error using the function 'specaccum' in the 'vegan' package (Oksanen et al. 2011) in R (R Development Core Team 2013).

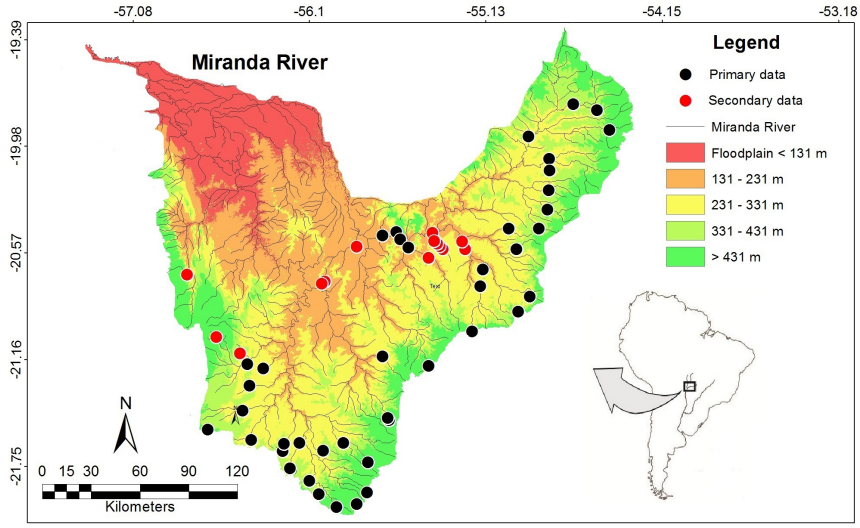

Figure 1: Locations of the sampling points in the Miranda River Basin of the Upper Paraguay River, Mato Grosso do Sul, Brazil. Black dots: Primary data; Red dots: Secondary data.

 http://dx.doi.org/10.1590/1676-0611-BN-2017-0344

Results

The datasets yielded a total of 143 species, 104 from the primary data (72.7%) and 39 from the secondary data (27.3%) data. Species were distributed among seven orders and 30 families (Table 1). Characiformes (75 species) and Siluriformes (48 species) were the predominant orders, representing together 86% of the recorded species. Among the families of these orders, the largest numbers of species were from Characidae and Loricariidae, representing 32.2% (46 species) and 15.4% (22 species) of the total sample, respectively (Figure 2).

The species accumulation curve shows that richness does not reach the asymptotic threshold (Figure 3), indicating the need for further collection efforts (i.e., increasing the number of sampling sites should increase estimates of species richness). The bootstrap method estimated approximately 169 with confidence interval (α=0.05) from 150 to 188 species, represent approximately 84.6% of the estimated by datasets (primary and secondary) the total number of species in the Miranda River basin.

In relation the species sampled *Piaractus mesopotamicus* (Holmberg 1887), *Pseudoplatystoma corruscans* (Linnaeus 1766) are on the National List

Table 1: Final list of species from sampled and compiled data from the Miranda River Basin, Upper Paraguay River. Location of voucher deposition: DZSJRP (Departamento de Zoologia e Botânica da Universidade Estadual Paulista, São José do Rio Preto – UNESP); ZUFMS (Coleção Zoológica da Universidade Federal do Mato Grosso do Sul – UFMS); LIRP (Coleção de Peixes do Laboratório de Ictiologia de Ribeirão Preto, Universidade de São Paulo - USP); MZUEL (Museu de Zoologia da Universidade Estadual de Londrina - UEL); NUP (Núcleo de Pesquisa em Limnologia, Ictiologia e Aquicultura da Universidade Estadual de Maringá – Nupelia/UEM).

Taxon	Voucher
BELONIFORMES	
Belonidae	
Potamorrhaphis eigenmanni Miranda-Ribeiro 1915	DZSJRP-12880
CHARACIFORMES	
Acestrorhynchidae	
Acestrorhynchus pantaneiro Menezes 1992	ZUFMS-PIS01657
Anostomidae	
Leporinus friderici (Bloch 1794)	ZUFMS-PIS01063
Leporinus lacustris Campos 1945	DZSJRP-12439
Leporinus striatus Kner 1858	DZSJRP-12438
Leporellus vittatus (Valenciennes 1850)	[5]LIRP-5334
Megaleporinus obtusidens (Valenciennes 1836)	DZSJRP-12858
Bryconidae	
Brycon hilarii (Valenciennes 1849)	DZSJRP-11992
Salminus brasiliensis (Cuvier 1816)	DZSJRP-000534
Characidae	
Galeocharax humeralis (Valenciennes 1834)	ZUFMS-PIS03418
Roeboides descalvadensis Fowler 1932	DZSJRP-12871
Phenacogaster tegatus (Eigenmann 1911)	ZUFMS-PIS03802
Odontostilbe pequira (Steindachner 1882)	ZUFMS-PIS03908
Odontostilbe paraguayensis Eigenmann & Kennedy 1903	ZUFMS-PIS03815
Serrapinnus calliurus (Boulenger 1900)	ZUFMS-PIS03847
Serrapinnus kriegi (Schindler 1937)	ZUFMS-PIS01399
Serrapinnus microdon (Eigenmann 1915)	[5]MZUEL-12591
Serrapinnus notomelas (Eigenmann 1915)	ZUFMS-PIS04040
Characidae Incertae Sedis	
Aphyocharax anisitsi Eigenmann &Kennedy 1903	ZUFMS-PIS01275
Aphyocharax dentatus Eigenmann & Kennedy 1903	ZUFMS-PIS03791
Prionobrama paraguayensis (Eigenmann 1914)	DZSJRP-12861
Astyanax abramis (Jenyns, 1842)	DZSJRP12873
Astyanax lacustris (Lütken 1875) (syn. *Astyanax asuncionensis*)	ZUFMS-PIS03848
Astyanax aff. *fasciatus* (Cuvier 1819)	NUP-17163
Astyanax lineatus (Perugia 1891)	NUP-17166
Astyanax marionae Eigenmann 1911	NUP17197
Astyanax sp. 1	NUP-17162
Astyanax sp. 2	NUP-17178
Astyanax sp. 3	NUP-17161
Hyphessobrycon cf. *arianae* Uj & Géry 1989	DZSJRP-12898
Hyphessobrycon eques (Steindachner 1882)	DZSJRP-12863
Hyphessobrycon elachys Weitzman 1984	DZSJRP-12866
Hyphessobrycon luetkenii (Boulenger 1887)	DZSJRP-11969
Psellogrammus kennedyi (Eigenmann 1903)	ZUFMS-PIS01427
Brachychalcinus retrospina Boulenger 1892	NUP-17213

[1]Sabino & Trajano (1997); [2]Ribeiro et al. (2007); [3]Zawadzki et al. (2014); [4]Terra & Sabino (2007); [5]Willink et al. (2000); 6Rizzato, Costa, Trajano & Bichuette (2011); [7]Shibatta (2016). * Species occurrence information, but not sampled.

Table 1: Continued...

Taxon	Voucher
Bryconops melanurus (Bloch 1794)	DZSJRP-12917
Hemigrammus lunatus Durbin 1918	DZSJRP-12882
Hemigrammus tridens Eigenmann 1907	DZSJRP-12885
Moenkhausia bonita Benine, Castro & Sabino 2004	NUP-17165
Moenkhausia forestii Benine, Mariguela & Oliveira 2009	ZUFMS-PIS04042
Moenkhausia intermedia Eigenmann 1908	ZUFMS-PIS03832
Moenkhausia oligolepis (Günter 1864)	ZUFMS-PIS03863
Moenkhausia sanctafilomenae (Steindachner 1907)	ZUFMS-PIS00173
Jupiaba acanthogaster (Eigenmann 1911)	NUP-17168
Gymnocorymbus ternetzi (Boulenger 1895)	ZUFMS-PIS01449
Poptella paraguayensis (Eigenmann 1907)	ZUFMS-PIS01450
Bryconamericus exodon (Eigenmann 1907)	NUP-17196
Bryconamericus stramineus Eigenmann 1908	NUP-17205
Creagrutus meridionalis Vari & Harold 2001	NUP-17195
Piabarchus analis (Eigenmann 1914)	NUP-17190
Piabarchus torrenticola Mahnert & Géry 1985	NUP-17214
Xenurobrycon macropus Myers & Miranda Ribeiro 1945	DZSJRP-12881
Oligosarcus perdido Ribeiro, Cavallaro & Froehlich 2007	[2]LIRP-5893
Oligosarcus pintoi Campos 1945	ZUFMS-PIS04038
Tetragonopterus argenteus (Cuvier 1816)	ZUFMS-PIS01541
Crenuchidae	
Characidium borellii (Boulenger 1895)	ZUFMS-PIS02505
Characidium aff. f*asciatum* Reinhardt 1866	DZSJRP-13743
Characidium laterale (Boulenger 1895)	DZSJRP-12855
Characidium aff. *zebra* Eigenmann 1909	NUP-17172
Characidium cf. *gomesi* Travassos 1956	DZSJRP-12876
Characidium sp. 1	NUP-17559
Characidium sp.	NUP-17181
Curimatidae	
Cyphocharax gillii (Eigenmann & Kennedy 1903)	ZUFMS-PIS03850
Steindachnerina brevipinna (Eigenmann & Eigenmann 1889)	ZUFMS-PIS03794
Erythrinidae	
Hoplias sp. 1	ZUFMS-PIS03877
Erythrinus erythrinus (Bloch & Schneider 1801)	DZSJRP-12900
Hoplerythrinus unitaeniatus (Agassiz 1829)	DZSJRP-12902
Iguanodectidae	
Piabucus melanostoma Holmberg 1891	DZSJRP-000620
Lebiasinidae	
Pyrrhulina australis Eigenmann & Kennedy 1903	DZSJRP-12864
Parodontidae	
Apareiodon affinis (Steindachner 1879)	DZSJRP-12910
Parodon nasus Kner 1859	ZUFMS-PIS04057
Prochilodontidae	
Prochilodus lineatus (Valenciennes 1836)	LIRP-5849
Serrasalmidae	
Metynnis maculatus (Kner 1858)	MZUEL-5235
Piaractus mesopotamicus (Holmberg 1887)	[5]DZSJRP-007798
Serrasalmus maculatus Kner 1858	[5]MZUEL-14023
Serrasalmus marginatus Valenciennes 1837	ZUFMS-PIS03836
GYMNOTIFORMES	
Apteronotidae	
Apteronotus albifrons (Linnaeus 1766)	DZSJRP-12407
Gymnotidae	
Gymnotus inaequilabiatus (Valenciennes 1839)	DZSJRP-12856
Gymnotus sp.	ZUFMS-PIS04043
Hipopomidae	

[1]Sabino & Trajano (1997); [2]Ribeiro et al. (2007); [3]Zawadzki et al. (2014); [4]Terra & Sabino (2007); [5]Willink et al. (2000); 6Rizzato, Costa, Trajano & Bichuette (2011); [7]Shibatta (2016). * Species occurrence information, but not sampled.

Table 1: Continued...

Taxon	Voucher
Brachyhypopomus sp. B	MZUSP-59444.0
Brachyhypopomus sp. C	ZUFMS-PIS3820
Brachyhypopomus sp.	DZSJRP-12862
Rhamphichthyidae	
Gymnorhamphichtys britskii Carvalho, Ramos & Albert, 2011	ZUFMS-PIS01487
Sternopygidae	
Eigenmannia trilineata López & Castello 1966	DZSJRP-12865
Sternopygus macrurus (Bloch & Schneider 1801)	ZUFMS-PIS03397
SILURIFORMES	
Auchenipteridae	
Tatia neivai (Ihering 1930)	ZUFMS-PIS01419
Callichthyidae	
Callichthys callichthys (Linnaeus 1758)	ZUFMS-PIS04046
Hoplosternum littorale (Hancock 1828)	ZUFMS-PIS01132
Lepthoplosternum pectorale (Boulenger 1895)	DZSJRP-12901
Corydoras aeneus (Gill 1858)	DZSJRP-12886
Corydoras areio Knaack 2000	ZUFMS-PIS01105
Corydoras hastatus Eigenmann & Eigenmann 1888	DZSJRP-12904
Corydoras sp.	ZUFMS-PIS05366
Cetopsidae	
Cetopsis gobioides (Kner 1858)	ZUFMS-PIS04039
Heptapteridae	
Imparfinis mirini Haseman 1911	ZUFMS-PIS02493
Imparfinis cf. *schubarti* (Gomes 1956)	DZSJRP-12911
Imparfinis stictonotus (Fowler 1840)	NUP-17194
Imparfinis sp. 1	DZSJRP-12913
Imparfinis sp. 2	DZSJRP-12887
Imparfinis sp.	NUP-17180
Pimelodella gracilis (Valenciennes in d'Orbigny 1835)	DZSJRP-12914
Pimelodella taenioptera Miranda-Ribeiro 1914	ZUFMS-PIS01052
Phenacorhamdia hoehnei (Miranda-Ribeiro 1914)	DZSJRP-12410
Rhamdia quelen (Quoy & Gaimard 1824)	ZUFMS-PIS01046
Loricariidae	
Otocinclus bororo Schaefer 1997	[4]NUP-13347
Otocinclus vittatus Regan 1904	DZSJRP-12874
*Hypostomus basilisko*Tencatt, Zawadzk i& Froehlich 2014	ZUFMS-PIS01294
Hypostomus boulengeri (Eigenmann & Kennedy 1903)	DZSJRP-12908
Hypostomus cochliodon Kner 1854	DZSJRP-12437
*Hypostomus khimaera*Tencatt, Zawadzki & Froehlich 2014	NUP-17207
Hypostomus aff. *latirostris* (Regan 1904)	NUP-17170
Hypostomus piratatu Weber 1986	ZUFMS-PIS02539
Hypostomus perdido Zawadzki, Tencatt & Froehlich 2014	[3]ZUFMS-PIS1468
Hypostomus sp.	NUP-17537
Ancistrus formoso Sabino & Trajano 1997	[1]MZUSP-51836
Ancistrus sp.	NUP-17209
Farlowella cf. *isbrueckeri* Retzer & Page 1997	ZUFMS-PIS01291
Farlowella paraguayensis Retzer & Page 1997	NUP-17202
Loricaria cf. *coximensis* Rodriguez, Cavallaro & Thomas 2012	NUP-17204
Loricaria luciae Thomas, Rodriguez, Cavallaro, Froehlich & Macedo Corrêa e Castro 2013	NUP-17171
Loricaria sp.	DZSJRP-12920
Proloricaria prolixa Isbrücker & Nijssen 1978	MZUEL-10006
Pyxiloricaria menezesi Isbrücker & Nijssen 1984	NUP-17203
Rineloricaria cacerensis (Miranda-Ribeiro 1912)	ZUFMS-PIS01344
Rineloricaria lanceolata (Günther 1868)	NUP-17192
Rineloricaria parva (Boulenger 1895)	ZUFMS-PIS03839
Pimelodidae	

[1]Sabino & Trajano (1997); [2]Ribeiro et al. (2007); [3]Zawadzki et al. (2014); [4]Terra & Sabino (2007); [5]Willink et al. (2000); 6Rizzato, Costa, Trajano & Bichuette (2011); [7]Shibatta (2016). * Species occurrence information, but not sampled.

Table 1: Continued...

Taxon	Voucher
Pseudoplatystoma corruscans (Spix & Agassiz 1829)	MZUSP-51269.0
Pseudoplatystoma reticulatum Eigenmann & Eigenmann 1889	*[5]
Pseudopimelodidae	
Microglanis leniceae Shibatta 2016	ZUFMS-PIS01657[7]
Pseudopimelodus mangurus (Valenciennes 1835)	ZUFMS-PIS03397
Rhyacoglanis pulcher (Boulenger 1887)	DZSJRP-12141
Trichomycteridae	
Paravandellia oxyptera Miranda-Ribeiro 1912	DZSJRP-12877
Trichomycterus dali Rizzato, Costa, Trajano & Bichuette 2011	MZUSP 166630[6]
Trichomycterus sp.	NUP-9351
CYPRINODONTIFORMES	
Poeciliidae	
Poecillia reticulata Peters 1859	ZUFMS-PIS03799
Cynolebiidae	
Melanorivulus punctatus (Boulenger 1895)	DZSJRP-12905
SYNBRANCHIFORMES	
Synbranchidae	
Synbranchus marmoratus Bloch 1795	ZUFMS-PIS03797
CICHLIFORMES	
Cichlidae	
Aequidens plagiozonatus Kullander 1984	DZSJRP-12906
Bujurquina vittata (Heckel 1840)	ZUFMS-PIS03843
Cichlassoma dimerus (Heckel 1840)	NUP-17187
Crenicichla lepidota Heckel 1840	DZSJRP-12889
Crenicichla vittata Heckel 1840	[5]ZUFMS-PIS01307
Crenicichla sp.	ZUFMS-PIS03800

[1]Sabino & Trajano (1997); [2]Ribeiro et al. (2007); [3]Zawadzki et al. (2014); [4]Terra & Sabino (2007); [5]Willink et al. (2000); 6Rizzato, Costa, Trajano & Bichuette (2011); [7]Shibatta (2016). * Species occurrence information, but not sampled.

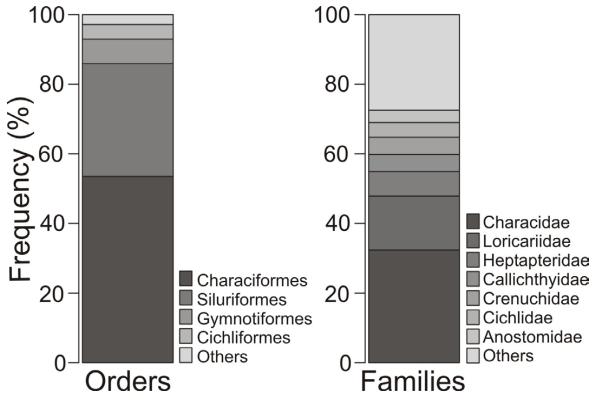

Figure 2: Frequency of orders and families from to primary and secondary data from the Miranda River Basin of the Upper Paraguay River, Mato Grosso do Sul, Brazil.

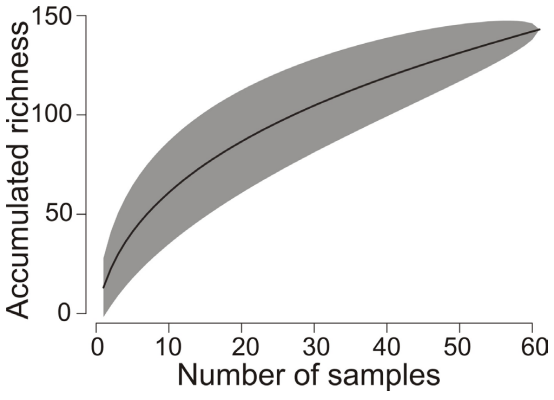

Figure 3: Species accumulated curve generated from to primary and secondary data from the Miranda River Basin of the Upper Paraguay River, Mato Grosso do Sul, Brazil.

of Near-threatened Species. Furthermore *Characidium* aff. *fasciatum* Reinhardt 1866, *Farlowella* cf. *isbrueckeri* Retzer & Page 1997 are listed as data deficient. The cave fishes *Ancistrus formoso* Sabino & Trajano 1997 and *Trichomycterus dali* Rizzato, Costa, Trajano & Bichuette 2011 are listed as vulnerable. We encountered six possible new species, including *Astyanax* sp. 1, *Astyanax* sp. 2, *Astyanax* sp. 3, *Characidium* sp. 1, *Imparfinis* sp. 1, *Imparfinis* sp. 2. Six species from our data sets were reported as only being found in the Paraná River basin, such as *Serrapinnus notomelas* (Eigenmann 1915), *Astyanax* aff. f*asciatus* (Cuvier 1819), *Imparfinis mirini* Haseman 1911, *Imparfinis* cf. *schubarti* (Gomes 1956), *Proloricaria prolixa* Isbrücker & Nijssen 1978 and *Hoplias* sp. 1 from our primary data set, and *Oligosarcus pintoi* Campos 1945, *Rineloricaria lanceolata* (Günter 1868) from our secondary data set.

Discussion

Studies of fishes from the Paraguay River basin usually concentrate on the main rivers of the Pantanal region (Britski et al. 2007, Terra & Sabino 2007, Polaz et al. 2014), due mainly to the easy access into these areas, when compared to the headwaters, this makes the knowledge of the

fauna of streams almost non-existent (Krinski et al. 2015). However, to understand the environmental structural dynamics, the accomplishment of ichthyofauna inventories and systematic studies are extremely important. Besides, they constitute the basis for better understanding the dynamics of species distribution (Vilar et al. 2011), providing data on the species composition, management and conservation (Pains-Silva et al. 2014).

Our results showed predominance of Characiformes and Siluriformes, and the families Characidae and Loricariidae. Other studies conducted in streams of the Paraguay River Basin reported similar results (Oliveira et al. 2015, Vizzotto & Castro 2015), which reflect typical species patterns for Neotropical icthyofauna (Reis et al. 2016).

The combination of primary and secondary data for the Miranda River Basin produced a data set from a greater number of sample sites, over longer time periods, and at larger spatial scales, and the end product is a more complete assessment of regional fish fauna. Other studies of fish fauna in the Paraguay River Basin at smaller spatial scales report fewer numbers of species, including studies from streams of the headwaters of the Rio Vermelho (Oliveira et al. 2015, Vizzotto & Castro 2015) and Rio Sepotuba (Krinski et al. 2015) in northern Pantanal. In other words, by increasing spatial scale and the number of sample sites, we also increase the probability of greater among-site variation in species numbers by virtue of including a greater diversity of mesohabitats with different substrate types and riparian vegetation. These differences in habitat structural complexity (Teresa et al. 2010, Teresa Romero & 2010, Krinski et al. 2015, Vizzotto & Castro 2015) result in a gradient of heterogeneity that, through niche differentiation, favors a greater number of species.

Some species in the current study should be highlighted due to conservation status. Serrasalmidae and Pimelodidae, *Piaractus mesopotamicus* and *Pseudoplatystoma corruscans* are on the National List of Near-threatened Species (NT) in Brazil (data published by ICMBio 2014), despite this, these species have broad distribution in the Paraguay River Basin, in addition, they are important species for artisanal and sports fishing in the region, being *P. corruscans* represent approximately 32% and *P. mesopotamicus* 17.3% of artisanal fisheries in 2015 (Catella et al. 2016). So, this results suggest a need of effort to better definition of conservation status at upper Paraguay basin scale.

Among the species sampled were *Characidium* aff. *fasciatum* and *Farlowella* cf. *isbrueckeri* from the families Crenuchidae and Loricariidae, respectively, both of which are listed at Brazilian law as Data Deficient (DD) (data published by ICMBio 2014) due to low numbers of recorded occurrences or absence in study samples. *Ancistrus formoso* and *Trichomycterus dali* are the only encountered species listed as vulnerable, likely a result of its limited distribution due to restriction to cave habitats in the karst environments of the Serra da Bodoquena (Cordeiro et al. 2014); the restricted range and the frequent change of the landscape to harbor crop fields in the region represent a great menace to these species. The Miranda River Basin seems to offers sufficient resources to maintain numerous species, in particular species of concern with respect to conservation. The collective data thus suggest that preservation of this basin ecosystem is critical for perpetuation of natural resources and biodiversity.

There are roughly 270 described species in the Pantanal floodplain (Britski et al. 2007), and our list presents 39 additional species not included in that estimate. Several species from our data sets were reported as only being found in the Paraná River basin, this suggests dispersion during the formation of the Pantanal, and serves as evidence of connectivity between the headwaters of the Paraná and Paraguay River Basins. This finding illustrates the importance of expanding sampling effort for interface regions of the basins, and reviewing the material deposited in biological collections.

In addition to future studies of species richness in the Paraguay River Basin, more detailed information on species distributions is needed to better gauge conservation status of fish in the area. There have been a limited number of studies in the area, particularly in headwater streams and their tributaries (Oyakawa & Menezes 2011, Krinski et al. 2015). Many species of headwater streams are potentially geographically isolated (Lowe-McConnell 1999) that are specific to these areas (Krinski et al. 2015), whereby headwaters may host very different fauna than exists in major rivers (Pedroza et al. 2012, Volcan et al. 2012). Based on previous experience and distribution maps from SpeciesLink, we can point out in this whor *Astyanax lineatus*, *A. marionae*, *Creagrutus meridionalis*, *Oligosarcus perdido*, *Hypostomus basilisko*, *H. perdido* and the cave fish *Ancistrus formoso* and *Trichomycterus dali* as exclusive species that inhabit headwaters. This understanding of fish fauna in headwater streams and associated tributaries is essential for maintaining fish biodiversity in the Paraguay River Basin. Inventory studies in the basin would also be useful for evaluation of potential environmental impacts on ichthyofauna, as these environments are subject to anthropogenic modification (e.g., due to the construction of hydroelectric dams, which has increased in last years). Such anthropogenic impacts have potential to modify species distribution (Mariano et al. 2012), by limiting species dispersion and altering resource availability in the entire plateau region of the Upper Paraguay Basin. In the Miranda River Basin, at least eleven small hydroelectric projects have recently approved for construction, two in Miranda sub-basin and nine in Aquidauana sub-basin. More attention should be given to the actual and potential negative impacts of these and other anthropogenic activities upon fish diversity and distributions in the basin area.

Acknowledgments

We thank the Biota-MS program in association with the Superintendência de Ciência e Tecnologia de MatoGrosso do Sul (SUCITEC), CAPES, CNPq and FUNDECT for financial and logistical support. We are grateful to Walmir B. F. Mundim Jr., Wagner Vicentin, Marcelo S. Maldonado and Gabriel Nakamura for help with field work.

Author Contributions

Fabiane S. Ferreira, Gabriela S. V. Duarte, Francisco Severo Neto, Otávio Froehlich and Yzel R. Súarez contributed to the field work and in secondary data collection. FSF and YRS also realized a statistical analysis and all authors contributed to manuscript preparation and critical revision.

Conflicts of Interest

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

References

ALHO, C.J.R. & SABINO, J. 2012. Seasonal Pantanal flood pulse: implications for biodiversity conservation – A review. Oecol. Aust. 16(4): 958-978. doi: http://dx.doi.org/10.4257/oeco.2012.1604.17.

BAGINSKI, L.J., FLORENTINO, A.C., FERNANDES, I.M., PENHA, J.M.P. & MATEUS, L.A.F. 2007 The spatial and temporal dimension of fish diversity of the vegetated littoral zone of marginal lagoons of the Cuiabá river floodplain, Pantanal, Brazil. Biota Neotrop 7(3): 233-238. http://www.biotaneotropica.org.br/v7n3/pt/abstract?article+bn04007032007 (Accessed 24 Jun 2016).

BOTINI, A.F., BARROS, C.A., SOUZA, T.H., BOTINI, N., MOURA, N.A. 2015. Diversidade de peixes no Rio Mutum e baía marginal no Pantanal – Matogrossense através da coleta ativa. Enciclop Biosf 11(21): 2183-2197.

BRITSKI, H.A., SILIMON, K.Z.S. & LOPES, B.S. 2007. Peixes do Pantanal: manual de identificação. 2 ed. Embrapa, Brasília, 227p.

CASATTI, L., ROMERO, R.M., TERESA, F.B., SABINO, J. & LANGEANI, F. 2010. Fish community structure along a conservation gradient in Bodoquena Plateau streams, central West of Brazil. Acta Limnol Brasil 22(1): 50-59. doi: http://dx.doi.org/10.4322/actalb.02201007.

CASTRO, R.J. & VIZZOTTO, P.C. 2013. Fishes of the Vermelho River, São Lourenço River basin, MatoGrosso state, Brazil. Check List 9(1): 001-003.

CATELLA, A.C., CAMPOS, F.L.R., ALBUQUERQUE, S.P. 2016. Sistema de controle de pesca de Mato Grosso do Sul SCPESCA/MS 22- 2015. Corumbá: Boletim de pesquisa e desenvolvimento – Embrapa Pantanal. p. 55.

CATELLA, A.C. & PETRERE-JR, M. 1996. Feeding patterns in a fish community of Baia da Onça, a foodplain lake of the Aquidauana River, Pantanal, Brazil. Fisheries Manag Ecol 3: 229-237.

CORDEIRO, L.M.; BORGHEZAN, R. & TRAJANO, E. 2014. Subterranean biodiversity in the Serra da Bodoquena karst area, Paraguay river basin, Mato Grosso do Sul, Southwestern Brazil. Biota Neotropica14: 1-28. doi: http://dx.doi.org/10.1590/1676-06032014011414.

ESCHMEYER, W.N., FRICKE, R. & VAN DER LAAN, R. (eds.). 2017. Catalog of Fishes: Genera, Species, References.http://researcharchive.calacademy.org/research/ichthyology/catalog/fishcatmain.asp (Accessed 20 May 2017).

JESUS, F. 2003. Classificação dos ecossistemas aquáticos do Pantanal e da bacia do Alto Paraguai. Brasília: The Nature Conservancy. p. 136.

JUNK, W.J., CUNHA, C.N., WANTZEN, K.M., PETERMANN, P., STRÜSSMANN, C., MARQUES, M.I. & ADIS, J. 2006. Biodiversity and its conservation in the Pantanal of Mato Grosso, Brazil. Aquat Sci 68: 278-309. doi: http://dx.doi.org/10.1007/s00027-006-0851-4.

KRINSKI, D., CARMO, E.J. & MIYAZAWA, C.S. 2015. Ichthyofauna of headwaters from Sepotuba River Basin, Upper Paraguay River Basin, Tangará da Serra, Mato Grosso state, Brazil. Panamjas 10(4): 283-292.

MARIANO, J.R., MAKRAKIS, M.C., KASHIWAQUI, E.A.L., CELESTINO, E.F. & MAKRAKIS, S. 2012. Longitudinal habitat disruption in Neotropical streams: fish assemblages under the influence of culverts. Neotrop Ichthyol 10(4):771-784. doi: http://dx.doi.org/10.1590/S1679-62252012000400010.

OKSANEN, J., BLANCHET, F.G., KINDT, R., LEGENDRE, P., O'HARA, R.B., SIMPSON, G.L., STEVENS, M.H.H. & WAGNER, H. 2011. Vegan: community ecology package. Version 1.17-11. Available from: http://vegan.r-forge.r-project.org/

OLIVEIRA, V.A., MATEUS, L.A., LOVERDE-OLIVEIRA, S. & PIETRO-SOUZA, W. 2015. Fish from urban tributaries to the Vermelho River, upper Paraguay River Basin, Mato Grosso, Brazil. Check List 11(1): 1-6. doi: http://dx.doi.org/10.15560/11.1.1516.

OYAKAWA, O.T. & MENEZES, N.A. 2011. Checklist of fresh water fishes from São Paulo State, Brazil. Biota Neotrop 11(1a): 19-32. doi: http://dx.doi.org/10.1590/S1676-06032011000500002.

PACHECO, E.B. & SILVA, C.J. 2009. Fish associated with aquatic macrophytes in the Chacororé-Sinhá Mariana lake system and Mutum River, Pantanal of Mato Grosso Brazil. Braz J Biol 69(1): 101-108. doi: http://dx.doi.org/10.1590/S1519-69842009000100012.

PAINS-SILVA, H., SOUZA, F. & CORRÊA, F. 2014. Ictthyofauna of the Bento Gomes River in the Pantanal Matogrossense, Brazil. Panamjas 9(1): 48-53.

PAINS-SILVA, H., PETRY, A.C. & DA SILVA, C.J. 2010. Fish communities of the Pantanal wetland in Brazil: evaluating the effects of the Upper Paraguay River flood pulse on baía Caiçara fish fauna. Aquat Ecol 44: 275-288. doi: http://dx.doi.org/10.1007/s10452-009-9289-9.

PEDROZA, W.S., RIBEIRO, F.R.V., TEIXEIRA, T.F., OHARA, W.M. & PY-DANIEL, L.H.R. 2012. Ictthyofauna survey of stretches of the Guariba and Roosevelt Rivers, in Guariba State Park and Guariba Extractive Reserve, Madeira River basin, Amazonas, Brazil. Check List 8(1): 8-15.

PLANO DE RECURSOS HÍDRICOS DA BACIA HIDROGRÁFICA DO RIO MIRANDA. 2014. http://www.imasul.ms.gov.br/wp-content/uploads/sites/74/2015/06/Diagn%C3%B3stico-Final-Plano-de-Bacia-Miranda.pdf (Acessed 20 May 2017).

POLAZ, C.N.M., MELO, B.F., BRITZKE, R., RESENDE, E.K., MACHDO, F.A., LIMA, J.A.F. & PETRERE jr, M. 2014. Fishes from the Parque Nacional do Pantanal Matogrossense, upper Paraguai River basin, Brazil. Check List 10(1): 122-130. doi: http://dx.doi.org/10.15560/10.1.122.

R DEVELOPMENT CORE TEAM. 2013. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. http://www.R-project.org/.

REIS, R.E., ALBERT, J.S., DI DARIO, F., MINCARONE, M.M., PETRY, P. & ROCHA, L.A. 2016. Fish biodiversity and conservation in South America. J. Fish Biol.89(1):12–47. doi: http://dx.doi.org/10.1111/jfb.13016

RIBEIRO, A.C., CAVALLARO, M.R. & FROEHLICH, O. 2007. *Oligosarcus perdido* (Characiformes, Characidae), a new species of fresh water fish from Serra da Bodoquena, upper Rio Paraguai basin, Brazil. Zootaxa 1560: 43-53.

SABINO, J. & TRAJANO, E. 1997. A new species of blind armoured catfish, genus *Ancistrus*, from caves of Bodoquena region, Mato Grosso do Sul, southwestern Brazil (Siluriformes, Loricariidae, Ancistrinae). Revue Fr Aquariol 23: 73-78.

SEVERO-NETO, F., TENCATT, L.F.C., COSTA-PEREIRA, R. & TAVARES, L.E.R. 2015. Fishes from Baía da Medalha, southern Pantanal, Brazil: A 20 years review. Biota Neotrop 15(2): 1-9. doi: http://dx.doi.org/10.1590/1676-06032015011614.

SILVA, J.S.V. & ABDON, M.M. 1998. Delimitação do Pantanal Brasileiro e suas sub-regiões. Pesq. Agropec. Bras. 33: 1703-1711.

SHIBATTA, O.A. 2016. A new species of bumblebee catfish of the genus *Microglanis* (Siluriformes: Pseudopimelodidae) from the upper rio Paraguay basin, Brazil. Neotrop Ichthyol 14(3): e160031. http://dx.doi.org/10.1590/1982-0224-20160031.

SMITH, E.P. & VAN BELLE, G. 1984. Nonparametric estimation of species richness. Biometrics 40(1):119-129. doi: http://dx.doi.org/10.2307/2530750.

SÚAREZ, Y.R., FERREIRA, F.S. & TONDATO, K.K. 2013. Assemblage of fish species associated with aquatic macrophytes in Porto Murtinho Pantanal, Mato Grosso do Sul, Brazil. Biota Neotrop 13(2): 182-189. http://www.biotaneotropica.org.br/v13n2/en/abstract?inventory+bn02313022013 (Accessed 24 Jun 2016)

SÚAREZ, Y.R., VALÉRIO, S.B., TONDATO, K.K., FLORENTINO, A.C., FELIPE, T.R.A., XIMENES, L.Q.L. & LOURENÇO, L.S. 2007. Fish species diversity in headwaters streams of Paraguay and Paraná basins. Braz Arch Biol Techn 50(6): 1033-1042. doi: http://dx.doi.org/10.1590-89132007000700014.

TERESA, F.B. & ROMERO, R.M. 2010. Influence of the riparian zone phytophysiognomies on the longitudinal distribution of fishes: evidence from a Brazilian savanna stream. Neotrop Ichthyol 8(1): 163-170. doi: http://dx.doi.org/10.1590/S1679-62252010000100019.

TERESA, F.B., ROMERO, R.M. & LANGEANI, F. 2010. Pisces, Aquidauana and Miranda drainages, upper Paraguay River basin, Mato Grosso do Sul, Brazil. Check List 6(4): 596-601.

TERRA, L.C.C. & SABINO, J. 2007. Composição da ictiofauna de dois riachos, com diferentes graus de conservação, na bacia do Rio Formoso, município de Bonito, Mato Grosso do Sul, Brasil. Redalyc 11(1): 49-58. http://www.redalyc.org/articulo.oa?id=26012838005 (Accessed 24 Jun 2016).

TONDATO, K.K., FANTIN-CRUZ, I., PEDROLLO, O.C., SÚAREZ, Y.R. 2013. Spatial distribution of fish assemblages along environmental gradients in the temporary ponds of Northern Pantanal, Brazil. J Limnol 71(1): 95-102. doi: http://dx.doi.org/10.4081/jlimnol.2013.e8.

VILAR, C.C., SPACH, H.L. & SOUZA-CONCEIÇÃO, J.M. 2011. Fish assemblage in shallow areas of Baía da Babitonga, southern Brazil: structure, spatial and temporal patterns. Panamjas 6(4): 303-319.

VIZZOTO, P.C. & CASTRO, R.J. 2015. Ichthyofauna of tributaries of the Vermelho River, upper Paraguay River basin, region of Rondonópolis, state of Mato Grosso, Brazil. Check List 11(5): 1-5. doi: http://dx.doi.org/10.15560/11.5.1750.

VOLCAN, M.V., LANÉS, L.E.K., GONÇALVES, A.C., FONSECA, A.P. & CIRNE, M.P. 2012. The fish fauna of the Corrientes stream basin, Patos lagoon system, state of Rio Grande do Sul, southern Brazil. Check List 8(1): 77-82. doi: http://dx.doi.org/10.15560/8.1.077.

WILLINK, P.W., FROEHLICH, O., MACHADO-ALISSON, A., MENEZES, N., OYAKAWA, O., CATELLA, A., CHERNOFF, B., LIMA, F.C.T., TOLEDO-PIZA, M., HORTEGA, H., ZANATA, A.M. & BARRIGA, R. 2000. Diversidade, distribuição e habitats críticos dos peixes dos rios: Negro, Negrinho, Taboco,

Taquari e Miranda, e sua importância para conservação e desenvolvimento sustentável do Pantanal, Mato Grosso do Sul, Brasil. Pp. 63-81. In: WILLINK, P. W., CHERNOFF, B., ALONSO, L., MONTAMBAULT, J.R. & LOURIVAL, R. (eds). RAP Bulletin of Biological Assesment, 18: Uma Avaliação Biológica dos Ecossistemas Aquáticos do Pantanal, Mato Grosso do Sul, Brasil. Conservation International, Washington.

ZAWADZKI, C.H., L.F.C. TENCATT, and O. FROEHLICH. 2014. A new unicuspid-toothed species of *Hypostomus* Lacépède, 1803 (Siluriformes: Loricariidae) from the rio Paraguai basin. Neotrop Ichthyol 12(1): 97-104. doi: http://dx.doi.org/10.1590/S1679-62252014000100010.

Received: 15/03/2017
Revised: 20/07/2017
Accepted: 21/07/2017
Published online: 14/08/2017