ISSN 1809-127X (online edition)

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Lists of Species

Pisces, Aquidauana and Miranda drainages, upper Paraguay River basin, Mato Grosso do Sul, Brazil

Fabrício Barreto Teresa*, Renato de Mei Romero and Francisco Langeani

Universidade Estadual Paulista, Instituto de Biociências, Letras e Ciências Exatas, Laboratório de Ictiologia, Departamento de Zoologia e Botânica. Rua Cristóvão Colombo, 2265, CEP 15054-000. São José do Rio Preto, SP, Brazil
* Corresponding author. E-mail: *fabricioteresa@yahoo.com.br*

Abstract: An inventory of the ichthyofauna of the Aquidauana and Miranda basins is presented. A total of 9,559 individuals of six orders, 21 families and 68 species were sampled in streams (n = 6), rivers (n = 2), and reservoirs (n = 5) during the dry and wet seasons. Streams and rivers were the sites with higher richness, with 97% of the total richness. On the other hand, the highest abundance was recorded for reservoirs, with homogeneous assemblages dominated by nektonic species. Structural heterogeneity and proximity to the mainstem seem to be the main factors influencing fish richness in streams. This study reports a high regional richness and reinforces the necessity for the preservation of the lotic environments of the Cerrado.

Introduction

The La Plata system is the second largest drainage in South America (Lowe-McConnell 1999), occupying an area of approximately 3.2 million km^2. The Paraguay basin is an important drainage of this system and can be divided into two distinct regions: a floodplain known as the Pantanal, which is one of largest wetland areas in the world, and a plateau, limiting the Pantanal, which has areas of altitudes higher than 200 m. These two regions are distinguished by geologic and geomorphologic characteristics, but are interdependent since the headwaters of the most important rivers draining to the Pantanal are in the plateau region, providing high hydrologic connectivity (Willink *et al.* 2000).

The Miranda river basin is a subunit of the upper Paraguay system and is formed by two main rivers, Miranda and Aquidauana as well as by their tributaries. The rivers and streams of the Miranda basin flow into the Brazilian Cerrado (savanna) biome. In this basin, siltation and deforestation of riparian zones are the most important impacts affecting aquatic environments (Mendes *et al.* 2004; Casatti *et al.* 2010).

Recent studies have shown high fish diversity in the Miranda and Aquidauana drainages (Valério *et al.* 2007; Súarez *et al.* 2007; Teresa and Romero 2010; Casatti *et al.* 2010). However, accumulated knowledge about their ichthyofauna is still poor when compared to the territorial extension and high diversity of the aquatic environments. In this study we describe the ichthyofauna of streams, rivers and reservoirs of the Miranda and Aquidauana drainages, providing basic information that may permit management strategies for the conservation of aquatic resources in the region.

Materials and Methods

Study site

All sample sites were located in the municipalities of Anastácio and Dois Irmãos do Buriti, state of Mato Grosso do Sul (Figure 1). The studied region belongs to the Maracaju plateau, a region characterized by plain relief and wide hills, presenting rainy summer (October to March) and dry winter (April to September), with low annual temperature range (Mendes *et al.* 2004).

Data collection

In order to represent the diversity of water bodies in the region, rivers (n = 2), streams (n = 6), and reservoirs (n = 5) were sampled (Table 1). Samplings were conducted in both wet (February 2008) and dry seasons (September 2008). Fish were collected with a hand seine (2.5 m width x 1.5 m height, 3 mm mesh) and a dip net (0.9 m width x 0.45 m height, 3 mm mesh) during 60 minutes in each sample site. Fish were fixed in 10 % formalin solution and afterwards transferred to 70 % EtOH solution. Collected fish identification was based on Bristki *et al.* (2007). Voucher specimens were deposited in the fish collection of the Departamento de Zoologia e Botânica da Universidade Estadual Paulista, São José do Rio Preto, (DZSJRP), state of São Paulo, Brazil. Collects were authorized by IBAMA (collecting permit number 017/2008; process number 02014.000112/2008-01).

Results and Discussion

A total of 9,559 individuals representing 68 species belonging to six orders and 21 families were collected (Table 2). Characiformes and Siluriformes were the predominant orders, presenting 86.76% of the registered species, following the Neotropical pattern for freshwater fish diversity (*e.g.* Lowe-McConnell 1999). Other studies conducted in the Miranda and Aquidauana drainages recorded a lower number of species. Willink *et al.* (2000) recorded 57 species in streams of the Miranda (Bodoquena plateau) and Aquidauana drainages. Recently Casatti *et al.* (2010) studying streams along a conservation gradient in the Miranda drainage (Bodoquena plateau) recorded 36 species and Teresa and Romero (2010) found 45 species along the longitudinal gradient of a stream in the same region of this study, including eight species not registered in the present study: *Parodon nasus Kner*, 1859, *Leporinus striatus* Kner, 1858, *Cetopsis gobioides* Kner, 1858, *Hypostomus cochliodon* Kner, 1854, *Phenacorhamdia hoehnei* (Miranda Ribeiro, 1914), *Tatia neivai* (Ihering, 1930), *Apteronotus albifrons* (Linnaeus, 1766) and *Sternopygus macrurus* (Bloch and Schneider, 1801). The higher number of species registered in this study is probably due to the diversity of environments sampled (*i.e.* streams, rivers and reservoirs). However, the diversity may have been underestimated, especially in the rivers, where the sampling of larger species was probably not ideal due to the used sampling methods. In fact, larger fish such as *Prochilodus lineatus* (Valenciennes, 1837) and *Brycon hilarii* (Valenciennes, 1850) were seen but not captured in the rivers stretches. Some species could not be identified to species level, because they belong to complex taxonomic groups or represent undescribed species. The same was also mentioned in other studies in streams of the region (Teresa and Romero 2010; Casatti *et al.* 2010).

Streams presented a higher total richness (54 species) in relation to rivers (32) and reservoirs (26) and similar mean richness when compared with rivers (Table 2). Reservoirs presented higher abundance, lower mean richness and a lower number of exclusive species than the other environments (Table 2). Higher richness in streams may be explained by the structural heterogeneity among samples. The sampled streams varied according to the predominant mesohabitat, substrate, distance from rivers, and riparian zone phytophysiognomies. These factors are known to be important in structuring fish communities (Matthews 1998; Teresa and Romero 2010) and different combination of these features could lead to distinct composition of the ichthyofauna among streams, resulting in higher beta and gamma diversities. In the opposite sense, artificial reservoirs are environments submitted to great physical, chemical and biological modifications (Agostinho *et al.* 2007), where deep waters and slow flow habitat predominate. Rheophilic species tend to disappear in artificial reservoirs, whereas species with few requirements to feed and reproduce tend to dominate the community (Agostinho *et al.* 2008). In this study, the latter species were represented by *Moenkhausia bonita* Benine, Castro and Sabino, 2004, *Psellogramus kennedyi* (Eigenmann, 1903), *Serrapinnus calliurus* (Boulenger, 1900), *Pyrrhulina australis* Eigenmann and Kennedy, 1903, and *Characidium* aff. *zebra* Eigenmann, 1909. High abundance observed in the reservoirs may be explained by the eutrophy of these environments, due to excessive nutrient accumulation and high incidence of solar radiation, which in turn favors development of macrophytes and phytoplankton (Gomes *et al.* 2005). In fact, some of the dominant species in reservoirs were herbivorous, such as *P. kennedyi*, *S. calliurus*, and *P. australis* (Casatti 2004; Santos *et al.* 2009).

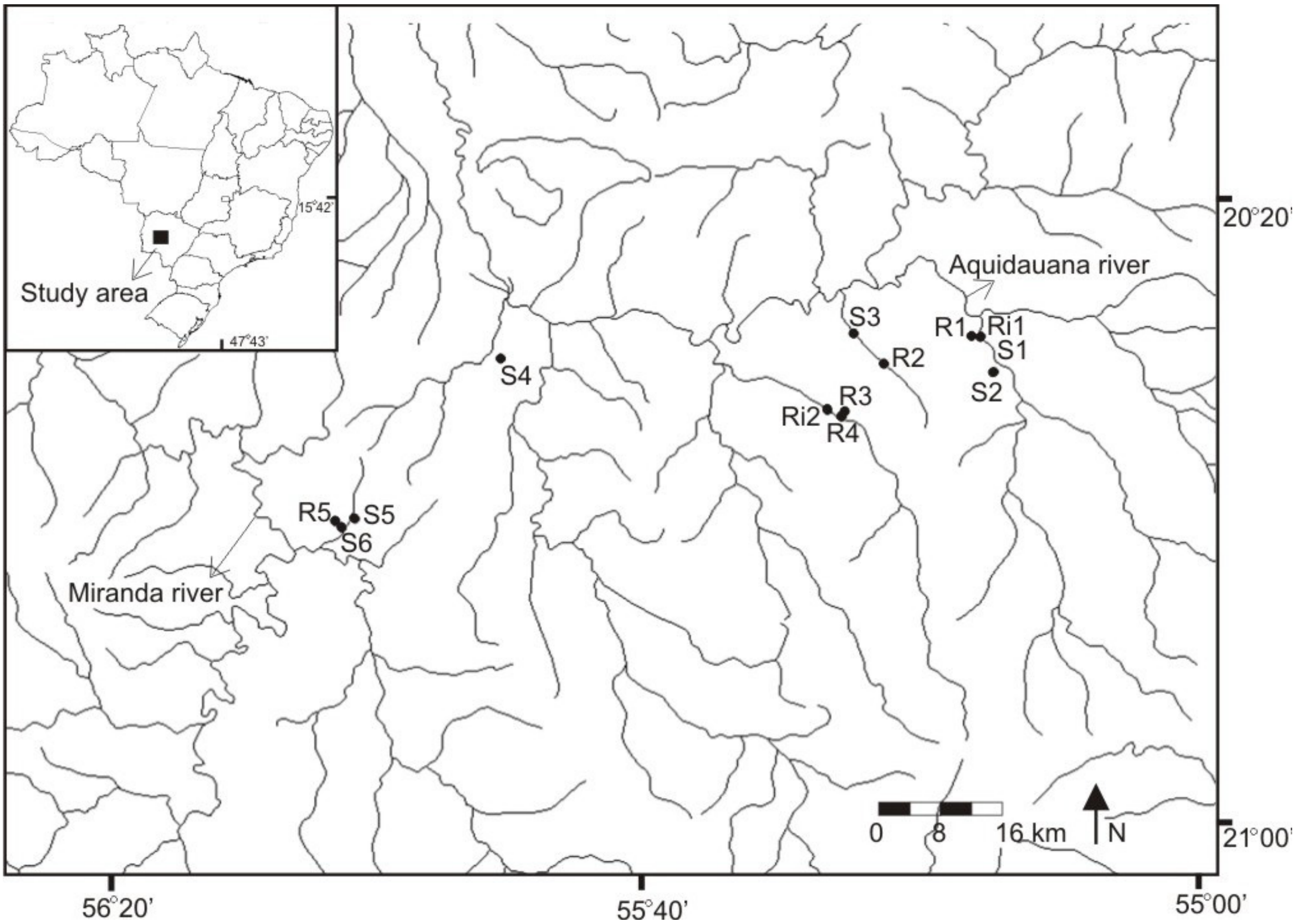

FIGURE 1. Map showing localization of the sampled sites in the Miranda and Aquidauana drainages, state of Mato Grosso do Sul, Brazil. S = streams; R = reservoirs; Ri = rivers.

A lower richness among streams was observed in the S3 and S4 stretches. Both are first order streams, silted, slow flow and with low water volume, characteristics usually related to low richness sites (Garutti 1988; Casatti *et al.* 2006). Moreover, the dominance of tolerant species such as *Aequidens plagiozonatus* Kullander, 1984*, Pyrrhulina australis*, and species of Callichthyidae and Erythrinidae are probably related to low physical integrity in these sites (Casatti *et al.* 2009). On the other hand, S1 and S6 were the richest stream sites sampled. This may be due to higher structural heterogeneity observed in these sites, which usually is positively correlated to micro-habitat availability for species with distinct requirements (Garutti 1988; Casatti 2005). Moreover, S1 stretch is located near the mouth of the Cachoeirão River and fish movement from mainstem could contribute to the increase of species richness in this stream (Gorman 1986; Fernandes *et al.* 2004).

Streams and rivers presented, respectively, 19 and 11 exclusive species and together were responsible for 97% of total richness. Many of these species have specialized habitats and their occurrence depends on the presence of specific features. For example, Gymnotiformes and Loricariidae species registered in this study are dependent on banks of roots and leaves for shelter and feeding (Teresa and Romero 2010), and these tend to disappear in deforested streams (Barrela *et al.* 2001; Casatti *et al.* 2009). Other species are dependent on a more stable substrate such as rocks, gravel and logs (Parodontidae and some species of Heptapteridae and Loricariidae), being negatively affected by siltation (Casatti 2004; Casatti *et al.* 2009). In conclusion, conservation of regional diversity of fishes is highly dependent on the integrity of its lotic environments; so it is imperative to control deforestation and erosion, two of the major alterations affecting water bodies in the Miranda basin (Mendes *et al.* 2004).

Table 1. General description of the sampled sites in the Miranda and Aquidauana drainages, state of Mato Grosso do Sul, Brazil. S = streams; R = reservoirs; Ri = rivers.

Sites	Coordinates	Main mesohabitats	Riparian vegetation	Main substrate	Observations
S1	20°30’11” S 55°15’29” W	Run, pool and marginal pools	Gallery forest	Sand, rocks, litter and branches	Near the mouth of the Cachoeirão river
S2	20°32’44” S 55°14’28” W	Run, riffles and pools	Deforested (right margin) and gallery forest (left margin)	Rocks, sand, litter, adhered algae, logs and branches	
S3	20°30’00” S 55°24’42” W	Run and pool	Savanna (Cerrado *strictu sensu*)	Sand	Low water volume and slow flow
S4	20°31’48” S 55°50’26” W	Run	Flooded forest	Sand and litter	Low water volume and slow flow
S5	20°43’27” S 56°01’02” W	Run and marginal pools	Gallery forest	Sand	Logs and branches abundant
S6	20°44’10” S 56°02’02” W	Run pool marginal pools	Wet grassland	Sand, clay adhered algae and macrophytes	Low water volume
R1	20°30’08” S 55°16’07” W	-	Wet grassland	Sand, macrophytes and adhered algae	220 meters long and 65 meters wide
R2	20°35’41” S 55°25’22” W	-	Wet grassland (right margin) and exotic grass (left margin)	Sand	60 meters long and 60 meters wide
R3	20°36’01” S 55°25’32” W	-	Wet grassland	Sand and adhered algae	80 meters long and 70 meters wide
R4	20°32’09” S 55°22’28” W	-	Exotic grass (right margin) and wet grassland (left margin)	Sand, macrophytes and adhered algae	80 meters long and 40 meters wide
R5	20°43’41” S 56°02’31” W	-	Wet grassland	Sand	120 meters long and 100 meters wide
Ri1	20°30’07” S 55°15’26” W	Run and marginal pools	Gallery Forest	Rocks and sand	20 meters wide; fast water flow
Ri2	20°35’34” S 55°26’36” W	Run and marginal pools	Gallery Forest	Sand, rocks, gravel, logs and branches	Eight meters wide; moderate water flow

Table 2. Fish fauna and community descriptors of streams, reservoirs and rivers in the Miranda and Aquidauana drainages, state of Mato Grosso do Sul, Brazil. "D" indicates dominant species in each site.

Taxon	Voucher DZSJRP	Stream						Reservoir					River	
		S1	S2	S3	S4	S5	S6	R1	R2	R3	R4	R5	Ri1	Ri2
BELONIFORMES														
Potamorrhaphis eigenmanni Miranda-Ribeiro, 1915	12880												X	
CHARACIFORMES														
Acestrorhynchus pantaneiro Menezes, 1992	12857	X												
Apareiodon affinis (Steindachner, 1879)	12910			X										
Aphyocharax cf. *anisitsi* Eigenmann and Kennedy, 1903	12878												X	X
Astyanax abramis (Jenyns, 1842)	12873		X	X		X	X					X	X	X
Astyanax asuncionensis Géry, 1972	12869	X	X	X			X		X			X	X	X
Astyanax lineatus (Perugia, 1891)	12890	X	X	X										
Astyanax marionae Eigenmann, 1911	12895													X
Bryconamericus exodon Eigenmann, 1907	12879					D							X	X
Bryconops melanurus (Bloch, 1794)	12917									X				
Characidium aff. *gomesi* Travassos, 1956	12876												X	
Characidium laterale (Boulenger, 1895)	12855	X					X		X					
Characidium aff. *zebra* Eigenmann, 1909	12875		X	X		X	X	X		X	D	X	X	X
Creagrutus meridionalis Vari and Harold, 2001	12892													X
Cyphocharax gillii (Eigenmann and Kennedy, 1903)	12918	X					X		X	X				
Erythrinus erythrinus (Bloch e Schneider, 1801)	12900				X									
Gymnocorymbus ternetzi (Boulenger, 1895)	12868	X							X					
Hemigrammus lunatus Durbin, 1918	12882												X	
Hemigrammus tridens Eigenmann, 1907	12885	X	X						X					
Hoplerythrinus unitaeniatus (Spix, 1829)	12902	X												
Hoplias malabaricus (Bloch, 1794)	12903	X			X			X	X	X		X		
Hyphessobrycon cf. *arianae* Uj and Géry, 1989	12898				X									
Hyphessobrycon elachys Weitzman, 1984	12866	X												
Hyphessobrycon eques (Steindachner, 1882)	12863	X					X	X	X			X		
Jupiaba acanthogaster (Eigenmann, 1911)	12884		X							X			X	X
Leporinus obtusidens (Valenciennes, 1837)	12858	X											X	
Moenkhausia cf. *bonita* Benine, Castro and Sabino, 2004	12907		D	X			X	D	X	D		D	X	
Moenkhausia forestii Benine, Mariguela and Oliveira, 2009	12854	X	X			X	X						X	
Moenkhausia intermedia Eigenmann, 1908	12891													X
Odontostilbe paraguayensis Eigenmann and Kennedy, 1903	12894													D
Odontostilbe pequira (Steindachner, 1882)	12896			D		X	X						X	X
Piabarchus analis (Eigenmann, 1914)	12912					X	X							
Piabarchus torrenticola Mahnert and Géry, 1988	12893					X							X	X
Poptella paraguayensis (Eigenmann, 1907)	12872									X			X	
Psellogrammus kennedyi (Eigenmann, 1903)	12861	X							D					
Pyrrhulina australis Eigenmann and Kennedy, 1903	12864	X	X	X	D		X	X	X	X	X	X		
Roeboides descalvadensis Fowler, 1932	12871												X	
Serrapinnus calliurus (Boulenger, 1900)	12870	D		X	X		D	X	X	X		X	X	
Serrapinnus kriegi (Schindler, 1937)	12897				X				X					
Steindachnerina brevipinna (Eigenmann and Eigenmann, 1889)	12915						X		X					
Tetragonopterus argenteus Cuvier, 1816	12860	X												
Xenurobrycon macropus Myers and Miranda-Ribeiro, 1945	12881	X		X		X	X		X	X			D	X

Table 2. *Continued.*

Taxon	Voucher DZSJRP	Stream						Reservoir					River	
		S1	S2	S3	S4	S5	S6	R1	R2	R3	R4	R5	Ri1	Ri2
SILURIFORMES														
Ancistrus sp.	12888		X	X		X							X	
Callichthys callichthys (Linnaeus, 1758)	12899				X									
Corydoras aeneus (Gill, 1858)	12886	X	X	X			X							
Corydoras hastatus Eigenmann and Eigenmann, 1888	12904	X												
Farlowella paraguayensis Retzer and Page, 1997	12921					X							X	X
Hypostomus boulengeri (Eigenmann and Kennedy, 1903)	12908			X										
Hypostomus sp.	12909			X					X				X	
Imparfinis cf. *schubarti* (Gomes, 1956)	12911					X							X	
Imparfinis sp. 1	12913					X								
Imparfinis sp. 2	12887		X			X								
Lepthoplosternum pectorale (Boulenger, 1895)	12901				X									
Loricaria sp.	12920												X	
Otocinclus vittatus Regan, 1904	12874												X	
Paravandellia oxyptera Miranda-Ribeiro, 1912	12877					X							X	X
Pimelodella cf. *gracilis* (Valenciennes, 1835)	12914					X	X							
Rhamdia quelen (Quoy e Gaimard, 1824)	12867	X	X			X	X							
Rineloricaria cacerensis (Miranda-Ribeiro, 1912)	12919	X	X			X	X							
Rineloricaria lanceolata (Günther, 1868)	12883		X			X	X						X	
GYMNOTIFORMES														
Brachyhypopomus sp.	12862	X	X			X								
Eigenmannia trilineata López and Castello, 1966	12865	X				X	X		X	X		X		
Gymnotus sp.	12856	X			X		X		X					
PERCIFORMES														
Apistograma trifasciata (Eigenmann and Kennedy, 1903)	12916								X					
Aequidens plagiozonatus Kullander, 1984	12906	X			X		X	X	X	X		X		
Crenicichla lepidota Heckel, 1840	12889	X	X	X					X	X			X	
SYNBRANCHIFORMES														
Synbranchus marmoratus Bloch, 1795	12859	X			X								X	
CYPRINODONTIFORMES														
Rivulus punctatus Boulenger, 1895	12905			X	X		X		X					
Richness		**28**	**17**	**16**	**12**	**20**	**23**	**7**	**21**	**13**	**2**	**10**	**28**	**15**
Total richness		**54**						**26**					**32**	
Mean richness		**19.17**						**10.60**					**21.50**	
Mean abundance		**382.17**						**1177.2**					**690**	
Exclusive species		**19**						**2**					**11**	

Acknowledgments: This study is part of the Reflorestar Legal project, a partnership comprising MMX Metálicos Corumbá Ltda and Fundação Neotrópica do Brasil. The authors thank MMX Metálicos Corumbá Ltda – Unidade Florestal and the Fundação Neotrópica do Brasil for financing and operational support; José L.Veronezzi-Junior for helping with fish collecting; two reviewers for helpful suggestion and comments that improved the manuscript. FBT and RMR received grants from FAPESP (2008/03583-9, 2007/05400-6) and FL from CNPq (306988/2008-9).

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Received: June 2010
Revised: September 2010
Accepted: November 2010
Published online: November 2010
Editorial responsibility: Javier A. Maldonado O.