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Fish fauna in tributaries of the Suiá-Miçú River (upper Xingu river basin), in the Cerrado-Amazon transition zone, eastern state of Mato Grosso, Brazil

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Abstract. Studies on the fish fauna of the Xingu river basin are mainly concentrated in the main channel of the river or its large tributaries, due to requirements all faunal surveys in hydroelectric power plant projects. Our goal was to conduct a survey of the composition of fish fauna in headwater streams (lotic environments) and small reservoirs (artificial lentic environments) built on these streams in the upper Xingu River region. Fish were sampled in the dry period, July 2013, using active sampling methods in a 100 meter-section at each sampling site. We recorded the occurrence of 33 species of five orders and 16 families. Characiformes was the most species-rich order, with 19 species, followed by Siluriformes, Gymnotiformes and Perciformes, with four species each.

Key words: Streams; checklist; diversity; deforestation; Neotropical region

INTRODUCTION

The Neotropical region has the highest diversity of freshwater fish worldwide. In this region, about 5,160 species of fish are known and estimates point to the existence of more than 8,000 species (Reis et al. 2003, Lévêque et al. 2008, Winemiller et al. 2008, Reis et al. 2016). This richness may be even higher considering that 1,000 new fish species were described in South America in the past decade alone, and that the rate of species descriptions is limited by the numbers of active taxonomists and publication outlets (Reis et al. 2016). The high diversity of fish living in South American rivers and streams is a result of historical, geological, ecological and evolutionary factors (Winemiller et al. 2008). The Amazon basin has the highest diversity of fish with an estimated richness of more than 2,100 species (Reis et al. 2003, Lévêque et al. 2008, Albert et al. 2011).

The Amazon basin is made up of 13 freshwater ecoregions (Abell et al. 2008, Albert et al. 2011); among these is the Xingu ecoregion, whose main rivers arise from the central plateau of Brazil. The Xingu ecoregion has a richness of approximately 467 species (Camargo et al 2004), including 36 endemic species (Albert et al. 2011), but these values may be even higher, as there are few studies on fish fauna in this ecoregion. In recent years, due to several hydropower plant projects, the number of studies on the ichthyofauna in this ecoregion has increased; however, these studies are mainly concentrated in the main channel of the Xingu River or in larger tributaries, while studies on the fish fauna inhabiting streams are still scarce (but see Albert & Fink 1996, Camargo et al. 2004, Andrade et al. 2016, Fitzgerald et al. 2016, Zuluaga-Gómez et al. 2016). The lack of taxonomic and distribution knowledge are known as Linnaean and Wallacean shortfall respectively (Whitaker et al. 2005, Hortal et al. 2015), and pose problems for effective strategies for conservation of most species in tropical environments (Whittaker et al. 2005, Diniz-Filho et al. 2010, Hortal et al. 2015). A simple measure to decrease these shortfalls is to concentrate sampling efforts in regions where the knowledge gap is present (Diniz-Filho et al. 2010).

Unfortunately the recent expansion of cattle farming and agriculture in the upper Xingu region are replacing the native forests and savanna with pasture and croplands (Nepstad et al. 2007, Macedo et al. 2013, Castello & Macedo 2016). These changes have direct effects on stream headwaters ecosystems (DeFries et al. 2013, Macedo et al. 2013) and can lead to local extinction of sensitive species before they have been described. Although the number of studies on ichthyofuna in the Xingu basin have increased in recent years (Camargo et al. 2004, Andrade et al. 2016, Fitzgerald et al. 2016, Zuluaga-Gómez et al. 2016) the knowledge gap on stream fishes still persists. Our goal was to survey the composition of the fish fauna in headwater streams (lotic environments) and small reservoirs (artificial lentic environments) built on these streams in the upper Xingu region, which may eventually support future studies on fish biology and conservation practices in the region.

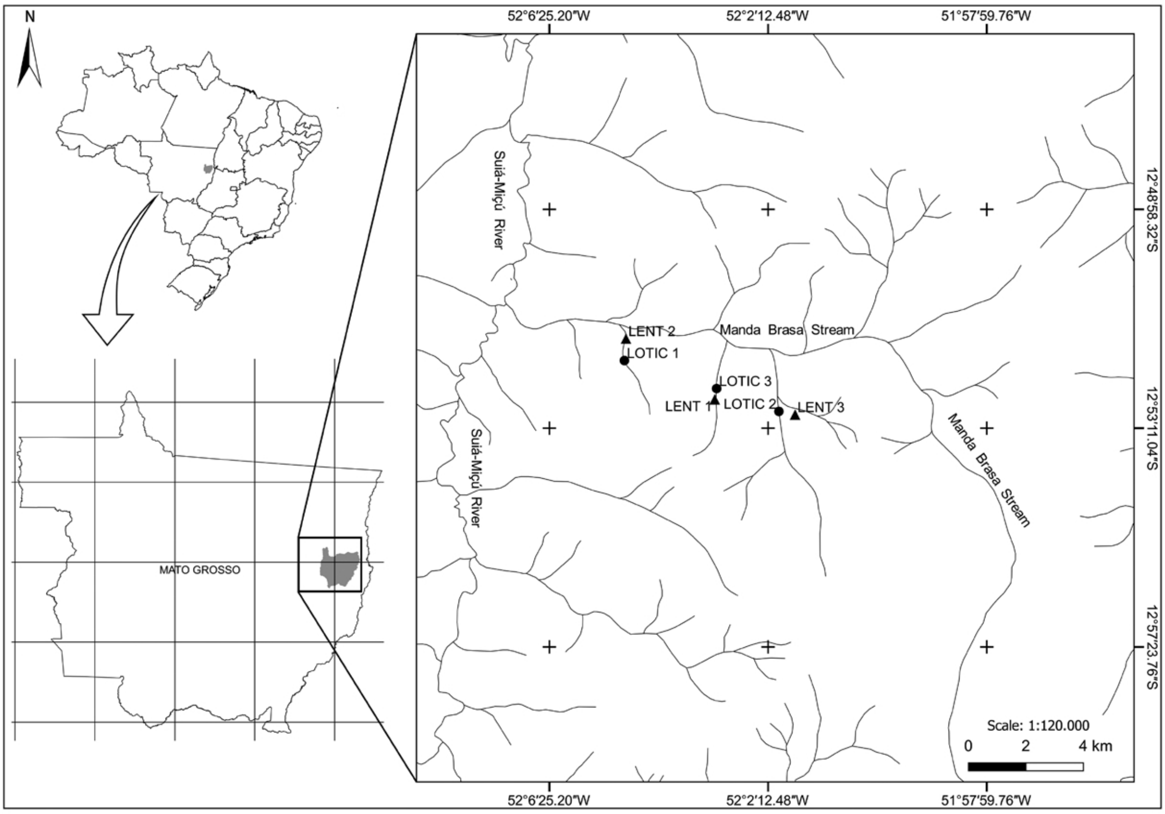

Figure 1. Map showing localization of the sampled sites in tributaries of the Manda Brasa Stream, Suiá-Miçú River sub-basin, Xingu ecoregion, state of Mato Grosso, Brazil, (black circles, LOTIC = streams; black triangles, LENTIC = small reservoirs).

MATERIAL AND METHODS

Study area

The studied streams are located in the municipality of Ribeirão Cascalheira, in eastern Mato Grosso state, Brazil, in the Cerrado-Amazon transition zone (Fig. 1). This region is characterized by fragmented forest, mainly due to the conversion of forest into pasture for cattle farming (Nepstad et al. 2007). The vegetation of the region is classified as perennial seasonal forest, and the climate, according to the Köppen classification, is Aw warm and humid, with two periods: rainy, from October to March, and dry, from April to September (Marimon et al. 2006). The rainfall index varies from 2,200 to 2,500 mm, with an average annual temperature of 24–26 °C (Alvares et al. 2013). The sampled sites are localized in three headwater streams, in which artificial reservoirs for livestock drinking water have been constructed (Table1). The water bodies sampled are part of the Suiá-Miçú river basin, a tributary of the Xingu River.

Fish sampling

Fish were collected during the dry period (July 2013), when the flows are low and fishes are captured more efficiently, using the active sampling method (Uieda & Castro 1999), with a hand seine made from nylon screen (3 m width × 1.5 m height, mesh size 3 mm). For each of the three stream sampling sites (Fig. 1), a 100 m long segment was delimited, divided into 10 transects of 10 m each. In each segment, data for environmental variables (depth, water velocity, temperature, width, type of substrate and water transparency) were also determined. At the small reservoirs, the collections were carried out in a marginal strip 100 m long and 5 m wide, using 4 passes of seine nets perpendicular to the margin in each segment.

The specimens collected were fixed in 10% formalin and placed in plastic vials. After 72 h, they were washed in tap water and stored in 70% alcohol for later identification and cataloging. Voucher specimens were deposited in the fish collection of

Table 1. Geographic location of the sampled sites in the Suiá-Miçú River sub-basin, Xingu ecoregion, state of Mato Grosso, Brazil, (LOTIC = streams; LENT = small reservoirs).

Sites	Local	Altitude (m)	Geographic coordinates	
			Latitude (S)	Longitude (W)
LENT 1	small reservoir	324	12°51′27.6″	052°04′56.7″
LENT 2	small reservoir	339	12°52′37.7″	052°03′14.1″
LENT 3	small reservoir	337	12°52′55.6″	052°01′03.8″
LOTIC 1	unnamed stream	339	12°51′52.0″	052°04′57.9″
LOTIC 2	unnamed stream	333	12°52′25.2″	052°03′10.9″
LOTIC 3	unnamed stream	330	12°52′51.7″	052°02′03.6″

Table 2. List of fish species and their respective abundances for each sites sampled in the Suiá-Miçú River sub-basin, Xingu ecoregion.

	Reservoir			Stream				
Taxa	**LENT 1**	**LENT 2**	**LENT 3**	**LOTIC 1**	**LOTIC 2**	**LOTIC 3**	**N**	**Lilunx lot #**
Characiformes								
Characidae								
Astyanax aff. *argyrimarginatus* Garutti, 1999						52	52	3779
Bryconops sp.	1					45	46	3796
Hemigrammus aff. *levis* Durbin, 1908	379	594	169	1		4	1147	3793; 3803; 3813
Hemigrammus cf. *ocellifer* (Steindachner 1882)		7	10				17	3818; 3819
Hemigrammus levis Durbin 1908	16	2					18	3816
Hemigrammus sp.				12	7		19	3769
Hemigrammus sp. 1			1				1	3805
Hemigrammus sp. 2		14	58				72	3810
Macropsobrycon xinguensis Géry, 1973	31						31	3790
Moenkhausia colletti (Steindachner, 1882)	1					11	12	3780; 3795
Moenkhausia dichroura (Kner, 1858)	133						133	3789
Moenkhausia phaeonota Fink, 1979				127	98	23	248	3761; 3772; 3783
Thayeria boehlkei Weitzman, 1957	27	7	3				37	3792; 3806; 3815
Crenuchidae								
Characidium cf. *zebra* Eigenmann, 1909					1	2	3	3786; 3768
Curimatidae								
Curimatopsis sp.			1				1	3808
Erythrinidae								
Hoplerythrinus unitaeniatus (Agassiz, 1829)					2		2	3762
Hoplias malabaricus (Bloch, 1794)			3	1			4	3798
Lebiasinidae								
Pyrrhulina australis Eigenmann & Kennedy, 1903		12					12	3814
Serrasalmidae								
Metynnis sp.			2				2	3802
Cyprinodontiformes								
Poenciliide								
Pamphorichthys araguaiensis Costa, 1991	81	633	1134		1		1849	3763; 3794; 3804; 3812
Rivulidae								
Melanorivulus zygonectes Myers, 1927						1	1	3788
Gymnotiformes								
Gymnotidae								
Gymnotus aff. *carapo* Linnaeus, 1758				1			1	3774
Gymnotus sp.				18	1		19	3776
Sternopygidae								
Eigenmannia trilineata López & Castello, 1966				6	2		8	3764; 3770
Sternopygus aff. *macrurus* (Bloch & Schneider, 1801)				1			1	3775
Perciformes								
Cichlidae								
Aequidens tetramerus (Heckel, 1840)		1	49	11	8	2	71	3777; 3784; 3797; 3817
Crenicichla sp.			2				2	3800
Laetacara sp.		18	2				20	3807; 3809
Satanopercus jurupari (Heckel, 1840)			11				11	3799
Siluriformes								
Callichthyidae								
Aspidoras pauciradiatus (Weitzman & Nijssen, 1970)			1			6	7	3782
Cetopsidae								
Helogenes marmoratus Günther, 1863				12			12	3773
Heptapteridae								
Pimelodella sp.				15	6	2	23	3787
Loricariidae								
Hisonotus acuen Silva, Roxo & Oliveira, 2014					5	2	7	3766; 3785
Total number of specimens	**669**	**1288**	**1446**	**205**	**131**	**150**	**3889**	

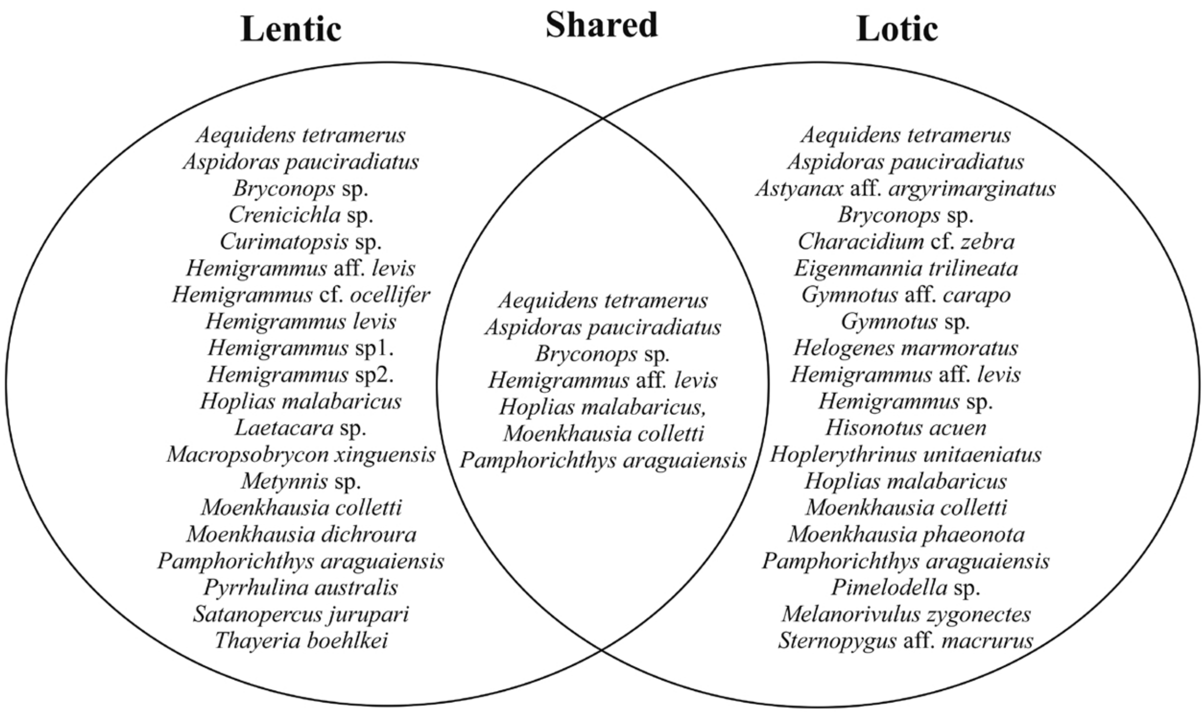

Figure 2. Species recorded in lentic, lotic, or both lentic and lotic environments.

the Laboratory of Ichthyology and Limnology of UNEMAT, Campus of Nova Xavantina (LILUNX), state of Mato Grosso, Brazil. Fish were collected under permit Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis (IBAMA) license number # 15226-1.

RESULTS

We caught 3,889 individuals in 33 species, 16 families and five orders (Table 2). We found 20 species in each of lotic and lentic environments. In lotic environments we found five orders: Characiforms, Siluriforms, Gymnotiforms, Cyprinodontiforms, and Perciforms with nine, four, four, two and one species respectively. In lentic environments we found four orders: Characiforms, Perciforms, Siluriforms, Cyprinodontiforms with 14, four, one and one species, respectively. These environments share seven species (Fig. 2). The three species with greatest abundances were *Pamphorichthys araguaiensis*, *Hemigrammus* aff. *levis* and *Moenkhausia phaeonota*, which together accounted for 83.41% of the individuals caught (with 47.54, 29.49 and 6.38% individuals, respectively, Fig. 3). The most abundant species in lotic environments were *Moenkhausia phaeonota* and *Astyanax* aff. *argyrimarginatus*, with 61.72% individuals caught, while in lentic environments, the species *Pamphorichthys araguaiensis* and *Hemigrammus* aff. *levis* represented 87.86% of the individuals caught. Among the five orders found, Characiforms presented the highest richness, with 19 species (55.9% species), followed by Siluriforms, Gymnotiforms and Perciforms, with four species each, while Cyprinodontiforms showed the lowest richness—only two species.

The order Characiforms was the most abundant in five out of the six sampled environments, while Cyprinodontiforms had high abundance only in lentic environments (Lentic 1, Lentic 2 and Lentic 3). Considering the abundance of individuals per environment, the orders Cypridontiformes and Characiformes were the most abundant in lentic systems and together were responsible for approximately 97.5% of sampled individuals. For lotic environments, the most abundant orders were Characiforms and Siluriforms, with approximately 89.9% individuals (80.0% and 9.6% respectively).

The families showing the highest abundances were Poecillidae, with 1,849 individuals, followed by Characidae, with 1,833 specimens. The high abundance for Poeciliidae was due to a single species, *Pamphorichthys araguaienses*, while the high abundance for the family Characidae is mainly due to three species (*Hemigrammus* aff. *levis*, *Moenkhausia dichroura* and *Moenkhausia phaeonota*). Among the Siluriforms, we recorded *Hisonotus acuen*, an endemic species recently described from this region.

DISCUSSION

In the study we found a species richness of 33, greater than that reported by Zillmer-Oliveira (2009), 31 species, in a study conducted on streams and artificial reservoirs in the same ecoregion. The dominance of the orders Characiforms, Siluriforms, Gymnotiforms and Perciforms verified herein is explained by the fact that these are the orders with the highest number of species present in inland waters in the Neotropical region (Reis et al. 2003, Winemiller et al. 2008). However, the dominance of Cyprinodontiforms and Characiforms in lentic environments in our study differs from the results found in Amazonian natural environments (Goulding et al. 1988, Reis et al. 2003).

The high abundance of Cyprinodontiforms in lentic environments is related to the contribution from *Pamphorichthys araguaienses*, with approximately 54.3% of the individuals

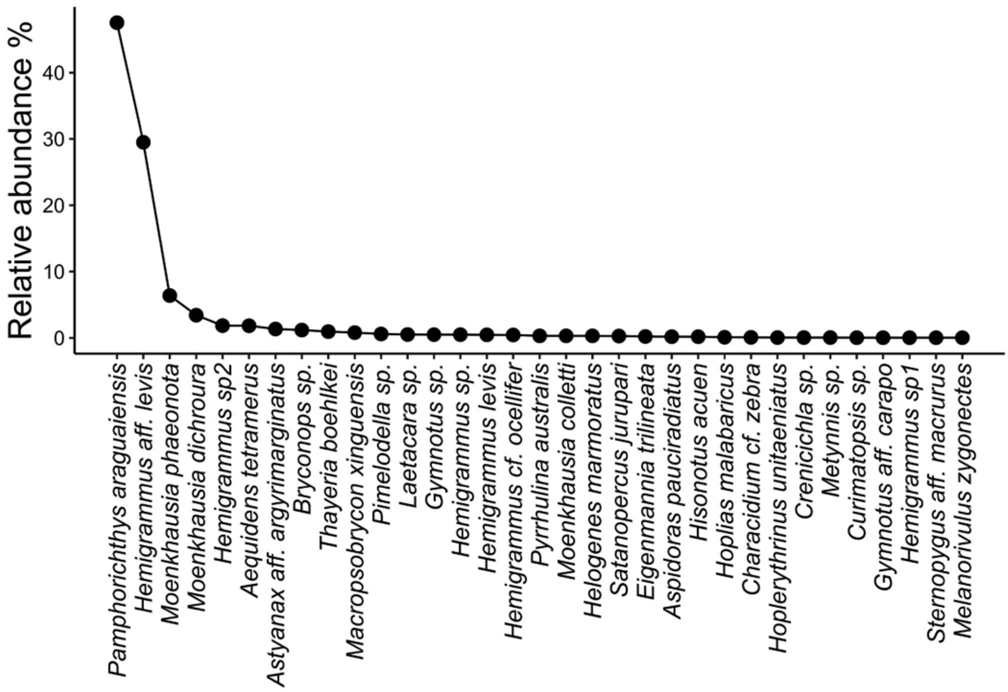

Figure 3. Ranking of the relative abundance of the species for the six sites sampled in tributaries of the Manda Brasa Stream, Suiá-Miçú River sub-basin, Xingu ecoregion.

sampled. Nevertheless, when comparing dominance in lotic environments, Cyprinodontiforms presented low abundance, and this shows that the conversion of lotic into lentic environment changes the dominance patterns of species (Lowe-McConnell 1999). The high abundance of Cyprinodontiforms (Poeciliidae) collected in lentic environments may be attributed to their opportunistic life strategy. Species with opportunistic life-history strategy usually exhibit small adult body sizes, rapid sexual maturity, high reproductive effort, and low juvenile survival (Winemiller 1989, 2005, Winemiller et al. 2008), characteristics that favor establishment in altered environments (Cunico et al. 2011). Another important life history feature of *P. araguaienses* is that it is a non-migratory species; the loss of connectivity by the construction of reservoir benefits non-migratory fish species over those with dispersion affinity (Perkin et al. 2015).

In lotic environments, the dominance of Characiforms and Siluriforms are consistent with expected patterns for environments with little environmental change in freshwater Neotropical habitats. The dominance of Characiforms in the streams is mainly due to three species, *Moenkhausia phaeonota*, *Astyanax* aff. *argyrimarginatus* and *Bryconops* sp., which together account for 71.0% of the individuals caught (51.0%, 10.7% and 9.5% of the totals, respectively). This result corroborates patterns found in previous studies, in which the occurrence of few species with high dominance is a characteristic of Amazonian streams with high environmental integrity (Goulding et al. 1988, Lowe-McConnell 1999).

The dominance of the family Characidae in four out of the six sampled environments is related to its great representativeness in continental waters of Brazil (Lowe-McConnell 1999, Reis et al. 2003, Silva et al. 2007). This family has the greater diversity in the order Characiformes, containing species with very different feeding behaviors and morphologies (Melo et al. 2005), which allow the colonization of altered environments (Casatti et al. 2006). One species of this family, *Hemigrammus* aff. *levis*, occurred in all environments, but exhibited increased numbers in the reservoirs, where it was the second most abundant species. The genus *Hemigrammus* is widely distributed in Amazonian aquatic environments (Goulding et al. 1988, Lowe-McConnell 1999) and some species of this genus exhibit opportunistic life-history strategy (Winemiller 1989). Species that present high plasticity in relation to the use of microhabitats and feeding can inhabit both preserved and altered environments (Casatti et al. 2006, Ferreira & Casatti 2006). However, the increase in abundance of *Hemigrammus* aff. *levis* in lentic environments is possibly because this species has an opportunistic life history and preferences for shallow habitats, such as the marginal areas of the small reservoirs.

Headwater streams of the upper Xingu basin are characterized by a relatively great number of endemic fish species (Camargo et al. 2004). The presence of *Hisonotus acuen* in lotic environment supports the prediction of Camargo et al (2004). Our results highlight the importance of preservation of the integrity of headwaters ecosystems. However, the rapid environmental change observed in this region for agriculture or livestock has affected the water quality of the streams (Macedo et al. 2013, Matos et al. 2013). Furthermore, this represents a threat to the biodiversity of this ecoregion putting many species at risk of disappearing before they are described. Thus this checklist contributes with important taxonomic information and distribution of fish species in headwaters streams in upper Xingu basin, where studies of stream fishes are still scarce.

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