




Fishes community composition and patterns of species distribution in Neotropical streams

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Abstract: The ichthyofauna of streams in the Neotropical region is not yet fully known. This study aims to investigate the ichthyofauna composition of six streams of the Ijuí River sub-basin, Rio Grande do Sul State, inserted in the Uruguay River basin, as to contribute to the knowledge of fishes species richness and distribution in the south of Brazil. Sampling was carried out between July 2015 and May 2016, bimonthly, using the technique of electric fishing to collect the fishes. Spatial variations (per sampled stream) in the ichthyofauna composition were tested with a permutational multivariate analysis of variance. In total, we collected 5,029 individuals from 55 species, 13 families and five orders. From these species, 17 are endemic to the Uruguay River basin. Five species alone represented approximately 70% of the ichthyofauna abundance sampled. Our hypothesis that the fish community composition is not homogeneous along the streams sampled was confirmed and we observed that species complexity increases from the upstream closest area to the downstream according to the river continuum concept.

Keywords: *Abundance, Characidae, Heptapteridae, Loricariidae, Richness, Uruguay River basin.*

Composição da comunidade de peixes e padrões de distribuição de espécies em riachos Neotropiacais

Resumo: A ictiofauna de riachos na região Neotropical ainda não é totalmente conhecida. Este estudo objetiva investigar a composição da ictiofauna de seis riachos da sub-bacia do rio Ijuí, estado do Rio Grande do Sul, inseridos na bacia do rio Uruguai, de forma a contribuir no conhecimento da riqueza e distribuição de espécies de peixes no sul do Brasil. A amostragem foi realizada entre julho de 2015 e maio de 2016, bimestralmente, utilizando a técnica da pesca elétrica. Variações espaciais (por riacho amostrado) na composição da ictiofauna foram testadas com uma análise de variância multivariada permutacional. No total, coletamos 5029 indivíduos de 55 espécies, 13 famílias e cinco ordens. Destas espécies, 17 são endêmicas da bacia do rio Uruguai. Cinco espécies sozinhas representaram aproximadamente 70% da abundância da ictiofauna amostrada. Nossa hipótese de que a composição da comunidade de peixes não é homogênea ao longo dos riachos amostrados foi confirmada e observamos que a complexidade das espécies aumenta de áreas à montante em direção à jusante, conforme o conceito do rio contínuo.

Palavras-chave: *Abundância, bacia do rio Uruguai, Characidae, Heptapteridae, Loricariidae, Riqueza.*

Introduction

The ichthyofauna of the Neotropical region comprises 4,475 valid species, and perhaps more than 1,550 undescribed ones (Reis 2013). It is estimated that there are 6,025 species and that this number could be surpassed, overcoming the 8,000 species (Schaefer 1998, Reis 2013). In South America, this ichthyofauna occupies a variety of habitats, from large rivers to small and medium-sized streams, swamps, lagoons, high altitude lakes, among others (Vari & Malabarba 1998, Reis 2013).

Among the habitats occupied by the ichthyofauna, streams are known as lotic environments, with unidirectional water flows from headwaters to mouth and may have non-persistent flooding areas during rainy seasons (Esteves & Aranha 1999, Uieda & Castro 1999). They are known to have a wide variety of mesohabitats due to environmental gradients ranging from rocky riffles and runs to sandy pools and backwaters, in addition to a variety of marginal vegetation in the stream bank (Araújo-Lima et al. 1995, Esteves & Aranha 1999). In southern and southeastern Brazil, the streams may present high dissolved oxygen concentration and large seasonal temperature variation, with influence of drainage basin geomorphology under abiotic components as transparency, pH and conductivity (Araújo-Lima et al. 1995, Esteves & Aranha 1999).

The streams have high biological diversity and great importance in maintaining the integrity of the entire ecosystem (Meyer et al. 2007). These environments frequently present isolated populations of fish, often undescribed, with a high degree of endemism (Langeani et al. 2007, Reis 2013, Vidotto-Magnoni et al. 2015). The assessment of species in these sites contributes, therefore, to the understanding of the distribution of the species already described and to the description of new taxa (Pereira et al. 2014). Studies of species distribution assist in estimating changes in habit susceptibility to anthropogenic impacts that influence the composition of aquatic communities and are useful in the definition of priority areas for conservation (Bailly et al. 2016, Rose et al. 2016).

Freshwater ecosystems are particularly vulnerable to anthropogenic impacts that often promote the proliferation of some populations in the face of the decline, or even the extinction of others (Agostinho et al. 1999, Bailly et al. 2016). In streams, the susceptibility to these impacts may be higher because of the reduced size of these habitats and the sensitivity of microhabitats (Galves et al. 2009, Bonato & Fialho 2016). The fishes community is an indicator of the biological integrity of freshwater systems (Moore et al. 1997) and the knowledge of streams ichthyofauna is an informative tool to propose mitigation measures to these impacts (Vidotto-Magnoni et al. 2015). In the hydrographic region of River Uruguay, Brazil, anthropogenic impacts consist mainly on the environmental degradation in areas of high population and industrial density caused by agricultural activities, by the construction of hydroelectric dams, with the disappearance of lotic environments, and by the constant introduction of exotic species (Malabarba et al. 2009).

The Uruguay River is one of the main tributaries of the La Plata River basin which, in South America, comprehends the second largest drainage system, behind only the Amazonas (Cappato & Yanosky 2009). The Uruguay River has an extension of 2,200 km (ANA 2016) with a drainage area of about 365,000 km² (Di Persia & Neiff 1986, Albert & Reis 2011). Its main tributaries are the Negro River, Quarai River, Ibicuí River and Ijuí River (Carvalho & Reis 2009). The ichthyofauna of the

Uruguay River drainage system comprises about 275 species known; from these, 78 (28%) are endemic (Bertaco et al. 2016).

The “river continuum concept” proposed by Vannote et al. (1980) explains the distribution pattern of fishes fauna following the upstream-downstream gradient. This theory describes the structure and functions of communities along river systems, considering gradients of physical factors, formed by the drainage network, which include energy input, organic matter transport and use by macroinvertebrates functional feeding groups (Vannote et al. 1980). In addition, this concept proposes that community complexity increases from upstream to downstream, with the alteration on the composition of species and trophic guilds being influenced by continuum gradients (Vannote et al. 1980).

This study aims, therefore, to evaluate the composition of the fishes community and the pattern of species distribution in streams located along a longitudinal gradient (upstream-downstream) in the hydrographic sub-basin of the Ijuí River, tributary of Uruguay River, intending to contribute to the knowledge of the richness and abundance of species in this region of the south of Brazil. The hypothesis is that the composition of the fishes community is not homogeneous along the streams sampled, and that its complexity increases from the upstream closest area to the downstream (mouth of the Ijuí River sub-basin in the Uruguay River basin), according to the “river continuum concept”.

Material and Methods

Collections were carried out in six streams, located in rural areas of the Ijuí River sub-basin, at the northwest region of the Rio Grande do Sul State, southern Brazil. With a drainage of 10,649.13 Km², it is located in the middle portion of the Uruguay River hydrographic network (FEPAM 2016) (Figure 1). In order to sample different portions of the Ijuí River sub-basin (high, middle and low), chosen streams were distributed along the longitudinal gradient, from upstream to downstream areas, near the mouth of the Ijuí River sub-basin in the Uruguay River (Figure 1). From the sampled streams, two are located in an upper portion of the sub-basin: stream 1 (28°18'58.4"S, 53°54'17.9"W) (Figure 2a) and stream 2 (28°25'56.2"S, 53°58'14.9"W) (Figure 2b); two are in the mid portion: stream 3 (28°12'06.2"S, 54°13'06.9"W) (Figure 2c) and stream 4 (28°23'41.5"S, 54°27'05.9"W) (Figure 2d); and two are in the lower portion: stream 5 (28°13'40.8"S, 54°57'24.8"W) (Figure 2e) and stream 6 (28°10'13.5"S, 55°03'57.4"W) (Figure 2f). Anthropogenic activities developed nearby the streams consist mainly in agriculture (soybean crops) and cattle farming, with swine farming in the corresponding area to the stream 4. The riparian vegetation, next to the streams, is poorly preserved at all sampling sites, corresponding to narrow tree lines running along the streams, often less than 5m width.

Biological samples were collected bimonthly, from July 2015 to May 2016, summing up six capture expeditions for each stream (July, September, and November 2015, and January, March, and May 2016). Fishes were collected using the electric fishing technique, in an extension of 100m in each stream, for the period of an hour. Fieldwork and sampling were carried out under a scientific collection permit (Permit Number 48291-1) issued by the Instituto Chico Mendes de Conservação da Biodiversidade, Ministério do Meio Ambiente, Brasília – Distrito Federal, Brazil. This study was conducted in accordance with protocols approved in their ethical and methodological aspects, for the

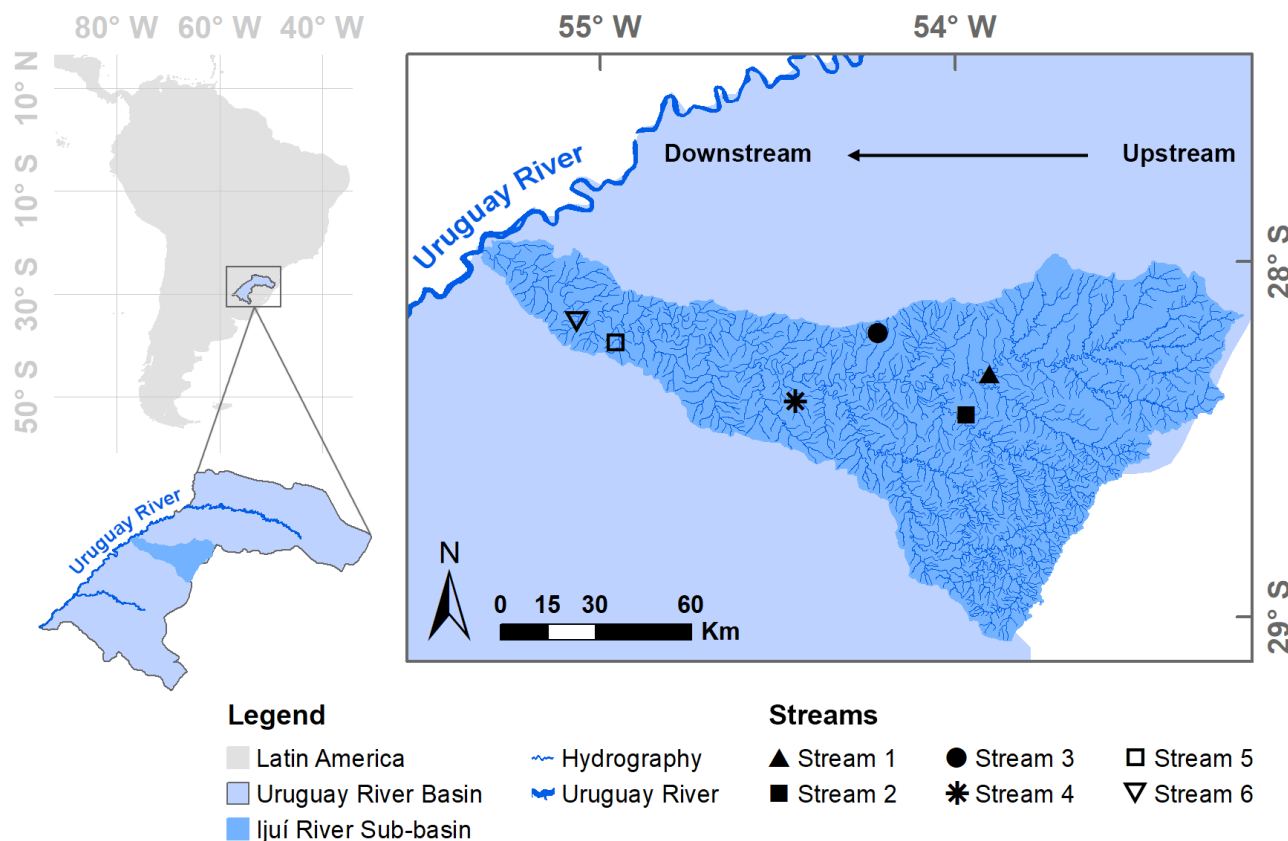


Figure 1. Location of the sampled streams in the Ijuí River sub-basin and its respective position into the Uruguay River hydrographic basin, Brazil.

use of fish, by the Ethics Committee on Animal Use of the Universidade Federal do Rio Grande do Sul, Brazil (Permit Number 35495).

In the field, individuals were anesthetized and euthanized with eugenol 10% (Jenkins et al. 2014) and fixed with formalin 10%. In the laboratory, specimens were selected and identified before being preserved in alcohol 70%. Species identification was made according to criteria of the literature (Buckup & Hahn 2000, Casciotta et al. 2002, Lucena 2007, Ghazzi 2008, Carvalho & Reis 2009, Malabarba et al. 2015) and specialists. The classification and nomenclature followed Eschmeyer et al. (2018) and Betancur-R et al. (2017) for Cichlidae. Voucher specimens were deposited in the ichthyologic collection of the Departamento de Zoologia, Universidade Federal do Rio Grande do Sul, Brazil. The fish community was described considering the abundance (number of individuals collected) and richness (number of species).

Spatial variations (for each sampled stream) on the ichthyofauna composition were tested using the permutational multivariate analysis of variance (PERMANOVA; $\alpha < 0.05$), based on a dissimilarity matrix constructed with the Bray-Curtis index (Anderson 2001, Anderson et al. 2011, Borcard et al. 2011). Abundance data were standardized using $\log_{10}(y+1)$ (Legendre & Legendre 1998, Anderson et al. 2011). The Bray-Curtis index was chosen as it considers the abundance data and enables the exclusion of joint absences (Anderson et al. 2011). This decision was made because we did not consider two samples to be more similar due to the sharing of absence of a particular species, since we do not have *a priori* information if the species does not actually exist in the local, or was simply not captured (Anderson et al. 2011). The pattern

of species spatial distribution, if identified with the PERMANOVA, was visualized with a principal coordinates analysis (PoCA), using a dissimilarity matrix made with the Bray-Curtis index (Legendre & Legendre 1998, Borcard et al. 2011). In the PCoA graph presenting the species composition along the sampled streams, only those species that contributed with a minimum of 10% of the explanation of the data distribution (eigenvectors $\geq \pm 0.10$) were shown, for the first two axis, in order to improve the visualization of distribution patters and avoid visual pollution. In the PCoA graph presenting the distribution of fish families, all species were shown. Statistical tests were carried out using R Project for Statistical Computing software, version 3.4.1. with the Vegan statistical package, version 2.4-5 (Oksanen et al. 2017).

Results

The ichthyofauna found in the six sampled streams in the Ijuí River basin is distributed within five orders, 13 families, 33 genera and 55 species, totalizing 5,029 individuals sampled (Table 1). The orders Characiformes and Siluriformes presented five families each, while Cichliformes, Gymnotiformes and Synbranchiformes were represented by a single family. The order Siluriformes was the most abundant in number of collected individuals (3,051 specimens), representing 60.68% of the total sampled, distributed within 17 genera. Characiformes presented the highest richness (23 species) and the second highest abundance (36.85% of individuals collected), comprised by 11 genera. Cichliformes had eight species and 1.25% of the total abundance,



Figure 2. Sampling sites in the streams of the Ijuí River sub-basin, Brazil. Upper portion (upstream): (a) Stream 1 and (b) Stream 2; mid portion (midstream): (c) Stream 3 and (d) Stream 4; lower portion (downstream): (e) Stream 5 and (f) Stream 6.

Fishes composition in streams

Table 1. List of occurrence and abundance of species of the ichthyofauna sampled in six streams in the Ijuí River sub-basin, Brazil. a Species endemic to the Uruguay River basin.

Taxa	Upper portion			Mid portion			Lower portion			Total	% of total	Voucher		
	Stream 1	Stream 2	Stream 3	Stream 4	Stream 5	Stream 6	Stream 1	Stream 2	Stream 3				Stream 4	Stream 5
CHARACIFORMES														
Characidae														
<i>Astyanax abramis</i> (Jenyns 1842)					4			19				1853	36.85	
<i>Astyanax aramburui</i> Protogimo, Miquelarena & López 2006					4			11				791	15.73	UFRGS 22179; 22180; 22182; 22187; 22373
<i>Astyanax eigenmanniorum</i> (Cope 1894)					3			1				4	0.08	UFRGS 21981; 21985; 21997; 21998
<i>Astyanax lacustris</i> (Lütken 1875)	12	41	2	2	13	81						151	3	UFRGS 21968; 21969; 21970; 21974; 21984; 21991; 21995; 22002; 22076; 22178; 22181; 22183; 22184; 22185; 22186; 22188; 22189; 22190; 22191; 22192; 22193; 22194; 22372; 22374
<i>Astyanax laticeps</i> (Cope 1894)			7	1								8	0.16	UFRGS 21971; 21976; 21987; 21992
<i>Astyanax ojilara</i> Azpelicueta & Garcia 2000	1	12	1									14	0.28	UFRGS 22473; 22477; 22723; 22724; 22725; 22726
<i>Astyanax paris</i> Azpelicueta, Almirón & Casciotta 2002				7								20	0.4	UFRGS 21927; 21928; 21929
<i>Astyanax saguazu</i> Casciotta, Almirón & Azpelicueta 2003					5			15				20	0.4	UFRGS 21919; 21980; 21982; 21986; 21988
<i>Astyanax</i> sp.					1			7				8	0.16	UFRGS 21972; 21990; 21994
<i>Astyanax xiru</i> Lucena, Castro & Bertaco 2013				2	1			7				12	0.24	UFRGS 21975; 21983; 21989; 21999; 22000; 22001; 22003
<i>Bryconamericus iheringii</i> (Boulenger 1887)	3	75	21	18	98	125						340	6.76	UFRGS 22478; 22481; 22544; 22702; 25454; 25456
<i>Bryconamericus uporas</i> Casciotta, Azpelicueta & Almirón 2002 ^a	9	5	34	41	1							99	1.97	UFRGS 22479; 22480; 22703; 22713; 22714; 25449
<i>Diapoma uruguayense</i> (Messner 1962) ^a								3				3	0.06	UFRGS 22474
<i>Galeocharax humeralis</i> (Valenciennes 1834)								1				1	0.02	UFRGS 25405
<i>Hyphessobrycon luetkenii</i> (Boulenger 1887)				1				9				10	0.2	UFRGS 22475; 22476
<i>Hyphessobrycon togoi</i> Miquelarena & López 2006									1			1	0.02	UFRGS 22472
<i>Oligosarcus</i> sp.												2	0.04	UFRGS 25450
<i>Piabarchus stramineus</i> (Eigenmann 1908)	1				47							60	1.19	UFRGS 22699; 22704; 22715
Crenuchidae														
<i>Characidium pterostictum</i> Gomes 1947	10	68	162	196	328	207						971	19.31	UFRGS 24564; 24565; 24566; 25425; 25426; 25427
<i>Characidium tenue</i> (Cope 1894)					5							5	0.1	UFRGS 25385; 25397

Continuation Table 1.

Taxa	Upper portion			Mid portion			Lower portion		Total	% of total	Voucher
	Stream 1	Stream 2	Stream 4	Stream 3	Stream 4	Stream 5	Stream 6				
Curimatidae											
<i>Steindachnerina biornata</i> (Braga & Azpelicueta 1987)	1								1	0.02	UFRGS 25460
Erythrinidae									5	0.1	
<i>Hoplias malabaricus</i> (Bloch 1794)	2				2	1			5	0.1	UFRGS 25355
Parodontidae									80	1.59	
<i>Apareitodon affinis</i> (Steindachner 1879)					77	3			80	1.59	UFRGS 25363; 25367
SILURIFORMES									3051	60.67	
Callichthyidae									94	1.87	
<i>Corydoras longipinnis</i> Knaack 2007					94				94	1.87	UFRGS 22177; 25433; 25452
Heptapteridae									1312	26.09	
<i>Cetopsorhamdia iheringi</i> Schubart & Gomes 1959	20								20	0.4	UFRGS 25402; 25409
<i>Heptapterus mandimbusu</i> Aguilera, Benitez, Terán, Alonso & Miranda 2017	23				66	1			90	1.79	UFRGS 25357; 25366; 25373; 25408
<i>Heptapterus mustelinus</i> (Valenciennes 1835)	145	358		69	115	214			1087	21.61	UFRGS 21107; 21955; 25434; 25435; 25436; 25437; 25438; 25447
<i>Heptapterus</i> sp1	23						2		23	0.46	UFRGS 25400; 25401; 25404; 25455
<i>Rhamdella longiuscula</i> Lucena & da Silva 1991 ^a									2	0.04	UFRGS 25362
<i>Rhamdia</i> aff. <i>quelen</i> (Quoy & Gaimard 1824)	21	22		7	11	10			90	1.79	UFRGS 25440; 25441; 25442; 25443; 25444; 25448; 25451
Loricariidae									1464	29.11	
<i>Ancistrus taunayi</i> Miranda Ribeiro 1918 ^a	101	198		119	132	35			700	13.92	UFRGS 25350; 25358; 25364; 25371; 25372; 25375; 25403
<i>Eurycheilichthys pantherinus</i> (Reis & Schaefer 1992) ^b					3				3	0.06	UFRGS 21811; 21978
<i>Hemiancistrus fuliginosus</i> Cardoso & Malabarba 1999	84	31		11	57	43			270	5.37	UFRGS 25360; 25361; 25370; 25391; 25395; 25396; 25459
<i>Hisonotus aky</i> (Azpelicueta, Casciotta, Almirón & Koerber 2004) ^c				2	4	2			8	0.16	UFRGS 25381; 25382; 25383
<i>Hypostomus commersoni</i> (Valenciennes 1836)	3	10				4			22	0.44	UFRGS 25354; 25410
<i>Pareiorhaphis hystrix</i> (Pereira & Reis 2002)	45	7		120	179	1			352	7	UFRGS 25359; 25369; 25374; 25392
<i>Pareiorhaphis</i> sp. ^a	1								1	0.02	UFRGS 21977
<i>Rineloricaria reisi</i> Ghazzi 2008 ^a	2								2	0.04	UFRGS 25353; 25412
<i>Rineloricaria sanga</i> Ghazzi 2008 ^a	1	31		5	6	3			62	1.23	UFRGS 25418; 25419; 25420; 25421

Fishes composition in streams

Continuation Table 1.

Taxa	Upper portion			Mid portion			Lower portion			Total	% of total	Voucher
	Stream 1	Stream 2	Stream 3	Stream 4	Stream 5	Stream 6	Stream 1	Stream 2	Stream 3			
<i>Rineloricaria stellata</i> Ghazzi 2008 ^a			12							12	0.24	UFRGS 25416; 25417
<i>Rineloricaria zaina</i> Ghazzi 2008 ^a	13	7	8	3			1			32	0.64	UFRGS 25413; 25414; 25415
Pseudopimelodidae										97	1.93	
<i>Microglanis malabarbai</i> Bertaco & Cardoso 2005 ^a	27		41	15	11		3			97	1.93	UFRGS 20253; 20254; 25376; 25380; 25387; 25388; 25389; 25390; 25394
Trichomycteridae										85	1.69	
<i>Ituglanis</i> sp.	2									2	0.04	UFRGS 21920; 21921
<i>Scleronema</i> sp. ^a		1		6	38		16			61	1.21	UFRGS 21958; 21959; 21961; 21962; 21963; 21964; 21965; 21966; 21973; 21979; 22579; 22583; 22584; 22585; 22586; 22587; 22588; 22589
<i>Trichomycterus perkos</i> Datovo, Carvalho & Ferrer 2012	4		18							22	0.44	UFRGS 25377; 25378; 25379; 25393; 25399; 25422; 25423; 25424
GYMNOTIFORMES										39	0.78	
Gymnotidae										39	0.78	
<i>Gymnotus cuiia</i> Craig, Malabarba, Crampton & Albert 2018		33	4	1	1					39	0.78	UFRGS 25429; 25445; 25446
CICHLIFORMES										63	1.25	
Cichlidae										63	1.25	
<i>Crenicichla hadrostroma</i> Lucena 2007 ^a	1									1	0.02	UFRGS 25458
<i>Crenicichla lepidota</i> Heckel 1840	1		1		3		1			6	0.12	UFRGS 25356; 25384; 25406; 25407
<i>Crenicichla missioneira</i> Lucena & Kullander 1992 ^a	3				2		2			7	0.14	UFRGS 25351; 25431
<i>Crenicichla scottii</i> (Eigenmann 1907) ^a			1	2	4		7			14	0.28	UFRGS 25457
<i>Crenicichla</i> sp.							3			3	0.06	
<i>Crenicichla tandybaguassu</i> Lucena & Kullander 1992	1									1	0.02	UFRGS 21996
<i>Geophagus brasiliensis</i> (Quoy & Gaimard 1824)	2	12								14	0.28	UFRGS 25368; 25386; 25432; 25439; 25461
<i>Gymnogeophagus constellatus</i> Malabarba, Malabarba & Reis 2015 ^a					3		14			17	0.34	UFRGS 25453
SYNBRANCHIFORMES										22	0.44	
Synbranchiidae										22	0.44	
<i>Synbranchus marmoratus</i> Bloch 1795	16		1		4		1			22	0.44	UFRGS 25352; 25365; 25398; 25411; 25428; 25430
Total	575	1010	650	864	1032	898	5029	898	5029	5029		

followed by Gymnotiformes and Synbranchiformes, with one species each, and 0.78% and 0.44% of the total number of collected specimens, respectively (Table 1). From the 55 fish species collected, 17 are endemic to the Uruguay River hydrographic basin and no exotic species were collected (Table 1).

Characidae had the highest number of species recorded, 18, followed by Loricariidae, Cichlidae, Heptapteridae, and Trichomycteridae, with 11, eight, six and three, respectively. In relation to the total of individuals captured, the most representative families were Loricariidae (29.11%), Heptapteridae (26.09%), Crenuchidae (19.41%) and Characidae (15.73%). The species with the highest number of individuals collected were *Heptapterus mustelinus* (Valenciennes 1835) (21.61%), *Characidium pterostictum* Gomes 1947 (19.31%), *Ancistrus taunayi* Miranda Ribeiro 1918 (13.92%), *Bryconamericus iheringii* (Boulenger 1887) (7.00%) and *Pareiorhaphis hystrix* (Pereira & Reis 2002) (6.76%), representing together approximately 70% of the ichthyofauna abundance. The abundance of the other species was inferior to 6% for each taxon (Table 1).

The distribution of species and the representativity of families were not homogenous throughout the altitudinal gradient of the Ijuí River sub-basin (Figure 3-4). A pattern of spatial variation on the ichthyofauna composition was detected, with differences in richness and species abundance from upstream (upper portion of the sub-basin) to downstream areas, near the mouth in the Uruguay River (sub-basin lower portion) according to PERMANOVA results (Df: 5, pseudo-F: 10.29, R²: 0.63, p: 0.0001), which indicates that species distribution does not occur randomly. The streams were more similar to each other regarding the ichthyofauna composition, according to the geographical location along the sub-basin (upper, mid, and lower portion) (Figure 3). Species richness varied between sampled streams, detecting a higher number of species in the lower portion of the sub-basin: 34 in stream 6 and 31 in stream 5. In the sub-basin mid portion, stream 3 and stream 4 presented 23 and 21 species, respectively, while in the upper portion were recorded 28 species in the stream 1 and 20 in the stream 2.

The most abundant species although appearing in all sampled sites, contributed to the segregation of the streams in the Principal Coordinates Analysis (Table 2; Figure 3). *Ancistrus taunayi* and *H. mustelinus* were associated with the upper portion of the sub-basin (streams 1 and 2), *P. hystrix* was associated to the mid portion (streams 3 and 4), while *B. iheringii* and *C. pterostictum* were linked to the stream in the lower areas (streams 5 and 6). Less abundant species also contributed to this segregation, the most important being, according to the PCoA eigenvectors (Table 2): *Corydoras longipinnis* Knaack 2007, Callichthyidae family, recorded only in the upper portion of the sub-basin, with 92 individuals collected in the stream 2, and *Gymnotus cuia* Craig, Malabarba, Crampton & Albert 2018, with approximately 85% of the individuals collected in this same location; *Bryconamericus uporas* Casciotta, Azpelicueta & Almirón, 2002 and *Microglanis malabarbai* Bertaco & Cardoso, 2005, with 76% and 58%, respectively, of individuals collected in the mid portion of the sub-basin (streams 3 and 4); and *Scleronema* sp., with 89% of the specimens collected in the lower portion (stream 5) (Figure 3).

A pattern in the representativity, abundance, and number of species and families in Characiformes, Siluriformes and Cichliformes is observed in relation to the second axis of PCoA (Figure 4). Siluriformes richness was higher in the upper portion of the Ijuí River sub-basin

(streams 1 and 2), with 18 out of 22 collected species occurring in the area, from which six have been exclusive to it (considering only this study data). Stream 1 (upper portion) presented the highest richness of Siluriformes (16 species) and the highest number of this order taxa with exclusive occurrence, namely: *Cetopsorhamdia iheringi* Schubart & Gomes 1959; *Pareiorhaphis* sp.; *Rineloricaria reisi* Ghazzi 2008; *Ituglanis* sp.; and Heptapteridae (identified only at family level). Siluriformes richness declined along the sub-basin, with 14 species recorded in the mid portion (streams 3 and 4) and 13 in the lower portion (streams 5 and 6) of Ijuí River (Figure 4).

The highest representativity of the Characiformes order occurred within the Characidae family, in the lower portion of the sub-basin (streams 5 and 6). Of the 18 species captured, 15 occurred in this area and eight were recorded exclusively for these two sampled streams (data from this study only). Likewise, the Cichliformes of the Cichlidae family are associated with the lower portion of the sub-basin, where their greatest abundance appeared (streams 5 and 6) (Figure 4).

Discussion

The species richness found in the streams of the Ijuí River sub-basin follows the pattern of freshwater fishes in the Neotropical region, with Characiformes and Siluriformes as the richest orders in number of species (Lowe-McConnell 1999, Malabarba & Malabarba 2014). Our hypothesis that the fish community composition is not homogeneous along the streams sampled was confirmed and we observed that species complexity increases from the upstream closest area to the downstream according to the river continuum concept. The latitudinal variation of the richness within the Ijuí River sub-basin, smaller in the upstream streams (closer to the headwaters of the sub-basin), increasing towards the mouth in Uruguay River (streams 5 and 6), is an expected pattern, according to the “river continuum concept” proposed by Vannote et al. (1980). Although, upstream and midstream areas present virtually the same (or higher) number of species, the richness has increased considerably towards the streams located in the lower portion of the basin (downstream) and we believe this is due to the influence of the Uruguay River, located very close to streams 5 and 6. According to the river continuum concept, the complexity of community structure and function increases along a river system as the increases of the complexity of the physical gradients dynamics formed by a drainage network (Vannote et al. 1980). Furthermore, the three streams with the smallest longitude (streams 1, 3 and 6) in relation to the correspondent streams (streams 2, 4 and 5), which occupy the same portion in the sub-basin (upper, mid, and lower) presented a higher number of species, respectively.

The knowledge about the influence of the global longitudinal gradient on the distribution of species richness is well established and, for freshwater fishes, remains the same even in anthropomorphized habitats, such as in large spatial reservoirs, although this distribution is better explained by the overlapping of factors, rather than a single hypothesis (Brown 2014, Bailly et al. 2016). For freshwater fishes, the species richness tends to decrease within the latitude and increase along the longitudinal fluvial gradients (Osborne & Lewis 1992, Ibañez et al. 2009, Bailly et al. 2016) (same pattern found in our samplings). The further away from the headwaters, within a hydrographic basin, the greater the species richness, as new species are added downstream more easily

Fishes composition in streams

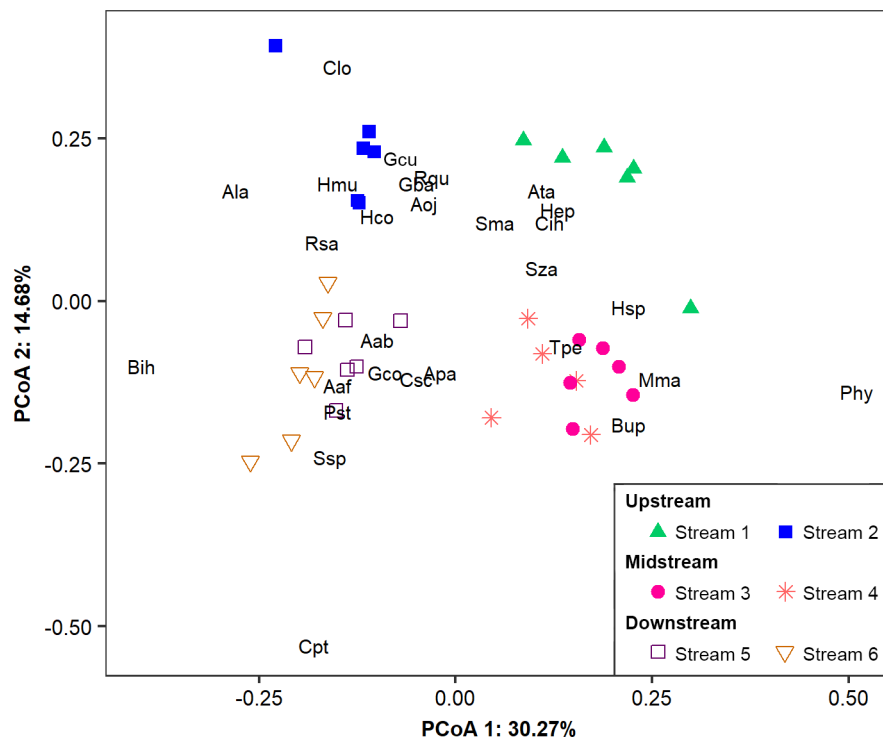


Figure 3. Principal Coordinates Analysis (PCoA) of the composition of species sampled in the upper (streams 1 and 2), mid (streams 3 and 4), and lower portion (streams 5 and 6) of the Ijuí River sub-basin, Brazil. Abbreviations list of species is in Table 2.

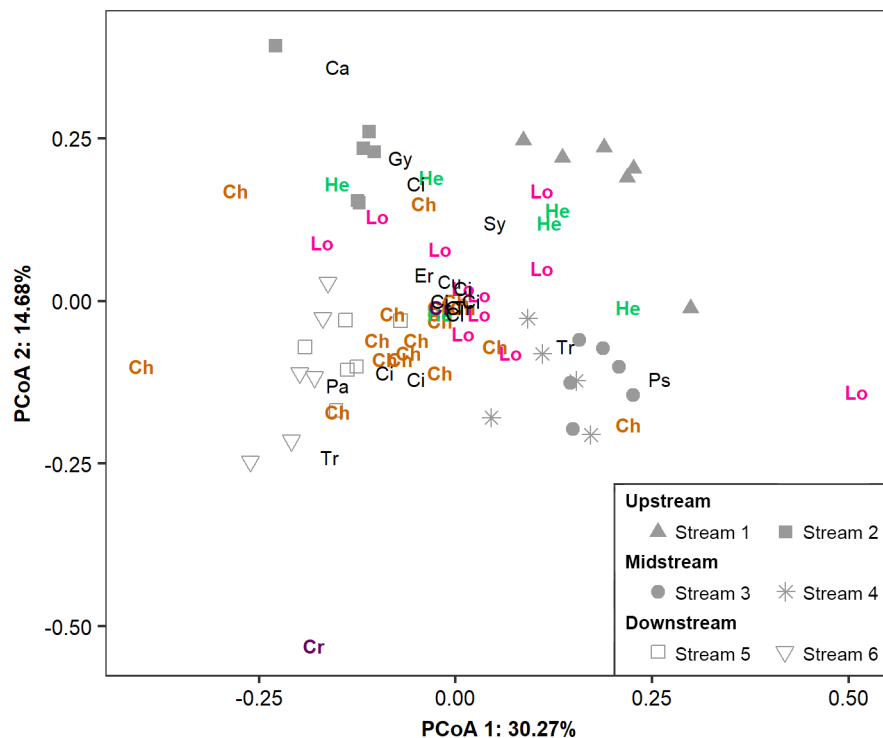


Figure 4. Principal Coordinates Analysis (PCoA) of the composition of species, indicating the representativeness of families, sampled in the upper (streams 1 and 2), mid (streams 3 and 4), and lower portion (streams 5 and 6) of the Ijuí River sub-basin, Brazil. The four most abundant are highlighted by bold typing: Ch: Characidae; Cr: Crenuchidae; Cu: Curimatidae; Er: Erythrinidae; Pa: Parodontidae; Ca: Callichthyidae; He: Heptapteridae; Lo: Loricariidae; Ps: Pseudopimelodidae; Tr: Trichomycteridae; Gy: Gymnotidae; Ci: Cichlidae; Sy: Synbranchidae.

Table 2. Eigenvalues and eigenvectors from the Principal Coordinates Analysis (PCoA) of the composition of species sampled in six streams of the Ijuí River sub-basin, Brazil.

		PCoA 1	PCoA 2
Eigenvalue		1.31	0.63
Proportion Explained		30.27	14.68
Cumulative Proportion		30.27	44.95
Taxa	Abbreviation	PCoA 1	PCoA 2
CHARACIFORMES			
Characidae			
<i>Astyanax abramis</i> (Jenyns 1842)	Aab	-0.10	-0.06
<i>Astyanax aramburui</i> Protogino, Miquelarena & López 2006	Aar	-0.07	-0.09
<i>Astyanax eigenmanniorum</i> (Cope 1894)	Aei	-0.02	-0.02
<i>Astyanax lacustris</i> (Lütken 1875)	Ala	-0.28	0.17
<i>Astyanax laticeps</i> (Cope 1894)	Alat	0.05	-0.07
<i>Astyanax ojiara</i> Azpelicueta & Garcia 2000	Aoj	-0.04	0.15
<i>Astyanax paris</i> Azpelicueta, Almirón & Casciotta 2002	Apa	-0.02	-0.11
<i>Astyanax saguazu</i> Casciotta, Almirón & Azpelicueta 2003	Asa	-0.09	-0.09
<i>Astyanax</i> sp.	Asp	-0.05	-0.06
<i>Astyanax xiru</i> Lucena, Castro & Bertaco 2013	Axi	-0.08	-0.02
<i>Bryconamericus iheringii</i> (Boulenger 1887)	Bih	-0.40	-0.10
<i>Bryconamericus uporas</i> Casciotta, Azpelicueta & Almirón 2002	Bup	0.22	-0.19
<i>Diapoma uruguayense</i> (Messner 1962)	Dur	-0.02	-0.03
<i>Galeocharax humeralis</i> (Valenciennes 1834)	Gum	0.00	0.00
<i>Hyphessobrycon luetkenii</i> (Boulenger 1887)	Hyl	-0.06	-0.08
<i>Hyphessobrycon togoi</i> Miquelarena & López 2006	Hto	0.01	-0.01
<i>Oligosarcus</i> sp.	Osp	-0.02	-0.01
<i>Piabarchus stramineus</i> (Eigenmann 1908)	Pst	-0.15	-0.17
Crenuchidae			
<i>Characidium pterostictum</i> Gomes 1947	Cpt	-0.18	-0.53
<i>Characidium tenue</i> (Cope 1894)	Cte	-0.02	-0.01
Curimatidae			
<i>Steindachnerina biornata</i> (Braga & Azpelicueta 1987)	Sbi	-0.01	0.03
Erythrinidae			
<i>Hoplias malabaricus</i> (Bloch 1794)	Hom	-0.04	0.04
Parodontidae			
<i>Apareiodon affinis</i> (Steindachner 1879)	Aaf	-0.15	-0.13
SILURIFORMES			
Callichthyidae			
<i>Corydoras longipinnis</i> Knaack 2007	Clo	-0.15	0.36
Heptapteridae			
<i>Cetopsorhamdia iheringi</i> Schubart & Gomes 1959	Cih	0.12	0.12
<i>Heptapterus mandimbusu</i> Aguilera, Benitez, Terán, Alonso & Miranda 2017	Hsp	0.22	-0.01
<i>Heptapterus mustelinus</i> (Valenciennes 1835)	Hmu	-0.15	0.18
<i>Heptapterus</i> sp1	Hep	0.13	0.14

Continuation Table 2.

		PCoA 1	PCoA 2
Eigenvalue		1.31	0.63
Proportion Explained		30.27	14.68
Cumulative Proportion		30.27	44.95
Taxa	Abbreviation	PCoA 1	PCoA 2
<i>Rhamdella longiuscula</i> Lucena & da Silva 1991	Rlo	-0.02	-0.02
<i>Rhamdia</i> aff. <i>quelen</i> (Quoy & Gaimard 1824)	Rqu	-0.03	0.19
Loricariidae			
<i>Ancistrus taunayi</i> Miranda Ribeiro 1918	Ata	0.11	0.17
<i>Eurycheilichthys pantherinus</i> (Reis & Schaefer 1992)	Epa	0.03	-0.02
<i>Hemiancistrus fuliginosus</i> Cardoso & Malabarba 1999	Hfu	-0.02	0.08
<i>Hisonotus aky</i> (Azpelicueta, Casciotta, Almirón & Koerber 2004)	Hak	0.01	-0.05
<i>Hypostomus commersoni</i> (Valenciennes 1836)	Hco	-0.10	0.13
<i>Pareiorhaphis hystrix</i> (Pereira & Reis 2002)	Phy	0.51	-0.14
<i>Pareiorhaphis</i> sp.	Psp	0.01	0.02
<i>Rineloricaria reisi</i> Ghazzi 2008	Rre	0.03	0.01
<i>Rineloricaria sanga</i> Ghazzi 2008	Rsa	-0.17	0.09
<i>Rineloricaria stellata</i> Ghazzi 2008	Rst	0.07	-0.08
<i>Rineloricaria zaina</i> Ghazzi 2008	Sza	0.11	0.05
Pseudopimelodidae			
<i>Microglanis malabarbai</i> Bertaco & Cardoso 2005	Mma	0.26	-0.12
Trichomycteridae			
<i>Ituglanis</i> sp.	Isp	0.01	-0.01
<i>Scleronema</i> sp.	Ssp	-0.16	-0.24
<i>Trichomycterus perkos</i> Datovo, Carvalho & Ferrer 2012	Tpe	0.14	-0.07
GYMNOTIFORMES			
Gymnotidae			
<i>Gymnotus cuia</i> Craig, Malabarba, Crampton & Albert 2018	Gcu	-0.07	0.22
CICHLIFORMES			
Cichlidae			
<i>Crenicichla hadrostroma</i> Lucena 2007	Cha	0.02	0.00
<i>Crenicichla lepidota</i> Heckel 1840	Cle	0.00	-0.01
<i>Crenicichla missioneira</i> Lucena & Kullander 1992	Cmi	0.00	-0.02
<i>Crenicichla scottii</i> (Eigenmann 1907)	Csc	-0.05	-0.12
<i>Crenicichla</i> sp.	Csp	-0.02	0.00
<i>Crenicichla tendybaguassu</i> Lucena & Kullander 1992	Cten	0.01	0.02
<i>Geophagus brasiliensis</i> (Quoy & Gaimard 1824)	Gba	-0.05	0.18
<i>Gymnogeophagus constellatus</i> Malabarba, Malabarba & Reis 2015	Gco	-0.09	-0.11
SYNBRANCHIFORMES			
Synbranchidae			
<i>Synbranchus marmoratus</i> Bloch 1795	Sma	0.05	0.12

than species of headwaters are lost (Osborne & Lewis, 1992). Therefore, a stream fish community structure changes over time and space, and more changes may occur between different parts of the same stream than between different streams in the same drainage basin, in some cases, such as changes on species richness or diversity of functional groups that change along a headwaters (upstream) toward the mouth (downstream) gradient (Vannote et al. 1980, Araújo-Lima et al. 1995).

Stream 1, upper portion of the sub-basin, presented more species than the streams in the mid portion (streams 3 and 4), becoming an exception to the pattern of longitudinal distribution found for the species richness. We believe this result has been influenced by the size of the stream (wider and with a greater water flow than the others) and by the proximity of the sampling site to the stream discharge into a larger river (about 200 meters), the Ijuí River, the main river of the sub-basin. In addition, information available in the literature indicates size, volume, flow speed and diversity of habitats, among others, as factors known to influence the pattern of ichthyofauna richness distribution (Winemiller 1983, Tejerina-Garro et al. 2005, Ibañez et al. 2009, Bailly et al. 2016). The characteristics of this stream could also be responsible for the association of Siluriformes to the upper portion of the Ijuí River sub-basin, in relation to the representativeness of the families Heptapteridae and Loricariidae.

Regarding the conservation status of the species, *Crenicichla hadrostigma* Lucena 2007, *Microglanis malabarbai* Bertaco & Cardoso 2005 and *Trichomycterus perkosi* Datovo, Carvalho & Ferrer 2012 are included in the list of threatened species, officially recognized by the 51.797 act of September 8, 2014, state of Rio Grande do Sul, and classified as “near threatened” (category VI), according to the criteria defined by the International Union for Conservation of Nature (IUCN) (FZB 2014). The other species captured appear as “least concern” (FZB 2014), or there is no information about the status of conservation due to the species description be posterior to the act publishing. Another reason for the lack of information is the existence of possible new species, like *Heptapterus* sp1, *Pareiorhaphis* sp., *Ituglanis* sp. and *Scleronema* sp., identified only to the genre level (Buckup 1988, Malabarba et al. 2013, J. Ferrer 2017, oral communication, Universidade Federal do Rio Grande do Sul). Therefore, we understand that studies like this contribute to the knowledge of the biological diversity of the south of Brazil, bringing complementary information about richness and abundance of endemic, threatened or of large distribution, grounding future research that could contribute to the conservation of fish biodiversity in Neotropical streams.

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Author Contributions

Laísa W. Cavalheiro: Substantial contribution in the concept and design of the study;

Clarice B. Fialho: Substantial contribution in the concept and design of the study.

Conflicts of interest

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

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