Biota Neotropica 19(3): e20180638, 2019
www.scielo.br/bn

biotaneotropica
ISSN 1676-0611 (online edition)
Inventory

Fish fauna of the Pelotas River, Upper Uruguay River, southern Brazil

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DELARIVA, R. L., NEVES, M. P., BAUMGARTNER, G., BAUMGARTNER, D. **Fish fauna of the Pelotas River, Upper Uruguay River, southern Brazil**. Biota Neotropica 19(3): e20180638. http://dx.doi.org/10.1590/1676-0611-BN-2018-0638

Abstract: The fish fauna of the Pelotas River, in the Upper Uruguay ecoregion of southern Brazil was inventoried. Samplings were performed quarterly between August 2013 and May 2014 at 14 sites in the Pelotas River and its tributaries, using gill nets of different mesh sizes, sein nets, cast nets and electrofishing. In total, 7,745 specimens were recorded, comprising 46 species, belonging to 13 families and five orders. Approximately 80% of the species belonged to the orders Characiformes and Siluriformes, as well as the families Characidae and Loricariidae, which included a greater number of species. Of the total species, 24% were endemic to the Upper Uruguay River, four were identified only at the genus level and none was considered non-native. Approximately, half of the 98 species previously recorded for the Upper Uruguay basin were also detected in this study. The tributaries of the Pelotas River exhibited different faunas with five exclusive species. Thirty species were present in both the tributaries and the main channel. In addition, higher species richness, as well as the presence of larger-sized species were observed in the main channel. Many of the species not restricted to the Upper Uruguay River have already been reported as part of the Taquari-Antas River fauna. However, the local biodiversity of this region is under several threats, such as land use and installation of small hydroelectric plants. These results highlight the importance of the conservation of plateau/upland rivers, especially in the Upper Uruguay ecoregion, which shows a peculiar fish fauna and endemism.
Keywords: *Freshwater, upland river, ichthyofauna, inventory, species richness.*

Fauna de peixes do rio Pelotas, Alto rio Uruguai, sul do Brasil

Resumo: A fauna de peixes do rio Pelotas, bacia do Alto Uruguai foi inventariada. As amostragens foram realizadas trimestralmente entre agosto de 2013 e maio de 2014, em 14 pontos da bacia do rio Pelotas, utilizando-se redes de emalhar de diferentes tamanhos, redes de arrasto, tarrafas e pesca elétrica. No total, foram registrados 7.745 exemplares, compreendendo 46 espécies pertencentes a 13 famílias e cinco ordens. Aproximadamente 80% das espécies foram pertencentes as ordens Characiformes e Siluriformes, assim como as famílias Characidae e Loricariidae, que tiveram maior número de espécies. Do total de espécies amostradas, 24% são endêmicas do Alto rio Uruguai, quatro foram identificadas apenas em nível de gênero e nenhuma foi considerada não nativa. Aproximadamente metade das 98 espécies anteriormente registradas na bacia do Alto rio Uruguai foi registrada nesse estudo. Os tributários do rio Pelotas exibiram distinta fauna com cinco espécies exclusivas. Trinta espécies foram comuns aos afluentes e canal principal. Verificou-se maior riqueza, bem como a presença de espécies de maior porte no canal principal. Muitas das espécies não restritas ao alto rio Uruguai já foram relatadas como parte da fauna da bacia do rio Taquari-Antas. No entanto, a biodiversidade local da região de estudo está sob diversas ameaças, como o uso do solo e a instalação de pequenas centrais hidrelétricas. Esses resultados destacam a importância da preservação dos rios de planalto, especialmente na ecorregião do Alto rio Uruguai, que apresenta uma fauna de peixes peculiar e endemismos.
Palavras-chave: *Água doce, rio de planalto, ictiofauna, inventário, riqueza de espécies.*

Introduction

The Pelotas River originates in the Serra Geral Formation, on the border between the states of Santa Catarina and Rio Grande do Sul, southern Brazil, and, along with the Canoas River forms the Uruguay River. In this region, due to the geomorphological characteristics of the Serra Geral Formation, there is a considerable slope, where the river flows over steep and rocky terrain marked by narrow channels with rapids and falls (Feow 2018). The tributaries of this river are generally short and also disrupted by waterfalls (Zaniboni-Filho & Schulz 2003). The climate of the ecoregion is characterized by rainfall well distributed throughout the year (humid subtropical – Cfa) (Köppen 1936), unlike that of other ecoregions of the La Plata basin, and also marked by the absence of flood pulse, floodplains and marginal lakes. These characteristics are strong environmental filters in the selection of species, which, together with other biogeographic factors, favor a peculiar fauna.

Bertaco et al. (2016) recorded 275 fish species from the Uruguay River, of which 78 (28%) are endemic and 25 (9%) are undescribed. Other studies highlighted the high endemism observed in the Araucária Plateau (750 m a.s.l.). Approximately 46% of the species found in the tributaries of the Upper Uruguay River exhibited some degree of endemism. Among these, 16.7%, present high endemism, occurring only in Campos de Cima da Serra (Malabarba et al. 2009). The highest species richness was observed in the drainage of the Pelotas and the Canoas rivers (Uruguay River basin- 60 species), compared to the basins of the Caí and the Taquari-Antas rivers (Jacuí River basin- 46 species). Despite this richness, the geomorphology of the Pelotas River basin makes it a target of incentive programs to install small hydroelectric plants (SHPs). The increase in the construction of hydroelectric dams and agro-industrial activities has implications for the biodiversity, affecting different trophic levels of fish assemblages (Becker et al. 2013, Jorgensen et al. 2013, Schork & Zaniboni-Filho 2017).

Some regions of southern Brazil have been poorly explored, mainly due to the lack of funding, or economic interest and possibly also to the difficulty of access to mountain river. This lack of data is a major drawback for the isolated regions with high endemism. Inventories have been carried out in adjacent ecoregions of the Upper Uruguay River, where is located the Pelotas River, such as the Iguaçu River basin (Abilhoa et al. 2008, Baumgartner et al. 2012, Frota et al. 2016, Larentis et al. 2016, Delariva et al. 2018), Taquari-Antas basin (Becker et al. 2013). Other studies have investigated the fish fauna after the construction of hydroelectric plants in the Uruguay River (Schork & Zaniboni-Filho 2017). However, there is little information specifically on the headwaters of the Pelotas River. Neves et al. (2018) evaluated the trophic guilds at six sites on the main channel of the Pelotas River. Notwithstanding inventories of the fish fauna of the tributaries of the Pelotas River in the same region were not contemplated. Thus, we emphasize that the present contribution is an updated version of this list, including tributaries of the Pelotas River with the use of electric fishing, which increases the probability of sampling small-sized and restricted species. Along with this concern, there are six hydroelectric plants currently installed in the Upper Uruguay region, three of them in the Uruguay River and three in its tributaries (Pelotas, Canoas, and Passo Fundo). In addition to hydroelectric dams, overfishing and industrial waste from pulp and paper mills are additional threats to the Upper Uruguay River basin (Reis et al. 2003).

This inventory presents the checklist of the fish fauna of the Pelotas River and its tributaries. The sampling design of this study, covering 14 sites, allowed us to determine the composition and species richness in this region and discusses the similarities among the local fish fauna in relation to adjacent drainage basins of the Taquari-Antas River. In addition, this inventory provides valuable information about the threat status of the fish fauna especially with a view to the installation of dams and SHPs already planned for this region.

Material and Methods

1. Study area

The Pelotas River rises in Serra Geral 64 km from the Atlantic Ocean and has an area of approximately 35,813 Km^2. It has a high slope, with an elevation ranging from 1,600 m to 840 m (Kröhling et al. 2011). The Pelotas River stands out for its ecological importance, agro-industrial activities, and hydroelectric potential.

In this region, the climate is classified as subtropical with rainfall events throughout the year, but with significant amplitude (Strassburger 2005). The vegetation of the region is composed of meadow areas that usually occur at altitudes above 800 m and of the Mixed Ombrophilous Forest, which occupies almost half of the basin and includes two formations: Mountain Forest (500 and 1000 m altitudes) and High Mountain Forest (1000 m altitudes) (Vieira 1984, Strassburger 2005).

2. Data collection

Samples were taken quarterly between August 2013 and May 2014 (August, November, February and May) at 14 sampling sites (Figure 1), eight in the channel of the Pelotas River (C01 to C08) and six tributaries (T01 to T06) (Figure 2, Table 1). Fishing gears consisted of gill nets (mesh sizes of 2.5, 3.0, 4.0, 5.0, 6.0, 7.0, 8.0, 9.0, 10.0, and 12.0 cm between opposite knots) and trammel nets (inner mesh sizes of 6, 7 and 8 cm between opposite knots), with lengths of 20 m (Pelotas River) and 10 m (tributaries), installed at 16:00 h and inspected at 22:00 h and 08:00 h, remaining exposed for approximately 16 hours. Cast nets with 2.5, 3.0, 4.0, and 6.0 cm between opposite knots and 15 m diameter were operated during daytime, each net being thrown for 15 min. In the littoral region, seine nets of 10 m length, 2 m depth, and 5 mm mesh size were operated during twilight at each sampling site. At sites T02 and T05, due to their size and depth, only electrofishing was performed in 50 m stretches (three consecutive passes in the mouth-headwaters direction). After capture, fish were anesthetized, fixed in 10% formaldehyde and preserved in 70% alcohol. Fish were collected under license from Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis (IBAMA) (process numbers 1372, 1373, 1374 and 1376/2012). This study was conducted in accordance with the protocols in their ethical and methodological aspects, for the use of fish, approved by the Ethics Committee on Animal Use (CEUA) of the Universidade Estadual do Oeste do Paraná.

Fish were identified in the laboratory following published procedures (Zaniboni-Filho et al. 2004, Ghazzi 2008, Serra et al. 2014) and expert assistance, and then measured (total and standard length in cm) and weighed (g). Voucher specimens were deposited at the fish collection of Gerpel (Grupo de Pesquisas em Recursos Pesqueiros e Limnologia, Universidade Estadual do Oeste do Paraná) and the fish

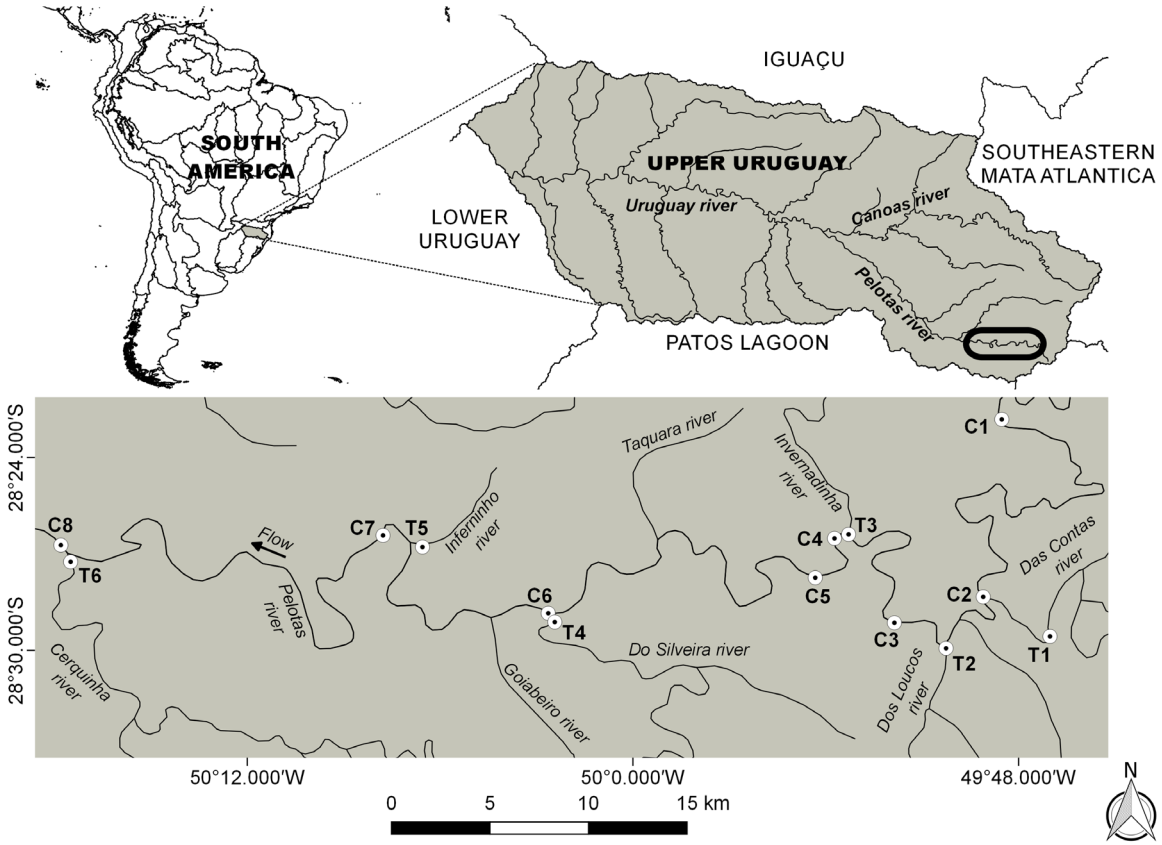

Figure 1. Study area in context of Freshwater Ecoregions of the World (modified from http://www.feow.org/) (Feow 2018). Sampling sites: main channel=C and tributaries (T), Upper Uruguay ecoregion, Brazil.

collection of Nupelia (Núcleo de Pesquisas em Limnologia, Ictiologia e Aquicultura, Universidade Estadual de Maringá).

Fish were categorized based on their distribution, as endemic (species with distribution restricted to the Upper Uruguay basin) or native (species indigenous from the Uruguay River basin, but not restricted to it) (Zaniboni-Filho et al. 2004, Ghazzi 2008, Becker et al. 2013, Bertaco et al. 2016, Schork & Zaniboni-Filho 2017, Froese & Pauly 2018). In addition, the species composition was compared with that of previous inventories carried out at the Taquari-Antas adjacent basin (Becker et al. 2013, Bertaco et al. 2016) (Table 2). Also added was the threat status of species registered according to the Brazilian Red List of Threatened Species (ICMBio 2018).

Results

A total of 7,745 specimens were recorded, comprising 46 species, belonging to 13 families and five orders (Table 2). The most species-rich orders were Characiformes (45.7%), followed by Siluriformes (34.8 %) and Cichliformes (15.2%). Gymnotiformes and Atheriniformes had only one species each (Figure 3). Characidae was the most representative family (11 species; 23.9%), followed by Loricariidae (nine species; 19.5%) and Cichlidae (eight species; 17.3%) (Figure 4). The other 10 families were responsible for 40% of the species. Four were identified only up to the genus level (*Hyphessobrycon* sp., *Imparfinis* sp., *Odontesthes* sp., *Trichomycterus* sp.) (Figure 5) and none was considered non-native.

In general, higher species richness was recorded in sites located in the main channel. The C02 recorded the highest richness (28 species), followed by C06 (26 species). The lowest richness in the main channel of the Pelotas River was observed at site C01, with only 15 species. Tributaries had richness ranging from 8 species in T05 to 23 species in T01. The fish fauna was characterized by small-sized species, considering that approximately 50% had a standard length lower than 150 mm (Table 2) and occurred in both the main channel and the tributaries. Only seven species (15%) were considered large-sized: 3 of them (*Hoplias australis*, *H. lacerdae* and *Rhamdia quelen*) occurred in both the main channel and the tributaries; while the remaining 4 species (*Schizodon nasutus*, *H.* aff. *malabaricus*, *Hypostomus commersoni* and *H. luteus*) occurred only in the main channel of the Pelotas River.

The most frequent species were *Astyanax dissensus*, *Astyanax xiru*, *Bryconamericus patriciae*, *Oligosarcus brevioris*, *Rhamdia quelen*, and *Crenicichla igara*, all of which were found in all sites. Distinct fish fauna was observed at the different environments, given that five species (*Cheirodon* cf. *interruptus*, *Crenicichla empheres*, *Heptapterus mustelinus*, *Trichomycterus* sp. and *Imparfinis* sp.) occurred only at the tributaries. Except for *C. empheres*, the other species are small-sized. Eleven species, including some medium- and large-sized ones, occurred exclusively in the main channel (Table 2).

Regarding the origin of the species, 11 (24%) are endemic to the Upper Uruguay River basin (Figure 5) and none registered as non-native (Table 2). Of the nearby drainages with available inventories, the only one sharing most of the species with the Pelotas River is the Taquari-Antas River basin (17 species) (Table 2).

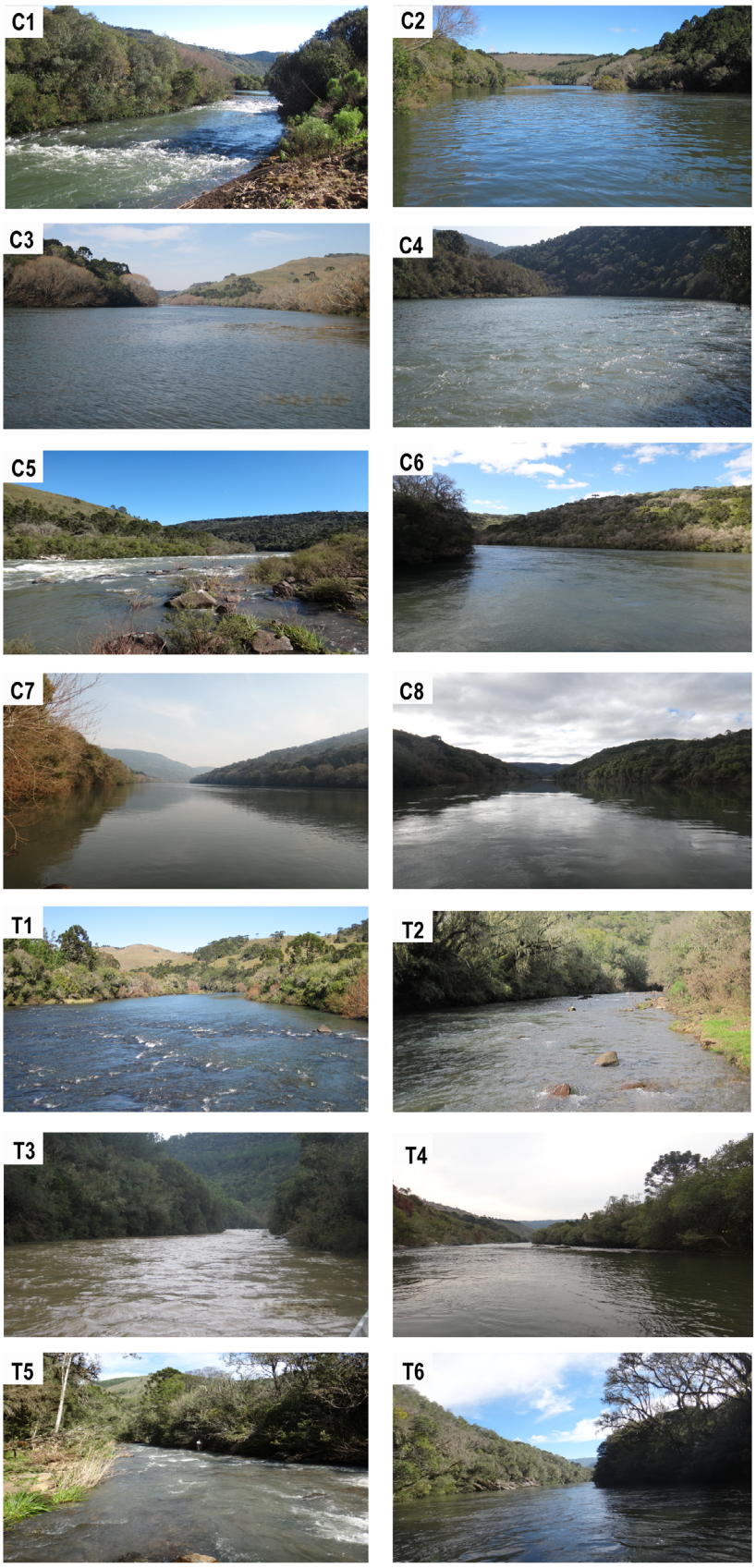

Figure 2. Reaches sampled in the tributaries (T) and main channel (C) of the Pelotas River, Upper Uruguay ecoregion, Brazil.

Table 1. Characteristics of the sampled sites in the Pelotas River basin, Upper Uruguay, Brazil.

Sites	River	Latitude/Longitude	Altitude (m)	river width (m)	flow	river bank	adjacent areas
C01	Pelotas	28º22'49"S/49º48'31"W	1089	35	Rapid waters and backwaters	Both banks ≈10m forested	Extensive cattle raising, agriculture and apple cultivation
C02	Pelotas	28º28'19"S/49º48'60"W	980	60	Rapid Waters and deep wells	Right bank more than 50m and left bank ≈ 10m forested	Extensive cattle raising
C03	Pelotas	28º29'20"S/49º51'57"W	956	80	Rapid Waters and deep wells	Right bank well preserved e left bank ≈ 10m forested	Extensive cattle raising
C04	Pelotas	28º26'25"S/49º53'25"W	939	70	Rapid Waters	Both banks well preserved	Forest area, with little apple culture and pasture areas
C05	Pelotas	28°27'28.53"S/49°55'8.9"W	926	60	Rapid Waters and backwaters	Right banks ≈ 20m and left banks more than 50m	Intensive agriculture and extensive cattle raising
C06	Pelotas	28°28'46"S/50°02'36"W	867	100	Moderate flow	Right banks well preserved and left banks ≈ 10m forested	Preserved, with presence of pasture
C07	Pelotas	28º29'20"S/49º51'57"W	850	150	Moderate flow and backwaters	Right banks ≈ 20m forested. Left banks well preserved	Preserved, with presence of pasture
C08	Pelotas	28°26'43.8"S/50°17'48.4"W	782	100	Rapid Waters and backwaters	Both banks with more than 50m forested	Livestock and diverse family culture
T01	Arroio das Contas	28º29'36"S/49º46'57"W	990	55	Rapid Waters and backwaters	Both banks with more than 50m forested	Extensive areas of apple culture, cattle raising and livestock family culture
T02	Arroio do Louco	28º29'50"S/49º50'19"W	966	15	Rapid Waters	Right banks preserved and left banks unpreserved less than 10m	Extensive cattle raising and livestock family culture
T03	Arroio Invernadinha	28º26'28"S/49º53'16"W	939	30	Rapid Waters and backwaters	Right banks preserved and left banks unpreserved less than 10m	Apple culture, cattle raising and livestock family culture
T04	Arroio Silveira	28°29'10"S/50°02'24"W	899	15	Rapid Waters	Both banks well preserved	Preserved, with little pasture.
T05	Arroio Sem Nome	28°26'38.22"S/50°6'30.3"W	855	6	Shallow rapid waters	Preserved, but with presence of apple culture	Preserved, with little apple and pasture areas.
T06	Arroio Cerquinha	28°27'11.6"S/50°17'38.6"W	787	30	Rapid Waters	Preserved, but with presence of pasture	Preserved, with little pasture

Table 2. Fish species recorded and their respective occurrences at sampling sites in the Pelotas River basin, Upper Uruguay ecoregion, Brazil. The classification of fishes followed Betancur et al. (2013) and species name update according to Fricke et al. (2019). Abundance in numerical percentage (%N) and biomass (%B) and SL= standard lengths (minimum – maximum; cm). The column "Origin" refers to species classified in endemic (EN) and native (NA) to the Upper Uruguay River (*=Asterisks represents an inability to categorize the origin because it is an unidentified species). BRD= Brazilian Red List of Threatened Species: VU= Vulnerable; NT= Near Threatened; DD = Data Deficient; LC = Least Concern; NE= Not Evaluated (ICMBio 2018). Size= reported size that the species can reach: Small (S)= fish less than 20 cm; Medium (M)= 20-40 cm and Large (L)= more than 40 cm. T= tributaries; C= main channel Pelotas River. Voucher specimens: individuals deposited in Ichthyology Collection of GERPEL (CIG) and Fish Collection of Núcleo de Pesquisas em Limnologia, Ictiologia e Aquicultura (NUP). Staining in the table indicates the occurrence of the species according to the literature: Becker et al. (2013) for the Taquari-Antas (TqA), Bertaco et al. (2016) involving Uruguay (Uru) and Taquari-Antas/Patos lagoon (TqA).

Taxonomic position/species	%N	%B	SL (cm)	Origin	BRD	Uru	TqA	Size	T01	T02	T03	T04	T05	T06	C01	C02	C03	C04	C05	C06	C07	C08	Voucher specimens
CHARACIFORMES																							
Parodontidae																							
Apareiodon affinis (Steindachner, 1879)	0,1	0,1	9.2 - 11.5	NA	LC			S						x								x	CIG 2270
Curimatidae																							
Steindachnerina biornata (Braga & Azpelicueta, 1987)	10,6	9,7	4.4 - 14.0	NA	LC			S	x		x	x		x		x	x	x	x	x	x	x	CIG 2334
Steindachnerina brevipinna (Eigenmann & Eigenmann, 1889)	0,5	0,2	2.0 - 8.6	NA	LC			S														x	CIG 2295
Anostomidae																							
Leporinus amae Godoy, 1980	1,8	2,1	7.4 - 15.7	NA	LC			S	x			x			x	x	x	x	x	x	x		CIG 2285
Schizodon nasutus Kner, 1858	0,0	0,2	27.0	NA	LC			L														x	CIG 2373
Characidae																							
Cheirodon cf. *interruptus* (Jenyns, 1842)	0,1	0,0	3.3 - 4.2	NA	LC			S						x									NUP 16271
Astyanax aff. *fasciatus* (Cuvier, 1819)	0,7	0,4	6.9 - 11.8	NA	LC			S			x			x		x	x		x	x	x	x	CIG 2276
Astyanax dissensus Lucena & Thofehrn, 2013	4,1	0,7	2.3 - 10.2	NA	LC			S	x	x	x	x	x	x	x	x	x	x	x	x	x	x	CIG 2265
Astyanax paris Azpelicueta, Almirón & Casciotta, 2002	3,4	1,1	2.7 - 10.1	EN	NE			S	x	x	x	x			x	x	x	x				x	CIG 2276
Astyanax cf. *procerus* Lucena, Castro & Bertaco, 2013	0,1	0,0	6.0 - 6.1	NA	LC			S				x				x							CIG 2288
Astyanax saguazu Casciotta, Almirón & Azpelicueta 2003	9,4	2,8	2.8 - 12.1	NA	LC			S	x	x	x	x		x	x	x	x	x	x	x	x	x	CIG 2271
Astyanax xiru Lucena, Castro & Bertaco, 2013	16,1	10,5	2.4 - 12.9	NA	LC			S	x	x	x	x	x	x	x	x	x	x	x	x	x	x	CIG 2267
Bryconamericus patriciae da Silva, 2004	22,6	3,1	2.0 - 8.4	NA	LC			S	x	x	x	x	x	x	x	x	x	x	x	x	x	x	CIG 2257
Hyphessobrycon sp.	0,1	0,0	3.6 - 5.2	NA*	NE			S						x			x					x	CIG 2255
Oligosarcus brevioris Menezes, 1987	3,5	9,0	2.2 - 25.6	EN	LC			M	x	x	x	x		x	x	x	x	x	x	x	x	x	CIG 2341
Oligosarcus jenynsii (Günther, 1864)	0,8	2,5	8.0 - 24.7	NA	LC			M	13			x		x	x	x	x	x	x	x	x		CIG 2331

http://dx.doi.org/10.1590/1676-0611-BN-2018-0638

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Taxonomic position/species	%N	%B	SL (cm)	Origin	BRD	Uru	TqA	Size	T01	T02	T03	T04	T05	T06	C01	C02	C03	C04	C05	C06	C07	C08	Voucher specimens
Acestrorhynchidae																							
Acestrorhynchus pantaneiro Menezes, 1992	0,0	0,0	16.4	NA	LC			M	1													x	CIG 2310
Erythrinidae																							
Hoplias australis Oyakawa & Mattox, 2009	0,1	1,3	26.1 - 29.1	EN	LC			L				x		x		x	x		x				CIG 2368
Hoplias lacerdae Miranda Ribeiro, 1908	0,5	8,1	9.6 - 54.0	NA	LC			L	x							x	x	x	x	x	x	x	CIG 2332
Hoplias aff. *malabaricus* (Bloch, 1794)	0,0	0,2	27.1 - 27.1	NA	LC			L														x	CIG 2365
SILURIFORMES																							
Trichomycteridae																							
Trichomycterus sp.	1,9	0,1	2.7 - 7.7	NA*	NE			S		x			x										NUP 18123
Loricariidae																							
Hemiancistrus fuliginosus Cardoso & Malabarba, 1999	4,2	6,3	5.9 -22.6	NA	LC			S	x		x	x		x	x	x	x	x	x	x	x	x	CIG 2329
Hypostomus commersoni Valenciennes, 1836	0,1	0,5	16.3 -21.3	NA	LC			L										x	x	x		x	CIG 2366
Hypostomus isbrueckeri Reis, Weber & Malabarba, 1990	4,3	16,4	6.5 - 24.9	NA	LC			M	x			x		x		x	x	x	x	x	x	x	CIG 2354
Hypostomus luteus (Godoy, 1980)	0,0	0,1	17.0	EN	LC			L												x			NUP 16848
Pareiorhaphis hystrix (Pereira & Reis, 2002)	2,0	0,1	8.0 - 9.9	NA	LC			S		x			x		x					x			CIG 2333
Rineloricaria anitae Ghazzi, 2008	0,2	0,1	10.2 - 14.4	EN	NE			M								x		x		x	x		CIG 2297
Rineloricaria capitonia Ghazzi, 2008	0,6	0,3	10.1 - 15.3	EN	LC			M	x	x	x				x	x		x	x	x	x		CIG 2299
Rineloricaria reisi Ghazzi, 2008	0,5	0,2	8.7 - 15.3	NA	LC			M	x		x	x			x	x		x					CIG 2324
Rineloricaria tropeira Ghazzi, 2008	0,2	0,1	11.6 - 15.1	EN	LC			M	x							x	x	x					CIG 2298
Heptapteridae																							
Heptapterus mustelinus (Valenciennes, 1835)	1,0	0,5	2.9 - 22.8	NA	LC			S		x			x										CIG 2041
Imparfinis sp.	0,0	0,0	9.7	NA*	NE			S		x													NUP 18133
Rhamdella longiuscula Lucena & da Silva, 1991	2,0	1,9	9.2 - 20.8	NA	LC			M	x	x	x	x		x	x	x	x	x	x	x	x		CIG 2349
Rhamdia quelen (Quoy & Gaimard, 1824)	2,5	10,4	11.1 - 34.2	NA	LC			L	x	x	x	x	x	x	x	x	x	x	x	x	x	x	CIG 2369
Pimelodidae																							
Iheringichthys labrosus (Lütken, 1874)	0,1	0,3	14.3 - 20.5	NA	LC			M						x					x		x	x	CIG 2326
Pimelodus maculatus Lacepède, 1803	0,3	3,7	22.9 - 32.0	NA	LC			M	x								x	x	x	x	x	x	CIG 2360

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http://dx.doi.org/10.1590/1676-0611-BN-2018-0638

Continuation Table 2.

Taxonomic position/species	%N	%B	SL (cm)	Origin	BRD	Uru	TqA	Size	T01	T02	T03	T04	T05	T06	C01	C02	C03	C04	C05	C06	C07	C08	Voucher specimens
GYMNOTIFORMES																							
Sternopygidae																							
Eigenmannia trilineata López and Castello, 1966	0,0	0,0	30.3	NA	LC			S											x				CIG 3285
ATHERINIFORMES																							
Atherinopsidae																							
Odontesthes sp.	0,6	1,2	2.4 - 26.9	NA*	NE			S	x		x	x		x		x	x	x	x	x			CIG 2360
CICHLIFORMES																							
Cichlidae																							
Australoheros taura Ottoni & Cheffe, 2009	0,1	0,1	7.2 - 9.2	NA	DD			S			x					x	x		x				CIG 2246
Crenicichla celidochilus Casciotta, 1987	1,5	1,9	5.8 - 21.1	NA	LC			M	x	x		x		x		x	x	x	x	x	x	x	NUP 18131
Crenicichla empheres Lucena, 2007	0,0	0,0	11.2-12,6	EN	VU			M	x														
Crenicichla igara Lucena & Kullander, 1992	2,6	3,2	5.1 - 19.4	EN	NT			M	x	x	x	x	x	x	x	x	x	x	x	x	x	x	CIG 2279
Crenicichla jurubi Lucena & Kullander, 1992	0,0	0,0	10,5-12,5	EN	NT			M								x							
Crenicichla missioneira Lucena & Kullander, 1992	0,1	0,2	13.1 - 15.6	NA	LC			M								x		x		x			CIG 2307
Crenicichla tendybaguassu Lucena & Kullander, 1992	0,1	0,1	8.1 - 17.0	EN	LC			S								x		x		x			CIG 2254
Geophagus brasiliensis (Quoy & Gaimard, 1824)	0,3	0,3	2.3 - 12.1	NA	LC			S									x		x	x		x	CIG 2248
Species richness									23	15	16	19	8	20	15	28	24	25	25	26	20	24	

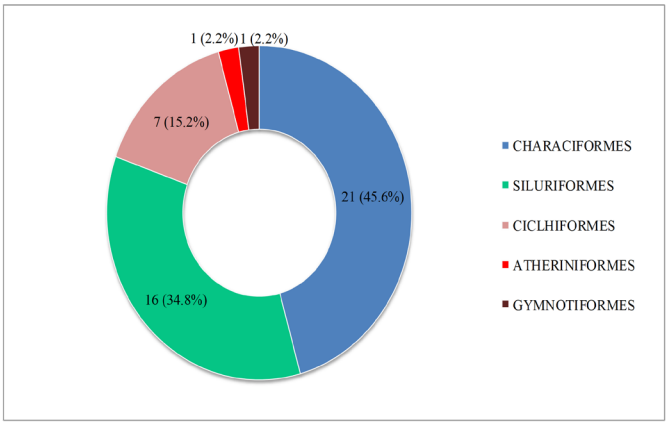

Figure 3. Specific richness to fish orders recorded in Pelotas River basin, Upper Uruguay ecoregion, Brazil. In side numbers represents the absolute and percentage species richness, respectively, to each order.

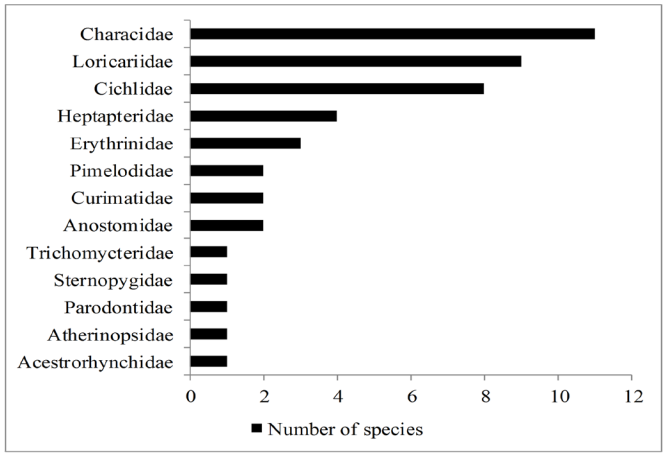

Figure 4. Specific richness to fish families recorded in Pelotas River basin, Upper Uruguay ecoregion, Brazil.

Discussion

The species richness recorded at each sites ranged from 8 to 28, totaling 46 species. This value is almost 50% of the 98 species previously recorded for the Upper Uruguay River (Zaniboni-Filho et al. 2004, Schork & Zaniboni-Filho 2017). The dominance of Characiformes and Siluriformes, corresponding to 82% of the recorded species, was similar to that documented for Neotropical fish fauna in general (Reis et al. 2016). Many previous studies already demonstrated that this dominance occurs not only in the Upper Uruguay (Schork & Zaniboni-Filho 2017), but also at its lower course (Zaniboni-Filho et al. 2004) and in adjacent basins (Becker et al. 2013, Bertaco et al. 2016). The lower richness of Atheriniformes and Gymnotiformes (2.2%) is in line with the findings of Bertaco et al. (2016) in three drainages of the Rio Grande do Sul State. However, it contrasts with reports referred to other Neotropical basins in which Gymnotiformes have greater contribution (Ota et al. 2018).

Characidae, Loricariidae and Cichlidae are the dominating families with approximately 60% of total richness. The proportional composition of species by family found in the study area is similar to that observed in the Taquari-Antas system, in the Patos Lagoon ecoregion (Bertaco et al. 2016). Characidae, with a great number of smaller-sized and generalist species (*sensu* Abelha et al. 2001), is usually co-dominant with Loricariidae (Reis et al. 2016); however, Characidae showed higher richness in the Pelotas River. In this sense, small characids (especially of the genera *Astyanax* and *Bryconamericus*), with compressed bodies and nektonic habit, have the ability to explore all the compartments of the lotic environments. This includes, for example, being successful in rapidly flowing environments, typical of upland rivers, as well as in backwaters. In a similar way, Loricariidae was here represented mainly by two genera, *Rineloricaria* Bleeker (four species described in 2008) and *Hypostomus* Lacépède (three species), which is by far the largest genus of Loricariidae and the second largest genus of catfish (Oyakawa et al. 2005). The dorsally flattened body and the suckermouth present in most Loricariidae provide greater attachment to the substrate and favor the displacement in stretches of rapids (Oliveira et al. 2010).

Cichlidae dominated among the families due to the occurrence of six species of *Crenicichla*, four of them endemic to the Upper Uruguay ecoregion. The Cichlidae family is exceptional among the Actinopterygii in relation to its high rate of phenotypic diversification and is found over most of the tropical and subtropical cis-Andean South America (Lucena & Kullander 1992).

The predominant landscape in the Upper Uruguay is considered of great ecological importance, particularly due to its geomorphological and hydrographic characteristics such as the plateau, with high altitude and slope. Most of the species had small geographic ranges, with more than half restricted to the ecoregion (Bertaco et al. 2016). The sampling sites established in the Pelotas River were essentially constituted by rapids and falls, which have greatly influenced the geographical distribution of the fish fauna. These peculiarities reflected in a fish fauna dominated by species that exhibit favorable performance to explore faster waters, with restricted dispersion. In addition, the presence of large waterfalls contributes to the low occurrence of migratory species, generally restricted to the Uruguay River and lower tributaries (Schork & Zaniboni-Filho 2017).

Physiographic characteristics, water quality, chemical composition of the soil (Albert & Reis 2011), and other environmental filters (Leitão et al. 2018), can affect the occurrence of species and lead to local variations in species richness. These factors may explain the finding that only six species were common to all sampling sites, especially those of the genus *Astyanax*. The wide distribution and abundance of this genus is a common pattern in the Uruguay basin, as well as in other adjacent basins (Baumgartner et al. 2012, Bertaco et al. 2016). In contrast, many species occurred at a single site, for example, *Cheirodon* cf. *interruptus*, and *Imparfinis* sp. (which occurred in the tributaries), and *Acestrorhynchus pantaneiro*, *Eigenmannia trilineata*, *Crenicichla empheres*, *Crenicichla jurubi*, *Schizodon nasutus*, *Steindachnerina brevipinna*, *Hoplias* aff. *malabaricus*, and *Hypostomus luteus* (which occurred in the main channel). It should be noted that, in addition to the 4 species unresolved taxonomy (*i.e.*, are still undescribed) (*Hyphessobrycon* sp., *Imparfinis* sp., *Odontesthes* sp., and *Trichomycterus* sp.), which may be species restricted to the Pelotas river basin, three other species (*Astyanax* cf. *procerus*, *Eigenmannia trilineata*, and *Australoheros taura*) were records not mentioned in previous inventories available for the Upper Uruguay River.

The comparison between the species recorded in the present study and those reported in previous studies performed by Becker et al. (2013) and Bertaco et al. (2016) in the Taquari-Antas basin, allows making some generalizations about the regional fish fauna. The Pelotas

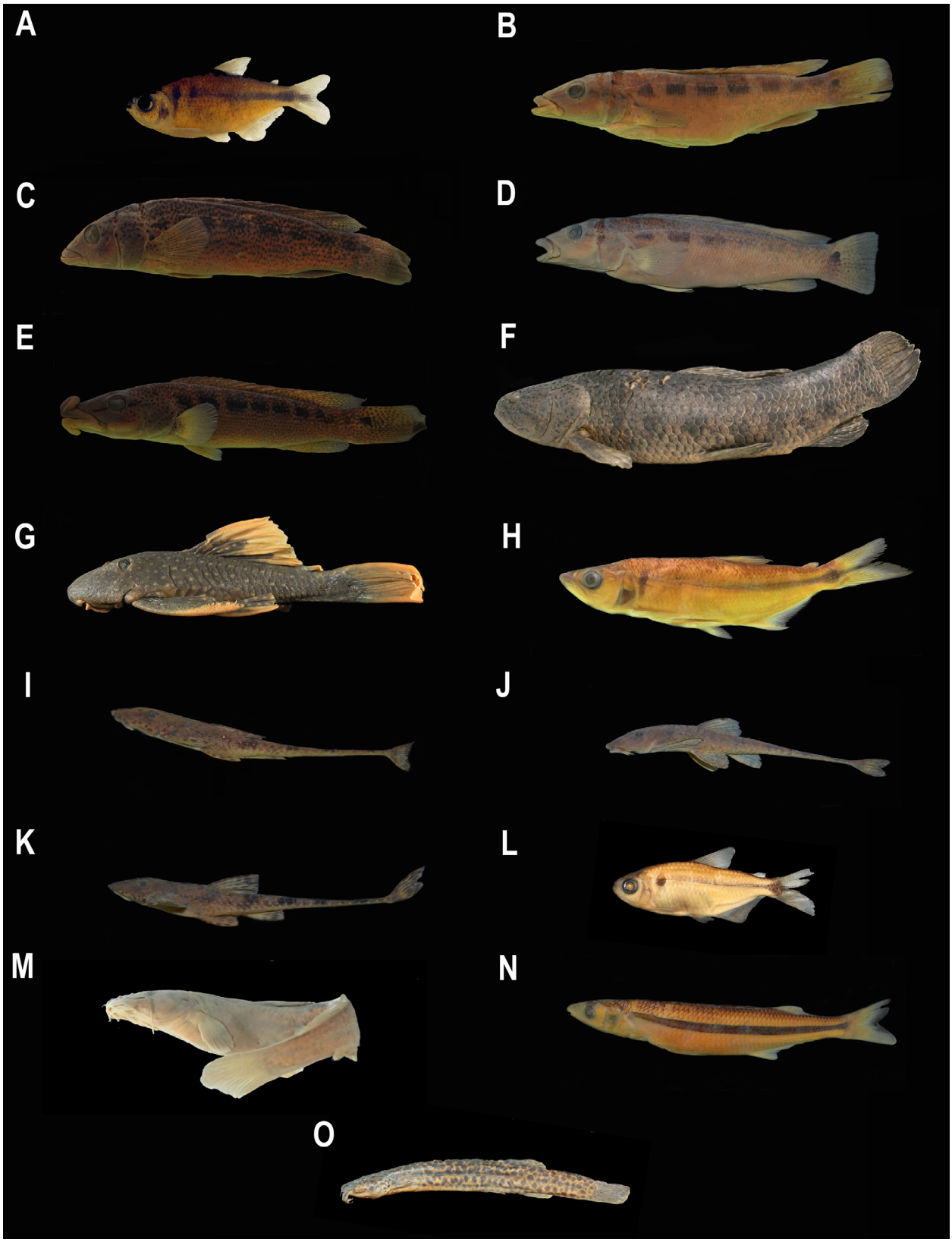

Figure 5. Representative's specimens sampled in the Pelotas River basin that are considered endemic to the Upper Uruguay ecoregion (A-K) and those specimens identified only at the genus level and possibly new species (L-O). The standard length (SL-mm) of the exemplar pictured is presented after the name of species. A) *Astyanax paris* (65 mm); B) *Crenicichla empheres* (110 mm); C) *Crenicichla igara* (125 mm); D) *Crenicichla jurubi* (115 mm); E) *Crenicichla tendybaguassu* (170 mm); F) *Hoplias australis* (257 mm); G) *Hypostomus luteus* (170 mm); H) *Oligosarcus brevioris* (150 mm); I) *Rineloricaria anitae* (120 mm); J) *Rineloricaria capitonia* (133 mm); K) *Rineloricaria tropeira* (116 mm); L) *Hyphessobrycon* sp. (39 mm); M) *Imparfinis* sp. (97 mm); N) *Odontesthes* sp. (147mm); O) *Trichomycterus* sp. (69 mm).

http://dx.doi.org/10.1590/1676-0611-BN-2018-0638

River drainage shares 17 species (36.9%) with the Lagoon of the Patos system. Furthermore, when analyzed in terms of higher taxa (family and genera) as well as aspects of habitat occupation, a peculiar similarity is observed, especially in relation to three factors: i) high endemism within Loricariidae and the genera *Astyanax*; ii) a high number of small-sized species; (iii) absence of long-range migratory species. In this aspect, the composition of species was more similar with inventories conducted in the adjacent basin of the Taquari-Antas River (Becker et al. 2013, Bertaco et al. 2016), than the fauna of lower reaches of the basin of the Uruguay River itself (Zaniboni-Filho et al. 2004, Schork & Zaniboni-Filho 2017). The highest similarity with the Taquari-Antas drainage basin is possibly associated with a greater sharing of headwater streams divided by the tectonic processes that culminated in the emergence of the Serra do Mar (Ribeiro 2006, Reis 2017). Also, natural drainage evolution over geological time includes drainage rearrangement, which severs connections and provides new interdrainage links (Bishop 1995). In this sense, further speculation on the genesis of the sharing of high endemism, but in distinct taxa, could serve as encouragement for future studies of particular interest to evolutionary biology.

According to Bertaco et al. (2016), the species richness knowledge has been always strictly related to collecting efforts. Small-sized species represents an important source of new species, along with regions or unexplored habitats, sometimes associated with restricted distribution of species. Four species identified only at the genus level in this study are considered small-size and are under expert review (*Hyphessobrycon* sp., *Imparfinis* sp., *Odontesthes* sp., *Trichomycterus* sp.). The genus *Hyphessobrycon* has approximately 130 species already described (Carvalho & Langeani, 2013), being polyphyletic and still without taxonomic resolution. In the Uruguay River, 11 species of *Hyphessobrycon* were reported by Betancur et al. (2013) (*H. anisitsi*, *H. bifasciatus*, *H. boulengeri*, *H. eques*, *H. igneus*, *H. isiri*, *H. luetkenii*, *H. meridionalis*, *H. nicolasi*, *H. reticulatus*, *H. togoi*). *Hyphessobrycon* sp. was recorded in samples obtained from the main channel and from tributaries. These specimens differ from the above-mentioned species by at least one of the following characteristics: lack of spots on the dorsal fin and distal region of the anal; presence of longitudinal strips strongly touching the stalk of the peduncle; body shape; humeral spot; number of cusps on teeth; number of rays in the anal fin (hard or branched); number of longitudinal line scales; number of scales above lateral line; and fins bony hooks. The specimens collected from the Pelotas River basin do not have the characters of *Hyphessobrycon* s.s. (sensu, Carvalho & Malabarba, 2015), thereby, further studies are needed, including an osteological analysis, for a final decision about the taxonomic status of these specimens.

Imparfinis sp. presents characteristics divergent from those exhibited by *I. mishky*. In one specimen captured, the adipose fin reaches the caudal fin that is not strongly forked. This specimen is under review by Flávio Bochmann, who is considering the possibility of being in front new species. Specifically in the case of *Odontesthes* sp., it differs from other species occurring in the Uruguay River basin (*O. bonariensis*, *O. perugiae* and *O. yucuman*) by the presence of 21 or less gill rakers on the lower branch (Wingert et al., 2017). In addition, other morphological and osteological features are being investigated to confirm the identity of this species. In relation to *Trichomycterus* sp., the captured specimens from the Pelotas River basin do not resemble the species described for Upper Uruguay River, like *T. perkos* (Datovo et al., 2012), that present different color pattern and to *T. tropeiro* (Ferrer & Malabarba 2011), described for Antas River, that show absence of pelvic fin. On the other hand, *Trichomycterus* sp. is very similar to *T. balios* (Ferrer & Malabarba 2013), a species of the Patos Lagoon system and upper portions of the Mampituba basin. However, because of the small number of specimens captured, they were not diaphanized; this prevented performing osteological evaluations and more accurate comparisons with this species of the neighboring basin. Bertaco et al. (2016) mention the presence of *T. perkos* and several other species not yet described for the Upper Uruguay, and the species observed at the Pelotas River may be one of them. It should be noted, however, that there is still the possibility of being in front of a new and endemic species of the Pelotas River.

The main threats in continental waters are changes in habitats arising from land uses and impoundments (Pelicice et al. 2017) and these are also imminent in the Pelotas River basin (Model et al. 2018). A growing number of hydroelectric projects are being established in the Upper Uruguay River basin in Brazil. Of a total of six large power plants planned for the region, five have already been built (Schork & Zaniboni-Filho 2017). Additionally, the installation of four small hydroelectric plants in the Pelotas River is under planning. Owing to these drastic changes in the local landscape, there is an urgent need to establish measures for the conservation of fish fauna. The impoundments facilitate the dispersion of species that are now endemic to the Pelotas River, or to their local extinction, and also can allow species that are currently absent from the Pelotas River basin to colonize it.

Considering all species registered in this study, according to Brazilian Red List of Threatened Species (ICMBio 2018), one (*C. empheres*) is considered "Vulnerable", two (*C. igara* and *C. jurubi*) Near Theatened (NT), one (*A. taura*) as Deficient Data (DD), thirty six were classified as Least Concern (LC) and six still Not Evaluated (NE) (Table 2). *C. empheres, C. igara* and *C. jurubi* as well as most species are associated with environments of rapids. In this respect, the scenario of alterations in the Pelotas River will strongly affect a still little-known fauna which is already threatened of global extinction.

In summary, this study is important not only because it describes fish richness, but also because it highlights the enormous challenges to be faced by ichthyologists, that is, to obtain basic knowledge of occurrence and status of conservation of fish fauna in areas of relevant biogeographic importance. Since most of the species reported in this study have restricted distribution, especially those of the genera *Rineloricaria*, *Hypostomus* and *Crenicichla*, the preservation of lotic stretches is essential to ensure their conservation. In view of the current scenario of fragmentation of the Upper Uruguay basin, our findings highlight the need to establish careful and consistent policies for the conservation and management of an ichthyological area of the paranoplatensean basin that encompasses many endemic species and others possibly still unknown to science.

Acknowledgments

We thank the Gerpel (Grupo de Pesquisa em Recursos Pesqueiros e Limnologia) of the Universidade Estadual do Oeste do Paraná (Unioeste) for providing logistical support for sampling. We also

are deeply grateful to researcher Juliana Mariani Wingert for the identification of characteristics of *Odontesthes* sp. We are grateful for the feedback from the two anonymous reviewers and the Editor for helping us improve this manuscript.

Author Contributions

Rosilene Luciana Delariva: Substantial contribution in the concept and design of the study, data analysis, interpretation and manuscript preparation.

Mayara Pereira Neves: Contribution to data analysis, interpretation and manuscript preparation.

Gilmar Baumgartner: Contribution to data collection, to critical revision, adding intellectual content.

Dirceu Baumgartner: Contribution to data collection, to critical revision, adding intellectual content.

Conflicts of Interest

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

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Received: 15/08/2018
Revised: 24/04/2019
Accepted: 08/05/2019
Published online: 27/06/2019