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Structure dynamics of a fish community over ten years of formation in the reservoir of the hydroelectric power plant in upper Uruguay River

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(With 6 figures)

Abstract

The objective of this study was to evaluate the structure of the fish assemblage in the ten years following the closing of the lake of the Itá Hydroelectric Power Plant. Seasonal collections were conducted from 2001 to 2010. During this period, 44,834 fish were captured, totaling 3,818.01 kg, among 8 orders, 24 families and 84 species. In general, profound changes were not observed in the fish assemblage in the ten years after the formation of the Itá lake. Few species changed in dominance over time, while many were rare in the environment. The ichthyofauna in the reservoir was dominated by small and medium size opportunist species that conduct short or no migratory movements. Among the most abundant, six species were responsible for more than 50% of the numeric representation: *Steindachnerina brevipinna*, *Astyanax fasciatus*, *Apareiodon affinis*, *Hypostomus isbrueckeri*, *Iheringichthys labrosus* and *Loricariichthys anus*. The increase in the representation of the later species stood out. The biomass was dominated by *Steindachneridion scriptum*, *Prochilodus lineatus*, *I. laborsus*, *Schizodon nasutus*, *Hoplias malabaricus*, *Acestrorhynchus pantaneiro*, *Hoplias lacerdae*, *H. isbrueckeri* and *L. anus*. Despite the presence of large migrators in the region of the reservoir, their vulnerability was revealed by the low numeric abundance and accidental capture. The k-dominance curve of numerical abundance and biomass indicates a moderately disturbed community, in which the representation of small species was also important to the amounts of biomass.

Keywords: dam, ichthyofauna, southern Brazil, temporal variation, Itá.

Dinâmica da estrutura da comunidade íctica ao longo de dez anos da formação do reservatório da usina hidrelétrica no Alto Rio Uruguai

Resumo

O objetivo deste trabalho foi avaliar a estrutura da assembleia de peixes nos dez anos seguintes ao fechamento do lago da Usina Hidrelétrica de Itá. Para isto, foram realizadas coletas com periodicidade sazonal no período compreendido entre 2001 e 2010. Durante o período de estudo, foram capturados 44834 peixes, totalizando 3818,01 kg, distribuídos em 8 ordens, 24 famílias e 84 espécies. De uma forma geral, a assembleia de peixes não mostrou alterações profundas nos dez anos após a formação do lago de Itá. Poucas espécies alternam-se na dominância ao longo do tempo, enquanto muitas mostraram-se como raras no ambiente. A ictiofauna do reservatório foi dominada por espécies oportunistas, de pequeno e médio porte e que realizam curtos ou nenhum movimento migratório. Entre as mais abundantes, seis espécies foram responsáveis por mais de 50% da representatividade numérica, sendo elas: *Steindachnerina brevipinna*, *Astyanax fasciatus*, *Apareiodon affinis*, *Hypostomus isbrueckeri*, *Iheringichthys labrosus* e *Loricariichthys anus*. Destaque para aumento da representatividade deste último. Já para a biomassa, destacaram-se: *Steindachneridion scriptum*, *Prochilodus lineatus*, *I. labrosus*, *Schizodon nasutus*, *Hoplia smalabaricus*, *Acestrorhynchus pantaneiro*, *Hoplias lacerdae*, *H. isbrueckeri* e *L. anus*. Apesar da presença de grandes migradores na área do reservatório, sua vulnerabilidade ficou evidenciada pelas baixas abundâncias numéricas e capturas acidentais. A curva de k-dominância de abundância numérica e de biomassa indicou uma comunidade moderadamente perturbada, na qual a representatividade de espécies de pequeno porte foi importante também para os valores de biomassa.

Palavras-chave: barragem, ictiofauna, sul do Brasil, variação temporal, Itá.

1. Introduction

Electrical energy production in Brazil still depends essentially on hydroelectricity, which is responsible for approximately 65% of the national energy supply (Brasil, 2015). Thus, the construction of dams for hydroelectric energy generation is now among the main anthropogenic impacts on Brazilian watersheds, substantially modifying most of the country's large rivers. The interruption in the natural flow of the rivers damages their hydrological connectivity (Vannote et al., 1980), causing a series of changes so intense that a new ecosystem is formed (Baxter, 1977).

This substitution of lotic waters for lentic waters causes changes in the water retention time, in the size of the sediments and nutrients and in various limnological variables (Souza-Filho, 2009; Ribeiro-Filho et al., 2011). Therefore, implications for the biodiversity of the location altered are felt at different trophic levels, even on the fish assemblage (Jorgensen et al., 2013). The main changes described for the ichthyofauna in reservoirs include the proliferation of opportunist species and the decline of species with greater ecological demands (Agostinho et al., 1999).

Migratory species are particularly affected by the interruption of their migratory routes and the decrease in the number of habitats needed to complete their life cycle (Agostinho et al., 2003). Normally, the reproduction habitats are located in the upper portions of large rivers and affluents (Vazzoler et al., 1997) and for this reason, the dams form obstacles to the migratory routes of adults upriver and to the drift of fish eggs and larva. These impacts are accentuated in so-called cascading reservoirs which, arranged in sequence, form systems of extreme complexity (Tundisi and Straskraba, 1999) and make even more rare the remaining lotic stretches that are so necessary for the migratory species.

The Upper Uruguay River Basin in Brazil has received a growing number of hydroelectric projects. Of a total of six large power plants planned for the region, five have already been built, all installed to form a cascading system. The Itá hydroelectric dam is located on the Uruguay River, the main river in the watershed, formed by the confluence of the Pelotas and Canoas Rivers. On this portion, the river flows over a typically hilly terrain with stretches of waterfalls and the presence of a narrow channel. Thus, unlike other rivers in the Prata watershed, the regions marked by the absence of floodplains and marginal lakes, and by tributaries that are not very long.

Despite the various recent studies conducted at Brazilian reservoirs (Petesse and Petrere-Junior, 2012; Araujo et al., 2013; Novaes et al., 2014; Sanches et al., 2016; Montenegro et al., 2012), there are few researchers that have had the opportunity to study the ichthyofauna through scientific monitoring over a long period. Only continuous accompaniment of the environment can construct a long-term investigation that is capable of providing responses that can often not be observed in another manner (Elliott, 1990; Cody, 1996) and assist in possible mitigating actions. Thus, this study sought to evaluate the composition and structure of the ichthyofauna in the Itá reservoir. Based on this characterization, it studied possible changes in the fish assemblage over the ten years following the formation of the lake.

2. Material and Methods

The Itá hydroelectric power plant is located between the municipalities of Itá (SC) and Aratiba (RS) and was the first large power plant built on the upper portion of the Uruguay River (Zaniboni-Filho et al., 2008), initiating operations in March 2000. The reservoir formed by the project has a total area of 141 sq. km and average depth of 36 meters with a maximum depth of 125 m. With a perimeter of approximately 800 km, it encompasses eight municipalities; four in Rio Grande do Sul State and four in Santa Catarina. Composing a cascading system of dams above the Itá hydroelectric power plant, there is the Machadinho hydroelectric dam, built in the bed of the Uruguay River, the Barra Grande hydroelectric power plant on the Pelotas River and the Campos Novos hydroelectric power plant built on the Canoas River.

The information was obtained at the Itá reservoir through seasonal collections that began in January 2001 and continued until December 2010. A total of 40 collections were conducted at six sample points distributed among the different environments formed by the reservoir: lentic, lotic and transition (Figure 1).

The fishing equipment used in the collection included: gillnets with spaces of 1.5; 2.0; 2.5 and 3.0 cm between the cords – all 1.6 m tall with length varying from 10 to 30 m – and gillnets with 8 cm spaces, 8 meters tall and 60 to 120 m long. In addition, trammel nets with 3.0 to 5.0 cm gaps, 1.8 m tall and 15 to 40 m long. All of the nets were always placed in the environment at nightfall and collected in the morning, after remaining in the water for approximately 12 hours. The same procedure was used for a long-line (with 100 hooks). At each point, three casts were also made using seine nets (mesh with 8 mm gaps and 7 m long) and ten casts of a throw net (mesh of 8 mm and 13.5 m in diameter), always during the day.

After harvesting fish, specimens were identified up to species levels according to a taxonomic key. Measurements of total weight (g) and total length (cm) were taken in the field. The specimens were fixed in 10% formalin solution and then placed in containers with ethanol at 70%. Specimens that could not be identified in the field were transported to the Ichthyology Laboratory of Londrina State University in the state of Paraná or to the Museum of Science and Technology of Pontifícia Universidade Católica of Rio Grande do Sul (PUC), where they were identified.

Assemblage structure was evaluated by richness index (number of species), total biomass (g), total number of individuals, Shannon-Wiener index (H') (Krebs, 1998), equitability (E) (Pielou, 1966) and dominance (Simpson, 1949). The constancy among species was calculated according to Dajoz (1973).

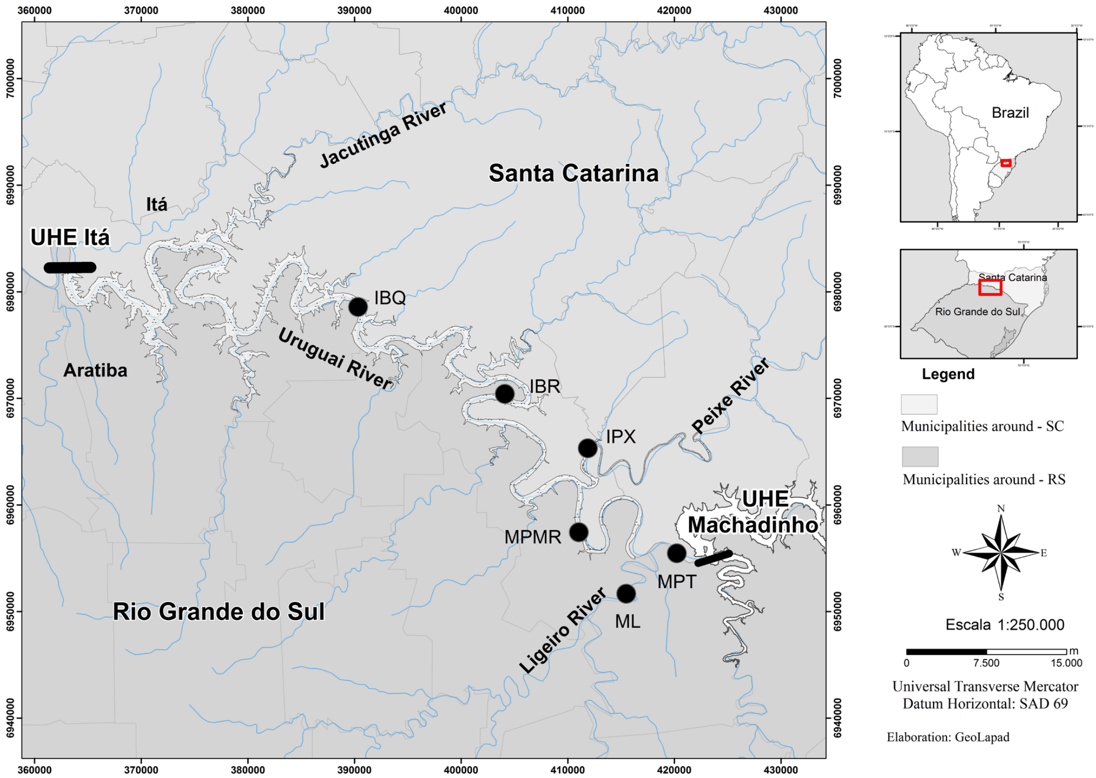

Figure 1. Location of the Itá hydroelectric plant on the Uruguay River between Santa Catarina and Rio Grande do Sul states.

To evaluate the differences between the various samples, variance analyses were conducted (ANOVA with repeated measures). Before this, the data were tested for normality (Shapiro-Wilk test) and homoscedasticity (Levene test). To meet the presumptions, the data for biomass and dominance were transformed by log(x+1). When significant differences were present ($p<0.01$), the Tukey test was applied to identify the level of difference of the factor. When the presumptions for normality and homoscedasticity were not achieved, the corresponding non-parametric test was applied (Friedman ANOVA).

The non-metric ordination method – NMDS - was used to verify temporal variations in the composition and numeric abundance of the ichthyic assemblage (Clarke and Warwick, 2001). According to these authors, the values for the number of individuals were transformed in log(x+1) prior to the calculation of the Bray-Curtis similarity index to approximate the contribution of the rare species to those that were very abundant in the samples.

The analysis of similarity – ANOSIM – was applied to test the null hypothesis that there are no differences in the assemblies between the years with levels of significance of $p<0.01$ for 9.999 permutations. The R statistic allows recognizing how much the groups are separated, on an interval considered as follows: indistinguishable ($R<0.25$); minimally separable ($R>0,25$); overlapping, but clearly different ($R>0.5$); or well separated ($R>0.75$) (Clarke and Gorley, 2001). To determine the individual contribution of each species to the similarities found in each year similarity percentage analysis was conducted (SIMPER) using PRIMER 6 software. To indicate species with consistent contribution over the years, the cutoff was made at 80%. The same software was used to determine the ABC curve (Warwick, 1986) and the W statistic (Clarke, 1990).

3. Results

Over the entire sampling period at the Itá reservoir, a total of 44,834 fish were caught, with a total of 3,818.01 kg, distributed among 8 orders, 24 families and 84 species. The Characiformes order was the most abundant, representing more than 60% of the number of individuals caught, more than 50% of the biomass and approximately 40% of the species and families observed. They were followed by the Siluriformes, representing 40% of the total biomass captured and nearly 30% of the species, families and number of individuals caught. Meanwhile, the Perciformes composed approximately 10% of the families and species caught, although with a much lower participation in the number of individuals and biomass than the above-mentioned orders. The other orders combined (Atheriniformes, Cypriniformes, Cyprinodontiformes, Gymnotiformesand Synbranchiformes) were responsible for 9% of the families, 25% of the species, 4% of the biomass caught and only 1% of the number of individuals caught during the sample period.

Because of their numeric abundance, six species totaled more than 50% of those caught, all of which are considered sedentary or short-distance migrators: the biru *Steindachnerina brevipinna* (15.9%), the lambari *Astyanax fasciatus* (12.1%), the canivete *Apareiodon affinis* (6.5%), the cascudos *Hypostomus isbrueckeri* (6.6%) and *Loricariichthys anus* (5.9%), and the mandi *Iheringichthys labrosus* (5.8%). In terms of biomass, nine species were responsible for more than 50% of those caught. Among them, only the curimba *Prochilodus lineatus* (4.9%) undertakes long reproductive migrations. The others are the voga *Schizodon nasutus* (9.2%), the traíra *H. malabaricus* (7.9%), the peixe-cachorro *Acestrorhynchus pantaneiro* (7.5%), the suruvi *Steindachneridion scriptum* (6,2%), the trairão *H. lacerdae* (5.4%) and the previously mentioned *I. labrosus* (4.6%), *H. isbrueckeri* (6,9%) and *L. anus* (4,9%) (Table 1).

Nineteen species were constant in the catches, present in more than 50% of the collections, and only eight species were classified as accessories. The highest number of species was those considered accidental (57), the category in which all the long distance migratory were classified (Table 1).

Three exotic species were found, the tilapia *Oreochromis niloticus* and the carp *Ctenopharingodon idellus* and *C. carpio*. For the two species of piranhas found in the reservoir, *Pygocentrus nattereri* and *Serrasalmus maculatus*, the low numeric abundance of the catch remained constant throughout the period of study.

Using variance analysis (ANOVA with repeated measures), a significant difference was found ($p<0.05$) only for the amount of richness between the years of the study. There was no difference for the number of individuals, biomass, and the other indicators analyzed – dominance (log(x+1)), equitability and Shannon H' (Figure 2).

Table 1. Identification number, absolute and relative abundance for the number of individuals [n and n(%)] and biomass [B and B(%)] of each species, beyond the Dajoz constant for the catches in the Itá reservoir from 2001 to 2010 (Cons – constant, Aces – accessory, Acid – accidental).

ID Nº	Nº - Identification number Scientific name	n	n(%)	B	B(%)	Cons
	ATHERINIFORMES	**94**	**0.21**	**2.28**	**0.06**	
	Atherinopsidae	**94**	**0.21**	**2.28**	**0.06**	
56	*Odontesthes perugiae* Evermann & Kendall 1906	94	0.21	2.28	0.06	Acid
	CHARACIFORMES	**30208**	**67.40**	**2,108.84**	**55.24**	
	Acestrorhynchidae	**2437**	**5.44**	**287.38**	**7.53**	
3	*Acestrorhynchus pantaneiro* Menezes 1992	2437	5.44	287.38	7.53	Cons
	Anostomidae	**2255**	**5.03**	**401.79**	**10.52**	
39	*Leporinus amae* Godoy 1980	45	0.10	1.46	0.04	Acid
75	*Leporinus macrocephalus* Garavello & Britski 1988	1	0.00	0.14	0.00	Acid
55	*Leporinus obtusidens* (Valenciennes 1837)	22	0.05	47.24	1.24	Acid
76	*Leporinus striatus* Kner 1858	2	0.00	0.02	0.00	Acid
7	*Schizodon nasutus* Kner 1858	2185	4.87	352.93	9.24	Cons
	Bryconidae	**24**	**0.05**	**57.12**	**1.50**	
65	*Brycon orbignyanus* (Valenciennes 1850)	10	0.02	6.37	0.17	Acid
41	*Salminus brasiliensis* (Cuvier 1816)	14	0.03	50.75	1.33	Acid
	Characidae	**14025**	**31.29**	**397.81**	**10.42**	
44	*Astyanax eigenmanniorum* (Cope 1894)	36	0.08	0.65	0.02	Acid
5	*Astyanax fasciatus* (Cuvier 1819)	5431	12.11	86.08	2.25	Cons
6	*Astyanax scabripinnis* (Jenyns 1842)	1426	3.18	27.48	0.72	Cons
8	*Astyanax jacuhiensis* (Cope 1894)	2497	5.57	33.95	0.89	Cons
58	*Astyanax sp 3*	88	0.20	1.78	0.05	Acid
16	*Bryconamericus iheringii* (Boulenger 1887)	680	1.52	0.72	0.02	Aces
4	*Bryconamericus stramineus* Eigenmann 1908	1320	2.94	1.3	0.03	Aces
66	*Charax leticiae* Lucena 1987	1	0.00	0.01	0.00	Acid
72	*Cynopotamus kincaidi* (Schultz 1950)	91	0.20	8.07	0.21	Acid
25	*Galeocharax humeralis* (Valenciennes 1834)	1250	2.79	110.49	2.89	Cons
60	*Oligosarcus brevioris* Menezes 1987	16	0.04	1.6	0.04	Acid
10	*Oligosarcus jenynsii* (Günther 1864)	1187	2.65	125.5	3.29	Cons
82	*Roeboides sp.*	2	0.00	0.18	0.00	Acid
	Crenuchidae	**16**	**0.04**	**0.02**	**0.00**	
37	*Characidium zebra* Eigenmann 1909	16	0.04	0.02	0.00	Acid

Table 1. Continued...

ID Nº	Nº - Identification number / Scientific name	n	n(%)	B	B(%)	Cons
	Curimatidae	**7247**	**16.17**	**142.63**	**3.74**	
73	*Cyphocharax sp*	4	0.01	0.19	0.00	Acid
83	*Steindachnerina biornata* (Braga & Azpelicueta 1987)	114	0.25	2.43	0.06	Acid
1	*Steindachnerina brevipinna* (Eigenmann & Eigenmann 1889)	7129	15.90	140.01	3.67	Cons
	Erythrinidae	**712**	**1.59**	**506.89**	**13.28**	
12	*Hoplias lacerdae* Miranda Ribeiro 1908	295	0.66	204.09	5.35	Cons
13	*Hoplias malabaricus* (Bloch 1794)	417	0.93	302.8	7.93	Cons
	Paradontidae	**2891**	**6.45**	**24.8**	**0.65**	
12	*Apareiodon affinis* (Steindachner 1879)	2891	6.45	24.8	0.65	Cons
	Prochilodontidae	**90**	**0.20**	**188.83**	**4.95**	
46	*Prochilodus lineatus* (Valenciennes 1837)	90	0.20	188.83	4.95	Acid
	Serrasalmidae	**511**	**1.14**	**101.57**	**2.66**	
79	*Piaractus mesopotamicus* (Holmberg 1887)	1	0.00	2.01	0.05	Acid
48	*Pygocentrus nattereri* Kner 1858	103	0.23	26.85	0.70	Acid
24	*Serrasalmus maculatus* Kner 1858	407	0.91	72.71	1.90	Cons
	CYPRINIFORMES	**64**	**0.14**	**111.47**	**2.92**	
	Cyprinidae	**64**	**0.14**	**111.47**	**2.92**	
71	*Ctenopharyngodon idella* (Valenciennes 1844)	2	0.00	6.8	0.18	Acid
30	*Cyprinus carpio* Linnaeus 1758	62	0.14	104.67	2.74	Acid
	CYPRINODONTIFORMES	**1**	**0.00**	**0.00**	**0.00**	
	Poeciliidae	**1**	**0.00**	**0**	**0.00**	
78	*Phalloceros caudimaculatus* (Hensel 1868)	1	0.00	0	0.00	Acid
	GYMNOTIFORMES	**220**	**0.49**	**34.96**	**0.92**	
	Gymnotidae	**75**	**0.17**	**31.58**	**0.83**	
36	*Gymnotus carapo* Linnaeus 1758	73	0.16	30.85	0.81	Acid
53	*Gymnotus sp*	2	0.00	0.73	0.02	Acid
	Sternopygidae	**145**	**0.32**	**3.38**	**0.09**	
31	*Eigenmannia virescens* (Valenciennes 1836)	145	0.32	3.38	0.09	Aces
	PERCIFORMES	**955**	**2.13**	**29.87**	**0.78**	
	Cichlidae	**942**	**2.10**	**29.44**	**0.77**	
68	*Crenicichla celidochilus* Casciotta 1987	41	0.09	1.24	0.03	Acid
69	*Crenicichla igara* Lucena & Kullander 1992	22	0.05	2.42	0.06	Acid
45	*Crenicichla jurubi* Lucena & Kullander 1992	52	0.12	2.31	0.06	Acid
52	*Crenicichla minuano* Lucena & Kullander 1992	42	0.09	1.25	0.03	Acid
35	*Crenicichla missioneira* Lucena & Kullander 1992	69	0.15	3.25	0.09	Acid
70	*Crenicichla tendybaguassu* Lucena & Kullander 1992	1	0.00	0.02	0.00	Acid
33	*Crenicichla vittata* Heckel 1840	171	0.38	11.36	0.30	Aces
23	*Geophagus brasiliensis* (Quoy & Gaimard 1824)	356	0.79	6.07	0.16	Aces
32	*Gymnogeophagus gymnogenys* (Hensel 1870)	127	0.28	0.38	0.01	Acid
38	*Gymnogeophagus rhabdotus* (Hensel 1870)	8	0.02	0.06	0.00	Acid
57	*Oreochromis niloticus* (Linnaeus 1758)	53	0.12	1.08	0.03	Acid
	Sciaenidae	**13**	**0.03**	**0.43**	**0.01**	
77	*Pachyurus bonariensis* Steindachner 1879	13	0.03	0.43	0.01	Acid
	SILURIFORMES	**13286**	**29.63**	**1,530.34**	**40.07**	
	Auchenipteridae	**387**	**0.86**	**22.93**	**0.60**	
49	*Auchenipterus sp.*	30	0.07	1.94	0.05	Acid
61	*Trachelyopterus ceratophysus* (Kner 1858)	1	0.00	0.05	0.00	Acid
14	*Trachelyopterus galeatus* (Linnaeus 1766)	326	0.73	19.5	0.51	Aces
29	*Trachelyopterus teaguei* (Devincenzi 1942)	30	0.07	1.44	0.04	Acid

Table 1. Continued...

ID Nº	Nº - Identification number Scientific name	n	n(%)	B	B(%)	Cons
	Callichthyidae	**1**	**0.00**	**0**	**0.00**	
67	*Corydoras paleatus* (Jenyns 1842)	1	0.00	0	0.00	Acid
	Cetopsidae	**6**	**0.01**	**0.13**	**0.00**	
42	*Cetopsis gobioides* Kner 1858	6	0.01	0.13	0.00	Acid
	Heptapteridae	**369**	**0.82**	**127.43**	**3.33**	
81	*Rhamdella longiuscula* Lucena & da Silva 1991	17	0.04	0.59	0.02	Acid
18	*Rhamdia quelen* (Quoy & Gaimard 1824)	352	0.79	126.84	3.32	Cons
	Loricariidae	**7046**	**15.72**	**750.4**	**19.65**	
47	*Ancistrus sp.*	5	0.01	0.06	0.00	Acid
51	*Ancistrus taunayi* Miranda Ribeiro 1918	3	0.01	0.09	0.00	Acid
28	*Pogonoma obscurum* Quevedo & Reis 2002	282	0.63	78.43	2.05	Aces
19	*Hemiancistrus fuliginosus* Cardoso & Malabarba 1999	306	0.68	14.42	0.38	Acid
22	*Hypostomus commersoni* Valenciennes 1836	380	0.85	93.89	2.46	Cons
2	*Hypostomus isbrueckeri* Reis, Weber & Malabarba 1990	2941	6.56	263.57	6.90	Cons
27	*Hypostomus luteus* (Godoy 1980)	112	0.25	34.42	0.90	Acid
54	*Hypostomus regani* (Ihering 1905)	80	0.18	36.09	0.95	Acid
34	*Hypostomus roseopunctatus* Reis, Weber & Malabarba 1990	77	0.17	17.65	0.46	Acid
74	*Hypostomus ternetzi* (Boulenger 1895)	4	0.01	0.24	0.01	Acid
59	*Hypostomus uruguayensis* Reis, Weber & Malabarba 1990	6	0.01	1.4	0.04	Acid
20	*Loricariichthys anus* (Valenciennes 1835)	2645	5.90	188.65	4.94	Cons
21	*Loricariichthys sp.m*	106	0.24	10.08	0.26	Acid
40	*Paraloricaria vetula* (Valenciennes 1835)	64	0.14	5.68	0.15	Acid
63	*Rineloricaria sp.*	35	0.08	5.73	0.15	Acid
	Pimelodidae	**5476**	**12.22**	**627.87**	**16.45**	
9	*Iheringichthys labrosus* (Lütken 1874)	2598	5.80	177.06	4.64	Cons
15	*Parapimelodus valenciennis* (Lütken 1874)	1779	3.97	24.61	0.64	Cons
80	*Pimelodella laticeps* Eigenmann, 1917	4	0.01	0.08	0.00	Acid
26	*Pimelodus absconditus* Azpelicueta 1995	180	0.40	10.41	0.27	Aces
50	*Pimelodus atrobrunneus* Vidal & Lucena 1999	150	0.33	6.41	0.17	Acid
11	*Pimelodus maculatus* Lacepède 1803	668	1.49	169.93	4.45	Cons
64	*Sorubim lima* (Bloch & Schneider 1801)	1	0.00	1.23	0.03	Acid
43	*Steindachneridion scriptum*(Miranda Ribeiro 1918)	96	0.21	238.14	6.24	Acid
	Pseudopimelodidae	**1**	**0.00**	**1.58**	**0.04**	
62	*Pseudopimelodus mangurus* (Valenciennes 1835)	1	0.00	1.58	0.04	Acid
	SYNBRANCHIFORMES	**1**	**0.00**	**0.12**	**0.00**	
	Synbranchidae	**1**	**0.00**	**0.12**	**0.00**	
84	*Synbranchus marmoratus* Bloch 1795	1	0.00	0.12	0.00	Acid

Large migrators, like the piava (*Leporinus obtusidens*), the dourado (*Salminus brasiliensis*) and the piracanjuba (*Brycon orbignyanus*) had low numeric abundance over the years of the study. Piracanjuba only began to be caught in 2006 and no piava were caught after 2007. The curimba (*Prochilodus lineatus*) was the only species in this category that was caught in a similar amount throughout the years of the study (Table 2).

Analyzing the numeric abundance of the catch, some species decreased their representation in relation to the initial years of formation of the Itá lake, including the: *A. pantaneiro* (3), *H. isbrueckieri* (2), *S. brevipinna* (1) and the lambaris *Astyanax scabripinnis* (6) and *Bryconamericus stramineus* (4). In contrast, *A. affinis* (12), *L. anus* (20) and the lambari *Bryconamericus iheringii* (16) increased their participation over time. Meanwhile the *A. fasciatus* (5) had peaks of abundance from 2006 to 2008 and the peixe-cachorro *Galeocharax humeralis* (25) from 2003 to 2004. For *S. nasutus* (7), the representation in the catches was constant over the years (Figure 3).

The analysis of grouping based on the data for numeric abundance shows a high similarity between the years

(>80%). Within this bidimensional plotting of NMDS, two groups were formed: one composed of the three initial years and another for the other years. The stress value of 0.08 indicates graphic distances in the two dimensions with excellent representation of the similarities (Figure 4).

The dissimilarity between the years, verified with the ANOSIM analysis, obtained an R-Global equal to 0.116 for levels of significance of $p<0.01$ in 9999 permutations. No pairwise comparison between the subsequent years presented a significant difference ($p>0.01$). With the

Table 2. Total number of individuals of the four species of large migrators captured in the Itá reservoir from 2001-2010.

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
B. orbignyanus						4	4		1	1
L. obtusidens	2	1	2	6	2	7	2			
P. lineatus	5	9	5	5	6	22	9	4	13	12
S. brasiliensis	7	2				3	1			1

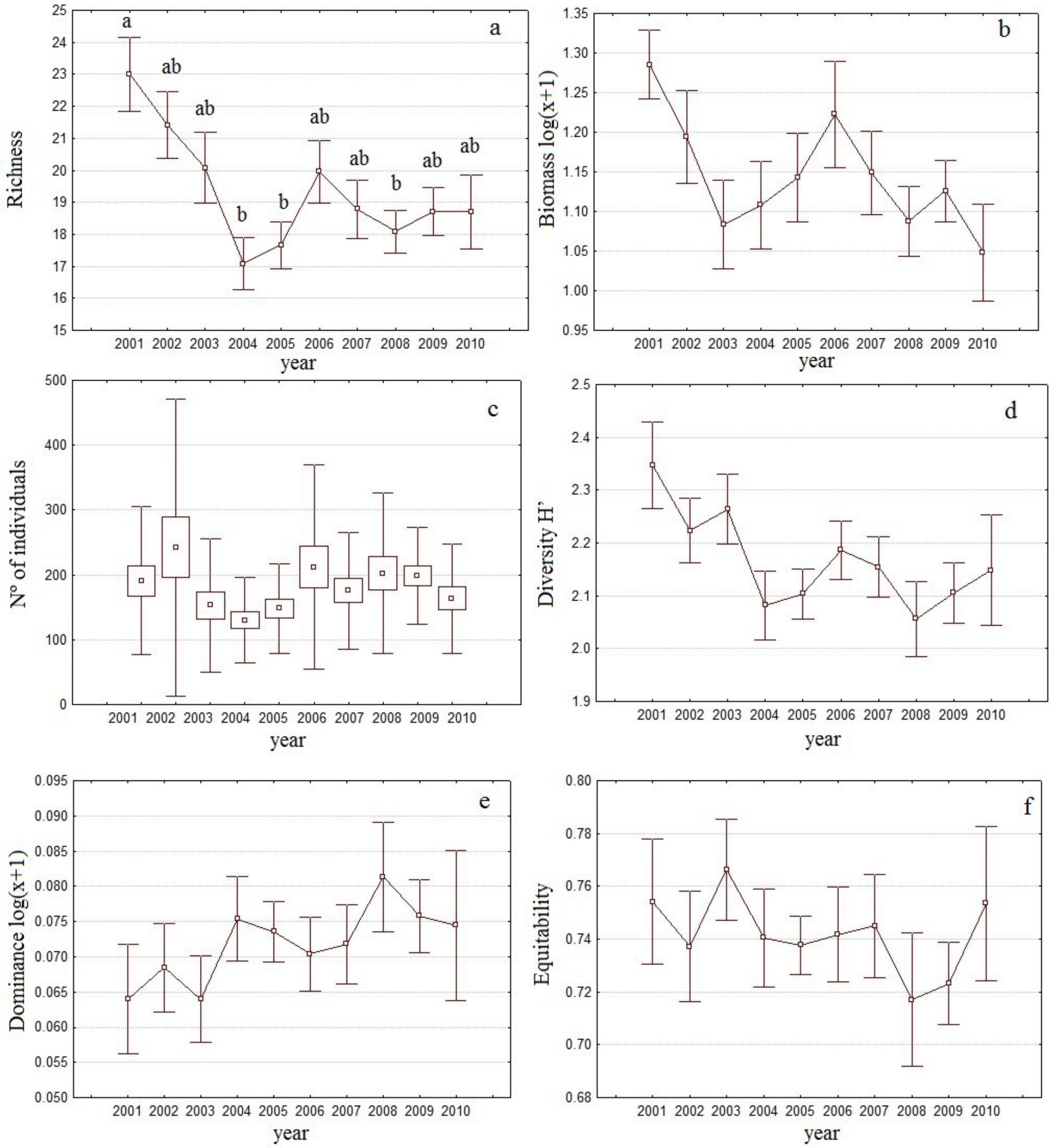

Figure 2. Statistical analysis (ANOVA with repeated measures) for (a) richness; (b) biomass log(x+1); (c) nº of individuals – using the non-parametric Anova Friedman test; (d) diversity H'; (e) dominance and (f) equitability referring to the capture of fish in the Itá reservoirs between 2001 and 2010. Distinct letters in the columns indicate a significant difference ($p<0.05$).

exception of the comparisons with the year 2001, all of the values for R remained below 0.3 (Figure 5).

A total of 19 species were responsible for explaining 80% of the similarity in all ten years of the study. The dissimilarity between the years of the first half of the period studied showed values a bit higher than the relationships between the final years (Table 3).

According to the ABC curve, although they are very close, the numeric abundance curves are above the biomass curves in all the years sampled after the formation of the

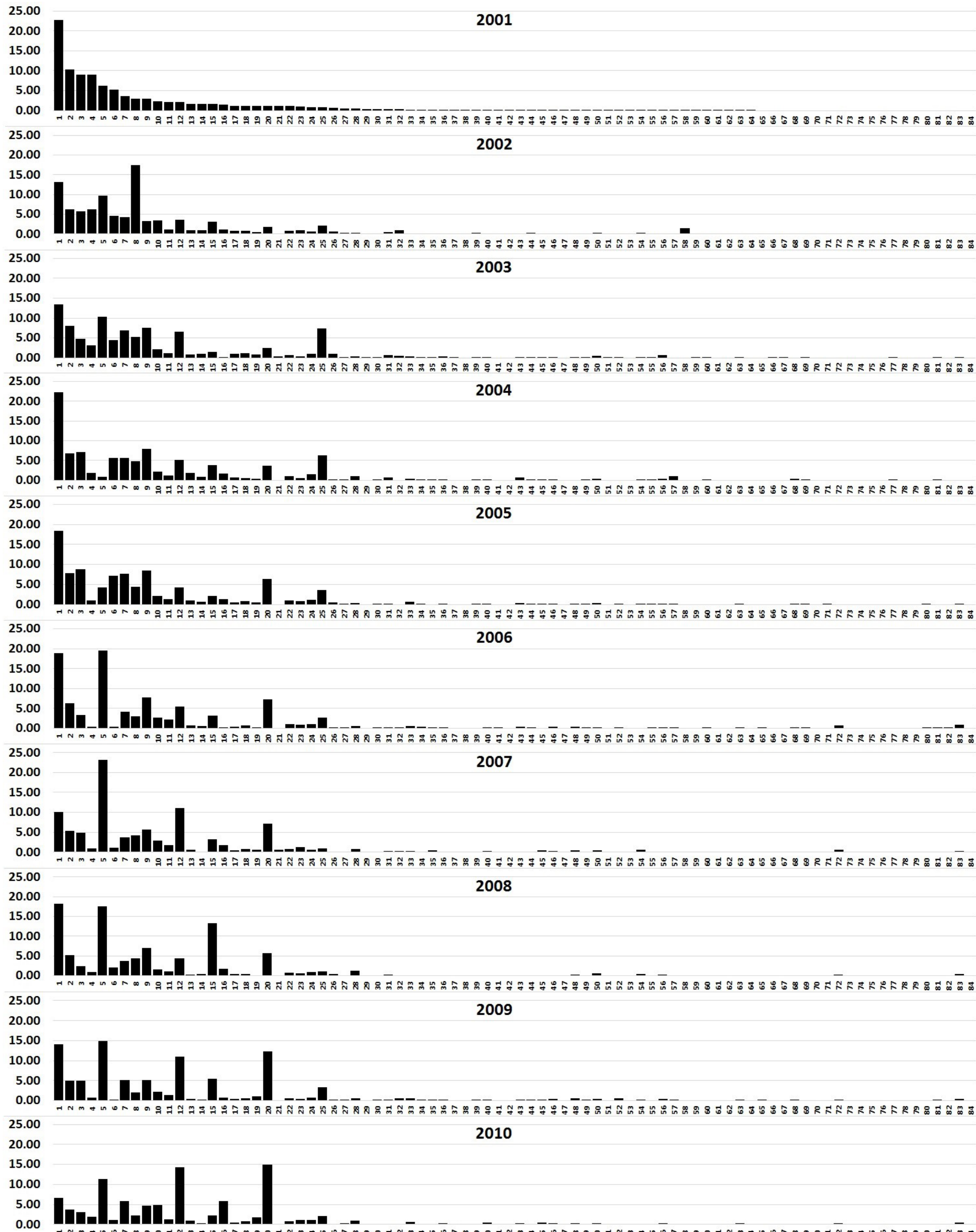

Figure 3. Representation of abundance expressed in percentage for the number of individuals of the species caught in the Itá reservoir between 2001 and 2010. The numbers on the x axis indicate the identification numbers of the species presented in Table 1.

Itá reservoir. By calculating the W statistic (Clarke, 1990), values close to zero were obtained in the entire period of the study (Figure 6).

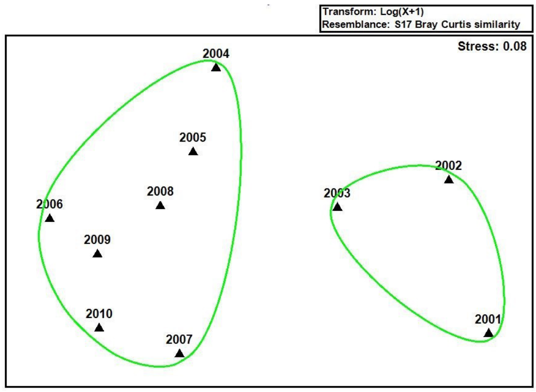

Figure 4. Analysis of ordination by the MDS method based on the data for numeric abundance of all the species caught in the Itá reservoir between 2001 and 2010. Groups delineated at the level of 84% are circled on the MDS ordination graph.

R Global = 0.116 *p*<0.01

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
2001										
2002	**0.05**									
2003	* 0.14	**0.01**								
2004	* 0.31	* 0.11	**0.06**							
2005	* 0.23	0.06	0.03	**- 0.01**						
2006	* 0.30	0.07	* 0.08	* 0.19	**0.07**					
2007	* 0.27	* 0.09	* 0.13	* 0.24	* 0.11	**- 0.01**				
2008	* 0.31	* 0.07	* 0.10	* 0.19	* 0.09	0.01	**- 0.04**			
2009	* 0.46	* 0.20	* 0.19	* 0.28	* 0.14	0.01	0.02	**0.04**		
2010	* 0.28	* 0.08	* 0.07	* 0.17	* 0.09	0.01	- 0.01	0.02	**0.01**	

Figure 5. Values for R for the comparisons between the years obtained through the analysis of similarity (ANOSIM) based on the data for numeric abundance of all the species captured in the Itá reservoir between the years 2001 and 2010. * indicates the comparisons with significant difference (p<0.01).

4. Discussion

During the entire period of the study, 84 species were found, a number that exceeds the average of 30 species reported by Agostinho et al. (2007) for 75 Brazilian reservoirs and that approaches the 98 species described previously for the Upper Uruguay River region (Zaniboni-Filho et al., 2004). The highest value of wealth found in 2001 certainly reflects the behavior normally described at the time following implantation of reservoirs, when we have the addition of new habitats and the consequent establishment of new species (Agostinho et al., 2008). The other indicators analyzed – diversity, dominance, equitability – and number of individuals and biomass did not reveal significant changes in the ichthyofauna during the years studied.

In general, there were no profound changes in the fish assemblage in the ten years after the formation of the Itá lake. The analysis of the grouping indicates a gradual change in the assemblage, which weakly distinguishes the three initial years from the others. The ANOSIM results clearly demonstrate that the changes took place in a highly tenuous manner, not leading to differences in comparisons between the subsequent years. Despite the differences found between the initial and final years, the values for R below 0.25 in the majority of the relations indicate groups that are very close over time. This tendency is accentuated in the final five years, when the dissimilarities found in the pairwise comparison become smaller, showing an ichthyofauna that is even more similar in the final period of study.

Only 19 species were responsible for explaining 80% of the similarity for all the years of study, showing that despite the high value of richness many species are rare in the environment. For this reason, in terms of this study, caution is necessary when evaluating the changes in ichthyofauna solely from the perspective of statistical analyses. In addition to observing the individual variations in the representation of the most abundant species over time, it is also necessary to pay attention to the evidently vulnerable species, such as the large migrators.

Only 22.62% of the species were classified as constant in the catches. This classification only included sedentary species or those that realize short movements for reproduction. Among them are the pintado *Pimelodus maculatus* and

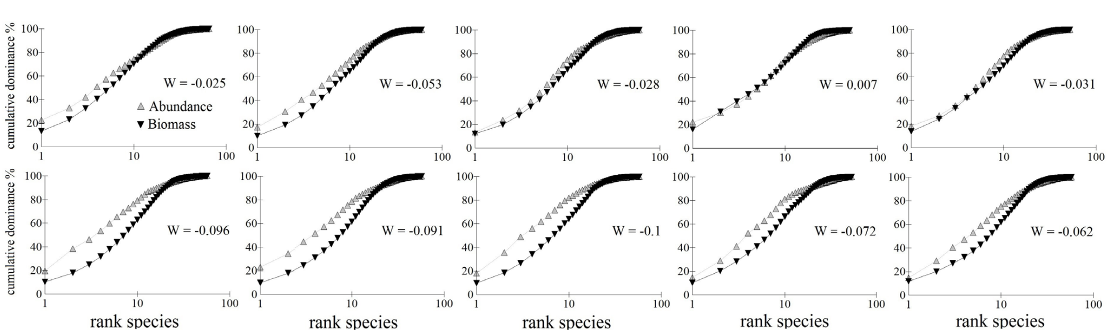

Figure 6. W Statistic and dominance curve for species "ABC plot" based on the number of individuals in the total biomass of fish caught annually at the Itá reservoir from 2001-2010.

Table 3. Analysis of similarity (SIMPER) for each year of study at the Itá reservoir. Results for species that when combined contribute, in each analysis, to more than 80% of the similarity. Values of the analysis of dissimilarity between the subsequent years presented for each relationship.

	2001	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
Average similarity %	48.25	47.94	44.42	45.98	46.9	51.39	47.96	48.61	51.48	45.41
Acestrorhynchus pantaneiro	9.13	5.06	4.65	5.22	7.45	5.12	5.11	3.72	3.94	5.35
Apareiodon affinis		2.45	4.93	3.04	5.2	4.96	4.13	2.79	10.18	6.93
Astyanax fasciatus	5.94	6.88	4.84			10.13	13.25	13.76	11.69	12.08
Astyanax scabripinnis	6.26	3.76		5.46	4.58					
Astyanax jacuhiensis	6.53	6.41	4	3.63	4.6	3.78	8.3	6.33		4.44
Galeocharax humeralis		2.98	5.87	8.51	4.54					3.59
Hemiancistrus fulginosus	2.27									
Hoplias lacerdae	3.52		3.7							
Hoplias malabaricus	2.35	2.97								
Hypostomus commersonii	2.73		2.52							
Hypostomus isbrueckeri	9.63	9.65	12.1	11.48	10.78	8.04	8.12	10.41	7.36	5.82
Iheringichthys labrosus	3.04	6.51	9.3	8.29	10.02	11.24	10.35	10.54	10.58	8.39
Loricariichthys anus		3.46		5.38	6.29	5.58	7.17	7.3	9.15	6.95
Oligosarcus jenynsii	5.33	5.35	4.53	3.14		3.57			4.96	6.34
Parapimelodus valenciennis							3.94	4		
Pimelodus maculatus	5.99	2.96	3.34		3.99	5.4	5.72	3.77	4.11	
Rhamdia quelen	4.84									
Schizodon nasutus	6.53	9.58	8.41	12.17	10.92	10.12	8.4	10.05	9.73	10.83
Steindachnerina brevipinna	7.45	12.64	12.24	14.97	12.37	14.14	8.55	9.91	8.9	9.76
Average dissimilarity %	2001 vs 2002	2002 vs 2003	2003 vs 2004	2004 vs 2005	2005 vs 2006	2006 vs 2007	2007 vs 2008	2008 vs 2009	2009 vs 2010	
	52.85	54.04	55.84	53.18	52	50.33	51.01	50.5	51.54	

the jundiá *Rhamdia quelen*, two species that are important in regional fishing (Schork et al., 2013) and that appear to be efficiently completing their lateral reproductive migrations, using tributary rivers to spawn (Zaniboni-Filho and Schulz, 2003).

According to Lemes and Garutti (2002), the constancy of occurrence reflects the biological ability that the species has in exploring the environmental resources available at a given time in the biotope. In this study, it was clear that one of these abilities is to be able to efficiently use the environments provided by the reservoir for reproduction. Fish that conduct long reproductive migrations require a greater number of habitats to complete their life cycle, and for this reason, the dams are obstacles that impede access to certain areas and strongly affect the abundance of their populations (Agostinho et al., 2007).

This is exemplified by the reduced numeric abundance observed of dourado *S. brasiliensis* and *L. obtusidens*. Only seven individuals of dourado were captured in the year immediately after the closing of the reservoir, and the species was even more scarce in the catches in the following years, while the piava was only present in catches up to 2007. Meanwhile, the piracanjuba *B. orbignyanus* was only captured after 2006. Present in the List of Brazilian Fauna Threatened with Extinction, and with its absence reported in the region for approximately twenty-five years (Bertoletti and Lucena, 1989; Beux and Zaniboni-Filho, 2008), this species was the target of an experimental release in 2004. In this year, approximately 3,000 juveniles were released by the staff of the Laboratory of Biology and Cultivation of Fresh Water Fish of the Federal University at Santa Catarina (LAPAD/UFSC), which was possibly related to the catches in this study and raises for discussion the use of stocking techniques as mitigatory and or compensatory measures in the installation of reservoirs.

In turn, the curimba *P. lineatus* stands out as a large migrator with the most expressive catches over the ten years of the study. Although classified as accidental and also vulnerable to the limitations caused by the loss of connectivity of the pristine fluvial environment, the species appears to be able to find minimal conditions to complete its life cycle within the reservoir. For the four species of large migrators caught, in addition to the conditions imposed by the dam, the pressure caused by fishing also appears to be a factor that strongly affects the abundance of their populations (Schork et al., 2013) and should also be considered.

In contrast with the low representation of the large migrators found here, the Itá reservoir had a dominance of small and medium size fish species, classified as sedentary or short-distance migrators, represented above all by birús, lambaris, canivetes, and cascudos. This result concurs with the trend normally found in reservoirs, where species that have less needs to complete their lifecycle are more capable of maintaining their populations, and for this reason, come to dominate the fish assemblage over time (Berkamp et al., 2000). In the same sense, in a study encompassing 75 Brazilian reservoirs, Agostinho et al. (2007) observed that only 5% of the reservoirs studied had more than three migratory species among the most abundant fish.

According to Fernando and Holcik (1991), the ichthyofauna that colonizes a reservoir is determined by the existence of species pre-adapted to the lacustrine way of life in the rivers that form the reservoir. This pattern is also observed in the formation of the Itá reservoir, where species already related to the Upper Uruguay River region (Zaniboni-Filho et al., 2008; Zaniboni-Filho et al., 2004; Bertoletti and Lucena, 1989; Godoy, 1987) that have opportunist characteristics were those that had greater success in approval of the new habitats created.

Among them, the most representative was the *S. brevipinna*, a species typical to the Upper Uruguay River (Zaniboni-Filho and Schulz, 2003) and that was already abundant in the region even before construction of the Itá hydroelectric power plant (Zaniboni-Filho et al., 2008). With efficient reproductive strategies and high alimentary plasticity (Hirt et al., 2011; Vidotto-Magnoni and Carvalho, 2009; Teixeira and Bennemann, 2007; Santos et al., 2004; Luz-Agostinho et al., 2006; Masdeu et al., 2011) *A. fasciatus*, *A. affinis* and *I. labrosus* were also abundant in the Itá reservoir, demonstrating good adaptability to the new environments formed.

From a reproductive perspective, the dominance of species with external fertilization, rapid development and that conduct short or no migratory movements was in keeping with the work of Reynalte-Tataje et al. (2008b) in the Itá reservoir. Other efficient reproductive tactics in the environment studied include the production of numerous small eggs, and low time required for embryogenesis and eclosion, as observed in the representative species of the genre *Astyanax* and *Apareidon* (Reynalte-Tataje et al. 2008a).

With different strategies, two species of cascudos stand out, *L. anus* and *H. isbrueckeri*. Although they have more complex reproductive tactics, like the production of large and adhesive eggs and parental care (Vazzoler, 1996), these species are among those most caught in the reservoir. For *L. anus*, the omnivorous iliophagous diet (Albrecht and Silveira, 2001) and a preference for muddy bottoms found in the new lentic environments must have favored its growing relative participation over the years. In addition, *L. anus* has a distinct type of parental care – carrying eggs in buccal structures – a strategy reported to be efficient for facing the variations in limnological conditions and the level of water in the reservoir (Moodie and Power, 1982), thus avoiding the competition for locations for construction of nests and the eventual exposure of eggs to the air.

A recurring pattern in various reservoirs, the increased population of forager species also leads to the development of piscivore species (Agostinho et al., 2007; Novakowski et al., 2007; Loureiro-Crippa and Hahn, 2006). This fact was previously reported by Zaniboni-Filho et al. (2008) for *Galeocharax humeralis, H. malabaricus* and mainly for *A. pantaneiro*, all of which increased in their relative participation in the catch after formation of the Itá lake. This study also found an importance of piscivore fish, with

H. malabaricus and *A. pantaneiro* combined, the second and third largest catches respectively in terms of biomass. The capacity of both to adapt their feeding according to the most abundant prey in the reservoirs (Cantanhede et al., 2008; Pompeu and Godinho, 2001; Novakowski et al., 2007), certainly favored the maintenance of these species under different conditions. Added to the adaptive qualities of the *A. pantaneiro*, portioned spawning with relatively high fertilization and an absence of parental care (Meurer and Zaniboni-Filho, 2012).

Another process strongly influenced by the formation of reservoirs and that deserves attention in the study of the Itá UHE is the development of aquatic macrophytes (Thomaz et al., 1999; Pelicice et al., 2008; Hermes-Silva and Zaniboni-Filho, 2012). Among the main effects of the presence of macrophytes is the supply of abundant food for herbivorous species, such as *S. nasutus* (Andrade and Braga, 2005), a fish that totaled the highest biomass captured. The species success in colonization of the reservoir should also be related to other ecological adaptations, such as portioned spawning and the absence of parental care (Reynalte-Tataje and Zaniboni-Filho, 2008; Vazzoler and Menezes, 1992).

In relation to the piranhas, contrary to that reported by traditional fishermen, who perceived an increased abundance of piranhas after the formation of the Itá reservoir (Schork et al., 2013), the relative participation in the number of *S. maculatus* and *P. nattereri* remained constant over the ten years of the study. It is possible that this difference is related to the different selectivity of the fishing gear and different locations used by the artisanal fishermen.

The k-dominance curves of the numeric abundance and biomass, corroborated by the W values, indicate a fish community that was moderately disturbed during the period of study. The proximity of the curves demonstrate the representation of the small and medium species not only numerically, but also in terms of biomass, and point to a discrete imbalance of the environment. This reflection of an ichthyofauna dominated by opportunist species, in which small characids, curimatids, and loricariids alternate as the most representative, with low abundance of large migratory species.

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