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INFLUENCE OF SPATIAL GRADIENT CAUSED BY A LARGE DAM ON FISH ASSEMBLAGE IN A SUBTROPICAL RESERVOIR – UPPER URUGUAY RIVER*

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ABSTRACT

The objective of this work was to evaluate the influence of different environments formed in the area of influence of a reservoir - lentic, transition and lotic - on the composition and structure of the fish fauna. For this, collections were made with seasonal periodicity in the Itá reservoir, Upper Uruguay River, from 2001 to 2010. The results showed that the spatial gradient plays an important role in the fish assemblage structure. The lotic stretch was the place with the largest values of CPUE, both in number and biomass. As well, species with dependence on certain original fluvial conditions managed to maintain their presence in this stretch. In the lotic area, catching fish that are considered large migratory species coincided with their reproductive periods. The transition stretch presented an intermediate productivity and shared species with the two adjacent sections. However, it had greater similarity with the lentic area. The lentic and transition zones presented the more profound changes, showing an increase of opportunistic species. Within the context of a system of reservoirs in cascade, this study points out the free stretches flowing into the Itá reservoir as being priority areas for the conservation of the Upper Uruguay River region.

Key words: reservoirs; lentic stretches; lotic stretches; fish fauna; spatial distribution.

INFLUÊNCIA DO GRADIENTE ESPACIAL SOBRE A ESTRURURA DA ICTIOFAUNA EM UM RESERVATÓRIO SUBTROPICAL – ALTO RIO URUGUAI

RESUMO

O objetivo deste trabalho foi avaliar a influência dos diferentes ambientes formados na área de influência de um reservatório – lêntico, transição e lótico – sobre a composição e estrutura da ictiofauna. Para isto, foram realizadas coletas com periodicidade sazonal no reservatório de Itá, Alto Rio Uruguai, no período compreendido entre 2001 e 2010. Os resultados demonstraram que o gradiente espacial desempenha importante papel para determinar a estrutura da assembleia íctica. O trecho lótico foi o local com os maiores valores de CPUE, tanto em número como em biomassa. Além disso, espécies presentes antes do barramento e com dependência de certas condições originalmente encontradas no ambiente fluvial conseguiram manter suas representatividades neste ambiente. Nestes trechos, as capturas de peixes considerados grandes migradores foram coincidentes com seus períodos reprodutivos. O trecho também foi caracterizado por uma maior instabilidade, com capturas que não responderam de forma clara a padrões sazonais. O trecho de transição apresentou a segunda maior produtividade e compartilhou espécies com os dois trechos adjacentes, porém, teve maior similaridade com a zona lêntica. Nas zonas lênticas e de transição as espécies oportunistas se fizeram mais presentes. Para estes dois trechos, pôde-se associar as variações nas capturas a padrões sazonais.

Palavras-chave: reservatório; trechos lêntico; trechos lóticos; ictiofauna; distribuição espacial.

INTRODUCTION

The construction of dams for the generation of hydroelectric power on the main channel of a river causes the loss of its connectivity and affects the entire ecosystem, causing changes in their physical, chemical and biological attributes (BERKAMP *et al*., 2000). According to KIMMEL *et al*. (1990), this interruption of the natural flow leads to a consequent transformation of the longitudinal axis of the river in three distinct zones: fluvial, transitional and lacustrine. The fluvial zone is classified as a lotic system, with relatively high chain speed, normally presenting a large quantity of suspended materials, low penetration of light, and a high availability of nutrients, with a source of mainly allochthonous organic matter. The transition zone is characterized by a decrease in water flow, smaller quantities of suspended solids, and good penetration of light, usually with high primary productivity. Finally, the lacustrine zone is an environment typically lentic, with elevated water residence time, greater depth and greater light penetration. It has low concentrations of dissolved nutrients, mainly autochthonous organic matters and is usually considered as oligotrophic (KIMMEL *et al*., 1990; JORGENSEN *et al*., 2013).

Responding to these particularities, the limitations of each species facing the abiotic characteristics found in the different environments added to the result of complex ecological interspecific relationships, determining spatial and temporal patterns of biodiversity (WARD *et al*., 1999). For fish species, the spatial gradient formed by reservoirs located in Neotropical regions it is an important attribute to be considered in studying the assemblage structure (OLIVEIRA *et al*., 2004; OLIVEIRA *et al*., 2005; AGOSTINHO *et al*., 2007; TERRA *et al*., 2010). The tendency in new environments created by the reservoir, the proliferation of opportunistic species (AGOSTINHO *et al*., 2016; SCHORK and ZANIBONI-FILHO, 2017), especially in areas with lacustrine characteristics, is the result of a combination of the use of food and efficient reproductive strategies. On the other hand, fish species with a more complex and dependent life cycle on certain fluvial characteristics are especially affected (ZANIBONI-FILHO and SCHULZ, 2003).

Within this context, this work evaluated the role of spatial gradient found in the reservoir of the Itá Hydroelectric Power Plant, located in Upper Uruguay River, on the composition and structure of the fish fauna. For this purpose, we compared the productivity and also the distribution of the species of fish in each stretch of the reservoir over ten years of study. Finally, on the basis of the results and knowing the peculiarities of the region of study, the definition of priority areas for conservation was proposed.

METHODS

Within the Brazilian context of electric power generation, the Basin of the Upper Uruguay River has been the target of increasing entrepreneurship of hydroelectric enterprises. Located in the south of the country, its main watercourse, the Uruguay River, is formed by the confluence of the Pelotas and the Peixe Rivers (SDM, 1997). With a total length of 2,200 km, the initial portion of the river runs on a typically rough terrain with rapids on a seated channel. In this way, unlike other rivers of the Prata Basin, the region is marked by the absence of floodplains and marginal lakes, as well as not very extensive tributaries. Currently, five large plants are operating in the region, forming a cascade system: Foz do Chapecó (885 MW), Itá (1315 MW), Machadinho (1060 MW), Barra Grande (690 MW) e Campos Novos (880 MW).

The Itá Hydroelectric Power Plant is located in the upper portion of the Uruguay River, a stretch that divides the States of Santa Catarina and Rio Grande do Sul, between the municipalities of Itá (SC) and Aratiba (RS) (Figure 1). The reservoir formed by the dam has a total area of 141 km^2, an approximate perimeter of 800 km and an average depth of 36 m. Its maximum depth is 125 m. The total length of the stretch between the area of the Itá dam and the Machadinho dam is 140 km, divided into three environments: lentic with 112 km, transition with 18 km and lotic with a 10 km. Flowing into this environment, Ligeiro River becomes an important addition to the lotic stretch, because of its large free stretches. Among the main tributaries, the Peixe River also stands out, being characterized by free short stretches that meet the transitional zone.

The data was obtained in the Itá reservoir through samples made with seasonal periodicity starting in January 2001 and ending in December 2010. In total, 240 collected samples were performed in the four seasons during 10 years in six sampling points distributed equally between the different environments formed by the reservoir: lentic (IBQ and IBR), transition (IPX and MPMR) and lotic (ML and MPT).

The fishing equipment used for the collections were gillnets with meshes of 1.5; 2.0; 2.5 and 3.0 cm between adjacent nodes - 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 (crossing nets). In addition, trammel nets with 3.0 to 5.0 cm gaps, 1.8 m tall, and 15 to 40 m long were used. All of the nets were always placed at dusk and collected at dawn, remaining in the environment for approximately 12 hours. The same procedure was used for a long-line (with 100 hooks). At each point, always during the day, three casts were also performed 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). The catches made by crossing nets, seine nets, throws nets and long-lines were used only in the qualitative approach to determine richness (number of species), minimum and maximum size, the exclusive species of each stretch and the presence of migratory fish.

After being caught, specimens were identified to determine species levels, according to a taxonomic key. Measurements of total weight (g) and total length (cm) were taken in the field. Specimens were then fixed in a solution of 10% formalin and subsequently kept in containers with 70% ethanol. Those samples that could not be identified in the field were transported to the Ichthyology Laboratory of the State University of Londrina (UEL), or the Museum of Sciences and Technology of the Pontifical Catholic University of Rio Grande do Sul (PUCRS), where they were later identified.

The structure of fish assemblages was evaluated through the catch-per-unit-effort (CPUE), calculated on the basis of the number of individuals (CPUEn) and biomass (CPUEb) (kg) captured in 100 square meters of net during twelve hours of exposure. For the analysis of diversity Shannon-Wiener index (KREBS, 1998), evenness (PIELOU, 1966) and dominance (SIMPSON, 1949) was used the CPUEn. The spatial variation of CPUE was assessed using a single factor analysis of variance (ANOVA) and applying *a posteriori* Tukey test for a comparison of averages.

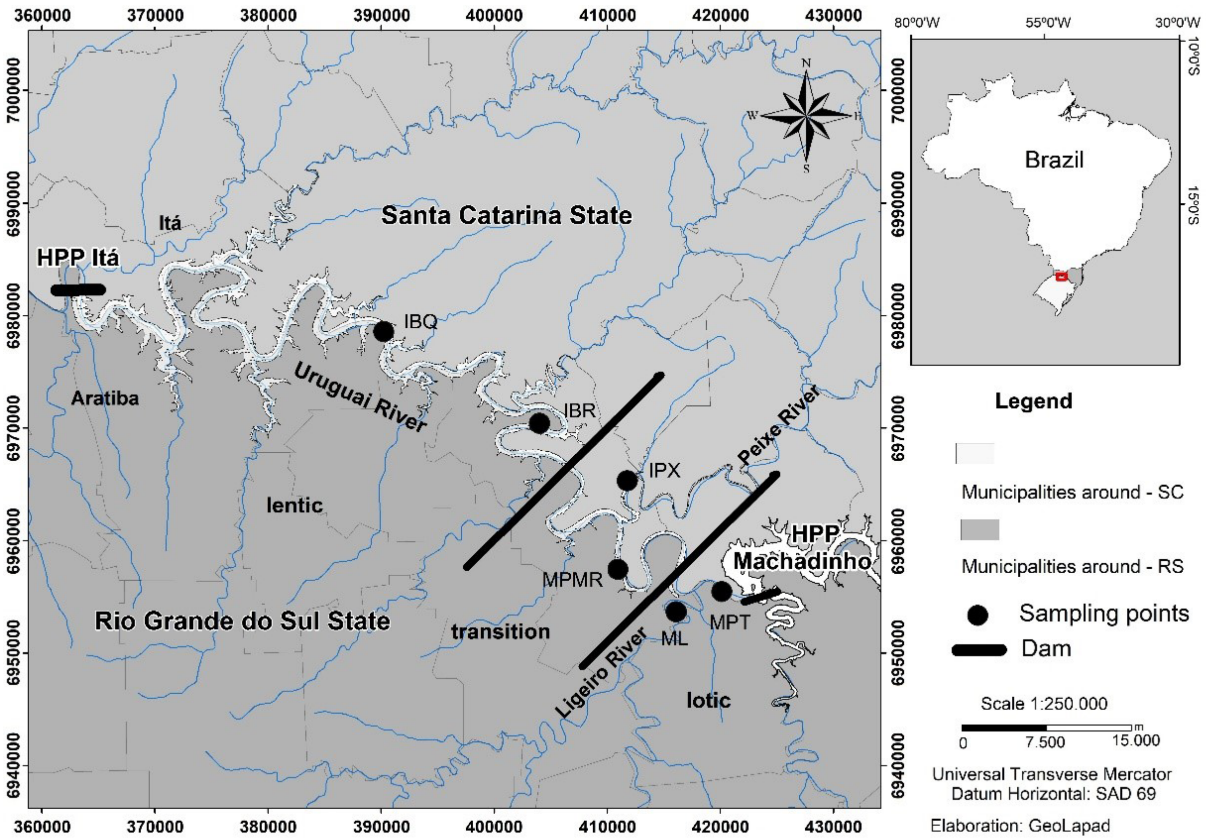

Figure 1. The location of sampling points distributed in different environments: lentic (IBQ and IBR), transition (IPX and MPMR) and lotic (ML and MPT) in the Itá Hydroelectric Power Plant (HPP) on the Uruguay River between the states of Santa Catarina and Rio Grande do Sul.

The data of CPUE was transformed by $\log_{10}(x+1)$ to achieve the assumptions of ANOVA. For the data that still did not meet the assumptions of normality (Shapiro-Wilk test) and homoscedasticity (Levene's test), a non-parametric Kruskal-Wallis test was used.

With the objective of checking spatial variations in the composition and the numerical abundance of the fish assemblage, both a grouping analysis (Cluster) and a technique of N-MDS ordination (non-metric) for verification and consolidation of the obtained results (CLARKE and WARWICK, 2001) were used. According to the second consideration of these same authors, to calculate the Bray-Curtis similarity index, CPUEn values were transformed by $\log_{10}(x+1)$ to approximate the contribution of the rare species with those which were very abundant in the samplings.

The non-parametric multivariate analysis of variance (PERMANOVA) (ANDERSON, 2001) was applied to test the null hypothesis that there are no differences in the assemblages between different environments, different years and interaction between them for significant levels of $p<0.05$ in 9999 permutations. Executed through the PAST 3.18 beta (HAMMER *et al*., 2001).

Aiming to determine the individual contribution of each species for the similarity found in each environment (lotic, lentic and transition), CPUEn data were used to analysis of similarity of percentages (SIMPER) using Primer Software 6 (CLARKE and GORLEY, 2001) was carried out. To indicate the species with consistent contributions over the years, the cutting line was made at 50%.

RESULTS

All three studied environments in the reservoir of the Itá Hydroelecric Power Plant were represented in more than 96% of the catches for the same orders, Characiformes, and Siluriformes. They also shared the representativeness of the same families, Characidae, Curimatidae, and Pimelodidae, which totaled approximately 80% of the catch in each section. The species *Steindachnerina brevipinna*, *Astyanax fasciatus*, *Loricariichthys anus* and *Acestrorhynchus pantaneiro* were among the most captured, contributing up to 50% of the CPUEn, in the lentic and transition stretches. *Astyanax scabripinnis* was also part of the group in the lentic stretch. In the lotic stretch, in decreasing order, the most representative were *A. fasciatus*, *Iheringichthys labrosus*, *Hypostomus isbrueckeri*, *Astyanax jacuhiensis* and *S. brevipinna*.

Comparing the data of catches between environments, the lentic stretch presented the lowest values of CPUEn, differing significantly from the others ($F_{2,24} = 7.99$ $p<0.001$). In relation to the CPUEb values, all of the stretches were different among themselves, with increasing values from the lentic to the lotic stretches (Table 1). For the values of diversity, evenness and dominance there was no significant difference between the environments.

Within the qualitative approach, the number of species found in the different sections was very close: lentic with seventy species and transition and lotic with sixty-nine species. Moreover, fifty - five species were present in all of the stretches (Table 2). The largest amount of exclusive species was observed in the lotic [*Charax leticiae* (LUCENA, 1987), *Crenicichla tendybaguassu* (LUCENA and KULLANDER, 1992), *Gymnotus* sp, *Hypostomus ternetzi* (BOULENGER, 1895), *Leporinus macrocephalus* (GARAVELLO and BRITSKI, 1988), *Trachelyopterus ceratophysus* (KNER, 1858) and *Pseudopimelodus mangurus* (VALENCIENNES, 1835)], followed by the lentic [*Gymnogeophagus rhabdotus* (HENSEL, 1870), *Phalloceros caudimaculatus* (HENSEL, 1868), *Piaractus mesopotamicus* (HOLMBERG, 1887), *Sorubim lima* (BLOCH and SCHNEIDER, 1801) and *Synbranchus marmoratus* (BLOCH, 1795)] and the transition [*Ctenopharingodon idella* (VALENCIENNES, 1844), *Corydoras paleatus* (JENYNS, 1842), *Cyphocharax* sp and *Roeboides* sp.]. In each stretch, the sum of all unique species represented less than 0.2% of the catches. At the end of ten years of study, the fall in the values of richness was higher in the transition stretch (Figure 2).

For the fish considered as large migratory species, from all of the fishing equipment used for sampling, catches were distributed in a distinct manner between the studied environments. The piracanjuba *Brycon orbignyanus* (VALENCIENNES, 1850) catches were concentrated in the lotic stretch, totaling nine individuals. The piava *Leporinus obtusidens* (VALENCIENNES, 1837), present in all of the three environments, had the largest catches in the transition stretch. With the largest catches among the large migratory species (87 individuals), the curimba *Prochilodus lineatus* (VALENCIENNES, 1837) distributed itself in order of representativeness throughout the lentic, lotic and transition stretches. The dourado *Salminus brasiliensis* (CUVIER, 1816) showed similar catches in different environments. Of the aforementioned catches, with the exception of a single event, all catches in the lotic stretch occurred during the spring and summer.

The grouping analysis based on CPUEn data for each species showed the formation of groups according to each environment studied. The transition stretches appeared to be closer to the lentic. The same result is demonstrated in the two-dimensional plotting of N-MDS, in which the value of stress of 0.12 indicates graphic distances in two dimensions with a good representation of similarities (Figure 3).

The PERMANOVA bi-factorial result showed no significant interaction between the years and the studied environments ($F_{2.23} = 0.85$, $p = 0.86$), but indicated significant differences between the years ($F_{1.44} = 1.89$, $p = 0.02$) and between the environments ($F_{2.54} = 8.76$, $p = 0.0001$).

According to the analysis of similarity of percentages (SIMPER), a higher dissimilarity (51.18%) was observed between the lentic and lotic stretches (Table 3). *S. brevipinna* and *A. fasciatus* were the main species that contributed to the similarity of the lentic habitat. For the transition environment, *A. pantaneiro* and, again, *S. brevipinna* stood out. *L. anus* was also important for the two environments cited. In the lotic stretch, *H. isbrueckeri* and *I. labrosus* were mainly important to contribute to the similarity.

Table 1. Statistical analysis (ANOVA) for the CPUE number of individuals (CPUEn), CPUE biomass (CPUEb) (kg), diversity, evenness and dominance in 100m^2 of net in 12h of exposure for each of the environments of study (lentic, transition and lotic) in the Itá reservoir from 2001 to 2010.

	CPUE n	CPUE b	Richnes	Evennes	Diversity	Dominance
Lentic	22.75^{a}	2.41^{a}	70 ^{a}	0.68 ^{a}	4.05 ^{a}	0.09 ^{a}
Transition	47.22^{b}	5.01^{b}	69 ^{a}	0.67 ^{a}	3.96 ^{a}	0.10 ^{a}
Lotic	78.34^{b}	7.70^{c}	69 ^{a}	0.70 ^{a}	4.19 ^{a}	0.08 ^{a}

Different letters in columns indicate significant difference ($p<0.05$).

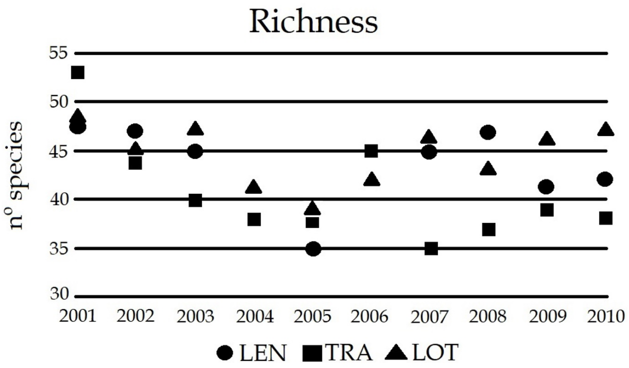

Figure 2. Number of species captured for each environment (LEN: lentic, TRA: transition, LOT: lotic), all of the fishing equipment included, from 2001 to 2010.

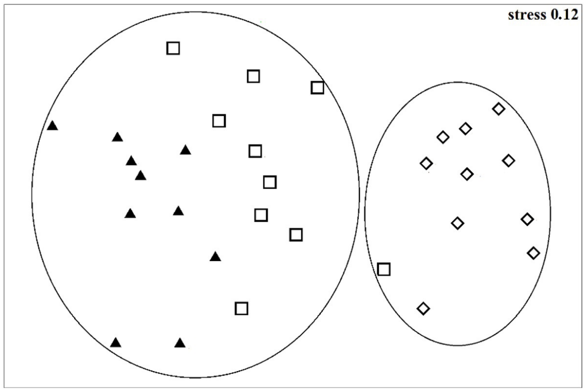

Figure 3. Analysis of ordination by the N-MDS method based on the CPUEn data of all species caught. Groups outlined in the level of 64% are surrounded in the N-MDS ordination graph (▲lentic, □ transition, ◊ lotic).

Table 2. Scientific name, abundance and sizes (mm) minimum and maximum for each environment (LEN: lentic, TRA: transition, LOT: lotic) catches in the Itá reservoir from 2001 to 2010.

	Lentic			Transition			Lotic		
		Size (mm)			Size (mm)			Size (mm)	
Scientific name	n	Min.	Max.	n	Min.	Max.	n	Min.	Max.
ATHERINIFORMES									
Atherinopsidae									
Odontesthes perugiae Evermann & Kendall 1906	37	37	202	26	38	193	31	143	206
CHARACIFORMES									
Acestrorhynchidae									
Acestrorhynchus pantaneiro Menezes 1992	1042	52	330	1076	47	379	319	122	335
Anostomidae									
Leporinus amae Godoy 1980	1	150	150	2	128	130	42	113	183
Leporinus macrocephalus Garavello & Britski 1988							1	255	255
Leporinus obtusidens (Valenciennes 1837)	4	473	730	13	140	710	5	430	690
Leporinus striatus Kner 1858	1	120	120	1	88	88			
Schizodon nasutus Kner 1858	597	65	402	718	45	395	870	100	386
Bryconidae									
Brycon orbignyanus (Valenciennes 1850)	1	585	585				9	235	440
Salminus brasiliensis (Cuvier 1816)	6	560	745	4	585	740	4	530	750
Characidae									
Astyanax eigenmanniorum (Cope 1894)	5	33	148	11	85	140	20	87	152
Astyanax fasciatus (Cuvier 1819)	2596	19	223	1374	17	230	1461	28	212
Astyanax scabripinnis (Jenyns 1842)	650	9	173	421	32	183	355	28	263
Astyanax jacuhiensis (Cope 1894)	553	36	166	564	25	221	1380	67	187
Astyanax sp 3	67	107	134	20	119	152	1		
Bryconamericus iheringii (Boulenger 1887)	289	20	100	312	10	72	79	17	85
Bryconamericus stramineus Eigenmann 1908	356	21	75	437	13	70	527	21	71
Charax leticiae Lucena 1987							1	115	115
Cynopotamus kincaidi (Schultz 1950)	5	190	260	20	122	225	66	150	300
Galeocharax humeralis (Valenciennes 1834)	196	100	290	398	100	360	656	22	309
Oligosarcus brevioris Menezes 1987	1	203	203	1	233	233	14	135	250
Oligosarcus jenynsii (Günther 1864)	217	62	293	256	50	287	714	84	360
Roeboides sp.				2	126	300			
Crenuchidae									
Characidium zebra Eigenmann 1909	11	42	67	5	53	61			
Curimatidae									
Cyphocharax sp				4	115	156			
Steindachnerina biornata (Braga & Azpelicueta 1987)	17	45	124	81	46	157	16	95	203
Steindachnerina brevipinna (Eigenmann & Eigenmann 1889)	2859	12	153	3000	50	215	1270	77	228
Erythrinidae									
Hoplias lacerdae Miranda Ribeiro 1908	54	247	605	62	182	540	179	167	710
Hoplias malabaricus (Bloch 1794)	185	202	650	85	147	532	147	235	630
Paradontidae									
Apareiodon affinis (Steindachner 1879)	1682	20	174	810	25	192	399	90	180
Prochilodontidae									
Prochilodus lineatus (Valenciennes 1837)	43	263	703	14	292	720	33	337	750
Serrasalmidae									
Piaractus mesopotamicus (Holmberg 1887)	1	485	485						

Table 2. Continued...

	Lentic			Transition			Lotic		
		Size (mm)			Size (mm)			Size (mm)	
Pygocentrus nattereri Kner 1858	53	73	280	44	110	275	6	121	320
Serrasalmus maculatus Kner 1858	226	60	422	104	47	280	77	115	322
CYPRINIFORMES									
Cyprinidae									
Ctenopharyngodon idella (Valenciennes 1844)				2	600	750			
Cyprinus carpio Linnaeus 1758	16	157	660	23	160	840	23	222	838
CYPRINODONTIFORMES									
Poeciliidae									
Phalloceros caudimaculatus (Hensel 1868)	1	25	25						
GYMNOTIFORMES									
Gymnotidae									
Gymnotus carapo Linnaeus 1758	40	262	750	15	158	730	18	355	895
Gymnotus sp							2	480	545
Sternopygidae									
Eigenmannia virescens (Valenciennes 1836)	51	160	347	39	140	315	55	158	346
PERCIFORMES									
Cichlidae									
Crenicichla celidochilus Casciotta 1987	34	120	180	1	192	192	6	123	271
Crenicichla igara Lucena & Kullander 1992	9	135	260				13	105	392
Crenicichla jurubi Lucena & Kullander 1992	42	101	187	2	162	217	8	135	347
Crenicichla minuano Lucena & Kullander 1992	39	43	201				3	225	270
Crenicichla missioneira Lucena & Kullander 1992	46	93	249	9	93	251	14	135	306
Crenicichla tendybaguassu Lucena & Kullander 1992							1	133	133
Crenicichla vittata Heckel 1840	86	60	276	55	67	265	30	102	315
Geophagus brasiliensis (Quoy & Gaimard 1824)	91	15	190	243	19	145	22	38	180
Gymnogeophagus gymnogenys (Hensel 1870)	122	10	122	4	18	78	1	51	51
Gymnogeophagus rhabdotus (Hensel 1870)	8	27	113						
Oreochromis niloticus (Linnaeus 1758)	5	18	84	48	22	212			
Sciaenidae									
Pachyurus bonariensis Steindachner 1879	10	143	198	1	177	177	2	192	207
SILURIFORMES									
Auchenipteridae									
Auchenipterus sp.	8	139	240	13	130	240	9	182	244
Trachelyopterus ceratophysus (Kner 1858)							1	165	165
Trachelyopterus galeatus (Linnaeus 1766)	136	73	296	106	114	202	84	98	282
Trachelyopterus teaguei (Devincenzi 1942)	2	124	164	15	115	175	13	105	175
Callichthyidae									
Corydoras paleatus (Jenyns 1842)				1	50	50			
Cetopsidae									
Cetopsis gobioides Kner 1858				4	107	126	2	118	122
Heptapteridae									
Rhamdella longiuscula Lucena & da Silva 1991	5	96	245	6	97	127	6	105	200
Rhamdia quelen (Quoy & Gaimard 1824)	63	146	443	117	148	485	172	87	550
Loricariidae									
Ancistrus sp.	1	118	118	4	78	97			
Ancistrus taunayi Miranda Ribeiro 1918				2	105	140	1	109	109
Pogonoma obscurum Quevedo & Reis 2002	18	190	354	36	163	343	228	204	381
Hemiancistrus fuliginosus Cardoso & Malabarba 1999	16	96	200	26	85	180	264	66	240

Table 2. Continued...

	Lentic			Transition			Lotic		
		Size (mm)			Size (mm)			Size (mm)	
Hypostomus commersoni Valenciennes 1836	98	137	380	167	114	430	115	120	470
Hypostomus isbrueckeri Reis, Weber & Malabarba 1990	725	75	335	656	73	278	1560	30	340
Hypostomus luteus (Godoy 1980)	7	184	285	17	82	302	88	145	520
Hypostomus regani (Ihering 1905)	4	278	335	4	38	350	72	130	440
Hypostomus roseopunctatus Reis, Weber & Malabarba 1990	16	183	315	15	153	363	46	132	420
Hypostomus ternetzi (Boulenger 1895)							4	151	186
Hypostomus uruguayensis Reis, Weber & Malabarba 1990	4	235	332	1	245	245	1	298	298
Loricariichthys anus (Valenciennes 1835)	1136	93	403	1410	105	396	99	182	391
Loricariichthys sp.m	47	195	401	59	93	362			
Paraloricaria vetula (Valenciennes 1835)	12	170	658	40	190	695	12	265	495
Rineloricaria sp.	13	175	333	16	220	362	6	275	393
Pimelodidae									
Iheringichthys labrosus (Lütken 1874)	464	105	339	698	99	330	1436	93	660
Parapimelodus valenciennis (Lütken 1874)	482	12	187	376	75	210	921	75	230
Pimelodella laticeps Eigenmann, 1917				1	128	128	3	170	174
Pimelodus absconditus Azpelicueta 1995	45	122	275	41	143	297	94	116	270
Pimelodus atrobrunneus Vidal & Lucena 1999	44	120	270	28	140	227	78	123	262
Pimelodus maculatus Lacepède 1803	219	133	530	212	138	543	237	130	550
Sorubim lima (Bloch & Schneider 1801)	1	542	542						
Steindachneridion scriptum (Miranda Ribeiro 1918)	4	452	700	7	422	690	85	232	800
Pseudopimelodidae									
Pseudopimelodus mangurus (Valenciennes 1835)							1	459	459
SYNBRANCHIFORMES									
Synbranchidae									
Synbranchus marmoratus Bloch 1795	1	440	440						

Table 3. Analysis of similarity and dissimilarity of percentages (SIMPER) between the environments (p<0.01). The results of the similarity (%) of the species that contributed, in each analysis, more than 50% of similarity. For results outside this criterion, it was marked "nd".

	Lentic	Transition	Lotic
Average Similarity (%)	69.79	67.88	71.06
Steindachnerina brevipinna (Eigenmann & Eigenmann, 1889)	15.43	14.69	8.87
Astyanax fasciatus (Cuvier, 1819)	11.08	5.12	6.85
Loricariichthys anus (Valenciennes, 1835)	9.72	9.37	nd
Hypostomus isbrueckeri (Reis, Weber and Malabarba, 1990)	9.18	5.43	11.35
Acestrorhynchus pantaneiro (Menezes, 1992)	7.47	10.13	3.34
Schizodon nasutus (Kner, 1858)	6.89	8.65	8.03
Iheringichthys labrosus (Lütken, 1874)	5.86	7.89	10.46
Oligosarcus jenynsii (Günther, 1864)	2.52	3.51	7.37
	LENxTRA	LENxLOT	TRAxLOT
The average dissimilarity (%)	37.37	51.18	42.65

DISCUSSION

The results showed that the construction of the Itá dam directly influenced the spatial heterogeneity of the structure of the fish assemblage. The special features of each environment altering her patterns of feeding and reproduction of the fish fauna and play a major role in determining which species will successfully occupy each environment. The lotic stretch was the environment with greater abundance and biomass numbers, indicating the importance of the preservation of these passages for the maintenance of a productive environment formed by the reservoir. Also, with the aging of the reservoir, this environment seems to have managed to ensure the permanence of a higher number of species that depend on certain lotic characteristics. This result reinforces the need for maintaining these stretches to ensure minimum conditions that meet the demands of the life cycle of certain species. It is worth highlighting that the few catches of fish considered as large migratory species found in these stretches coincided with the periods of greatest reproductive activity of these species. The transition stretch, with intermediate abiotic characteristics, presented the second highest productivity and shared species with the two adjacent stretches. However, in general, there was a greater similarity with the lentic zone. The latter had productivity far below the others. In these two stretches of calm waters, opportunistic species were more present.

Despite the transition stretch being associated with a higher primary productivity and fish density (KIMMEL *et al*., 1990), it was in the lotic stretch that the greatest catches were found. This particular superiority can be explained by the collection point being located in the main chute of the Uruguay River. A hypothesis for the high density of fish at this point is a relationship with the water poured into the lake of the Machadinho Hydroelectric Power Plant, in which the high concentration of plankton was probably still present after the passage through the turbines, affecting the other trophic levels. Also, species that perform short reproductive migrations found a final obstacle in their upward movement in the dam above, leading to a major concentration of fish in this location. The body of the Itá reservoir presented the smallest catches, a result that can be related to a location normally described as oligotrophic due to the lower availability of dissolved nutrients retained in the areas of transition, and with a pelagic zone with low densities of fish (OLIVEIRA and GOULART, 2000).

In relation to the total number of species collected, all of the stretches were similar. However, the lentic and transition stretches showed greater decreases in values of richness towards the end of the study period. Furthermore, it was the lotic stretch that presented the highest number of exclusive species. By keeping more consistently the original characteristics of the fluvial environment, the lotic zone guaranteed the certain conditions necessary for maintaining a greater number of dependent species of riverine habitats. This is a result that is commonly described in neotropical reservoirs (BAUMGARTNER *et al*., 2018; HOFFMANN *et al*., 2005; BRITTO and CARVALHO, 2006; PETESSE *et al*., 2007). In the same sense, comparing the composition of the fish fauna with studies done before the construction of the dams in this region (ZANIBONI-FILHO *et al*., 2008), we found that the most profound transformations occurred in the lentic and transition stretches, where the proliferation of opportunistic species became more present. This tendency is constant in the majority of the dams (AGOSTINHO *et al*., 2016).

A closeness in the composition of the fish fauna between the lentic and transition zones was also observed in other reservoirs (CARVALHO *et al*., 1998; BRITTO and CARVALHO, 2006; FERRAREZE *et al*., 2014). This portrays the biggest changes suffered in these places, with the establishment of a more distinct assemblage from those originally adapted to the region. On the other hand, the lotic stretch was notably presented completely separate groups in relation to each other, which once again shows the segregation of the fish assemblage facing the spatial heterogeneity.

Even if the transition and the lentic stretches presented a more similar fish fauna structure between them, several species were shared by the three environments studied. In this sense, *A. fasciatus* and *S. brevipinna* stand out. Despite a preference for certain stretches, the broad occurrence of these species in the reservoir demonstrates the flexibility with which they adapt to different environmental conditions. In the same way, SMITH and PETRERE-JUNIOR (2008) also reported the representativeness of *A. fasciatus* in a wide range of the Itupuraranga reservoir. Lambaris of the genus *Astyanax* possess efficient reproductive tactics - production of many eggs, rapid embryogenesis and hatching - (REYNALTE-TATAJE and ZANIBONI-FILHO, 2008; HIRT *et al*., 2011) and are commonly described as dominant species in reservoirs of the south and southeastern regions of Brazil (AGOSTINHO *et al*., 1995; OLIVEIRA *et al*., 2008). In its turn, *S. brevipinna,* registered as the most captured species in studies done before the construction of Itá dam (ZANIBONI-FILHO *et al*., 2008), also showed pre-adapted characteristics to the lacustrine conditions and maintained its importance in all compartments of the reservoir.

The distributions of *I. labrosus* and *H. isbrueckeri* were important to explain the similarity in the three environments, showing that they are species that access all areas, but pointed out a clear preference for lotic stretches. MASDEU *et al*. (2011) related the success of *I. labrosus* in the Uruguay River Basin to their generalist diet which gives them the ability to profit from among the food resources that are more abundantly available. This mandi presents partitioned spawning with the absence of parental care and, to perform their small side migrations, looks for channels of river tributaries (REYNALTE-TATAJE and ZANIBONI-FILHO, 2008). In the case of *H. isbrueckeri*, the association with rocky bottoms, found in shallow areas of lotic stretches, is fundamental for their food and to supply substrate necessary for placing their large adhesive eggs (GARAVELLO and GARAVELLO, 2004; VAZZOLER, 1996).

Even if their more frequent presence was in the transition stretch, another species that appeared distributed throughout the reservoir was the voga *S. nasutus*, showing its adaptation to the different environments. The presence of aquatic macrophytes, pointed out as one of the preferred foods of this species (ANDRADE and BRAGA, 2005; VILLARES-JUNIOR *et al*., 2011), is common in the Itá reservoir and is certainly providing abundant food in the different stretches studied. Furthermore, reproductive tactics such as partitioned spawning, the absence of reproductive displacements and parental care (VAZZOLER and MENEZES, 1992; NAKATANI *et al*., 2001) contribute to the colonization of these distinct spaces.

Differently, the cascudo *L. anus* showed high abundance in the lentic and transition stretches but was practically nonexistent in the lotic stretch. With increasing abundance over the years, and with catches massively concentrated in coastal areas, they demonstrated that their benthonic habit and their omnivorous iliophagous diet (ALBRECHT and SILVEIRA, 2001) are associated with the preference of the species for these shallow, calm environments with sandy soil or muddy bottoms (AGOSTINHO *et al*., 2000). The production of large adhesive eggs (VAZZOLER, 1996) is usually a little efficient strategy in the region of the body of the reservoir, but in this case, the use of a different technique of parental care seems to have provided a solution. With the eggs loading in buccal structures, this species obtains benefits in the competition for substrates and protects its eggs from air exposure during possible variations of the water level (ERIC *et al*., 1982).

In relation to the piscivores, the distribution of two species of characid pike characin was well defined, *A. pantaneiro* preferentially in the transition and lentic stretches and *O. jenynsii* in the lotic environment. MEURER and ZANIBONI-FILHO (2012) attributed the success of *A. pantaneiro* in the colonization of new lentic and semi-lentic environments formed by the Itá reservoir to an opportunistic behavior which includes features such as the ability to prey on the more abundant fish, a long reproductive period, multiple spawning and an absence of parental care. When compared to *O. jenynsii*, with similar trophic position and strategies (HARTZ *et al*., 1997), the same authors point to the production of minor oocytes and greater absolute fertility as being competitive advantages. On the other hand, in the lotic stretch, where the environmental characteristics are closer to the original settings, *O. jenynsii* found the necessary conditions for maintaining the representativity that it already had before the closure of the dam (ZANIBONI-FILHO *et al*., 2008) and continued to be caught more than the other species of pike characin in the region.

In relation to the fish considered as large migratory species, the catches were well distributed among the environments. They showed that these species go through the entire area of the reservoir looking for a more adequate environment for feeding and reproduction according to their needs. For all of them, their presence in the lotic stretch was practically restricted to spring and summer, when these species reproduce (REYNALTE-TATAJE *et al*., 2012). In the Basin of Upper Uruguay, despite the hydrological regimes, the month of November usually marks the beginning of the flood period when the migratory fish are stimulated by the flowing water to migrate up the river looking for places to spawn (REYNALTE-TATAJE and ZANIBONI-FILHO, 2008; ZANIBONI-FILHO *et al*., 2017). In the studied region, most of the tributaries are not very extensive with a lot of rapids. Consequently, the life cycle of the migratory species of larger size is normally limited to the main river and to the lower part of the tributaries (NUNES *et al*., 2015; ZANIBONI-FILHO and SCHULZ, 2003).

CONCLUSIONS

From the presented results, it is concluded that the compartmentalization of stretches with lentic, lotic and transitional characteristics in the influence area of the Itá reservoir plays a role of great importance in determining the distribution patterns of the fish fauna assemblage. The special features of each environment define which species have the necessary adaptations to occupy the reservoir. The lotic stretches, certainly for being the least modified by the dam, in this case, were particularly important for the maintenance of the productivity of the environment and to ensure the survival of the most dependent species on the fluvial habitat originally offered.

Lastly, remembering that the Itá Hydroelectric Power Plant is part of a system of reservoirs in cascade, it is also interesting to analyze its particularities within the context in which it is inserted. The region of the Upper Uruguay River is marked by the presence of stretches of rapids and has most of its main rivers dammed by hydroelectric enterprises of different sizes. The greatest part of the tributaries that feed the reservoirs of the region are not extensive, and the places with well-structured lotic characteristics are particularly rare. An exception is the Ligeiro River which presents a long free stretch that, in its final part, encounters the Pelotas River, a point that integrates the area of influence of the Itá reservoir. These characteristics of the region, added to the results found in the present work, highlights the importance for the preservation of these lotic stretches to maintain the species of fish that are more dependent on pristine fluvial environments. Thus, within a larger scale, this study points out the free stretches flowing into the Itá reservoir as being priority areas for the conservation of the Upper Uruguay River.

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