Assessment of the ichthyofauna in stretches under the influence of Salto Grande Reservoir (Middle Paranapanema River, SP/PR, Brazil)

Levantamento da ictiofauna nos trechos sob influência do reservatório de Salto Grande (Médio Rio Paranapanema, SP/PR, Brasil)

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Abstract: Aim: To analyze the composition, species richness and spatial distribution of the fish fauna in the area under influence of the Salto Grande Reservoir; **Methods:** Fish were caught every two months from November/05 to October/06, using gill nets, seining nets and sieve; **Results:** It was registered 67 fish species, 1,964 individuals and 146.2 kg, representing CPUEn of 1,964 and CPUEb of 278 kg. The most representative orders were Characiformes, with 29 species, Siluriformes (21 species) and Perciformes (11 species) Nine non-native species were registered. The most abundant species in the reservoir were *Astyanax altiparanae, Steindachnerina insculpta* and *Acestrorhynchus lacustris,* indicating the predominance of medium and small fishes in this reservoir. The dendrogram of similarity separated the Dam and Pedra Branca stretches from Pardo River Mouth, indicating differences in the assemblages. The species turnover among the stretches was demonstrated by the beta diversity, which may be related to the diversity of habitat; **Conclusions:** Although being a small reservoir, it displays great habitat diversity, reflecting in the composition and structure of fish assemblages.

Keywords: fish fauna, river damming, non-native species, spatial heterogeneity.

Resumo: Objetivo: analisar a composição, a riqueza e a distribuição espacial da fauna de peixes dos diversos trechos sob a área de influência do reservatório de Salto Grande; **Métodos:** Foram realizadas coletas bimestrais no período de novembro/05 a outubro/06, utilizando-se de redes de espera, arrasto e peneirão; **Resultados:** Foram registradas 67 espécies, 1.964 indivíduos e 146,2 kg, representando CPUEn de 3.804 indivíduos e CPUEb de 278 kg. As ordens mais representativas foram Characiformes, com 29 espécies, Siluriformes (21 espécies) e Perciformes (11 espécies). Cabe ressaltar que nove espécies são não-nativas. As espécies mais abundantes no reservatório como um todo foram *Astyanax altiparanae, Steindachnerina insculpta* e *Acestrorhyncus lacustris*, indicando o predomínio de peixes de médio e pequeno porte neste reservatório. O dendograma de similaridade distanciou os trechos Barragem e Pedra Branca do trecho Foz do rio Pardo, indicando diferenças nas assembleias. A análise da diversidade mostrou que ocorre substituição de espécies entre os trechos o que pode estar relacionado com a diversidade de habitats; **Conclusões:** Embora o reservatório seja pequeno, apresenta grande diversidade de habitats, o que reflete na composição e estrutura das assembléias de peixes.

Palavras-chave: ictiofauna, barragem, espécies não-nativas, heterogeneidade espacial.

1. Introduction

The Brazilian river basins present a great diversity of fish species and are placed in the Neotropical region, one of the most riches of the planet (Agostinho et al., 2007). In the upper Paraná River basin, many dams were constructed in cascade system along its large tributaries, and also in the main channel of Paraná River (Araújo-Lima et al., 1995), mainly to provide electric power to Southeastern region of Brazil (Woynarovich, 1991; Tundisi, 1999; Barrella and Petrere Jr., 2003).

Agostinho et al. (1999) and Carvalho et al. (2005b) emphasize that the construction of reservoirs causes the fragmentation of natural environments. However, besides the persistent effects of the dams construction and its functioning, the fish community suffers other effects that decrease the fish diversity, such as the deliberate or accidental introduction of non-native species (Orsi and Agostinho, 1999; Santos and Formagio, 2000), loss of the riparian vegetation, effluent contamination and border silting (Alvim and Peret, 2004; Smith et al., 2002).

The importance of studies about fish communities in areas under high risk of environmental disturbance, as Paranapanema River, is the aim of many discussions since 1970, when Bohlke et al. (1978) advertised the necessity of studies to guideline actions management to reduce these negative impacts. Therefore, studies in reservoirs, with emphasis on the fish communities are extremely important, due to the increasing number of new reservoirs build in Brazilian rivers and the impact that they exert in the ecosystem (Eletrobrás, 1995). This situation demonstrates the necessity of periodic supervision of these artificial environments to find adequate techniques for fish fauna management, directing to the better employment of the multiple uses of reservoirs (Roche and Rocha, 2005; Tundisi, 2003).

The information about species diversity in an area is fundamental to the understanding of the nature, and also to optimize its management in relation to low impact actions, resources conservation and recovering the degraded ecosystems (Melo, 2008). Therefore, the ichthyofauna of the Middle River Paranapanema was studied by other authors (Dias and Garavello, 1998, Orsi et al., 2004, Hoffmann et al., 2005), which demonstrates the importance of this river concerning to its maintenance and preservation.

Only relevant study about the fish fauna of Salto Grande Reservoir is available in the literature, recording the occurrence of 51 fish species (Dias and Garavello, 1998). There is no information available regarding to the fish fauna during the pre-damming period (before 1955), as found for most of Brazilian reservoirs built before the 1970/80's (Carvalho et al., 1998; Agostinho et al., 2007).

The aim of this study is to present an updated assessment of fish species, analyzing the species richness and spatial distribution of the fish fauna in the area under influence of the Salto Grande Reservoir, Middle Paranapanema River, Brazil.

2. Material and Methods

2.1. Study area

The Salto Grande Reservoir is located at 22° 50' 23" S and 49° 50' 50" W, and altitude of 384 m, close to the cities of Salto Grande (SP) and Cambará (PR), at the Middle Paranapanema River (Figure 1). This reservoir was the first hydroelectric power plant built in 1958 in the Paranapanema River basin (Ana, 2005). This reservoir presents little water level variation, independently of the flow, and there is no expansion of the aquatic environment even during the rainy season (Dias and Garavello, 1998). Its main tributaries are the Pardo and Novo rivers. The reservoir presents an area of 12.2 km^2, perimeter of 81 km,

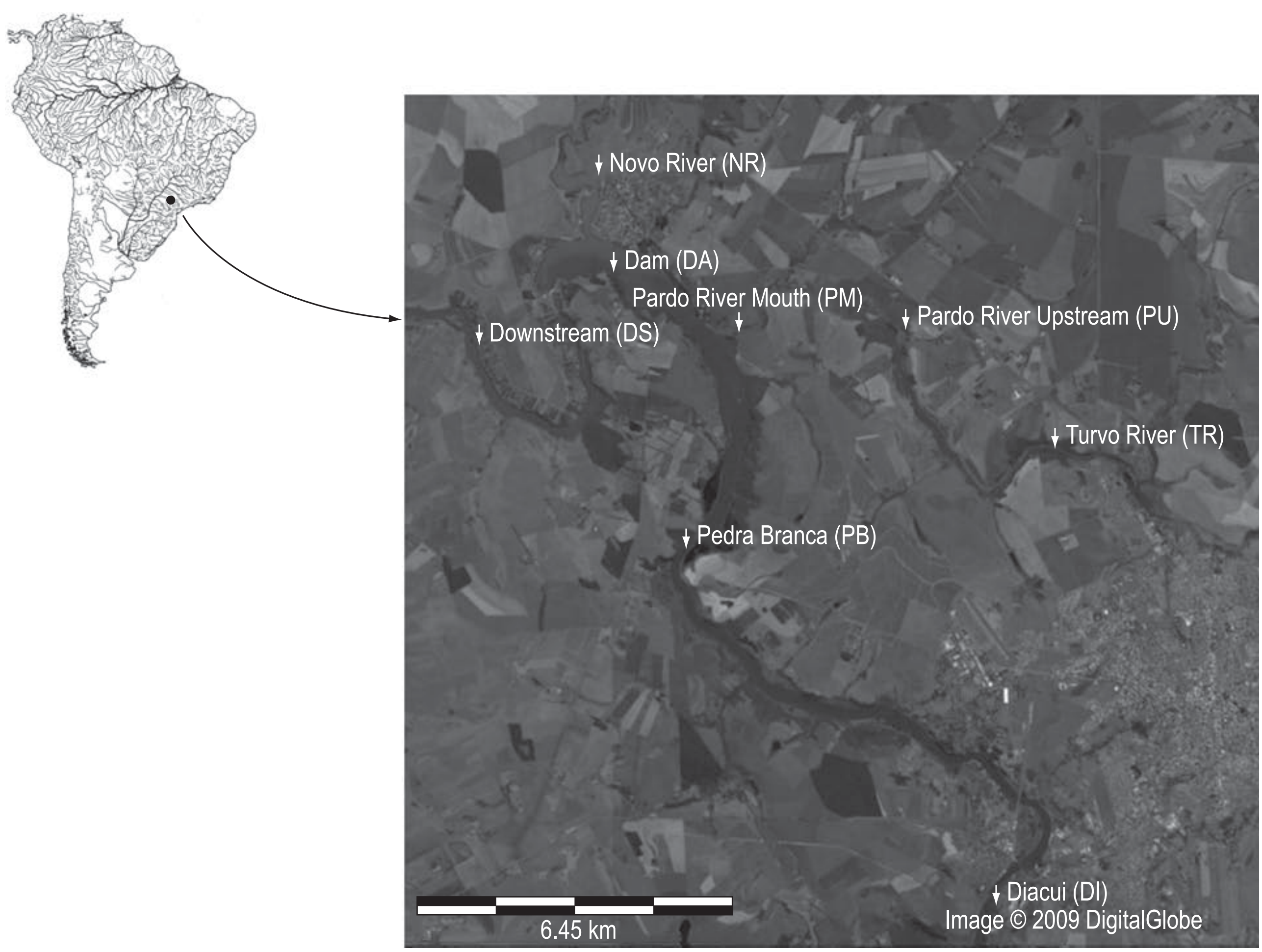

Figure 1. Localization of the Salto Grande Reservoir in the South America, indicating the sampling stretches of the reservoir. Source: DigitalGlobe (GoogleEarth).

total volume of 42.2 x $10^6 m^3$, and water permanence time of 1.5 days (Júnior et al., 2005).

2.2. Sampling procedure

The fish samplings were carried out in eight stretches of the reservoir, being three lentic stretches: Dam (DA), at 22° 54' 13.2" S and 49° 59'00.3" W, Novo River (NR) at 22° 52' 33.3" S and 049° 59' 49.8" W and a marginal lagoon of the Diacuí stretch (DI) at 23° 01' 59.2"S and 49° 54' 52.9" W; a transition stretch: Pedra Branca (PB) at 22° 57' 08.4" S and 049° 58' 22.0"W and in four lotic stretches: the Pardo River upstream (PU) at 22° 54' 14.0" S and 49° 57' 1.1" W and Pardo River Mouth (PM) at 22° 54' 22.1"S and 49° 56' 28,6" W into Paranapanema River, Turvo River (TR) at 22° 56' 07.78" S and 49° 52' 43.64" W and Downstream (DS) at 22° 56' 07.78" S and 49° 52' 43.64" W of the Salto Grande Reservoir.

Six fish samplings were made from November/05 to October/06 in the Dam, Pardo River Mouth and Pedra Branca stretches, four collections in the Novo River stretch, three collections in the Diacuí and Downstream stretches, two in the Pardo River Mouth and one sample in the Turvo River. Generally, the vicinities of the stretches are occupied by agricultural and pasture; however, on the Dam stretch it can be observed some fragments of mesophyllous semi-deciduous forest.

Fish samplings were made with gill nets of different mesh sizes (3 to 14 cm not opposite knots; height of 1.44 to 2.20 m), comprising 240 m of nets per stretch, with 16 hours of exposition. In addition, some collections were carried out with a sieve and seining net (5 × 2 m, 5 mm mesh), dragged six times into aquatic vegetation and margin of each stretch, to capture small and young fishes that occupy the littoral zones and aquatic macrophytes. All the fishes were identified, weighted and fixed with 10% formalin. Voucher specimens were deposited in the Laboratório de Biologia e Genética de Peixes (LBP), Instituto de Biociências, UNESP Botucatu and in the Museu de Zoologia do NUPÉLIA (NUP).

Analyses were separated in stretches with six samplings in DA, PB and PM and incomplete collection (RN, DI and DS). The stretches with one sampling (TR and PU) were considered only for qualitative data.

Ecological indices were calculated only for the species caught with gillnets, except for the cluster analysis. In addition, the abundance and distribution of species were analyzed by stretches according to the differences in samplings. Catch per unit effort (CPUE) was estimated in number (CPUEn) and biomass (CPUEb), expressed by fishes/kg of fishes by 1,000m^2 of gill nets, during 16 hours of exposure (Agostinho and Gomes, 1997); Ponderal Index (Nataragam and Jhingian, 1961, in Beaumord and Petrere Jr., 1994) with CPUE data of all stretches and for the reservoir and species richness (S) (Odum, 1988); frequency of sampling constancy (Dajoz, 1978), where the following categories were established: constant species (≥50%), accessory species (25% ≥ C < 50%) and accidental species (<25%).

A cluster analysis was performed with the presence and absence data of species, by using the Pearson distance and UPGMA linkage method. The analysis was carried out with the program Statistica 5.1 (StatSoft, Inc., 1996). The β diversity, that measures how much regional diversity exceed the local diversity (α diversity), was calculated by the following equations, according to Harrison et al. (1992): $\beta_1 = (S_R\ \alpha_{med}^{-1})$ and $\beta_2 = (S_R\ \alpha_{max}^{-1})\ \text{-1}\ (N\text{-}1)^{-1}$, where S_R = total number of species between the stretches, α_{med} = average number of species in N stretches and α_{max} = maximum number of species in N stretches. These indices range from zero, when the areas share all species, to 100, indicating species turnover between localities. The two indices differ only when α diversity is variable (Harrison et al., 1992).

3. Results

In the influence area of the reservoir and vicinities, 67 fish species were registered (Table 1), belonging to six orders and 20 families, 1,964 individuals and 146.2 kg, representing a CPUEn of 3,804 individuals and CPUEb of 278 kg. The most abundant taxonomic orders in numbers of species were Characiformes (29 species), followed by the Siluriformes (21 species) and Perciformes (11 species). The most diversified families were Characidae, Loricariidae and Cichlidae with 13, 12 and 10 species, respectively.

From the 67 species registered (Table 1), 55 were captured with gill nets (Table 3) and 23 with seining nets or sieve, and twelve species were captured only with this apparatus: *Apareiodon piracicabae*, *Brachyhypopomus pinnicaudatus*, *Bryconamericus* cf. *iheringii*, *Cheirodon stenodon*, *Hyphessobrycon eques*, *Piabina argentea*, *Planaltina britskii*, *Poecilia reticulata*, *Pyrrhulina australis, Serrapinnus notomelas, Serrassalmus* sp. e *Synbranchus marmoratus* (Table 2).

Nine introduced species were registered: *Astronotus crassipinnis*, *Brachyhypopomus pinnicaudatus*, *Cichla kelberi, Cichla piquiti*, *Leporinus macrocephalus, Oreochormis niloticus*, *Plagioscion squamosissimus, Hyphessobrycon eques*, and *Poecilia reticulata* (Table 1).

Considering the species captured with gill nets, Pedra Branca stretch presented the largest number of species (33), followed by Dam (30), Pardo River Mouth (25) and Diacuí (24 species). The species *Acestrorhynchus lacustris*, *Astyanax altiparanae* and *Steindachnerina insculpta* were the most abundant in most stretches (Table 3).

In Pedra Branca stretch, the most abundant species in terms of number was *Astyanax altiparanae*, and in terms of biomass was *Iheringichthys labrosus.* In the Dam stretch, *Astyanax altiparanae* was the most abundant in number,

Table 1. Taxonomic position of the fish species (according to Buckup et al., 2007 and Reis et al., 2003) captured in all stretches studied of the Salto Grande Reservoir (Middle Paranapanema River).

Taxonomic group	Voucher specimens
CHARACIFORMES	
Parodontidae	LBP 4793
Apareiodon affinis (Steindachner, 1879)	LBP 4856
Apareiodon piracicabae (Eigenmann, 1907)[1]	
Curimatidae	
Cyphocharax modestus (Fernández-Yépez, 1948)	LBP 4799
Steindachnerina insculpta (Fernández-Yépez, 1948)	LBP 4823
Anostomidae	
Leporinus amblyrhynchus Garavello & Britski, 1987	LBP 4581
Leporinus cf. *obtusidens* (Valenciennes, 1836)	LBP 2506
Leporinus macrocephalus Garavello & Britski, 1988*	LBP 4434
Leporinus paranensis Garavello & Britski, 1987	LBP 4845
Leporinus friderici (Bloch, 1794)	LBP 4437
Leporinus striatus Kner, 1858	LBP 4853
Leporinus octofasciatus Steindachner, 1915	LBP 4848
Schizodon intermedius Garavello & Britski, 1990	LBP 4805
Schizodon nasutus Kner, 1858	LBP 4821
Characidae	
Astyanax altiparanae Garutti & Britski, 2000	LBP 4794
Astyanax fasciatus (Cuvier, 1819)	LBP 4795
Bryconamericus cf. *iheringii* (Boulenger, 1887)[1]	LBP 4792
Cheirodon stenodon (Eigenmann, 1915)[1]	LBP 4825
Galeocharax knerii Steindachner, 1875	LBP 4801
Hyphessobrycon eques (Steindachner, 1882)*	LBP 4840
Metynnis maculatus (Kner, 1858)	LBP 4815
Myleus tiete (Eiggenmann & Norris, 1900)	LBP 4816
Piabina argentea Reinhardt, 1867[1]	LBP 4832
Planaltina britskii Menezes, Weitzman & Burns, 2003[1]	LBP 4833
Serrapinnus notomelas (Eigenmann, 1915)[1]	LBP 4824
Serrasalmus maculatus Kner, 1858	LBP 4822
Serrasalmus sp.[1]	LBP 4857
Acestrorhynchidae	
Acestrorhynchus lacustris (Lütken, 1875)	LBP 4790
Erythrinidae	
Hoplias aff. *malabaricus* (Bloch, 1794)	LBP 4803
Lebiasinidae	
Pyrrhulina australis Eigenmann & Kennedy, 1903[1]	LBP 4841
SILURIFORMES	
Callichthiydae	
Callichthys callichthys	LBP 4837
Hoplosternum littorale (Hancock, 1828)	LBP 4804
Loricaridae	
Loricaria prolixa Isbrücker & Nijssen, 1978	NUP 2711
Hypostomus ancistroides (Ihering, 1911)	NUP 6115
Hypostomus hermanni (Ihering, 1905)	NUP 5358
Hypostomus iheringii (Regan, 1908)	NUP 5310
Hypostomus margaritifer (Regan, 1908)	NUP 5380
Hypostomus cf. *nigromaculatus* (Schubart, 1964)	NUP 5359
Hypostomus aff. *paulinus* (Ihering, 1905)	NUP 5357
Hypostomus regani (Ihering, 1905)	NUP 6117
Hypostomus sp. 2	NUP 2444

*introduced species, [1]species collected with seining nets or sieve.

Table 1. Continued...

Taxonomic group	Voucher specimens
Hypostomus sp. 3	NUP 5320
Hypostomus strigaticeps (Regan, 1908)	NUP 6116
Hypostomus cf. *topavae* (Godoy, 1969)	NUP 5263
Pimelodidae	
Iheringichthys labrosus (Lütken, ex Kroyer, 1874a)	LBP 4811
Pimelodus maculatus LaCepède, 1803	LBP 4818
Steindachneridion scriptum	LBP 4849
Doradidae	
Rhinodoras dorbignyi (Kner, 1855)	LBP 4842
Auchenipteridae	
Ageneiosus valenciennesi (Bleeker, 1864)	LBP 4791
Heptapteridae	
Pimelodella avanhandavae Eigenmann, 1917	LBP 4817
Rhamdia quelen (Quoy & Gaimard, 1824)	LBP 4820
GYMNOTIFORMES	
Gymnotidae	
Gymnotus carapo Linnaeus, 1758	LBP 4802
Sternopygidae	
Eigenmannia trilineata López & Castello, 1966	LBP 4800
Sternopygus macrurus (Bloch & Schneider, 1801)	LBP 4835
Hypopomidae	
Brachyhypopomus pinnicaudatus (Hopkins, Comfort, Bastian & Bass, 1990) *[1]	LBP 4839
CYPRINODONTIFORMES	
Poeciliidae	
Poecilia reticulata Peters, 1859*[1]	LBP 4834
SYNBRANCHIFORMES	
Synbranchidae	
Synbranchus marmoratus Bloch, 1785[1]	LBP 4836
PERCIFORMES	
Cichlidae	
Astronotus crassipinnis (Heckel, 1840)*	LBP 4846
Cichla kelberi Kullander & Ferreira, 2006*	LBP 4796
Cichla piquiti Kullander & Ferreira, 2006*	LBP 4843
Cichlasoma paranaense Kullander, 1983	LBP 4826
Crenicichla haroldoi Luengo & Britski, 1974	LBP 4797
Crenicichla jaguarensis Hasemam, 1911	LBP 4838
Crenicichla niederleinii (Holmberg, 1891)	LBP 4798
Crenicichla britskii Kullander, 1982	LBP 4827
Geophagus brasiliensis (Quoy & Gaimard, 1824)	LBP 4828
Oreochromis niloticus (Linnaeus, 1758)*	LBP 4831
Sciaenidae	
Plagioscion squamosissimus (Heckel, 1840) *	LBP 4819

*introduced species, [1]species collected with seining nets or sieve.

while *Acestrorhynchus lacustris* was the most representative species in biomass. Pardo River Mouth presented *Steindachnerina insculpta* as main species in terms of number and biomass. Diacuí stretch had *Astyanax altiparanae* as the most abundant species while *Hoplias malabaricus* was the most representative in biomass.

Novo River stretch presented 17 species, where *Astyanax altiparanae* was the most numerous, and the highest biomass was presented by the species *Loricaria prolixa*. In the downstream stretch, 15 species were registered, where *Pimelodus maculatus* was the most important species in number and biomass.

In the samples performed in the Pardo River Upstream stretch nine species were collected, and *Acestrorhynchus lacustris* was the most abundant in numerical terms and *Loricaria prolixa* was the most representative in terms

Table 2. Numeric abundance of the species collected with trawl and sieve per stretch at the Salto Grande Reservoir, during the entire study period.

Species	PM	DA	PB	DI
A. lacustris	2	-	-	-
A. piracicabae	-	137	-	12
A.altiparanae	32	31	13	31
A. fasciatus	-	1	-	31
B. pinnicaudatus	5	-	-	‘
B. cf. iheringi	-	-	-	10
C. stenodon	-	-	-	26
C. paranense	4	-	-	-
G. brasiliensis	5	-	-	-
G. carapo	4	-	1	-
H. malabaricus	3	-	1	-
H. eques	86	-	-	-
M. maculates	1	-	-	-
O. niloticus	3	1	-	4
P. argentea	-	-	-	1
P. britskii	-	-	-	7
P. reticulates	-	-	-	4
P. australis	1	-	-	-
S. nasutus	1	-	-	-
S. notomelas	71	-	4	1
S. maculatus	1	-	-	2
Serrassalmus sp.	1	-	-	-
S. marmoratus	3	-	-	-
Total	223	170	19	129

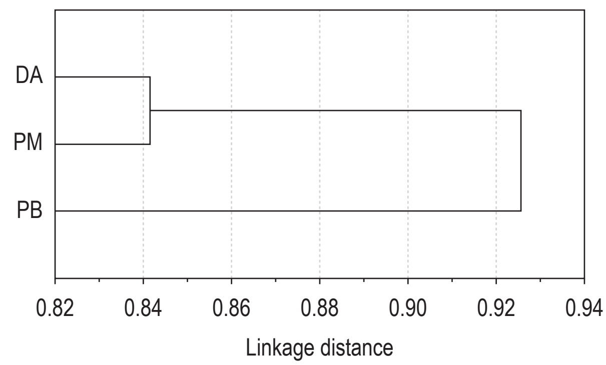

Figure 2. Cluster analysis (Pearson distance) among the sampling stretches of the Salto Grande Reservoir. DA = Dam, PM = Pardo River Mouth and PB = Pedra Branca.

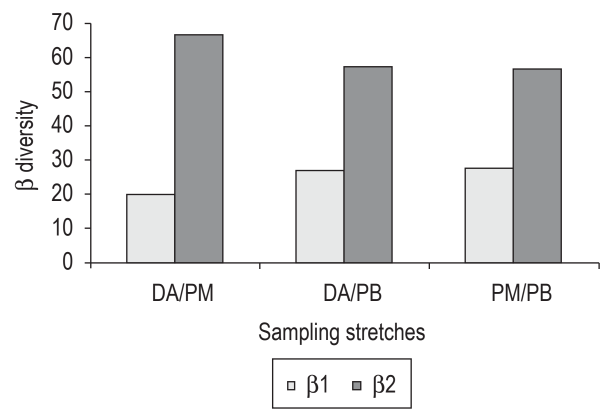

Figure 3. β diversity (β1 and β2) between the stretches of the Salto Grande Reservoir. DA = Dam, PM = Pardo River Mouth and PB = Pedra Branca.

of biomass. At the Turvo River stretch, five species were registered, of which *Hypostomus* aff. *paulinus* was the most important in numerical abundance and *Loricaria prolixa* had the highest biomass (Table 3).

The Ponderal Index (PI) demonstrated that for the reservoir, *Acestrorhynchus lacustris*, (32%) *Astyanax altiparanae* (24.9%) and *Steindachnerina insculpta* (20.3%) were the dominant species, but some differences were observed when the stretches were examined individually (Table 4). In the Pedra Branca stretch, the dominant species was *Iheringichthys labrosus* (PI = 35.2%), while in the Dam stretch was *Acestrorhynchus lacustris* (PI = 45.7%), in the Pardo River Mouth stretch was *S. insculpta* (PI = 51.3%), in the Diacuí stretch was *Astyanax altiparanae* (PI = 26.3%), in Novo River stretch was *Eigenmannia trilineata* (PI = 29.7%) and in the Downstream stretch, *Pimelodus maculatus* (PI = 75.2%).

The cluster analysis separated the Pardo River Mouth from the Dam and Pedra Branca stretches (Figure 2).

The β_1 diversity presented low values of species turnover for all stretches pairs, while for β_2, there was a high species turnover between sites, with the highest value observed between DA and PU (β_2 = 66.7) (Figure 3).

A total of eight species were constant in all stretches (*Acestrorhynchus lacustris, Astyanax altiparanae, Eigenmannia trilineata, Pimelodus maculatus, Plagioscion squamosissimus, Schizodon nasutus, Serrasalmus maculatus* and *Steindachnerina insculpta*), while *Astyanax fasciatus* and *Hypostomus ancistroides* were registered as accidental species in all stretches (Table 5).

4. Discussion

During the present study, 67 species of fish were registered in the area of influence of the reservoir and vicinity, where 30 of these species were already registered by Dias and Garavello (1998) and 37 are newly registered species. Considering the species registered in the present study and by Dias and Garavello (1998) we can verify the occurrence of 87 species in Salto Grande Reservoir.

A predominance of Characiformes and Siluriformes was observed, as reported by other authors in reservoirs of the Paranapanema River cascade (Hoffmann et al., 2005; Britto and Carvalho, 2006; CESP, 1996) and following the pattern of Brazilian and South-American rivers and reservoirs (Britski, 1992; Lowe-McConnell, 1999).

Table 3. Capture per unit effort in number (CPUEn) and biomass (CPUEb) of the collected species with gill nets per stretch of Salto Grande Reservoir during all the period.

Species	Pedra Branca (PB)		Dam (DA)		Pardo River Mouth (PM)		Diacuí (DI)		Novo River (NR)		Downstream (DS)		Turvo River (TR)		Pardo River upstream (PU)	
	CPUEn	*CPUEb*	*CPUEn*	*CPUEb*	*CPUEn*	*CPUEb*	*CPUEn*	*CPUEb*	*CPUEn*	*CPUEb*	*CPUEn*	*CPUEb*	*CPUEn*	*CPUEb*	*CPUEn*	*CPUEb*
Acestrorhynchus lacustris	181.1	9,246.0	209.0	15,535.0	154.2	10,221.7	85.6	5,089.9	6.1	166.4	24.3	898.0	-	-	6.1	262.8
Ageneiosus valenciennesi	17.6	843.8	6.6	275.3	6.6	310.9			4.1	361.2	15.6	1,232.4	-	-	2.0	51.2
Apareiodon affinis	12.3	476.6	16.8	645.9	33.3	1,994.6	16.4	608.3	-	-	-	-	-	-	-	-
Astronotus crassipinnis	-	-	6.1	233.2	-	-	-	-	-	-	-	-	-	-	-	-
Astyanax altiparanae	234.0	6,410.7	255.4	7,420.7	189.5	4,902.4	192.9	3,666.6	28.7	936.0	6.7	201.1	-	-	2.0	20.2
Astyanax fasciatus	2.0	51.6	1.0	64.1	4.1	74.3	-	-	2.0	62.7	-	-	-	-	-	-
Callichthys sp.	-	-	-	-	3.2	49.1	-	-	-	-	-	-	-	-	-	-
Cichla kelberi	4.1	190.8	10.2	1,454.0	-	-	-	-	-	-	-	-	-	-	-	-
Cichla piquiti	-	-	2.0	81.9	-	-	-	-	2.0	588.8	-	-	-	-	-	-
Cichlasoma paranaense	-	-			-	-	2.0	88.7	-	-	-	-	-	-	-	-
Crenicichla britskii	-	-	18.9	943.8	-	-	3.3	62.0	-	-	-	-	-	-	-	-
Crenicichla haroldoi	3.7	196.4	2.0	130.5	-	-	-	-	-	-	-	-	-	-	-	-
Crenicichla jaguarensis	-	-	-	-	1.6	124.3	-	-	-	-	-	-	-	-	-	-
Crenicichla niederleinii	2.0	174.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cyphocharax modestus	12.3	719.9	-	-	11.9	587.2	38.2	1,479.8	-	-	-	-	-	-	-	-
Eigenmannia trilineata	8.2	392.8	9.2	622.7	22.6	1,584.7	-	-	20.5	2,093.0	2.0	196.6	-	-	-	-
Galeocharax knerii	44.2	5,625.2	9.4	551.1	4.9	264.9	3.3	420.7	-	-	19.7	1,219.0	-	-	-	-
Geophagus brasiliensis	-	-	16.5	1,457.0	-	-	2.0	227.8	-	-	-	-	-	-	-	-
Gymnotus carapo	2.0	87.7	7.2	1,360.2	5.3	768.0	-	-	-	-	-	-	-	-	4.1	510.1
Hoplias malabaricus	3.3	783.7	6.1	990.6	4.1	1,135.8	36.8	13,633.6	6.1	1,985.9	-	-	-	-	-	-
Hoplosternum littorale	8.2	1,390.0	6.1	607.3	11.1	1,948.4	40.9	6,967.5	-	-	-	-	-	-	-	-
Hypostomus aff. *paulinus*	-	-	-	-	-	-	-	-	-	-	-	-	4.9	85.3	-	-
Hypostomus ancistroides	12.3	541.6	2.0	90.0	2.0	139.7	3.3	250.9	-	-	-	-	-	-	4.1	116.9
Hypostomus cf. *nigromaculatus*	-	-	-	-	-	-	-	-	-	-	-	-	3.3	62.0	-	-
Hypostomus cf. *topavae*	2.0	53.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hypostomus hermanni	-	-	-	-	-	-	-	-	-	-	-	-	1.6	198.5	-	-
Hypostomus iheringii	4.1	188.2	-	-	-	-	8.2	241.6	-	-	-	-	-	-	-	-
Hypostomus margaritifer	2.0	502.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hypostomus regani	-	-	-	-	-	-	-	-	4.1	1,046.8	-	-	-	-	-	-
Hypostomus sp 2	-	-	-	-	-	-	2.0	53.0	-	-	-	-	-	-	-	-
Hypostomus sp 3	4.1	196.9	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hypostomus strigaticeps	6.1	459.9	12.4	885.0	3.2	314.7	1.6	139.8	-	-	-	-	-	-	2.0	162.3
Iheringichthys labrosus	202.6	13,774.9	2.0	283.1	1.6	114.8	16.5	1,319.8	4.1	312.1	-	-	-	-	-	-
Leporinus amblyrhynchus	2.0	215.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 3. Continued...

Species	Pedra Branca (PB)		Dam (DA)		Pardo River Mouth (PM)		Diacuí (DI)		Novo River (NR)		Downstream (DS)		Turvo River (TR)		Pardo River upstream (PU)	
	CPUEn	*CPUEb*	*CPUEn*	*CPUEb*	*CPUEn*	*CPUEb*	*CPUEn*	*CPUEb*	*CPUEn*	*CPUEb*	*CPUEn*	*CPUEb*	*CPUEn*	*CPUEb*	*CPUEn*	*CPUEb*
Leporinus cf. *obtusidens*	2.0	91.8	-	-	-	-	-	-	4.1	646.1	-	-	-	-	-	-
Leporinus friderici	4.1	1022.7	-	-	-	-	-	-	-	-	10.0	4,209.5	-	-	-	-
Leporinus macrocephalus	-	-	2.0	505.1	-	-	-	-	-	-	-	-	-	-	-	-
Leporinus octofasciatus	-	-	4.4	199.5	-	-	-	-	-	-	-	-	-	-	-	-
Leporinus paranensis	-	-	-	-	-	-	-	-	2.0	185.8	-	-	-	-	-	-
Leporinus striatus	-	-	-	-	-	-	-	-	-	-	-	-	1.6	27.2		
Loricaria prolixa	-	-	-	-	14.3	1,615.4	1.6	735.4	12.3	2,397.3	6.7	718.0	1.6	406.1	4.1	526.4
Metynnis maculatus	4.1	131.7	14.8	692.4	16.4	691.6	13.9	340.6	-	-	-	-	-	-	-	-
Myleus tiete	1.6	26.4	-	-	-	-	1.6	40.5	-	-	-	-	-	-	-	-
Oreochromis niloticus	-	-	-	-	-	-	2.0	822.3	-	-	-	-	-	-	-	-
Pimelodella avanhandavae	4.1	102.9	-	-	-	-			-	-	3.3	44.9	-	-	-	-
Pimelodus maculatus	9.8	2,896.5	20.4	3,512.9	11.9	4,233.5	4.1	1,531.4	8.2	1,465.2	43.6	9,287.9	-	-	2.0	333.1
Plagioscion squamosissimus	16.4	4,738.2	17.6	2,708.2	22.6	3,664.1	-	-	-	-	3.3	531.5	-	-	-	-
Rhamdia quelen	3.7	481.0	9.5	1,279.5	1.6	219.4	-	-	2.0	468.7	-	-	-	-	-	-
Rhinodoras dorbignyi	-	-	-	-	-	-	-	-	-	-	3.3	362.6	-	-	-	-
Schizodon intermedius	-	-	-	-	-	-	-	-	-	-	2.0	966.7	-	-	-	-
Schizodon nasutus	42.6	9,024.0	69.8	7,041.2	27.5	6,236.2	9.0	3,395.1	2.0	608.8	7.4	1,662.4	-	-	-	-
Serrasalmus maculatus	34.8	7,216.4	103.4	6,950.0	9.8	3,830.0	39.0	4,997.7	-	-	5.4	389.8	-	-	-	-
Steindachnerina insculpta	164.2	5,487.7	124.6	3,875.0	278.2	11,485.3	112.2	3,747.1	12.3	371.7	5.4	105.1	-	-	-	-
Steindachneridion scriptum	-	-	2.0	6,344.7	-	-	-	-	-	-	-	-	-	-	-	-
Sternopygus macrurus	-	-	9.2	543.9	3.7	241.1	5.7	578.0	4.1	484.4	-	-	-	-	2.0	177.5
CPUE Total	1,058.0	73,741.1	977.1	67,283.8	845.4	56,751.9	642.6	50,437.9	124.8	14,180.9	159.0	22,025.3	13.2	779.2	28.7	2,160.6
Number of Species	33		30		25		24		17		15		05		09	

Table 4. Ponderal Index of the main species collected at the Salto Grande Reservoir (Total) and in each sample stretch.

Species	Total	PB	DA	PM	DI	NR	DS
A. altiparanae	24.9	18.9	26.7	14.9	26.3	18.6	-
A. lacustris	32.0	21.1	45.7	25.3	16.2	-	4.1
A. valenciennesi	-	-	-	-	-	-	3.6
E. trilineata	-	-	-	-	-	29.7	-
G. knerii	-	-	-	-	-	-	4.5
H. littorale	-	-	-	-	10.6	-	-
H. malabaricus	-	-	-	-	18.7	8.4	-
I. labrosus	-	35.2	-	-	-	-	-
L. friderici	-	-	-	-	-	-	7.8
L. prolixa	-	-	-	-	-	20.4	-
P. maculatus	-	-	-	-	-	8.3	75.2
P. squamosissimus	-	-	-	1.3	-	-	-
S. insculpta	20.3	11.4	6.8	51.3	15.6	-	-
S. maculates	5.2	-	10.1	-	-	-	-
S. nasutus	5.1	4.8	6.9	2.8	-	-	-
Other species	12.5	8.5	3.7	4.3	12.5	14.7	4.9

The dominance of Characiformes and Siluriformes, with the particular participation of the Characidae and Loricariidae families may be the result of the wide distribution of these families in continental waters. In addition, the Characidae family includes large species of interior water fish of Brazil (Britski, 1972). Furthermore, in Characiformes, small-sized species, able of adjusting to lentic environments, predominate (Orsi et al., 2002), occupying essentially the littoral zones (Casatti et al., 2003; Vidotto and Carvalho, 2007).

The stretches Novo River, Downstream, Turvo River and Diacuí, although with differences in the sampling effort from the other stretches, were important to the knowledge of the fish fauna composition, since eleven species were recorded exclusively in these areas, except Pardo River upstream. In Novo River, the following species were exclusively registered: *Hypostomus regain* and *Leporinus paranensis*; in the Downstream stretch, *Rhinodoras dorbignyi* and *Schizodon intermedius*; in the Turvo River stretch, *Hypostomus* aff. *paulinus*, *Hypostamus* cf. *nigromaculatus*, *Hypostamus hermanni* and *Leporinus striatus* and finally in the Diacuí stretch, *Cichasoma paranaense*, *Hypostamus* sp. 2 and the non-native species *Oreochromis niloticus*.

This information allows us to report that the fish assemblages fit differently according to the environment. In addition, Salto Grande Reservoir, although small sized, has great diversity of habitats (areas with high number of underwater and floating aquatic macrophytes, fragments of mesophyllous forest and some marginal lagoons), contributing to the species diversity recorded in these areas.

In this context, the Ponderal Index confirmed that *Acestrorhynchus lacustris, Astyanax altiparanae* and *Steindachnerina insculpta* are the most important species in

Table 5. Frequency of sampling constancy of species with gill nets at stretches Pedra Branca (PB), Dam (DA) and Pardo River Mouth (PM) of the Salto Grande Reservoir. Black: constant species; dark gray: accessory species; light gray: accidental species.

Species	PB	DA	PM
Acestrorhynchus lacustris	black	black	black
Ageneiosus valenciennesi	black	light gray	light gray
Apareiodon affinis	black	black	dark gray
Astronotus crassipinnis		dark gray	
Astyanax altiparanae	black	black	black
Astyanax fasciatus	light gray	light gray	light gray
Callichthys sp.			light gray
Cichla kelberi	light gray	dark gray	light gray
Cichla piquiti		light gray	
Cichlasoma paranaense			
Crenicichla britskii		black	
Crenicichla haroldoi	dark gray	light gray	
Crenicichla jaguarensis			light gray
Crenicichla niederleinii	light gray		
Cyphocharax modestus	dark gray		black
Eigenmannia trilineata	black	black	
Galeocharax knerii	black	black	
Geophagus brasiliensis		black	
Gymnotus carapo	light gray	black	dark gray
Hoplias malabaricus	light gray	dark gray	dark gray
Hoplosternum littorale	dark gray	dark gray	black
Hypostomus aff. *paulinus*			
Hypostomus ancistroides	light gray	light gray	light gray
Hypostomus cf. *nigromaculatus*			
Hypostomus cf. *topavae*	light gray		
Hypostomus hermanni			
Hypostomus iheringii	light gray		
Hypostomus margaritifer	light gray		
Hypostomus regani			
Hypostomus sp. 2			
Hypostomus sp. 3	dark gray		
Hypostomus strigaticeps	dark gray	black	light gray
Iheringichthys labrosus	black	light gray	light gray
Leporinus amblyrhynchus	light gray		
Leporinus cf. *obtusidens*	light gray		
Leporinus friderici	dark gray		
Leporinus macrocephalus		light gray	
Leporinus octofasciatus		light gray	
Leporinus paranensis			
Leporinus striatus			
Loricaria prolixa			black
Metynnis maculatus	dark gray	black	dark gray
Myleus tiete	light gray		
Oreochromis niloticus			
Pimelodella avanhandavae	light gray		
Pimelodus maculatus	black	black	black
Plagioscion squamosissimus	black	black	black
Rhamdia quelen	dark gray	dark gray	light gray
Rhinodoras dorbignyi			
Schizodon intermedius			
Schizodon nasutus	black	black	black
Serrasalmus maculatus	black	black	black
Steindachnerina insculpta	black	black	black
Sternopygus macrurus		black	dark gray
Steindachneridion scriptum		light gray	

the reservoir and in most of the studied stretches, demonstrating the predominance of the medium and small-sized species in this reservoirs, as widely observed in reservoirs of the High Paraná River basin (Agostinho et al., 1999; Carvalho et al., 1998). However, the dominant species may vary depending on the location, since in the Pedra Branca stretch *Iheringichthys labrosus* was the most important, while in the Novo River, *Eigenmannia trilineata*, indicating their ability to adjust in environments with physical, chemical and biological differences.

In the Downstream stretch, five species represented 95.1% of the Ponderal Index and, *Pimelodus maculatus* contributed with 75.2%. According to Britto and Sirol (2005), *Pimelodus maculatus* is one of the most abundant species in number and biomass in the fish ladders of the Canoas Complex of reservoirs. For that reason, these species probably achieve the Salto Grande dam, but is unable to proceed their migration and, consequently, present high abundance in this stretch.

The frequency of sampling constancy, considering Dam, Pardo River Mouth and Pedra Branca stretches presented the highest values of constancy for *Astyanax altiparanae, Acestrorhynchus lacustris*, *Steindachnerina insculpta, Schizodon nasutus* and *Serrasalmus maculatus.* These species are resident in the reservoir at least for one level of their life cycle. In contrast, the accessories present periodic instability along the samples and the accidental species are immigrants that appear only in certain periods of the year to feeding or reproduction (Uieda, 1984).

Among the constant species, we emphasize the presence of *Plagioscion squamosissimus*, also registered as constant species in several reservoirs of the Paranapanema River (Britto and Carvalho, 2006; Bennemann et al., 2006; Carvalho et al., 2006), Tietê River (Espíndola et al., 2005; Vidotto and Carvalho, 2007) and in many other Brazilian reservoirs (Hahn et al., 1998; Santos and Formagio, 2000). On the other hand, at the High Paranapanema River and, especially, at the Jurumirim Reservoir this species is not captured (Carvalho et al., 2005a), and the causes are unknown.

In addition to *Plagioscion squamosissimus*, another eight non-native species were registered in this study, introduced accidentally or deliberately, throughout the years. Even though no precise information is available, it is possible that *Poecilia reticulata, Astronotus crassipinnis* and *Brachyhypopomus pinnicaudatus* were introduced by aquarists, as discussed by Campos-da-Paz (2004) and Graça and Pavanelli (2007).

Langeani et al. (2007) argue that an increase of non-native species from Perciformes order, mainly Cichlidae, is been registered in reservoirs from the High Paraná River basin. This fact can be verified in the present study, when compared to the previous survey of Dias and Garavello (1998). From the nine non-native species recorded, six are Perciformes: *Astronotus crassipinnis*, *Cichla kelberi*, *Cichla piquiti*, *Oreochormis niloticus* and *Plagioscion squamosissimus*.

For this reason, we emphasize the ecological role of these species in the reorganization of the fish fauna, as observed by Santos and Formagio (2000) in reservoirs of the Grande River, since three of these introduced species are carnivores and can use fish as food resource: *Cichla kelberi, Cichla piquiti* and *Plagioscion squamosissimus* (Gomiero and Braga, 2004; Hahn et al., 1998). Thus, we suggest that the presence of these species in Salto Grande Reservoir also may have contributed to the changes in composition of the fish fauna observed between the present study and the one of Dias and Garavello (1998).

The cascade system of reservoirs contribute effectively in the decrease of stocks of great migratory fishes, imposing a reorganization in the ichthyofauna, as observed by Santos and Formagio (2000) and Carvalho et al. (2005a), and for most of the High Paraná River reservoirs. This fact can be observed in the present study, since no large-sized species were collected, and no migratory species are among the most important species in any of the stretches, with the exception of *Pimelodus maculatus* at the downstream stretch, located 5 km far from the dam.

The samples with sieve and seining net in shallow areas covered by macrophytes, 23 small sized or young fish species were sampled. It is known that these places develop important functions, such as the structural protection of habitats, food resources (Casatti et al., 2003), shelter for small-sized fish, grounds for fish spawning (Carvalho et al., 2005b), support for water quality, organic material supply and substrate for the fixation of the algae and periphyton (Smith et al., 2003; Winemiller and Jepsen, 1998). We reinforce the importance of this type of sampling in reservoirs, since twelve species were exclusively captured with this fishing gear, demonstrating the importance of this methodology in ichthyological surveys of fish fauna that inhabit the shallow areas.

The presence of young of *Acestrorhynchus lacustris, Astyanax altiparanae,* and the introduced species *Oreochromis niloticus, Brachypopomus pinnicaudatus* and *Hyphessobrycon eques* in littoral areas of the mouth of Pardo River in the Salto Grande Reservoir may indicate that such species are developing and completing their life cycle in this stretch. However, because of the selectivity of the fishing gears and low number of individuals, it may be necessary to carry out more collections to verify such assumption.

The cluster analysis indicate that the Dam and Pedra Branca stretches have similar fish fauna, while the Pardo River Mouth, due to differences in environmental attributes, such as high amount of suspended sediment (Nogueira et al., 2006), may lead to differences in the species composition in this site. In addition, the presence or absence of one or more species in a particular environment does not depend only on the specific conditions of the habitat, but also on the availability of resources such as food, refugee and places for reproduction (Lowe-McConnell, 1999; Orsi et al., 2004).

High species turnover among stretches was observed by the β diversity, particularly for the β_2, indicating that each locality has specific fish fauna structure and composition. In addition, the differences observed between β_1 and β_2 indicate that the local diversity (α) is important in the structure of fish assemblages (Harrison et al., 1992). According to Whittaker (1972), each species is distributed according to its own physiological and life-cycle characteristics and ways of relating to environment, adjusting to the conditions that the environment offers in terms of food and shelter.

The environmental characteristics and the distance of each site from the reservoir and between the areas sampled define the composition and abundance of fish assemblages. Information about littoral areas is fundamental to the understanding of the fish fauna, since these environments act as places for shelter, breeding and feeding for diverse fish species and other organisms.

In conclusion, the fish assemblages from the different stretches of Salto Grande Reservoir present variations in the species composition, number and biomass. Although being a small reservoir, it displays great habitat diversity, reflecting in the composition and structure of fish assemblages. In addition, among the registered species, nine are non-native, demonstrating the importance of the knowledge of the fish fauna and the permanent management to assist the administration and preservation of the aquatic ecosystem.

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