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## Spatial and temporal patterns and their influence on fish community at Ituparanga Reservoir, Brazil

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**Abstract:** The Ituparanga Reservoir is located at the Sorocaba River Basin, São Paulo State, Brazil. Five cities use the waters of this reservoir for human consumption. Despite this intensive use of the water resource, no study has been undertaken on the ichthyofauna of this reservoir. Collections were performed in nine sampling stations, where each three were located in the riverine, transitional and lacustrine zones. Fish specimens were collected using eight monofilament gillnets of 10 m length each, with varied mesh sizes, in the rainy and dry seasons, which corresponded to our spatial scale of analysis. Overall, 14 species of fish were identified, with the highest contribution from Characidae and Curimatidae. The most abundant species were: the “lambari”, *Astyanax fasciatus*, the “saguiú”, *Cyphocharax modestus*, the “lambari bocarra”, *Oligosarcus paranaensis*, and the “mandi”, *Iheringichthys labrosus*. Diversity tended to be higher during the dry season, although the difference was not statistically significant. Cluster analysis identified four season sampling groups differentiated by within-season distribution of species. Mantel's test showed that this distribution was little affected by environmental factors, suggesting that biotic factors were more important in determining the species distribution within the reservoir. Rev. Biol. Trop. 56 (4): 2005-2020. Epub 2008 December 12.

**Key words:** Sorocaba river, Ituparanga Reservoir, structure community, species diversity, species richness, ichthyofauna.

Reservoirs are important artificial ecosystems that modify the hydrological and ecological characteristics of a river (Tundisi 1993) and also cause the highest modifications to the physicochemical characteristics of a hydrographic basin (Agostinho & Zalewski 1996). These modifications subsequently affect the fish community structure (Godoy 1995). Notwithstanding these negative impacts, reservoirs contribute to the depuration of pollutants (Agostinho & Zalewski 1996), thereby serving as decantation areas (Petrere & Agostinho 1993).

Several studies reported the effects of damming on the fish community structure (Fernando & Holcick, 1991; Beaumord, 1991; Duncan & Kubecka, 1995). In this regard it is

worth mentioning those studies carried out in the reservoirs of the Paraná River Basin, especially at the Tiête River (Castro & Arcifa 1987; Romanini 1989; Castro 1994; Godoy 1995; Petrere 1996; Agostinho, Bini & Gomes 1997; Barrella 1998; Smith 1999; Smith & Petrere 2001; Smith *et. al.* 2002, Smith *et. al.*, 2003).

Damming, in some cases, can be an insurmountable barrier for any fish species, isolating sites and specific zones that otherwise would be routinely used for feeding or reproduction (Beaumord 1994; Godoy 1995; Agostinho & Zalewski 1996). This isolation can have a genetic effect on fish populations (Petrere 1985).

A reservoir creates a new, lentic environment, which is expected to impact on the also below remnant community above the dam

(Beaumord 1991; 1994). This community will suffer modifications related to a decrease in the abundance of some rheophilic species, and a concomitant increase in the number of species with a higher adaptive capacity for lentic environments, such as are the curimatids of the reservoirs of the Parana river basin (Castro & Arcifa 1987; Rodrigues, *et. al.* 1990; Barrella 1998; Smith & Petrere 2001) and *Hypophthalmus edentatus* and *Auchenipterus nuchalis* in the Itaipu reservoir (Agostinho *et. al.* 1994). According to Castro & Arcifa (1987), *Cyphocharax modestus* was the most abundant fish species in Southern Brazil reservoirs. Agostinho *et. al.* 1992 verified that before Itaipu damming, *Hypophthalmus edentatus* and *Auchenipterus nuchalis* were rare, but just after damming both became responsible for 20% of the catches.

This happens basically because not all species adapt to this new habitat, so that a reduction in fish diversity occurs. Given this background, the objective of the present work was to describe the fish community of Itapararanga reservoir in terms of its composition, spatial and temporal distribution, diversity and influences of environmental factors.

## MATERIALS AND METHODS

The Itapararanga reservoir is located in the head waters of the Sorocaba river, southeast Brazil. This reservoir receives water from the Sorocabaçu and Sorocamirim rivers, which, in turn, join to form the Sorocaba River (Fig. 1). The reservoir was built in 1912, has a drainage area of 851 km<sup>2</sup>, a maximum flow of 39.12 m<sup>3</sup>/s<sup>-1</sup> and a max volume of 286 millions of m<sup>3</sup>. The power generation capacity is 55 MW, and the mean annual production of 150 Gwh, is exclusively used by the large Votorantim Corporation. The reservoir is located at the municipality of Votorantim, but it also drains four other municipalities: Ibiúna, Mairinque, Alumínio and Piedade. All these five cities use the water of the reservoir for human consumption.

Samplings were performed in nine sampling stations (Fig. 1), where each three were located in the riverine, transitional and lacustrine zones. Fishes were collected using eight monofilament gillnets of 10 m length each, with varied mesh sizes (pairs of nets with 30, 40, 50, 60, 70, 80, 100 and 120 mm mesh sizes between opposite knots). Samplings were carried out in the rainy (January, February and March 1996) and dry (July and August 1996) seasons, which corresponded to our spatial scale of analysis. Gillnets were set overnight from 18:00 h to 06:00 h. The following information necessary for the environmental characterization of the Itapararanga reservoir were collected during sampling: water temperature, pH, transparency, dissolved oxygen, conductivity, presence or absence of the marginal vegetation and macrophyte vegetation, type of bottom (sandy, muddy or rocky) and depth.

Fishes captured were weighed (g), measured in cm (standard length). The specimens were preserved in formalin (10%). Identification was first performed using the identification keys of Britski (1972), Britski *et. al.* (1984) and later confirmed by Prof. Dr. Heraldo Britski of the Museum of Zoology, University of São Paulo. Voucher specimens were archived in the Museum of Zoology, University of São Paulo.

The following tools were used in studying the different aspects of the fish community: species richness and abundance plots (Magurram 1988), the Shannon-Wiener index of diversity (Magurram 1988) and the Whittaker plots, fit of the data for Log-Series, Lognormal, Geometric and Broken Stick models (Krebs, 1989) and jackknife estimation of species richness (Heltsh & Forrester 1983). Paired t-tests were used to compare differences in the Shannon-Wiener diversity index (in terms of number and weight) between the rainy and dry seasons. The sampling stations were grouped by their characteristics (water temperature, pH, transparency, dissolved oxygen, conductivity, presence or absence of the marginal vegetation and macrophyte vegetation, type of bottom

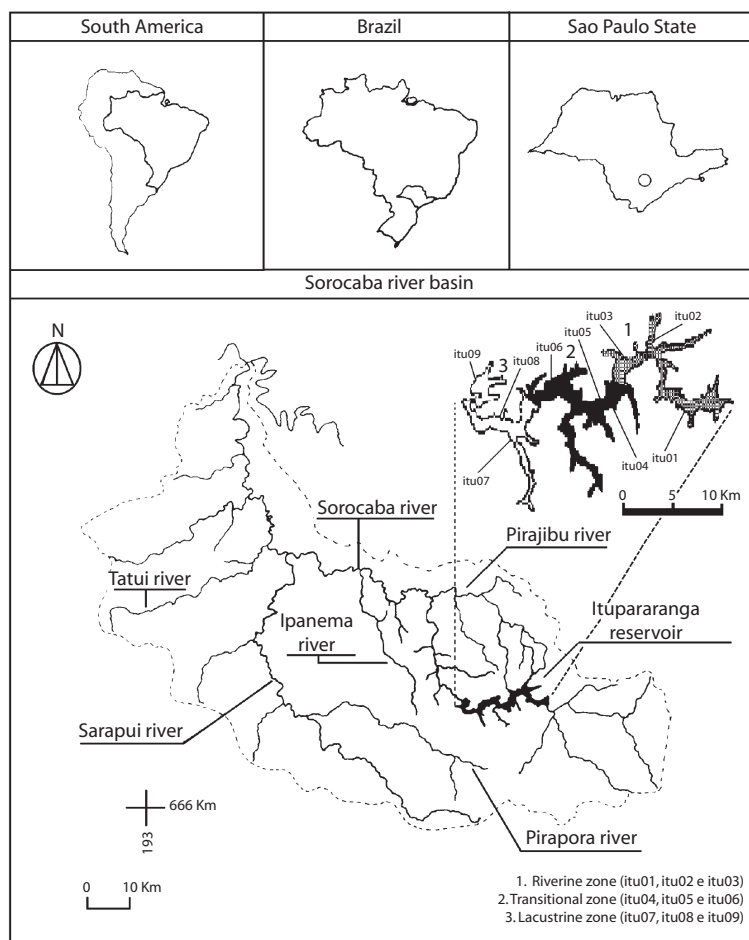


Fig. 1. The Sorocaba River basin, showing the location of the Itupararanga reservoir and the sampling stations.

(sandy, muddy or rocky) and depth) using Euclidian distance, as a metric and unweighted pair group method average (UPGMA) as the clustering method.

The fish species composition among sampling stations and seasons was compared using cluster analysis. Unweighted pair-group method using arithmetic averages (UPGMA) based on Morisita similarity coefficient (Manly 1986; Ludwing & Reynolds 1988) was used with the numerical abundance data. The cophenetic

correlations were calculated for all the dendrograms formed.

The Mantel/pairwise test was used to verify congruence between the similarity matrix (Morisita-Horn) for the abundance of fish species in the reservoir with the matrix (Euclidian distances) for the physical-chemical parameters of the sampling stations (Manly 1986; Ludwing & Reynolds 1988). Randomization was calculated with 10.000 permutations (Manly 1986; Ludwing & Reynolds 1988).

## RESULTS

**Environmental characterization of the Itupararanga Reservoir:** The abiotic variables for the nine sampling stations in Itupararanga reservoir, during the rainy and the dry seasons, are presented in Table 1. pH was higher than 7.0 at most stations, during both periods; dissolved oxygen was higher in the rainy season, with the lowest value being found during the dry season. Conductivity was low and oscillated between 51 and 63 $\mu$ S, indicating a low concentration of dissolved salts in the water as a consequence of the low dumping of sewage into the reservoir. Overall, the sampling stations showed a small depth, with presence of marginal vegetation. Macrophyte vegetation

and transparency, ranged between 0.4-0.5 m were observed for the stations itu01, itu02, itu05 and itu06 during the dry season. The bottom of most of the sampling stations were sandy; except stations itu04 and itu05, which were muddy, while station itu03 was rocky.

A clear distinction in environmental variables was discernible for the sampling stations during the rainy and dry seasons (Fig. 2). In the dry season, the most important variables for the grouping of the stations were those associated with habitat variables such as depth, bottom type and marginal vegetation. However, in the rainy season, physical and chemical variables were responsible for the grouping of the stations, as the within difference in these variables were higher during this season when

TABLE 1  
*Abiotic variables for 9 sampling stations in the Itupararanga reservoir during the dry (d) and rainy (r) seasons*

Stations	Temp	pH	Do	Cond	Trans	Mar	Mac	Sb	Mb	Rb	De
Itu01d	21.2	7.4	5.8	57	0.5	1	0.5	1	0	0	1.5
Itu02d	22.5	7.4	5.4	57	1	0	1	1	0	0	2
Itu03d	21.5	7.4	6.2	59	0.8	0	0	0	0	1	1.5
Itu04d	15.6	7.2	5.6	57	0.8	1	0	0	1	0	1.5
Itu05d	17	7.4	5.7	60	0.8	1	1	0	1	0	1.5
Itu06d	18.6	7.4	6	60	0.5	0.5	1	1	0	0	1.5
Itu07d	17	7.2	5.4	58	0.3	0.5	0	1	0	0	1
Itu08d	16.2	7.2	5.8	63	0.8	0.5	0	1	0	0	2.5
Itu09d	16	7.4	5.8	58	0.5	0.5	0	1	0	0	2
Itu01r	21.5	7.33	6.68	63	1	0.5	0	1	0	0	2
Itu02r	21	6.97	6.45	48	0.9	0.5	0	1	0	0	0.8
Itu03r	20.9	7.44	6.2	62	4	0.5	0	0	0	1	4.5
Itu04r	21	6.52	7.02	55	0.5	0.5	0	0	1	0	1.3
Itu05r	21	7.5	7.9	51	0.5	0.5	0	0	1	0	4
Itu06r	20	7.2	7.6	52	0.6	0.5	0	1	0	0	4.5
Itu07r	26	7.2	7.5	60	0.5	0.5	0	1	0	0	4.6
Itu08r	25	7.4	7.3	62	0.4	0.5	0	1	0	0	2.5
Itu09r	20.2	7.2	7.2	59	0.3	0.5	0	1	0	0	0.7

Temp ( $^{\circ}$ C) = temperature; Do (mg/l) = dissolved oxygen; Cond ( $\mu$ S.cm $^{-1}$ ) = conductivity; Trans (m) = transparency; Mar = marginal vegetation (0 = absence, 0.5 = 50% cover, 1.0 = 75%-100% cover); Mac = macrophyte vegetation (0 = absence, 0.5 = 50% cover, 1.0 = 75%-100% cover); Sb = sandy bottom (0 = absence, 1 = present); Mb = muddy bottom (0 = absence, 1 = present); Rb = rocky bottom (0 = absence, 1 = present); De (m) = depth.

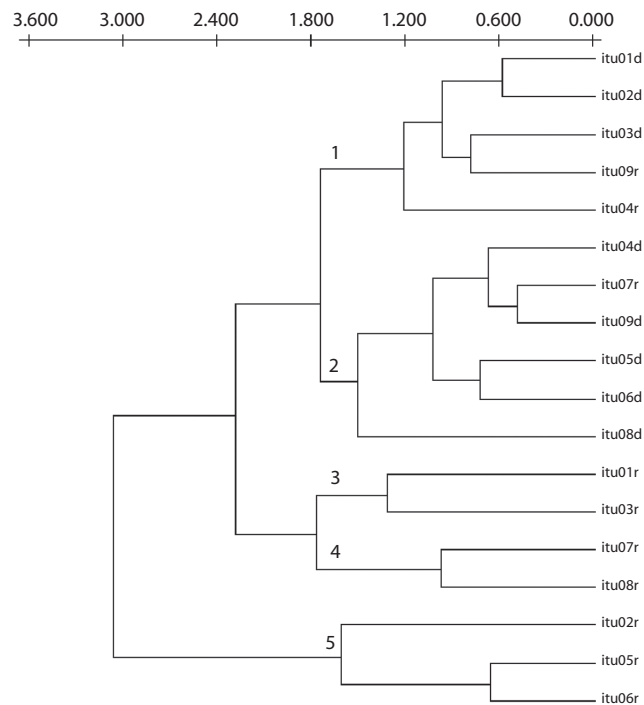


Fig. 2. Grouping of the sampling stations in the Itupararanga reservoir by abiotic variables, during the dry (d) and wet seasons (r). The cophenetic correlation coefficient obtained was  $r = 0.81$ .

compared to the values observed for the dry season. This differentiation might be related to the rains (summer), which modified the physical and chemical characteristics of the water by increasing the input of sediments and other compounds into the reservoir via the effluents.

The sampling stations were separated into five groups based on physico-chemical parameters. Group 1 was comprised by the stations itu01d, itu02d, itu03d, itu09r and itu04r, and is characterized by a low depth, low conductivity and low transparency. Group 2 was comprised by the stations itu04d, itu07d, itu09d, itu05d, itu06d and itu08d and was characterized by the lowest values of temperature and dissolved oxygen and the highest pH values. These were the stations with a sandy or muddy bottom, a depth of around 1.5 – 2 m, and where samplings were carried out in the dry season. Groups 3 and 4 were composed of the stations

itu01r, itu03r and itu07r, itu08r, respectively. They were characterized by higher values of conductivity and transparency as compared to the other groups. These stations were deeper and diverged from each other with respect to the bottom type. Finally, group 5 comprised the stations itu02r, itu05r and itu06r, and was characterized by the highest level of dissolved oxygen among all the groups, low values of conductivity and high depths. This group also contained stations sampled during the wet season (Fig. 2).

**Ichthyofauna: richness and species abundance:** Eight hundred and seventy two fish specimens belonging to 14 species from 9 families and 4 orders were collected. The family Characidae, mostly *Astyanax fasciatus* (Cuvier) represented 50% of the catch. Another important family in the reservoir,

mostly represented by *Cyphocharax modestus* (Steindachner), was the Curimatidae, with 19.4% of the captures (Table 2). The most abundant species in the total sampling were *Astyanax fasciatus*, *Cyphocharax modestus*, *Oligosarcus paranensis* (Menezes & Géry) and *Iheringichthys labrosus* (Kroeyer), with 313, 169, 115 and 110 individuals each (Table 2).

The species abundance curve (Whittaker plot), depicting the species richness and abundance in a decreasing order of importance (Fig. 3). Showed *Astyanax fasciatus*, *Cyphocharax modestus*, *Oligosarcus paranensis*, *Iheringichthys labrosus* and *Geophagus brasiliensis* were the most abundant species, with certain uniformity in abundance distribution, existing among them. In comparing Fig. 3 with theoretical curves (Krebs 1989; Margurram 1988) it was not possible to decide which model best fits the data for this community. Only the Log-Series ( $\alpha = 2.24$ ;  $x = 0.9977$ ;  $x^2 = 5.839 < x^2_{0.05,8} = 15.51$ ) and Lognormal

models (median = 0.9869;  $s^2 = 1.19$ ;  $S^* = 15.9$ ;  $x^2 = 10.21 < x^2_{0.05,6} = 12.59$ ) fitted the data for the Itupararanga reservoir, while it was not possible to adjust the data with the geometric and the Broken Stick models.

In relation to the mean weight of the individuals, *Rhamdia quelen* (Quoy & Gayard) (286.7 g), *Hoplias malabaricus* (Bloch) (253.7 g) and *Hoplosternum litoralle* (Hancock) (100 g) were the heaviest fishes sampled from the reservoir. On the other hand, *Hypostomus ancistroides* (Ihering) and *Sternopygus macrurus* (Bloch & Schneider), registered the lowest mean of 7 g each. In terms of length, *Gymnotus carapo* (Linnaeus) (30 cm), *Rhamdia quelen* (27.2 cm) and *Hoplias malabaricus* (23.13 cm) registered the highest mean standard length, while *Tilapia rendalli* (Linnaeus) (6.8 cm), *Hypostomus ancistroides* and *Sternopygus macrurus* (both 7.7 cm) registered the lowest mean standard length (Table 2).

TABLE 2  
Abundance, total weight (g), mean weight (g), and mean standard length (cm)  
of the species collected at the Itupararanga reservoir

Species	Code	Abundance	Percentage	Authorities	Total weight	Mean weight	Mean standard length
<i>Hoplias malabaricus</i>	sp01	14	1,61%	Bloch	3805	271.8	24.8
<i>Astyanax fasciatus</i>	sp02	313	36%	Cuvier	2377	29.7	13.2
<i>Gymnotus carapo</i>	sp03	1	0,11%	Linnaeus	25	25	30
<i>Hoplosternum litoralle</i>	sp04	1	0,11%	Hancock	100	100	15
<i>Acestrorhynchus lacustris</i>	sp05	11	1,26%	Reinhardt	200	25	30
<i>Tilapia rendalli</i>	sp06	2	0,23%	Linnaeus	15	7.6	6.8
<i>Geophagus brasiliensis</i>	sp07	99	11,36%	Quoy & Gainard	685	100	15
<i>Rhamdia quelen</i>	sp08	3	0,34%	Quoy & Gainard	860	286.7	27.2
<i>Pimelodus maculatus</i>	sp09	3	0,34%	Pacépèd	50	16.7	13.6
<i>Iheringichthys labrosus</i>	sp10	110	12,6%	Kroeyer	3460	31.5	13.4
<i>Cyphocharax modestus</i>	sp11	169	19,4%	Steidachner	6303	37.3	12.7
<i>Hypostomus ancistroides</i>	sp12	25	2,87%	Ihering	742	7,0	7.7
<i>Oligosarcus paranensis</i>	sp13	115	13,2%	Menezes & Géry	2173	18.2	10.8
<i>Sternopygus macrurus</i>	sp14	5	0,57%	Bloch & Schneider	35	7.0	7.7
TOTAL		871	100%		20830		

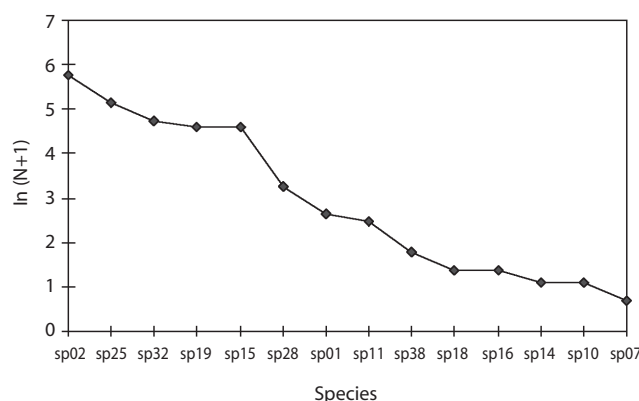


Fig. 3. Whittaker plot for the total collection of fish sampled at the Ituparanga reservoir.

**Spatial and Temporal Patterns of the Fish Community and the Influence of Environmental Factors:** The higher richness was detected in the riverine zone, when compared with transitional and lacustrine (Table 3). In the dry season, fish were more abundant in the transitional and riverine zones. In the other hand in the high water season fish were less abundant in the riverine zone. In conclusion the higher abundance in the transitional zone is due to the higher dominance of *Astyanax fasciatus*, *Iheringichthys labrosus* and *Geophagus brasiliensis*. These species also occur in the riverine zone together with *Cyphocharax modestus* and *Oligosarcus paranensis*. In this zone the numerical abundance of fish was more even.

The spatial distribution of the species (Fig. 4) indicated that *Hoplias malabaricus*, *Astyanax fasciatus*, *Cyphocharax modestus*, *Oligosarcus paranensis*, *Geophagus brasiliensis* and *Iheringichthys labrosus* were widespread throughout the reservoir. Among them, only *Iheringichthys labrosus* and *Hypostomus ancistroides* inhabited areas with flowing waters, while most of the other species were typical of lentic habitats. *Iheringichthys labrosus*, *Rhamdia quelen* and *Sternopygus macrurus* were mostly captured in the main channel of the reservoir, while *Hoplias malabaricus*, *Astyanax fasciatus*, *Geophagus brasiliensis*

and *Hypostomus ancistroides* were captured in greatest numbers in the arms of the reservoir.

Stations itu01, itu02, itu06, itu07, itu08 and itu09 had a sandy bottom; stations itu04 and itu05 had a muddy bottom and station itu03 a rocky bottom. High rates of capture occurred in stations with sandy bottom, which was the predominant type in the reservoir. Moreover, in the arms of the reservoir there was the highest concentration of marginal vegetation, thus providing a high number of shelters and feeding places.

A cluster analysis carried out in the abundance matrix of the species in the sampling stations, during the dry and wet seasons, discriminated 4 distinct groups due to the differences in numerical abundance of fish species (Fig. 5). Group 1 being formed by the stations itu01, itu02 and itu04 in the dry season. Were characterized by a high abundance of *Astyanax fasciatus* and *Oligosarcus paranensis*, suggesting either the utilization of the same resource by either species or a predator-prey relationship.

Group 2 was comprised the stations itu05 and itu06 in the dry season, and of the station itu01 in the wet season. A high abundance of *Cyphocharax modestus* and *Oligosarcus paranensis* was observed for this group. Again this pattern could be due to a predator-prey

TABLE 3  
Abundance of fish species captured per station and per season

Season	Dry itu									Wet itu								
Sampling station	01	02	03	04	05	06	07	08	09	01	02	03	04	05	06	07	08	09
Characiformes																		
Erythrinidae																		
<i>Hoplias malabaricus</i>	1	1			1	1		1	1	2				3		1		3
Characidae																		
<i>Astyanax fasciatus</i>	11	10	14	21	7	15	3	1	2	3		17	100		1	27	25	29
<i>Acestrorhynchus lacustris</i>							4	7										
<i>Oligosarcus paranensis</i>	9	3	10	9	8	30		1		5	1	2	7	8	5	12	3	2
Curimatidae																		
<i>Cyphocharax modestus</i>	5	44	8	8	12	19	6	6	10	5	8		24	2			3	9
Siluriformes																		
Loricaridae																		
<i>Hypostomus ancistroides</i>	3	1		4		8	3		1		1				1		2	
Pimelodidae																		
<i>Pimelodus maculatus</i>		1		1				1										
<i>Iheringichthys labrosus</i>				1						1	4	1	4	12	76	8	3	
<i>Rhamdia quelen</i>															2	1		
Gymnotiformes																		
Gymnotidae																		
<i>Gymnotus carapo</i>	1																	
Sternopygidae																		
<i>Sternopygus macrurus</i>							1		3									
Callichthyidae																		
<i>Hoplosternum litoralle</i>	1		1															
Perciformes																		
<i>Geophagus brasiliensis</i>	1		6	1	4	1	1	3	2	4	9	1	4	23	18		15	6
<i>Tilapia rendalli</i>	1										1							
Total	32	60	39	45	32	74	18	20	19	20	24	21	139	48	103	49	51	49

relationship or, by a resource partitioning mechanisms acting to avoid competition for shelter.

Group 3, comprised the stations itu03, itu04, itu05, itu07, itu08 and itu09 in the wet season, had a high abundance of *Astyanax fasciatus*, *Oligosarcus paranensis*, *Geophagus brasiliensis* and *Iheringichthys labrosus*. Group

4, comprised stations itu02, itu07, itu08 and itu09 in the dry season, and itu02 in the wet season, had a high abundance of *Astyanax fasciatus*, *Cyphocharax modestus*, *Gymnotus carapo* and *Acestrorhynchus lacustris*. Station itu06, during the wet season, was separated from the other groups as it showed a different pattern, with a high abundance of the predator

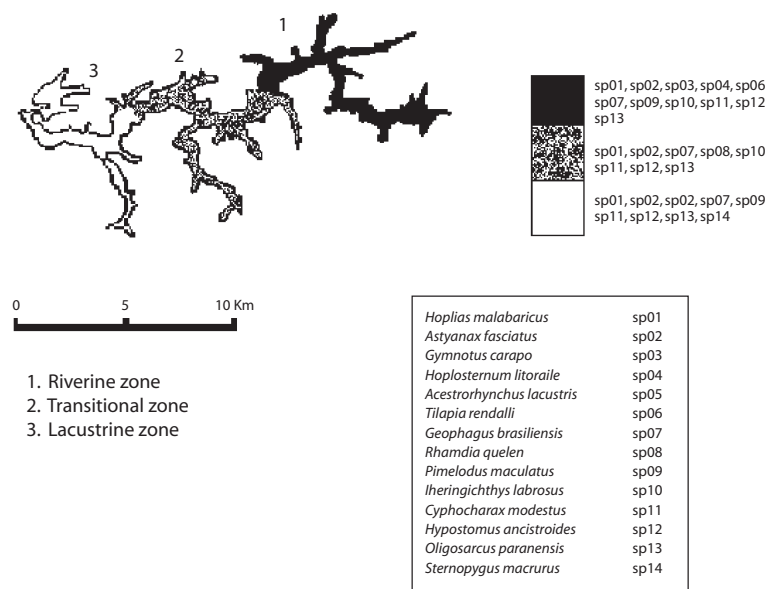


Fig. 4. Spatial distribution of fish species in the Itupararanga reservoir.

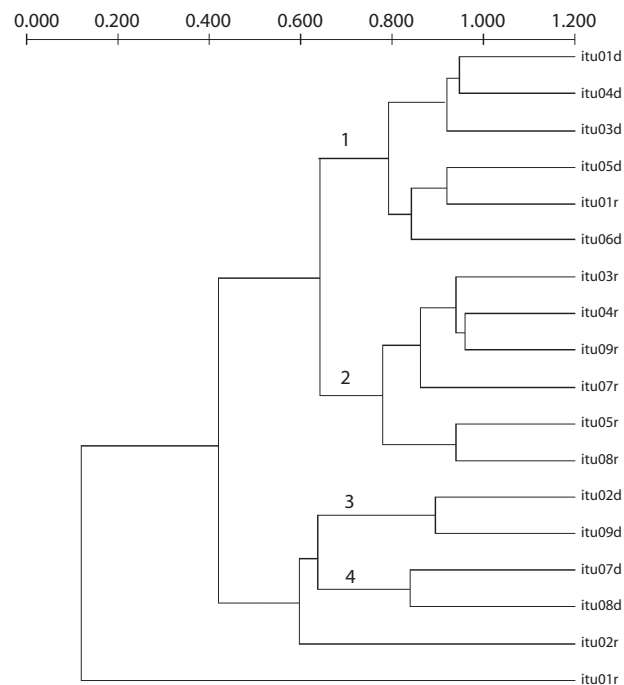


Fig. 5. Dendrogram of sampling stations in the Itupararanga reservoir during the dry (d) and wet seasons (r) clustered according to species abundance. The cophenetic correlation coefficient obtained was  $r = 0.82$ .

species, *Iheringichthys labrosus*. The Mantel test was used to analyze the effects of abiotic variables on the abundance pattern of the species in the sampling stations. The correlation was significant ( $r = -0.24$ ;  $P = 0.0096$ ), the results suggested that abiotic factors had effect on the abundance pattern.

**Fish Species Diversity:** The Shannon-Weiner diversity index for the reservoir was 2.7, while the values for each sampling station (with data from the total abundance) showed seasonal similarity. The highest diversity was found at station itu02 and the lowest at station itu03, with values of 2.57 and 1.97 respectively (Fig. 6). The three stations located on the riverine zone presented higher diversity when compared to the two others.

The diversity calculated for the nine sampling stations during the rainy and dry seasons is shown in Figure 7 (abundance) and Figure 8 (weight). Overall, diversity in abundance was higher during the dry season for most of the stations, although the difference has not statistically significant ( $t = 1.148$  with  $t_{0.05,8} = 2.316$ ). By comparing the stations with the highest

or the lowest diversity with their respective species richness and total abundance for each season, the resulting patterns were the same as observed for the basin as a whole. Stations with the highest diversity also possessed the highest species richness; this correlation was not so strong with respect to total abundance. In the rainy season the lacustrine zone presented higher diversities (itu01 and itu02) while in the dry season diversity was higher in the lacustrine zone stations.

It seems that there was an increase in the weight diversity of the samples close to the dam and those in areas located at the head of the reservoir, indicating higher diversities in weight from the riverine zone down river in both seasons.

Furthermore, a high difference was observed in the biomass diversity among the stations itu03, itu04 and itu06 between the dry and wet seasons. This observation reinforced the seasonal difference in weight diversity, with the highest values being found during the dry season (Fig. 8) although the difference was not statistically significant ( $t = 2.057$ ;  $t_{0.05,8} = 2.316$ ).

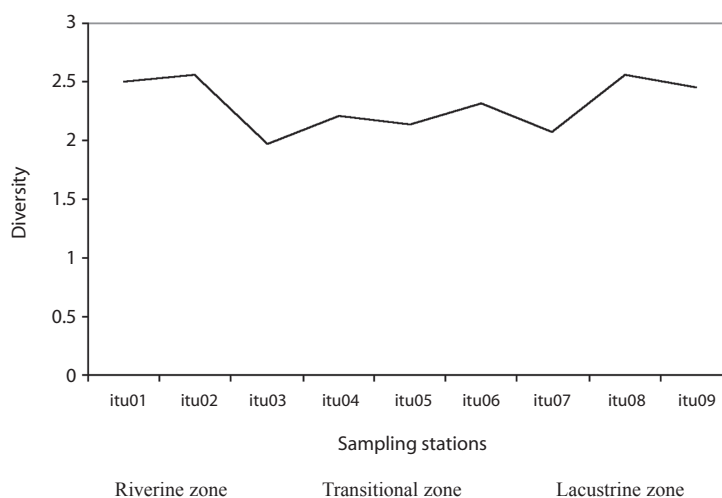


Fig. 6. Shannon diversity index for the Itupararanga Reservoir, using numeric abundance.

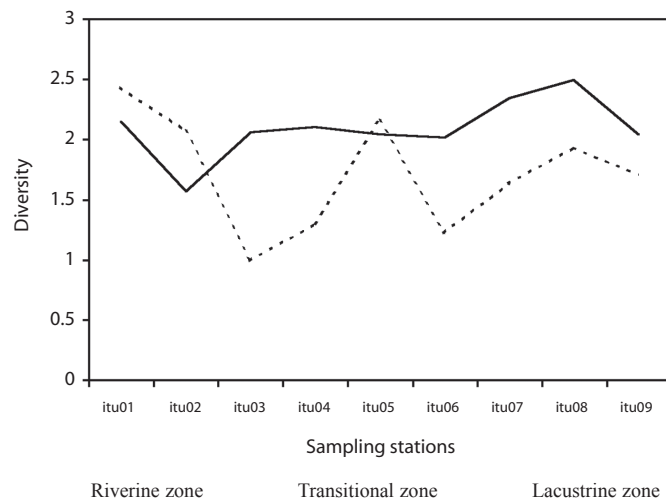


Fig. 7. Variation in numeric diversity in the sampling stations at the Itupararanga reservoir for the dry (—) and wet (---) seasons.

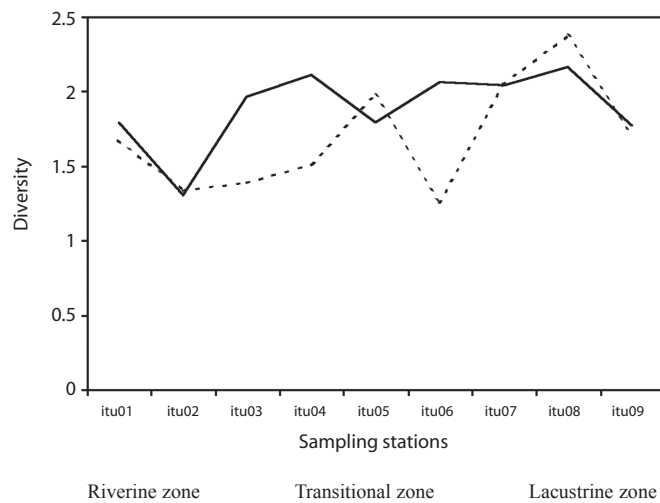


Fig. 8. Variation in the Shannon-Weiner diversity index, calculated from the biomass data, in the sampling stations at the Itupararanga reservoir for the dry (—) and wet (---) seasons.

## DISCUSSION

The low species richness found in the reservoir might be due to the fact that the area is close to the river head, thus presenting a lower richness and diversity than areas located below. Moreover, a decrease in species richness might have happened in the years following the dam constructions, due to a decrease in habitats suitable for reproduction and initial development of some species (Agostinho *et al.* 1997). These hypotheses however, are difficult to corroborate, as there is no study that attempted to follow species richness before and after the dam construction. Another interesting find is the higher richness in the riverine zone, perhaps due the presence in this area of those species also common downriver. This is confirmed by Agostinho *et al.* (1999) for the Itaipu reservoir.

Petrere (1996) reported several effects of the damming upon the ichthyofauna, the most important ones being related to the isolation of populations and a decrease in the number of migratory species. Damming, can constitute, in several cases, an insurmountable barrier for any fish species, isolating sites and specific zones of the river where some species normally use for reproduction or as a feeding area (Beaumord 1991; Godoy 1995). This is verified in the Itupararanga reservoir where migratory fish species were rare. By the other hand there is a dominance of *Astyanax fasciatus* and *Cyphocharax modestus*, better adapted to lacustrine biotops. These two species are partial spawners, do not care for the eggs and larvae and present high fecundity (Barbieri & Barbieri 1988; Barbieri & Hartz 1995). They also utilize with efficiency the local resources in this lacustrine zone.

Castro & Arcifa (1987) reported that the most abundant and frequent species at several reservoirs in the São Paulo State were *Geophagus brasiliensis*, *Hoplias malabaricus*, *Astyanax bimaculatus*, *Astyanax fasciatus*, *Tilapia rendalli* and *Cyphocharax modestus*. This observation was confirmed at the Itupararanga reservoir, where *Astyanax*

*fasciatus* and *Cyphocharax modestus* were the most frequent species. Besides the higher abundance in the transitional zone of *Astyanax fasciatus* and *Iheringichthys labrosus* is due probably the lentic characteristics and the habitat structure favorable to these species. Moreover, we cannot forget the influence of the sampling, therefore the devices of fish can have captured a shoal of fish of each species.

More recent studies at the Barra Bonita (Castro 1994), Promissão (Amaral & Petrere 1994) and Americana (Romanini 1989) reservoirs also corroborate these results. This similarity was expected, as all these reservoirs are located at the same hydrographic basin. It is noteworthy that, as far as the reservoirs at the Tiête River basin are concerned, the species with the highest level of pre-adaptation to a lentic environment are: *Geophagus brasiliensis*, *Hoplias malabaricus*, *Astyanax bimaculatus*, *Astyanax fasciatus*, *Cyphocharax modestus*, *Iheringichthys labrosus* and *Oligosarcus paranensis*.

The remnant fish community in the reservoir is derived from the ichthyofauna that already existed in the dammed river (Fernando & Holcick 1991; Castro & Arcifa 1987; Agostinho *et al.* 1997). Colonization is performed mainly by species pre-adapted to the lacustrine conditions of the new environment. This was clear in the damming stations both at the Sorocaba River and at its affluent. collected in the reservoir creeks basically the some species of the reservoir, as *Hoplias malabaricus*, *Steindachnerina insculpta*, *Rhamdia quelen*, *Iheringichthys labrosus* and *Oligosarcus paranensis*, which corroborates what was stated above.

Several factors are responsible for the structuring of fish assemblages in continental aquatic ecosystems (Agostinho *et al.* 1997). Physical-chemical factors are also important for structuring the fish community in a reservoir. This factor is directly determined by the operation of the reservoir and can eliminate or decrease the populations that spawn on the border of the reservoir (Castro & Arcifa 1987). Factors such as seasonality, water volume,

morphometry, retention time, intra and interspecific interactions and habitat structure can also affect the fish community structure of a reservoir (Agostinho *et al.* 1997). Amaral & Petrere (1994) concluded that environmental factors determined the first scale of the fish community structure at the Promissão reservoir.

Although there were abiotic differences between the sampling stations these were minimal. This seems to contribute to reduce the abiotic variables influences upon fishing communities, stressing the role played by biotic interactions.

The structuring of the fish community at the Itupararanga reservoir seems to be affected by the actual environmental characteristics, such as depth, bottom type, marginal and macrophytes vegetation, as these habitats are important as shelters and feeding areas (Petrere, 1996). These effects are more pronounced in the littoral zone of the reservoir (Fernando & Holcick 1991), as the abundance distribution in the sampling stations were little affected by the physical-chemical characteristics of the water (as indicated by the Mantel test), even though congruence, albeit small, existed between the abiotic data matrix and the abundance matrix.

The small congruence between the abundance and abiotic matrix might be due to the small number of variables used to characterize the habitats of the reservoir. Thus, a high congruence would have been expected, had we used a large number of different variables to characterize the reservoir.

The cluster analysis, using the environmental variables, clearly separated the sampling stations between the wet and dry seasons. In the dry season, the most important variables were depth, bottom type and marginal vegetation, while during the wet season the physical and chemical variables were responsible for clustering the stations. Thus, in the Itupararanga reservoir, depending on the time of the year, a series of different environmental variables may affect the spatial distribution of the fish community.

Despite the wide distribution of species throughout the reservoir, the abundance is

affected by coexistence, an observation supported by the preponderance of different species in different seasons. The cluster analysis of the sampling stations showed that, in stations where *Astyanax fasciatus* and *Cyphocharax modestus* were predominant, only one species of predator occurred, normally *Oligosarcus paranensis*. On the other hand, stations with a high abundance of *Astyanax fasciatus*, *Cyphocharax modestus* and *Geophagus brasiliensis*, showed a high number of predators, since the food availability also increased. Accordingly to Matthews (1998), areas with a high number of piscivorous also show a high number of prey. Agostinho *et al.* (1997) also confirmed that interspecific interactions, especially predation, were the main processes affecting the distribution and composition of the fish community in a reservoir.

The separation of these groups was based on the abundance data, suggesting the existence of different patterns, which were linked to the habitat structure and biotic relationships. These patterns can be resumed into four types: 1) coexistence between *Astyanax fasciatus* and *Oligosarcus paranensis*; 2) coexistence between *Cyphocharax modestus* and *Oligosarcus paranensis*; 3) coexistence between *Astyanax fasciatus*, and *Geophagus brasiliensis*, associated with other carnivorous species such as *Hoplias malabaricus*, *Oligosarcus paranensis*, and *Iheringichthys labrosus* and 4) coexistence between *Astyanax fasciatus* and *Cyphocharax modestus* with other carnivorous species such as *Acestrorhynchus lacustris* and *Sternopygus macrurus*.

The coexistence pattern observed at Itupararanga reservoir may be an indication of competitive exclusion (niche segregation) or habitat use, since the *Astyanax fasciatus* and the *Geophagus brasiliensis* are omnivorous, feeding on insects, plants and crustaceans. On the other hand, *Rhamdia quelen*, *Iheringichthys labrosus*, *Hoplias malabaricus* and *Oligosarcus paranensis* are carnivorous and *Cyphocharax modestus* is an illiophagous (Romanini 1989). Analysis of stomach contents is needed to corroborate this hypothesis. Although the

correlation was significant (Mantel's test), the results suggested that abiotic factors had little effect on the abundance pattern. Thus, in the Itupararanga reservoir, the widespread distribution of the 14 identified species was mostly affected by biotic relationship.

The low diversity in Itupararanga reservoir may related to the high dominance. According to Agostinho *et. al.* (1999) diversity is higher in the riverine zone, in order to keep the original characteristics of the habitat. Another finding is that diversity is the same in both seasons. This may be explained that seasonal fish migration is negligible. Castro (1997) verified the same result in Barra Bonita reservoir. Gido & Matthews (2000) suggest that fish assemblages in reservoirs present low temporal variability as its composition is composed by species tolerant to damming consequences, as in Itupararanga.

The Itupararanga reservoir presents homogeneous abiotic characteristics, it is shallow, with low water conductivity, high transparency presenting good drinking water quality. Its fish fauna is relatively poor, due to its location near to the headstreams. There is a predominance of lentic pre-adapted fish species. It seems that interactions between species play a major role than abiotic factors in order to structure of the fish community. Seasonal variations in fish diversity were not verified.

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#### RESUMEN

El embalse Itupararanga está localizado en la cuenca del río Sorocaba, estado de São Paulo, Brasil, donde cinco ciudades usan sus aguas para consumo humano. A pesar del uso intensivo del recurso agua, ningún estudio se ha llevado a cabo para investigar la ictiofauna de este embalse. Recolectamos los peces en estación seca y lluviosa, en nueve estaciones de muestreo, tres estaciones en cada

zona (riverina, transicional y lacustrina). Los peces se recolectaron con ocho atarrayas de un filamento de 10 m cada una. En total, hallamos 14 especies de peces, con la contribución más alta de Characidae y Curimatidae. Las especies más abundantes fueron: el "lambari", *Astyanax fasciatus*, el "saguiru", *Cyphocharax modestus*, el "lambari bocarra", *Oligosarcus paranaensis*, y el "mandi", *Iheringichthys labrosus*. La diversidad tendió a ser mayor durante la estación seca, aunque la diferencia no fue estadísticamente significativa. El análisis identificó cuatro grupos de estaciones de muestreo diferenciadas con base en la distribución de especies dentro de cada estación. La prueba de Mantel mostró que esta distribución fue poco afectada por factores ambientales, lo que sugiere que los factores bióticos fueron más importantes al determinar la distribución de especies dentro del embalse.

**Palabras clave:** río Sorocaba, embalse Itupararanga, estructura de la comunidad, diversidad de especies, riqueza de especies, ictiofauna.

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