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Ichthyofauna of the Ribeirão Taboão, Paraíba do Sul river basin, Mogi das Cruzes, SP

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Abstract: We present herein a list of fish species from Ribeirão Taboão, a tributary of Rio Paraíba do Sul basin that is located in the metropolitan region of São Paulo. Fish were caught with trapezoid hand nets, mesh nets and fish traps. We sampled 145 specimens, belonging to 18 species, distributed in eight families and six orders. The most representative order was Characiformes, with six species, followed by Siluriformes with five species, Gymnotiformes with three species, Labriformes with two species, and Cyprinodontiformes and Synbranchiformes with a single species each. The four more abundant species were the livebearer *Phalloceros reisi*, the catfish *Imparfinis piperatus*, the cichlid *Geophagus brasiliensis* and the tetra *Astyanax* aff. *fasciatus*, which summed approximately 66% of the total sampled specimens. The 18 species of fish sampled in the present study correspond to almost 5% of the species registered for the Rio Paraíba do Sul drainage in the State of São Paulo, indicating a high diversity for a headwater stream. Endangered or introduced species were not found, but five species remain with indefinite taxonomical status.

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Introduction

The São Paulo metropolitan region has nearly 9,300 km^2 in area with approximately 21 million inhabitants (Secretaria dos Transportes Metropolitanos 2013). Mogi das Cruzes is situated east of São Paulo City, being part of the metropolitan region with approximately 710 km^2. Mogi das Cruzes City is drained by headwaters of the Rio Tietê basin as well as by streamlets of the upper Rio Paraíba do Sul (Prefeitura do Município de Mogi das Cruzes 2013). The latter river is formed by the confluence of the Rio Paraitinga and the Rio Paraibuna, at the Bocaina Mountain Chain, São Paulo State, and runs eastwards until it empties in the Atlantic Ocean in the district of Atafona, northern Rio de Janeiro State (Comitê das Bacias Hidrográficas do Paraíba do Sul 2013).

The Rio Paraíba do Sul basin has an important role in southeastern Brazil as it crosses three of the most populated states in the country (São Paulo, Minas Gerais and Rio de Janeiro), covering an area of 57,000 km^2 with high demographic density and industrialization (Castro and Menezes 1998, Bizerril 1999, Araújo *et al.* 2003, Melo *et al.* 2006). The impacts due to this historic occupation of the area resulted in drastic changes to the local water bodies that have decreased the local fish diversity, especially in São Paulo State, the most populated area of the basin. The human activities representing the most significant changes in the aquatic environment includes cattle and agriculture (coffee, greens, flowers and eucalyptus), deforestation of the marginal vegetation along the headwaters of rivers, sand mining, untreated domestic and industrial sewage discharge, establishment of industrial sites along the water bodies, canalization and damming of rivers for different purposes, and the installment of port complexes (Bizerril 1999, Araújo *et al.* 2001, Teixeira *et al*. 2005, Mattox and Cunningham 2010).

The Paraíba do Sul drainage has at least 167 known species (Bizerril, 1994, 1999). In São Paulo State, the Rio Paraíba do Sul basin houses 71 fish species belonging to 18 families, 18% of the known species in the whole state (Oyakawa and Menezes 2011). Despite of the major cited impacts registered for the region including Mogi das Cruzes, the Ribeirão Taboão presents relatively well preserved portions and is, therefore, of great importance for the maintenance of local fish biodiversity. The present study aims to describe the ichthyofauna from the Ribeirão Taboão, emphasizing on a few ecological features of its fishes.

Materials and Methods

Study Area

The Ribeirão Taboão belongs to the upper Paraíba do Sul drainage, municipality of Mogi das Cruzes, approximately 50km in a straight line from the center of São Paulo City. The region belongs to the Tropical Atlantic Domain (Ab'Saber 1977) with remains of Atlantic Rainforest. The studied area is located near the upper Rio Tietê basin (Paraná basin), in the far west of the Paraíba do Sul basin belonging to the upper reaches of this drainage (Teixeira *et al*., 2005).

Five stations were sampled along the stream, which are listed and described below (Figure 1 and Table 1).

Sampling

Samples were taken at July 31st and August 1st in five stations sampled for three hours each one. Trapezoid hand nets with 1m^2 of area and 0.1cm of internode distance

were used in stations 2-5, in addition to seine nets 2-3m wide, 1.5m deep and 1.5-2cm of internode distance. Since Station 1 presented a different landscape from the other stations, it was sampled with mesh nets 10-20m wide, 1.5m deep and 2-5cm of internode distance, in addition to fish traps approximately 1m long and 15cm wide when mounted. Fish traps were baited with commercial dog and cat food. Mesh nets and fish traps operated for 3 hours. Each station was photographed and georeferenced with a GPS device. Abiotic data such as depth, water transparency and soil were observed *in situ*. Stations were sampled in different periods of the day to cover all diel cycle following common recommendations for this type of survey (Mattox and Cunningham 2010).

Collection permit was granted by Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis (SUPES/SP 119/2010, registration number IBAMA 57217). Fish were anesthetized with clove-oil (10ml/liter), put in plastic bags, fixed in formalin for 48 hours and transferred to 70% ethanol. The material was then counted and identified to the lowest level possible using specific studies on Neotropical fishes (Britski 1972, Géry 1977, Albert *et al.* 1999, Oyakawa *et al.* 2006, Menezes *et al.* 2007, Lucinda 2008, Ottoni and Costa 2008, Oyakawa and Mattox 2009; Marceniuk and Hilsdorf 2010; Barbosa and Costa 2012) and comparisons with material deposited in the fish collection. Voucher specimens were deposited in the fish collection of Museu de Zoologia da Universidade

Figure 1. Map of the study area (Ribeirão Taboão, upper Paraíba do Sul basin, Mogi das Cruzes, SP) showing the five stations sampled in the present survey.

Table 1. Sampling Stations located on Ribeirão Taboão, upper Paraíba do Sul basin, Mogi das Cruzes, SP.

STATION	PLACE	GEOGRAPHIC COORDINATES	TRAPS	DESCRIPTION OF THE STATION
1	Lagoon near Ribeirão Taboão	23°24′06″ S, 46°13′35″ W	Mesh nets and fish traps	Slow to still waters with its margins poorly vegetated. Soil composed of mud and clay. Water with low transparency and dark muddy coloration due to high amount of suspension matter
2	Ribeirão Taboão near Station 1	23°24′05″ S, 46° 13′36″ W	Hand nets and seine nets	Medium current with little to moderate amount of marginal vegetation. Soil composed of mud, clay and sand. Water more transparent than previous station. Part of the station was silted.
3	Ribeirão Taboão at its confluence with Rio Parateí	23°23′14″ S, 46°13′44″ W	Hand nets and seine nets	Medium to fast flow with little marginal vegetation. Soil composed of mud, clay and rocks. Water with dark coloration and high amount of suspension matter, garbage and construction wastes with a small human settlement and a pig farm upstream.
4	Flooded area along Ribeirão Taboão	23°24′38″ S, 46°13′34″ W	Hand nets	Slow current with moderate amount of marginal vegetation, including aquatic plants such as *Typha* sp. ("*taboa*"). Soil composed of mud and clay. Water transparency similar to that of Station 2.
5	Ribeirão Taboão	23°24′47″ S, 46°13′32″ W	Hand nets	Fast current with moderate amount of marginal vegetation, predominantly grasses. Soil composed of mud and clay. Water transparency similar to that on the previous station. Station 5 includes a vast flooding plain with many small pools along the stream, with the main channel fitting a deep valley of 1-2,5m, approximately 1-2m wide.

de São Paulo (MZUSP) and their catalog numbers are given in table 2. The list of species is organized in systematic sequence of orders and families following Nelson (2006), Buckup *et al*. (2007) and Wiley and Johnson (2010), with genera listed in alphabetical order within each family. The trophic category of each sampled species follows Oyakawa *et al.* (2006), Menezes *et al.* (2007), Marceniuk and Hilsdorf (2010) and Araújo *et al.* (2003). *Gymnotus carapo* Linnaeus, 1758 was categorized as piscivorous (Winemiller, 1989), carnivorous (Pereira and Resende, 2006), invertivorous (Pompeu and Godinho, 2006) and omnivorous (Braga and Gomiero, 2009) in the literature. These differences can be due to taxonomic issues in *G. carapo* or to the effect of feeding plasticity of the species in different sampling sites (Abelha *et al.* 2006). In order to better characterize the diet of *Gymnotus carapo*, *Gymnotus pantherinus* (Steindachner, 1908) and *Gymnotus sylvius* Albert & Fernandes-Matioli, 1999 and trying to minimize the effect of feeding plasticity we characterized the diet of these species according to Braga and Gomiero (2009), a study developed at the Serra da Mantiqueira, São Paulo, Brazil.

Conservation status of each species was verified in the studies of Buckup *et al.* (2007), Rosa and Lima (2008) and Oyakawa *et al.* (2009).

Specimens were counted for each species and sampling stations, and the data were organized in tables and graphs.

Results and Discussion

A total of 145 specimens from 18 species belonging to eight families and six orders were sampled along the five stations (Table 2). The most diverse order was the Characiformes with six species sampled. Characidae was the most species-rich family of the order. Siluriformes was the second most diverse order with five species sampled, three of them belonging to the Heptapteridae. We sampled three species of Gymnotiformes, all of them gymnotids. The order comprises species capable of intraspecific electromagnetic communication and are usually poorly sampled due to their habit of hiding among the marginal vegetation among plants, rocks and tree trunks (Oyakawa *et al*. 2006; Menezes *et al*. 2007). We also sampled two species of the Labriformes belonging to the Cichlidae , one species of the Cyprinodontiformes, *Phalloceros reisi*, and two juveniles of the swamp-eel *Synbranchus marmoratus* Bloch, 1795 (Order Synbranchiformes), a widespread species in South America (Kullander 2003) (Figure 2).

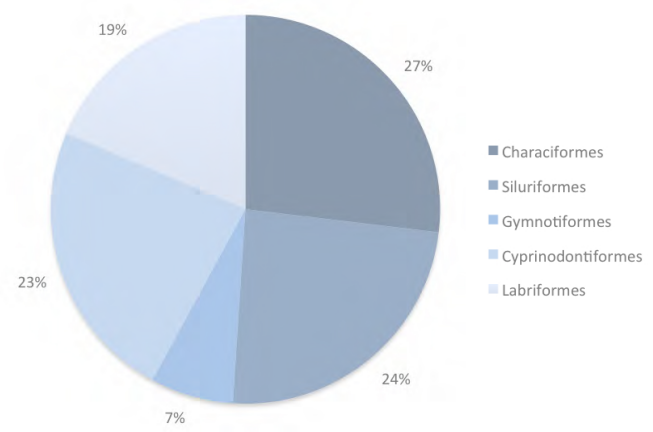

Figure 2. Relative diversity of species among the six orders registered in Ribeirão Taboão, upper Paraíba do Sul basin, Mogi das Cruzes, SP.

Eight of the 18 species sampled herein were already mentioned to the Rio Paraíba do Sul basin by Bizerril (1999), that registered a total of 120 species for the entire basin. More recently, Teixeira *et al.* (2005) registered 81 species for the entire Rio Paraíba do Sul basin, nearly 22% of which are species registered in the present study. Considering only the portion of Rio Paraíba do Sul basin in São Paulo State, Oyakawa and Menezes (2011) registered 71 species. In addition, considering Braga (2004), Braga and Andrade (2005), Oyakawa and Menezes (2011) and Rondinelli *et al.* (2011) 11 of the 18 species of fish sampled herein were registered previously in the Rio Paraíba do Sul basin in São Paulo State.

According to Bizerril (1999), the Siluriformes was the most diverse order in the Paraíba do Sul, followed by the Characiformes, however, Teixeira *et al.* (2005) registered the Characiformes as the most diverse order. Most species of Siluriformes are dependent on the substrate as they are inhabitants of the bottom of water bodies such as *Hypostomus ancistroides* (Ihering, 1911), *Rineloricaria* sp. and *Imparfinis piperatus* Eigenmann & Noris, 1900, species typical of fast flowing waters. The studied sampling sites are mostly characterized by medium to slow water, which can explain the lower frequency of Siluriformes in comparison to Characiformes registered in our study.

The four more abundant species in the sampled area were the livebearer *Phalloceros reisi* Lucinda, 2008, the catfish *I. piperatus*, the cichlid *Geophagus brasiliensis* Quoy & Gaimard, 1824 and the tetra *Astyanax* aff. *fasciatus*, which summed 96 specimens sampled, approximately 66% of the total sampled specimens. Araújo *et al.* (2001) registered two omnivore species as the most abundant species in their study. According to Odum (1969) and Krebs (1985), with shifts in natural resources, species with specifics foraging habits tend to be substituted by opportunistic species due to the limited amount of food or to the incapacity to tolerate the environmental changes on biotic and abiotic factors. High abundances of opportunistic species in impacted environments of the Rio Paraíba do Sul drainage have been already reported in the current literature (*e.g.* Pinto *et al.* 2006).

The most constant species was the cichlid *G. brasiliensis*, which was found in all sampling stations, followed by the livebearer *P. reisi*, registered in four of the five sampling stations. Two species were registered only at Station 1, *Oligosarcus hepsetus* (Cuvier, 1829) and *Australoheros* sp., and two species occurred exclusively at Station 2, the armored catfishes *H. ancistroides* and *Rineloricaria* sp. The knifefish *Gymnotus sylvius* Albert & Fernandes-Matioli, 1999 was sampled solely at Station 3 and the knifefish *G. pantherinus* and the swamp-eel *Synbranchus marmoratus* Bloch, 1795 were captured only at Station 5.

In the spatial context, the sites with higher species richness were Stations 2 and 5, with 12 and 11 species sampled respectively (Figure 3). At the station 3, located more downstream, near the confluence between Ribeirão Taboão and Rio Parateí, was registered the lowest number of species and abundance, with only three specimens of two species (two livebearers *P. reisi* and one knifefish *G. sylvius*, a species exclusive of this station). This

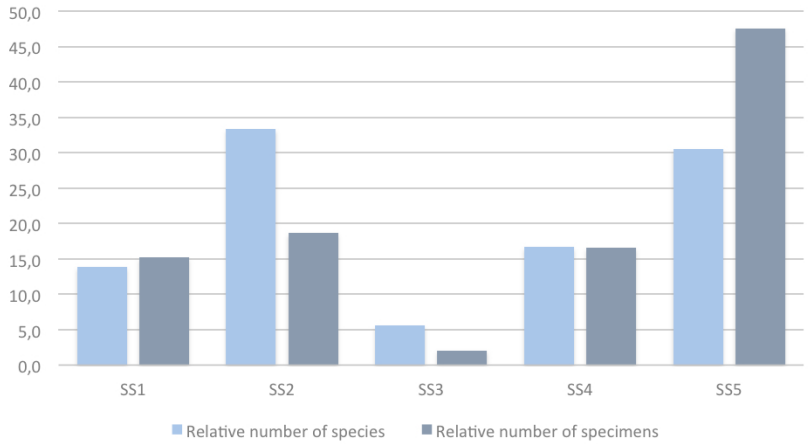

Figure 3. Relative abundance of number of species and number of individuals registered in each sample station in Ribeirão Taboão, upper Paraíba do Sul basin, Mogi das Cruzes, SP.

unexpected result can be explained by the high degree of anthropogenic alterations in this area due to the discharge of sewage from livestock and possibly the contamination of a clandestine sanitary landfill as mentioned by some local settlers. In contrast, far from the confluence between Ribeirão Taboão and Rio Parateí (*i.e.*, Station 5), the Ribeirão Taboão has fast current and a moderate amount of marginal vegetation, including a vast flooding plain with many small pools along the stream, with the main channel fit in a deep valley of 1-2.5m, approximately 1-2m wide. These characteristics can explain the highest number of species registered in the area. Station 2 is also far from the confluence between Ribeirão Taboão and Rio Parateí, and has moderately preserved environment putting this station among the ones with the highest species richness registered.

Considering the trophic structure of the ichthyofauna, we verified that it is composed of invertivores, carnivores, piscivores, herbivores and omnivores that feed either on vegetal matter or animal matter, including scales such as the tetra *Probolodus heterostomus* Eigenmann, 1911, a species endemic of the coastal rivers of southeast Brazil (Oyakawa *et al*. 2006; Menezes *et al*. 2007). Approximately 17% of the species sampled were carnivores, 28% were invertivores, 33% omnivores and 11% herbivores. Approximately 11% of the specimens collected were exclusively piscivorous species, including the pike-characin *Oligosarcus hepsetus* and the trahira *Hoplias malabaricus* (Figure 4).

It is interesting to mention that invertivorous and carnivorous species summed up to 45% of the sampled specimens, demonstrating the high importance of the terrestrial environment in providing food items for the local ichthyofauna, for example larvae and adult insects. Hence, it is possible that radical alterations in the terrestrial environment may cause considerable changes in the ichthyofauna due to the availability of food items.

According to Karr (1981), Araújo (1998) and Araújo *et al.* (2003) the analysis of the trophic structure of a given fish community is an interesting tool for evaluation of environmental degradation. Karr (1981) and Araújo (1998) cited that an area can be analyzed using three major criteria: the proportions of omnivorous and insectivorous species in the environment and the presence of top piscivores. Karr (1981) and Araújo (1998) mentioned a strong negative correlation between the proportion of omnivorous and insectivorous species in disturbed environments. In our study we found a high abundance of omnivorous species, however we also found a high abundance of insectivorous species. Contradicting Karr (1981) and Araújo (1998) that mentioned also the absence of top piscivores in disturbed environments, we registered two piscivorous species at the study area, constituting the top of the trophic chain in their environments. This may indicate that the environment studied is not highly disturbed despite its proximity to a dense urban area.

Four species could not be identified to the species level due to taxonomic problems of their genera and related species: the characiform *Astyanax* aff. *fasciatus* (Cuvier), the catfish *Pimelodella* cf. *lateristriga*, the armored catfish *Rineloricaria* sp. and the cichlid *Australoheros* sp.. *Rineloricaria* sp. may belong to an undescribed species (Fichberg, *pers. obs.*), so it is important to assure its maintenance in the study area to allow future studies. *Australoheros* sp. may constitute another undescribed species, highlightening the importance of the study area. *Astyanax* aff. *fasciatus* (Cuvier) and *Pimelodella* cf. *lateristriga* are taxa in need of further taxonomic studies. We did not find endangered or introduced species in the sampling stations.

Summarizing our main results, one-fourth of the total number of species known from the Paraíba do Sul drainage in the State of São Paulo were registered in the area of

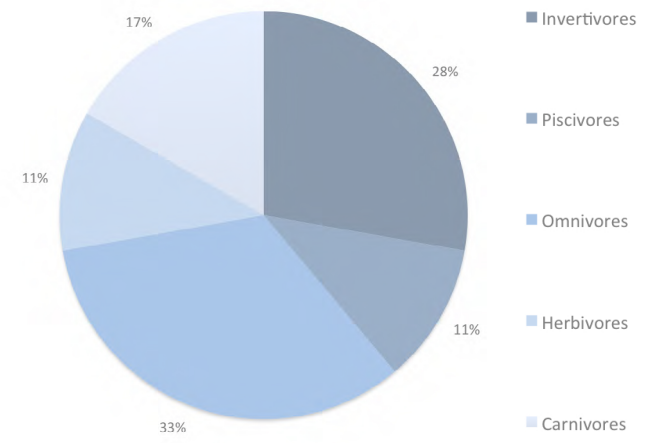

Figure 4. Relative number of species recorded in each of the five trophic categories in Ribeirão Taboão, upper Paraíba do Sul basin, Mogi das Cruzes, SP.

study. Also, we found a high number of invertivorous species, that rely on the terrestrial environment as a source of food items, and the presence of top piscivorous species, At last, the study area comprises at least one new species, and potentially two other new species.

Araújo (1998) and Araújo *et al.* (2003) found that the lowest quality in fish assemblages occurred near cities that receive large amount of organic and industrial pollutants. Even though our data include a relatively low number of species probably due to limited sampling, our main results added to the close proximity of the study area to large urban centers show the need of improved public policies aiming at the conservation of its ichthyofauna, as well as programs of environmental education to raise the awareness of local settlers regarding their land and its fishes.

Table 2. List of species registered in five sampling stations along Ribeirão Taboão, upper Paraíba do Sul basin, Mogi das Cruzes, SP. Trophic categories according to Oyakawa et al. (2006), Menezes et al. (2007), Marceniuk and Hilsdorf (2010), Araújo et al (2003) and Braga and Gomiero (2009): C – carnivore, H – herbivore, I – insectivore, O – omnivore, P – piscivore. Voucher specimens are deposited in MZUSP.

TAXON	TROPHIC CATEGORY	STATION					TOTAL SPECIMENS	VOUCHER MZUSP
		1	2	3	4	5		
Characiformes								
Characidae								
Astyanax aff. *fasciatus*	I	9	1				**10**	MZUSP 106521
Hyphessobrycon bifasciatus Ellis, 1911	I		3		3		**6**	MZUSP 106510
Hyphessobrycon luetkeni (Boulenger, 1887)	I		2			1	**3**	MZUSP 106509
Oligosarcus hepsetus (Cuvier, 1829)	P	5					**5**	MZUSP 106502
Probolodus heterostomus Eigenmann, 1911	O		1			7	**8**	MZUSP 106505
Erythrinidae								
Hoplias malabaricus (Bloch, 1794)	P	3			1	3	**7**	MZUSP 106524
Siluriformes								
Heptapteridae								
Imparfinis piperatus Eigenmann & Norris, 1900	I		2		1	25	**28**	MZUSP 106506
Pimelodella cf. *lateristriga* (Lichtenstein, 1823)	I		1			1	**2**	MZUSP 106512
Rhamdia quelen (Quoy & Gaimard, 1824)	C		1			1	**2**	MZUSP 106525
Loricariidae								
Hypostomus ancistroides (Ihering, 1911)	H		1				**1**	MZUSP 106518
Rineloricaria sp.	H		2				**2**	MZUSP 106515
Gymnotiformes								
Gymnotidae								
Gymnotus carapo Linnaeus, 1758	O		2		2	4	**8**	MZUSP 106522
Gymnotus pantherinus (Steindachner, 1908)	O					1	**1**	MZUSP 106526
Gymnotus sylvius Albert & Fernandes-Matioli, 1999	O			1			**1**	MZUSP 106503
Cyprinodontiformes								
Poeciliidae								
Phalloceros reisi Lucinda, 2008	O		8	2	15	7	**32**	No vouchers
Synbranchiformes								
Synbranchidae								
Synbranchus marmoratus Bloch, 1795	C					2	**2**	MZUSP 106513
Labriformes								
Cichlidae								
Australoheros sp.	C	1					**1**	MZUSP 1065
Geophagus brasiliensis (Quoy & Gaimard, 1824)	O	4	3	3	2	17	**26**	MZUSP 106756
Total number of specimens		**22**	**27**	**3**	**24**	**69**	**145**	
Total number of species		**5**	**12**	**2**	**6**	**11**	**18**	

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