A review on the fishfauna of Mogi-Guaçu River basin: a century of studies

Uma revisão da ictiofauna da bacia do Rio Mogi-Guaçu em um século de estudos

Meschiatti, AJ. and Arcifa, MS.

Departamento de Biologia, Faculdade de Filosofia, Ciências e Letras de Ribeirão Preto, Universidade de São Paulo – USP, Av. Bandeirantes, 3900, CEP 14040-901, Ribeirão Preto, SP, Brazil
e-mail: ajmeschiatti@ig.com.br, marcifa@usp.br

Abstract: Aim: The aims of this review were to synthesize information scattered in the literature, during *ca.* a century of studies on the fishfauna composition of Mogi-Guaçu River basin; the species distribution in the habitats, such as river, tributaries, and floodplain lakes; the diet, feding habits, migration, growth and reproduction of several species; and the influence of environmental degradation. **Material and Methods:** Analysis and synthesis of information obtained in the literature from 1900 to 2008 and comparison of similarities of the fishfauna composition in the habitats were done. The first studies on fish migration in South America using tagging and recapture were performed in Mogi-Guaçu River. **Results:** A hundred and fifty species were recorded in the river basin, distributed in the river, tributaries, floodplain lakes and a reservoir. Data on the diet of 73 species and the reproduction of 27 species were included. The similarity is higher between river and tributaries (47%) than between tributaries and lakes (42%) and river and lakes (37%). **Conclusions:** Several factors, such as sand dredging in the river channel, domestic and industrial sewage, pesticides and fertilizers used in the agriculture contribute to the environmental degradation, reducing nurseries and suitable conditions for the maintenance of populations.

Keywords: neotropical fishes, diet, migration, nurseries, environmental degradation.

Resumo: Objetivo: O objetivo desta revisão foi sintetizar as informações da literatura, durante cerca de um século de estudos, sobre a composição da ictiofauna da bacia do Rio Mogi-Guaçu; a distribuição das espécies nos vários habitats, como rio, tributários e lagoas marginais; a dieta, os hábitos alimentares, a migração, o crescimento e a reprodução de várias espécies; e a influência da degradação ambiental. **Material e Métodos:** Foram feitas análise e síntese das informações obtidas na literatura no período de 1900 a 2008 e comparação da similaridade da composição da ictiofauna nos vários habitats. Os primeiros estudos de marcação e recaptura de peixes migradores na América do Sul foram feitos no Rio Mogi-Guaçu. **Resultados:** Cento e cinquenta espécies de peixes ocorrem na bacia, distribuídos no rio, tributários, lagoas marginais e um reservatório. Há informações sobre a dieta de 73 espécies e sobre a reprodução de 27 espécies. A similaridade é maior entre rio e tributários (47%) do que entre tributários e lagoas (42%) e rio e lagoas (37%). **Conclusões:** Diversos fatores, tais como a dragagem de areia do leito do rio, despejo de esgotos doméstico e industrial, pesticidas e fertilizantes usados na agricultura contribuem para a degradação ambiental, reduzindo as áreas de berçário e condições adequadas para a manutenção das populações.

Palavras-chave: peixes neotropicais, dieta, migração, berçários, degradação ambiental.

Review Article

1. Historic Review

The fishfauna of the Mogi-Guaçu basin has been studied since the end of the XIX century. The first study (Boulenger, 1900) described *Loricaria latirostris* from specimens caught in this river. In 1927, the zoologist Rodolpho Von Ihering, was assigned by the Bureau of Agriculture of São Paulo State to lead the Committee of Fish Migration Studies, for gathering information on reproduction of fish species of Mogi-Guaçu River, aiming to use them for fish cultures (Schubart et al., 1952). These investigations, as well as those on the parasitic worms of the fishes (Travassos et al., 1928), were published in the book "The Life of our Fish: Essays and Scenes of Fishing" (Von Ihering, 1929 apud Godoy, 1954) and in a paper containing the first record of the number of eggs and early life stages of some species (Von Ihering et al., 1928). During the upriver reproductive migration of 1933-34 the first assays on hypophyzation, for inducing the spawning of "curimbatá" (*Prochilodus lineatus*), were made at Cachoeira de Emas (Schubart et al., 1952), which was later extended to other species, with the development of this technique (Menezes, 1944).

By the end of 1937, Von Ihering was invited by the Brazilian Government to organize the Experimental Station Pirassununga, inaugurated in 1939, this town being chosen by the fish abundance in this stretch of the Mogi-Guaçu (Schubart et al., 1952). Otto Schubart, Alcides Lourenço Gomes and Manuel Pereira de Godoy, among others, have continued the studies on the fishfauna of the river. At that time, the knowledge on the ecology of riverine fish was incipient, especially issues such as migrations, grounds and conditions for spawning (Schubart et al., 1952). The "piracema", the Brazilian designation for massive fish reproductive migration, was the primary interest of some researchers (Godoy, 1945; Schubart, 1954); a comprehensive study on fish migration, the first made in a South American river, was carried out from 1954 to 1963, when 27,000 specimens belonging to 15 species were tagged (Godoy, 1957, 1959, 1967, 1972a, b).

Advances in fish taxonomy have generated the description of several species, such as *Glanidium cesarpintoi* (Von Ihering, 1928), *Phallotorynus jucundus* (Von Ihering, 1930), *Oligosarcus pintoi* (Campos, 1945), *Imparfinis schubarti* (Gomes, 1956), *Chasmocranus brachynema* (Gomes and Schubart, 1958), *Cetopsorhamdia iheringi* (Schubart and Gomes, 1959), *Astyanax schubarti* (Britski, 1964), *Sternarchella curvioperculata* (Godoy, 1968), *Hypostomus topavae* (Godoy, 1969), *Astyanax trierythropterus* (Godoy, 1970a), and *Pimelodus heraldoi* (Azpelicueta, 2001).

With the taxonomic progress on fish of the Mogi-Guaçu basin, 80 species were listed in the 1940's (Schubart, 1949), half of them belonging to the Characiformes (Campos, 1945). In 1962, the inventory increased to 97 species (Schubart, 1962), and in 1975 Godoy published his famous book "Fish of Brazil, Suborder Characoidei, Mogi-Guaçu River basin" (Godoy, 1975), containing the study of 46 species of Characiformes. In the book, the author comments on the occurrence of 106 species in the river, without, however, listing them.

Between 1970 and 1990 new studies focused on the biology of several species (Castagnolli, 1971; Nomura 1975a, b, 1976a, b, 1977, 1979, 1985, 1988; Nomura et al., 1972, 1978; Nomura and Mueller, 1978a, b, 1980, 1983; Nomura and Taveira, 1979; among others), including anatomy and histology (Godinho, 1967; Godinho et al., 1970; Godoy, 1970b; Barcelos et al., 1972), parasitology (Kohn and Fernandes, 1987), as well as the biology of *Prochilodus lineatus* (curimbatá) (Toledo Filho, 1983; Romagosa et al., 1985; Toledo Filho and Santos, 1987; Toledo et al., 1986, 1987), previously investigated by Rosa Jr. and Schubart (1945) and Godoy (1959), due to its abundance in the river.

From 1990 to 2000, several researches were devoted to the knowledge of fish assemblages in several habitats, such as floodplain lakes (Vieira and Verani, 2000; Esteves et al., 2000), especially those located within the Ecological Station of Jataí, in the town of Luiz Antônio (Galetti Jr. et al., 1990; Esteves and Galetti Jr., 1995; Esteves, 1996; Ferreira et al., 2000; Meschiatti et al., 2000a, b).

Lately, tributaries have been studied (Oliveira and Garavello, 2003; Birindelli and Garavello, 2005; Oliveira, 2006; Ferreira, 2007; Perez-Junior and Garavello, 2007; Apone et al., 2008), floodplains (Marçal-Simabuku, 2005; Gonçalves and Braga, 2008), and two migratory species - *Salminus brasiliensis* (dourado) (Esteves and Lobo, 2001; Moreira et al., 2002; Barbieri et al., 2001; Ranzani-Paiva et al., 2003) and *Prochilodus lineatus* (curimba) (Barbieri et al., 2000, 2004; Capeleti and Petrere Jr., 2006; Campagna et al., 2006).

In addition, several studies on physiology (Affonso and Rantin, 2005), genetics (Artoni et al., 2006) and citogenetics (Pazza et al., 2008; Rubert et al., 2008) have been undertaken using fish species from Mogi Guaçu River.

2. Objectives

In this review we gather information, available in the literature during *ca.* a century, on the species composition of the fishfauna of Mogi-Guaçu River basin; the species distribution in diverse habitats, such as the main river, tributaries and floodplain lakes; feeding habits and dietary items of several species; migratory species; growth and reproduction of some species; the influence of environmental degradation.

3. Mogi-Guaçu River Basin

Mogi-Guaçu River ("Big Snake" in the native language tupi guarani) belongs to the Upper Paraná River basin and runs for 473 km (95.5 km in Minas Gerais State and 377.5 km in São Paulo State), its source is located in Morro do Curvado, in the town of Bom Repouso, MG, at an average altitude of 1,650 m. The watershed covers an area of 17,303 km^2, 2,650 km^2 in Minas Gerais State (SIGRH, 2000), the river discharging into Pardo River, in Bico do Pontal, at the town of Pontal (Figure 1).

The main tributaries in São Paulo State (located between 21° 45' and 22° 45' S; 46° 15' and 47° 45' W) are the rivers Oriçanga, Itupeva, Cloro, and Jaguari Mirim, on the right margin, and the rivers Eleutério, Peixe, Roque, Quilombo, and Mogi Mirim, on the left margin. Due to a high declivity from the source to the mouth, several rapids, riffles, and wa-

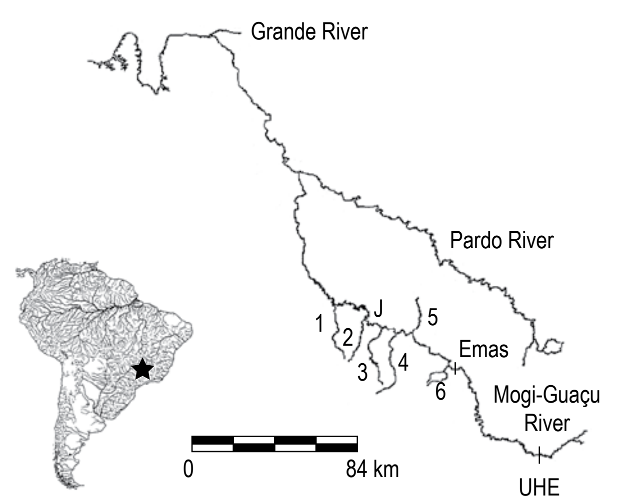

Figure 1. Map of Mogi-Guaçu River basin containing the habitats mentioned in the text: (1) Cabaceiras Stream, (2) Araras Stream, (3) Quilombo River, (4) Pântano Stream, (5) Paulicéia Stream, (6) Ouro Stream, (J) Jataí Ecological Station, (Emas) Cachoeira, and (UHE) Mogi-Guaçu Reservoir. Black star is location of Mogi-Guaçu River in South America.

terfalls are spread along its course, the most important being Salto do Pinhal in Espírito Santo do Pinhal, Cachoeira de Cima in Mogi Mirim, Cachoeira de Baixo in Mogi-Guaçu, Cachoeira de Emas in Pirassununga, Corredeira da Escaramuça in Santa Rita do Passa Quatro, and Corredeira dos Três Cordões in Guariba (SIGRH, 2000).

The river meanders along a floodplain in its middle reach, where several floodplain (mostly oxbow) lakes are located. They are permanent or temporary lakes, curved, narrow, and shallow, permanently or seasonally connected to the main river.

There are two defined seasons: warm-wet (October-March) and cool-dry (April-September), the climate being typically Tropical of Central Brazil (Nimer, 1989).

The watershed soil is primarily occupied by sugar cane plantation (39%), nude soil (22%), pastures (20%), forests (10%), reforestation areas (4%), and other cultures (1%) (Silva et al., 2007). Fifty three towns are located in Mogi-Guaçu River watershed, 12 in Minas Gerais State and 41 in São Paulo State, totaling approximately 1.7 million people (Brigante and Espíndola, 2003). Only 29% of the towns of São Paulo State (12 towns) have any sewage treatment, the remaining ones discharging sewage effluents directly into the water bodies (Espíndola et al., 2003). The main agricultural production is sugar cane, which supplies 10 sugar and alcohol plants, other industries produce paper and cellulose, among the 250 existing in the region. Secondary cultures are potatoes, strawberries, orange, corn, eucalyptus, and pine trees. Pesticides and fertilizers are used in the agricultural activities (Espíndola et al., 2003).

Tens of dams are located in the watershed, most for water supply for farms and towns, and *ca*. twenty for hydroelectric generation, the majority already inactive (Carpi Jr., 2001). Three active hydroelectric dams are located in Mogi-Guaçu River: Pinhal and Eloy Chaves at Espírito Santo do Pinhal, and Mogi-Guaçu at the town of the same name. Nine dams are under study for viability and evaluation of ecological impacts (SIGRH, 2000). Seven conservation units are inserted in the watershed, occupying 9,093 ha: two Ecological Stations, in Luiz Antônio and Mogi-Guaçu, two State Parks, in Porto Ferreira and Santa Rita do Passa Quatro, two Biological Stations, in Sertãozinho and Mogi-Guaçu, and one State Reserve in Águas da Prata (SIGRH, 2000).

4. Background

This review gathers information contained in studies developed in Mogi-Guaçu River's channel, in tributaries, and in floodplain lakes.

The inventory of species of the Mogi-Guaçu channel was based on Barbieri et al. (2000, 2001, 2004), Barbieri and Santos (1988), Boldrini et al. (1983), Boulenger (1900), Britski (1964), Campos (1945), Castagnolli (1971), Esteves and Lobo (2001), Godoy (1954, 1957, 1959, 1969, 1970a, 1975), Gomes (1956), Gomes and Schubart (1958), Gosline (1947), Von Ihering (1928, 1930), Kohn and Fernandes (1987), Menezes (1969, 1976), Nomura (1975a, b, 1976a, b, 1977, 1979, 1985, 1988), Nomura et al. (1972, 1978), Nomura and Nemoto (1983), Nomura and Mueller (1978a, b, 1980, 1983), Nomura and Taveira (1979), Ribeiro (1947), Schubart (1962, 1964a, b), Schubart and Gomes (1959), Toledo-Filho (1983), Toledo-Filho and Santos (1987), Toledo-Filho et al. (1986, 1987), Travassos (1951, 1952, 1955, 1956, 1960), Travassos and Pinto (1957); and that of the river backwaters was based on Marçal-Simabuku (2005).

The tributaries reported here are: Cabaceiras Stream (Oliveira and Garavello, 2003; Oliveira, 2006), Araras Stream (Birindelli and Garavello, 2005; Marçal-Simabuku, 2005; Oliveira, 2006), Pântano Stream (Oliveira, 2006; Perez-Junior and Garavello, 2007), Quilombo River (Oliveira, 2006; Apone et al., 2008), Ouro Stream (Marçal-Simabuku, 2005), and Paulicéia Creek (Ferreira and Castro, 2005; Ferreira, 2007).

The floodplain lakes are: Campo, Diogo, Infernão, Patos, Piaba, Quilômetro, as well as Beija-Flor Reservoir, formed by damming Beija-Flor Creek, all located within the Jataí Ecological Station, in Luiz Antônio, SP (Galetti Jr. et al., 1990; Esteves and Galetti Jr., 1994, 1995; Esteves, 1996; Ferreira et al., 2000; Meschiatti et al., 2000a, b; Marçal-Simabuku and Peret, 2002; Marçal-Simabuku, 2005); Cortado, Vital, and Diogo 2 located in the surroundings of the Jataí Ecological Station (Vieira and Verani, 2000); Catingueiro, Barrinha (Esteves et al., 2000; Gonçalves and Braga, 2008), Pedra and Fundão (Gonçalves and Braga, 2008) in Mogi-Guaçu Ecological Station, in Mogi-Guaçu, and Rio das Pedras, in Pirassununga (Esteves et al., 2000); a reservoir in the river, Mogi-Guaçu Reservoir, was also included (Gonçalves and Braga, 2008).

The fish assemblages in the habitats - river, tributaries, and floodplain lakes - were compared in pairs using Jaccard's similarity index (Pielou, 1984), $q = [c/(a + b - c)] \times 100$, where q = similarity index, a = number of species in A, b = number of species in B, and c = number of species in common.

The diet of the species, reported in the literature, allowed grouping them in general trophic categories and, for this reason, a disagreement with any specific category mentioned in publications may occur.

5. Updating the Nomenclature of Fish Species

Along a century of fish studies, nomenclature shifts have occurred. Nomenclature updating has been made in this review based on the following publications Menezes (1969, 1976), Garavello (1979), Vari (1991, 1992), Reis et al. (2003), Buckup et al. (2007), Ferraris Jr. (2007), Langeani et al. (2007), Ribeiro and Lucena (2007), as well as on the site www.fishbase.org. One criterium adopted for organizing the list of species (Table 1) was that species or

Table 1. Fish fauna of Mogi-Guaçu River with updated nomenclature. Between brackets the original nomenclature as cited in publications, identified by numbers.

CHARACIFORMES
Acestrorhynchidae
Acestrorhynchus lacustris [*A. falcatus* (4, 22, 40, 60), *A. lacustris* (30, 54, 66, 71, 74, 75, 87, 90, 93, 94)]
Anostomidae
Leporellus vittatus [*Leporinodus vittatus* (4), *Leporellus retropinnis* (40), *Leporellus vittatus* (11, 16, 22, 37, 40, 49, 54, 60, 85, 87, 90, 92, 94)]
Leporinus elongatus [*L. elongatus* (4, 11, 12, 16, 22, 27, 38, 40, 66, 73, 74, 75)]
Leporinus friderici [*L. copelandii* (4, 12, 11, 16, 22, 27, 34, 37, 38, 40, 45, 46), *L. reinhardti* (4), *L.* aff. *friderici* (79, 90, 94), *L.* cf. *friderici* (92), *L. friderici acutidens* (81), *L.* cf. *friderici acutidens* (85), *L. frederici* (4), *L. friderici* (66, 54, 65, 72, 74, 87)]
Leporinus lacustris [*L. lacustris* (4, 16, 22, 40, 54, 66, 71, 72, 74, 75, 79, 81, 87, 90, 93, 94)]
Leporinus obtusidens [*L. bahiensis* (4), *L. copelandii* (4, 22, 40), *L. obtusidens* (54, 66, 72, 73, 74, 90, 92, 93, 94)]
Leporinus octofasciatus [*L. fasciatus* (4, 22, 40, 60), *L. octofasciatus* (11, 12, 16, 22, 37, 38, 40, 54, 60, 73, 85, 87, 90, 92, 93)]
Leporinus paranensis [*L. paranensis* (90, 92, 94)]
Leporinus striatus [*L. striatus* (4, 9, 22, 40, 50, 54, 60, 72, 73, 74, 81, 85, 87, 90, 92, 94)]
Leporinus sp. [*Leporinus* sp. (54, 73, 74, 87, 90, 94)]
Schizodon nasutus [*S. nasutus* (16, 22, 37, 38, 40, 54, 60, 66, 71, 72, 74, 75, 79, 81, 87, 90, 93, 94)]
Characidae
Aphyocharacinae
Aphyocharax dentatus [*A. difficilis* (4, 22, 40, 66, 73, 74), *A. dentatus* (87, 90, 94)]
Bryconinae
Brycon cephalus [*B. cephalus* (87)]
Brycon orbignyanus [*Triurobrycon lundii* (4, 11, 12, 16, 22, 37, 38, 40, 60)]
Characinae
Galeocharax knerii [*Cynopotamus humeralis* (4, 11, 22, 40, 60), *G. humeralis* (54), *G. knerii* (44, 90, 94)]
Roeboides descalvadensis [*Roiboides paranaensis* (72), *Roeboides* sp. (75)]
Cheirodontinae
Aphyocheirodon hemigrammus [*A. hemigrammus* (4, 22, 40)]
Odontostilbe microcephala [*O. microcephala* (4, 22, 40, 66)]
Odontostilbe sp. [*Odontostilbe* sp. (87, 90, 94)]
Serrapinnus heterodon [*Holoshestes heterodon* (22, 40), *S. heterodon* (81, 85, 87, 90, 92, 93, 94)]
Serrapinnus notomelas [*Cheirodon notomelas* (4), *S. notomelas* (81, 85, 87, 90, 92, 93, 94)]
Serrasalminae
Metynnis maculatus [*M. maculatus* (93)]
Metynnis sp. [*Metynnis* sp. (75, 90)]
Myleus tiete [*Myloplus asterias* (4, 11, 16, 37, 38, 40, 22, 60), *Myleus tiete* (87, 90, 94), *Myleus* sp. (85)]
Piaractus mesopotamicus [*Colossoma mitrei* (40)]
Serrasalmus maculatus [*S.* cf. *maculatus* (90, 94)]
Serrasalmus marginatus [*S.* cf. *marginatus* (90)]
"Serrasalmus spilopleura" [*Serrasalmus spilopleura* (40, 60, 66, 71, 72, 73, 74, 75, 81, 87, 93)]
Characidae Incertae Sedis
Astyanax altiparanae [*A. bimaculatus* (4, 11, 22, 40, 41, 42, 54, 66, 68, 69, 72, 73, 74, 75), *A. bimaculatus lacustris* (60), *A. altiparanae* (81, 85, 87, 90, 93, 92, 94)]
Astyanax fasciatus [*A. fasciatus* (4, 22, 40, 41, 42, 54, 66, 68, 69, 72, 73, 74, 75, 81, 85, 87, 90, 91, 92, 93, 94), *A. fasciatus fasciatus* (60)]
Astyanax paranae [*A. scabripinnis paranae* (4, 40, 81, 85), *A. scabripinnis* (22, 86), *A. paranae* (90, 91, 92, 94)]
Astyanax schubarti [*A. schubarti* (23, 40, 41, 42, 54, 66, 68, 69, 72, 74, 75, 87, 90), *A. bimaculatus schubarti* (60), *A.* cf. *schubarti* (90, 93)]
Astyanax trierythropterus [*A. trierythropterus* (32, 40)]
Astyanax sp. [*Astyanax* sp. (22, 73, 74, 90)]
Bryconamericus stramineus [*B. stramineus* (4, 22, 40, 81, 85, 87, 90, 91, 92, 93, 94)]
Cheirodon stenodon [*C. stenodon* (69, 81, 85, 87, 90, 93, 92, 94), *Cheirodon* sp. (66, 73, 74, 87)]
Gymnocorymbus ternetzi [*G. ternetzi* (66, 72, 73, 74, 75, 81, 85, 87, 92)]
Hemigrammus marginatus [*Hemigrammus* sp. (22), *H. marginatus* (40, 66, 81, 85, 87, 90, 92, 94)]
Hollandichthys multifasciatus [*H. multifasciatus* (4)]
Hyphessobrycon anisitsi [*H. anisitsi* (90, 92, 93, 94)]
Hyphessobrycon bifasciatus [*H. bifasciatus* (40, 85, 87, 92, 93)]
Hyphessobrycon eques [*H. callistus* (66, 73, 74), *H. eques* (81, 85, 87, 90, 92, 93, 94)]

Table 1. Continued...

- *Hyphessobrycon* sp. [*Hyphessobrycon* sp. (75, 87)]
- *Moenkhausia intermedia* [*M. intermedia* (66, 67, 72, 73, 74, 75, 87, 90, 93, 94)]
- *Moenkhausia sanctaefilomenae* [*M. sanctaefilomenae* (73, 74, 81, 85, 90, 92, 94)]
- *Oligosarcus pintoi* [*Hemibrycon marciae* (35), *Paroligosarcus pintoi* (40, 72), *O. pintoi* (4, 22, 66, 72, 74, 81, 85, 87, 90, 92, 93, 94)]
- *Piabina argentea* [*P. argentea* (4, 22, 40, 72, 81, 85, 87, 90, 91, 92, 93, 94)]

Salmininae

- *Salminus brasiliensis* [*S. maxillosus* (4, 11, 12, 16, 22, 27, 34, 37, 38, 40, 54, 60, 66, 72, 74, 75, 76, 77, 80, 82, 83), *S. brasiliensis* (87)]
- *Salminus hilarii* [*S. hilarii* (4, 11, 16, 22, 37, 38, 40, 54, 60, 66, 72, 74, 75, 81, 85, 87, 90, 92, 94)]

Crenuchidae

- *Characidium fasciatum* [*C. fasciatum* (4, 15, 22), *C. fasciatum fasciatum* (40, 60), *C* cf. *fasciatum* (66)]
- *Characidium gomesi* [*C. gomesi* (15, 22, 40, 81, 85, 90, 91, 92, 94)]
- *Characidium zebra* [*C. zebra* (85, 87, 92), *C.* cf. *zebra* (73, 74, 81, 90), *Characidium* aff. *zebra* (94)]
- *Characidium* sp. [*Characidium* sp. (90)]

Curimatidae

- *Cyphocharax modestus* [*Curimata gilberti* (4, 22, 54), *Pseudocurimata gilberti gilberti* (40, 60), *Cyphocharax modesta* (72, 73, 74), *C. modestus* (75, 79, 85, 87, 90, 92, 93, 94)]
- *Cyphocharax nagelii* [*Curimatus elegans* (4), *Curimatus plumbeus* (4), *Pseudocurimata plumbea* (40, 60), *Cyphocharax nagelii* (72, 74, 75, 79, 87, 90, 94), *Cyphocharax* cf. *nagelii* (93)]
- *Cyphocharax* sp. [*Cyphocharax* sp. (66)]
- *Steindachnerina insculpta* [*Pseudocurimata elegans elegans* (40, 60), *Curimatus elegans* (47, 52), *Curimata elegans* (11, 22, 54), *S. insculpta* (66, 71, 72, 73, 74, 75, 81, 85, 87, 90, 92, 93, 94)]

Erythrinidae

- *Hoplerythrinus unitaeniatus* [*H. unitaeniatus* (72, 75, 81, 85, 87, 92, 93)]
- *Hoplias malabaricus* [*H. malabaricus* (4, 22, 54, 66, 71, 72, 74, 75, 79, 81, 85, 86, 87, 91, 92, 93, 94), *Hoplias malabaricus malabaricus* (33, 40, 60), *H.* aff. *malabaricus* (90), *H.* cf. *malabaricus* (93)]
- *Hoplias microcephalus* [*H.* cf. *lacerdae* (73, 74)]

Lebiasinidae

- *Pyrrhulina* sp. [*Pyrrhulina* sp. (73, 74)]

Parodontidae

- *Apareiodon affinis* [*Parodon affinis* (4), *A. affinis* (14, 22, 40, 48, 54, 81, 87, 90, 94)]
- *Apareiodon ibitiensis* [*Apareiodon mogiguaçuensis* (10, 14, 22, 40), *Apareiodon ibitiensis* (40)]
- *Apareiodon piracicabae* [*A. piracicabae* (74, 90, 94)]
- *Parodon nasus* [*Apareiodon pirassunungae* (4, 14, 22, 40), *P. tortuosus* (4, 14, 22, 40, 43, 51, 54, 81, 85), *P. tortuosus tortuosus* (60), *P. nasus* (87, 90, 92, 94)]

Prochilodontidae

- *Prochilodus lineatus* [*P. hartii* (4), *P. scrofa* (4, 5, 6, 11, 12, 16, 19, 22, 27, 34, 37, 38, 40, 54, 57, 59, 60, 61, 62, 63, 66, 72, 73, 74, 75, 79), *P. lineatus* (70, 71, 81, 83, 85, 87, 88, 89, 90, 92, 94)]
- *Prochilodus vimboides* [*P. vimboides* (4, 22, 40, 60, 90)]

GYMNOTIFORMES

Apteronotidae

- *Apteronotus albifrons* [*A. albifrons* (22)]
- *Apteronotus brasiliensis* [*A. brasiliensis* (21, 22)]
- *Sternarchella curvioperculata* [*S. schotti* (21, 22), *S. curvioperculata* (28)]

Gymnotidae

- *Gymnotus carapo* [*G. carapo* (22, 66, 72, 73, 74, 75, 87, 92, 93), *G.* cf. *carapo* (81, 94), *G.* aff. *carapo* (85)]
- *Gymnotus* sp. [*Gymnotus* sp. (90)]

Hypopomidae

- *Brachyhypopomus pinnicaudatus* [*B.* aff. *pinnicaudatus* (85, 90), *Brachyhypopomus* sp. (92), *Hypopomus* cf. *artedi* (87)]

Rhamphichthyidae

- *Rhamphichthys hahni* [*Sternarchorhamphus hahni* (22)]

Sternopygidae

- *Eigenmannia trilineata* [*E. trilineata* (87, 93), *E.* cf. *trilineata* (75)]
- *Eigenmannia virescens* [*E. virescens* (21, 22, 60, 86, 91, 92), *E.* aff. *virescens* (85), *E.* cf. *virescens* (94)]
- *Eigenmannia* sp. [*Eigenmannia* sp. (54, 66, 73, 74, 81, 90)]
- *Sternopygus macrurus* [*S. macrurus* (22, 74)]

Table 1. Continued...

SILURIFORMES
Aspredinidae
Bunocephalus larai [*B. larai* (22), *Bunocephalus* sp. (90, 94)]
Auchenipteridae
Glanidium cesarpintoi [*G. cesarpintoi* (2, 22)]
Parauchenipterus galeatus [*P. galeatus* (73, 74, 93)]
Tatia neivai [*T. aulopygia* (75), *T. neivai* (87)]
Trachelyopterus coriaceus [*Trachycorystes striatus* (22), *Trachycorystes* sp. (66), *Trachelyopterus coriaceus* (87)]
Callichthyidae
Callichthyinae
Callichthys callichthys [*C. callichthys* (22, 85, 90, 92, 93, 94)]
Hoplosternum littorale [*H. littorale* (71, 72, 73, 74, 75, 81, 84, 85, 87, 90, 92, 93, 94)]
Lepthoplosternum pectorale [*L. pectorale* (90, 94)]
Megalechis personata [*M. personata* (81, 85, 87, 90, 92, 94)]
Corydoradinae
Corydoras aeneus [*C. aeneus* (81, 85, 90, 94), *C.* cf. *aeneus* (92)]
Corydoras difluviatilis [*C. difluviatilis* (86, 90, 91)]
Corydoras sp. [*C.* cf. *garbei* (92)]
Cetopsidae
Cetopsis gobioides [*Pseudocetopsis chalmersi* (22), *Pseudocetopsis gobioides* (85), *C. gobioides* (90, 94)]
Doradidae
Rhinodoras dorbignyi [*R. dorbignyi* (22, 60, 90)]
Heptapteridae
Cetopsorhamdia iheringi [*C. iheringi* (20, 22, 24, 81, 85, 90, 91, 94)]
Chasmocranus brachynema [*C. brachynema* (18, 22, 24, 87)]
Imparfinnis schubarti [*Nannorhamdia schubarti* (13, 22, 24), *I. schubarti* (81, 85, 90, 92, 94)]
Imparfinis sp. [*Imparfinis* sp. (87)]
Phenacorhamdia tenebrosa [*Imparfinis tenebrosus* (22, 24), *P. tenebrosa* (85, 90, 91, 92, 94)]
Pimelodella boschmai [*P. insignis* (22, 24)]
Pimelodella gracilis [*P. gracilis* (81, 92)]
Pimelodella meeki [*P. meeki* (85)]
Pimelodella sp. [*Pimelodella lateristriga* (22, 24, 60), *Pimelodella* sp. (54, 74, 87, 90, 94)]
Rhamdia quelen [*Rhamdia hilarii* (66, 72), *R. quelen* (22, 24, 81, 85, 91, 93, 92, 94), *R.* cf. *quelen* (90), *Rhamdia* sp. (54, 74, 90)]
Loricariidae
Hypoptopomatinae
Hisonotus depressicauda [*H. depressicauda* (85, 90, 92, 94)]
Hisonotus insperatus [*H. insperatus* (85, 87, 90, 92, 94)]
Hisonotus sp. [*Hisonotus* sp. (86, 81, 91)]
Hypostominae
Hypostomus albopunctatus [*Plecostomus albopunctatus* (7, 16, 22, 25, 37, 38, 60), *H. albopunctatus* (90)]
Hypostomus ancistroides [*Plecostomus ancistroides* (22, 25, 60), *H. ancistroides* (85, 90, 91, 92, 93, 94)]
Hypostomus fluviatilis [*Plecostomus fluviatilis* (22, 25), *H. fluviatilis* (64), *H.* cf. *fluviatilis* (92)]
Hypostomus hermanni [*Plecostomus hermanni* (7, 22, 25, 53), *H.* cf. *hermanni* (90)]
Hypostomus iheringii [*H.* cf. *iheringi* (90)]
Hypostomus margaritifer [*Plecostomus margaritifer* (16, 15, 22), *H.* cf. *margaritifer* (90)]
Hypostomus nigromaculatus [*Plecostomus nigromaculatus* (22, 25), *H. nigromaculatus* (90, 94, 95)]
Hypostomus paulinus [*Plecostomus paulinus* (7, 22, 25, 56), *H.* cf. *paulinus* (90, 92)]
Hypostomus regani [*Plecostomus regani* (7, 16, 22, 25, 37, 38, 60), *H. regani* (58, 92), *H.* cf. *regani* (90)]
Hypostomus strigaticeps [*Plecostomus strigaticeps* (7, 22, 25, 60), *H. strigaticeps* (55, 92, 93), *H.* aff. *strigaticeps* (90), *H.* cf. *strigaticeps* (90)]
Hypostomus tietensis [*H. tietensis* (72), *H.* cf. *tietensis* (75)]
Hypostomus topavae [*Plecostomus topavae* (29)]
Hypostomus sp. [*Plecostomus* sp. (60, 54), *Hypostomus* sp. (66, 73, 74, 81, 85, 87, 90, 92, 94)]
Pterygoplichthys anisitsi [*P. gigas* (22, 25), *Lipsarchus* cf. *aculeatus* (75), *P. anisitsi* (87)]

Table 1. Continued...

Loricariinae
Loricaria lentiginosa [*L. lentiginosa* (90, 92, 93)]
Loricaria prolixa [*L. prolixa* (87)]
Loricaria sp. [*Loricaria* sp. (54, 60, 90)]
Rineloricaria latirostris [*Loricaria latirostris* (1), *R. latirostris* (22, 25, 81, 85, 90, 92, 94)]
Neoplecostominae
Neoplecostomus paranensis [*Neoplecostomus granosus* (22, 25), *N. paranensis* (90, 94)]
Pimelodidae
Iheringichthys labrosus [*I. labrosus* (22, 24, 60, 93)]
Pimelodus heraldoi [*P. heraldoi* (78)]
Pimelodus maculatus [*P. clarias* (11, 16, 27, 37, 38, 22, 24, 39, 60), *P. maculatus* (26, 27, 31, 36, 54, 66, 72, 73, 74, 75, 81, 87, 92, 93)]
Pimelodus microstoma [*Pimelodus* cf. *fur* (90, 93)]
Pimelodus sp. [*Pimelodus* sp. (75)]
Pseudoplatystoma corruscans [*P. corruscans* (24)]
Steindachneridion sp. [*S. parahybae* (22, 24, 60)]
Zungaro jahu [*Paulicea lütkeni* (22, 24, 60), *Pseudopimelodus zungaro* (54)]
Pseudopimelodidae
Pseudopimelodus mangurus [*P. roosevelti* (22, 24, 60)]
Pseudopimelodus sp. [*Pseudopimelodus* sp. (87)]
Trichomycteridae
Parastegophilus paulensis [*Pseudostegophilus scarificator* (3), *Parastegophilus maculatus* (22), *Parastegophilus paulensis* (90, 92, 94)]
Paravandellia oxyptera [*P. oxyptera* (8, 22, 85, 87, 90, 92, 94)]
PERCIFORMES
Centrarchidae
Micropterus salmoides [*M. salmoides* (22, 60)]
Cichlidae
Astronotus ocellatus [*A. ocellatus* (22)]
Australoheros facetus [*Cichlasoma facetum* (66, 72, 73, 92)]
Crenicihla jaguarensis [*Crenicihla jaguarensis* (17, 22, 85), *C.* cf. *jaguarensis* (90, 92, 94)]
Crenicichla sp. [*Crenicichla* sp. (81)]
Geophagus brasiliensis [*G. brasiliensis* (17, 22, 54, 66, 73, 74, 81, 85, 87, 90, 92, 93, 94)]
Geophagus sp. [*Geophagus* sp. (75)]
Tilapia rendalli [*Tilapia melanopleura* (22), *T. rendalli* (54, 60, 85, 87, 90, 92, 94)]
Scianidae
Plagioscion squamosissimus [*P. squamosissimus* (54)]
CYPRINIFORMES
Cyprinidae
Cyprinus carpio [*C. carpio* (22)]
CYPRINODONTIFORMES
Poeciliidae
Phalloceros caudimaculatus [*P. caudimaculatus* (22, 90, 92, 93), *Phalloceros* sp. (94)]
Phallotorynus jucundus [*P. jucundus* (3, 22, 73, 74, 86, 91)]
Poecilia reticulata [*P. reticulata* (66, 85, 87, 90, 92, 94)]
Rivulidae
Rivulus sp. [*Rivulus* sp. (87)]
SYNBRANCHIFORMES
Synbranchidae
Synbranchus marmoratus [*S. marmoratus* (22, 60, 81, 85, 87, 90, 91, 92, 93, 94)]
Systematics doubts Absent in this basin: Characiformes: *Astyanax lacustris* (4, 11, 22), *Brycon carpophagus* (22, 40), *Cheirodon piaba* (22, 40, 66), *Holoshestes pequira* (4), *Oligobrycon* sp. (73, 74), *Schizodon knerii* (11); Siluriformes: *Ancistrus stigmaticus* (22, 25), *Bergiaria westermanni* (22, 24, 60), *Loricaria macrodon* (22, 25), *Microlepidogaster bourguyi* (22, 25), *Oxydoras knerii* (54); Perciformes: *Aequidens* sp. (66), *Laetacara* sp. (90, 92). Lack of systematic correspondenc e: Characiformes: *Curimata* sp. (22, 54), *Lahilliella knerii* (4), Tetragonopterinae sp. (60); Siluriformes: *Callichthys microps* (22), *Paratocinclus* sp. (22, 25), *Plecostomus macrops* (7, 22, 25), *Pygidium brasiliense* (22).

Table 1. Continued...

Source: 1. Boulenger (1900), 2. Von Ihering (1928), 3. Von Ihering (1930), 4. Campos (1945), 5. Rosa Jr. and Schubart (1945), 6. Godoy (1947), 7. Gosline (1947), 8. Ribeiro (1947), 9. Travassos (1951), 10. Travassos (1952), 11. Godoy (1954), 12. Schubart (1954), 13. Gomes (1956), 14. Travassos (1955), 15. Travassos (1956), 16. Godoy (1957), 17. Travassos and Pinto (1957), 18. Gomes and Schubart (1958), 19. Godoy (1959), 20. Schubart and Gomes (1959), 21. Travassos (1960), 22. Schubart (1962), 23. Britski (1964), 24. Schubart (1964a), 25. Schubart (1964b), 26. Godinho (1967), 27. Godoy (1967), 28. Godoy (1968), 29. Godoy (1969), 30. Menezes (1969), 31. Godinho et al. (1970), 32. Godoy (1970a), 33. Godoy (1970b), 34. Castagnolli (1971), 35. Godoy (1971), 36. Barcelos et al. (1972), 37. Godoy (1972a), 38. Godoy (1972b), 39. Nomura et al. (1972), 40. Godoy (1975), 41. Nomura (1975a), 42. Nomura (1975b), 43. Britski (1976), 44. Menezes (1976), 45. Nomura (1976a), 46. Nomura (1976b), 47. Nomura (1977), 48. Nomura et al. (1978), 49. Nomura and Mueller (1978a), 50. Nomura and Mueller (1978b), 51. Nomura (1979), 52. Nomura and Taveira (1979), 53. Nomura and Mueller (1980), 54. Boldrini et al. (1983), 55. Nomura and Mueller (1983), 56. Nomura and Nemoto (1983), 57. Toledo Filho (1983), 58. Nomura (1985), 59. Romagosa et al. (1985), 60. Kohn and Fernandes (1987), 61. Toledo Filho et al. (1986), 62. Toledo Filho and Santos (1987), 63. Toledo Filho et al. (1987), 64. Nomura (1988), 65. Barbieri and Santos (1988), 66. Galetti Jr. et al. (1990), 67. Esteves and Galetti Jr. (1994), 68. Esteves (1996), 69. Esteves and Galetti Jr. (1995), 70. Barbieri et al. (2000), 71. Esteves et al. (2000), 72. Ferreira et al. (2000), 73. Meschiatti et al. (2000a), 74. Meschiatti et al. (2000b), 75. Vieira and Verani (2000), 76. Barbieri et al. (2001), 77. Esteves and Lobo (2001), 78. Azpelicueta (2001), 79. Marçal-Simabuku and Peret (2002), 80. Moreira et al. (2002), 81. Oliveira and Garavello (2003), 82. Ranzani-Paiva et al. (2003), 83. Barbieri et al. (2004), 84. Affonso and Rantin (2005), 85. Birindelli and Garavello (2005), 86. Ferreira and Castro (2005), 87. Marçal-Simabuku (2005), 88. Campagna et al. (2006), 89. Capeleti and Petrere (2006), 90. Oliveira (2006), 91. Ferreira (2007), 92. Perez-Jr. and Garavello (2007), 93. Gonçalves and Braga (2008), 94. Apone et al. (2008), 95. Rubert et al. (2008).

subspecies designated as *aff.* or *cf.* in the original papers have been included in the corresponding species (see, for example, *Leporinus friderici*). The updating adopted for Table 1 was extended to the whole text, whenever dealing with species cited in the literature.

Steindachneridion parahybae (Schubart, 1962, 1964a) has been replaced by *Steindachneridion* sp. as in the upper Paraná River two species have been recorded, *S. punctatum* and *S. scriptum* (Garavello, 2005).

According to Langeani et al. (2007) there are two species of *Serrasalmus* - *S. marginatus* and *S. maculatus* - in upper Paraná River. Therefore, we have designated as "*S. spilopleura*" the citations of this species in the literature, due to the impossibility of differentiating both species in the literature.

6. Fish Fauna Composition

All gathered literature, from the last century to recent times, resulted in an inventory of 150 species (50% of the entire fauna described for the upper Paraná River, 310 species distributed in 38 families, according to Langeani et al., 2007). These fishes are distributed in 87 genera, 30 families and 7 orders described for the Mogi-Guaçu basin (Table 2). The fish orders can be ranked: Characiformes with 66 species (44%), Siluriformes with 58 species (39%), Gymnotiformes with 11 species (7%), Perciformes with 9 species (6%), Cyprinodontiformes with 4 species (3%), Synbranchiformes and Cypriniformes with 1 species each (1%).

Godoy (1975) mentioned a lower richness (106 species) for the Mogi-Guaçu River basin. Although the fish fauna is relatively well known (Castro et al., 2003), the fish diversity can be richer, considering that 19% of of the species have been recorded in recent studies (from 2003 onward). Fifteen species are probably locally extinct as they were never caught again after the period studied by Schubart (1962) and Godoy (1975) (Table 2), despite the increasing number of studies carried out in Mogi Guaçu basin.

The orders Characiformes and Siluriformes do not differ much in number of species, but data on fisheries in the 1940's (Schubart, 1949) showed that the first order predominated in biomass, *Prochilodus lineatus* being the main species captured (Table 3). The most abundant species among the Siluriformes was *Pimelodus maculatus* (mandi) (Schubart et al., 1952). *Steindachneridion* sp. (sorubim) and *Zungaro jahu* (jaú) were rare and *Pseudoplatystoma corruscans* (pintado) did not occur in the Mogi-Guaçu (Schubart, 1949); however, Schubart (1964a) reported that, in 1959, specimens of *P. corruscans* were introduced in the river and included it in the taxonomic list.

7. Species Distribution in the Habitats

Ninety six species (64%) were caught in the Mogi-Guaçu channel, 98 (65%) in tributaries and 73 (49%) in floodplain lakes (Table 2).

Forty eight species inhabit at least two habitats (river and tributaries, river and floodplain lakes, and tributaries and floodplain lakes) (Figure 2). Thirty seven species occurred in the three habitats, most belonging to Characiformes (30 species), five species to Siluriformes, one to Perciformes, and one to Gymnotiformes. *Astyanax altiparanae*, *A. fasciatus*, *Hoplias malabaricus*, *Leporinus friderici*, *Parodon nasus*, *Piabina argentea*, and *Geophagus brasiliensis*, have been also recorded in the upper reaches of tributaries (Oliveira and Garavello, 2003; Birindelli and Garavello, 2005; Perez-Junior and Garavello, 2007; Apone et al., 2008).

Some species were restricted to one of the three habitats. Among the 25 species caught only in the river channel, Siluriformes predominated (64%) – *Glanidium cesarpintoi*, *Rhinodoras dorbignyi*, *Chasmocranus brachynema*, *Imparfinnis* sp., *Pimelodella boschmai*, *Hypostomus*

Table 2. Occurrence of fish species in Mogi-Guaçu River (R), in tributaries (T), in floodplain lakes (L), and in Mogi-Guaçu Reservoir (Re). A: native species; B: allochthonous species; C: exotic species (according to Langeani et al. 2007); and (?) unknown origin. (*) Habitat non indicated; (♣) not caught after 1975.

CHARACIFORMES	Origin	R	T	L	Re
Acestrorhynchidae					
Acestrorhynchus lacustris (Lütken, 1875)	A	•	•	•	
Anostomidae					
Leporellus vittatus (Valenciennes, 1850)	A	•	•		
Leporinus elongatus Valenciennes, 1850	A	•		•	
Leporinus friderici (Bloch, 1794)	A	•	•	•	
Leporinus lacustris Campos, 1945	A	•	•	•	
Leporinus obtusidens (Valenciennes, 1836)	A	•	•	•	
Leporinus octofasciatus Steindachner, 1915	A	•	•	•	•
Leporinus paranensis Garavello and Britski, 1987	A		•		
Leporinus striatus Kner, 1859	A	•	•	•	
Leporinus sp.	A	•	•	•	
Schizodon nasutus Kner, 1858	A	•	•	•	•
Characidae					
Aphyocharacinae					
Aphyocharax dentatus Eigenmann and Kennedy, 1903	A	•	•	•	
Bryconinae					
Brycon cephalus (Günther, 1869)	B	•			
Brycon orbignyanus (Valenciennes in Cuvier and Valenciennes, 1850)	A	•			
Characinae					
Galeocharax knerii (Steindachner, 1879)	A	•	•	•	
Roeboides descalvadensis Fowler, 1932	B			•	
Cheirodontinae					
Aphyocheirodon hemigrammus Eigenmann, 1915 ♣	A	•			
Odontostilbe microcephala Eigenmann, 1907	A	•		•	
Odontostilbe sp.		•	•		
Serrapinnus heterodon (Eigenmann, 1915)	A	•	•	•	•
Serrapinnus notomelas (Eigenmann, 1915)	A	•	•	•	
Serrasalminae					
Metynnis maculatus (Kner, 1858)	B			•	
Metynnis sp.	B			•	
Myleus tiete (Eigenmann and Norris, 1903)	A	•	•		
Piaractus mesopotamicus (Holmberg, 1887) ♣	A	•			
Serrasalmus maculatus Kner, 1858	A		•		
Serrasalmus marginatus Valenciennes, 1837	A		•		
"Serrasalmus spilopleura" Kner, 1858		•	•	•	•
Characidae Incertae Sedis					
Astyanax altiparanae Garutti and Britski, 2000	A	•	•	•	•
Astyanax fasciatus (Cuvier, 1819)	A	•	•	•	•
Astyanax paranae Eigenmann, 1914	A	•	•		
Astyanax schubarti Britski, 1964	A	•		•	•
Astyanax trierythropterus Godoy, 1970 ♣	A	•			
Astyanax sp.				•	
Bryconamericus stramineus Eigenmann, 1908	A	•	•		
Cheirodon stenodon Eigenmann, 1915	A	•	•	•	•
Gymnocorymbus ternetzi (Boulenger, 1895)	B	•	•	•	
Hemigrammus marginatus Ellis, 1911	A	•	•	•	
Hollandichthys multifasciatus (Eigenmman and Norris, 1900) * ♣	A				
Hyphessobrycon anisitsi (Eigenmann, 1907)	A		•	•	•
Hyphessobrycon bifasciatus Ellis, 1911	A		•	•	

Table 2. Continued...

	Origin	R	T	L	Re
Hyphessobrycon eques (Steindachner, 1882)	A	•	•	•	•
Hyphessobrycon sp.		•		•	
Moenkhausia intermedia Eigenmann, 1908	A		•	•	
Moenkhausia sanctaefilomenae (Steindachner, 1907)	A		•	•	
Oligosarcus pintoi Campos, 1945	A	•	•	•	•
Piabina argentea Reinhardt, 1867	A	•	•	•	•
Salmininae					
Salminus brasiliensis (Cuvier, 1816)	A	•		•	
Salminus hilarii Valenciennes, 1850	A	•	•	•	
Crenuchidae					
Characidium fasciatum Reinhardt, 1866	A	•	•	•	
Characidium gomesi Travassos, 1956	A		•		
Characidium zebra Eigenmann, 1909	A	•	•	•	
Characidium sp.	?		•		
Curimatidae					
Cyphocharax modestus (Fernández-Yépez, 1948)	A	•	•	•	•
Cyphocharax nagelii (Steindachner, 1881)	A	•	•	•	•
Cyphocharax sp.				•	
Steindachnerina insculpta (Fernández-Yépez, 1948)	A	•	•	•	•
Erythrinidae					
Hoplerythrinus unitaeniatus (Agassiz, 1829)	B		•	•	
Hoplias malabaricus (Bloch, 1794)	A	•	•	•	•
Hoplias microcephalus (Agassiz, 1829)	A			•	
Lebiasinidae					
Pyrrhulina sp.				•	
Parodontidae					
Apareiodon affinis (Steindachner, 1879)	A	•	•	•	
Apareiodon ibitiensis Campos, 1944 ♣	A	•			
Apareiodon piracicabae (Eigenmann, 1907)	A		•	•	
Parodon nasus Kner, 1859	A	•	•	•	
Prochilodontidae					
Prochilodus lineatus (Valenciennes, 1836)	A	•	•	•	
Prochilodus vimboides Kner, 1859	A	•		•	
Prochilodus spp.					•
GYMNOTIFORMES					
Apteronotidae					
Apteronotus albifrons (Linnaeus, 1766) * ♣	B				
Apteronotus brasiliensis (Reinhardt, 1852) ♣	B	•			
Sternarchella curvioperculata Godoy, 1968 ♣	A	•	•		
Gymnotidae					
Gymnotus carapo Linnaeus, 1758	A		•	•	•
Gymnotus sp.	?	•	•		
Hypopomidae					
Brachyhypopomus pinnicaudatus (Hopkins; Comfort; Bastian and Bass, 1990)	B		•		
Rhamphichthyidae					
Rhamphichthys hahni (Meinken, 1937) * ♣	B				
Sternopygidae					
Eigenmannia trilineata López and Castello, 1966	A		•	•	•
Eigenmannia virescens (Valenciennes, 1847)	A	•	•		
Eigenmannia sp.		•	•	•	
Sternopygus macrurus (Bloch and Schneider, 1801)	A			•	

Table 2. Continued...

SILURIFORMES	Origin	R	T	L	Re
Aspredinidae					
Bunocephalus larai Ihering, 1930	A		•		
Auchenipteridae					
Glanidium cesarpintoi Ihering, 1928 ♣	A	•			
Parauchenipterus galeatus (Linnaeus, 1766)	A			•	
Tatia neivai (Ihering, 1930)	A	•		•	
Trachelyopterus coriaceus Valenciennes, 1840	A	•		•	
Callichthyidae					
Callichthyinae					
Callichthys callichthys (Linnaeus, 1758)	A		•		•
Hoplosternum litoralle (Hancock, 1828)	A		•	•	•
Lepthplosternum pectorale (Boulenger,1895)	A		•		
Megalechis personata (Ranzani, 1841)	B		•	•	
Corydoradinae					
Corydoras aeneus (Gill, 1858)	A		•		
Corydoras difluviatilis Britto and Castro, 2002	A		•		
Corydoras sp.	A		•		
Cetopsidae					
*Cetopsis gobioide*s Kner, 1857	A		•		
Doradidae					
Rhinodoras dorbignyi (Kner, 1855)	A	•			
Heptapteridae					
Cetopsorhamdia iheringi Schubart and Gomes, 1959	A	•	•		
Chasmocranus brachynema Gomes and Schubart, 1958	A	•			
Imparfinis schubarti (Gomes, 1956)	A	•	•		
Imparfinis sp.	A	•			
Phenacorhamdia tenebrosa (Schubart, 1964)	A	•	•		
Pimelodella boschmai Van der Stigchel, 1964 ♣	A	•			
Pimelodella gracillis (Valenciennes, 1835)	A		•		
Pimelodella meeki Eigenmann, 1910	A		•		
Pimelodella sp.	?	•	•	•	
Rhamdia quelen (Quoy and Gaimard, 1824)	A	•	•	•	•
Loricariidae					
Hypoptopomatinae					
Hisonotus depressicauda (Miranda-Ribeiro, 1918)	A		•		
Hisonotus insperatus Britski and Garavello, 2003	A	•	•		
Hisonotus sp.	A		•		
Hypostominae					
Hypostomus albopunctatus (Regan, 1908)	A	•			
Hypostomus ancistroides (Ihering, 1911)	A	•	•	•	•
Hypostomus fluviatilis (Schubart, 1964)	A	•	•		
Hypostomus hermanni (Ihering, 1905)	A	•	•		
Hypostomus iheringi (Regan, 1908)	A		•		
Hypostomus margaritifer (Regan, 1908)	A	•			
Hypostomus nigromaculatus (Schubart, 1967)	A	•	•		
Hypostomus paulinus (Ihering, 1905)	A	•	•		
Hypostomus regani (Ihering, 1905)	A	•	•		
Hypostomus strigaticeps (Regan, 1908)	A	•	•		•
Hypostomus tietensis (Ihering, 1905)	A			•	
Hypostomus topavae (Godoy, 1969) ♣	A	•			
Hypostomus sp.		•	•	•	•
Pterygoplichthys anisitsi Eigenmann and Kennedy, 1903	A			•	

Table 2. Continued...

	Origin	R	T	L	Re
Loricariinae					
Loricaria lentiginosa Isbrücker, 1979	A	•	•		
Loricaria prolixa Isbrücker and Nijssen, 1978	A	•		•	
Loricaria sp.	?	•			
Rineloricaria latirostris (Boulenger, 1900)	A	•	•		
Neoplecostominae					
Neoplecostomus paranensis Langeani, 1990	A		•		
Pimelodidae					
Iheringichthys labrosus (Lütken, 1874)	A	•			•
Pimelodus heraldoi Azpelicueta, 2001	A	•			
Pimelodus maculatus La Cepède, 1803	A	•	•	•	•
Pimelodus microstoma Steindachner, 1877	B	•			•
Pimelodus sp.				•	
Pseudoplatystoma corruscans (Spix and Agassiz, 1829) ♣	A	•			
Steindachneridion sp.	A	•			
Zungaro jahu (Ihering, 1898)	A	•			
Pseudopimelodidae					
Pseudopimelodus mangurus (Valenciennes, 1835)	A	•			
Pseudopimelodus sp.			•		
Trichomycteridae					
Parastegophylus paulensis (Miranda-Ribeiro, 1918)	A	•	•		
Paravandellia oxyptera Miranda-Ribeiro, 1912	A	•	•		
PERCIFORMES					
Centrarchidae					
Micropterus salmoides (La Cepède, 1802)	C	•			
Cichlidae					
Astronotus ocellatus (Agassiz, 1831) * ♣					
Australoheros facetus (Jenyns, 1842)	A		•	•	
Crenicichla jaguarensis Haseman, 1911	A	•	•		
Crenicichla sp.			•		
Geophagus brasiliensis (Quoy and Gaimard, 1824)	A	•	•	•	•
Geophagus sp.				•	
Tilapia rendalli (Boulenger, 1897)	C	•	•		
Scianidae					
Plagioscion squamosissimus (Heckel, 1840)	B	•			
CYPRINIFORMES					
Cyprinidae					
Cyprinus carpio Linnaeus, 1758 * ♣	C				
CYPRINODONTIFORMES					
Poecilidae					
Phalloceros caudimaculatus (Hensel, 1868)	A		•	•	
Phallotorynus jucundus Ihering, 1930	A		•	•	
Poecilia reticulata Peters, 1859	B		•	•	
Rivulidae					
Rivulus sp.	A		•		
SYNBRANCHIFORMES					
Synbranchidae					
Synbranchus marmoratus Bloch, 1795	A	•	•		
Total	150	96	98	73	29

Table 3. Relative abundance of species from 1942-1943 (Schubart, 1949) and the proportion of marked and recaptured specimens in the migration studies during 1954-1956 (Godoy, 1957) in Cachoeira de Emas. The species marked with * totalize 7.2% of the fish biomass.

Characiformes	1942-43	1954-56	
	Biomass	Marking	Recapture
Astyanax spp.	*	-	-
Brycon orbignyanus	4	0.14	0
Galeocharax knerii	*	-	-
Leporellus vittatus	*	0.68	0.2
Leporinus elongatus	9.1	2.23	1.8
Leporinus friderici	8.8	16.68	15.1
Leporinus lacustris		0.02	0
Leporinus octofasciatus	1.9	5.35	2.2
Myleus tiete	*	0.36	0.6
Prochilodus lineatus	52.8	61.2	54.9
Salminus brasiliensis	8.1	4.42	5.9
Salminus hilarii	*	0.72	0.9
Schizodon nasutus	*	0.26	0.2
Steindachenrina insculpta	*	-	-
Siluriformes			
Hypostomus albopunctatus	-	0.08	0
Hypostomus margaritifer	-	0.02	0
Hypostomus regani	-	0.04	0.2
Pimelodus maculatus	8.1	7.80	18.0
Total	100%	100%	100%

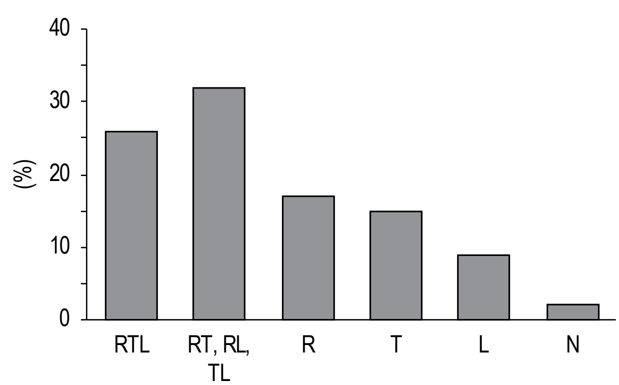

Figure 2. Proportion of species occurring in three, two or one of the habitats (R: river, T: tributaries, L: lakes, N: habitat unknown).

albopunctatus, *H. margaritifer*, *H. topavae*, *Iheringichthys labrosus*, *Loricaria* sp., *Pimelodus heraldoi*, *P. microstoma*, *Pseudoplatystoma corruscans*, *Steindachneridion* sp., *Zungaro jahu*, and *Pseudopimelodus mangurus* – followed by Characiformes (24%) – *Brycon cephalus*, *B. orbignyanus*, *Aphyocheirodon hemigrammus*, *Piaractus mesopotamicus*, *Astyanax thrierythropterus*, and *Apareiodon ibitiensis* – Perciformes (8%) – *Micropterus salmoides* and *Plagioscion squamosissimus* – and Gymnotiformes (4%) – *Apteronotus brasiliensis.*

Information on fish dwellers of the river channel is large but not recent, except on *Salminus brasiliensis*, *Prochilodus lineatus*, and *Leporinus friderici* (Esteves and Lobo, 2001; Barbieri et al., 2004; Barbieri and Santos, 1988). Twenty two species (17 Characiformes and 5 Siluriformes) were caught in the river channel at Cachoeira de Emas, during the upriver migration of the summer of 2002-2004 (Marçal-Simabuku, 2005).

Siluriformes also predominated in tributaries, where, among the 21 species restricted to this habitat, *ca*. 62% were Siluriformes and 24% Characiformes. *Corydoras aeneus*, *Hisonotus depressicauda*, *Characidium gomesi*, and the gymnotid *Brachyhypopomus pinnicaudatus* have been caught in several tributaries. Others have been reported for one tributary, such as *Pimelodella meeki* for Araras Stream (Birindelli and Garavello, 2005), and *Neoplecostomus paranensis* for Quilombo River (Apone et al., 2008); *Rivulus* sp. was caught in temporarily flooded areas (Marçal-Simabuku, 2005).

In the upper reach of creeks and streams small-sized species dominated, such as *Astyanax paranae, Characidium* spp., *Corydoras aeneus, Hisonotus* sp. and *Poecilia reticulata*. A few mid-sized species like *Gymnotus carapo*, *Hoplias malabaricus*, and *Rhamdia quelen* were distributed from the upper to the lower reaches. Among the many species recorded for the middle and lower reaches of tributaries some are relatively rare, such as *Cetopsis gobioides*, *Paravandellia oxyptera*, and *Parastegophilus paulensis* (Birindelli and Garavello, 2005; Perez-Junior and Garavello, 2007; Apone et al., 2008). The latter two species are parasites and also recorded in the Mogi-Guaçu channel (Von Ihering, 1930; Ribeiro, 1947). *Leporinus paranensis* is also scarce, being recorded in low numbers in two tributaries (Perez-Junior and Garavello, 2007; Apone et al., 2008).

The fish assemblage composition of the lower reaches of tributaries are influenced by the main river. Usually, richness and fish abundance are higher in the lower reaches (Oliveira and Garavello, 2003; Birindelli and Garavello, 2005; Perez-Junior and Garavello, 2007; Apone et al., 2008), the same mid- and large-sized species of the river channel being found: *Salminus hilarii*, *Leporinus friderici*, *L. octofasciatus*, *L. obtusidens*, *Leporellus vittatus*, *Schizodon nasutus*, and *Prochilodus lineatus*. *Lepthoplosternum pectorale*, *Bunocephalus* sp. (Oliveira, 2006; Apone et al., 2008), and *Pimelodella meeki* (Birindelli and Garavello, 2005) were exclusively caught in the lower reaches.

Roeboides descalvadensis, *Metynnis maculatus*, and *Hoplias microcephalus* (Characiformes), *Sternopygus macrurus* (Gymnotiformes), *Parauchenipterus galeatus*, *Hypostomus tietensis,* and *Pterygoplichthys anisitsi* (Siluriformes) have occurred only in lakes. Other non-identified species, such as *Metynnis* sp., *Astyanax* sp., *Cyphocharax* sp., *Pyrrhulina* sp. (Characiformes), *Pimelodus* sp. (Siluriformes), and

Geophagus sp. (Perciformes) also occurred in foodplain lakes.

Comparing the assemblages of the three habitats, the similarity index decreases from river versus tributaries (47%), tributaries versus lakes (42%), and river versus lakes (37%). Comparing these habitats with the reservoir the indices are 28% for reservoir versus lakes, decreasing to 23% for reservoir versus tributaries and to 20% for reservoir versus river. The most abundant species in Mogi-Guaçu Reservoir are *Cyphocharax modestus*, *Steindachnerina insculpta*, *Astyanax fasciatus*, *Cyphochrax* cf. *nagelii*, and *A. altiparanae* (Gonçalves and Braga, 2008), which are also abundant in the floodplain lakes (Meschiatti et al., 2000b). Some species found in the reservoir, so far, were only recorded in the river, such as *Iheringichthys labrosus* and *Pimelodus microstoma*, or in tributaries like *Callichthys callichthys*.

8. Endemism, Introductions, and Threatened Species

Endemic and rare species at the time they have been described are *Chasmocranus brachynema* (Gomes and Schubart, 1958), *Sternarchella curvioperculata* (Godoy, 1968), *Hypostomus topavae* (Godoy, 1969), and *Astyanax thrierytropterus* (Godoy, 1970a). Only 3 specimens of *Chasmocranus brachynema* have been caught (Gomes and Schubart, 1968; Schubart, 1964a; Marçal-Simabuku, 2005), *Phallotorynus jucundus* being also rare (Von Ihering, 1930; Meschiatti et al., 2000; Ferreira, 2007), both species being included in the list of threatened species (MMA, 2004).

Brycon orbignyanus (piracanjuba), an abundant species in 1943, suffered a population reduction of 80% in 20 years due to human impacts (Godoy, 1972b, 1975). Lately, it is rare in natural habitats (Feiden and Hayashi, 2005) and is, probably, one of the 19 species considered extinct in Mogi-Guaçu basin by Godoy (SIGRH, 2000). *Brycon orbignyanus* and *Myleus tiete* are threatened species (MMA, 2004), and *Zungaro jahu* overexploited, species omitted by the Ministry of Environment, which should be added to the list (Boletim Ictiológico, 2004, http://www.sbi.bio.br/boletim/Boletins75.pdf).

Several introductions of allochthonous and exotic species have occurred since 1959. *Pseudoplatystoma corruscans* and *Rhinelepis aspera*, originated from the upper Paraná River (Schubart, 1964a, b); *Astronotus ocellatus*, *Cichla ocellaris*, and *Trachycorystes striatulus* have been introduced from other Neotropical basins and the exotic species *Carassius auratus*, from the Experimental Station of Pirassununga, where fingerlings have escaped to the river in several occasions (Schubart et al., 1952). More than 3,000 specimens of *Cyprinus carpio* reached the river, in 1941, after a fishpond ruptured (Schubart et al., 1952). Lately, Toppa et al. (2000) report that specimens of *Clarias* sp. (bagre africano) and *Cichla ocellaris* (tucunaré) were caught in floodplain lakes, likely introduced by fishermen for increasing fisheries, or by escaping from fishponds, flooded by the river. Hundreds of fishponds, used for sport fishing, are located in the Mogi-Guaçu basin, which contribute to species dispersion (Fernandes et al., 2003). The Amazonian species *Brycon cephalus*, common in those ponds (Eler et al., 2001), was observed in low number at Cachoeira de Emas during the "piracema" of 2002-04 (Marçal-Simabuku, 2005). Native species of other Neotropical basins have been introduced in the Mogi-Guaçu River for several reasons, such as *Gymnocorymbus ternetzi* (aquaculture), *Poecilia reticulata* (mosquito control), *Hoplerythrinus unitaeniatus*, *Brachyhypopomus pinnicaudatus*, and *Plagioscion squamosissimus* (fishery) and *Megalechis personata* (invasion after the disappearance of a natural barrier following the construction of Itaipu Reservoir) and the exotic African species *Tilapia rendalli* (fishery) (Langeani et al., 2007).

9. Feeding Habits and Dietary Items

The feeding habits and diet of 73 species, 48% of the total fishfauna, are known. They were grouped in nine trophic categories (Table 4). Near half of them (44%) were insectivores or predominantly insectivores. Aquatic insects are the main dietary item, followed by plants, terrestrial insects, and other minor items (Figure 3).

10. Species Growth and Reproduction

There are data on reproductive aspects, meristic characteristics and growth parameters for 27 species - 19 Characiformes and 8 Siluriformes (Table 5). Reproductive aspects listed are the average size at first maturation, fecundity, spawning type and reproductive period. The main meristic characteristics quantify fin rays, lateral line scales, vertebras, teeth, gill rakers of the first arch. Growth parameters are the age-size and size-weight relationships.

Fish reproduction of Mogi-Guaçu River basin follows general patterns observed in the upper Paraná River, *i.e.*, the reproductive period of most species extends from October to March, during the warm-wet season (Vazzoler and Menezes, 1992). Generally, those which are long-distance migrants have total spawning and high fecundity (hundreds of thousands of eggs); the non-migrants without parental care show partial spawning and intermediate fecundity; the non-migrant with parental care have low fecundity, reaching maturity under 16 cm length (Vazzoler and Menezes, 1992).

Some small species reproduce all year round, such as *Astyanax paranae* and *Hisonotus* sp., in Paulicéia Creek (Ferreira, 2007) and *Characidium zebra*, *Gymnocorymbus ternetzi*, *Hyphessobrycon eques*, *Moenkhausia sanctaefilomenae*,

Table 4. Fish diet in the Mogi-Guaçu River basin.

Insectivores	**Periphyton feeders**
Aphyocharax dentatus (4, 15)	*Apareiodon affinis* (4, 7)
Astyanax paranae (4, 18, 19)	*Apareiodon ibitiensis* (4)
Cetopsorhamdia iheringi (2, 19)	*Apareiodon piracicabae* (13, 15)
Characidium gomesi (4, 19)	*Cheirodon stenodon* (12)
Characidium zebra (15)	*Hisonotus* sp. (18, 19)
Corydoras difluviatilis (18, 19)	*Hypostomus ancistroides* (19)
Eigenmannia virescens (18, 19)	*Hypostomus hermanni* (10)
Eigenmannia sp. (15)	*Hypostomus paulinus* (21)
Gymnocorymbus ternetzi (15)	*Parodon nasus* (4, 9)
Hemigrammus marginatus (4)	*Synbranchus marmoratus* (19)
Hyphessobrycon eques (15, 22)	
Imparfinis schubarti (1)	**Omnivores with tendency to herbivory**
Leporinus obtusidens (15)	*Astyanax schubarti* (4, 12, 13, 14, 15)
Moenkhausia sanctaefilomenae (15)	*Leporellus vittatus* (4, 5)
Parauchenipterus galeatus (15)	*Leporinus elongatus* (4, 15)
Phenacorhamdia tenebrosa (19)	*Leporinus friderici* (4, 13, 15, 17)
Piabina argentea (4, 19)	*Leporinus lacustris* (4, 13, 15, 17)
Pyrrhulina sp. (15)	*Leporinus octofasciatus* (4)
Rhamdia quelen (18)	*Leporinus striatus* (4, 6, 13, 15)
Sternopygus macrurus (15)	
	Iliophagous
Omnivores with tendency to insectivory	*Cyphocharax nagelii* (15, 17, 22)
Astyanax altiparanae (4, 12, 13, 14, 15, 22)	*Cyphocharax modestus* (15, 17, 22)
Astyanax fasciatus (4, 12, 13, 14, 15, 19, 22)	*Prochilodus lineatus* (4, 13, 15, 16, 17)
Astyanax trierythropterus (4)	*Prochilodus vimboides* (4)
Aphyocheirodon hemigrammus (4)	*Steindachnerina insculpta* (8, 13, 15, 22)
Bryconamericus stramineus (4)	
Characidium fasciatum (4)	**Herbivores**
Gymnotus carapo (15, 22)	*Brycon orbignyanus* (4)
Moenkhausia intermedia (11, 13, 15)	*Leporinus fasciatus* (4)
Odontostilbe microcephala (4)	*Myleus tiete* (4)
Pimelodella boschmai (20)	*Schizodon nasutus* (4, 15, 17, 22)
Serrapinnus heterodon (4)	
Serrapinus piaba (4)	**Carnivores**
	Geophagus brasiliensis (13, 15)
Piscivores	*Hoplosternum littorale* (15, 22)
Acestrorhynchus lacustris (13, 15)	*Hyphessobrycon bifasciatus* (22)
Hoplerythrinus unitaeniatus (22)	*Iheringichthys labrosus* (22)
Hoplias malabaricus (4, 13, 15, 17, 18, 19, 22)	*Pimelodus maculatus* (3, 15)
Hoplias microcephalus (15)	
Salminus hilarii (4, 13, 15)	**Omnivores**
Salminus brasiliensis (4, 13, 15, 16)	*Piaractus mesopotamicus* (4)
"Serrasalmus spilopleura" (4, 13, 15, 22)	*Phallotorynus jucundus* (15)

Source: 1. Gomes (1956) 2. Schubart and Gomes (1959) 3. Nomura et al. (1972) 4. Godoy (1975) 5. Nomura and Mueller (1978a) 6. Nomura and Mueller (1978b) 7. Nomura et al. (1978) 8. Nomura and Taveira (1979) 9. Nomura (1979) 10. Nomura and Mueller (1980) 11. Esteves and Galetti Jr. (1994) 12. Esteves and Galetti Jr. (1995) 13. Meschiatti (1995) 14. Esteves (1996) 15. Meschiatti et al. (2000b) 16. Esteves and Lobo (2001) 17. Marçal-Simabuku and Peret (2002) 18. Ferreira and Castro (2005) 19. Ferreira (2007) 20. Schubart (1964a) 21. Nomura and Nemoto (1983) 22. Gonçalves (2007)

Pyrrhulina sp., *Phallotorynus jucundus*, in areas covered by macrophytes in floodplain lakes (Meschiatti, 1998). In those areas, also larger species, such as *Eigenmannia* sp. and *Gymnotus carapo*, reproduce along the year.

Parental care is observed in *Hoplerythrinus unitaeniatus*, *Hoplias malabaricus*, *Serrasalmus marginatus* (Characiformes), *Callichthys callichthys, Hoplosternum littorale, Hypostomus ancistroides, H. regain, Loricaria prolixa*

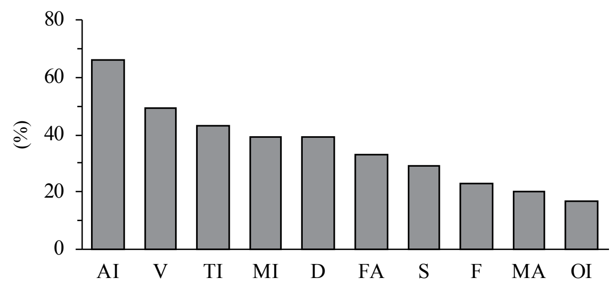

Figure 3. Proportion of species per dietary items: (AI) Aquatic insects, (V) Vegetal matter, (TI) Terrestrial insects, (MI) Microcrustaceans, (D) Detritus, (FA) Filamentous algae, (S) Sediment, (F) Fish, (MA) microalgae, (OI) others invertebrates.

(Siluriformes), *Astronotus ocellatus* (Perciformes) (Suzuki et al., 2002). Internal fecundation is shown by the silurid *Parauchenipterus galeatus* (Suzuki et al., 2002) and the cyprinodontid *Phalloceros caudimaculatus, Phallotorynus jucundus, Poecilia reticulata* e *Rivulus* sp., the latter group comprising viviparous species.

11. Fish Migration

The first study on fish migration in Mogi-Guaçu River was undertaken by Godoy, in 1954 (Godoy, 1957). Five thousand specimens of selected species were tagged, from 1954 to 1956, a higher number of specimens from the most abundant species (Table 3), 9.1% being recaptured (Godoy, 1954). Until 1963, 27,000 specimens were tagged (Godoy, 1967, 1972a, b) and were released in the same place they were caught and also in the rivers Pardo and Grande (Godoy, 1972b). Ten percent were recaptured, 1.9% in the same place of capture, in consecutive years, indicating the periodicity of migration (Godoy, 1967, 1972a, b).

The results of those large studies revealed the migratory trajectories, as well as the spawning and feeding grounds. Every year, the fishes move from Grande River towards the upper Mogi-Guaçu River, Salto do Pinhal being the migration limit. After spawning, between November and February (high water and wet season), they move downstream, continuing in Pardo River until its mouth, attaining the middle reach of Grande River, which is their feeding site, travelling *ca*. 1200-1400 km/year (Godoy, 1957, 1967, 1972a, b, 1975).

The reproductive biology of the migratory species *Prochilodus lineatus* is the best documented. Its migratory range varies from 150 km upstream to 500 km downstream of Cachoeira de Emas. Specimens pass by Cachoeira de Emas twice a year, between October and December, during the upstream migration (piracema period), and January and February during the dowstream migration (Toledo Filho et al., 1986). The highest velocities attained were 220 km/month in October (upstream migration) and 200 km/month in January (downstream migration).

Migration is performed by several species, for many purposes, daily or yearly, for a few meters (lateral migration within the habitat), to thousands of kilometers for reproduction, for feeding or unknown reasons (Capeleti and Petrere Jr., 2006). Reproductive migration during certain periods of the year is known for a long time (Von Ihering, 1928). Schubart (1954) described a sequence of fish appearance during the piracema: first, the small-sized species of *Aphyocharax*, *Cheirodon, Aphyocheirodon, Odontostilbe*, *Characidium*, *Bryconamericus*, *Piabina, Apareiodon*, and *Parodon* swim near the river banks and through the trickles of riffles. One or two months later, shoals of the larger fishes *Prochilodus*, *Leporinus*, and *Salminus* appear.

During the upriver migration, they gather below Cachoeira de Emas, where there is a fish ladder (Godoy, 1954). The 3 m high-ladder allows larger species, such as curimbas and dourados as well smaller ones, to ascend it; benthic species, like cascudos and mandis, pass through their openings (Godoy, 1987). Recent observations showed that 20% of the specimens of *Prochilodus lineatus* were able to ascend the ladder, the remaining specimens concentrating near the spillway (Capeleti and Petrere Jr., 2006). After ascending the 7 m high-ladder of Mogi-Guaçu Dam, the specimens reach Salto de Pinhal (Godoy, 1957, 1967), which is an unsurmountable barrier and is the end of migration.

The primary spawning ground is located near Cachoeira de Emas, *ca*. 4 km downstream (Godoy, 1954). Other secondary sites are situated ca. 7.5 to 11 km downstream Cachoeira de Emas and other places upstream (Godoy, 1954).

The tributaries and floodplain lakes included in this review are located downstream Cachoeira de Emas (Figure 1). The tributaries of the middle reach of Mogi-Guaçu River are alternative spawning grounds, judging by the lower number of specimens caught. In Cabaceiras Stream, the lower declivity allows the free displacement of fishes till its upper reach (Oliveira and Garavello, 2003). The fishes, mainly *Leporinus friderici*, move upstream at the beginning of the wet season, before the flooding period, and the juveniles grow in the flooded areas in the lower reach of Cabaceiras Stream (Oliveira and Garavello, 2003). Upstream, in Araras Stream, *Leporinus friderici* and *Salminus hilarii* are distributed in the middle and lower reaches, attaining the 20 m high Cachoeira Água Vermelha, which is a limit for their migration (Birindelli and Garavello, 2005). In Quilombo River, upstream Araras Stream, Capão Preto Dam is a barrier for the species migration, which remains in its middle and lower reaches (Apone et al., 2008). Quilombo River has the highest number of migratory species, among the tributaries included here, which are, however, not abundant. In Pântano Stream, located upstream of Quilombo River, *Leporinus friderici*, *L. octofasciatus*, *Prochilodus lineatus*, and *Leporellus vittatus* are restricted to the middle and

Table 5. Size at first maturation (L_{50}) for females (F) and males (M); fecundity (A: number of ovocites/female, B: number of ovocites/g of ovary); spawning (S): Total (T) and parcelled (P) spawning; reproductive period (RP); meristic characteristics (♦); growth parameters (♣); reproductive strategy (•) (according to Suzuki et al. 2002) of some species from Mogi-Guaçu basin.

Species	L_{50} (mm)		Fecundity		S	RP		Source
	F	M	A	B				
Long distance migrant •								
Brycon orbignyanus	-	-	856.575	1.215	T*	-	-	(5)
Leporellus vittatus	-	-	34.683	1.051	T*	-	♦♣	(5, 11)
Leporinus elongatus	-	-	1.541.762	1.305	T*	-		(5)
Leporinus friderici	-	-	91.400	1.828	P	Nov.-Feb.	♦♣	(3, 5, 8, 20)
Leporinus octofasciatus	-	-	176.000	1.380	-	-	-	(5)
Pimelodus maculatus	-	-	-	-	P*	-	♦♣	(4)
Prochilodus lineatus	248	241	>1.000.000	1.400	T	-	♣	(2, 3, 5, 21, 23, 25)
Salminus brasiliensis	347	447	1.555.291	1.200	T	Nov.-Jan.	♣	(1, 3, 22, 23)
Salminus hilarii	-	-	52.259	885	T*	-	-	(5)
Schizodon nasutus	-	-	72.280	1.610	-	-	-	(5)
Short distance migrant or non-migrant •								
Apareiodon affinis	-	-	2.021	1.750	P*	-	♦♣	(13)
Astyanax altiparanae	104	92	9.567	5.479	T	Nov.-Feb.	♣	(6, 7)
Astyanax fasciatus	119	111	4.363	4.799	T	Nov.-Feb.	♣	(6, 7)
Astyanax paranae	37	32	-	-	-	Jan.-Dec.		(24)
Astyanax schubarti	107	105	2.884	5.791	T	Nov.-Feb.	♣	(6, 7)
Hisonotus sp.	21	16	-	-	P	Jan.-Dec.	-	(24)
Leporinus striatus	-	-	-	-	-	-	♦♣	(12)
Myleus tiete	-	-	7.000	500	-	-		(5)
Parodon nasus	-	-	-	-	P*	-	♦♣	(14)
Steindachnerina insculpta	-	-	8.455	4.207	-	-	♦♣	(9, 15)
Non-migrant with parental care •								
Hoplias malabaricus	-	-	46.318	1.095	P*	-	-	(5)
Hypostomus fluviatilis	140	150	61	46	-	-	♦♣	(19)
Hypostomus hermanni	120	140	96	60	-	-	♦♣	(16)
Hypostomus nigromaculatus	115	115	-	-	-	-	-	(19)
Hypostomus paulinus	102	114	92	-	-	-	♦♣	(10)
Hypostomus regani	191	193	2.453	49	-	-	♦♣	(18)
Hypostomus strigaticeps	163	170	137	-	-	-	♦♣	(17)

Source: 1. Von Ihering (1928) 2. Godoy (1959) 3. Castagnolli (1971) 4. Nomura et al. (1972) 5. Godoy (1975) 6. Nomura (1975a) 7. Nomura (1975b) 8. Nomura (1976a, b) 9. Nomura (1977) 10. Nomura and Nemoto (1983) 11. Nomura and Mueller (1978a) 12. Nomura and Mueller (1978b) 13. Nomura et al. (1978) 14. Nomura (1979) 15. Nomura and Taveira (1979) 16. Nomura and Mueller (1980) 17. Nomura and Mueller (1983) 18. Nomura (1985) 19. Nomura (1988) 20. Barbieri and Santos (1988) 21. Barbieri et al. (2000) 22. Barbieri et al. (2001) 23. Barbieri et al. (2004) 24. Ferreira (2007) 25. Romagosa et al. (1985) * Vazzoler and Menezes (1992)

lower reaches as a 70 m high-waterfall (Cachoeira Salto do Pântano) precludes the ascending movement to the upper reach (Perez-Junior and Garavello, 2007). In one creek, Paulicéia, migratory species are absent.

Another indication of the use of tributaries as spawning grounds, by part of migratory species populations, and for young fish recruitment, is the occurrence of juveniles of *Myleus* sp., *Leporinus friderici*, *Schizodon nasutus*, *Salminus hilarii*, *Prochilodus lineatus*, and *Pimelodus maculatus* in their lower reaches (Table 6). The presence of *Leporellus vittatus* in tributaries and its absence in lakes may indicate its reproduction in the first habitat. Conversely, *Leporinus elongatus*, *L. obtusidens*, *L. octofasciatus*, and *Salminus brasiliensis* do not explore tributaries, in general. These species spawn in the river channel and eggs and larvae develop in backwaters and floodplain lakes, where juveniles can be found (Table 6).

Leporinus friderici, *L. striatus*, *Schizodon nasutus*, *Salminus hilarii*, *Prochilodus lineatus*, and *Pimelodus maculatus* are widely distributed in the basin, including river channel, tributaries, and floodplain lakes. *L. friderici* has been also caught in the upper reach of Cabaceiras Stream (Table 6).

Table 6. Range of standard length (cm) of migratory species in several environments of Mogi-Guaçu River basin. Size of specimens not available (+); total length (*).

Species	River	Tributaries			Lakes	
		Superior reach	Middle reach	Inferior reach	Permanent connection	Temporary connection
Brycon cephalus	+	-	-	-	-	-
Brycon orbignyanus	+	-	-	-	-	-
Galeocharax knerii	-	-	-	13.2	-	-
Leporellus vittatus	10.5-27.5*	-	14.5-15.7	+	-	-
Leporinus elongatus	-	-	-	-	3-17.2	7.8-23.9
Leporinus friderici	19-41*	13.6-21.7	12.6-16.9	2.2-23.8	8.4-27.2	6.5-35.0
Leporinus obtusidens	-	-	27.3	-	2.4-21.1	1.8-2.8
Leporinus octofasciatus	-	-	-	+	-	2.5-18.3
Leporinus striatus	8.5-13.5*	-	+	4.4-11.8	3-12.3	-
Myleus sp.	-	-	-	1.6-3.9	-	-
Salminus brasiliensis	28-87	-	-	-	18.8-29	+
Salminus hilarii	-	16.6	-	14.8-29.7	9.2-23.3	11.4-19.1
Schizodon nasutus	-	-	26.0	18.2-18.8	7.8-30.6	9.2-15.8
Piaractus mesopotamicus	+	-	-	-	-	-
Pimelodus maculatus	11-39 *	-	+	11.8	8.7-21.2	4.5-24
Prochilodus lineatus	16.9-63.5*	-	22.3-28.2	8.1-17.6	8.3-43.5	8.2-28.5
Pseudopimelodus mangurus	+	-	-	-	-	-
Zungaro jahu	+	-	-	-	-	-

12. Nurseries and Environmental Degradation

Eggs derived from migratory species float, reaching the river banks after fecundation, especially bays and backwaters, where they can shelter within the vegetation (Von Ihering, 1930). Similarly, floodplain lakes and flooded lowlands are suitable habitats for the development of eggs, larvae, fingerlings, and juveniles (Schubart, 1949; Godoy, 1954). During the piracema of 1944-1945, a large number of eggs was observed floating in the river flow (Godoy, 1945); in several lakes, located in Porto Ferreira and other towns, and downstream Corredeira da Escaramuça there were many juveniles of several species, such as curimba, dourado, piracanjuba, several species of *Leporinus*, peixe-cachorro, among others (Schubart et al., 1952) (respectively *P. lineatus, S. brasiliensis, B. orbignyanus*, *Leporinus* spp., *Acestrorhynchus lacustris*). Tens of thousands of fingerlings were caught in floodplain lakes near Cachoeira de Emas and Porto Ferreira, from 1944 to 1946, for repopulating the rivers Camanducaia and Paraíba and several reservoirs of São Paulo State (Schubart et al., 1952).

Unfortunately, the observations of Von Ihering, Schubart, and Godoy on eggs, larvae, and early life stages were not coupled with quantitative data for comparisons with recent data. Recently, eggs and larvae were found in higher densities in backwaters downstream from Cachoeira de Emas (20.6 eggs.m^{-3} and 0.7 larvae.m^{-3}) than in the river channel (8.4 eggs.m^{-3}, no larvae) (Marçal-Simabuku, 2005). The migratory fishes apparently occupy several habitats, including flodplain lakes, where the smallest specimens were found (Table 6).

The role of floodplain lakes as nurseries has been lately subject to controversy. For example, Galetti Jr. et al. (1990) considered the floodplain lakes Diogo and Infernão as natural shelters for growth and feeding of young *P. lineatus*. Meschiatti et al. (2000a, b) discussed that although at least ten migratory species were present in both lakes, the number of specimens were low, their role as true nurseries being doubtful. Esteves et al. (2000) and Gonçalves and Braga (2008) did not consider five floodplain lakes, located within the reproductive area of migratory species (Godoy, 1954, 1967), as nurseries. Mogi-Guaçu Dam, upstream Jataí Station, controls river flow, altering the flood pulse in this stretch, increasing the risk of losing the river-floodplain lakes connection. Sand dredging in the river channel coupled with the flow control by the dam decrease the river overflow episodes, during the wet season, causing the reduction of flooded areas and water volume in the lakes (Gonçalves and Braga, 2008).

The declining role of floodplain lakes as nurseries can be related to natural causes as well to human activities. In years of lower precipitation the river overflow may not reach a lake and human activities, such as sand dredging in the river, can influence the flood regime. Therefore, both natural and anthropogenic factors affect the entrance and survival of early life stages of fish in lakes.

Sand dredging in the river channel is one of the factors contributing for the environmental degradation of Mogi-Guaçu basin. Along 150 km, there are around 15 sand dredging areas in lowlands, totaling 120 dredging sites (Brigante et al., 2003a). Clay and crushed rocks are also extracted in several places in the basin and the impacts include shifts in transversal profiles of the river channel, siltation, higher turbidity, and destruction of lowlands and riparian vegetation (Carpi Jr., 2001).

Discharge of increasing amounts of non-treated domestic sewage, associated to industrial effluents, pesticides and fertilizers used in agriculture are responsible for the water quality and sediment degradation of the river basin (Brigante et al., 2003a; Silva et al., 2005). Other influences on the system are pesticides used in aquaculture activities, for decreasing fish ectoparasites (Santos, 2007). Crescent urbanization, industrial and agricultural activities are accelerating the natural budgets of several metals like copper, cadmium, cobalt, chromium, zinc, magnesium, manganese, iron, plumb, and nickel in the river basin, increasing the impacts on the aquatic life and humans (Brigante et al., 2003c).

Cadmium and plumb accumulation has been detected in bivalve mollusks, concentrations increasing towards the Mogi-Guaçu River mouth (Tomazelli et al., 2003). Mercury concentrations are not high in the water and sediments and in fish tissues its concentration was below the established threshold (1 $mg.kg^{-1}$, ANVISA, 1998) (Tomazelli et al., 2007). Other study, however, revealed that among 2,282 fish specimens in the 1980's, caught in nine stations along Mogi-Guaçu, omnivorous and carnivorous species presented mercury concentrations in muscles (~27% of 481samples) and viscera (18% of 549 samples) higher than 0.5 $\mu g.g^{-1}$, the threshold for human consumption established at that time (Boldrini et al., 1983).

The presence of organochlorine insecticides, in the river sediments, from the source to its mouth, is risky for aquatic communities and the water quality, as the substances in the water column can be supplied by the sediment (Brigante et al., 2003b). Histological alterations in gills, kidney, and liver have been detected in fishes submitted to tests with sediments of Mogi Guaçu River (Meletti et al., 2003).

The survival of early life stages of fish can be reduced by the river pollution. Eggs and larvae of *Prochilodus lineatus* have experienced high mortality in assays with dimethoate 40%, largely used in Brazilian agriculture (Campagna et al., 2006). Mortality rates were 20-30% in several doses, increasing in the highest concentration where *ca.* 73% of the larvae died; larvae motility have been also affected what can increase predation rates in nature. Campagna et al. (2006) supposed that the massive mortality of 30 tons of fish in Mogi-Guaçu, in October of 2002, was related with that pesticide.

The contribution of *Prochilodus lineatus* to the fish yield increased from 50% in the past (Godoy, 1954) to 90% in the 1980's (Petrere Jr., 1989). This increase may result from the decrease of other populations and/or release of fingerlings by CPFL Energy Generation S.A. (www.cpfl.com.br), one of the owners of the small dams in Mogi-Guaçu River; in Mogi-Guaçu Reservoir the AES Tietê S.A. also releases fingerlings of *P. lineatus*, as well as *Piaractus mesopotamicus* and *Leporinus obtusidens* (www.aestiete.com.br).

A strategy to thrive under adverse environmental conditions or overexploitation is to reduce the age at first maturation (Barbieri et al., 2004). Both species, *Prochilodus lineatus* (curimbatá) and *Salminus brasiliensis* (dourado), adopted this strategy in Mogi-Guaçu River. Lately, curimba matures in one year, instead of 2 and 3 years for male and female, respectively, as previously reported. Curimba population is in equilibrium and has not been drastically reduced in Mogi-Guaçu as in other river basins of São Paulo State, what do not preclude adopting management policies to prevent its extinction or the population decrease below the level of economic interest for commercial fishery (Barbieri et al., 2004).

Environmental degradation can be responsible for decreasing fish yield in this river as well as in other rivers in São Paulo State, according to data on commercial fishery from 1994 to 1999 (Vermulm Jr. et al., 2001). A general reduction in fish production has been observed in Mogi-Guaçu, where the capture per unit effort (CPUE) decreased 80%, and the specimens have a lower average total length (Petrere Jr., 1989); in Grande River, where the Pardo River discharges, production was reduced in 41%. Observations made by researchers, who have been studying the river for 50 years, reinforce the data on declining production: "fishery in Mogi-Guaçu decreased and fish is short" (Godoy, 1987). Several causes can be pointed out - pollution, riparian forest devastation, floodplain lakes destruction, reduction in feeding grounds in Grande River middle reach and overexploitation (Godoy, 1987). Sixty years ago, Schubart (1949) warned on the danger of basin deforestation, siltation of the river, floodplain lakes, and flooded areas, drainage of lowlands for agriculture, the new pesticide DDT, and the crescent industrialization. Management and protection policies are urgent for fish stock restoration, but progress can prevent the success of most of them.

According to the map on biodiversity of São Paulo State, areas of the Mogi-Guaçu basin are priorities for conservation, preservation, and restoration strategies for reestablishing the biodiversity of São Paulo State (Pesquisa Fapesp, 2007). Fast action is needed considering the environmental degradation level and the threat of extinction of several fish species. However, coupling progress and environmental conservation is a difficult task for optimists and an impossible one for pessimists.

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