The High River Paraná Basin: Limnological and Ichthyological Aspects

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ABSTRACT

This chapter is concerned with the limnological and ichthyological aspects of the high River Paraná, delimited by the confluence of Rivers Paranaíba and Grande up to the former Sete Quedas Waterfalls (619 km). The intensive use of the water bodies of this basin and the construction of many dams have had a great influence on the limnological characteristics which affect the structure and the functioning of the biological community that inhabit them. Among the limnological parameters, phosphorus deserves special attention since it is the main nutrient associated with the eutrofication process and it can be an indicator of anthropogenic interference. A model concerning the main routes of phosphorus in different water bodies of the basin is proposed. The flood pulses are the main forcing function that regulates the exchange between the river and its floodplain. Two hundred and twenty-one fish species were registered in the different environments of the basin. More than 20 species from other basins were introduced and, at least 17 other species were dispersed after the barrier of the former Sete Quedas Waterfalls had been submerged when the Itaipu Reservoir was formed. Piscivorous and detritivorous species are dominant in the fish assemblages of the basin alternating in importance according to the environment. The first group predominates in rivers, while the second one in lagoons and secondary channels. Information on some reproductive tatics of 71 species of teleosts is available. There is a prevalence of species with external fecundation, partial spawning, marked reproductive seasonality and short reproductive period. The beginning of gonadal development is related to water temperature and day-length increase; spawning begins with the flood which widens the environmental areas, while the end of this period is determined by the flood peak. Information about growth parameters is restrict to only about 10% of the species: loricarids and pimelodids present low growth rates, while characids and curimatids present higher growth rates. The inverse relation between growth rate values and those of first maturity length reflects the relationship between somatic and reproductive investment. The pressure of anthropic activities, especially those related to damming and pollution, has deeply changed fishery yield and its specific composition. The integrity maintenance of the remaining free stretches of the high River Paraná is essential to the permanence of the access routes to the spawning sites, and to the floodplain, vital to the juvenile phases of development. This is still possible through the definitive suspension of the construction of Ilha Grande Reservoir and of a suitable flow manipulation of the reservoirs upstream.

INTRODUCTION

The River Paraná, the principal river of the La Plata basin, is the tenth largest river in the world in water discharge and the fourth in drainage area (5.0.108 m^3/year; 2.8.106 km^2 respectively). Its basin includes all the south-central part of South America from the Andes to the Serra do Mar near the Atlantic Ocean. From its source in the central plateau to its estuary the River Paraná flows 4,695 km, crossing sedimentary and vulcanic rocks of the Paraná and Chaco sedimentary basin whose borders are made up of highlands on the Eastern coast of the Andes and the Precambrian rocks of the Brazilian Shield on the North and East (Petri & Fulfaro, 1983). Its upper stretch (the River Paranaíba = 1,070 km), its high section (the confluence of the Rivers Paranaíba and Grande up to the former Sete Quedas Waterfalls = 619 km) and part of the middle section (from the former Sete Quedas Waterfalls to the mouth of the River Iguaçu = 190 km) are within Brazilian territory. These sections drain an area of 891,000 km² which corresponds to approximately 10.5% of the area of the country (Paiva, 1982) (Fig.1).

The two rivers that form the River Paraná (Grande and Paranaíba) have the same characteristics of plateau rivers, with an average declivity of approximately 0.8 m/km, decreasing towards its lower parts (0.3 and 0.4 m/km respectively). From Três Lagoas (state of Mato Grosso do Sul), the high River Paraná, with an average declivity of 0.18 m/km, presents a wide floodplain specially on the right margin which may reach up to 20 km in width and extend itself to 480 km in length. This section represented the only remaining stretch of the River Paraná in Brazilian territory free from dams. One may exclude a stretch of approximately 30 km downstream from the Itaipu Reservoir already occupied by the Argentine-Paraguayan project of the Corpus hydroelectric plant. Approximately half this stretch, however, is being subtracted from the system due to the Porto Primavera hydroelectric plant. The last lotic environment of the river Paraná and its floodplain will disappear with the construction of the Ilha Grande reservoir, at present halted.

In the third lower part of the high River Paraná, with a declivity of 0.09 m/km (where the Universidade Estadual de Maringá has developed a program of research work), the river presents a wide braided channel, sometimes with an extensive alluvial plain and great accumulation of sediments in its bed (giving rise to sandbanks and small islands), sometimes with big islands and a more restricted floodplain (Agostinho, 1994). The complex anastomosis in this section of the river involves secondary channels, the river Baía and the lower courses of the rivers on the right bank (rivers Ivinheima, Amambaí and Iguatemi). On the left margin the rivers present great declivity (0.6 m/km for the Paranapanema; 1.30 m/km for the Ivai and 2.2 m/km for the Piquiri) with restricted floodplains. In Guaíra the river narrows down to 4.5 km and flows into the Itaipu Reservoir in the area where the Sete Quedas Waterfalls are submerged. Previously the waterfalls represented a natural barrier and hindered the dispersion of fish. From this point (middle River Paraná) the river flowed into a narrow tectonic rift as far as the Argentine town of Pousadas. However, this stretch has been altered in the first 150 kilometers from the Itaipu Reservoir.

Flowing in direction North-South-Southeast the high River Paraná is situated in tropical-subtropical regions with annual average monthly temperature of 15°C and rainfall superior to 1,500 mm per year (IBGE, 1990).

THE ANTHROPIC USE OF THE BASIN

The basin of the Paraná in its Brazilian section has the greatest demographic density in the coun-

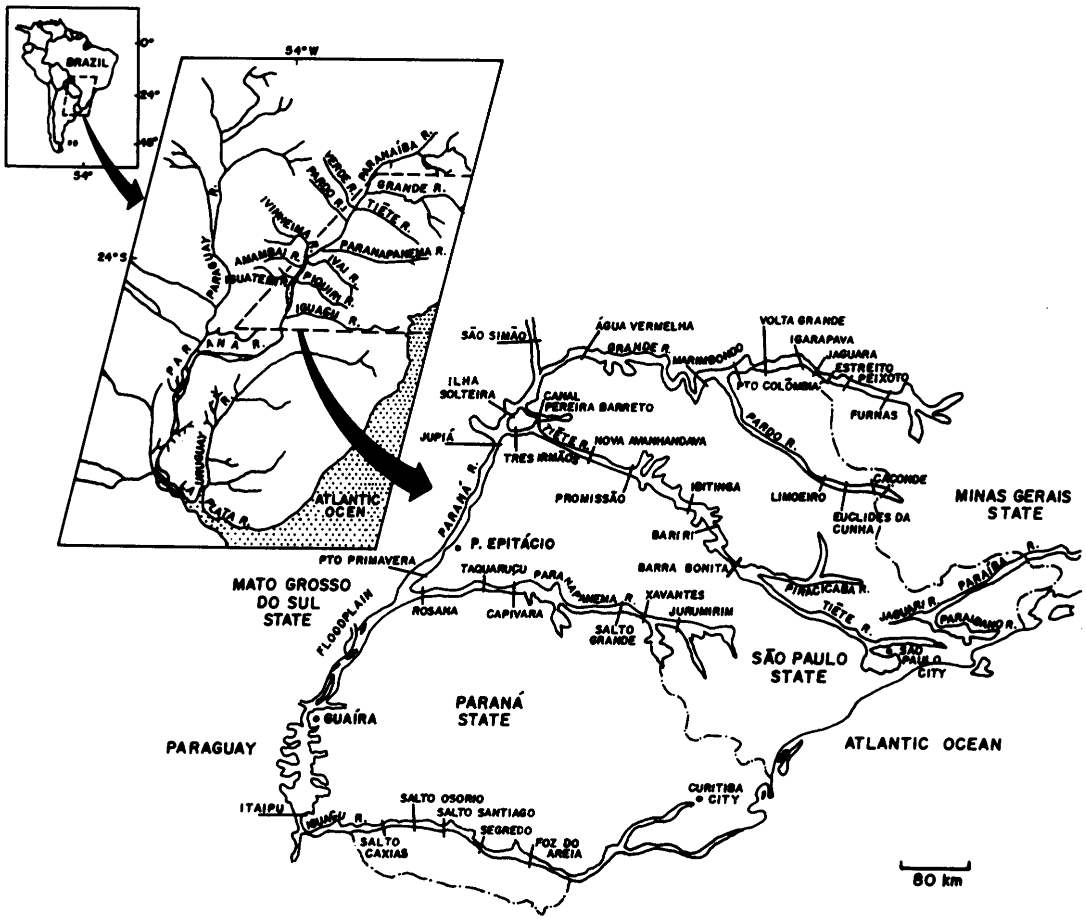


Fig. 1 – The high River Paraná basin and the main reservoirs

try. In the state of São Paulo where urban centres are greater and more populous the urban water demand is estimated to be around 87m^3/s with 50% returning to the water bodies. Only 8% of return has any type of treatment. Two thousand and three hundred industries out of 4,300 registered at the National Department ofWater and Electric Energy in the state of São Paulo have a demand of 113 m^3/s with a 68% return. The use of water for irrigation purposes (data of demand are not available) is very high in the basin. In the state of São Paulo the irrigated area is estimated at 470,000 ha by the IBGE (CERH-SP, 1990). The ever-increasing demands in consumption, intensive agriculture and cattle-raising (with an inadequate use of soil management technique), a heavy use of agricultural chemical agents and the elimination of riparian vegetation have contributed to increase the degenerative level of the water quality in the chief affluents of the River Paraná.

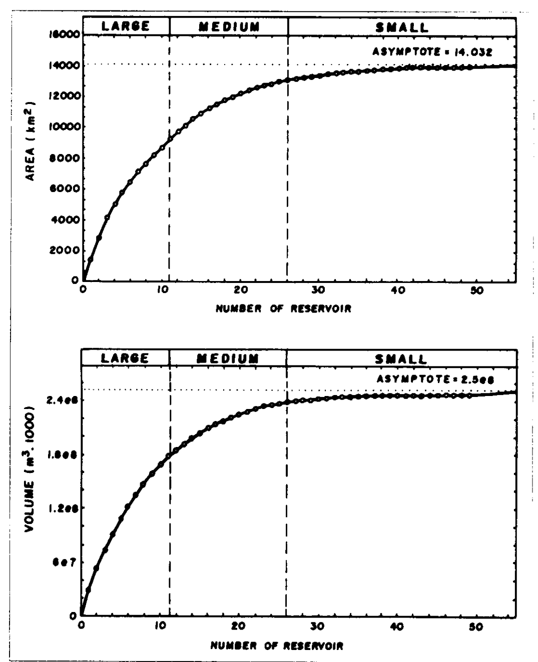


Fig. 2 – Cumulative area and volume of the high River Paraná reservoirs.

Among the human actions that modified to a great extent the physiographical characteristics of the basin, dammings have virtually affected all the principal affluents, especially those situated in the upper half of the high River Paraná. In this region there are 130 dams with heights superior to 10 meters. Twenty-six have an area bigger than 100 km^2, covering an extension of c. 93% of 14,000 km^2 of flooded area and containing a similar percentage of total volume accumulated (250.109 m^3, Fig. 2). These reservoirs are distributed among the Rivers Grande (13 reservoirs; 3,511 km^2 of flooded area; 53.109 m^3 of accumulated volume), Tietê (9 reservoirs; 2,326 km^2; 29.109 m^3), Paranaíba (7 reservoirs; 2,536 km^2; 65.109 m^3), Paranapanema (6 reservoirs; 1,844 km^2; 28.109 m^3), Iguaçu (4 reservoirs; 542 km^2; 17.109 m^3) and the main channel of the River Paraná (3 reservoirs; 3,150 km^2; 54.109 m^3). Approximately 80% of these reservoirs were built after 1960 and a pronounced increase in number and principally in the dammed area has been programmed till the end of the century with the hydroelectrical exploitation of other non-regulated rivers.

LIMNOLOGICAL ASPECTS

The intensive use of the water bodies of the high Paraná basin as receivers of material originated from agriculture, industry and wastewater as well as the construction of many dams have had a great influence on the patterns of ecological functioning and on the limnological characteristics of these water bodies.

The values of some limnological parameters of different aquatic environments of the high Paraná basin are shown in Table 1. Among these parameters phosphorus deserves special attention since it is the main nutrient associated with the eutrofication process and it can be an indicator of anthropogenic interference. The water bodies situated in the state of São Paulo receive the largest loadings of this element from the basin which comes from activities related to agriculture, industry and wastewater (Tundisi et al., 1988), resulting in elevated phosphorus concentration in the rivers that are not dammed (annual average = 283 µg P-total l^{-1} 157 SD - Table 1)(Mussara, 1994). On the other hand the bigger rivers of the Paraná basin have several reservoirs where phosphorus is precipitated and consequently accumulated in the sediment (Esteves, 1983; Tundisi and Matsumura-

Tundisi, 1990). This fact is suggested by the reduced phosphorus concentration obtained in the water leaving the Jupiá reservoir (annual average = 20 µg l^{-1} 8 SD - Table 1)(Mussara, 1994), the last one of a series of reservoirs situated in the rivers Grande, Tietê and Paraná. The role of the reservoirs in the reduction of phosphorus concentration is still suggested by the data obtained in the Itaipu reservoir: 30 µg total-P l^{-1} (11 SD) upstream and only 18 µg total-P l^{-1} (10 SD) downstream the reservoir (Surehma/Itaipu Binacional, 1989)(Table 1).

Along the stretch between Jupiá and Itaipu reservoirs (approximately 480 km long) the main channel of the River Paraná presents a successive increase of phosphorus concentration (Figure 3). Phosphorus input to the main channel can be attributed to the undammed rivers that come from the states of São Paulo and Mato Grosso do Sul (Table 1), as well as to the wide floodplain that borders this stretch. The input from the floodplain is suggested by the pattern of temporal variation of phosphorus concentration obtained in the main channel of the River Paraná and in several lagoons of its floodplain (Figure 4b). This figure shows that the reduction of phosphorus concentration in the lagoon water was registered in February, during the period of highest water level (Figure 4a). At the same time phosphorus concentration increased in the main channel. This pattern indicates that part of the phosphorus originated from sediment resuspension during the low water period (Thomaz, 1991; Thomaz et al., 1991) and by decomposition of the floodplain vegetation during the beginning of the high water period (Thomaz et al., 1992a), was exported to the main channel of the River Paraná. Consequently, instead of fertilising the floodplain (a common process in other big rivers), the high River Paraná exhibits a dilution effect, impoverishing the floodplain water bodies. It can be emphasized that the exportation of material from the floodplain during the high water periods is facilitated by the water fluctuation pattern of the River Paraná characterized by lack of symmetry between the falling and the rising water. Thus, several flood pulses are observed in a seasonal cycle (Figure 4a). The short falling water periods following these pulses make possible the export of dissolved and particulated material from the floodplain to the river channel. The same conclusion may be applied to the dissolved phosphorus fractions and total nitrogen Kjeldahl since they exhibited the same pattern commented on for total phosphorus (Thomaz, 1991). Nevertheless, an inverse pattern is exhibited by medium size rivers that flow to the floodplain since they can export phosphorus to the floodplain lagoons (Thomaz et al., 1992b).

An increase of chlorophyll-a concentration was observed simultaneously with phosphorus increase along the undammed stretch of the River Paraná (Figure 3). In addition to the autochthonous production, this increase can be attributed to the import of phytoplanktonic biomass from the floodplain lagoons in a similar process observed with regard to phosphorus. This pattern is suggested by the values of chlorophyll-a obtained during a period of one year in the main channel of River Paraná and in several lagoons of its floodplain (Figure 4c). This figure shows that the decrease of chlorophyll-a concentrations in November 1987 occurred after the first flood pulse of that year and it was followed by an increase of chlorophyll-a concentration in the main channel of the

TABLE I

Limnological parameters of some water bodies of the high River Paraná basin. Data were not necessarily obtained in the same time intervals. Data refer to the amplitude. Average and standard deviation are shown between parentheses.

	Temperature	Secchi Disk	pH	Conductivity	Dissolved Oxygen	Total Phosphorus	Total Kjeldahl Nitrogen	Chlorophyll - *a*
	(°C)	(m)		(μS/cm)	(mg/l)	(μg/l)	(mg/l)	(μg/l)
23 reservoirs of the state of São Paulo (1)	-	0.69 - 4.66 (2.47 ± 1.19)	-	25 - 103 (50 ± 25)	-	5.3 - 22.3 (11.4 ± 5.7)	-	1.6 - 10.4 (4.2 ± 2.8)
4 medium sized affluents (state of Mato Grosso do Sul) (2, 3)	16.8 - 29.5 (23.3 ± 3.7)	0.15 - 1.55 (0.69 ± 0.36)	5.9 - 7.7 (6.9 ± 0.5)	23 - 55 (38 ± 9)	3.9 - 10.0 (7.5 ± 1.5)	24 - 139 (68 ± 32)	0.04 - 0.68 (0.27 ± 0.17)	< 0.1 - 4.5 (1.7 ± 1.1)
3 medium size afluents (state of São Paulo) (3)	18.0 - 26.7 (23.5 ± 3.4)	0.10 - 0.40 (0.26 ± 0.09)	5.5 - 7.4 (6.4 ± 0.6)	75 - 149 (120 ± 21)	2.1 - 7.9 (5.8 ± 1.6)	99 - 649 (283 ± 157)	0.15 - 0.68 (0.40 ± 0.19)	2.2 - 22.5 (6.9 ± 5.4)
6 floodplain lagoons (2, 3)	15.8 - 29.3 (24.2 ± 4.2)	0.60 - 4.50 (0.75 ± 0.58)	5.1 - 9.5 (6.8 ± 0.6)	16 - 60 (29 ± 12)	0.3 - 11.3 (6.1 ± 2.6)	12 - 244 (85 ± 52)	0.14 - 1.95 (0.67 ± 0.41)	0.4 - 119.1 (7.9 ± 11.3)
2 floodplain secondary channels (2,4)	16.4 - 29.4 (24.4 ± 4.3)	0.45 - 1.40 (0.74 ± 0.24)	6.5 - 7.7 (7.0 ± 0.3)	16 - 47 (25 ± 8)	1.6 - 12.6 (7.3 ± 2.0)	31 - 90 (52 ± 16)	0.22 - 0.87 (0.43 ± 0.18)	0.4 - 10.4 (4.2 ± 2.4)
Main channel of the River Paraná:								
- **downstream Jupiá reservoir (3)**	20.0 - 27.0 (24.2 ± 2.8)	1.50 - 4.00 (2.78 ± 1.31)	5.8 - 6.9 (6.4 ± 0.4)	48 - 61 (56 ± 5)	6.8 - 9.2 (7.9 ± 0.8)	12 - 36 (20 ± 8)	0.03 - 0.22 (0.13 ± 0.07)	1.1 - 2.6 (1.6 ± 0.6)
- **upstream River Paranapanema (3)**	20.5 - 27.4 (24.0 ± 2.6)	0.96 - 2.00 (1.43 0.45)	6.2 - 6.7 (6.5 ± 0.2)	46 - 59 (51 ± 5)	6.9 - 10.5 (7.8 ± 1.2)	6 - 74 (37 ± 29)	0.11 - 0.36 (0.21 ± 0.11)	0.8 - 4.5 (2.6 ± 1.3)
- **downstream River Paranapanema (2)**	19.0 - 30.1 (24.8 ± 3.3)	0.80 - 2.15 (1.01 ± 0.49)	7.1 - 7.8 (7.6 0.2)	48 - 72 (55 ± 6)	7.6 - 10.6 (8.8 ± 0.9)	7 - 54 (27 ± 11)	0.14 - 0.52 (0.26 ± 0.10)	0.7 - 6.3 (3.0 ± 1.4)
- **upstream Itaipu reservoir (5)**	18.8 - 29.8 (24.7 ± 3.6)	0.40 - 1.10 (0.60 ± 0.21)	6.8 - 7.7 (7.4 ± 0.2)	42 - 53 (47 ± 3)	6.6 - 8.8 (7.7 0.7)	20 - 50 (30 ± 11)	0.26 - 0.90 (0.51 ± 0.20)	5.5*
- **downstream Itaipu reservoir (5)**	17.2 - 28.7 (26.3 ± 3.8)	0.40 - 2.30 (1.15 ± 0.62)	6.1 - 7.7 (7.3 ± 0.4)	42 - 60 (50 ± 4)	10.3 - 12.9 (11.1 ± 0.8)	4 - 37 (18 ± 10)	0.18 - 0.65 (0.40 ± 0.14)	1.7*
Main body of Itaipu Reservoir (5)	17.9 - 28.8 (26.4 ± 3.4)	0.40 - 2.30 (1.03 ± 0.50)	6.7 - 7.5 (7.0 ± 0.2)	46 - 60 (51 ± 4)	6.0 - 8.9 (8.1 ± 0.9)	10 - 42 (22 ± 8)	0.17 - 0.74 (0.48 ± 0.17)	3.6*

(1) Values obtained by annual averages of the reservoirs, Tundisi et al. (1988); (2) Thomaz (1991); (3) Mussara (1994); (4) Thomaz et al. (1991); (5) Surehma-Itaipu Binacional (1989); * = only annual averages.

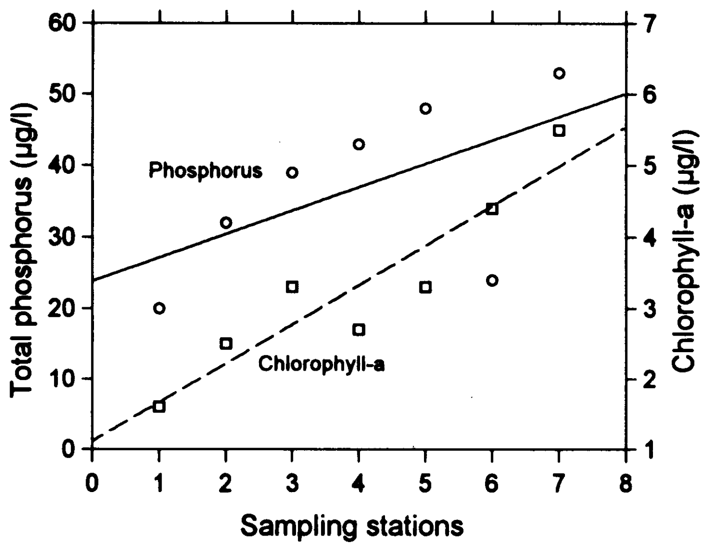


Fig. 3 – Total phosphorus and chlorophyll-a concentrations along a transection in the main channel of the River Paraná. 1 = 4 km downstream Jupiá reservoir; 3 = near the town of Presidente Epitácio; 6 = 40 km downstream the River Paranapanema; 7 = 5 km upstream Itaipu Reservoir. This stretch is undamaged and situated along the floodplain system. Data from Mussara (1994), PADCT-CIAMB/FUEM (unpublished) and Itaipu Binacional (unpublished). Data correspond to annual averages obtained between September 1992 and July 1993.

River Paraná. The clear increase of chlorophyll-a concentration observed in the undammed stretch of the River Paraná and its pattern of seasonal variation suggest that a small portion of the phytoplankton biomass of the main channel comes from the reservoirs situated upstream. Small exports of phytoplankton from upstream reservoirs to the main channel of the River Paraná may be due to the fact that the water flushes out of the lacustrine zone of the reservoirs where the phytoplankton biomass and productivity are usually limited by nutrient shortages (Kimmel et al., 1990).

On the other hand the floodplain lagoons present a considerable increase of ionic concentration due to the entrance of water from the River Paraná during the high water period. During this period the values of the conductivity of the floodplain lagoons can be two times higher than the values obtained during the low water periods (Figure 4d). A similar pattern is registered in temporary pools in islands of the high Paraná (Pagioro et al., in press). According to Thomaz (1991), bicarbonate is among the dominant ions and it has an important role in buffering the water bodies of the floodplain during the high water periods since they exhibit high degree of heterotrophy during these phases and, consequently, are subject to considerable changes of pH values. In addition to bicarbonate the River Paraná presents high silicate concentrations when compared to the floodplain lagoons and, thus, the river is an important source of this element to the floodplain water bodies during the high water periods (PADCT-CIAMB/FUEM, unpublished data).

A schematic model concerning the main routes of phosphorus in the different water bodies of the high River Paraná basin is shown in Figure 5. According to this figure a high proportion of the phosphorus carried to the big rivers in the state of São Paulo is retained in the reservoirs by sedimentation. Downstream to Jupiá reservoir, the main channel of the River Paraná receives a considerable input of phosphorus from rivers that are not dammed and from the floodplain water bodies. In this undammed stretch the river presents an intensive exchange with its floodplain. The floodplain water bodies receive silicate and bicarbonate and export phosphorus, nitrogen and organic matter derived basically from the phytoplankton, aquatic and terrestrial macrophytes. It can be considered that the flood pulse is the main forcing function that regulates the exchange between the river and its floodplain.

The export of nutrients from the floodplain to the channel of the River Paraná is one of the main characteristics of this model and it has a practical importance to the management of this area. Nevertheless the lack of long series of data does not permit one to conclude whether this is a natural functioning pattern of this stretch of the high River Paraná or the result of the cascades of reservoirs recently constructed in the main tributaries of its basin.

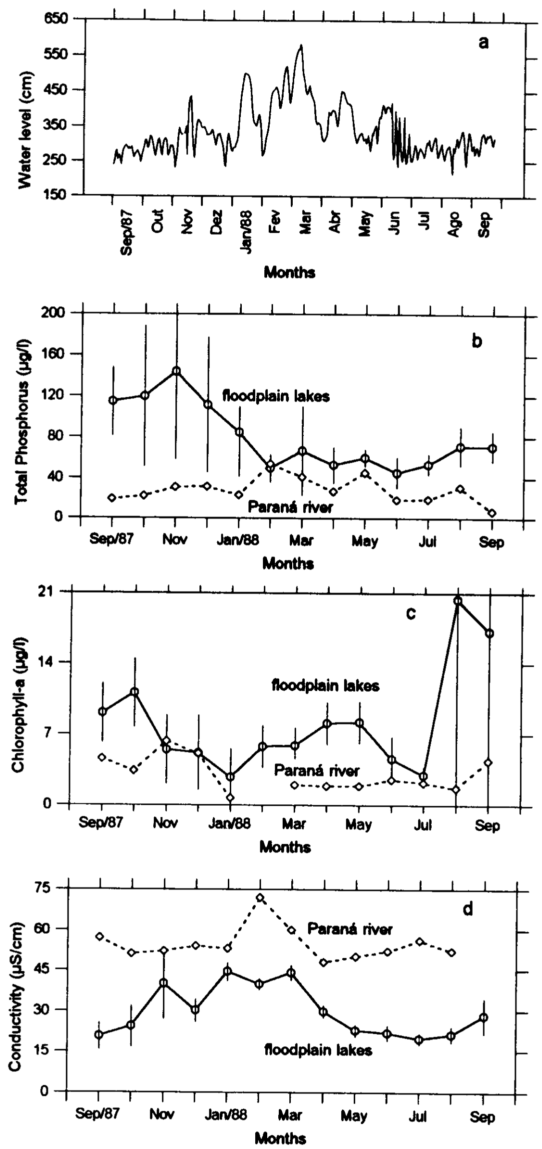


Fig. 4 – Water level (a), total phosphorus (b), chlorophyll-a (c), and conductivity (d) obtained in a sampling station of the River Paraná and in four lagoons of its floodplain (average SD). Modified from Thomaz (1991).

STRUCTURE OF FISH COMMUNITIES

Although survey of fish fauna in the high River Paraná floodplain is still incomplete and there is no agreement on the taxonomic status of some species, a revision of the survey work undertaken in approximately 110 sampling sites in rivers, streams, lagoons, creeks, temporary pools, secondary channels and reservoirs reveals the presence of at least 221 species (Table 2). Only surveys accompanied by a fish taxonomist for the identification of the collected biological material were considered. The number of species mentioned above represents approximately 37% of that calculated by Bonetto (1986) for all the La Plata basin. However, the same author considers that the fauna of the upper Paraná province, which includes the Iguaçu basin (not dealt with in this study), is composed of c. 130 species. Surveys at a reservoir in the middle stretch of the River Iguaçu (Segredo Reservoir) revealed the presence of 38 endemic species representing 75% of the species found in this environment (FUEM/COPEL, 1994). These numbers, added to those that would be obtained in the revision of taxa marked by the generic name+spp, may

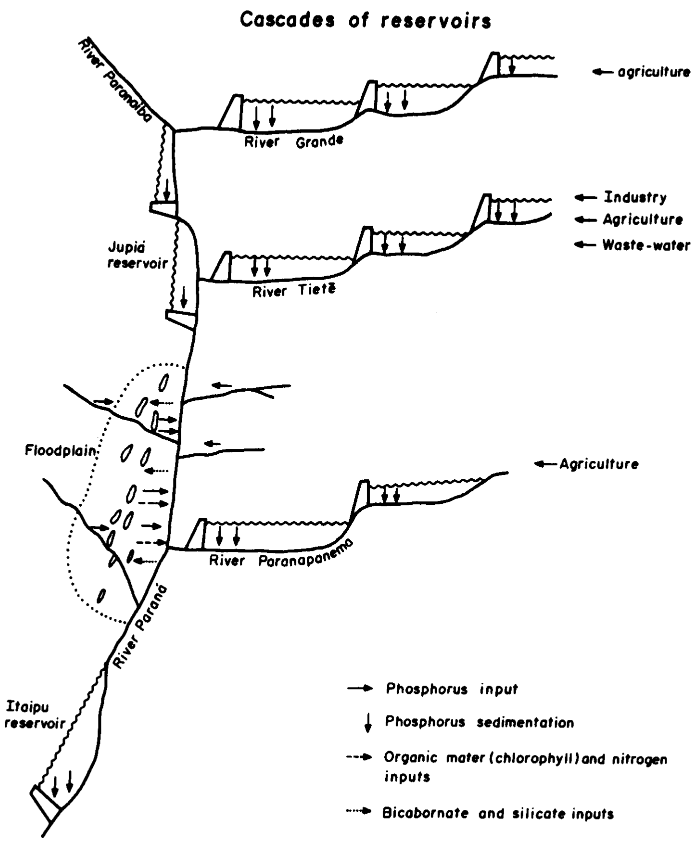


Fig. 5 – Model representing the interactions that determine the phosphorus concentration of the main water bodies of the high River Paraná basin. A more detailed model including other limnological parameters is shown for the river-floodplain system.

reach up to 300 species.

Among the species recorded in all the categories of the cited environments (Table 2) the following are conspicuous: peixe-cachorro *A. lacustris*, traíra *H. malabaricus*, saguiru *S. insculpta*, curimba *P. lineatus*, piranha *S. spilopleura*, lambaris *A. bimaculatus* and *A. schubarti*, piaus *L. friderici* and *L. obtusidens*, mandi *P. maculatus* and mandi-chorão *Pimelodella gracilis* (Table 2). Another eighteen species occurred in 8 out of 9 categories of the environments analysed. With the exception of streams which were insufficiently sampled, absence in the other environments should be related to restrictions imposed on local conditions as, for instance, typical and active predators (*P. corruscans* and *S. maxillosus*) in low order rivers where prey availability is generally low and lentic species (*L. lacustris* and *L. platymetopon*) in rivers with great declivity.

Creeks, (CRK) considered as low order rivers where riffles and pools alternate in their course, present a fauna characterized by small-sized, sometimes endemic, species. The information about 15 creeks of the River Paraná basin were analised (Schroeder-Araujo, 1980; Garutti, 1983; Uieda, 1984; Caramaschi, 1986; Penczak et al., 1994 and Agostinho, unpublished data). Within the environmental categories under consideration, this category presented the greater number of fish species (146). Forty-six are exclusive and may be attributed to the diversity of conditions it presents (extension, declivity, bottom type, availability of shelter, riparian vegetation etc.). Its fauna is composed of small characids (*Astyanax* spp, *Cheirodon* spp, *Characidium* spp, *Oligosarcus* spp), loricarids (*Rhineloricaria, Microlepidogaster, Hypostomus)*, poecelids, lebiasinids, small pimelodids *(Imparfinis, Rhamdia* spp, *Cetopsorhamdia, Nannorhamdia, Charmoscranus, Pimelodella*), trichomychterids and cichlids among others. Perhaps because of their small water volume these environments are more sensitive to anthropic action, such as canopy removal, canalization, sand silting, dams and pollution. Such actions have been damaging almost all of the creeks of the high Paraná basin. Penczak et al. (1994) registered conductivity and water pH besides availability of shelter, riparian vegetation, submerged macrophytes, depth and width of the river as relevant factors with regard to the communities present in two creeks of the third inferior section of this basin. Agostinho and Penczak (in press) show that the biomass and the average production of fish assemblage of these two creeks are positive and highly correlated to depth and availability of shelter ($p=0.01$).

Streams (STR) are intermediate-sized water courses 5 m to 20 m wide and up to 1 m deep in the upper central section. These environments in the high River Paraná basin are not sufficiently studied, possibly due to difficulties in managing fishing equipments proper to river and creek environments. The small number of species (40), none exclusive, registered in this type of environment is due to this fact. The available data refer to 10 sampling station distributed in the basins of Ivai and Paraná rivers (Mussara, 1994; Agostinho, unpublished data). Among the fauna components the following are conspicuous: **the piau** *L. amblirhynchus* and the **tabarana** *S. hilarii* (which share high declivity rivers), the **bagre** *Rhamdia* and the **cascudos** *Hypostomus* which are also recorded in creeks and other species with large

TABLE II

Species registered in distinct environments in the high River Paraná basin. (PRC = Paraná River Channel; HDT = High Declivity Tributaries; LDT = Low Declivity Tributaries; SCH = Secondary Channels; STR = Streams; CRK = Creaks; LAG = Lagoons; POL = Temporary Pools; RES = Reservoirs.

ENVIRONMENTS	PRC	HDT	LDT	SCH	STR	CRK	LAG	POL	RES
CLASS CHONDRICHTHYES ORDER RAJIFORMES POTAMOTRYGONIDAE									
Potamotrygon falkneri	+			+					+
Potamotrygon motoro	+		+	+			+	+	+
Potamotrygon sp.	+	+							
CLASS OSTHEICHTHYES ORDER CHARACIFORMES CHARACIDAE									
Acestrorhynchus lacustris	+	+	+	+	+	+	+	+	+
Acestrorhynchus sp.									
Aphyocharax dentatus	+					+			
Aphyocharax nasutus	+	+	+	+		+	+	+	+
Aphyocharax difficilis						+			
Aphyocheirodon hemigrammus						+	+		
Astyanax fasciatus	+	+	+	+		+	+		+
Astyanax marionae	+								
Astyanax scabripinnis		+				+			
Astyanax schubarti	+	+	+	+	+	+	+	+	+
Astyanax eigenmaniorum		+				+	+		
Astyanax bimaculatus	+	+	+	+	+	+	+	+	+
Astyanax sp.	+	+				+			+
Brycon orbignyanus	+	+	+	+		+	+	+	+
Brycon sp.		+							
Bryconamericus iheringi		+				+			
Bryconamericus stramineus		+	+			+		+	+
Bryconamericus spp.		+	+	+		+	+		+
Characidium fasciatum		+		+		+	+	+	+
Characidium spp.	+		+	+		+	+		
Cheirodon notomelas	+	+	+	+		+	+	+	+
Cheirodon piaba						+			
Cheirodon sp.	+		+	+		+	+	+	
Galeocharax knerii	+	+	+	+		+			+
Hemigrammus marginatus	+	+	+	+		+	+	+	
Hemigrammus sp.		+		+		+	+		
Holoshestes heterodon						+			+

TABLE II (cont.)

ENVIRONMENTS	PRC	HDT	LDT	SCH	STR	CRK	LAG	POL	RES
CHARACIDAE (cont.)									
Hyphessobrycon callistus	+		+	+		+	+	+	+
Hyphessobrycon anisitsi						+			
Hyphessobrycon bifasciatus						+		+	
Hyphessobrycon sp.		+				+			
Moenkhausia dichroura						+	+		
Moenkhausia intermedia	+	+	+	+		+	+	+	+
Moenkhausia sanctae-filomenae				+		+	+	+	
Moenkhausia argentea						+			
Moenkhausia sp.						+			+
Odontostilbe microcephala				+		+	+		
Odontostilbe sp.		+	+	+		+	+	+	
Oligosarcus pintoi						+			+
Oligosarcus paranensis		+				+			+
Oligosarcus planaltinae						+			
Oligosarcus sp.						+			
Piabina argentea		+				+			+
Planaltina sp.						+			
Pseudocorynopoma heterandria						+			
Roeboides paranensis	+	+	+	+		+	+	+	+
Roeboides sp.	+		+				+		
Salminus hilarii		+	+		+				+
Salminus maxillosus	+	+	+	+	+		+	+	+
Triportheus angulatus									+
SERRASALMIDAE									
Colossoma macropomum							+		+
Myloplus levis	+	+	+	+	+			+	+
Myloplus cf *tiete*		+					+		+
Myloplus sp.	+	+							
Metynnis cff. *maculatus*		+							
Mylossoma orbignyanum			+						+
Piaractus mesopotamicus	+		+	+			+		+
Serrasalmus marginatus	+	+	+	+	+		+	+	+
Serrasalmus spilopleura	+	+	+	+	+	+	+	+	+
ANOSTOMIDAE									
Leporellus vittatus	+	+	+	+	+	+		+	+
Leporinus amblirhynchus		+			+	+			+
Leporinus elongatus	+	+	+	+	+		+		+

TABLE II (cont.)

ENVIRONMENTS	PRC	HDT	LDT	SCH	STR	CRK	LAG	POL	RES
ANOSTOMIDAE (cont.)									
Leporinus friderici	+	+	+	+	+	+	+	+	+
Leporinus lacustris	+		+	+	+	+	+	+	+
Leporinus obtusidens	+	+	+	+	+	+	+	+	+
Leporinus octofasciatus	+	+				+	+		+
Leporinus paranensis							+		+
Leporinus silvestris						+			+
Leporinus striatus	+	+		+		+	+	+	+
Leporinus macrocephalus						+			
Schizodon altoparanae	+	+	+	+	+		+	+	+
Schizodon borelli	+		+	+	+		+	+	+
Schizodon intermedius		+							+
Schizodon nasutus	+	+	+	+		+			+
Schizodon spp.		+							
PARODONTIDAE									
Apareiodon affinis	+	+	+	+		+	+		+
Apareiodon ibitiensis						+			
Apareiodon piracicabae	+	+		+		+			+
Apareiodon sp.		+							
Parodon tortuosus	+	+				+			+
Parodon sp.						+			
CURIMATIDAE									
Curimata vanderi						+			
Curimata sp.	+					+			
Cyphocharax modesta	+	+	+	+		+	+		+
Cyphocharax nagelii	+	+	+	+			+	+	+
Steindachnerina insculpta	+	+	+	+	+	+	+	+	+
PROCHILODONTIDAE									
Prochilodus scrofa	+	+	+	+	+	+	+	+	+
ERYTHRINIDAE									
Hoplerythrinus unitaeniatus		+	+	+		+	+		
Hoplias lacerdae		+	+			+			+
Hoplias malabaricus	+	+	+	+	+	+	+	+	+
LEBIASINIDAE									
Pyrrhulina australis			+			+	+	+	
Pyrrhulina sp.						+			+
CYNODONTIDAE									
Rhaphiodon vulpinus	+	+	+	+	+		+		+

TABLE II (cont.)

ENVIRONMENTS	PRC	HDT	LDT	SCH	STR	CRK	LAG	POL	RES
ORDER SILURIFORMES GYMNOTIDAE									
Gymnotus carapo	+	+	+	+		+	+	+	+
STERNOPYGIDAE									
Eigenmania trilineata	+	+	+		+		+	+	
Eigenmania virescens	+	+	+	+	+	+	+		+
Eigenmania sp.	+	+	+			+		+	+
Sternopygus macrurus	+	+	+	+	+	+	+		+
APTERONOTIDAE									
Apteronotus albifrons	+	+	+	+		+	+		+
Apteronotus brasiliensis		+							
Apteronotus sp.	+	+	+	+		+	+		+
RHAMPHICHTHYIDAE									
Gymnoramphichthys cf. *hypostomus*							+		
Rhamphichthys rostratus	+		+	+			+	+	+
Sternarchorhynchus sp.	+	+							
DORADIDAE									
Doras eigenmanni			+	+			+		
Platydoras armatulus	+		+						
Pterodoras granulosus	+		+	+			+	+	+
Rhinodoras d'orbignyi	+	+	+	+			+		+
Trachydoras paraguayensis	+	+	+	+			+		+
AUCHENIPTERIDAE									
Auchenipterus nuchalis	+	+	+	+	+		+	+	+
Parauchenipterus galeatus	+		+	+		+	+	+	+
Tatia neivae		+				+			+
Trachelyopterus coriaceus			+	+			+		+
AGENEIOSIDAE									
Ageneiosus brevifilis	+		+	+			+		+
Ageneiosus ucayalensis	+		+	+			+		+
Ageneiosus valenciennesi	+		+	+			+		+
CETOPSIDAE									
Pseudocetopsis gobioides		+	+			+			
PIMELODIDAE									
Cetopsorhamdia iheringi						+			
Cetopsorhamdia sp.						+			
Chasmocramus sp.						+			
Hemisorubim platyrhynchos	+		+	+	+		+		+

TABLE II (cont.)

ENVIRONMENTS	PRC	HDT	LDT	SCH	STR	CRK	LAG	POL	RES
PIMELODIDAE (cont.)									
Heptapterus sp.						+			
Iheringichthys labrosus	+	+	+	+		+	+		+
Imparfinis mirini						+			
Imparfinis sp.						+			
Megalonema platanus	+	+	+	+	+		+		
Microglanis sp.						+			
Nannorhamdia schubarti						+			
Nannorhamdia sp.		+				+			
Phenacorhamdia sp.						+			
Pariolius sp.						+			
Paulicea luetkeni	+		+						+
Pimelodella avanhandavae									+
Pimelodella gracilis	+	+	+	+	+	+	+	+	+
Pimelodella insignis									+
Pimelodella cf. *lateristriga*						+			
Pimelodella meeki						+			
Pimelodella sp.	+	+	+	+		+	+		
Pimelodus maculatus	+	+	+	+	+	+	+	+	+
Pimelodus ornatus	+	+	+	+			+		+
Pimelodus paranaensis	+			+			+		+
Pimelodus blochii									+
Pimelodus fur	+	+							+
Pimelodus sp.				+					
Pinirampus pirinampu	+	+	+	+			+		+
Pseudopimelodus zungaro	+	+	+						+
Pseudoplatystoma corruscans	+	+	+	+	+		+	+	+
Rhamdia minuta						+			
Rhamdia hilarii					+	+			+
Rhamdia quelen		+		+		+			
Rhamdia sp.		+	+	+		+	+		+
Sorubim lima	+		+	+	+		+	+	+
Steindachneridion sp.		+							+
HYPOPHTHALMIDAE									
Hypophthalmus edentatus	+		+	+			+	+	+
TRICHOMYCTERIDAE									
Paravandellia sp.						+			
Trichomycterus spp.		+				+			

TABLE II (cont.)

ENVIRONMENTS	PRC	HDT	LDT	SCH	STR	CRK	LAG	POL	RES
CALLICHTHYIDAE									
Aspidoras fuscoguttatus						+			
Callichthys callichthys	+	+	+			+	+	+	+
Corydoras aeneus						+			
Corydoras sp.						+			
Hoplosternum littorale	+	+	+	+			+	+	+
LORICARIIDAE									
Ancistrus cirrhosus						+			
Farlowella hahni		+				+			
Farlowella sp.	+	+				+			+
Hypostomus ancistroides						+			
Hypostomus aff. *albopunctatus*						+			
Hypostomus derbyi		+				+		+	
Hypostomus margaritifer	+				+				
Hypostomus myersi					+	+			
Hypostomus regani		+							
Hypostomus tietensis	+	+	+	+	+	+	+		
Hypostomus variipictus	+		+		+		+		
Hypostomus wuchereri	+								
Hypostomus a						+			
Hypostomus b						+			
Hypostomus spp.	+	+	+	+	+	+	+		+
Hypoptomatinae		+				+			
Loricaria carinata	+			+			+		
Loricaria prolixa	+	+	+	+				+	+
Loricaria spp.	+	+	+	+		+	+		+
Loricariichthys platymetopon	+		+	+	+	+	+	+	+
Loricariichthys sp.	+		+	+			+		+
Megalancistrus aculeatus	+	+	+	+					+
Microlepidogaster cf. *depressicauda*						+			
Microlepidogaster sp.						+			
Neoplecostomus paranensis						+			
Neoplecostomus sp.						+			
Rineloricaria sp.						+			
Rhinelepis aspera	+		+	+					+
ASPREDINIDAE									
Bunocephalus sp.						+			
POECILIIDAE									
Cnesterodon decemmaculatus						+			

TABLE II (cont.)

ENVIRONMENTS	**PRC**	**HDT**	**LDT**	**SCH**	**STR**	**CRK**	**LAG**	**POL**	**RES**
POECILIIDAE (cont.)									
Phalloceros caudimaculatus						+			
Phalloceros sp.						+			
Poecilia reticulata						+			+
RIVULIDAE									
Rivulus spp.						+	+		
ORDER SYNBRANCHIFORMES SYNBRANCHIDAE									
Synbranchus marmoratus		+		+		+	+	+	
ORDER PERCIFORMES SCIAENIDAE									
Plagioscion squamosissimus	+		+	+	+		+		+
CICHLIDAE									
Aequidens plagiozonatus		+	+	+		+	+		
Aequidens portalegrensis						+			
Aequidens sp.						+			
Astronotus ocellatus			+						+
Cichla monoculus	+		+	+	+		+	+	+
Cichla temensis									+
Cichlasoma fascetum				+					+
Cichlasoma paranaense		+	+	+		+	+	+	+
Cichlasoma sp.		+		+			+		
Crenicichla britskii	+	+		+	+	+	+	+	+
Crenicichla haroldoi	+	+	+	+	+				+
Crenicichla jaguarensis									+
Crenicichla lepidota	+	+	+	+		+	+		+
Crenicichla nierderleinii		+		+			+		+
Crenicichla sp.	+	+	+	+		+	+		+
Geophagus brasiliensis		+				+	+		+
Geophagus sp.									+
Gymnogeophagus sp.						+			
Laetacara sp.				+		+		+	
Oreochromis niloticus						+	+		+
Satanoperca pappaterra	+		+	+			+	+	+
Tilapia rendalli						+			+
ORDER PLEURONECTIFORMES SOLEIDAE									
Catathyridium jenynsii	+		+	+	+		+	+	+
TOTAL NUMBER OF SPECIES	**103**	**108**	**98**	**102**	**41**	**142**	**101**	**55**	**125**

distribution such as the genera *Astyanax*, *Leporinus* and *Schizodon*.

High Declivity Tributaries (HDT) of the River Paraná (rivers Ivaí, Piquiri and Tibagi) are characterized by strong rapids and predominantly rocky bottom. These characteristics, however, are less conspicuous in the lowest stretches (Bennemann et al.,1995; Agostinho & Julio Jr., in press; Agostinho, unpublished data). Only seven out of 108 registered species were not captured in other types of environment. Besides the widely distributed species (*Astyanax* sp, *A. lacustris, S. insculpta, Apareiodon* sp, *P. lineatus* among others), other species, extremely abundant, are characterized by a rheophilic behaviour: the **pacus** *Myloplus* and *Metynnis*, the **peixe-cadela** *G. knerii* and *Oligosarcus* spp, the **solteira** *L. vittatus*, the bagre *Steindachneridion*, **piau** *L. amblirhynchus*, *Schizodon nasutus*, the **dourado** *S. maxillosus*, the **pintado** *P. corruscans* and the piapara *L. obtusidens*.

Low Declivity Tributaries (LDT) of the River Paraná (rivers Iguatemi, Ivinheima, Verde, Peixe, Pardo and Aguapei - Mussara, 1994; Agostinho & Julio Jr., in press) are rivers whose inferior halves are meandering, with weak water current and generally with a sandy or sandy-clay bottom. Among the 98 species registered in these environments, none was exclusive. In the basin's upper stretches the fauna was similar to that of high declivity rivers. Among other migratory species, the **curimba** *P. lineatus*, the **dourado-cachorro** *R. vulpinus*, the **armado** *P. granulosus*, **the piapara** *L. elongatus*, the **dourado** *S. maxillosus*, the **pintado** *P. corruscans*, the **piracanjuba** *B. orbignyanus* are the most conspicuous. Besides the first three species, the **manduvês** *Ageneiosus* spp, the **cascudo** *L. platymetopon*, the **mandi-beiçudo** *I. labrosus*, the **piranha** *Serrasalmus* spp, **surumanha** *A. nuchalis*, the **traíra** *H. malabaricus* predominate in the lowest sections. This assemblage, generally characterized by a high dominance of some species, is thus composed of piscivorous, detritivorous and omnivorous species.

The Paraná River Channel (PRC), with lotic characteristics, presents variable depths and a rocky sandy bottom. In its free stretch it has 103 species with two exclusive ones (FUEM-FINEP, 1989; PADCT-CIAMB/FUEM, 1993, 1994; Mussara, 1994; Agostinho et al., in press). The fact that these species belong to genera still lacking a taxonomic revision gives slight importance to their exclusiveness. Species such as the **mandi** *Pimelodus fur*, **peixe-espada** *Sternarchorhynchus* and pacu-prata *Myloplus* (all present in high declivity rivers), the **bagre-sapo** *P. zungaro* and the **jaú** *P. luetkeni* (both present in low declivity rivers and in the third upper section of the Itaipu Reservoir) are typical of this section of the system even though they have a rather moderate capture frequency. The **jaú**, the biggest fish in the basin, inhabits preferentially the great depressions of the river bed (depths superior to 30 m). Besides these species, the adults of great migratory species also inhabit the river channel (Agostinho & Julio Jr, in press).

Lagoons are shallow environments (with a maximum depth of 3 m during the dry season) with mud, sandy bottom, abundant aquatic vegetation and highly variable environmental conditions. Among the 101 species registered in these environments only one was considered exclusive (FUEM/FINEP, 1989; PADCT-CIAMB/FUEM, 1993, 1994; Agostinho et al., in press). Fish assemblages are dominated by species capable of bearing drastic oxygen and temperature conditions, such as the **cascudo** *L. platymetopon*, the caboja *H. littorale*, corró *L. lacustris*, young *P. lineatus* and other rheophilic species. Other species (*S. marginatus*, *S. spilopleura*) may be temporary abundant in these environments which they abandon when conditions become hostile (Agostinho & Julio Jr, in press).

Temporary Pools are defined as water bodies which occur in depressions of the floodplain of the River Paraná and which are affected by drastic retractions in their perimeter during the dry period. During the years with low rainfall they may dry altogether. Environmental conditions are extremely variable and hostile with intense predatory activity caused by aquatic and terrestrial organisms. Few surveys have been made in such environments of this basin. Analysing three complexes of temporary pools in the River Paraná, Verissimo (1994) registered 55 species, none exclusive. The author confirms the presence of 21 species in a pool 5 cm deep with juveniles of big migratory species as the curimba *P. lineatus* and the piapara *L. obtusidens*. Although the composition of assemblages which occupy these environments varies widely during the year, the fauna is dominated till desiccation by *A. bimaculatus, C. notomelas, P. lineatus, C. fasciatum* and *H. malabaricus* (the latter is the only piscivorous species). Besides the stress caused by environmental conditions, including competition and predation in the aquatic environment, predation from terrestrial organisms exert great selective pressure especially on the most conspicuous species.

Secondary Channels are permanent water courses which link the lagoons to the rivers of the floodplain. They are semi-lentic and the flux direction of the water depends largely on the connected environmental water levels. Although varied, the bottom is predominantly muddy and sandy. The fish assemblages of these channels (102 species) contain such representative species as the **armadinho** *T. paraguayensis*, the **mandi-beiçudo** *I. labrosus* and the **piranhas** *S. marginatus* and *S. spilopleura* (FUEM/FINEP, 1989; PADCT-CIAMB/FUEM; 1993, 1994; Agostinho et al., in press).

Reservoirs are the dominant environments in the River Paraná basin. Fish assemblages inhabiting these environments are considerably changed in relation to those that originated them. This is especially true with regard to their composition and structure, with an excessive proliferation of some species and a decrease or even local extinction of others (Agostinho et al. 1992). The degree of impact on the biological diversity is chiefly related to characteristics of the local fauna, to the localization of the dam with regard to the area of population distribution, to the basin's morphometry (patterns of circulation, depth, area), to the presence of other dams upstream, to the design of the dam and to the operational procedures of the hydroelectric plants (Agostinho, 1992). In the great majority of the reservoirs analysed a decreasing ichthyofauna gradient towards the dam is verified (Romanini, 1989; Castro, 1994; Agostinho et al., 1994; Dias, 1995). This is more pronounced in those reservoirs with free stretches upstream. In the initial third section of the Itaipu Reservoir (riverine zone; Thorton, 1990) all the species of the other zones are represented together with various big-sized rheophilic representatives of the free stretch of the Paraná. Analysis of species distribution in five reservoirs (Amaral, 1993; Romanini, 1994; Castro, 1994; Dias, 1995; Agostinho et al., in press) reveals that the following species have a generalized occurrence: the **mandis** *P. maculatus* and *I. labrosus*, the **tambiú** *A. bimaculatus*, the **piranha** *S. spilopleura*, the **peixe-cachorro** *A. lacustris*, the saguiru *S. insculpta,* the **peixe-cigarra** *G. knerii*, the **curvina** *P. squamosissimus*, the **traíra** *H. malabaricus* and the **ximboré** *S. nasutus*. The correlation matrix was estimated between the richness of the species in eleven reservoirs of the high River Paraná basin (reservoir of Jurumirim: Carvalho, in press; Salto Grande: Dias, 1995; Rosana and Americana: Romanini, 1989, 1994; Furnas and Marimbondo and Volta Grande: Santos, 1994; Barra Bonita: Castro, 1994; Promissão: Cruz et al., 1990; Amaral, 1993; Itumbiara: Santos, 1994; Itaipu: Agostinho & Julio Jr, in press) and their age, areas, volumes, average and maximum depths and the basin's area. Correlations were positive with regard to the basin's area (r = 0.52) and negative with regard to age (r = - 0.68) and residence time (r = - 0.47). It should be emphasized that data for this type of analysis are precarious.

Calculated according to Sorensen's coefficient (Krebs, 1989) ichthyofauna similarity in the great environments varied between 0.52 and 0.92. This means that the number of common species between any pair of environmental categories repre-

TABLE III

Introduced species registered in experimental or professional fisheries in the high River Paraná (* = only registered; + = rare; ++ = esporadic; +++ = less abundant; ++++ = abundant; +++++ = very abundant).

	Natural Distribution	Abundance	Feeding Habit	Reproduction
Plagioscion squamosissimus	Amazon basin	+++++	piscivorous	yes
Cichla monoculus	Amazon basin	+++	piscivorous	yes
Cichla temensis	Amazon basin	+	piscivorous	yes
Astronotus ocellatus	Amazon/Paraguay	+	omnivorous	yes
Colossoma macropomum	Amazon basin	+	omnivorous	?
Triportheus angulatus	Amazon basin	++	insectivorous	yes
Hoplias lacerdae	East basin (?)	++	piscivorous	yes
Oreochromis niloticus	Nile, Chari, Israel	+++	algivorous	yes
Tilapia rendalli	Africa	+++	algivorous	yes
Cyprinus carpio	Asia	+	detritivorous	yes
Micropterus salmoides	North America	+	piscivorous	?
Odonthestes bonariensis	SE Argentina	+	omnivorous	yes
Clarias gariepinus	Nile and Niger	+	omnivorous	?
Ctenopharyngodon idella	China	*	herbivorous	?

sents between 26% and 46% of the pair's totality. The greatest similarities were verified between the main channel of the River Paraná and its high declivity affluents and between the secondary channels, lagoons and the low declivity affluents. Pools, creeks and streams presented low similarities between themselves and with the other environmental categories.

INTRODUCED SPECIES

In the last fifty years more than 20 species of fishes from other basins were introduced in the high River Paraná basin. Fourteen have been registered in experimental fisheries (Table 3). The curvina *P. squamosissimus* was extremely successful in the colonization of the new environments and is abundant in all biotopes. Three cichlid species were abundant only in reservoirs of the River Grande and in small pools of low order rivers. Introduction was intentionally undertaken in 70% of cases to give new options to artisanal or sport fishing and to increase fishery yields. Other introductions occurred accidentally through the bursting of dams or fish tanks and even through escape.

Besides these species, the high River Paraná basin received at least 17 new species as from 1982 when the Itaipu Reservoir was formed and submerged the Sete Quedas waterfalls which, according to Bonnetto (1986), divided the Upper Paraná from the Paraná-La Plata Provinces. Conspicuous are three species of stingray, four species of doradids, two species of auchenipterids, two species of ageneiosids and one species of pimelodids, besides the **piranha** *S. marginatus*, the armoured catfish *L. platymetopon* and the **mapará** *H. edentatus* (Julio Jr & Deitós, 1995). Deitós (1990) suggests that the present fauna of this section contains at least twelve other species which have dispersed likewise. After 12 years of dispersion process, the latter species had the greatest biomass in Itaipu and is one before the last in the floodplain upstream (Agostinho, 1993). Experimental and professional fishery data suggest, however, that distribution limits upstream are adjusted by the Jupiá dam in the River Paraná and by the Capivara dam in the River Paranapanema.

FISH BIOLOGY

Trophic aspects

The majority of the fish species in the high River Paraná basin presents high diet plasticity. Species that present morphological restrictions to euriphagy are relevant exceptions, as the case of iliophagous and planktophagous-filterers (Agostinho & Julio Jr, in press). Due to the characteristics of new environments, the reservoirs furnish interesting opportunities to evaluate this plasticity. In the Itaipu Reservoir, for example, the **surumanha** *Auchenipterus nuchalis*, considered as an insectivorous species during the first years of the formation of this environment (Chironomidae in the first year, Ephemeroptera in the second year), is now essentially zooplanktophagous (Hahn, unpublished data). The curvina *P. squamosissimus*, which has been considered a piscivorous species since more than 95% of its diet is composed of fish (Hahn, 1991), preferentially fed on crustaceans in dammed pools of Northeastern Brazil (Chacon & Silva, 1971) and in the rivers of the Amazonian region (Annibal, 1983; Goulding and Ferreira, 1984).

High fluctuations in the availability of feeding resources caused by biotope changes may explain these variations. Wooton (1990) suggests that the diet of a fish can determine which types of food are available and thus an analysis of the diet composition can furnish a reasonable idea on the food availability. Besides the variability in diet composition as a function of food availability, fish species show relevant changes with regard to ontogenetic development and environment alterations (Cruz et al., 1986; Lowe-McConnell, 1987; Hahn, 1991).

Piscivorous and detritivorous species are dominant in number and biomass in the fish assemblages of the high River Paraná basin. This is verified when one takes as a criterion the dominant item of their diet. The two categories may alternate in importance according to the environment under consideration. Hahn (1991) analyzed changes in the trophic structure in three types of environment of the River Paraná floodplain. She found that piscivorous species were more important than the detritivorous-iliophagous ones in river environments (54% and 21% of weight respectively). This is opposite to that registered in biotopes of lagoons (27% and 47%) and is an intermediate situation in secondary channels (32% and 40%) which are generally a link between the two former environments.

It should be emphasized that among the detritivorous special attention should be given to the iliophagous group (for instance, *P. lineatus* and *S. insculpta*) and to the *stricto sensu* detritivorous group as *Loricariichthys platymetopon* (Fugi et al., 1994). The authors registered evident morphological differences between these two groups (gizzard, length of intestines, gill rakers). They found in the stomach contents of the first group a predominance of fine particles, inorganic sediments and algae and in the stomach contents of the second group a predominance of organic matter in early stages of decomposition with a lesser incidence of inorganic sediments.

Besides piscivorous and detritivorous groups, omnivorous are dominant trophic categories in the fish biomass of the basin's reservoirs. The latter may be dominant in some of these reservoirs, such as Jurumirim (Carvalho, unpublished data) and Rosana (Romanini, 1994). The introduced **curvina** *P. squamosissimus* is the principal piscivorous species in the vast majority of the reservoirs. Exception is made only with regard to those reservoirs in the upper sections of the Rivers Grande (reservoir of Furnas; Santos, 1994) and Paranapanema (reservoir of Jurumirim; Carvalho, unpublished data) where the species either has not arrived or has arrived very recently (reservoir of Salto Grande; Dias, 1995). In these reservoirs, the dominant piscivorous species are the peixe cadela *Galeocharax knerii*, the piranha *Serrasalmus spilopleura* and the traíra *H. malabaricus* respectively. Among the detritivorous the **curimba** *P. lineatus* and the saguiru *Steindachnerina,* with a greater biomass, are the most noteworthy. The **mandi** *P. maculatus* and the **armado** *P. granulosus* predominate among the omnivorous. The latter is exclusively found in the reservoirs of Itaipu and Rosana (closed after the dispersion of the species to the high Paraná as a consequence of the submersion of the Sete Quedas waterfalls by Itaipu).

In the Itaipu Reservoir (its colonization occurred from communities coming from the high and middle Paraná) the dominant trophic categories are the piscivorous (34% of the biomass) and the planktivorous species (30% of the biomass). The **curvina** *P. squamosissimus* and the mapará *H. edentatus*, respectively, are the most important. The trophic structure of this reservoir varies with the respective zone. Thus, in the riverine zone the piscivorous and the insectivorous species are dominant in similar proportions (30%) while in the lacustrine zone (close to the dam) the piscivorous species (41%) and the only planktophagous-filterer species of the community (40%) are predominant. It should be emphasized, however, that among the piscivorous species of the first zone the great migratory pimelodids are predominant, while in the innermost zone this advantage is held by the curvina. In the transitional zone (the intermediary third part of the reservoir) the planktophagous species (34%) are conspicuous, followed by the insectivorous (19%) and by the piscivorous species (19%) (Hahn, 1991).

The importance of the different feeding resources of the floodplain of the high River Paraná with regard to the number and the biomass of the species that make use of it and independent of the trophic category to which they belong is shown in Figure 6. It may be verified that insects (chiefly aquatic), other benthonic invertebrates (protozoa, rotifers, nematods, bryozoa, annelids, oligochaetas, arachnids) and fish (approximately 50 species) are utilized as primary, secondary or accessory food by a great number of species whose biomass is high. Besides the piscivorous species, insectivorous, benthophagous and omnivorous species are found in this group. The species of fish that utilize unicellular algae or detritus in their diet (few since they need morphological specialization) represent a great part of the captured biomass which includes the iliophagous, detritivorous, omnivorous species and the only planktophagous-filterer of the basin (*H. edentatus*). Molluscs are consumed either as a secondary or an accessory item by omnivorous and benthophagous. Even microcrustaceans are a secondary, accessory or accidental food for almost all the trophic categories, and the **mapará** *H. edentatus* is the only specialized species in its consumption. In the Americana reservoir, a small reservoir in the Tietê basin (11.5 km^2 in area), detritus, insects and fish are the chief food sources for the 31 species present (Romanini, 1989).

Studies undertaken by Agostinho & Zalewski (in press) reveal that fishes whose diet is based on items of ecotonal origin (leaves, fruits, insects falling into the water and detritus) and iliophagous species (aufwuchs and mud eaters) present density and biomass proportionally higher in lagoons and in secondary channels in the River Paraná floodplain than in the main channel of rivers and in the Itaipu Reservoir. The seasonal incorporation of great extensions of land-inland water ecotone to the aquatic environment is responsible for this tendency. The importance of the flooding regime on the nutritional state of juvenile **curimbas** *P. lineatus* was shown by Gomes and Agostinho (in press). These authors show that the mean values of the Condition Factor and the Visceral-Somatic Relationship directly related to the average annual fluviometric levels of the Paraná.

Reproductive aspects and Migration

Information on some reproductive tactics of teleosts in the high River Paraná basin comprise 23 families. The greatest quantity of information is available for species of Characidae (10),

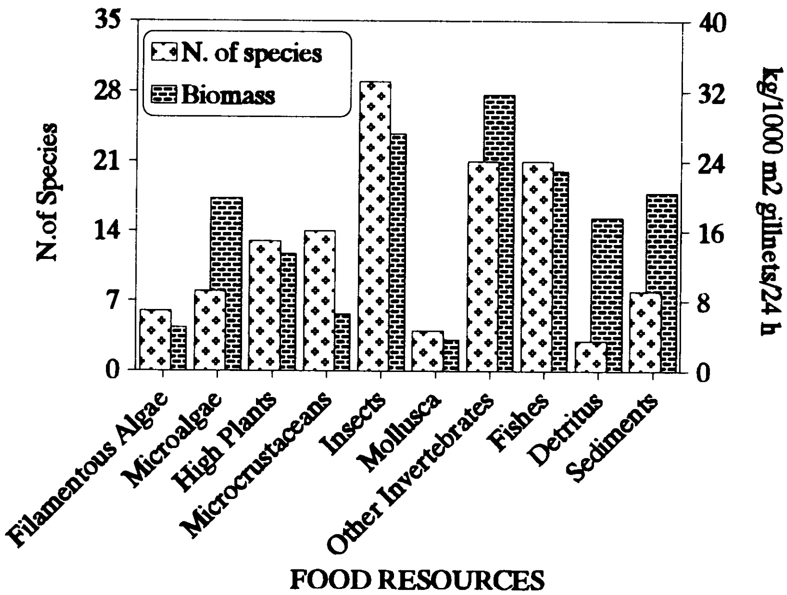


Fig. 6 – Number and biomass of species that exploit distinct food resources.

Anostomidae (9),and Pimelodidae (9). The number and frequency (%) of species per family are shown in Table 4.

Data on maximum length (L_{max}), length of first maturation (L_{50}), length with which all individuals are capable of reproducing (L_{100}) and maximum gonadosomatic index (GSI_{max}) are available for 71 species. Data on type of spawning are available for 41 species, on reproductive behavior for 57 species, on average diameter of mature oocytes for 52 species and on fecundity for only 20 species. Some of these data come from diverse sources presented in synthesis studies (Vazzoler, 1992; Vazzoler & Menezes, 1992), technical reports (FUEM-FINEP, 1989; PADCT-CIAMB/FUEM, 1993, 1994), MSc and PhD theses and other unpublished works presented in several congresses.

The ichthyofauna of the high River Paraná consists predominantly of small- (L_{max}<20cm) and medium- (20cm<L_{max}<40cm) sized species (70.5%). Big-sized species (L_{max}>40cm) are less frequent (29.5%). The small-sized species (24 species) have external fecundation and the great majority (80%) do not show parental care. The others (20%) show parental care to some degree. Small sized species of Ciprinodontiforms which were not considered in this survey present internal fecundation. Among the medium-sized (26 species), there are species with external fecundation, migratory (6.4%) and non-migratory species (11.1%),

TABLE IV
Number of species per family from the high River Paraná basin with availiable information about reproduction

Family	N. of Species	Frequency (%)
Characidae	10	14.1
Anostomidae	09	12.7
Pimelodidae	09	12.7
Loricariidae	06	8.4
Cichlidae	04	5.6
Doradidae	04	5.6
Serrasalmidae	04	5.6
Ageneiosidae	03	4.2
Curimatidae	03	4.2
Auchenipteridae	02	2.8
Callichthyidae	02	2.8
Erythrinidae	02	2.8
Parodontidae	02	2.8
Sternopygidae	02	2.8
Apteronotidae	01	1.4
Cynodontidae	01	1.4
Engraulidae	01	1.4
Gymnotidae	01	1.4
Hypophthalmidae	01	1.4
Prochilodontidae	01	1.4
Rhamphychthyidae	01	1.4
Sciaenidae	01	1.4
Soleidae	01	1.4
TOTAL	71	

with parental care species (12.7%) and internal fecundation species (6.4%). The majority of big-sized species (21 species) undertake reproductive migrations (12.4%); some are non-migratory (7.8%), with parental care (7.8%) and one has internal fecundation (1.6%) (Vazzoler, unpublished data).

The great majority of species (85.9%) reach maturity with less than 20 cm in length, with modal lengths between 5 cm to 15 cm (63.4%). For the majority of species (93%) all individuals are capable of reproduction with less than 30 cm, with modal lengths between 5 cm and 20 cm (69%)

(Vazzoler, 1991). External fecundation species (91.2%) are predominant and among these the ones without parental care and non-migratory constitute the majority (42.1%). Migratory species (21.0%) and species with parental care (28.1%) are less frequent, as well as those with internal fecundation (8.8%). With regard to species with total spawning (26.8%) the great majority consists of reproductive migratory species (17.1%). The others are non-migratory (7.3%), with a parental care minority (2.4%). Among the species that present partial spawning (the great majority with 73.2%), sedentary (31.4%), with parental care (28.8%), internal fecundation (7.8%) and migratory (5.2%) species are dominant (Vazzoler, unpublished data).

There is a prevalence of species with a reproductive period ranging between November and February. At a lesser proportion this period may be anticipated to September or may prolong itself until April. Few species reproduce between May and September. The groups of species of the same reproductive behavior have reproductive periods with distinct amplitudes: more than 50% of the migratory species have a well-marked peak between November and February; between 30% and 40% of the species extend this period from October to March and few further it till July. Non-migratory species have similar behavior, differing only by the fact that few species have their reproductive period between April and September. Species with parental care have a reproductive peak (>50%) between October and January, with less frequency in February and March and few reproduce in April-May and in September. Internal fecundation species present a marked reproductive period, between November and January; few, however, reproduce in February and during September-October (Vazzoler, unpublished data). The fact that migratory species exhibit a more extensive global period of reproduction than the others must be due to their capacity of displacement within the total area in search of proper sites for the elimination of their gametes. Thus, it's common to register mature individuals in distinct stretches of the area during successive months till they reach the reproduction area. Sedentary species must strictly observe the period in which environmental conditions are best, qualitatively and quantitatively, in terms of protection and proper food for their young. Lowe-McConnell (1987) states that floodings in floodplain rivers may increase up to 50% the area of the aquatic environment. Floods bring nutrients that stimulate the rapid growth of microorganisms, invertebrates and plants and thus offering abundant food and shelter for fish during this period. Anthropic actions that interfere with the cyclic variations of the fluviometric level, such as operations of hydroelectric plants situated in the area upstream may determine faults in the reproductive process which bear reflections on the recruitment of new generations (Gomes & Agostinho, in press). Machado-Allison (1990) refers to evidences that support the hypothesis of seasonal reproduction of fish in tropical areas: (a) reproductive migrations that generally occur during the rainy season or rising water period; (b) the gonadal maturation which occurs immediately before the rainy season in such a way that they are ready for spawning at the beginning of the rising; (c) the appearance of larvae and juveniles immediately after rising water. The same author also refers to the fact that the reproduction period is determined by influences of food abundance, shelter increase and physical and chemical changes in the water. The amplitude of the reproduction period varies from one to nine months. The majority of the species (62%) have a short reproduction period (one to four months), followed by those (32.7%) with a medium reproduction period (five to seven months) (Vazzoler, unpublished data). Species with long reproduction periods (eight to nine months) are rare (5.4%). A long reproduction period does not mean that all individuals have the same pattern. Different populational segments, with short reproduction periods, may reproduce sequentially through the global period (Munro, 1990). Similar to other reproductory tactics, the duration of the reproduction period presents a certain plasticity within a limit determined by intrinsic factors which permit the synchronization of spawning with the appropriateness of environmental conditions adequate for the development of the initial stages of the life cycle.

Associating the period of the year in which species reproduce with cyclical variation of the fluviometric level, some seasonal patterns in reproduction may be verified in the high River Paraná: (a) seasonal with peak pattern (November to February); (b) prolonged seasonal pattern (for rising water: September to March or flood: October to April); (c) non-seasonal pattern. Among the species under analysis 36.4% present pattern (a), 52.7% pattern (b) and only 10.9% pattern (c). As a general rule the species that have a prolonged reproduction period (medium-long) are those that inhabit and spawn in the system as a whole or in its lentic environments. In their great majority they have a partial spawning and eliminate successive batches of oocytes (Vazzoler, unpublished data). The species with a shorter period (short-medium) utilize lotic environments as their reproduction habitats and have total spawning. It becomes evident the role of lentic environments as reproduction habitats of non-migratory species or of species with small displacements, of small and medium sized species, many of them foragers. The lentic environments have also a great importance as areas in which the young grow and where adults recover from reproductive process. The majority of the species that support professional and amateur fisheries are those that use the main channel of the rivers (lotic environments) as reproduction habitats and the lakes and channels as areas of growth and recovery.

The exigency of the species to use different compartments of the system in different phases of their life cycle renders more complex protection actions and their management and the planning of initiatives that interfere with the structure of the system as a whole (cyclical variations of fluviometric levels, the flooding of marginal lagoons, etc.). The preservation of this floodplain is essential for the maintenance not only of the diversity but also of the production level of fishery stocks.

The great majority of the species (71.8%) have a maximum gonadosomatic index between 6 and 18. For 15.5% this value stands between 3 and 6; for 12.6% it stands between 21 and 30. The GSImax for 71 species varied between 3.34 in the case of *P. squamosissimus* (Sciaenidae) and 28.39 for *S. insculpta* (Curimatidae). This means that immediately before spawning mature ovaries may represent 3.34% to 28.39% of the female's total weight. There is no relation between GSImax and Lmax values (Vazzoler & Agostinho, 1991; Vazzoler, unpublished data).

TABLE V
Maximum length (Lmax), oocyte diameter (Doo), fecundity and reproductive behavior (RB) of some teleosts from the high River Paraná basin.

Species	Family	Lmax. (cm)	Doo (μm)	Fecundity	RB (Number)
A. fasciatus	Characidae	13.2	785.3	10,000	2
A. affinis	Parodontidae	15.0	971.0	6,500	2
P. tortuosus	Parodontidae	15.5	766.1	20,500	2
A. bimaculatus	Characidae	19.5	775.5	3,200	2
P. galeatus	Auchenipteridae	22.0	1,615.3	10,330	4
G. knerii	Characidae	24.0	1,106.6	130,000	2
L. vittatus	Anostomidae	24.5	1,211.9	34,600	2
A. nuchalis	Auchenipteridae	27.0	1,315.9	14,950	4
G. carapo	Gymnotidae	32.9	2,785.5	3,000	3
S. nasutus	Anostomidae	33.6	1,232.3	77,000	2
L. friderici	Anostomidae	37.0	1,059.5	194,000	1
R. aspera	Loricariidae	37.2	1,338.5	200,000	1
H. malabaricus	Erytrinidae	48.6	2,445.2	61,000	3
P. granulosus	Doradidae	54.3	1,056.1	296,000	1
S. maxillosus	Characidae	77.6	1,350.6	2,600,000	1
P. lineatus	Prochilodontidae	77.9	1,450.1	1,600,000	1
H. edentatus	Hypophthalmidae	78.2	753.5	83,000	2

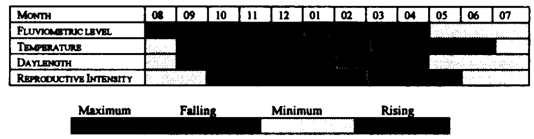
(1) External fecundation, migratory, without parental care.
(2) External fecundation, non-migratory, with parental care.
(3) External fecundation, non-migratory, parental care.
(4) Internal fecundation.

Concerning the diameter of mature oocytes, only 1.9% of the species have a diameter up to 500μm. The great majority (80.8%) has diameters ranging between 500μm and 2000μm, whilst 17.3% ranged between 2000μm and 5000μm. Average diameter of mature oocytes varies between 427.4μm for *C. jenynsii* (Soleidae) and 4,789.3μm for *M. aculeatus* (Loricariidae). There is no relationship between values of average diameter of mature oocytes and L_{max} in the case of these species. The oocyte diameter seems to be more related to the reproduction behavior of the species. In the case of migratory species, diameter varies between 770.3μm for *P. maculatus* (Pimelodidae) and 1,545.9μm for *B. orbignyanus* (Characidae). In non-migratory species diameter varies between 427.4μm for *C. jenynsii* and 1,259.2μm for *L. lacustris* (Anostomidae). In the case of the species with parental care diameter varies between 1,467.3μm for *E. trilineata* (Sternopygidae) and 4,789.3μm for *M. aculeatus*; for the internal fecundation species diameter varies between 1,315.9μm for *A. nuchalis* (Auchenipteridae) and 1,849.5μm for *A. ucayalensis* (Ageneiosidae). Migratory or non-migratory external fecundation species and internal fecundation ones present small and/or medium oocytes, whilst the external fecundation, parental care ones have big oocytes (Suzuki, 1992; Vazzoler, unpublished data).

The total volume of mature oocytes is determined by their number (fecundity) and by the volume of an individual oocyte. Even though fecundity (number) in fish increases with the size of its body there is no general tendency in big-sized species to produce bigger oocytes. Table 5 shows data on maximum length, fecundity, average diameter of mature oocytes and reproduction behavior for some teleosts of the high River Paraná.

Though data set is reduced, it shows that (a) parameters are not the same for species of the same family; (b) generally, fecundity shows a direct relationship neither to the average diameter of mature oocytes nor to the size of the species. However, groups of similar reproduction behavior present similar levels of fecundity: high in migratory species (average of 978,000 oocytes) followed by non-migratory species without parental care (45,600 oocytes) and non-migratory species with parental care (32,000 oocytes) and internal fecundation species (12,640 oocytes).

Cyclical variations of the reproductive intensity of the dominant community occur related to variations of environmental factors, such as fluviometric level, daylength and water temperature (Vazzoler et al., 1993), as shown below:



Comparing these variations one may verify that:

(a) within the reproductive period of this community determined by terminal factors such as environmental quality and occurrence of cyclic events, the reproductive intensity is a function of the variation of some environmental characteristics;

(b) there is an increase in the reproductive intensity with water temperature and daylength rise, proximal factors which trigger the beginning of gonadal development;

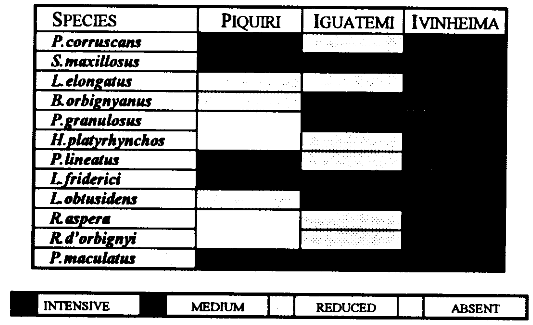
(c) the factor that regulates the beginning of spawning (proximal synchronizer) is the flood which widens the environment and gives appropriate shelter and food for the initial phases of development;

(d) the end of the period with the highest reproductive intensity is determined by the flood peak (final proximal factor) when the values of the daylength and of temperatures are decreasing. During this period the young would have already reached the juvenile stage and are capable of bearing the resulting environmental pressures of a decrease in the fluviometric level, daylength and temperature.

P. lineatus is the best studied among the migratory species. It undertakes big reproductive migrations which were studied by Godoy (1957, 1959, 1962, 1972 1975) in the River Mogi-Guaçu.

In spite of the controversy on the capacity of migratory species to undertake oriented displacements in reservoirs, upward and downward seasonal movements in the Itaipu reservoir were confirmed. There is a tendency of upward movements as from September and downwards between March and August. Results obtained in marking-capture experiments showed that in October the adult specimens (standard length > 18.9cm) abandon the reservoir, migrate to areas upstream and penetrate the tributaries (Agostinho et al., 1993). These authors evidence a stratification of specimens within the studied area, according to the phase of the life cycle and, among adults, according to the functional stage of the gonads. Individuals up to two years, with length pattern lower than that of first maturation (L50), occur in the lakes. In the channels the majority of specimens captured have lengths which correspond to the one-year or two-year-old classes. However, specimens of up to 5-years old occurred too. In the River Paraná lengths corresponding to two-year old or more predominate and are larger than L_{50}. In the Itaipu Reservoir no specimen was registered with lengths corresponding to less than two-year old and all presented a standard length superior to L50. A pronounced predominance of juveniles in lagoons (73%) and channels (60%), and of adults in the River Paraná (82%) and the reservoir (100%) is registered. In the lagoons individuals that have not began their reproductive activity (99%) occur almost exclusively; the same situation is verified in the channels (95%). In the River Paraná 38% of individuals present gonads with evidence of reproductive activity and spawning (22% in maturation, 11% in reproduction, 5% spent), whilst in the reservoir a similar fraction (37%) shows imminent (25% in maturation) or recent (12% spent) reproductive activity. These results show that juveniles are distributed in the marginal lakes and channels, considered natural lentic and semi-lotic environments respectively. Adults are registered chiefly in the River Paraná and in the Itaipu Reservoir, considered a natural lotic and a dammed environment respectively. In the River Paraná and in its tributaries Piquiri, Iguatemi and Ivinheima maturation begins in the period July-September. Spent individuals and in reproduction are registered from October to March, whilst in the period April-June some spent individuals and others recommencing their reproductive cycle have been recorded. A high incidence of individuals at rest was also verified. The annual reproductive cycle of *P.lineatus* comprises three phases: recovering phase which extends from April to August; maturation phase from August to November; reproduction phase from November to March. Because of these evidences Agostinho et al. (1993) have proposed a descriptive model of the behavior of this species. As from spawning which occurs between November and March in the lotic environments of the River Paraná and its tributaries, the sequence of events comprises: (a) the admittance in the floodplain of specimens which result from spawning, where they feed and grow till they reach the average length of the initial stage of first maturation (standard length = 18.9 cm; total length = 22.1 cm) which occurs at approximately two years of age; in the first year juveniles concentrate in the most lentic regions of the floodplain (lagoons) and disperse towards the semi-lotic regions (channels) in the second year. (b) When they reach lengths related to the transition towards the adult phase (L50), they abandon these feeding and initial growth areas and integrate themselves into the older adult segment which is distributed in the river and, in a special manner, in the Itaipu Reservoir, where recruitment is registered essentially in the bimester May-June (FUEM-ITAIPU BINACIONAL, 1987). (c) With the beginning of the gonadal maturation process, verified between August and November, at least a part of this adult segment of the population abandons the reservoir and migrate river upstream towards the areas of reproduction. (d) After spawning and during the gonadal recovery phase (April to June), the adults return and disperse throughout the rivers, penetrate the channels and occupy the dammed environment of the reservoir. In this place they feed and prepare themselves for another new reproductive cycle. Thus the species exploits lentic environments in the juvenile phase or during the first year of life; in the adult phase it begins to exploit cyclically semi-lotic and lotic environments.

Besides the River Paraná the migratory species utilize the tributaries as reproductive habitats and as a route for migration between their reproductive and trophic areas. This conclusion is suggested by occurrence of individuals with extreme degrees of gonadal development - reproducing or without reproductive activity in the tributaries. Considering only the rivers Ivinheima, Iguatemi and Piquiri, the highest frequency of migratory species in the stage of reproduction is registered in the first river, followed by the second and third one, as shown below.



The reproductive habitats in these rivers are localized at the highest stretch. This is specially evident to the River Piquiri, where the individuals in reproductive stages represented almost half the captures in the highest segment and only 15% in the lowest one. In two out of three rivers that form the River Ivinheima there was an elevated frequency of individuals reproducing. In the lowest segments the occurrence of individuals in reproduction is considerably reduced. In the River Iguatemi, individuals in the stage of reproduction are more frequent in the highest segments and in its lowest third segment (Agostinho et al., unpublished data). In these rivers, Nakatani (unpublished data) registered the highest densities of eggs in the same segments where the reproductive activity was elevated, with a gradual decrease at sites near their mouth as summarized below.

River Ivinheima

River Piquiri

River Iguatemi

The Itaipu Reservoir in the River Paraná, its tributaries and its floodplain form a system responsible for the stock of exploited species in the area. The maintenance of the unhindered entrance to the rivers where spawning occurs and of the integrity of the floodplain, essential to the development of juveniles, is possible by means of halting definitely the construction of the Ilha Grande hydroelectric plant and of a proper management in the discharge of the reservoirs upstream. Both are decisions of a high economical and conservationist significance.

Growth Aspects

Few studies are extant on the growth of fish in the high River Paraná basin and they refer only to about 10% of the ichthyofauna registered in the area. In tropical environments a great effort is necessary to interpret the marks of apposition structures which are not so evident and regular as in the temperate zones. However, in the floodplain-river systems, where seasonal variations in environmental conditions are striking, these studies may be made easier.

Growth parameters of the basin's species are in Table 6. These data permit some inferences on growth patterns and life cycle strategies. They may also be compared to those data on average length at the beginning of the first gonadal maturation (L_{50}) and thus giving information on the relationship between somatic and reproductive investment:

a. Loricarids and pimelodids, middle and big sized species, present low growth rates (k), characteristics of k-strategists which invest in somatic growth;

b. Small sized species, such as the characids and curimatids, present higher growth rates related to r-strategists which invest in reproductive production;

c. Contrary to the general pattern in species with parental care, such as the cichlids, the males, which generally take care of the young, are larger than the females since part of their available resources is invested in parental care.

Within a certain amplitude, growth rate presents variations determined by biotic (food availability and predation) and abiotic (e.g. temperature which affects the speed of metabolic processes) environmental conditions and by their interactions (degree of utilization of food availability as a function of temperature). These variations occur between distinct environments (spatial) and periods (temporal). Even though scarce, the available data evidence the following variations:

a. *L. friderici* presents a higher growth rate in a natural environment (in the River Mogi-Guaçu) than in a dammed environment (Lobo Reservoir). On the other hand, *P. lineatus* presents higher rates in the Itaipu reservoir than in the River Mogi-Guaçu. Probably this is due to the differences in the trophic categories of the two species. The omnivorous *L. friderici* has a greater food availability in a lotic environment while the iliophagous *P.lineatus* finds the Itaipu environment much richer because of the great quantity of submerged vegetation which forms the substratum for the periphyton.

b. *P. albopunctatus* and *P. squamosissimus* showed distinct rates at the same sites in successive years, due to differences in environmental conditions.

TABLE VI
Growth parameters of some species from the high River Paraná basin.

SPECIES	L_{ma}	L_∞ (mm)	k (mm)	t_0 -	L_∞ (year)	k (mm)	t_0 -	L_∞ (year)	k (mm)	t_0 -	L_{50} (year)	Sources (mm)
		FEMALES			MALES			TOTAL				
ANOSTOMIDAE												
L. friderici (Rep.Lobo)	370	379.0	0.20	0.00	0.31	0.00					194/185	Barbieri & Santos,1988
L. friderici (R.Mogi)	450	339.0	0.24	0.00	296.0	0.40	0.00				190/198	Barbieri & Santos,1988
												FUEM/FINEP,1989
L. octofasciatus	700	415.0	0.22	-0.32	430.0	0.21	-0.24					Nomura,1973
L. copelandii	230	506.0	0.10	-0.70	344.0	0.20	-0.25					Nomura,1973
AUCHENIPTERIDAE												
A. nuchalis	270	326.0	0.59	-0.70	309.0	0.61	-0.59				160	Agostinho et al.,1987
CHARACIDAE												
A. b. lacustris	150	208.2	0.14	1.77	155.1	0.26	1.16				92.5/104	Nomura,1975*a*
A. fasciatus	145	176.4	0.23	0.95	141.7	0.32	0.82				119/111	Nomura,1975*a*
A. schubarti	138	235.6	0.09	3.20	114.8	0.54	0.61				107	Nomura,1975*a*
A. schubarti	106	235.6	0.09	3.20	114.8	0.54	-0.61				107/105	Nomura,1975*b*
CICHLIDAE												
C. bimaculatum	200	146.4	0.40	-1.45	159.9	0.41	1.10					Nomura & Barbosa,1980
G. brasiliensis	245	131.0	0.39	0.00	146.0	0.44	0.00					Barbieri et al..1980
G. brasiliensis	245	198.0	0.36	-0.28	222.0	0.34	-0.29					Barbieri,1974
CURIMATIDAE												
C. gilberti	160	155.2	0.38	-1.55	151.9	0.38	1.63				112.5	Nomura & Hayashi,1980
ERYTHRINIDAE												
H. malabaricus	260							405.0	0.42	0.00	167	Barbieri,1989
CYNODONTIDAE												
R. vulpinus								107.1	0.15	-0.64	263	Lizama, 1994
GYMNOTIDAE												
G. carapo	600							546.0	0.43	0.00	248	Barbieri & Barbieri,1980
G. carapo	600	500.0	0.31		6.0	0.31					248	Barbieri & Barbieri,1983
LORICARIIDAE												
H. aff plecostomus	350							236.0	0.44	0.00	98	Barbieri & Santos,1987
H. fluviatilis	240	351.3	0.09	-2.76	315.3	0.10	-2.75				140/150	Nomura,1988
P. albopunctatus (75)	340	541.0	0.07	-3.28							178	Antoniutti et al.,1985
P. albopunctatus (76)	340	440.2	0.10	-2.86							168	Antoniutti et al.,1985
P. commersonii	381	454.6	0.24	0.00	523.6	0.20	0.00				169	Goulart,1981
P. hermani	210	318.0	0.07	4.43	288.0	0.10	3.00				120/140	Nomura & Mueller,1980
R. aspera	372	585.0	0.18	0.00	534.0	0.22	0.00				220/240	Agostinho,1985
PIMELODIDAE												
P. clarias	390	520.0	0.11	0.91	520.0	0.11	0.64					Nomura et al., 1972
P. maculatus	360	565.0	0.19	-0.36	454.0	0.21	-0.61				60	Fenerich et al.,1975
PROCHILODONTIDAE												
• *P. lineatus*	779	714.8	0.20	0.01	626.8	0.24	0.00				100	Hayashi et al.,1989*b* ◆
P. lineatus	779	830.0	0.11	0.00	645.0	0.15	0.00				250	Toledo Filho,1981
SCIAENIDAE												
P. squamosissimus (84)	479	437.1	0.50	-0.06	401.6	0.57	-0.05				211/178	Hayashi et al., 1989*a* Hayashi & Verissimo, 1990
P. squamosissimus (85)	479	491.1	0.24	0.06	463.3	0.43	-0.05					Hayashi et al., 1989*a* Hayashi & Verissimo, 1990
P. squamosissimus (86)	479	89.4	0.42	-0.06	471.0	0.41	0.06				285/215	Hayashi et al., 1989*a* Hayashi & Verissimo, 1990
SERRASALMIDAE												
S. spilopleura	257	307.1	0.26	0.00				307.1	0.26	0.00	88.5	Rodrigues et al.,1978
S. spilopleura	257	259.4	0.21	-0.85	249.8	0.21	-1.06					Agostinho, 1993
S. marginatus	241	215.5	0.21	-0.69	201.2	0.22	-0.69					Agostinho, 1993

The relationship between somatic and reproductive investments is evidenced by the variations of L_{50} values: when k values are higher, determining lower L values, L_{50} values are also smaller. Lizama & Vazzoler (1993) discuss the relationship between these parameters and show their dependence.

In the river-floodplain system the reproduction and growth of initial stages of development of fish species depend on the simultaneous occurrence of a series of environmental factors such as temperature, daylength and water level fluctuation. These factors act as cue to reproduction, and increase the availability of new environments rich in food for larvae and juveniles. Thus, it seems that the strategy aims to reach the physiological condition to reproduce and occupy these new areas while they still present optimal environmental condition.

Fishery Resources

Like all other South American basins, information on the exploitation of fishery resources in the high River Paraná basin are scarce and are generally intermittently collected or are taken from only some specific point. The scantiness of information both in quality and quantity does not produce correct evaluations on the status of resources and their exploitation.

It is obvious that the pressure of anthropic activities, especially those linked to damming and pollution, has deeply changed fisheries yield and its specific composition. Surveys undertaken in the section at present occupied by the Itaipu Reservoir showed a remarkable predominance of big-sized migratory species (Itaipu Binacional, 1979). Nine out of ten species that composed fishery belonged to this category. The great pimelodids (*Pseudoplatystoma corruscans*, *Paulicea luetkeni*) and characiforms (*Salminus maxillosus*, *Piaractus mesopotamicus*) were extremely abundant. At present these species are sporadic in captures restricted to fishery landings in the Guaíra region, in the fluvial zone of the reservoir (Agostinho et al., 1994).

The composition of fishery and fishery yields show great heterogeneity in different segments of the basin. In the free stretches, professional fishery is composed of great migratory species, such as *P. corruscans*, *S. maxillosus*, *Pinirampu pirinampu*, *Leporinus elongatus*, *Leporinus obtusidens* and recently *Pterodoras granulosus* (Petrere & Agostinho, 1993). In these sections predominant fishery modalities are the following: (a) artisanal fishery undertaken by fishermen living in the small towns along the River Paraná; (b) amateur fishery undertaken by persons who live in major urban centers; (c) subsistence fishery undertaken by small farmers or day workers that live on the numberless islands of the River Paraná or in the small villages near its banks (Agostinho, 1994).

Table 7 summarizes the results obtained in the artisanal fishery landings in seven reservoirs of the basin undertaken by the Centrais Energéticas de São Paulo (Energetic Centers of São Paulo) and Itaipu Binacional (Torloni et al., 1993; Petrere & Agostinho, 1993). Table 7 shows the predominance of the **curvina** (*Plagioscion squamosissimus*) followed by the mandis (*Pimelodus maculatus* and *Iheringichthys labrosus*) and the **curimba** (*Prochilodus lineatus*) in the fishery of the reservoirs. It also evidences that (a) fishery yield in the reservoirs of the high River Paraná is extremely low if compared with that of the inland pools of the Brazilian Northeastern region (151.8 kg/ha/year, Paiva et al., 1994) and those of Africa (99.5 kg/ha/year, Marshall, 1984) in spite of the great effort in stocks maintenance developed by the hydroelectric companies; (b) the reservoirs with the greater fishery yield are those with free stretches upstream (Itaipu, Barra Bonita) or great lateral tributaries (Jupiá). The existence of free stretches upstream or great lateral tributaries are also essential for a greater participation of big sized migratory species in landings, as may be seen in Figure 7.

Since 1986 captures, consisting chiefly of immature forms, are stable in the Itaipu Reservoir where fishery yield is the highest among the yields of the high Paraná basin. According to Agostinho et al. (in press), the exploitation level of the fishery resources in the Itaipu Reservoir is very close to the maximum yield possible when strategies of present fisheries are taken into account. For the majority of migratory species (45% of captures), critical thresholds of fishery efforts have already been surpassed. An increase in effort is still bearable with regard to sedentary species. In the Itaipu Reservoir the zonation in the water quality and specific composition of fish landed bear reflections on fishery strategy, yield and socioeconomic

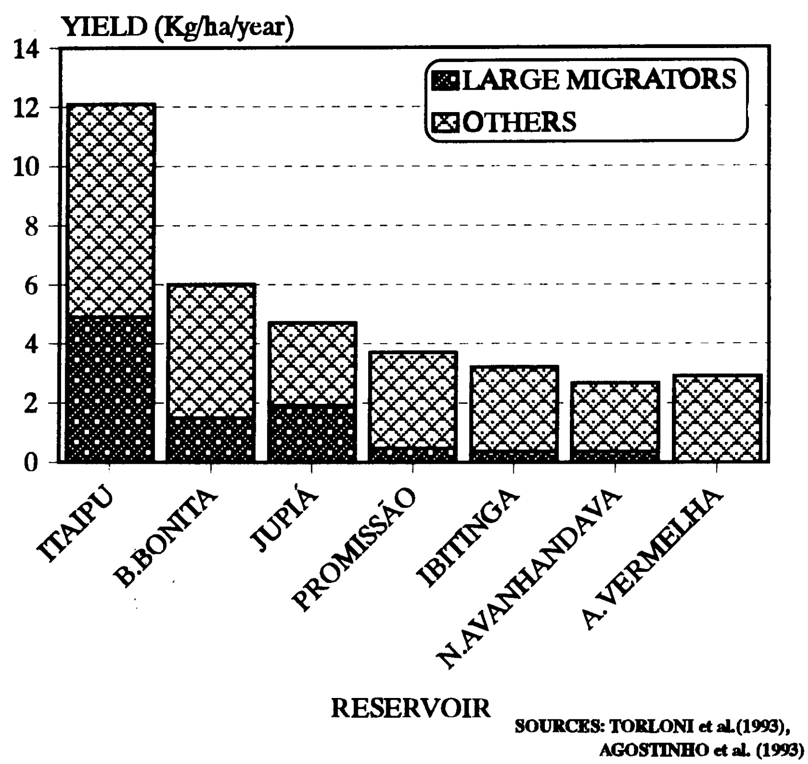


Fig. 7 – Yield average of artisanal fisheries in seven reservoir of the high River Paraná basin, between 1989-1993 (After Agostinho, 1994 b)

characteristic of the fishermen. In the riverine zone of the reservoir (the third upper part) where processes are essentially of the transport type (Kimmel et al., 1990), fishery is based on migratory species and captures are undertaken with hooks. Since these equipments practically have no costs, the fishermen concentrated in this zone have low income and are generally excluded from the other productive sections. In the transitional zone characterized by predominant deposition processes, landings chiefly consist of sedentary species and captures are undertaken by nets. Due to its high costs, this fact restricts fishing to people with better socioeconomic conditions.

TABLE VII

Artisanal fisheries yield in reservoir of the high River Parana and landing specific composition (modified from Agostinho, 1994).

Reservoirs	[1]Barra Bonita	[2]Ibitinga	[2]Promissão	[2]Nova Avanhandava	[2]Três Irmãos	[2]Agua Vermelha	[1,3]Jupiá	[1]Itaipu
Yield and Number of Species in Artisanal fisheries								
Total yield (t/ano)	229	42	173	43	249	184	166	1600
Yield (kg/ha/ano)	6.0	3.2	3.7	2.5	3.4	2.9	4.7	12.0
Number of species	39	41	43	42	42	34	34	52
Composition of Landing (%)								
Plagioscion sqamosissimus[I]	**24.7**	**22.5**	21.6	**29.2**	15.8	28.2	11.1	17.2
Hoplias malabaricus	11.9	11.2	2.0	6.6	-	7.0	2.9	-
Pirinampu pirinampus[D]	-	-	-	-	5.8	-	3.6	1.1
Serrasalmus spilopleura	1.9	1.5	1.6	4.3	4.2	1.0	3.9	-
Salminus maxillosus[D]	0.1	-	-	0.05	-	-	-	0.5
Pseudoplatystoma corruscans[D]	0.2	0.3	0.1	0.2	-	0.2	-	1.7
Cichla monoculus[I]	-	0.4	0.02	0.2	-	2.7	4.0	-
Paulicea luetkeni[D]	-	-	-	-	-	-	-	2.6
Pimelodus + Iheringichthys	8.4	15.9	**43.6**	26.0	10.6	**34.0**	11.6	2.9
Prochilodus lineatus[D]	22.7	11.7	12.7	14.5	34.3	-	**36.9**	13.7
Anostomideos	10.2	8.5	-	-	7.1	-	5.2	-
Curimatideos	7.3	-	-	-	-	-	-	-
Tetragonopterineos	-	15.6	9.3	3.2	-	-	-	-
Geophagus sp	-	-	-	-	8.2	9.4	8.7	-
Oreochromis + Tilapia[I]	-	-	-	-	-	8.9	-	-
Loricarideos	-	-	-	-	-	-	5.1	2.6
Hypophthalmus edentatus[J]	-	-	-	-	-	-	-	**27.0**
Pterodoras granulosus[JD]	-	-	-	-	-	-	-	16.1
% of total	87.4	88.6	90.9	84.2	86.0	91.4	83.0	85.4
General Characteristics of the reservoirs								
river	Tietê	Tietê	Tietê	Tietê	Tietê	Grande	Paraná	Paraná
closing year	1962	1969	1974	1982	1990	1978	1968	1982
area (km)	354	114	530	217	717	644	352	1,350
perimeter (km)	788	375	1423	462	1,400	1,190	482	-
water turnover (days)	74.0	1.2	38.5	6.4	56.8	29.1	2.3	40.0
catchment area (km^2)	32,330	43,500	57,610	62,300	70,600	139,900	470,000	822,150
depth (avg, m)	10.2	8.1	12.6	13.7	(?)	17.1	11.0	21.0

[1] = more then 100 km free upstream; [2] = another dam imediatelly higher up; [3] = large lateral affluents; 0 = migrators; I = introduced; J = restricted to the middle River Paraná before the closing of Itaipu Dam; hatched rectangles = most abundant; empty rectangles = second most abundant species

Sources: Carvalho Jr. et al .(1993a, b); Correa et al (1993a, b); Torloni et al. (1993); Moreira et al (1993); FUEM-ITAIPU BINACIONAL (1993); Petrere and Agostinho (1993); Cruz et al. (1994)

The participation of species from other basins in landings at the reservoirs of the high Paraná is very low in spite of the stock efforts (more than 20 species have been introduced) made by the hydroelectric companies. The **curvina** *Plagioscion squamosissimus* is an exception and takes first or second position in all the reservoirs. However, recent studies at the Itaipu Reservoir reveal that the fishery yield of this species in a given year is negatively related to that of its principal prey, the **mapará** *H. edentatus*, in the following year. (Agostinho et al., in press)

RESEARCH AND MANAGEMENT OF FISHERY RESOURCES

Pioneer studies on fish biology in the high River Paraná basin were carried out by researchers of the Fishing and Hunting Division of the Ministry of Agriculture through its experimental station in Pirassununga, State of São Paulo, pertaining to the Fishery Institute of the Secretary of Agriculture of the State of São Paulo, Brazil (R. von Ihering, P. Azevedo, M.P. Godoy, S.B. Barker, C.M. Machado, M.B. Morais Filho and F. Alzuguir, among others). Emphasis was on migratory forms with the aim of exploitation of these species in pisciculture. Besides doing research work in other basins and in other types of environment, H.M. Godinho, M.A. Basile-Martins, H. Britski and H. Nomura formed a new generation of researchers working on the subject matter and at present distributed in at least ten university institutions. Taking into account their geographical distribution, emphasis should be given to the Universidade Federal de Minas Gerais (basins of the Rivers Paranaíba and Grande); Universidade Federal de São Carlos (basins of the Rivers Grande and Tietê); Universidade de São Paulo at São Carlos and at Riberão Preto (basin of the Tietê); Universidade Estadual Paulista at São José do Rio Preto (basins of the Tietê and Grande), at Rio Claro (basin of the Tietê), and at Botucatu (basins of the Tietê and Paranapanema); Universidade Estadual de Londrina (basin of the Tibagi-Paranapanema); Universidade Estadual de Maringá through NUPELIA (River Paraná and the basins of the Ivai, Piquiri, Iguaçu, Ivinheima, Iguatemi and Amambai). Besides the above higher institutions whose research work is generally restricted to post-graduate programs, surveys and studies have been undertaken by public institutions as the Institute of Fisheries (São Paulo) and the Brazilian Institute of Environment and Renewable Natural Resources and the hydroelectrical companies.

The operations aimed at minimizing the impact of anthropic actions, preserving fishery stocks and increasing yield in the basin are in a very incipient stage and only undertaken by the hydroelectric companies. Management techniques are restricted to stock and control of fisheries.

Initially done only with allochthonous species, at present priority of stocks is the species proper to its own basin. Exotic species were not very successful in the occupation of distinct environments. The **curvina** *P. squamosissimus*, a piscivorous species which dominate captures in all the reservoirs, is an exception. The great majority of species which were introduced in the basin of the high River Paraná are sporadic in fisheries (Table 2). Even the captures of native species do not show any relation with stock effort. This fact can be demonstrated by the significant participation of species that have never been the object of management (*P. maculatus* and *I. labrosus*) and of *P. lineatus* whose biomass captured in each reservoir does not depend on stock intensity (Agostinho, 1994).

Fishery control is exercised by restrictions to certain fishing equipment, minimum size of captures and prohibition of fishery activity in areas or periods relevant for the success of recruitment. Unfortunately, lack of human resources and equipments for adequate enforcement transforms the above laws into inefficient means.

Unsuccessful efforts for the preservation of ichthyofauna and the maintenance or bettering of stocks may be attributed, among other specific factors, to (a) the insufficiency or inadequacy of available information with regard to fishery system; (b) the reductionist approach with which actions are planned and implemented; (c) the absence of fish stock monitoring which would permit the evaluation and eventually the redirectioning of actions; (d) historical equivocations of legislation which, during a certain period of time, made obligatory constructions (fish transposition facilities or pisciculture stations) an aim in themselves and not instruments to make management viable; (e) the lack of inter-institutional integration and use of different approaches by the institutions. The surmounting of these obstacles will certainly lead to an increase in the efficiency of management and the preservation of fishery resources.

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