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Chapter 11
Review of the fisheries in the Brazilian portion of the Paraná/Pantanal basin

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Abstract

The status of the commercial fisheries in the Brazilian part of the Paraná river basin, including the Pantanal is reviewed. The Paraná is nearly completely regulated by a cascade of dams built for hydroelectric power generation. Only 230 km of main river remain as running waters. The basin has the highest population density in the country, and a high concentration of industry and intensive agriculture. Despite the variable quality of data, fish stocks have been severely degraded by flow regulation and pollution. Large migratory fishes are rare or even absent in some stretches of the main river and in some important tributaries. Fisheries are now dominated by small, low commercial value specimens preadapted to lacustrine habitats. Species introductions are also a major concern.

Keywords: Brazil, commercial fisheries, inland fisheries, Paraná river.

11.1 Introduction

The continent of South America, and Brazil in particular, has a large number of rivers which have been subjected to intense damming in the last 30 years. The first hydroelectric power plant built in Brazil was on the Paraibuna river, in the city of Juiz de Fora, in the State of Minas Gerais. This reservoir was inaugurated in 1889, generating 252 kW. By 1980, 154 large dams had been built generating 33 140 MW. By 2000 nominal generating capacity reached 78 139 MW and the eventual target is an estimated 106 450 MW. Presently, 90% of energy consumed in the country is of hydroelectric origin and 70% of the reservoirs are concentrated in the southeast region mostly in the Paraná basin (Figs 11.1 and 11.2) (Paiva 1982; ELETROBRÁS 1991).

Among the main river basins in South America, the Paraná is the most intensively dammed. It is expected that by the end of the decade, 69 hydroelectric impoundments with areas greater than 200 ha will be created in the Brazilian portion of the basin alone. The 45 existing reservoirs in the basin have transformed the main Paraná river and its tributaries (Grande, Paranaíba, Tietê, Paranapanema, Iguaçu) into a cascade of

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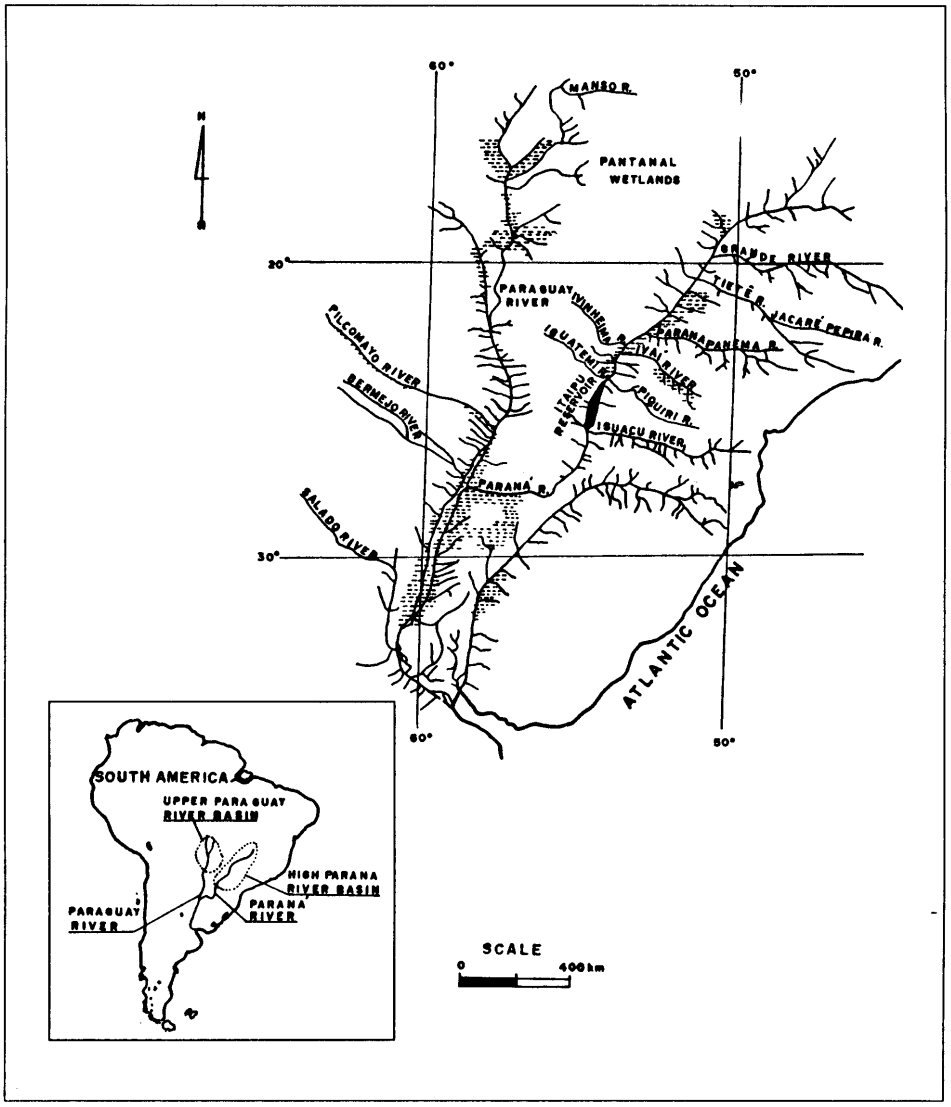

Figure 11.1 Map of the Paraná basin showing location of reservoirs

lakes (Table 11.1). Of the 809 km of the Paraná flowing in the Brazilian territory, 250 km is running water. The remaining Brazilian 30 km below the Itaipu reservoir (Fig. 11.2) will also be dammed by the Argentinean–Paraguayan reservoir of Corpus.

Data on fish stocks are sparse and it is only since the building of the Itaipu reservoir, and with the Convention Universidade Estadual de Maringá (UEM/ITAIPU BINACIONAL), that information on fish landings in the reservoir area have been made available. The present paper examines information on Itaipu, the Tietê reservoirs and the Pantanal, which is part of the Great Paraná basin.

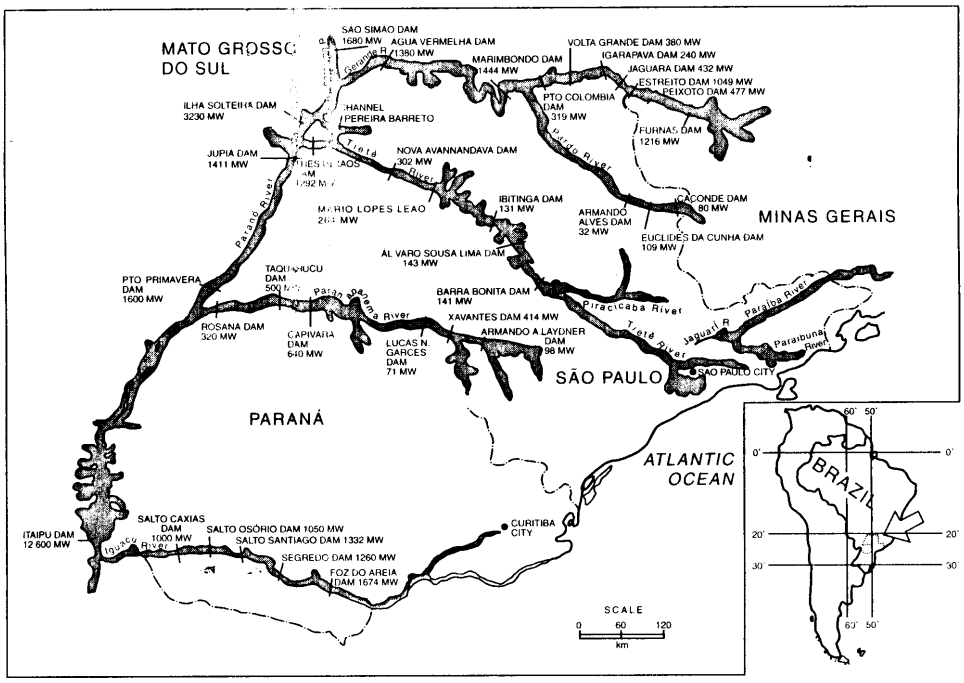

Figure 11.2 Location of main reservoirs on the Paraná Tietê rivers

11.2 Paraná basin

The Paraná basin has a catchment of 2.8 million km^2 draining all south-central South America, from the borders of the Andes to the Serra do Mar adjacent to the Atlantic Coast. Its main river, the Paraná, is 4695 km long, being the 10th longest river in the world, and the second largest in South America, after the Amazon. Its major tributary is the Paraguay river (2550 km). The climate may be classified as sub-tropical to humid-tropical with 1 or 2 dry months, with an average monthly temperature >20°C. Precipitation is >1500 mm year^{-1} (IBGE 1990). River discharge in its upper course varies from 8400 to 13 000 m^3 s^{-1} (minimum of 2550 m^3 s^{-1} and maximum 33 740 m^3 s^{-1}). It is formed by the rivers Paranaíba and Grande (Figs 11.1 and 11.2), which rise in the Brazilian shield but then cut into the sedimentary strata. Most of the tributaries of the Upper Paraná present high deposits of sediments in two main areas along the Grande–Paraná channel in the region of Cachoeira (Falls) de Marimbondo and in the stretch of the Três Lagoas and Guaíra in the Paraná river (Souza Filho 1993). Sediment yields reach 3 million t year^{-1} (Stevaux 1994). The Paraná floodplain is 20 km wide in places along its right bank from the city of Três Lagoas to the mouth of the Ivaí river. It has many lagoons with a wide range of habitats. Its main left bank tributaries are the Tietê, Paranapanema, Ivaí, Piquiri and Iguaçu, and in the right bank the rivers Verde, Pardo, Ivinheima, Amambaí and Iguatemi (Fig. 11.1). In this stretch, the river exhibits two distinct morphological patterns. The first comprises the upper course with an

Table 11.1 Some characteristics of selected reservoirs of the Paraná river basin

River	Reservoirs	Inundated area (ha)	Perimeter (km)	Discharge ($m^3 s^{-1}$)	Volume ($10^6 m^3$)	Mean water residence time	Nominal generating capacity (MW)	Year filled
Tietê	Barr bonita	33 430	788	402	2566	73.9	141	1962
	Bariri	5461	203	443	60	1.5	143	1965
	Ibitinga	12 216	375	525	56	1.2	131	1969
	Promissao	53 000	1423	640	2128	38.5	264	1974
	N. Avanhandava	21 700	462	688	380	60.4	302	1982
	Três Irmaos	81 700		733	3600	56.8	1292	1990
Paraná	Ilha Solteira	123 100	1513	5121	12 328	29.0	3230	1973
	Jupiá	35 200	482	6158	1230	2.3	1411	1968
	Porto Primavera	260 000		6931	4643	7.7	1814	1998
	Itaipú	135 000	3060	9670	29 000	35.0	12 600	1983
Grande	Água Vermelha	64 400	1190	2056	5169	29.1	1380	1978
Paranapanema	Jurumirim	54 648	1286	200	3165	183.2	97.75	1961
	Xavantes	42 760	1085	307	3041	114.6	414	1969
	Capivara	64 405	1550	1024	5724	64.7	640	1975
	Salto Grande	1587	81	413	29.4	0.8	70.38	1958
	Taquaruçu	64 405	1550	1024	5724	64.7	640	1992
	Rosana	27 614		1195	407	3.9	320	1996
Pardo	Cacondew	3737	269	56.8	504	102.7	80.40	1965
	Euclides da Cunha	114	16	88.9	4.68	0.6	108.80	1979
	Limoeiro	269	21	90.3	16.36	2.1	32.20	1979

approximate extension of 619 km between the confluence of rivers Paranaíba and Grande and the now inundated Guaíra Falls, which originally was a geographical barrier to fish dispersal. In this sector the river has an irregular course with variable width, numerous islands and bars and an extensive floodplain, mainly on its right bank. In the second sector, now nearly completely inundated, the river runs through a basaltic canyon down to the city of Posadas in Argentina where, it turns west, receives the Paraguay river, then runs south through a very extensive floodplain receiving the Uruguay river near the Atlantic Ocean in its estuary known as La Plata river. The waters of the Paraná, as many other large tropical rivers, have low salinity, low calcium and high silica concentration. The upper river exhibits high turbidity during floods, albeit suspended solids remain relatively low (5–100 mg L^{-1}), reducing light penetration. Secchi disc readings during low water are around 1.0 m. Average conductivity is below 50 μS cm^{-1}, varying with water levels and inside reservoirs; pH is around neutrality; dissolved oxygen concentrations towards supersaturation. Dominant ions are $HCO_3 > Cl^- > SO_4$ and $Ca^- > Mg^{2+} > Na^+ > K^+$ (Bonetto 1986). Although pollution problems are not intense in the main river, mercury concentration, at least in the region of Porto Rico, exceed the maximum concentrations permissible for protection of aquatic communities (Rodrigues, Lenzi, Luchese & Rauber 1992).

The Pantanal is a humid area of extensive alluvial plains with an average altitude below 200 m. It originates from subsidence associated with the rising of the Andes. Its estimated area is around 140 000 km^2 in the States of Mato Grosso and Mato Grosso do Sul (Fig. 11.1), and is fed by 12 main rivers of which the Paraguay and Cuiabá are the most important. The dominant climate is tropical with relative humidity varying from 60% to 80%, and an average annual temperature of around 25°C. Due to the influence of polar air masses, temperature may drop as low as 0°C for short periods. Average precipitation is about 1200 mm $year^{-1}$ and is highest in January. The dry season extends from May to September and the rainy season from October to March. The main soils are classified as hydromorphic podzols (Petrere 1992). In the Pantanal the only reservoir to be constructed is the Manso dam (38 000 ha, 210 MW, 0.55 MW km^{-2}) on the river with the same name, which joins the Cuiabazinho river to form the Cuiabá river.

The aquatic landscape of the Pantanal exhibits floodplain lakes (baías) of varying shape and dimension seasonally connected to the main river. Sandy strips (cordilheiras) are located between the baías with average elevation of 2 m above high water level. Depressions between the cordilheiras are called vazantes, which drain the water at the beginning of the dry season. The corixos are small intermittent creeks. The salinas are inundated depressions which store rain water, are brackish, and are not influenced by the main river – and do not contain fish (Petrere 1992).

11.3 The fish fauna

The Paraná–Paraguay basin has about 600 species (Bonetto 1986). Ferraz de Lima (1981) estimated that there are 400 fish species in the Pantanal, predominantly Characiformes and Siluriformes, the main families probably being of pre-Gondwania origin (Garavello 1986).

Experimental fishing between 1983 and 1996, using gillnets, long lines, cast nets and trawl seines in the different biotopes in the Paraná river between the mouths of the rivers Paranapanema and Iguaçu, including the whole area of the 170-km long Itaipu reservoir, collected 261 fish species. Of these, 114 species (43.7%) were Characiformes and 110 (42.2%) Siluriformes, although the latter contributed with more than half the fish caught by number. Other orders which also appeared in the catches were: Perciformes (22 species), Cyprinodontiformes (6 species), Rajiformes (3 species), Clupeiformes (2 species), Pleuronectiformes (1 species), Synbranchiformes (1 species), Cypriniformes (1 species, introduced) and Atheriniformes (1 species, introduced). The main families were Characidae (68 species), Pimelodidae (39 species) and Loricariidae (26 species). The fish fauna is more diverse in creeks (153 species), and channels and lagoons (125 species), followed by the main river channel and Ivinheima river where 117 and 100 species were caught, respectively. There was a decreasing richness from its upper third (80 species) of River Iguaçu ichthyofauna toward the dam (53 species). Twenty eight small-sized adult species were restricted to the small creeks in the region of the reservoir and above it. From the species caught below the reservoir (90 species), 16 are exclusive, i.e. they did not occur above it. From the total of 172 species, 20 were responsible for 94% of biomass of the catches (Agostinho, Júlio & Petrere 1994). Terminal desiccating lagoons also exhibit a high species diversity, but numbers reduce by some 50% as pools dry up (Verissimo 1994).

Detritivorous and piscivorous are responsible for more than 75% of the catches in the floodplain, while in the reservoir the fish communities are dominated by piscivores, one of planktophagous species and insectivores. The fish fauna in lagoons is dominated by *Loricariichthys*, *Hoplosternum*, *Leporinus lacustris* Campos, young of *Prochilodus lineatus* (Val.) and others rheophilic species. In the main channel of the Paraná river the typical species are *Paulicea luetkeni* (Steindachner), *Loricaria* and adults of large migratory fishes (*Pseudoplatystoma corruscans* (Spix & Agassiz), *Salminus maxillosus* Val.). In large tributaries, the characteristic species associated with meandering biotopes belong to Doradidae, Ageneiosidae, *Schizodon*, *Hoplias*, *Rhaphiodon*, Auchenipteridae *Pimelodus*, *Roeboides*; in rapid waters, *Leporinus amblirhynchus* Garavello & Britski, *Schizodon nasutus* Kner, *Galeocharax knerii* Steindachner, *Apareiodon*, *Myloplus*; and in small streams *Steindachneridion*, small specimens of Cheirodontidae, Tetragonopterinae, small Pimelodidae, Loricariidae and Trichomycteridae are typically found. In the Itaipu reservoir, with a large floodplain upstream, the main species are *Plagioscion squamosissimus* (Heckel) (introduced) and *Hypophthalmus edentatus* Spix & Agassiz in the middle sector; *Pterodoras granulosus* (Val.), *Rhinelepsis aspera* Spix & Agassiz, *Prochilodus lineatus* in the upper section and *Iheringichthys* and *Auchenipterus* throughout the reservoir (Agostinho & Julio Jr 1999).

Barrella (1989) studying the fish fauna of the Jacaré Pepira river, the only unpolluted tributary of the Tietê river (Fig. 11.1), during the dry season, employed a combination of different fishing gears and collected 52 species. Beaumord (1991) sampled the fish community of the River Manso, which together with River Cuiabazinho forms the River Cuiabá (Fig. 11.1), from September 1987 to July 1989, employing gillnets of different mesh sizes set from 18:00 to 6:00 h and found 80 fish species, of which 72 were identified.

Catella & Petrere (1996) studied the Baía da Onça, a floodplain lake of the River Aquidauana in the Pantanal of the State of the Mato Grosso do Sul. From July to December 1988, when the lake was separated from the main river, they collected 75 fish species and verified the presence of many small-sized adult species. The most abundant families in terms of number of individuals were Characidae (79.5%), Curimatidae (13.1%) and Pimelodidae (3.6%). In terms of biomass, the most abundant were Curimatidae (38.3%), Characidae (28.1%), Loricariidae (10.4%), Pimelodidae (10.1%) and Erythrinidae (4.5%). Catches made with trawl seines showed that the highest abundance occurs at sunset and sunrise. The lowest abundance was detected in May ($2.2\,g\,m^{-2}$), the highest in July ($43.6\,g\,m^{-2}$) with intermediary rates in December ($16.7\,g\,m^{-2}$). The authors interpreted these figures through the direction of the migration lake–river–lake, depending on the water regime of the River Aquidauana. The fish communities which occupied the lake in the periods of July 1988 and June 1989 were distinct in relation to species composition with a proportional similarity PS = 39%, showing the complex and poorly studied dynamics of habitat colonisation in tropical rivers following annual floods.

11.4 The fisheries

Given the available data, the fisheries in the Paraná basin may be divided into six sectors, in:

(1) the Grande river, the former of Paraná river;
(2) the Tietê reservoirs;
(3) the lotic waters of the River Paraná;
(4) Jupiá reservoir;
(5) Itaipu reservoir; and
(6) the Pantanal.

11.4.1 *The fisheries in the River Grande*

The artisanal fishermen in the River Grande below the small Marimbondo reservoir (Fig. 11.2) utilise four main fishing gears (Castro 1992). Cast nets are used mostly in the high water period from November to March for catching corimba, the main fish species in the region, which schools below the dam during its reproductive migration. As a result, the catch per fishing trip is highest at this time of the year. Long lines are used in the transition periods (April and October), when the catch per trip decreases sharply. This fishery is markedly territorial, and catches mainly barbado *Pinirampus pirinampu* (Spix & Agassiz), which sells at twice the price of corimba, compensating for the low catches. Gillnets, and hooks and line are used in the dry season (May to September), when the catch per trip is low and most of the fish caught have low market value, obliging many fishermen to give up fishing for alternative occupations. The most important fish species in order of abundance are: corimba (42%), barbado (20%) and

mandi-guaçu *Pimelodus maculatus* Lacepède (17%), all migratory species. There is also an intense sport fishery, which does not compete with the artisanal fishery because it tends to concentrate upon different fishing sites and fish species. In the high water season there is a conflict between the artisanal and sport fisheries, as the power boats used by the tourists interfere with the long lines used by the commercial fishermen.

The artisanal fisheries of Água Vermelha reservoir (Table 11.1, Fig. 11.2) are based on gillnets (Corrêa dos Santos, Ferreira & Torloni 1993). Total annual catches in 1990 and 1991 were 119 and 259 t, respectively. The average catch for 34 fish species was 678 kg fisherman^{-1} month^{-1}, the most abundant of which were mandi-guaçu (34%), curvina (28%); acarás: acará-geo *Geophagus brasiliensis* (Quoy & Gaimard) and acará-geo-bengala *Geophagus* sp. (9%); Nile tilapia *Oreochromis niloticus* (L.) (9%) and traíra *Hoplias malabaricus* (Bloch) (7%).

11.4.2 *The fisheries in the River Tietê*

The River Tietê (Fig. 11.2) is the main affluent of the left margin of the River Paraná and has its head streams in the town of Salesópolis. It is 1050 km long and it is very polluted where it crosses the city of São Paulo, receiving industrial and domestic sewage from an urban concentration of 12 million people. The River Tietê has been under intense cultural stress since the 1920s linked to industrialisation of the city and State of São Paulo. At the end of the 1940s it was no longer possible to swim in its waters. Presently it receives 4500 t year^{-1} of sewage from the Great São Paula area.

There are around 24 million inhabitants in the Tietê river basin (72 000 km^2), 96% of whom live in urban areas. It is the most densely populated region of South America, with 210 towns and cities, and where the majority of the industries of the country are located (São Paulo 1990).

In addition to pollution, the Tietê river and its major tributaries are impaired by:

(1) bank erosion, due to felling of marginal vegetation;
(2) sedimentation, mainly due to sugar cane plantations, where the soil is ploughed every year and left bare until the cane starts to grow;
(3) dams, at present, the Tietê river has six reservoirs along its length (Table 11.1, Fig. 11.2), whose total capacity is 2273 MW. Tundisi, Matsumura-Tundisi, Henry, Rocha & Hino (1988), in comparing the trophic state of the Tietê reservoirs, concluded that all are eutrophic, although the condition of the reservoirs slowly improves from eutrophic to mesotrophic as the water approaches the confluence with the River Paraná.

Below the Nova Avanhandava reservoir, the water is visually clean, compared with Barra Bonita reservoir. The cascade of reservoirs plays the role of settling lagoons, retaining particulate material, N and P. This situation may continue to degrade as the cities of the basin continue to grow without sewage treatment or land use control. There are no commercial fisheries in the River Tietê above Barra Bonita reservoir. There is a marginal sport fishery which becomes more intense during high floods, when better oxygenation of the water permits upstream movement.

After the main period of dam construction during the 1960s, CESP (Companhia Energética de São Paulo) translocated several Brazilian fish species exotic to the basin into these reservoirs. Those included the apaiari *Astronotus ocellatus* (Agassiz), curvina *Plagioscion squamosissimus*, tucunaré *Cichla* sp. and sardinha *Triportheus angulatus* (Spix & Agassiz) from the Amazon basin and the shrimp camarão sossego *Macrobrachium jelskii* (Miers) from north-east Brazilian reservoirs. Alien carp, *Cyprinus carpio* L., and tilapias (*Oreochromis niloticus*, *Oreochromis hornorum* (Trewavas), *Tilapia rendalli* (Boulenger)) were also introduced. Of these only the curvina, and on a lesser scale tucunaré, appear to have been successful (Torloni, dos Santos, Carvalho Jr & Corrêa 1993a; C.E.C. Torloni, personal communication).

In Barra Bonita reservoir, fish are mostly caught by gillnets with different mesh sizes but are strongly predated upon by the pirambeba *Serrasalmus spilopleura* Kner. The total annual catches were: 1989 – 122 t; 1990 – 254 t; 1991 – 129 t, with an average production of 809 kg fisherman^{-1} month^{-1} (Carvalho, dos Santos, Gonçalves & Torloni 1993a). Here 39 fish species were caught, the most important being curvina (24.7%); corimba (22.7%); traíra (11.9%); the piavas: piava-catinguda *Leporinus friderici* (Bloch), piava-da-asa-amarela *L. cf. paranensis* and piava-três-pintas *Schizodon borelli* (Boulenger) (10.2%); the mandis mandi-guaçu, mandi-chorão *Pimelodella* sp., mandi-boca-de-velha *Iheringichthys labrosus* (Lütken), mandi-serrote *Rhinodoras dorbignyi* (Krøyer) (8.4%); the saguirus: saguiru-branco *Steindachnerina insculpta* (Fernándes-Yépes); saguiru-curto *Cyphocharax modesta* (Fernándes-Yépes) and saguiru-comprido *C. nageli* (Steindachner) (7.3%).

In Ibitinga reservoir, fishermen only employ gillnets with different mesh sizes (Corrêa *et al.* 1993). The total annual catches are: 1989 – 22 t; 1990 – 64 t; 1991 – 24 t. The average production is 327 kg fisherman^{-1} month^{-1}. Here 41 fish species were caught, the most important of which were: curvina (22.5%); mandis (15.9%); lambaris: lambari-prata *Astyanax schubarti* (Britski), lambari-tambiú *A. bimaculatus* (L.) and lambari-corintiano *Moenkhausia intermedia* Eigenmann (16%); corimba (11.7%); traíra (11%) and piavas (8.5%).

In Promissão reservoir, fishermen usually employ gillnets and cast nets (Cruz, Moreira, Verani, Girardi & Torloni 1990; Torloni, dos Santos, Moreira & Giradi 1991). Gillnets have variable lengths from 30 to 40 m, an average height of 1.5 m and meshes from 7 to 14 cm bar. Each fisherman utilises an average of 2000 m of gillnets, which are set at sunset and lifted at sunrise. They fish 240 days per year on average, with a major concentration of effort from October to March. Forty-two fish species were caught in this reservoir, six of which are responsible for 85% of total landings. The total annual catches were: 1986/1987 – 267 t, 1987/1988 – 266 t, 1989/1990 – 255 t. The most important fish species in 1988/1989 were mandi-guaçu, corimba, curvina and lambaris. Characiformes predominated in every year making up 75% of the catches, followed by Siluriformes (15%) and Perciformes (10%). Torloni, Carvalho Jr, Corrêa, Santos & Cruz (1993b) gave slightly different figures for these annual catches. Average production was 888 kg fisherman^{-1} month^{-1}.

Moreira, Santos, Silva & Torloni (1993) described the fisheries in Nova Avanhandava reservoir, where fishermen only use gillnets of different mesh sizes to catch 42 different fish species. The total annual catches were: 1988 – 76 t; 1989 – 53 t; 1990 – 41 t;

1991 – 44 t. The average production was 457 kg fisherman^{-1} month^{-1}. The main species landed were: curvina (29%); mandis (26%); corimba (15%); traíra (7%), pirambeba (4%) and lambaris (3%).

11.4.3 *The fisheries in the River Paraná*

Carvalho, Santos, Deus & Torloni (1993b) described the fisheries in Jupiá reservoir (Table 11.1, Fig. 11.2) where the professional fishermen exclusively employ gillnets set between 16:00 and 6:00 h. The total catches were 1989 – 162 t; 1990 – 182 t and 1991 – 152 t. The average production was 737 kg fisherman^{-1} month^{-1}. Thirty-four fish species appear in the catches, the most important of which were corimba (37%); mandi-guaçu (12%); curvina (11%); acarás (9%); piavas (5%); cascudos: cascudo-chinelão *Rhinelepis aspera* Spix & Agassiz, cascudo-chita *Hypostomus regani* (Ihering), cascudo-voador *Loricaria vetula* (Thering) and cascudo-caborja *Callichthys callichthys* (L.) (5%); pirambeba (4%) and barbado (4%).

Information about the lotic fisheries of the Paraná river are sparse. Preliminary surveys carried out by the Universidade Estadual de Maringá, revealed three kind of fisheries in the region:

(1) artisanal fisheries by fishermen from Port Rico and Guaíra, small towns at the river bank;
(2) sport fisheries performed by citizens, from larger urban centres around the region;
(3) subsistence fisheries performed by small farmers and part-time workers who cut sugar cane in the harvest time and live on the innumerable islands of the river cultivating cereals or living in small settlements at the river margin.

The professional fisheries are different in character from those practised in reservoirs in the basin. They target preferentially the large Pimelodidae, such as the pintado *Pseudoplatystoma corruscans* and barbado, Characidae (dourado *Salminus maxillosus*), Anostomidae (piaparas *Leporinus elongatus* (Val.), *L. obtusidens* (Val.)), Prochilodontidae (corimba) and Erythrinidae (traíra). More recently Doradidae (armado) have appeared in catches in the middle reaches of the river through its dispersion up river after the building of the Itaipu reservoir. It seems that the pintado is still reasonably abundant. Marques (1993) studied its biology by sampling the commercial fisheries in the town of Porto Rico (Fig. 11.1) and measured 4800 individuals totalling 24 t in 1987–1988. The large Pimelodidae and dourado are caught with hooks baited with live fishes. Bait fish are drawn from species which are more resistant to manipulation and harsh conditions while being held in the boats before being utilised. These typically consist of species such as the morenita *Gymnotus carapo* L., caboja *Hoplosternum littorale* (Hancock) or some abundant floodplain fishes such as corró *Leporinus lacustris*, muçum *Synbranchus marmoratus* Bloch and young corimba. Fisheries for pintado, which is the most sought after species, use a strategy called 'anzóis de galho', where hooks are set in the early hours of the night to avoid pirambeba attacks on the baits. The movements of pintado schools in this stretch of the river are sometimes followed by fishermen for more than 100 km (Buck 1988). Although long lines employed for

catching dourado, jaú and barbado, the fisheries are more usually performed during the day or at sunset with hook and line.

Corimbas and armados are essentially caught with gillnets, whilst armados are also caught with long lines. Some variations in these fisheries are observed during the piracema (reproductive up river migration) for species like corimba and cascudo-preto, when they are caught by beach seining on sandy banks. During the winter, when there is a decrease in catch per unit effort in the main river channel, fishermen fish in the floodplain lakes and channels. At this time of the year smaller specimens of large fish are caught together with traíra. Professional fishermen also catch morenita in lagoons covered by macrophytes for sale to sport fishermen. The professional fisheries are forbidden during the months of November–February and during the whole year on the right margin where the floodplain is wider (20 km). Nets with meshes below 7.0 cm stretched mesh are not allowed, although mesh control is always difficult. The absence of data does not allow inferences about fishing yields.

Sport fisheries operate mostly at weekends throughout the year. They mainly target dourado, piracanjuba *Brycon orbignyanus* (Val.), pacu *Piaractus mesopotamicus* (Holmberg), piaparas, pintados and jaú. Sport fishing is restricted to the main river channel and its main tributaries, to hook and line or pole and line, baited with live baits for catching dourado and jaú, or fruits of the season for the remaining species. Annual fishing contests are crowded events in some river-side towns.

The subsistence fisheries are practised by virtually all islanders and by a considerable portion of the river-side population, fish being the main protein source for these people. The islanders employ gillnets and to a lesser degree hook and line or pole and line, to catch medium sized specimens, while in smaller settlements fishing is carried out by women and children using pole and line for catching small Pimelodidae, such as mandis and *Characidium* as lambarís.

11.4.4 *Fisheries in Itaipu reservoir*

Itaipu reservoir is the largest in the Paraná basin and up to now the largest in South America in nominal power generating capacity (Figs 11.1 and 11.2, Table 11.1). Its gates were closed in 1982. Professional fisheries in the reservoir only started in February 1984. Prior to that date, fishing was forbidden with the intention of avoiding intense catches of juvenile dourado, piracanjuba, etc. The Universidade Estadual de Maringá established a system for collecting professional catch and effort data in the reservoir from 1987.

The number of professional fishermen working in the reservoir oscillates around 1000, of which 35% are permanent. In 1997 there were 941 and in 1998, 619. The fall was due to IBAMA effort restrictions, mainly in the fluvial zone of the reservoir (Agostinho, Okada & Ambrosio 1999a). Most (73%) work in the upper half of the reservoir, due to the increased abundance of fish. The average profit of the fishing activity is only US$25 fisherman^{-1} month^{-1}. In 1998, 91.3% were affiliated in seven professional fishermen associations. (FUEM/ITAIPU BINACIONAL 1989; Agostinho *et al.* 1994; 1999a). Fishing effort is controlled mainly by mesh regulations, where

meshes smaller than 7 cm stretched mesh are forbidden. Professional and sport fisheries are forbidden in all the reservoir's tributaries. In the reservoir, professional fisheries are allowed all year round and sport fisheries are negligible. The gillnets (meshes ranging from 7 to 24 cm, between knot to knot, 50 m length in average, depth 2.0 m), are the most important gear employed and in 1998 about 711 247 m^2 (mostly 8 cm mesh) were set in the reservoir by 80% of the fishermen. They are mainly set for sardela *Hypophthalmus edentatus*, corimba, corvina, and more recently, *Pterodoras granulosus* (Val.). Long lines are set only in the transitional lotic/lentic zone by 43% (in 1998) of the fishermen, baited with seasonal fruits for catching the armado. In 1998, 72 800 hooks were used, nearly double that used in 1993 (49 055 hooks) (Agostinho, Okada & Ambrosio 1999b). The average number of hooks per long line is 75 (150 m length of nylon filament), with different sizes. The cast net, which is 3 m high, is employed only in the reservoir entrance for catching cascudo-preto and cascudo abacaxi *Megalancistrus aculeatus* (Perugia).

Total catches were fairly constant from 1987 to 1998: 1563, 1500, 1727, 1427, 1589, 1573, 1542, 1297, 1373, 1411 and 1192 t respectively. The CPUE (kg fisherman^{-1} day^{-1}) was 23.2, 20.2, 19.3, 15.9, 15.9, 12.8, 11.6, 12.0, 12.1 and 11.2, respectively (Okada, Agostinho & Petrere Jr 1996; Agostinho *et al.* 1999b). The average fish yield for the period was 11.2 kg ha^{-1} year^{-1} and the average price per kilo was US$ 0.60. Nearly 50 fish species were caught in different years, of which nine were responsible for 90% of the landings. The most important were sardela, armado, corvina, corimba and mandi, which were responsible for 78.7% of the catches (Table 11.2); (Agostinho *et al.* 1994, 1999b; Okada *et al.* 1996).

11.4.5 *Fisheries in the Pantanal*

There are three main cycles of fish migration in the Pantanal, which, on the whole, determine fishing strategies:

(1) the Iufada which designates lateral fish migration coming from the floodplain lakes towards the main river at the end of the dry season. For a short period they concentrate in large schools in the lake mouths, thus becoming very vulnerable to fishing at that time. In the River Cuiabá the phenomenon occurs in April–June, generally during the full moon;
(2) the 'piracema' which designates fish migration up-river, occurring in Cuiabá river in October–November; and
(3) the 'rodada' which describes the behaviour exhibited by fish at reproduction. Spawning for the vast majority of the species happens from December–February (Aguirre 1945; Ferraz de Lima 1984; 1986; Petrere 1989; 1992; EMBRAPA/CPAP 1991).

Professional and sport fisheries are traditional in the whole region. The main gears employed are gillnets, trawl seines, long lines, cast nets, igaratéia (a special type of multiple hook) and harpoons. There are legal restrictions for the employment of nets during the reproductive season (Aguirre 1945; Ferraz de Lima 1981; Ferraz de Lima & Chabalin

Table 11.2 Catch (t) and catch per unit effort (CPUE = t fisherman^{-1} year^{-1}) for the main species in the professional fisheries on the Itaipu reservoir

	Period																					
	1987		1988		1989		1990		1991		1992		1993		1995		1996		1997		1998	
Species	Catch	CPUE	Catch	CPUE	Catch	CPUE	Catch	CPUE	Catch	CPUE	Catch	CPUE	Catch	CPUE	Catch	CPUE	Catch	CPUE	Catch	CPUE	Catch	CPUE
P. lineatus	494.4	8.60	227.2	4.17	253.8	4.22	197.7	3.10	215.3	3.20	257.5	4.17	190.9	3.18	83.8	1.68	102.4	1.83	97.9	1.75	101.8	1.78
H. edentatus	241.9	5.76	463.5	8.52	443.9	6.87	392.6	5.98	515.3	7.25	411.8	6.43	364.8	4.81	232.4	3.23	215.6	3.16	180.9	2.82	154.2	2.55
P. squamosissimus	232.4	4.21	225.9	3.66	257.2	3.66	251.5	3.46	304.2	3.81	317.1	4.19	323.7	3.71	240.6	2.76	256.6	2.89	236.7	2.98	177.8	2.46
P. granulosus	176.5	3.17	168.8	2.79	288.8	3.98	225.6	3.07	233.6	3.03	289.1	3.46	334.0	3.40	398.6	4.47	455.2	4.92	544.8	5.44	466.8	4.83
H. malabaricus	23.2	0.74	19.8	0.58	23.3	0.61	28.0	0.67	21.6	0.53	23.8	0.68	32.9	0.71	48.3	0.97	46.6	0.96	57.0	1.08	42.8	0.92
R. aspera	62.7	2.20	46.2	1.95	81.1	3.22	75.3	2.79	63.0	2.58	30.0	1.40	26.6	1.10	40.0	0.91	21.8	0.68	14.4	0.46	11.2	0.42
P. luetkeni	59.5	1.39	56.8	1.59	78.0	2.16	31.4	1.15	24.1	0.93	17.1	0.83	9.7	0.96	3.1	0.51	4.3	0.82	2.3	0.44	2.6	0.32
P. pirinampu	49.8	1.13	41.2	0.97	23.8	0.72	13.6	0.47	25.0	0.67	26.4	0.76	20.1	0.56	33.8	1.05	46.2	1.36	48.7	1.51	52.8	1.56
P. corruscans	4.9	0.10	2.9	0.07	6.4	0.16	6.5	0.20	5.6	0.20	7.0	0.29	4.4	0.24	1.7	0.26	1.5	0.21	1.5	0.14	5.1	0.38
P. maculatus	42.1	1.12	66.1	1.35	75.4	1.34	46.4	0.87	45.9	0.81	54.3	0.96	68.5	0.98	52.4	0.76	42.6	0.62	45.0	0.70	33.2	0.57
Total	1563		1500		1727		1430		1589		1663		1542		1297		1373		1411		1192	

Source: Agostinho *et al.* (1994; 1999); Okada *et al.* (1996).

1984; Silva 1986; Resende 1988). In the State of Mato Grosso do Sul, where traditionally gear restrictions are more severe due to the pressure of sport fishermen, the cast net is allowed only for catching corimba. Other fish species are only caught by hook and line.

Collection of statistics of fish landings in the region has been discontinuous. In 1983 the official yield was 7505 t. Of these 2069 t (28%) were landed in the State of Mato Grosso do Sul, where there is a marked preference for catching large migratory catfishes represented by the pintado and cachara, *Pseudoplatystoma fasciatum*; 5436 t (72%) were landed in the State of Mato Grosso, where the corimba was the predom inant species. This means that professional fisheries were more important in this State as corimba is not traditionally a sport fish, being an illiophage it is not caught by hooks. Silva (1986) estimated that clandestine fisheries in the State of Mato Grosso do Sul may reach 50% of the official landings. Half of the production is exported, mainly to the State of São Paulo. Sport fishermen are much more numerous in the State of Mato Grosso do Sul and are allowed to catch a TAC of 30 kg plus one fish of any size. They generally come from the States of São Paulo, Paraná and Rio de Janeiro.

Catella, Peixer & Palmeira (1996) showed that from May 1994 to April 1995, 1434 t of fish were recorded for the whole State of Mato Grosso do Sul, of which 72% was caught by sport fishermen and the rest by professionals. The main species caught were pacu *Piaractus mesopotamicus* (656 t), pintado *Pseudoplatystoma coruscans* (254 t), cachara *Pseudoplatystoma fasciatum* (104 t), piranha (77 t), piavuçu *Leporinus macrocephalus* (69 t), barbado *Pinirampus pirinampu* (Spix & Agassiz) (69 t), dourado *Salminus maxillosus* (63 t), jau *Paulicea luetkeni* (42 t) and corimba *Prochilodus lineatus* (21 t). The following rivers were most heavily exploited: Paraguay (43%), Miranda (26%), Aquidauana (8.5%). Around 46 000 sport fishermen visited the State, mainly from July to October, spending about 4–6 days per trip and caught between 20 and 27 kg $trip^{-1}$. Professional fishermen spend 4–7 days per week fishing and catch between 45 and 82 kg $fisherman^{-1}\,trip^{-1}$.

11.5 Discussion

Yields from seven Paraná basin reservoirs are shown in Table 11.3. Their production are low (average = 4.51 kg $ha^{-1}\,year^{-1}$) when compared with international reservoirs (58.4 kg $ha^{-1}\,year^{-1}$ for African lakes (Bayley 1988) 99.5 kg $ha^{-1}\,year^{-1}$ for African reservoirs (Marshall 1984) and 151.8 kg $ha^{-1}\,year^{-1}$ for 17 north-east Brazilian reservoirs with inundated areas >1000 ha (Paiva, Petrere Jr, Petenate, Nepomuceno & de Vasconcelos 1994)). Possible reasons for these low productions include the following.

(1) Comparatively low fishing intensity (Table 11.3), 0.2 ± 0.2 fishermen $km^{-2}\,year^{-1}$ [CV (coefficient of variation) = 113%, n = 7]. This contrasts with the north-east reservoirs with 3.2 ± 2.6 fishermen $km^{-2}\,year^{-1}$ [CV = 80%, n = 17] and with African lakes 1.5 ± −1.3 fishermen $km^{-2}\,year^{-1}$ [CV = 85%, n = 31] (Henderson & Welcomme 1974). Welcomme (1990) in a review of the status of fisheries in South American rivers, considered that fishermen densities less than

Table 11.3 Comparison among the yield characteristics of seven different reservoirs in the Paraná river basin

Reservoirs	Jupiá Grande river[1]	A. Vermelha Grande river[2]	Barra Bonita Tietê river[3]	Ibitinga Tietê river[4]	Promissão Tietê river[5]	N. Avanhandava Tietê river[6]	Itaipú Paraná river[7]
Yield ($t\,year^{-1}$)	165	189	202	37	222	54	1800
Inundated area (ha)	35 200	64 400	33 430	11 400	53 000	21 700	135 000
Production ($kg\,ha^{-1}\,year^{-1}$)	4.7	2.9	6.0	3.2	3.7	2.5	13.3
Number of active fishermen	49	66	79	26	80	39	1000
Number of fishermen km^{-2}	0.14	0.10	0.23	0.23	0.15	0.18	0.74
CPUE $kg\,fisherman^{-1}\,month^{-1}$	737	678	809	327	888	457	187
CPUA $kg^{-1}\,fisherman^{-1}\,year^{-1}\,ha^{-1}$	0.25	0.13	0.03	0.34	0.20	0.26	0.02

[1]Carvalho Jr *et al.* (1993a), Torloni (1993).
[2]Corrêa *et al.* (1993).
[3]Carvalho Jr. *et al.* (1993b).
[4]Corrêa *et al.* (1993b).
[5]Torloni *et al.* (1993b).
[6]Moreira *et al.* (1993).
[7]Relatório Annual de Projeto (1990).

0.5 fishermen km^{-2} would mean an underfished floodplain. Density was as high as 29.8 fishemen km^{-2} for the Oueme in Africa, the average for a set of 19 floodplains being 4.36 ± −8.06, (CV of 185%). Welcomme (1990) also considered 1.0 fisherman km^{-2} appropriate for African reservoirs. Comparing the higher CV = 185% of floodplains with the above CVs for lakes and reservoirs which are nearly 50% lower, perhaps indicates that for fishermen, these biotopes are more predictable habitats than floodplains.

(2) Systematic stocking – the lack of systematic fish stocking in the Paraná basin reservoirs compared with the Brazilian NE reservoirs where stocking is a common practice. According to fishermen from Pereira de Miranda reservoir in the State of Ceará, stocking is efficient for the purpose of raising commercial landings, mainly of the migratory fish species. The local fishing community is highly organised and always pressing DNOCS (Departamento Nacional de Obras Contra as Secas) to continue stocking. Stocking to maintain fisheries in Cuban reservoirs is only effective where natural reproduction of the stocked species is low (Quiros & Mari 1999) and used to overcome this bottleneck.

(3) Possible low densities of lacustrine-adapted species such as tilapia which could occupy a probably empty plankton-grazing niche in the open waters of the reservoirs (see discussion by Fernando 1991 and Fernando & Holcik 1991). All the Tietê, Grande and Paraná river reservoirs have tilapias of which *O. niloticus* is by far the most important. In the Tietê river reservoirs, millions of tilapia fry were introduced to take advantage of cultural eutrophication. The only reservoirs supporting considerable commercial production of tilapia are Água Vermelha and Marimbondo, on the River Grande. In these impoundments a fishery for tilapia and corvina is allowed (Decree number 33/IBAMA, from 31/7/1992) using a particular net called rede louca (crazy net) where the nets are hand made with sliding (11 mm stretched mesh) knots using a fine filament. This net is set in a sinuous curve while fishermen beat the water forcing the fish to become entangled. According to professional fishermen from different river systems in Brazil, tilapias are not caught by passive nets because they retreat as soon as they come into contact with the gear (Câmara, dos Santos, Campos, Barbosa 1988). In 1988, CESP officers took fishermen skilled in crazy net fishing to Promissão reservoir where they did not catch any tilapia after a whole days fishing. Tilapia nests are not seen in any of the Tietê reservoirs and are only observed in marginal lagoons. They are probably predated on by lambaris and pirambeba, as soon as parental care ceases. Predation pressure by these species, which are absent in the north-east reservoirs, would be maximal in the Tietê reservoirs which do not have a well developed littoral zone and where macrophytes are not abundant (C.E.C. Torloni, personal communication). Hahn (1991) explained the rarity of pirambebas in Itaipu, where tilapias are also never caught, by a combination of low littoral development and low occurrence of macrophyte cover.

The most successfully introduced species in the Paraná basin is the corvina, which is now widely distributed in South America (Goulding & Ferreira 1984). It belongs to the family Sciaenidae, which in Brazil alone is represented by 37 marine and 10

freshwater species belonging to the genera *Pachyurus*, *Pachypops* and *Plagioscion* (Nomura 1984; Hahn 1991). The main reasons for the success of corvina are as follows.

(1) Reproduction – being predominantly a species inhabiting lentic habitats, which is able to reproduce in still waters, it was pre-adapted to live in reservoirs.
(2) Feeding – Hahn (1991) studying the feeding habits of corvina in Itaipu reservoir considered the species as a generalist piscivore, preying preferentially upon the sardela, the dentudo *Roeboides paranensis* (Pignalberi) and *Astyanax bimaculatus* and to a lesser extent insects (mostly Odonata nymphs), crustacean Decapoda, Arachnidae and vegetative remains. As the fish become larger they become piscivorous, so occupying the majority of niches in the reservoir. Being a generalist, with a wide geographical range, corvina feeding habits change widely to eat whatever is available, although Goulding & Gerreira (1984) characterised it as a specialised shrimp eater, consuming other items only when shrimps are less abundant. Lowe-McConnell (1987) suggested that despite the numerous feeding specialisation presented by many piscivores, in tropical regions they are very flexible in exploiting alternative resources.
(3) Habitat – despite its external morphology, corvina live in meso-pelagic habitats, Hahn (1991) argued that there is some evidence that corvina is preferentially a pelagic species in Itaipu reservoir and the present author has noticed its increased occurrence in impoundments with well developed pelagic zones. Where commercial catches occur preferentially in these zones, corvina has a high proportion of sardela in its diet. So corvina feeds from mid-waters to the surface, where resources are probably most abundant in Itaipu.

Studies of fish communities are only now starting in the Pantanal (Catella & Petrere 1996; Súarez 1998). Information about fisheries in this important region is urgently needed. A recent problem was the accidental introduction, perhaps less than 10 years ago, of tucunaré (*Cichla* sp.) in the region. This fish is able to reproduce and is probably establishing a sustainable population for commercial fisheries. It is still not known what the impact of this voracious predator upon the fish fauna in the Pantanal will be (Ferraz de Lima 1993).

In the last 30 years the fisheries in the Paraná river have undergone tremendous changes in their strategy due to the disappearance of the large migratory species and these being replaced by small sized sedentary ones with low commercial value. Even in the lotic stretches of the river these large migrators are now rare and this tendency coincided with river regulation, pollution and introduction of exotic species. Pollution, including siltation, has degraded breeding sites in small tributaries, which are vital in the life cycle of several migratory species.

The impoundments, which occupy more than 70% of the main river reaches and to the same extent in most of its tributaries, are effective barriers for migratory species. The combined effect of the cascade of reservoirs has eliminated from the upper reaches of the river the large Pimelodidae (pintado *Pseudoplatystoma corruscans* and jaú *Paulicea luetkeni*) and Characidae (dourado *Salminus maxillosus*, pacu *Piaractus mesopotamicus* and piracanjuba *Brycon orbignyanus*). With the exception of the pacu,

which is still abundant in the Pantanal, these species are still important in the commercial catches from the remnant 230 km of running waters. In this stretch the spawning areas are located in the upper portion of the non-regulated larger tributaries (Ivinheima, Piquiri, Ivaí, Iguatemi) and the nursery areas are located in the adjacent floodplain which extends for 20 km from the margins of the main river (Agostinho, Vazzoler, Gomes & Okada 1993; Nakatani, Baumgartner & Cavicchioli 1997). The maintenance of these stocks, the last in the Brazilian stretch of the River Paraná, will only be possible with effective measures to protect the spawning and nursery areas through reservoir operation to assure adequate flows to connect the main river with the floodplain water bodies (Agostinho & Zalewski 1996). A major concern is the recent intensification of agriculture in the upper Ivinheima, now the most important tributary for the spawning of the large migrators, with the consequent loss of the riparian vegetation and of large floods in some years (1986–1987, 1995–1996) due to increased water retention in the reservoirs induced by man (Nakatani *et al.* 1997).

Six exotic species have been reported in the area, most of them introduced by accident due to fish-culture, i.e. blackbass, *Micropterus salmoides* (Lacepède), carp, *Cyprinus carpio* (L.) tilapias, the African catfish, *Clarias gariepinus* (Burchell), and channel catfish, *Ictalurus punctatus* (Rafinesque), besides the corvina already cited. With the raising of the backwater level above Itaipu, 16 fish species which were originally unable to jump Sete Quedas cascades have dispersed upstream. Although at the moment there are no studies in the area, the parasite copepod *Lernaea cyprinacea* is a major threat to natural fish populations since it was introduced by infected carps.

The dams, combined with intense human occupation of the Paraná basin, have contributed to the reduction of fish catches and the disappearance of large migratory fish species, mainly in the upper courses of the River Paraná.

The lack of historical data on the fish fauna hampers a better understanding of impacts over the last 30 years. Catch and effort data from the Tietê reservoir suggest that the yield was lower in those reservoirs with exotic species, but corvina is more abundant (CESP 1996). In Itaipu reservoir, catches of curvina are negatively correlated with catches of sardela *Hypophthalmus edentatus* (Agostinho & Júlio Jr 1996).

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