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Chapter 16
Itaipu reservoir (Brazil): impacts of the impoundment on the fish fauna and fisheries

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Changes in the fish fauna of Itaipu reservoir following completion in 1982 are described. Of 113 species identified prior to inundation, only 83 were caught after impoundment. Fish species diversity increased (1985–86) initially but declined thereafter. The predominance of Characiformes and Siluriformes found before impoundment was maintained in the reservoir. Of the species abundant in the river, only *Plagioscion squamosissimus*, a piscivore introduced in 1968, remained among the most abundant in the reservoir fishery. The planktivore *Hypophthalmus edentatus* and the insectivore *Auchenipterus nuchalis*, both sporadic in the catch before inundation, were prolific in the catches from the reservoir. The Paraná basin has five species of Siluriformes with internal fertilization and three of them were among the seven most frequent in the reservoir. Any proposed reservoir management for the future will depend on future construction of reservoirs upstream of Itaipu.

16.1 Introduction

Amongst the main river basins in South America, the Paraná is the one most intensively dammed, primarily for hydropower. By the end of the twentieth century it is expected that 69 hydroelectric dams, with areas greater than 200 ha, will have been built in the Brazilian portion of the basin alone. The 45 existing reservoirs have transformed the main Paraná tributaries (Grande, Paranaíba, Tietê, Paranapanema, Iguaçu) into a succession of lakes. Only 483 km of the original 809 km of the river are now flowing. The construction of the Porto Primavera reservoir, planned for 1995, will decrease the proportion flowing to less than 50%. Later the building of the Ilha Grande reservoir will eliminate the last lotic stretch of the river, in the wake of the last Brazilian 30 km, below the Itaipu reservoir, being dammed by the Argentinean–Paraguayan reservoir at Corpus. These dams, combined with excessive human population density, have contributed to a reduction in catches and the disappearance of large migratory fish species, mainly in the upper reaches of the Paraná river.

This chapter examines the present status of the fish fauna and fisheries and assesses the impact of building the Itaipu reservoir on the Paraná river between the mouths of the Paranapanema and Iguaçu rivers with a view to improving the fisheries.

16.2 Study area

The Paraná basin has a drainage area of 2 800 000 km^2. It is the second largest in South America, after the Amazon basin. Its main tributary, the Paraná, is 4695 km long (Maack, 1968) and is formed by the rivers Paranaíba and Grande (Fig. 16.1).

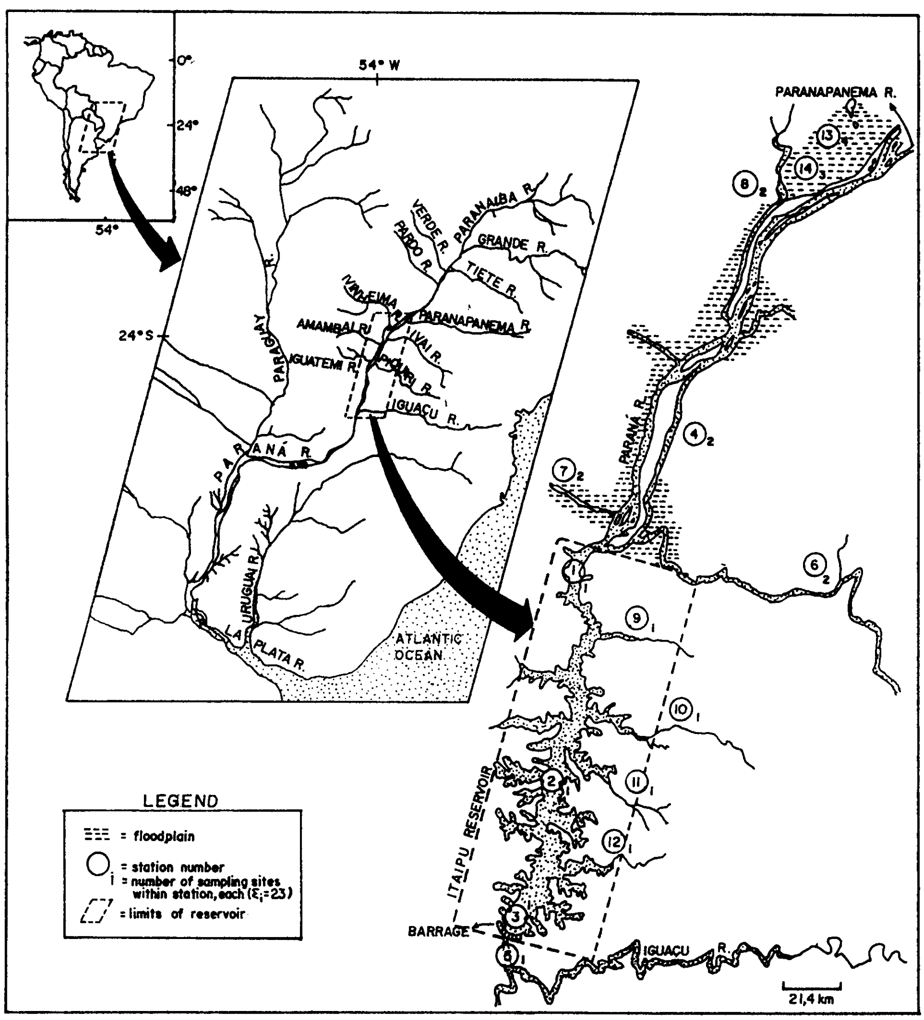

Fig. 16.1 Map of the area showing sampling stations. Station numbers: (1) Guaíra; (2) Santa Helena; (3) Foz; (4) Paraná river; (5) Jusante (downstream dam); (6) Piquirí river; (7) Iguatemi river; (8) Ivinheima river; (9) Guaçu river; (10) São Francisco Verdadeiro river; (11) São Francisco Falso river; (12) Ocoí river; (13) floodplain lagoons; (14) floodplain channels; (15) small creeks (not shown).

The main tributaries on the left bank are the Tietê, Paranapanema, Ivaí, Piquiri and Iguaçu rivers, and on the right bank the rivers Verde, Pardo, Ivinheima, Amambaí and Iguatemi. In this stretch, the river exhibits two distinct morphological patterns. The first comprises the upper 619 km, between the confluence of the rivers Paranaíba and Grande and the now inundated Guaíra Falls, the latter being a geographical barrier to fish dispersion. In this sector the river has an irregular course of variable width, with numerous islands and bars and an extensive floodplain, mainly in its left margin. The second sector comprises the intermediate reaches as it runs through a basaltic canyon. Here, the river is nearly completely impounded as far downstream as the city of Posadas in Argentina. There it runs west, receives the Paraguay river, and flows south in an extensive floodplain until it receives the Uruguay river near the Atlantic Ocean, in its estuary known as La Plata river.

The study area comprises about 370 km of the Paraná river, located between the mouths of the rivers Paranapanema and Iguaçu (Fig. 16.1). Twenty-three sites were sampled for fish community structure, and physical and chemical parameters. Fifteen sites were located in the wide Upper Paraná above Itaipu reservoir (Bonetto, 1986), of which eight were located in lotic (rivers and creeks), three in semi-lotic (channels) and four in lentic (lagoons) habitats. In the reservoir seven sites were sampled, three in the reservoir itself and four in lotic habitats in its lateral tributaries. One sampling station was situated 5 km below the reservoir. Several creeks above the dam were also sampled. Table 16.1 shows the physical and chemical characteristics of the main biotopes in the study region.

Itaipu reservoir was closed in October 1982. It is 15 km long and covers an area of 1460 km^2. Its average depth is 22 m, reaching 170 m near the dam wall. The water's residence time is approximately 40 days and water surface velocity in its central part is about 0.6 m s^{-1}. Limnological studies indicate that the central part of the reservoir becomes thermally stratified on an annual basis over the spring and summer period (Brunkow *et al.*, 1988). Low concentrations of oxygen occur in the metalimnion and hypolimnion and anoxy may occur in restricted areas (Surehma/Itaipu-Binacional, 1989). Andrade *et al.* (1988) consider it a mesotrophic reservoir with a tendency to eutrophication in some coves in the spring. They consider that low phosphorus (< 0.01 mg l^{-1}) concentration in the winter and spring, high abiotic turbidity in the summer and the low ratio of euphotic zone to maximum depth are limitations to the primary production.

16.3 The fish fauna

16.3.1 *Fish species and methods*

Intensive fishing was carried out in the study area with different combinations of fishing gears (12 gill nets, with stretched mesh sizes ranging from 3 to 16 cm, totalling 1080 m^2; longlines with 50 hooks; castnets; trawls) from November 1983 to February 1988. A total of 172 fish species were collected during 527 fishing

Table 16.1 Physical and chemical parameters of the main habitats in the studied region. The main body of the table shows the averages from October 1987 to September 1988, their SD and range (sources: Surehma, 1989; Thomas, 1991)

Locality[1]		Temperature (°C)	Dissolved oxygen ($mg\,l^{-1}$)	pH	Conductivity ($S\,cm^{-1}$)	Transparency (m)	Total phosphorus ($g\,l^{-1}$)	Total nitrogen ($mg\,l^{-1}$)
Paraná river[fp]	x (s)	24.8 (3.3)	8.81 (0.90)	7.6 (0.2)	55.53 (6.02)	1.01 (0.49)	26.8 (11.5)	0.26 (0.100)
	min–max	19.0–30.1	7.60–10.60	7.1–7.8	48.00–72.00	0.80–2.15	6.7–53.6	0.14–0.52
Channels[fp]	x (s)	23.3 (4.4)	7.14 (2.30)	7.0 (0.3)	25.20 (8.08)	0.74 (0.24)	51.9 (15.7)	0.38 (0.333)
	min–max	16.7–30.4	2.3–10.9	6.5–7.7	16.00–48.00	0.40–0.95	28.2–77.7	0.14–0.89
Lagoons[fp]	x (s)	23.0 (4.3)	6.44 (2.40)	6.7 (0.4)	25.90 (8.89)	0.64 (0.33)	67.4 (45.0)	0.66 (0.370)
	min–max	15.8–29.3	1.00–11.30	5.1–9.5	16.00–47.00	0.90–1.40	28.0–208.0	0.22–1.95
Paraná river[ur]	x (s)	24.7 (3.6)	7.70 (0.74)	7.4 (0.2)	47.60 (3.35)	0.60 (0.21)	30.0 (11.0)	0.51 (0.203)
	min–max	18.6–30.1	6.60–8.80	6.8–7.7	42.00–53.00	0.40–1.10	20.0–50.0	0.26–0.90
Guaira[ir]	x (s)	24.7 (3.5)	7.88 (0.70)	7.4 (0.2)	50.92 (3.38)	0.62 (0.24)	26.0 (12.0)	0.55 (0.205)
	min–max	18.8–29.8	6.50–8.80	6.9–7.7	46.00–60.00	0.30–1.10	6.0–50.0	0.30–0.97
Santa Helena[ir]	x (s)	26.4 (3.4)	8.05 (0.89)	7.0 (0.2)	50.64 (3.62)	1.03 (0.50)	22.0 (8.0)	0.48 (0.172)
	min–max	17.9–28.8	6.00–8.90	6.7–7.5	46.00–60.00	0.40–2.30	10.0–42.0	0.17–0.74
Foz[ir]	x (s)	26.6 (3.2)	7.63 (1.26)	7.2 (0.3)	50.27 (3.41)	1.17 (0.61)	19.0 (10.0)	0.45 (0.180)
	min–max	18.4–28.1	4.50–9.00	6.7–7.6	48.00–60.00	0.40–2.30	8.0–45.0	0.22–0.83
Jusante[dr]	x (s)	23.6 (3.8)	11.15 (0.76)	7.3 (0.4)	50.25 (4.12)	1.15 (0.62)	18.0 (10.0)	0.40 (0.142)
	min–max	17.2–28.7	10.30–12.90	6.1–7.7	42.00–60.00	0.40–2.30	4.0–37.0	0.18–0.65

x (s), Average (standard deviation).

[1] fp, floodplain; ur, upstream of reservoir; ir, Itaipu reservoir; dr, downstream of reservoir.

days. This number represents 26% of the 600 species estimated for the whole Paraná–Paraguay basins (Bonetto, 1986).

As in the rest of South America, the fish fauna is dominated by Characiformes and Siluriformes (Lowe-McConnell, 1987), both in terms of number of species (42.4% and 44.2%, respectively) and number of individuals (26.7% and 61.2%, respectively). The marked predominance of individual Siluriformes in the experimental fishing was because four of the five most abundant species in the reservoir are Siluriformes. Other orders which appeared in the catches were: Perciformes (13 species, representing 115 of the catch by number), Rajiformes (3), Clupeiformes (2), Cyprinodontiformes (2), Pleuronectiformes (1), Cypriniformes (1, introduced) and Synbranchiformes (1).

The fish fauna was most diverse in the main channel of the river Paraná, above and below the reservoir (stations 4 and 5 = 97 species), followed by its large tributaries (stations 6, 7 and 8 = 88) and the reservoir (stations 1, 2 and 3 = 83). In the reservoir there was a decline in the richness from its upper third (station 1 = 80) towards the dam (station 3 = 53). Twenty-three small-sized species were restricted to the small creeks in the region of the reservoir and above it. Of the species caught below the reservoir (station 5), 16 were not found elsewhere. Of these, the following are typical of the lower reaches of the Paraná and Paraguay rivers: *Brycon hilarii*, *Schyzodon platae*, *Pseudoplatystoma fasciatum*, *Serrasalmus nattereri*, *Luciopimelodus pati*, *Oxydoras knerii*, *Roeboides bonariensis* and *Pachyurus bonariensis*, and two, *Lycengraulis olidus* and *Pellona flavipinnis*, are anadromous (Bonetto, 1986; Di Persia & Neiff, 1986).

Several species have been introduced from the Amazon basin (curvina, *Plagioscion squamosissimus*, tucunaré, *Cichla ocellaris*, trairao, *Hoplias lacerdae*, and apaiari (oscar), *Astronotus ocellatus*), the tilapia (*Oreochromis niloticus*) from Africa, and carp (*Cyprinus carpio*) from Asia. Curvina, introduced in the upper reaches of the river Paraná in 1968 (Cruz *et al.*, 1990), is the most abundant of these species.

16.3.2 *Fish abundance*

Relative fish abundance between 1986 and 1988 was estimated using a standard set of gill nets comprising ten nylon monofilament nets (each 50 m long and with an average depth of 1.80 m) with a range of stretched mesh sizes between 30 and 160 mm.

Between October 1986 and September 1988 the highest catch per unit effort (number of individuals $1000\,m^{-2}$ gill net $24\,h^{-1}$) was recorded in lagoons (560) followed by floodplain channels (423), the reservoir (239), its tributaries (144) and main river channels (average of 133 for the rivers Paraná, Piquiri, Iguatemi and Ivinheima). In terms of biomass (kg $1000\,m^{-2}$ gill net $24\,h^{-1}$), the sequence was lagoons (58), reservoir (44), channels in the floodplain (31), main rivers (28) and reservoir tributaries (14) (Table 16.2). These results are typical of those found in floodplains elsewhere (Welcomme, 1979; Neiff, 1990) and confirm the tendency

Table 16.2 Catch per unit effort in the main biotopes for the trophic categories in the studied area. Data from experimental gill net fisheries from October 1986 to September 1988 (CPUE = kg 1000 m^{-2} gill net 24^{-1}). Sites for each habitat are numbered as in Fig. 16.1

	Itaipu reservoir (1, 2, 3)		Reservoir tributaries (9, 10, 11, 12)		Rivers (4, 5, 6, 7, 8)		Lagoons (13)		Channels (14)	
Trophic status	CPUE	%	CPUE	%	CPUE	%	CPUE	%	CPUE	%
Piscivores	16.14	37.0	3.37	24.3	13.55	49.2	24.95	43.1	11.54	37.6
Planktivores	11.08	25.4	0.55	4.0	0.08	0.3	1.05	1.8	0.40	1.3
Insectivores	5.73	13.1	1.32	9.5	1.20	4.4	1.24	2.1	1.19	3.9
Omnivores	4.64	10.6	3.76	27.1	3.48	12.6	3.61	6.2	2.44	8.0
Detritivores	4.63	10.6	4.11	29.7	6.99	25.4	22.70	39.2	11.49	37.4
Benthivores	1.02	2.3	0.51	3.7	0.43	1.6	2.40	4.2	1.79	5.8
Herbivores	0.40	0.9	0.23	1.7	1.83	6.6	1.88	3.2	1.84	6.0
Total	43.64		13.84		27.72		57.83		30.69	

for juveniles and small-sized species to concentrate in lagoons and channels in the floodplain. With the exception of the reservoir tributaries, piscivores dominate the catches in all habitats. Thereafter detritivores were the most important except in the reservoir, where the planktivore sardela (*Hypophthalmus edentatus*) dominated.

Nearly 94% of the biomass of fish caught in the experimental fishing in Itaipu reservoir (Table 16.3) was contributed by 20 species. Of these, five species (*H. edentatus*, curimba, *Prochilodus scrofa*, *P. squamosissimus*, armado, *Pterodoras granulosus*, and cascudo preto, *Rhinelepis aspera*) with standard lengths (SL) < 450 mm were of particular importance to the commercial fisheries.

16.3.3 *Post-impoundment changes in the fish fauna of Itaipu reservoir*

Surveys performed in 1978, in the region of the reservoir before dam closure, found 113 fish species, excluding 16 species of *Hypostomus* (armoured catfishes, cascudos) of complex taxonomony (Itaipu-Binacional, 1979, 1981). In the 52 months after dam closure 83 species (again excluding *Hypostomus* species) were registered, of which eight had not been caught previously. Among the species which disappeared from catches after inundation, five (*Otocinclus vittatus*, *Xenurobrycon macropus*, *Roeboides prognatus*, *Cochliodon cochliodon* and *Oligosarcus jenynsii*) were rare, small-sized species.

The data collected during the experimental gill net fishing before and after dam closure show an increase followed by a decrease in fish diversity (Fig. 16.2; Simpson index) and species richness. Several factors probably account for these changes:

- the dispersion of some species, previously confined to the upper reaches by the Guaíra Falls (90 m high), towards the reservoir area

Table 16.3 Some characteristics of the main species caught in the many experimental gill net fisheries from November 1983 to February 1989

Species	Range SL (mm)	Predominant habitat[1]	Feeding habit	Maturity[2] SL (mm)	Spawning habitat[1]	Spawning period[2]	Reservoir fishery[3] Experimental (% CPUE)	Reservoir fishery[3] Professional (abundance)
H. edentatus	80–460	Rs–St	Planktivores	242	Rs	Oct–Dec	19.3	++++
P. scrofa	50–560	Except St	Iliophagous	222	Rv	Nov–Jan	15.5	++++
P. squamosissimus	50–490	Except Lg	Piscivores	198	St	Nov–Dec	14.3	++++
A. nuchalis	50–280	All	Insectivores	167	Rv	Oct–Jan	6.9	+
P. luetkeni	200–800	Rs*–Rv	Piscivores	?	Rv	?	6.2	+++
P. granulosus	90–650	Rs†-Rv-St*	Omnivores	337	Rs†-Rv	Jan–Mar	5.0	++++
P. corruscans	150–1300	Rs*-Rv-Lg*	Piscivores	580	Rv	Nov–Dec	4.8	++
S. maxillosus	80–800	Rv	Piscivores	413	Rv	Oct–Dec	4.3	0
P. pirinampu	150–775	Rs-Rv	Piscivores	370	Rv	Nov–Dec	2.7	++
R. vulpinus	150–660	Rs-Rv	Piscivores	394	Rv	Oct–Dec	2.7	++
P. galeatus	50–230	Rs-Rv-St	Insectivores	107	Except Lg	Oct–Jan	2.0	+
I. labrosus	70–270	Except Lg	Benthivores	160	Rs†-Rv	Oct–Dec	1.6	+++
P. maculatus	60–370	All	Omnivores	159	Rs^{+}-Rv	Nov–Jan	1.4	+++
S. marginatus	20–250	All	Piscivores	121	Except Rv	Oct–Jan	1.2	+
R. aspera	120–500	Rs†-Rv	Iliophagous	220	Rv	Nov–Feb	1.2	+++
S. borellii	70–300	All	Herbivores	184	Rv	Nov–Jan	1.2	++
A. ucayalensis	90–230	Rs†-St	Insectivores	179	Rs^{+}-Rv	Dec–Feb	0.9	0
L. friderici	90–380	Rs†-Rv-St*	Omnivores	168	Rv	Nov–Feb	0.8	++
Loricariichthys sp.	90–290	Rs-St	Iliophagous	157	Rs-St	Sep–Feb	0.6	0
H. malabaricus	50–490	All	Piscivores	150	Except Rv	Oct–Jan	0.6	++

[1] Ch, channels; Lg, lagoons; Rs, Itaipu reservoir; Rv, rivers; St, streams; *, young individuals; †, upper part (river–reservoir transition).
[2] SL, standard length; ?, insufficient data.
[3] CPUE, kg $1000\,m^{-2}$ gill net $24\,h^{-1}$; abundance: +, present, ++, frequent; +++, abundant; ++++, very abundant; 0, absent.

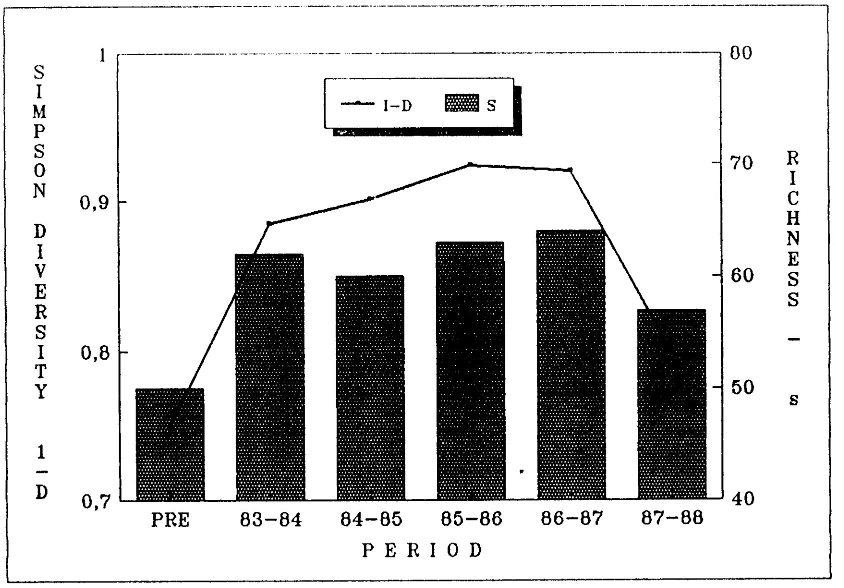

Fig. 16.2 Species diversity index (Simpson) and richness (s) for experimental gill net catches from the main river in the pre- (1978–79) and post- (1983–88) impoundment periods.

- semi-lentic conditions in the superior one-third of the reservoir, resulting in the coexistence of lotic and lentic species
- the high numerical contribution of *Auchenipterus nuchalis* (38%) and *H. edentatus* (21%) in the experimental catches in 1987 and 1988.

Colonization of large species in the reservoir has been variable. Some species like the pacu (*Piaractus mesopotamicus*) and the piracanjuba (*Brycon orbignyanus*) are now only found above and below the reservoir, while other migratory species not expected to live in the reservoir have been able to cope with the new habitat and have become important to the commercial fisheries. These species spawn in lotic habitats, in the floodplains upstream and return to the reservoir as adults (e.g. *P. scrofa*, the piapara, *Leporinus obtusidens*, and the piava, *L. elongatus*). *S. maxillosus*, the largest characiform in the basin, was not common in the reservoir, although the abundance of their young increased markedly in years of intense and prolonged flooding.

Marked shifts in the relative abundance of the important species occurred between the pre- (Itaipu-Binacional, 1981) and post-impoundment (this study) periods. Of the most important species caught before closure, only *P. squamosissimus* and *P. scrofa* continued to hold prominence in the catches. In the immediate post-impoundment phase, *P. squamosissimus*, *A. nuchalis* and *H. edentatus* dominated the experimental catches (nearly 50%), despite the relative unimportance of the latter two species before flooding (Figs 16.3 and 16.4). These species, which are short lived, mature early and are prolific breeders, exploited

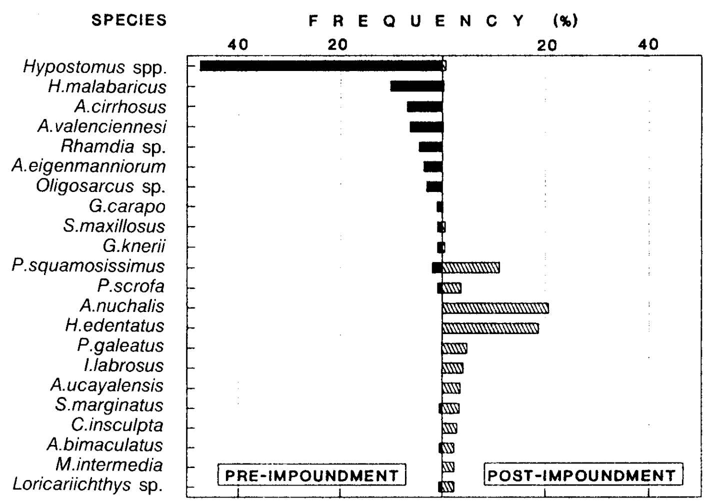

Fig. 16.3 Frequency of abundance of the predominant fish species in the pre- and post-impoundment periods.

the early high productivity of the reservoir. *A. nuchalis* also exhibits vivipary which was important to its reproductive success. *P. squamosissimus* is an opportunist feeder and benefited from the initial high abundance of *H. edentatus* which formed the main item in its diet (Hahn, 1991).

Broadly categorizing the trophic status of the fish community structure, detritivores, especially the running-water cascudos (*Hypostomus*) species, dominated

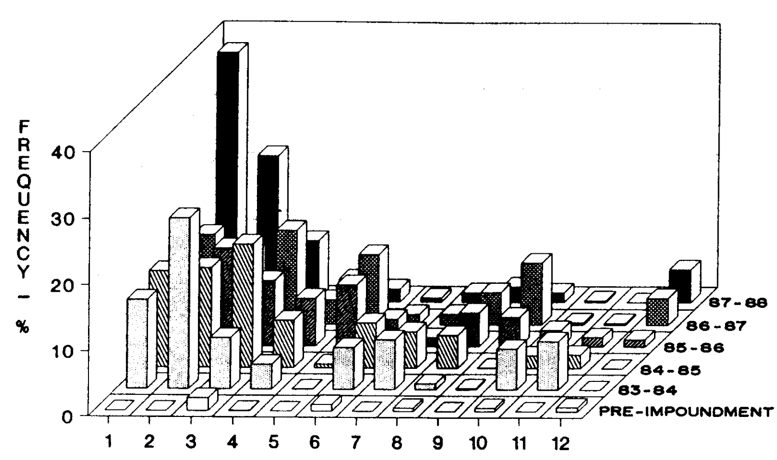

Fig. 16.4 Abundance of the 12 most common fish species during colonization: 1, *Auchenipterus nuchalis*; 2, *Hypophthalmus edentatus*; 3, *Plagioscion squamosissimus*; 4, *Parauchenipterus galeatus*; 5, *Iheringichthys labrosus*; 6, *Prochilodus scrofa*; 7, *Ageneiosus ucayalensis*; 8, *Serrasalmus marginatus*; 9, *Curimata insculpta*; 10, *Astyanax bimaculatus*; 11, *Roeboides paranensis*, 12, *Loricariichthys* sp.

numerically the experimental catches before dam closure (Itaipu-Binacional, 1979, 1981). Detritivores still predominated numerically after closure, but with a different species composition represented by saguiru *Curimata insculpta*, *P. scrofa* and cascudo *Loricariichthys* sp. (Hahn, 1991).

In the first five years after closure, a major component (CPUE) of the catches, in terms of biomass, consisted of the piscivores (37%; Table 16.4), of which *P. squamosissimus* was responsible for 14%. Detritivores were markedly present in 1984-85 (28%), 1985–86 (18%) and 1986–87 (22%), apparently reflecting the effects of large floods in 1983–84, but declined thereafter. The marked variability in the species composition of the catches between the different trophic categories (Table 16.4) suggests that the reservoir fish community has not yet stabilized and that large fluctuations in discharge in the floodplain above have added to the instability. It is possible that another reservoir immediately above Itaipu would bring it to a climax state much faster, but with reduced fish abundance and diversity.

The inundation of the natural barrier created by the Guaíra Falls after impoundment also enabled the dispersion of several species upstream. At least 17 fish species appear to have colonized the upper reaches of the river, the most abundant being the surumanha (*A. nuchalis*), armadinho (*Trachydoras paraguayensis*), *P. granulosus*, piranha (*Serrasalmus marginatus*), cangati (*Parauchenipterus galeatus*) and the mandi (*Pimelodus ornatus*) (H.A. Britski, MZUSP – Sâo Paulo, pers. comm.).

16.4 The reservoir fisheries

To avoid intense catches of juveniles of *S. maxillosus*, *B. orbignyanus*, etc., commercial fishing was not possible in the reservoir until 1984.

Fishing effort is now controlled mainly through mesh regulations, with a minimum mesh size of 70 mm. Professional and sport fishing are forbidden in all tributaries and professional fishing is not allowed in the main river during the spawning season from November to February. Gill nets (stretched mesh sizes between 60 and 240 mm, 50 m long, 2.0 m deep) were the predominant gear employed (83% of the fishermen set a total of 614 000 m of net in 1987). *H. edentatus*, *P. scrofa* and *P. squamosissimus* were the main target species. Longlines, baited with seasonal fruits, were used by 43% of the fishermen in the transitional lotic/lentic zone for catching the armado (*Pterodoras granulosus*) (Fuem/Itaipu-Binacional, 1989). The average number of hooks per longline was around 75 (150 m length). Three-metre castnets were employed in the reservoir entrance for catching *R. aspera* and cascudo abacaxi (*Megalancystrus aculeatus*).

The number of professional fishermen now oscillates around 1000, of whom 35% are permanent. In 1987, 42% of the total were earning US$ 120–240 per month, which is high when compared with the minimum salary for the country of US$ 40 per month. Most fishermen (73%) worked the upper half of the reservoir,

Table 16.4 Catch per unit effort for the trophic categories during the fish fauna colonization process in the Itaipu reservoir. Data from experimental gill net fisheries (CPUE, kg $1000\,m^{-2}$ gill net^{-1} $24\,h^{-1}$; *S*, no. of species)

	1983–84		1984–85		1985–86		1986–87		1987–88	
Tropical status	CPUE	*S*	CPUE	*S*	CPUE	*S*	CPUE	*S*	CPUE	*S*
Piscivores	15.54	16	20.05	19	13.76	20	12.64	19	19.64	14
Planktivores	7.35	1	4.50	1	5.84	1	4.28	1	17.88	1
Insectivores	2.24	11	2.89	14	3.43	18	2.48	18	8.98	17
Omnivores	1.48	11	3.90	10	3.57	9	3.72	9	5.55	11
Detritivores	7.12	10	12.35	10	11.04	8	3.99	8	5.26	7
Benthivores	0.04	4	0.25	4	1.69	4	1.40	5	0.63	5
Herbivores	1.11	7	0.95	2	0.61	3	0.19	4	0.60	2
Total	34.87	62	44.89	60	39.93	63	28.72	64	58.55	57
Catch (t)	3.2		2.6		2.1		1.7		1.5	
Catch (no. of fish)	15 594		9517		10 318		9705		8162	

where fish abundance was highest. Nearly 80% of fishermen are organized into two associations (Colônias) (Fuem/Itaipu-Binacional, 1989).

Between 1987 and 1990, total catches were fairly stable: 1515 t, 1502 t, 1729 t and 1416 t, respectively. The CPUE (kg $fisherman^{-1}$ yr^{-1}) was 4030, 3944, 3986 and 3828, respectively. The average fish yield for the period was 10.7 kg ha^{-1} yr^{-1}, which is comparable to that in other large reservoirs in Brazil (Petrere, 1989). The average fishing intensity was 0.027 kg ha^{-1} $fisherman^{-1}$ yr^{-1}. Currently, the average price per kilo is US$ 0.60.

Nearly 50 fish species were caught, of which 9 account for 90% of the landings (Table 16.5). The most important are *H. edentatus* (25.1%), *P. scrofa* (18.8%), *P. squamosissimus* (15.6%), *P. granulosus* (14.0%) and *R. aspera* (4.2%). A reduction in abundance of *P. scrofa*, barbado (*Pinirampus pirinampu*), *P. corruscans* and an increase in *P. granulosus* and *H. edentatus* were also evident.

16.5 Future prospects

Future management for the Itaipu reservoir must take into consideration the construction of other reservoirs in the catchment and the rate of inhabitation in the region as a whole. In 1995 the Porto Primavera dam (1800 MW, 2250 km^2), 200 km above Itaipu, will be completed and a second reservoir, the Ilha Grande (2400 MW, 3270 km^2), to be built between these two, is planned for the beginning of the twenty-first century. If it is built, there will be no flowing waters in the Brazilian stretch of the Paraná river: it will become a cascade of reservoirs.

At present the distance between Itaipu and the next dam above it in the river Paraná, the Jupiá reservoir (1411 MW, 330 km^2), is 520 km. As a consequence, regulation effects on fish spawning behaviour exerted by Jupiá are moderate and reduced by large tributaries joining the main river. When Porto Primavera starts operation, the regulation effects will be exacerbated, with extreme impact on migratory species. It is likely that the fisheries will shift towards lentic species,

Table 16.5 Catch (t) and catch per unit effort (CPUE, t $fisherman^{-1}$ yr^{-1}) for the main species in the professional fisheries on Itaipu reservoir

	1987		1988		1989		1990	
Species	Catch	CPUE	Catch	CPUE	Catch	CPUE	Catch	CPUE
P. scrofa	484.3	1.288	228.0	0.598	254.3	0.586	193.6	0.523
H. edentatus	248.4	0.661	468.3	1.230	445.1	1.025	382.8	1.033
P. squamosissimus	233.4	0.621	226.5	0.595	256.3	0.590	243.8	0.658
P. granulosus	160.8	0.428	178.3	0.486	295.4	0.680	227.5	0.614
R. aspera	62.6	0.166	46.7	0.122	81.4	0.187	69.5	0.188
P. luetkeni	58.6	0.156	56.8	0.149	77.8	0.179	37.3	0.101
P. pirinampu	45.1	0.120	41.3	0.109	23.9	0.055	15.6	0.042
P. corruscans	43.0	0.114	32.3	0.085	38.2	0.088	24.1	0.065
P. maculatus	41.7	0.111	66.5	0.174	77.3	0.178	41.7	0.112

which are less valuable than the large migratory catfishes, thus affecting fishermen's profits (Petrere, 1989).

In the 1980s, stocking the reservoirs was a common practice to compensate for loss of spawning. However, this activity is unlikely to be effective on Itaipu to maintain stocks of the more valuable migratory fish species (*S. maxillosus*, *L. obtusidens* and *B. orbignyanus*, the catfishes barbado *Pinirampus pirinampu*, *P. corruscans* and jaú *Paulicea luetkni*). Most species only move down from the floodplain towards the reservoir when they are pre-adults and adults, and it is unlikely that the fry would survive in the reservoir.

Currently there are no fish passage facilities at Itaipu reservoir and their construction is not recommended because the 15 species that are typical of the lower reaches of the Paraná river could migrate upstream. Furthermore, fish passages could assist the colonization of the reservoir by the piranha preta (*Serrasalmus nattereri*), bringing undesirable consequences to the fisheries and swimmers.

Finally, the maintenance of fish stocks depends on conserving the integrity of the lotic and floodplain environments above Itaipu reservoir. This requires (a) rationalization of human occupation of this area, (b) compatibility of the operational procedures employed by the upstream dams with the minimum river flow requirements of fish species, particularly during the reproductive period, and (c) reconsideration of the cost–benefit ratio from the Ilha Grande hydroelectric scheme in relation to the loss to fisheries and biological diversity.

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