*Fisheries Management and Ecology* 1997, **4**, 263–274

# Influence of the flooding regime on the nutritional state and juvenile recruitment of the curimba, *Prochilodus scrofa*, Steindachner, in upper Paraná River, Brazil

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**Abstract** The relationship between the flooding pattern of the Paraná river floodplain and the nutritional state and juvenile growth of the curimba, *Prochilodus scrofa* Steindachner, over three years and its recruitment to the Itaipu reservoir fish stocks over six years were analysed. Seasonal and annual variation in the condition factor and visceral-somatic relationship were positively influenced by high water levels. A similar effect was found for growth during the second year of life. Recruitment success was found to be related to the occurrence of floods in summer and autumn. The importance of the annual floods to the availability of food, refuges and survival of *P. scrofa* are discussed in relation to the operation of the upstream dams.

KEYWORDS: condition factor, flood influence, floodplain, *Prochilodus scrofa,* recruitment, visceral-somatic relation,

## Introduction

The Brazilian sector of the Paraná river, about 810 km in extent, used to have a wide floodplain that extended on its right margin from Três Lagoas (MS) to the then Sete Quedas falls in Guaíra (PR), corresponding to about half of its length. With the building of hydroelectric reservoirs, the floodplain is now restricted to little over 200 km between Porto Primavera and Itaipu. However, this floodplain is considered fundamental to the maintenance of diverse species of medium and large-sized migratory fish because of appropriate conditions for their early development. Among these species, the curimba, *Prochilodus scrofa* Steindachner, stands out since it is the fourth most important species caught at the Itaipu reservoir (Agostinho, Júlio Jr & Petrere Jr 1994) and uses the floodplain upstream for the first two years of its development (Agostinho, Vazzoler, Gomes & Okada 1993).

The curimba is an iliophagous species that sucks fine and flock detritus from the surface of plants or from the bottom (Bowen 1983; Fugi, Hahn & Agostinho, 1996). In the Paraná-Paraguay river basin this species undertakes long spawning migrations (Godoy 1975; Bonetto, Cannon Veron & Roldán 1981; Petrere Jr 1985). For example, a considerable proportion of the stocks exploited at the Itaipu reservoir ascend the Paraná river at the beginning of the flood period, spawn in the higher parts of this river or its tributaries and return to the reservoir

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when the water level decreases (Agostinho *et al.* 1993). The larvae drift passively towards inundated areas. As the water recedes, the juveniles become confined to the water bodies remaining on the floodplain (lagoons and channels) for a maximum of two years before they are recruited to the adult stocks. The successive damming of the main rivers of the Paraná river basin formed obstacles to the migratory movements of this species, and also altered the intensity and duration of the floods, thus affecting the recruitment and survival of the stocks.

The aim of this study was to verify the influence of the floods at different intensities and intervals on the status of juvenile curimba in their natural nursery habitats in the Paraná river floodplain, as well as evaluating the relationships between flood level and recruitment of exploited stock on Itaipu reservoir.

## Material and methods

Data were obtained from samples in the floodplain of the upper Paraná river (22°40′–22°50′S and 53°15′–53°40′W) and from fishery landings along the Itaipu reservoir. Samples were taken monthly from the floodplain during the periods of October 1986 to September 1988 and October 1992 to September 1993, using 3–16 cm stretched-mesh gill nets at five sampling stations: two lagoons (Guaraná and Patos), one channel (Baia) and two rivers (Ivinheima and Paraná). On each occasion the standard length (SL, cm), sex, total weight (W, g) and visceral weight (Wv, g) were recorded for each individual, although the latter was available only for the first two periods.

Data of the fishery landings (kg) from Itaipu reservoir were registered daily by fishermen and/or trained recorders, during the period from January 1987 to December 1993, but were grouped annually for analysis. During the period from January 1988 to December 1992 monthly samples from the fishery landings were collected at 12 points around the Itaipu reservoir (Fig. 1), and the standard length (SL, cm) of all individuals was recorded. The length of fish at the time of recruitment to the reservoir fishery was considered to be at a standard length of 19 cm (Agostinho *et al.* 1993).

The mean water level data were calculated according to the phases of the hydrological regime determined quarterly from historical data (1960–93), (i.e. O-N-D = October, November and December – increasing water level; J-F-M = January, February and March – flood; A-M-J = April, May and June – decreasing water level; J-A-S = July, August and September – dry season) and the standard error was calculated from the daily data to examine the variation through time.

To assess the variation in the nutritional state of the individuals captured in the floodplain, two indexes were selected, the condition factor (*K*) (Le Cren, 1951) and the visceral-somatic relation (*RVS*). Variation in condition factor was analysed for separate sexes, initially among the size classes, based on individuals sampled during the whole period. Data from individuals within length intervals were used to determine variation in the mean annual values and according to the phase of the hydrological cycle. In this analysis, adults were excluded to eliminate the effects of the reproductive cycle over the condition values. Moreover, the presence and abundance of adults in the floodplain is very seasonal, so that the captures were based on juveniles (Agostinho *et al.* 1993). The selection of a size interval with little variation in the condition factor was to reduce the effect that length, or the least represented length classes in the samples, could have over the calculated values.

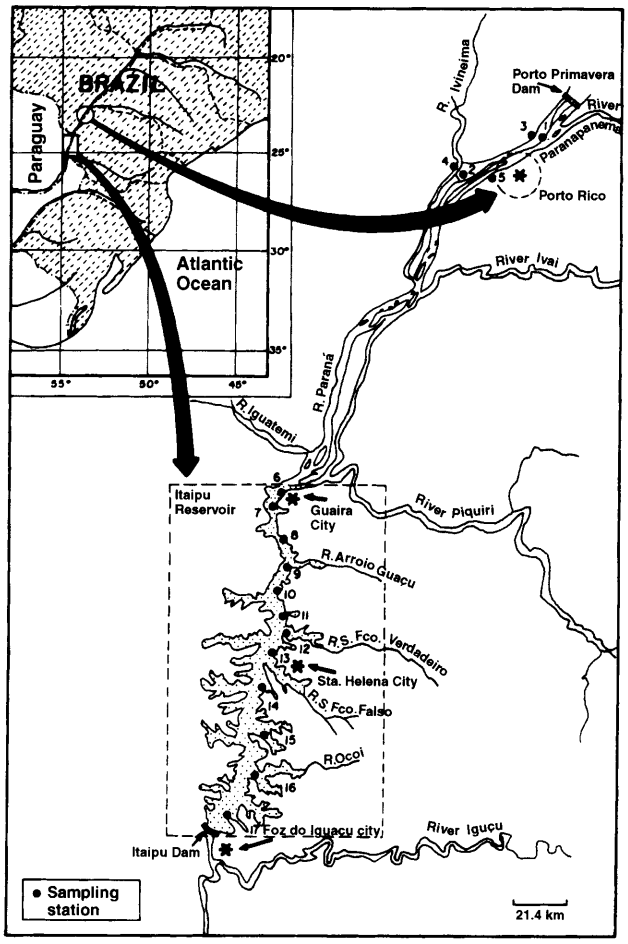


**Figure 1.** Map indicating the study area and the sampling stations (1 = Baia Channel, 2 = Patos lagoon, 3 = Guaraná lagoon, 4 = Ivinheima river, 5 = Paraná river and 6–17 = Itaipu reservoir).

For the same size interval, the visceral-somatic relation (*RVS*) was calculated as the percentage of visceral weight (*Wv*) represented in relation to the total weight (*W*). The variation in mean *RVS* according to the phase of the hydrological cycle was calculated. Differences between the condition factor means and those of the visceral-somatic relation were determined through one-way ANOVA. The Tukey test was applied for comparison of pairs of means in cases with significant differences.

Inference about possible differences in the growth rate of the individuals captured from the floodplain in different periods was based on modes of standard length classes. These were analysed in graphs over which was superimposed the growth curve for the species (Hayashi, Goulart, Verissimo & Fedatto Jr. 1989) in Itaipu reservoir for the period from March 1986 to February 1987. This growth curve was determined from scale reading, validated by temporal variation in the mean length and variance of each age class. Failures in recruitment were also identified by comparing the length frequency distribution data obtained from the floodplain and commercial fishing in Itaipu reservoir.

Correlations between the weight recruitment values and river water level in the preceding year were evaluated, since the floods in one year influence recruitment in the following year (Agostinho *et al.* 1993). The variables analysed were the mean annual water level (m), the intensity (maximum water level of the river; m) and the duration of the floods (number of days higher than 3.5 m – compensation flow) (Verissimo 1994) in each season of the year. The small number of observations ($n = 5$) restricted the use of more elaborate tests.

## Results

### *Hydrological regime*

The segment of the basin above the floodplain, where this study was undertaken, has 48 large reservoirs, all constructed after 1960. These reservoirs reduce and delay the peak flood, which is the main influence acting on the communities using this area (Agostinho 1994). In the last 10 years, inadequate water levels for inundating the floodplain were registered for two subsequent years (1984–5 and 1985–6). In the first year, the low water level of the Paraná river occurred because of the lack of rain in the upper basin; in the second year the absence of floods was attributed to the retention of water by the upstream reservoirs that received lower compensation flows than usual (Agostinho, Gomes & Zalewski, in press). Therefore, during the period of this study, the floods did not occur in the first year (1986–87), were restrained in the following year (1987–88), but reached higher values and lasted longer in 1992–93 (Fig. 2a,b). The mean water levels of the river, intensity and duration of the floods in each season between 1987 and 1991 are shown in Table 1.

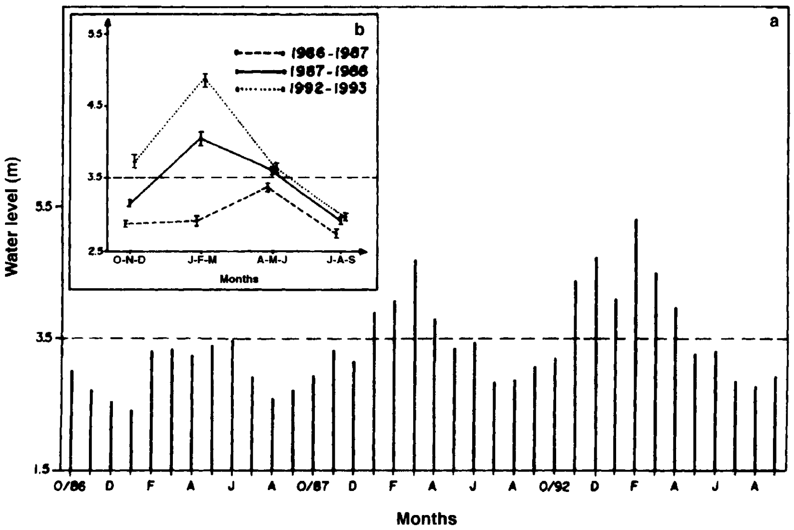


**Figure 2.** Water levels of the Paraná river in the different periods studied. (A) monthly means and (B) means based on the hydrological cycle (O-N-D = October, November and December – increasing water level; J-F-M = January, February and March – flood; A-M-J = April, May and June – decreasing water level; J-A-S = July, August and September – dry season). Vertical bars indicate standard error.

**Table 1.** Water level, intensity (maximum levels) and duration of the floods (number of days of flood with levels higher than 3.5 m) in the Paraná river.

| Year | Mean annual water level | maximum | total | summer | autumn | summer & autumn | winter | spring |
|---|---|---|---|---|---|---|---|---|
| 1987 | 3.07 | 4.62 | 37 | 0 | 15 | 15 | 22 | 0 |
| 1988 | 3.40 | 5.84 | 135 | 34 | 75 | 109 | 25 | 1 |
| 1989 | 3.39 | 6.02 | 90 | 19 | 58 | 77 | 3 | 10 |
| 1990 | 3.23 | 7.91 | 64 | 44 | 13 | 57 | 3 | 4 |
| 1991 | 3.54 | 6.96 | 115 | 4 | 77 | 81 | 34 | 0 |

## *Influence on the nutritional indicators*

*Condition factor*

The length weight relationships for fish from the study region were:

Males: $\ln W = \ln(-3.4009) + 2.93 \ln SL$; $n = 1950$

Females: $\ln W = \ln(-3.3438) + 2.91 \ln SL$; $n = 1875$

The mean condition factors for individuals sampled from the floodplain showed a marked variation among the size classes and sexes, especially in the early part of the life cycle (< 14.0 cm), and those corresponding to the sizes where all individuals reach sexual maturity

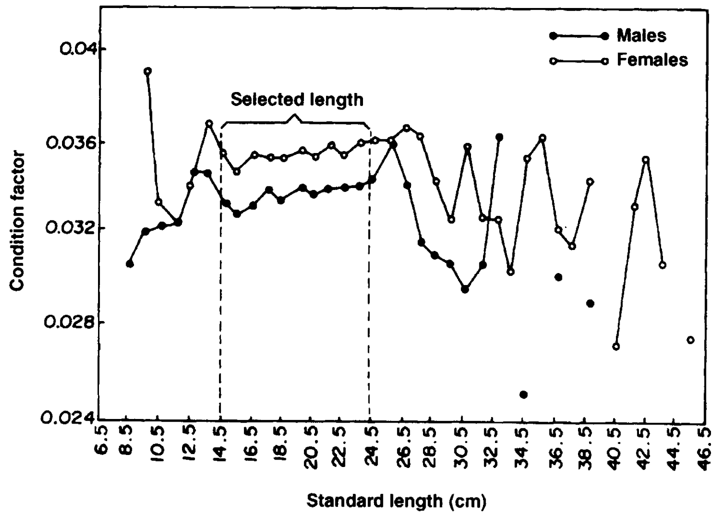


**Figure 3.** Variations in the condition factor per standard length class.

(> 24.0 cm) (Fig. 3). Individuals with an *SL* between 14.0 and 24.0 cm were used for the analysis of the temporal variations of the condition factor. The mean annual condition factors differed significantly between the sexes ($P = < 0.01$). The Tukey test revealed that the values were significant between all the periods for males ($P < 0.04$) and females ($P < 0.006$), except for females between 1986–87 and 1987–88 ($P = 0.19$). The condition factor had pronounced variations for both sexes with peaks from January to March, corresponding to the flood period (Fig. 4).

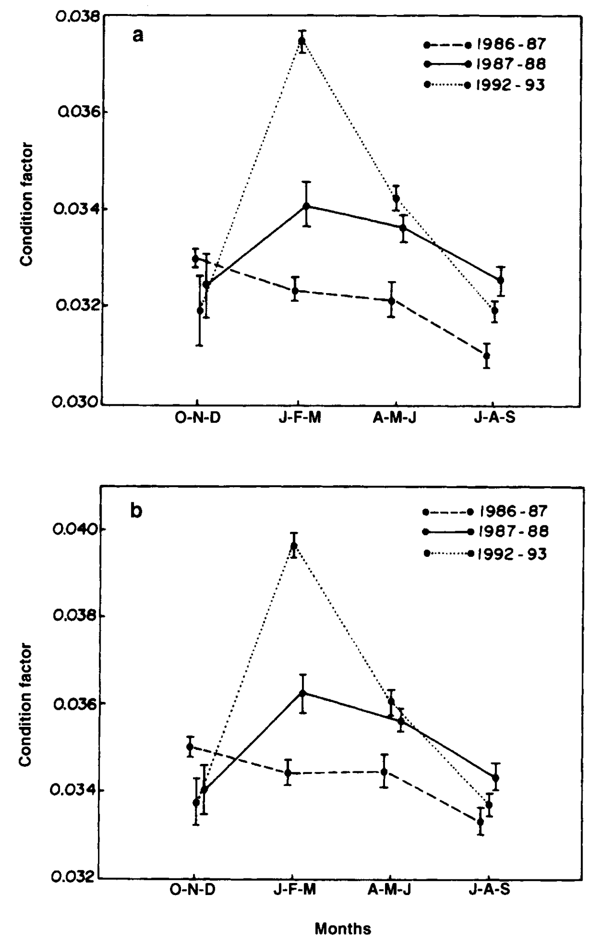


**Figure 4.** Means of the condition factor, based on the hydrologic cycle in the different periods studied, for the individuals with standard length varying from 14 to 24 cm. A = males; B = females; (O-N-D = October, November and December – increasing water level; J-F-M = January, February and March – flood; A-M-J = April, May and June – decreasing water level; J-A-S = July, August and September – dry season). Vertical bars indicate standard error.

*Visceral-somatic relation*

The contribution of the viscera to the total weight did not differ significantly between the sexes, and were grouped in subsequent analyses. Comparison of the mean *RVS* in the two first periods revealed significant differences ($P < 0.01$), with higher values in 1987–88 when the water levels were highest (Fig. 5). In the period from January to March 1987, when the expected floods did not occur, the *RVS* was at its lowest mean value.

## Influence on growth and recruitment

In the upper Paraná river juvenile curimba inhabit the floodplain during their initial development, leaving the river channel and recruiting to the stocks of the Itaipu reservoir in their second

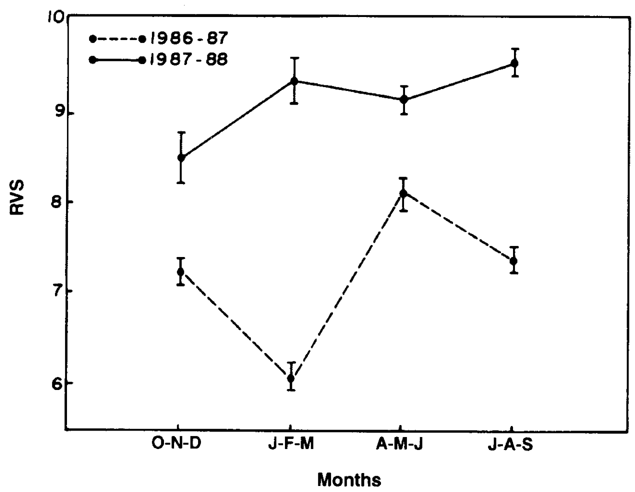


**Figure 5.** Mean values of the visceral-somatic relation (grouped sexes), based on the hydrologic cycle for the study period, for the individuals with standard length varying from 14 to 24 cm. (O-N-D = October, November and December – increasing water level; J-F-M = January, February and March – flood; A-M-J = April, may and June – decreasing water level; J-A-S = July, August and September – dry season). Vertical bars indicate standard error.

year of life (Godoy 1972; Toledo Filho 1983; Agostinho *et al.* 1993). This discrimination can be seen from two prominent modes in Fig. 6 which correspond to the first and second year, respectively.

The length frequency distribution showed variation in the position of the principal mode (1+). Hence, in the year 1986–87, when no floods occurred, the modal length was ≈15.0 cm, whereas in subsequent years this value increased to about 19.0 cm (Fig. 6). The employment of gill-nets was not adequate for the capture of juveniles in the first year of life (0+), especially when their length was less than 10 cm. However, the inefficient capture of juveniles in 1986–87, allied to the poor representation of the two-year-old cohort of fish in the subsequent period, suggest failure in recruitment and a growth rate less than that observed in 1986–87.

Analysis of the annual frequency distribution per standard length class of the samples obtained from commercial fishing at the Itaipu reservoir (Fig. 7), where the species is recruited in the second year of life, revealed a virtual absence of fish smaller than 30 cm in 1988.

In the other years, the capture of juveniles was always observed. Recruitment disclosed values of 89 kg in 1988, 3335 kg in 1989, 3481 kg in 1990, 962 kg in 1991 and 1093 kg in 1992. The influence of factors related to the floods (Table 1) on this variable, with a lag of one year, is presented in the form of a correlation matrix (Table 2), limited in power due to the small number of observations ($n = 5$ years).

Recruitment was better related to the duration of the floods than to the water level. It appears that flooding in summer and autumn were most important ($r = 0.83$) when grouped together compared with $r = 0.66$ and $r = 0.43$, respectively, for autumn and summer separately. The

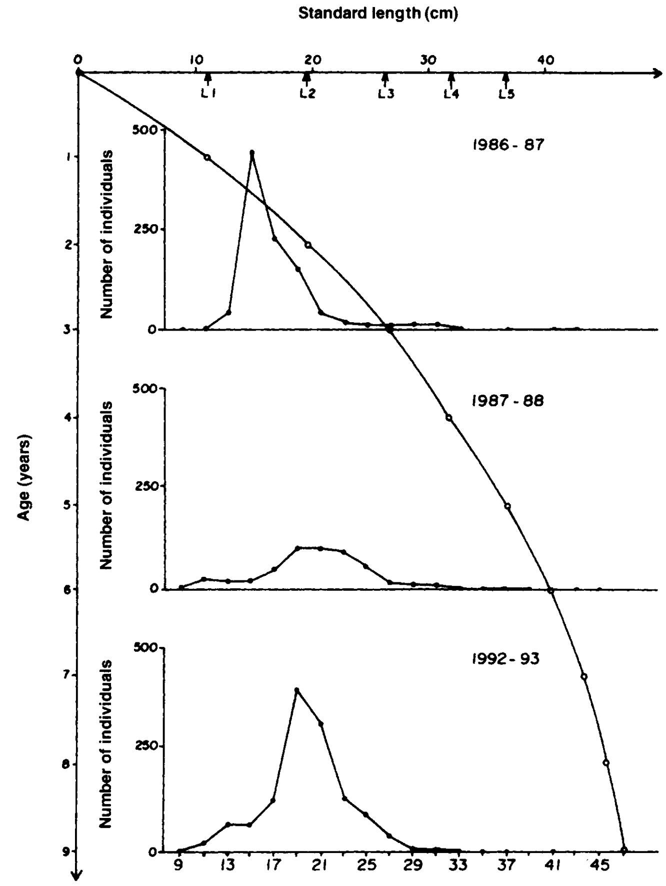


**Figure 6.** Number of individuals per standard length class of the captured individuals at the floodplain. The growth curve of *P. scrofa* (according to Hayashi *et al.* 1989) is superimposed on these data. $L_i$ is the length at age *i*.

intensity of the flooding, defined as the maximum level reached, was not correlated with recruitment.

## Discussion

Condition factor is considered to reflect the nutritional state, the fat content and the stage of maturity (De Silva 1985). However, in this study its estimation was restricted to juveniles, thus it only relates to nutritional condition or accumulated reserves. The seasonal differences in condition factor of juveniles of the curimba were more pronounced in the last period (1992–93) when the river reached very high levels. Changes in the visceral-somatic relation, which can also be used with success in the analysis of condition (Bolger & Connolly 1989), showed significant differences in 1986–87 and 1987–88, although they were more variable in the first study period because of a decrease in water levels in the season when high water levels were

**Table 2.** Correlation matrix among the diverse variables that could affect the recruitment, with a difference of one year (d.f. = 3).

| Variables | wa | max | tot | sum | aut | su & au | win | spr |
|---|---|---|---|---|---|---|---|---|
| wa | 1.00 | | | | | | | |
| max | 0.41 | 1.00 | | | | | | |
| Tot | 0.88 | 0.22 | 1.00 | | | | | |
| sum | 0.03 | 0.59 | 0.23 | 1.00 | | | | |
| aut | 0.91* | 0.02 | 0.93* | –0.12 | 1.00 | | | |
| su & au | 0.84 | 0.34 | 0.97* | 0.44 | 0.84 | 1.00 | | |
| win | 0.34 | –0.28 | 0.41 | –0.56 | 0.51 | 0.16 | 1.00 | |
| spr | 0.11 | 0.17 | –0.05 | 0.30 | –0.01 | 0.15 | –0.82 | 1.00 |
| Recru | 0.50 | –0.06 | 0.74 | 0.43 | 0.66 | 0.83 | –0.11 | 0.41 |

* = Significative correlations ($P < 0.05$).
wa = mean annual water level, in metres; max = maximum water levels, in metres; time span: number of days of flood (levels higher than 3.5 m); tot = annual total span; sum = summer span; aut = autumn span; su & au = summer and autumn span; win = winter span; spr = spring span; recru = recruitment

expected. The floods that inundate areas of vegetated land and connect isolated water bodies also create favourable conditions for shelter and increase the availability of food for curimba juveniles. Thus variation in the intensity and duration of the floods affects the nutritional state and growth of juveniles with concommitmant effect over the natural mortality rates.

Agostinho *et al.* (in press) verified that detritivorous, herbivorous and omnivorous species find better conditions in periods of elevated water levels due to the inundation and increased availability of new food materials. This flooding, coupled with curimba's bottom feeding habit, suggests food is not a limiting factor for the species (Sverlij, Ros & Orti 1993).

Low water levels persisting for a relatively long period may be responsible for the total absence of young-of-the-year (Welcomme 1979). This may explain, in part, the virtual absence of one-year-old individuals in the floodplain during the first study period (1986–87). This can alter the species stocks and, for commercial species, may have serious effects on future fishing, due to low or failure in recruitment.

These observations probably explain the decrease in the curimba commercial catches in the Itaipu reservoir. In 1987 this species was the most important in the catches at the reservoir (Agostinho *et al.* 1994), contributing about 500 t (1.3 t $\text{fisherman}^{-1}$ $\text{year}^{-1}$). In the following year it contributed only 220 t (0.6 t $\text{fisherman}^{-1}$ $\text{year}^{-1}$), stabilizing at this capture level during subsequent years. Although other factors such as overfishing and reduction in the periphyton substrate that serves as food (decomposition of the inundated arboreal and bush vegetation) might be responsible for the reduction in the stocks of this species at the Itaipu reservoir, the absence of floods certainly played a predominant role.

The correlation between the recruitment and variables related to the hydrological regime of the Paraná river indicates that the flood duration is more important for recruitment than the water level attained. Hence, the occurrence of high water levels at the beginning of summer, that was related to the success in spawning of migratory species (Godoy 1975; Vazzoler 1992; Agostinho *et al.* 1993), will be less important in the recruitment of juvenile individuals to the adult stocks if the floods are of short duration. An elevated water level during the summer and

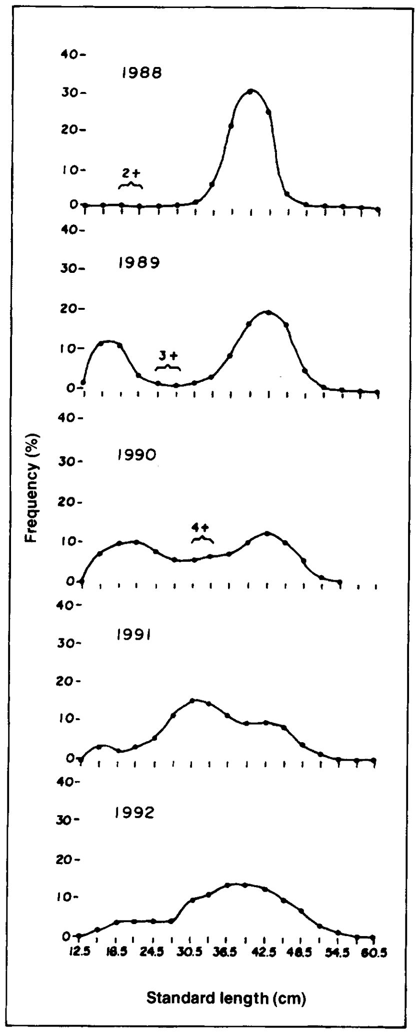


**Figure 7.** Frequency distribution per standard length class for the individuals captured in commercial fishery at the Itaipu reservoir.

autumn lowers juvenile mortality, possibly by reducing predation, supplying shelter for a longer period so individuals can reach larger sizes and thus have fewer aquatic or terrestrial predators. The stress linked to the dry period is also reduced, reducing mortality.

Annual variations in the floods produce different responses in the abundance of predators and prey in the floodplain of the Paraná river (Agostinho & Zalewski 1995). Moreover, Agostinho (1994) considered that the flooding regime affects the reproductive success of all fish species in a different and sometimes contradictory manner. It is possible, however, that the annual variations in the span and intensity of the floods of the Paraná river are responsible for the marked instability of the fish assemblages observed in the floodplain.

Hydroelectric power generation in the upper Paraná river, through the control which the reservoirs have on the intensity, period and duration of the floods on the stretches downstream of the dams, retains much of the power to decide about the fate of the fish stock and of the communities that occupy the remaining natural areas of the floodplain. Therefore, any fisheries management action in this area or relating to the exploited stock in Itaipu reservoir should consider the operational demands and constraints of the upstream dams.

## Acknowledgements

Acknowledgements are due to Itaipu Binacional, PADCT-CIAMB/CNPq for financial support; to Dr A. E. A. M. Vazzoler, Dr G. Barbieri, Dr M. Petrere, R. Angelini, Dr K. Winemiller, D. Jepsen and Dr M. Zalewski for valuable criticism and revision of the text and to Dr T. Bonici and A. Baldissori for translation of the manuscript into English.

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