FEEDING ECOLOGY OF CURVINA *Plagioscion squamosissimus* (HECHEL, 1840) (OSTEICHTHYES, PERCIFORMES) IN THE ITAIPU RESERVOIR AND PORTO RICO FlOODPLAIN

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RESUMO: Ecologia alimentar da curvina *Plagioscion squamosissimus* (Hechel, 1840) (Osteichthyes, Perciformes) no Reservatório de Itaipu e planície de inundação de Porto Rico. Capturas realizadas durante o período de novembro de 1983 a setembro de 1988, em diversos pontos da bacia do rio Paraná, no trecho compeendido entre os rios Paranapanema e Iguaçu, permitiram avaliar a dieta da curvina, *Plagioscion squamosissimus* e suas variações de acordo com o tamanho dos indivíduos e locais de coleta. Neste estudo a curvina foi considerada essencialmente piscívora, em função do notável predomínio de peixes em sua dieta, embora insetos (por vezes dominantes) e crustáceos tenham sido registrados. Os itens frequentemente encontrados, caracterizados como preferenciais na dieta global foram, *Hypophthalmus edentatus, Roeboides paranensis* e *Loricariichthys platymetopon*. Variações espaciais na dieta pareciam estar associadas à disponibilidade de presas no ambiente. O incremento em comprimento foi acompanhado por um aumento na piscivoria, bem como no tamanho médio da presa ingerida.

Palavras-chave: Alimentação de peixe, Piscivoria, *Plagioscion squamosissimus*, Rio Paraná.

ABSTRACT: Feeding ecology of curvina *Plagioscion squamosissimus* (Hechel,1840) (Osteichthyes, Perciformes) in the Itaipu Reservoir and Porto Rico floodplain. Fish samplings were carried out from November 1983 to September 1988, at different sites of the Paraná River basin, comprising the section between the Paranapanema and Iguaçu Rivers, with the purpose of analysing the diet diversity of curvina, *Plagioscion squamosissimus*, according to the spatial distribution and size of the individuals. The curvina was considered piscivorous, due to the predominance of fish in its diet, although insects (dominant in some ocasions) and crustaceans have been registered. The most frequently

items were *Hypophthalmus edentatus, Roeboides paranensis* and *Loricariichthys platymetopon.* Spacial changes in the diet seem associated with the availability of prey in the environment. Piscivory increased with the curvina length, as well as the average size of the ingested prey.

Key-words: Fish feeding, Piscivory, *Plagioscion squamosissimus,* River Paraná.

INTRODUCTION

The curvina, *Plagyoscion squamosissimus* (Heckel, 1840) is native of the Parnaíba, Trombetas, Negro and Amazonas rivers (Nomura, 1984) and has been introduced in dams of Northeastern of Brazil in 1940. In 1966 and 1967, it was also introduced in Pardo River, (State of São Paulo). Nowadays it is widely distributed throughout in South America (Goulding & Ferreira, 1984).

The curvina is an important species in the Brazilian freshwater fisheries (Petrere Jr. 1978; Worthmann 1983 and Annibal 1983) whose highest production has been recorded in Northeastern Brazil (Dnocs, 1986). In the Itaipu reservoir it attains second place in fisheries since the river damming (Agostinho et al, 1989). Here in 1990 the curvina yielded 243 tons (Agostinho et al, 1994).

The aim of this study was to investigate the feeding habits of the curvina in a man-made reservoir (Itaipu Reservoir) and in the, River Paraná floodplain (Porto Rico region, Paraná, Brazil).

STUDY AREA, MATERIAL AND METHODS

Samples were taken in Paraná River basin between the mouths of the Paranapanema and Iguaçu Rivers (Fig. 1). The Itaipu Reservoir (built in November 1982) weresampled in three stations with distinct characteristics, they are: Guaira (riverine area) Santa Helena (transitional area) and Foz (lacustrine area).

In Porto Rico fish were caught done at different sites, grouped according to their water dynamics as: lagoons lentic sites (Fechada, Guarana, Pousada das Garças and Patos); channels semi-lotic sites (Baía I and II, and Corutuba); and rivers predominantly lotic sites (Paraná, Ipoitã and Pedreira). Sampling frequencies are shown in table I.

Table I. Sampling frequency in the Itaipu Reservoir and Porto Rico area.

Place / Period	Frequency	
	1st semester	2nd semester
Itaipu Reservoir		
Nov/83 - Feb/85	monthly	monthly
Mar/85 - Feb/86	bimonthly	monthly
Mar/86 - Feb/87	bimonthly	monthly
Mar/87 - Feb/88	bimonthly	monthly
Porto Rico		
Oct/86 - Sept/87	monthly	monthly
Oct/87 - Sept/88	monthly	monthly

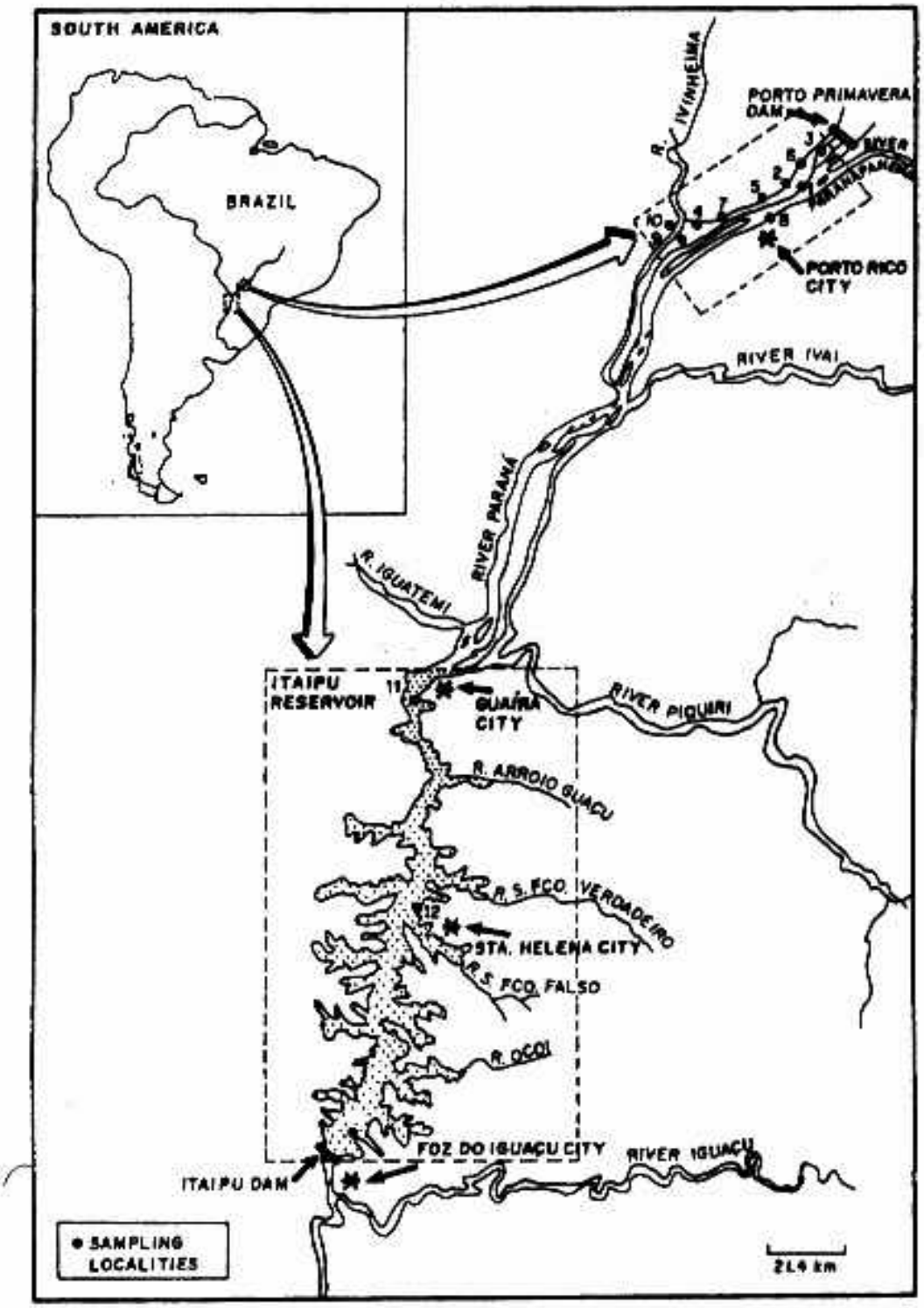

Figure 1. Geographic localization of sampling sites and reservoir stations. 1- Fechada, 2- Guarana, 3- Pousada das Garças, 4- Patos, 5- Baia I, 6- Baia II, 7- Corutuba, 8- Paraná, 9- Ipoitã, 10- Pedreira.

Fishes were captured with gillnets of different mesh sizes, which were set for 24 hours. Gillnets were examined in three separate turns: night-morning; daylight and; afternoon-night.

Fish standard length (Ls) and total weight (Wt) were measured and individual stomachs were extracted and fixed in 4% formaldehyde solution. Prey were identified, counted, weighed and, when they were fish they were measured.

Occurrence and gravimetric methods (Hynes, 1950; Hyslop, 1980) were used for the diet analysis. Results were expressed by Food Index (Kawakami & Vazzoler, 1980) modified as:

$$IAi = \frac{Fi \times Vi}{\sum Fi \times Vi} \times 100$$

where:

IAi = Food Index
i = 1, 2,...n, food items
Fi = occurrence frequency (%)
Wi= wet weight (%)

Prey were defined as preferential, secondary and accessory (Rosecchi & Nouaze, 1987).

Diet variations were analysed by sampling station localities: Guaíra, Santa Helena and Foz (**Itaipu Reservoir**), rivers, channels and lagoons (**Porto Rico**), length and reproductive classes (young: 4.5-14.4 cm, subadults: 14.5-22.4 cm; adults: 22.5-41.3 cm). The reproduction size were determined using a published gonadal maturation curve (Fuem/Nupelia/Surehma/Itaipu Binacional, 1987).

The percentage of similarity were calculated (Shorygin apud Clark, 1985) to express the prey importance in relation to the capture areas and size classes. It was calculated from:

$$SP = 100 - 0{,}5\sum|a - b|$$

where:

a = the i prey importance value for site a (or size class)
b = the i prey importance value for site b (or size class)

The calculation of "a" and "b" was based on the food index, which ranges from 0 (absence of similarity) to 100 (similar diets).

For evaluation of size relationship between curvina and their preys (SL prey/SL predator x 100), 395 preys were measured and their standard lengths measured. Data were grouped in 13 predator length groups.

RESULTS

The stomach contents analysis of all individuals of Itaipu Reservoir and Porto Rico area showed that curvina feeds basically on fish (> 80%) and insects (> 18%) (Tab. 2). Thirty-seven prey fishes were identified. This number could be higher since 12 species could only be identified to genera level . The Food Index has shown that, at the reservoir the selected prey was *Hypophthalmus edentatus* (46.5%) and *Roeboides paranensis* (26.6%). Among the insects, Odonata (18.5%) was the most important item. At Porto Rico *Loricariichthys platymetopon* (25.5%) and *Roeboides paranensis* (21.1%) were the main prey, and *Astyanax bimaculatus* (8.5%), *Synbranchus marmoratus* (6.23%) and *Hoplosternum littorale* (6.21%), and also Odonata (6.23%) were the secondary prey.

The curvina diet in Itaipu was more diversified in Guaíra station, decreasing towards the Foz station (Fig. 2). In Guaíra station the main prey were Odonata, *Trachydoras paraguayensis* and *Steindachnerina insculpta*. *R. paranensis* and *H. edentatus*, were the most abundant prey in Santa Helena and Foz station, respectively (Fig. 2).

In Porto Rico area a great variety of items were found in fish recorded in river sites.

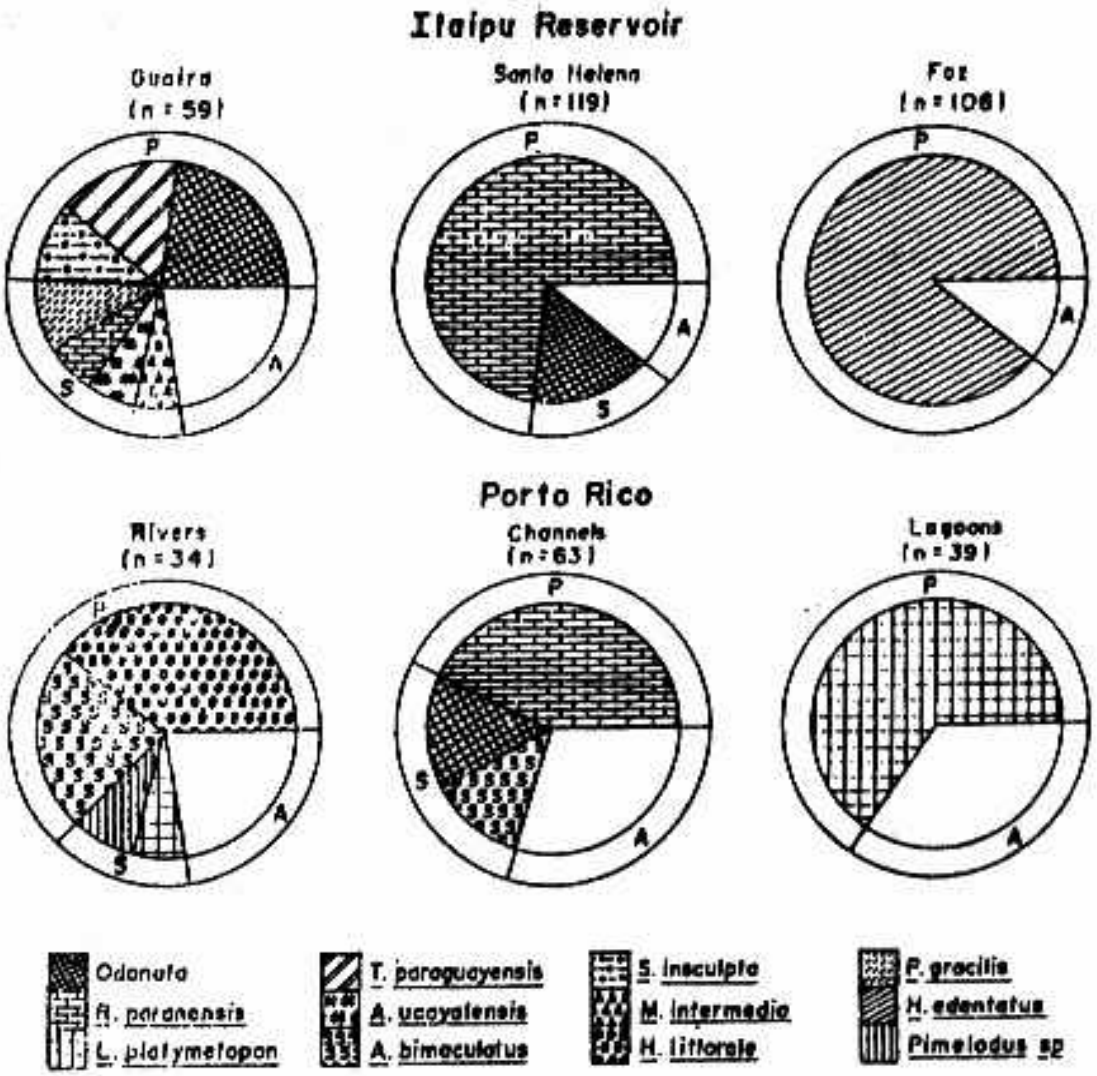

Figure 2. Relative contribution of food items in the diet of the curvina, (*Plagioscion squamosissimus*) at different localities in Itaipu Reservoir and Porto Rico floodplain. P= preferential, S= secondary, A= accessory prey.

However, diet diversity decreased in those fish collected in lagoons (Fig. 2). In rivers the most important items were *H. littorale* and *A. bimaculatus*. In channels *R. paranensis* was the main prey, differenty of lagoons where *L. platymetopon* index value exceeded 65%.

Similarities between all sampled areas were low (Tab. 3), even those of the same environment. The highest similarity (61.32%) was observed between individuals from Santa Helena (Reservoir) and those from the channels (Porto Rico).

In both environments, considerable variations occurred among differents life history stages (Fig. 3).

Young curvinas of the reservoir fed mainly on Odonata (86.0%), whereas those from Porto Rico has shown a diversified diet, including *Odontostilbe microcephala* and *Cheirodon notomelas* (small size fish) as the preferential prey, and immature piranhas (*Serrasalmus marginatus*) and ephemeropterans as the secondary ones.

Table II. Relative occurrence (O), food weight (G), Feeding Index (IAi) and each prey size item in stomach contents of curvina, *Plagioscion squamosissimus* of Itaipu Reservoir and Porto Rico.

Prey/Places	Prey	Itaipu Reservoir (n=283) Occurrence		Food weight		IAi	Porto Rico (n=136) Occurrence		Food weight		IAi
	Sl (cm)	n	%	g	%	%	n	%	g	%	%
PISCES											
Acestrorhynchus lacustris	11.9	1	0.35	20.89	1.70	0.06					
Aequidens sp	3.9						1	0.73	1.25	0.40	0.06
Ageneiosus ucayalensis	6.8-11.3	3	1.06	24.59	2.00	0.22					
Ageneiosus sp	9.4-9.9	2	0.71	14.74	1.20	0.09					
Apareiodon affinis	4.9-8.3	3	1.06	12.45	1.01	0.11					
Aphyocharax sp	2.4-3.5						2	1.47	0.36	0.12	0.04
Apteronotus sp	11.6-14	1	0.35	6.97	0.57	0.02	1	0.73	4.33	1.40	0.20
Astyanax bimaculatus	2.5-6.9	6	2.12	26.69	2.17	0.49	10	7.35	17.76	5.75	8.49
Astyanax fasciatus	4.8						1	0.73	1.83	0.59	0.09
Astyanax sp	1.6-17	4	1.41	17.06	1.39	0.21					
Auchenipterus nuchalis	7.5-16.5	4	1.41	21.46	1.75	0.26	1	0.73	37.56	12.17	1.78
Bryconamericus stramineus	1.9-4.6	8	2.83	4.23	0.34	0.10					
Calichthys callichthys	-						1	0.73	2.80	0.91	0.13
Cheirodon notomelas	1.7-3.7	3	1.06	1.76	0.14	0.01	11	8.09	7.22	2.34	3.80
Crenicichla lepidota	3.7-6.7	5	1.77	18.34	1.49	0.28					
Crenicichla nierdeleinii	9.5	3	1.06	14.81	1.20	0.13					
Cyphocharax modesta	4.5-6.9	2	0.71	13.33	1.08	0.08	2	1.47	11.69	3.79	1.12
Cyprinus carpio	7.0	1	0.35	7.09	0.58	0.02					
Eigenmannia virescens	10.0	1	0.35	3.78	0.31	0.01					
Galeocharax knerii	-	1	0.35	12.39	1.01	0.04					
Geophagus pappaterra	2.9-3.0	2	0.71	1.52	0.12	0.01					
Gymnotus carapo	6.0-11.0						4	2.94	25.7	8.32	4.92
Hemisorubim platyrhynchos	-						1	0.73	0.35	0.11	0.02
Holosthestes sp	3.6	1	0.35	0.81	0.06	0.01					
Hoplias malabaricus	2.4-7.4	5	1.77	12.65	1.03	0.19					
Hoplosternum littorale	-						5	3.68	25.95	8.40	6.21
Hyphessobrycon sp	1.9-2.6						4	2.94	4.94	1.60	0.94
Hypophthalmus edentatus	2.9-20.6	34	12.01	451.91	36.79	46.49	2	1.47	13.03	4.22	1.25
Hypostomus sp	3.9-4.5	1	0.35	1.79	0.14	0.01					
Iheringichthys labrosus	4.5-10.9	4	1.41	32.00	2.60	0.39					
Leporinus sp	1.9-3.0						2	1.47	0.60	0.19	0.06
Loricariichthys platymetopon	5.5-13.7	1	0.35	9.69	0.78	0.03	12	8.82	44.33	14.36	25.46
Moenkhausia intermedia	4.0-6.0	3	1.06	9.11	0.74	0.08	3	2.20	10.13	3.28	1.45
Odontostilbe microcephala	2.3-2.5						7	5.15	2.13	0.69	0.71
Parauchenipterus galeatus	8.0	1	0.35	12.79	1.04	0.04					
Pimelodella gracilis	6.4-10.7	8	2.83	50.31	4.10	1.23					
Pimelodus sp	1.9-6.2						3	2.20	6.29	2.04	0.90
Plagioscion squamosissimus	1.9-10.7	12	4.24	20.95	1.70	0.77	1	0.73	0.19	0.06	0.01
Pseudocetopsis gobioides	-	1	0.35	11.30	0.92	0.03					
Pterodoras granulosus	9.6						1	0.73	0.94	0.30	0.04
Raphiodon vulpinus	7.1	3	1.06	7.50	0.61	0.07					
Roeboides paranensis	3.0-7.7	48	16.96	181.04	14.74	26.59	13	9.56	35.20	11.40	21.91
Schizodon borelli	8.5						1	0.73	9.50	3.08	0.45
Serrasalmus marginatus	3.9-4.4						3	2.20	6.65	2.15	0.95
Serrasalmus sp	2.3-4.8	1	0.35	2.02	0.16	0.01	2	1.47	0.89	0.29	0.09
Steindachnerina insculpta	3.0-7.0	9	3.18	50.57	4.12	1.39	2	1.47	2.31	0.75	0.22
Sternarchorhynchus sp	17.8	1	0.35	16.06	1.31	0.05					
Synbranchus marmoratus	6.0-23.0	6	2.12	5.11	0.42	0.09	7	5.15	18.59	6.02	6.23
Trachydoras paraguayensis	5.0-7.5	9	3.18	40.05	3.26	1.10					
INSECTA											
Chironomidae		18	6.36	2.15	0.17	0.11					
Ephemeroptera		3	1.06	0.46	0.04	0.01	17	12.5	6.53	2.11	5.30
Odonata		83	29.33	72.82	5.93	18.50	25	18.38	5.66	1.83	6.76
CRUSTACEA											
Decapoda		3	1.06	15.03	1.22	0.14	2	1.47	4.03	1.30	0.38

Table III. Similarity (SP) between the feeding patterns of curvina, *Plagioscion squamosissimus*, at different collecting localities (Itaipu reservoir and Porto Rico).

	Guaíra	S. Helena	Foz	Rivers	Channels	Lagoons
Guaíra	-	29.35	10.53	8.0	27.46	9.93
S. Helena		-	10.37	5.46	61.32	9.88
Foz			-	3.94	9.02	7.42
Rivers				-	20.91	15.54
Channels					-	19.06
Lagoons						-

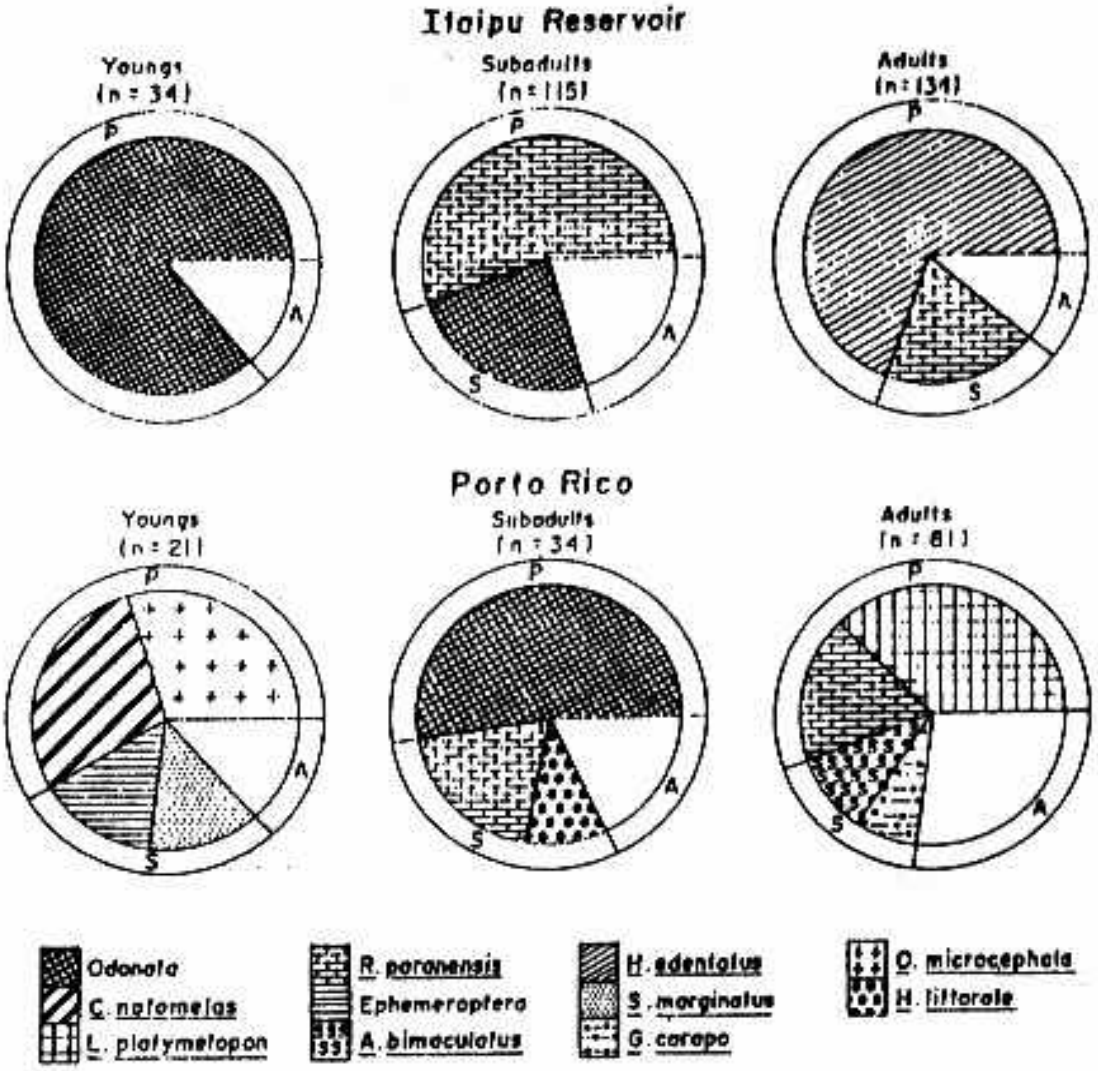

Figure 3. Relative contribution of food items in the diet of the curvina, (*Plagioscion squamosissimus*) at several development stages, for individuals of Itaipu Reservoir and Porto Rico floodplain. P= preferential, S= secondary, A= accessory prey.

Subadults in Itaipu, replaced Odonata by *R. paranensis*, which became the secondary prey, contrasting with Porto Rico curvinas, whose stomach contents showed a dominance of this insect complemented by *R. paranensis* and *H. littorale*.

Adult curvinas started to feed on *H. edentatus* and *R. paranensis* became a secondary prey in Itaipu. Odonata practically disappeared from the diet. In Porto Rico, *R. paranensis* increased in the diet composition and turned up as a preferential item, but *L. platymetopon* was the dominant fish in stomach contents.

A certain degree of similarity among individuals at different developmental stages for both environments was observed (Tab 4). The highest similarity were detected between young individuals of the reservoir and Porto Rico subadults.

The relationships between predator and prey lengths are shown in figure 4. This plot indicates that as the curvina grows, it feeds on larger prey. Minimum, maximum and relative prey lengths show a similar trend. The minimum length of prey remain constant for curvinas attaining 33.0 cm, following a similar trend of the prey relative length.

The same analysis was made for the two most frequent prey, of which a representative number of individuals could be measured. Results are shown in figure 5. For *H. edentatus* a sharp increment related to the curvinas' size was observed. Minimum, maximum and relative prey lengths showed similar variations. Curvinas between 15.0 and 30.0 cm preyed upon *R. paranensis*, of similar size. This can be observed in the decreasing of the prey's relative length as curvina length increased.

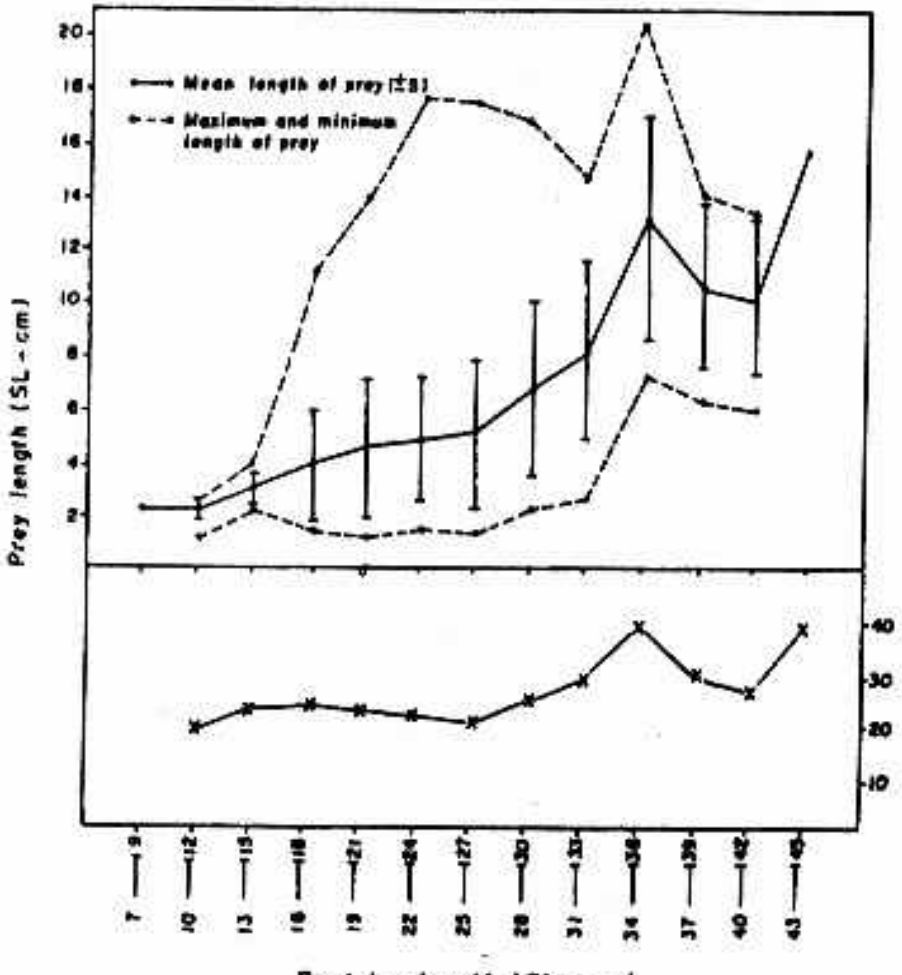

Figure 4- Relationships between the length of *Plagioscion squamosissimus*, its prey length. Vertical bar = standard deviation.

Table IV- Similarity (SP) between the feeding patterns of curvina, *Plagioscion squamosissimus*, at different development stages.

	Youngs1	Subadults1	Adults1	Youngs2	Subadults2	Adults2
Youngs1	-	31.27	1.85	4.38	52.86	1.77
Subadults1		-	31.44	6.07	44.72	22.7
Adults1			-	0.9	12.91	20.4
Youngs2				-	12.18	18.48
Subadults2					-	34.09
Adults2						-

1 =Reservoir; 2 = Porto Rico

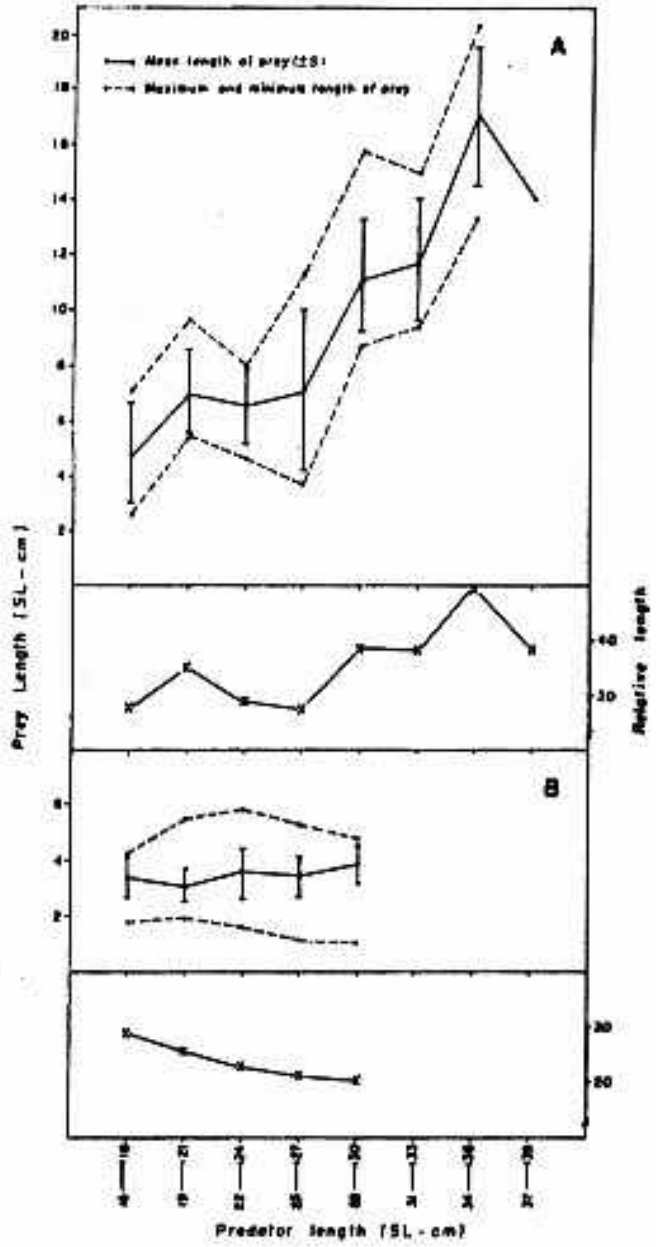

Figure 5- Relationship between the length of *Plagioscion squamosissimus*, and the prey:. A=*Hypophthalmus edentatus* and B=*Roeboides paranensis*. Vertical bar = standard deviation.

DISCUSSION

In the study area, *P. squamosissimus* can be considered an essentially piscivorous fish species. For Harmelin-Vivien & Bouchon (1976), this guild is verified fish totals exceeds 60.0% of the diet. Similar trends were observed by Silva & Menezes (1950) at Nazaré lagoon, (State of Piauí), and by Chacon & Silva (1971) at Amanari dam (State of Ceará) and by Braga (1990) at the River Tocantins (State of Tocantins).

In contrast, other authors found shrimps dominating the diet composition in several waters of the Amazonian region, though fish were also registered but in low proportions (Annibal, 1983; Goulding & Ferreira, 1984; Worthmann & Oliveira, 1987).

The variety of the fish and insects in the curvina's diet indicated a wide feeding spectrum, though a remarkable dominance of items occurs when the total, and diets are analysed. These fact may reveal a low alimentary specificity.

The comparison within and between the two different environments revealed differences in dominant items and in the relative number of ingested organisms. This is probably related to the prey abundance and availability. For exemple, the presence of *H. edentatus* in the stomachs of individuals captured in Foz, but with only one occurrence recorded in Guaíra is corroborated by Benedito (1989). She recorded the abundance of this prey in Foz and its absence in Guaíra. In Porto Rico the high proportion of *L. platymetopon* eaten by individuals from the lagoons relates, couples with its abundance in lentic habitats (Dei Tos, 1993). The high similarity observed between individuals collected in Santa Helena and those from semilotic environments can be attributed to the high consumption of *R. paranensis*, followed by Odonata. This is probably due to the high availability of these prey in both localities.

Variations of in the curvina diet at different developmental stages was mainly noted in the consumption of insects by juveniles, while adults gradually shifted to fish, especially in the reservoir. This observation has been previously documented (Nikolsky, 1963) and can be related to morphological development (Wooton, 1990) or to the occupation of different environmental strata (Lowe McConnell, 1975). This is also reinforced by a decreasing of Odonata nymphs and Chironomid larvae as the curvina grows. Hynes (1950), Pitcher & Hart (1982) and Pandian & Vivekanandan (1985), argued that the capture of small organisms becomes less convenient to larger predators.

As observed, prey are also larger as predator grows. Sub-adults preyed upon *R. paranensis*, a foraging fish, while adults fed on *H. edentatus* which attains large sizes. At floodplains, insects were present in the diet but fish dominated. This can be explained by a higher density of juvenile forms, belonging to several species, which are typical of such environments.

Plots of the relative size of the most frequent prey indicate that constant values for *R. paranensis*, differing from *H. edentatus*, are related to the fact that the former is a small species. Adult fish also feed on small prey suggesting that their feeding spectrum increased with increased length.

The feeding plasticity of the curvina shown in this study and in other regions, may explain the success of its colonization in Itaipu Reservoir. This success did not occur with other introduced species such as, *Cichla ocelaris* and *Cyprinus carpio*. The dominance of the curvina on native piscivorous fishes, suggest that further research is also required to determine its ecological role. The curvina voracity, shown by the great variety of fish recorded in its stomach contents, may suggest a heavy cost for the native fish fauna whose stocks could be altered.

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