Study on Feeding Habits of *Piaractus mesopotamicus* (*Pacu*) Larvae in Fish Ponds

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Abstract

A limnological study of an artificial fish pond and an analysis of the stomach contents of *pacu* (*Piaractus mesopotamicus*) larvae of 2 to 45 days age were made for a period of 45 days to evaluate their feeding preferences. A preference for chlorophytes and rotifers was noted, while other planktonic species remained constant in the stomach contents. Some limnological variables were found to have a strong influence on the feeding behavior of the *pacu*. A preference for feeding on smaller species in the first few days of larval development was also noted.

Introduction

Nature offers a great diversity of organisms used as food by fish and these differ in size and taxonomic group. Most fish species feed on plankton during the early developmental stages. The food items selected during different stages of fish growth depends not only on nutritional demands, but also on digestive tract morphology (Nikolsky 1963).

Efficiency in using available food is a vital requirement for all animals. Many fish larvae and postlarvae survive and grow better when fed on planktonic forms such as rotifers, cladocerans, copepods and free living protozoans (Chakrabarti and Jana 1991). For this reason, live food is extensively used in larval cultures (Wylie and Currie 1991). The success of larval culture depends to a great extent on the quality and quantity of food, the size of the particles and the composition of feed.

In Brazil, not much information is available on the feeding preferences of *pacu* larvae in fish ponds. The present study was undertaken to observe the feeding preferences of *pacu* larvae between 2 and 45 days of age, in relation to the abundance of plankton in the ponds.

P. mesopotamicus, a tropical freshwater fish from the Prata Basin in Brazil, has shown great potential for aquaculture as compared to other native species. Specimens of up to 18 kg in weight have been observed in nature, while the species was observed to grow only up to 10 kg in aquaculture operations. The species is an omnivore, feeding mainly on fruit, seed, grain, small molluscs, crustaceans and insects. It is a rheophylic species and does not lay eggs in fish ponds. Sexual maturation occurs at the age of four years. The flesh is very tasty and has a low percentage of fat (Proença and Bittencourt 1994). The main characteristics of *P. mesopotamicus* that make it suitable for culture are its endurance to handling, low dissolved oxygen concentration, high fertility rates and omnivorous feeding habits (Sá 1989).

Materials and Methods

The study was carried out at the "Centro de Aquicultura" of the Universidade Estadual Pauliste, Jaboticabal, Brazil in January 1993. A fish pond of 45 m^2 in area and 1.20 m deep was used. Two-day old larvae of *P. mesopotamicus* were stocked in the pond at a density of 250 larvae/m^2.

For 20 days, larvae were caught daily at 9:00 a.m. with a 58 μm mesh hand net. From the 21st to the 45th day the capture was made once every four days until the end of the experiment. After capture, the larvae were anaesthetized with benzocaine solution for 10 minutes in order to avoid regurgitation and were fixed in 10% formalin.

The food contents of the whole digestive tract were used for quantitative and qualitative analysis of the ingested material. Food items that were entirely and partially digested but identifiable were analyzed.

Water from the fish pond was collected with a Van Dorn bottle, always at the same point and at a depth of 60 cm, to assess the water quality and the availability of natural food (plankton) in the pond. Dissolved oxygen, chlorophyll *a*, dissolved nutrients (ammonia, nitrite, nitrate), alkalinity and inorganic carbon were determined according to the techniques described by Golterman et al. (1978). Water transparency was determined using a Secchi disc. For quantitative and qualitative analysis of phytoplankton and zooplankton, samples were obtained using a 25 μm and 58 μm mesh plankton net, respectively, and fixed in 4% formalin.

Spearman rank correlation coefficient analysis as applied to fish feeding (Fritz 1974; Siegel 1975) was used to study correlations between 5 000 items.

Results and Discussion

The study indicated the preference of *P. mesopotamicus* larvae for phytoplankton (Fig. 1) which constituted more than 90% of the stomach contents. This preference could probably be associated with the availability of phytoplankton in the environment.

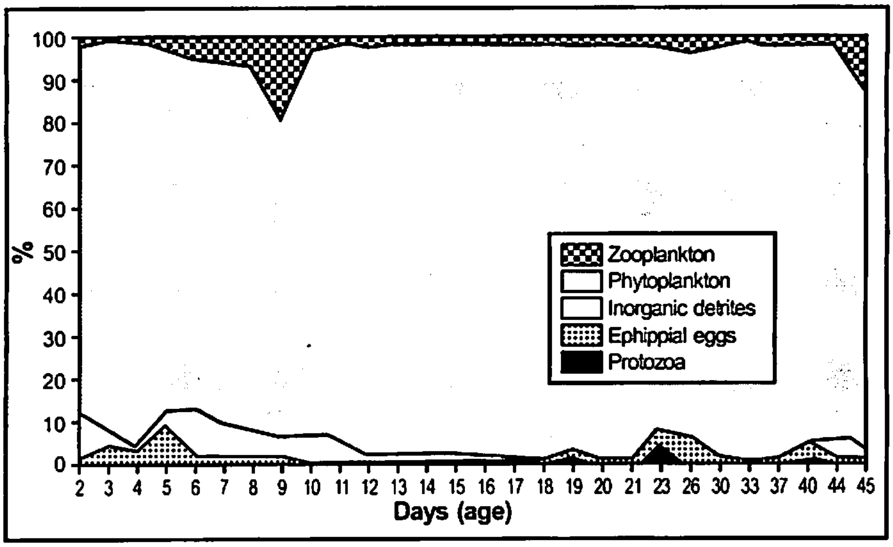

Fig. 1. Composition of food items in stomach of P. mesopotamicus *larvae.*

The phytoplankton found in the stomach contents were mostly chlorophytes, represented mainly by phytoflagellates, followed by *Ankistrodesmus falcatus, Chlorella vulgaris* and *Scenedesmus bijugus* (Table 1).

The phytoflagellate abundance in the larval stomach contents is associated with environments that have certain characteristics, such as high water flow and low nutrient concentration with maximum temperatures between 22 and 26°C. In addition, environments that have sediment composed of decomposing organic material show a flagellate-rich phytoplankton composition (Robertson 1980; Moreno 1996), as was the case in the pond studied here.

The low concentration of organisms belonging to Class Cyanophyta found in the pond (Fig. 2) is considered normal in this type of environment (Boyd 1990). This is directly associated with the low pH and low availability of nutrients

Table 1. Percentage of organisms (grouped by taxon) found in digestive tract of P. mesopotamicus *larvae and in the cultivation pond.*

Taxon	Species	% taxon in digestive tract	% per taxon in pond
Chlorophyta	*Actinastrum* sp.		11.43
	Ankistrodesmus densus		0.01
	A. falcatus	7.646	0.66
	A. gracilis	0.556	0.39
	Arthrodesmus sp.	0.001	
	Asterococcus limneticus		0.63
	A. planktonicus	1.127	
	Chaetospheridium		0.27
	Chlorella vulgaris	6.384	44.02
	Chlorococcum sp.	0.001	
	Closterium sp.	0.001	
	C. setaceum		0.02
	Coelastrum sp.		0.18
	C. microporum	0.010	0.02
	C. reticulatum	0.140	1.20
	Cosmarium sp.	0.074	0.10
	C. pachydermum	0.003	
	C. quadrum	0.001	
	Desmidium sp.	0.036	
	Dictyosphaerium pulchellum		0.18
	Dimorphococcus lunaris	0.035	
	D. lunatus		0.79
	Dispora sp.		0.07
	Dyctiosphaerium sp.	1.228	
	Enteromorpha sp.	0.037	
	Eremosphaeria sp.		2.81
	E. eremosphaeria	0.951	
	Euastrum sp.	0.001	0.01
	Eudorina sp.		0.01
	Fitoflagelados	67.002	
	Gloeocystis sp.	0.662	0.02
	G. pusilla		0.06
	G. vesiculare		1.31
	Golenkinia paucispina		0.33
	G. pusilla		0.02
	Hyalotheca sp.	0.145	0.22
	Kirchneriella sp.		0.03
	K. lunaris	0.746	
	Micrasterias laticeps	0.001	0.01
	M. simplex		0.38
	Micractinium sp.	0.008	
	Microspora sp.		0.04
	Monoraphidium brauni		0.01
	Mougeotia sp.	0.070	0.59
	Nephrocytium lunatum		0.01
	Oedogonium sp.	1.290	3.26
	Onephris obesa	0.504	
	Oocystis lacustris	3.515	0.23
	O. pusilla	0.007	0.41
	O. solitaria	0.194	0.03
	Pandorina sp.	0.002	
	Pediastrum boryanum	0.001	0.10
	P. duplex	0.013	2.60
	P. tetras	0.001	0.02

Continued

Taxon	Species	% taxon in digestive tract	% per taxon in pond
Chlorophyta	*Pennium* sp.		0.01
	Planktosphaeria sp.	0.013	0.24
	Pleurotaenium sp.		0.01
	Quadrigula sp.	0.010	0.01
	Radiococcus planktonicus	0.018	0.48
	Staurastrum sp.	0.001	
	Spirogyra sp.	0.012	0.57
	Scenedesmus acuminatus		11.16
	S. acutus		0.06
	S. bijugus	5.151	4.51
	S. denticulatus		0.02
	S. quadricauda	0.275	3.68
	Selenastrum sp.		0.04
	Sphaerocystis schroeteri	1.101	5.40
	Spondylosium sp.		0.01
	Staurodesmus lobatus		0.04
	S. validus	0.001	0.11
	Staurastrum leptocladium		0.01
	S. orbiculare		0.04
	Tetraedron sp.	0.012	0.09
	Tetrallantos sp.		0.08
	Tetraspora sp.		0.13
	Tetrasporidium sp.		0.04
	Tetrastrum sp.	1.014	0.42
Chrysophyta	*Anomoeneis* sp.	3.07	
	Botryococcus sp.	28.11	17.37
	B. boryanum		1.47
	Coxinodiscus sp.	30.21	
	Coelosphaerium sp.	3.30	
	Cyclotella sp.	0.60	
	Cymbella sp.	0.76	1.68
	Dinobryum sp.	0.07	
	Eunotia sp.	11.47	
	Eunotia sp1		3.96
	Eunotia sp2		0.91
	Frustulia sp.	0.07	
	F. rhomoboides		0.91
	Gomphonema sp.	0.07	9.71
	Melosira sp.	0.22	
	Melosira distans		6.38
	Navicula sp.	11.24	31.44
	Nitzchia sp.	0.16	
	Pinnularia sp.	3.09	
	P. gibba		6.49
	Phalansterium sp.		2.53
	Surirella sp.	6.60	17.15
	S. linharis	0.07	
	Stenopterobia sp.	0.45	
	Synedra sp.	0.37	
	Uroglena sp.	0.07	
Cyanophyta	*Anabaena* sp.	0.82	
	Aphanizomenom sp.	4.55	
	Coelosphaerium sp.	15.39	
	Gloeotrichia sp.	0.99	
	Merismopoedia sp.	62.74	7.62
	Microcystis sp.	11.37	38.33
	Nostoc sp.	4.14	3.44
	Oscillatoria sp.		0.20
	Scytonema sp.		50.41
Pyrrophyta	*Peridinium* sp.	100	
Rotifera	*Ascomorpha agilis*	4.83	
	Asplanchnella giroidi		0.22
	Asplanchnopus sp.		0.04
	Brachionus caudatus	19.39	34.77
	B. calyciflorus amplyc.	6.77	
	B. calyciflorus		9.94
	B. dolabratus	15.19	40.12
	B. falcatus	3.91	3.21
	B. mirus	0.10	
	B. patulus	0.10	
	B. quadridentatus	0.10	0.36
	B. q. mirabilis		1.94
	B. urceolaris	0.29	
	Cephalodella gibba	0.10	
	C. hemaine	8.46	
	C. remaini		0.07
	Colurella sp.		0.21
	Epiphanes macrocerus	0.29	0.09
	E. urceolaris		0.13
	Euchlanis dilatata	0.87	0.88
	Filinia longiseta	0.10	
	Hexarthra sp.		4.47
	Keratella cochlearis	2.08	0.09
	K. cruciformis		0.15
	Lecane monostyla	1.89	0.11
	L. m. decipiens		0.21
	Lepadella ovalis		0.10
	L. patella	0.48	
	Ploesoma sp.		0.08
	P. triacanthum	0.43	
	Polyarthra sp.	2.27	1.97
	Pompholyx triloba	0.29	
	Proales globulifera	1.45	0.17
	P. doliaris	23.31	0.38
	Synchaeta sp.	3.87	
	Testudinella ohlei	0.29	
	T. truncata	1.45	
	Trichocerca sp.		0.29
	T. bidens	1.16	
	T. tropis	0.58	
Copepoda	*Argyrodiaptomus furcatus*		
	nauplii	26.00	37.87
	copepodite	67.93	18.11
	adult	4.81	7.88
	Ergasillus sp.		3.03
	Thermocyclops sp. copepodite	1.26	
	T. decipiens		
	nauplii		8.03
	copepodite		18.57
	adult		6.51
Cladocera	*Alona* sp.	1.62	
	Bosmina sp.		7.81
	B. hagmani	0.54	
	B. tubiens		9.28
	Ceriodaphnia cornuta		6.24
	Daphnia gessneri		0.05
	Diaphanossoma birgei	8.69	35.28
	Disparalona dadayi		0.03
	Echinischa paulineis	14.90	7.95
	Eurialona orientalis	0.13	
	Macrothrix sp.	0.80	0.15
	Moina micrura	72.78	15.73
	Simocephalus serrulatus	0.54	
	Scapholeberis kingii		17.48
Protozoa	*Arcella discoides*	94.83	21.34
	Centropix sp.	0.07	
	Difflugia sp.	3.41	6.36
	Difflugia oblonga		72.30
	Discorbis sp.	1.48	
	Epistylis sp.	0.21	
Others	Ephippial eggs	24.98	
	Inorganic detritus	62.71	
	Oligochaeta	1.66	
	Ostracoda	10.65	

(Table 2). *Merismopedia* sp. was the main representative of this group in the stomach contents (Table 1).

Bowen (1982) suggests that a large part of the phytoplankton found in the digestive tract of fish larvae are those that recently formed sediment and detritus, becoming indistinct from the phytoplankton belonging to the water column. The ingestion of detritus was also observed by Patrick-Dempster et al. (1993) for tilapia species and carps, indicating that part of the ingested material came from the bottom of the pond. Protozoans, consisting mainly of *Arcella discoides* which are typical of the pond bottom fauna, were found in the digestive tract of *P. mesopotamicus* (Table 1). A certain quantity of inorganic detritus was

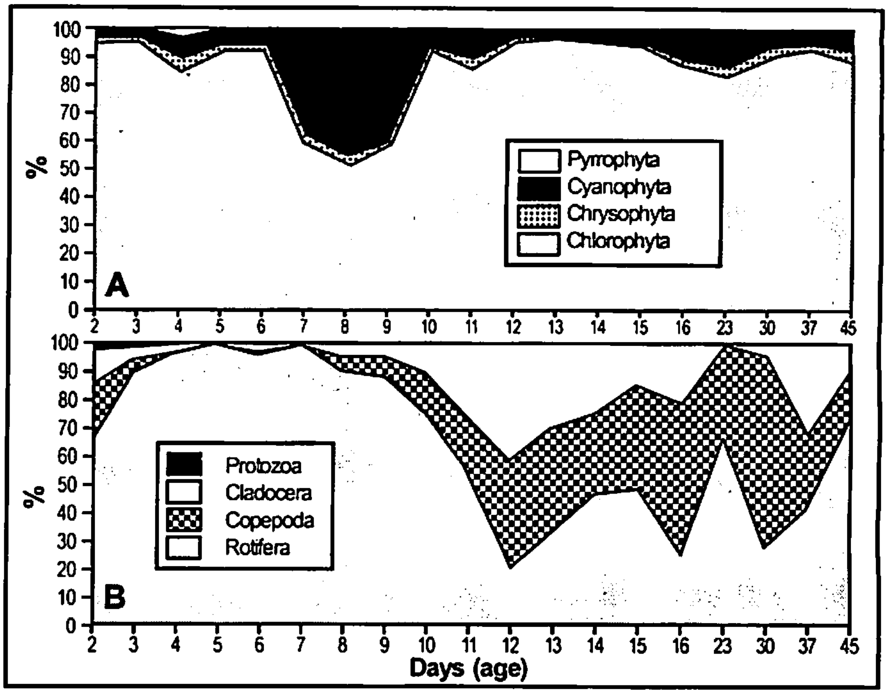

Fig. 2. Composition of phytoplankton (A) and zooplankton (B) in the fish pond where* P. mesopotamicus *larvae were cultivated for 45 days.

Table 2. Variations in environmental parameters in the pacu cultivation pond during the experimental period.

Environmental data	Experimental period (days)																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	23	30	37	45
Transparency (cm)	100	100	110	110	115	115	110	80	70	80	90	100	90	70	80	90	65	120	100	130
Temperature (°C)	28.0	27.0	28.0	27.8	26.0	26.5	26.3	27.0	26.0	25.0	25.0	24.8	24.0	26.0	26.7	24.0	27.0	26.8	26.9	27.0
Conductivity (µS/cm)	38	35	40	29	31	32	33	28	35	29	30	28	31	30	32	34	30	31	32	30
pH	7.0	7.2	6.8	6.8	6.6	6.8	6.2	6.5	6.4	6.5	6.5	6.6	6.6	6.5	6.6	6.8	6.9	6.7	6.4	6.2
Dissolved oxygen (mg/L)	8.0	7.0	5.0	4.0	2.5	4.0	4.0	7.0	6.0	4.0	3.0	2.5	1.0	4.0	7.0	6.5	6.5	7.0	8.5	8.0
Alkalinity (meq/L)	0.5	0.6	0.6	0.5	0.5	0.5	0.4	0.3	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.5	0.5	0.4
Total CO_2 (meq/L)	0.65	0.65	0.80	1.00	1.00	0.80	0.6	0.7	0.40	0.6	0.7	0.80	0.80	0.90	0.90	0.95	1.0	1.1	0.85	0.85
Bicarbonate (meq/L)	0.50	0.45	0.60	0.70	0.70	0.40	0.30	0.35	0.20	0.3	0.55	0.55	0.50	0.65	0.50	0.55	0.55	0.40	0.35	0.35
Free CO_2 (meq/L)	0.15	0.20	0.20	0.30	0.30	0.45	0.30	0.35	0.20	0.3	0.15	0.25	0.30	0.25	0.40	0.40	0.45	0.70	0.50	0.50
Chlorophyll *a* (µg/L)	52	45	37	30	37	42	37	39	33	25	21	27	37	34	36	35	25	17	27	42
Nitrate (µg/L)	*<0.2	100	50	*<0.2	20	200	100	10	80	40	*<0.2	40	100	200	380	100	420	97	*<0.2	100
Nitrate (µg/L)	*<0.2	*<0.2	*<0.2	8	5	9	15	30	9	1	4	5	7	8	10	12	3	*<0.2	*<0.2	*<0.2
Ammonia (µg/L)	*<0.2	25	*<0.2	*<0.2	*<0.2	30	40	100	50	100	650	750	630	150	80	75	*<0.2	*<0.2	*<0.2	*<0.2

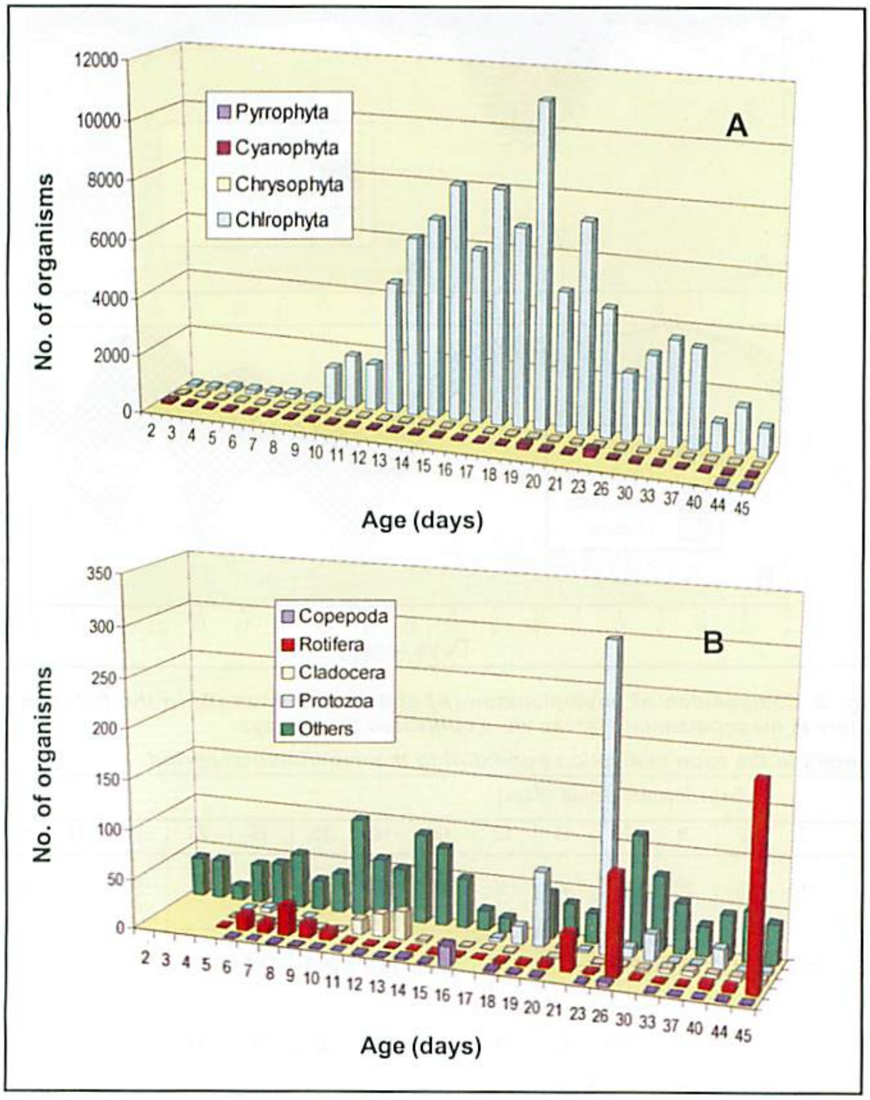

Fig. 3. Number of phytoplankton (A) and zooplankton (B) organisms ingested by P. mesopotamicus larvae 2 to 45 days of age.

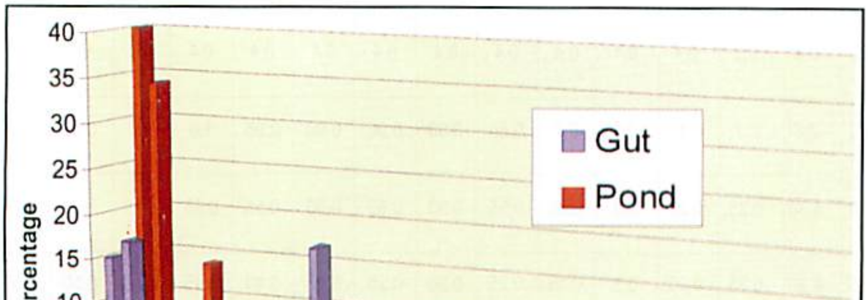

Fig. 4. Occurrence of phytoplankton of Phylum Chlorophyta in the digestive tract and in the pond. The numbers on X-axis are those of the species found in Table 1 whose frequencies were equal or superior to 0.1%.

also found. This indicates that the larvae have a tendency to widely explore their environment (Fig. 1).

The larvae had already ingested phytoplankton on the second day of life. On the fourth day, they also fed on rotifers, cladocerans, protozoans and copepod nauplii.

The fish pond environment favors the growth of opportunistic species like rotifers, thus their predominance over other zooplankton groups (Fig. 2). Rotifers are responsible for 50% of the zooplankton population by being associated to systems rich in detritus material, regions poor in dissolved oxygen and high water flow, mainly if the nutritional availability is high and there is low competition (Moreno 1996).

The higher concentrations of rotifers as compared to cladocerans in the larval stomach contents (Fig. 3) could initially be associated with the small size of rotifers (between 92 and 284 μm), compared to that of cladocerans (152 to 405 μm). Concentrations of nauplii (138 μm) and copepodites (500 μm) was greater than that of adult copepods (1 450 μm) in the digestive tract of *P. mesopotamicus* (Table 1).

Kerduchen and Legendre (1994) observed that three-day old *Heterobranchus longifilis* ingested prey larger than 500 μm such as *Artemia nauplii* and *Moina*. Yamanaka (1988) observed that, at first, *P. mesopotamicus* larvae would feed mainly on rotifers and copepod nauplii and would change to cladocerans after the 10th day. The same was observed by Lazzaro and Ribeiro (1984) for five-day old *Hoplias lacerda*.

The density of copepods and cladocerans in shallow tropical systems depends on factors such as nutrients suspended in the water, oxygen availability, water transparency and temperature changes. High density of nauplii and copepodites can be related to a preference for high energy levels and greater alimentary range (Hardy 1992). The same was observed in this study (Fig. 2; Table 1). There was a direct relationship between copepodite and nauplii availability in the pond environment and their presence in the stomach contents. The small size of these organisms also contributed to the fact that they are heavily consumed by the larvae.

The low occurrence of *Daphnia gesneri* in the environment and, consequently, in the larval stomach contents can be explained by the fact that in more eutrophic systems there is an exchange of *Daphnia* populations for *Diaphanosoma* populations.

Species belonging to Class Cladocera found in the larval stomach contents after the 5th day were mainly *Moina micrura*, *Echinischa paulineis* and *Diaphanosoma birgei*. Kerduchen and Legendre (1994) observed a preference for *M. micrura* by catfish over 3 days of age. According to Mellor (1975) and Patrick-Dempster et al. (1993), catfish and tilapia larvae have difficulty in digesting ephippial eggs. This fact and *M. micrura*'s great resistance and availability in a culture system explain their presence in the larval stomach contents. This was confirmed by the high proportion of ephippium found in digestive tract of the larvae in this study (Table 1).

Table 3 shows the results from the correlation analysis of Spearman classes for the most abundant taxa, in the digestive tract and in the plankton. There was correlation between the food items in the digestive tract and the plankton (P>0.05). It can be concluded that the larvae selected phytoplankton belonging to Phylum Chlorophyta and zooplankton belonging to Class Rotifera available in the fish pond (Figs. 4 and 5).

The study shows the importance of phytoplankton and zooplankton as a primary source of nutrition for the larvae. However, the feeding habits of larvae should be studied further to improve their survival in fish ponds, as one of the major problems in larval culture is the high mortality during the initial stages of larval development.

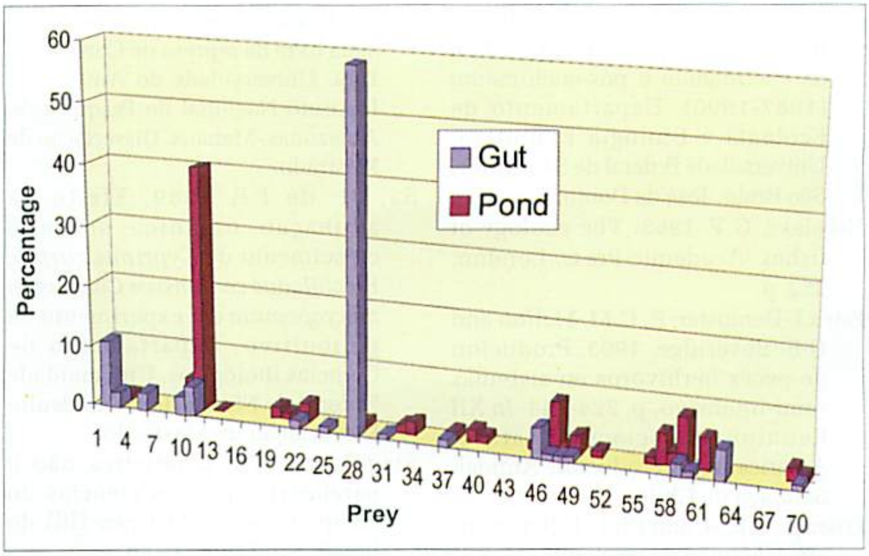

Fig. 5. Occurrence of zooplankton of Class Rotifera in the digestive tract and in the pond. The numbers on X-axis are those of the species found in Table 1.

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Table 3. Results from the Spearman class correlation method used to correlate chlorophyte and rotifer abundance in larval digestive tract and in pond.

Taxon	r_s	t_{rs}	GL	t'	c
Chlorophyta	0.076	0.52	43	1.96	NS
Rotifera	0.051	0.31	37	2.02	NS