



Diet and feeding strategy of the silverside *Odontesthes bonariensis* (Valenciennes 1835) (Atheriniformes: Atherinopsidae) from the Mirim Lagoon, Rio Grande do Sul, Brazil

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Abstract. This work aims to identify the diet and feeding strategy of *Odontesthes bonariensis* at Mirim Lagoon, RS. Diet analysis was described based on gravimetric percentages (%G), frequency of occurrence (%FO) and adjusted frequency of occurrence (%FOadj). Feeding strategy was analyzed and graphically represented, considering the above-cited indexes and grouping prey into higher taxonomic categories. Overall, 71.2% of the specimens presented prey in their digestive tracts and 28.8% were empty. Eight prey groups were identified from which only teleosteans, crustaceans and gastropod mollusks were considered important. The remaining preys identified in the diet were bivalve mollusks, insects, organic remains and plants. Prey grouping and the dominance index identified the gastropods *Heleobia* sp. (Hydrobiidae), tanaidaceans, fish remains and plants as frequent and important in weight. Prey considered only frequent were bivalve *Corbicula fluminea* (Müller, 1774), isopod, *Macrobrachium borelli* (Nobili, 1896) and organic remains. Based on these results we concluded that the silverside *O. bonariensis* inhabiting the Mirim Lagoon is an opportunistic and essentially carnivore species, that preys preferably on fish. However, it presents great trophic plasticity, feeding on the most available prey in the environment.

Key words: Amundsen method, Neotropical fish, prey items

Resumo. Dieta e estratégia alimentar do peixe-rei *Odontesthes bonariensis* (Valenciennes 1835) (Atheriniformes: Atherinopsidae) da Lagoa Mirim, Rio Grande do Sul, Brasil. O trabalho objetivou identificar a dieta e a estratégia alimentar de *Odontesthes bonariensis* na Lagoa Mirim, RS. A análise da dieta foi descrita com base nos percentuais gravimétrico (%G), de frequência de ocorrência (%FO) e de frequência de ocorrência ajustada (%FOaj). A estratégia alimentar foi analisada e representada graficamente, levando-se em conta os índices acima citados e agrupando-se as presas em categorias taxonômicas superiores. Ao todo, 71,2% dos exemplares apresentaram presas em seus tratos digestórios e 28,8% estavam vazios. Oito grupos de presas foram identificados, sendo os teleósteos, crustáceos e moluscos gastrópodes considerados os mais importantes. As demais presas identificadas pertenceram ao grupo dos moluscos bivalves, insetos, restos orgânicos e vegetais. O agrupamento das presas e o índice de dominância usado identificaram como presas frequentes e importantes em peso, os gastrópodes *Heleobia* sp. (Hydrobiidae), tanaidáceos, restos de peixes e vegetais. Presas somente frequentes foram o bivalve *Corbicula fluminea*, isópodes, *Macrobrachium borelli* e restos orgânicos. Com base nestes resultados conclui-se que o peixe-rei *O. bonariensis* que habita a Lagoa Mirim é uma espécie oportunista e essencialmente carnívora, que preda preferencialmente peixes. No entanto, possui grande plasticidade trófica, alimentando-se das presas disponíveis no ambiente.

Palavras chave: Método de Amundsen, peixes neotropicais, itens alimentares

Introduction

Species from the family Atherinopsidae show a wide geographic distribution, occurring in most temperate and tropical coastal marine regions. They also inhabit estuaries and freshwater environments, forming small schools in shallow waters (White 1985). Among the various Atherinopsidae species already described, the silverside *Odontesthes bonariensis* is considered of great recreational and commercial importance, as a fishery resource.

Studies addressing the biology of the Atherinopsidae are relatively scarce, being restricted in its majority to species listing (Evermann & Kendall 1906, de Buen 1953, Figueiredo & Menezes 1978) and systematic or phylogenetic studies (Dyer & Chernoff 1996, Bemvenuti 2002, 2005). In terms of trophic ecology studies, many authors have considered the Atherinopsidae species as planktophagous or primary/secondary consumers (Ringuelet 1942, Paiva & Schefer 1982, Bemvenuti 1990), as well as benthophagous (Rodrigues & Bemvenuti 2001).

Feeding is undoubtedly the most investigated aspect of *O. bonariensis* biology, especially in the Argentinean region, where scientific, commercial and recreational interest is very large. Ringuelet (1942) studied the trophic spectrum of *O. bonariensis* in various lagoons of Buenos Aires province, in Azulón Bay and the Comedero Lagoon. This work was pioneer in *O. bonariensis* feeding studies, being the starting point for other studies, such as those carried out by Iriart & Ringuelet (1966), Destéfani *et al.* (1967, 1969), Destéfani & Freyre (1972) and Ringuelet *et al.* (1980), where trophic complementation and efficiency relationships of plankton in this species' feeding were approached.

Odontesthes bonariensis belongs to a group of fish that filters particles present in the water column by means of thin and numerous gill rakers located in the pharyngeal cavity (Ringuelet *et al.* 1980). Their main prey are microcrustaceans (Casseiro *et al.* 2005); however, larger organisms, such as mollusks, are also part of their diet (Piedras & Pouey 2005).

The aim of this work was to perform a quantitative study of the diet composition of *O. bonariensis* captured at Mirim Lagoon, Rio Grande do Sul (Brazil), as well as identify the feeding strategy employed by this species in this environment.

Material and Methods

Study Area

The specimens were collected at Mirim Lagoon (Fig. 1), close to the Taim Ecological Station. The Mirim Lagoon extends for approximately 195 km, with a mean width of 22 km and a maximum width of 37 km. Its total area is 3750 km², of which 2382 km² are in Brazilian territory (Delaney 1965). The main rivers flowing into the Mirim Lagoon are the Jaguarão River (Brazilian side) and the Cebollati and San Luis Rivers (Uruguayan side).

Fish Sampling

The larger fish were obtained through a local fisherman duly authorized to fish with small mesh gill nets (Instituto Brasileiro de Meio Ambiente – IBAMA, License # 059/97). These specimens were collected in deeper areas (\approx 4 m) of Mirim Lagoon utilizing gill nets with meshes of 20, 35 and 40 mm between opposing knots, during three distinct periods: 1) January, February, April, June, July, August and September, 1996; 2) June, July, September and November, 1997; and 3) July 1998.

During these same periods, field expeditions were performed to sample small fish (juveniles), found mainly at the lagoon margins (Rodrigues & Bemvenuti 2001). For these samplings a beach seine was used at the shallow sandy beaches (depth < 1.5 m).

All specimens were fixed in 10% formalin and preserved in 70% ethanol. A number of 32 examined specimens were stored at the Ichthyological Collection of FURG: *Odontesthes bonariensis* FURG 96001 (N = 21) Mirim Lagoon, RS, 28 August 1996; FURG 97131 (N = 5) idem, 11 July 1997; FURG 98124 (N = 6) idem, July 1998.

Data analyses

For the descriptive analysis of the size structure of the collected specimens a histogram was utilized (standard length SL in mm). The diet of *O. bonariensis* specimens was evaluated based on the examination of the digestive tract, based in Bemvenuti (1990). When present, prey items were removed and placed on a Petri dish, for posterior separation and identification at the lowest possible taxonomic level.

The gut fullness degree was estimated by a visual method (Zavala-Camin 1996, Figueiredo & Vieira 1998), varying from full (digestive tract totally filled with prey), partially full (from 1/3 to 2/3 of its capacity occupied by preys), to empty (without content). Diet analysis was described based

on gravimetric percentages (%G), frequency of occurrence (%FO) and adjusted frequency of occurrence (%FOadj) (Hyslop 1980). The

gravimetric percentage was obtained by means of the wet weight of each food item (0.001 g).

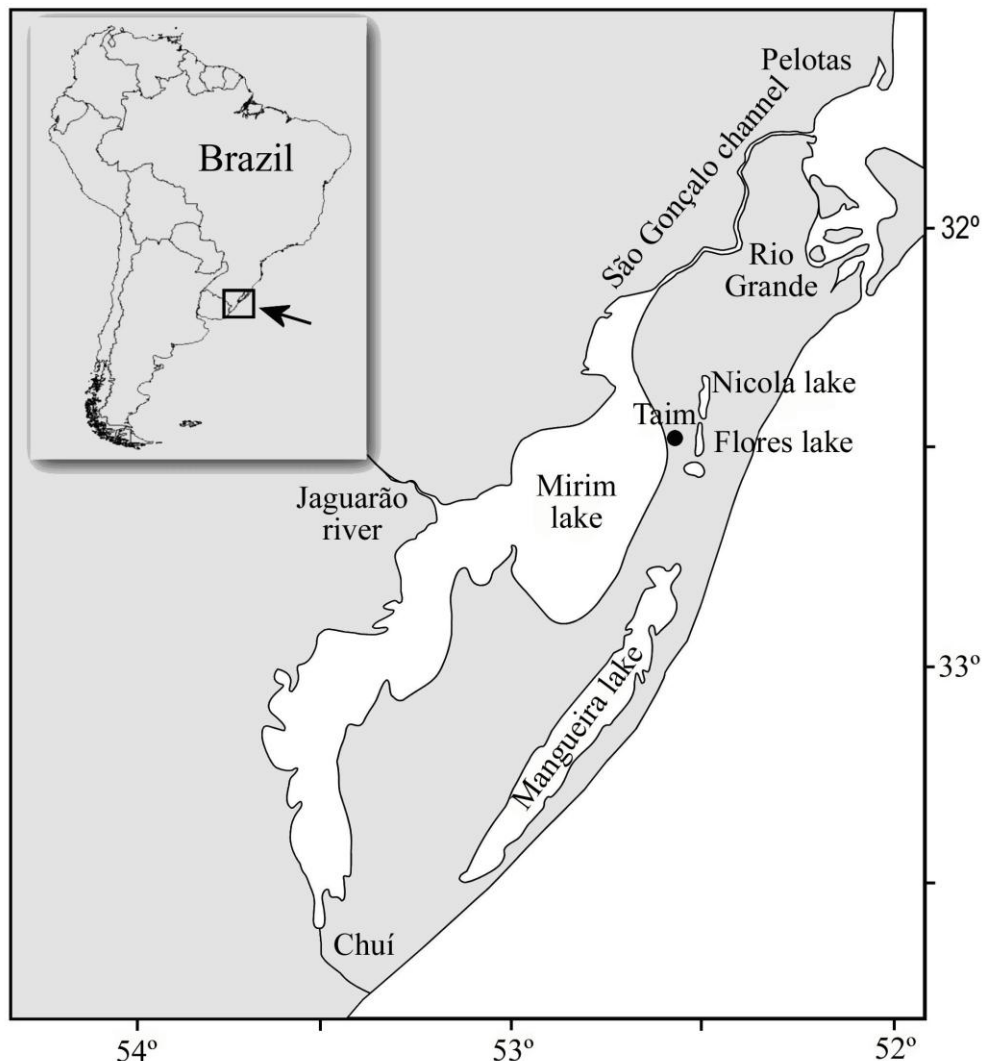


Figure 1. Location of the sample station (Taim) and Mirim Lagoon in the Southern portion of the Rio Grande do Sul state.

These indexes were calculated by grouping prey items into higher taxonomic categories (Crow 1981). Preys which obtained at least one of these indexes (%G or %FOadj) higher or equal to the $100/S$ relationship (dominance index, where S = number of preys in all analyzed specimens), were considered important and utilized for describing the species' diet. Graphically, diet and feeding strategy were represented by the method proposed by Amundsen *et al.* (1996), where items encountered below the dominance isolines are considered occasional and/or accidental in the species' diet.

Results

A total of 118 specimens distributed between 60 and 380 mm SL classes were analyzed.

Two distinct modal classes were observed, one in the 160 mm SL class, constituted by 21 specimens, and the other in the 300 mm SL class, formed by 17 specimens (Fig. 2a).

Specimens smaller than 40 mm SL were not caught. The occurrence of these two modal classes is directly related to the sampling methods employed. Specimens belonging to the smaller size classes were captured with the beach seine, in low depth areas, usually less than 1.5 m. On the other hand, specimens belonging to the larger size classes were captured with gill nets whose mesh sizes are selective for larger specimens. Fishes with full digestive tracts were observed only from class 200 mm SL onwards, while empty tracts were encountered in practically all length classes, with the

exception of the 60 and 380 mm SL.

The gut fullness degree frequency showed that 71.2% of the analyzed specimens presented

some kind of prey in their tracts (15.3% full and 55.9% partially full), while 28.8% were empty (Fig. 2b).

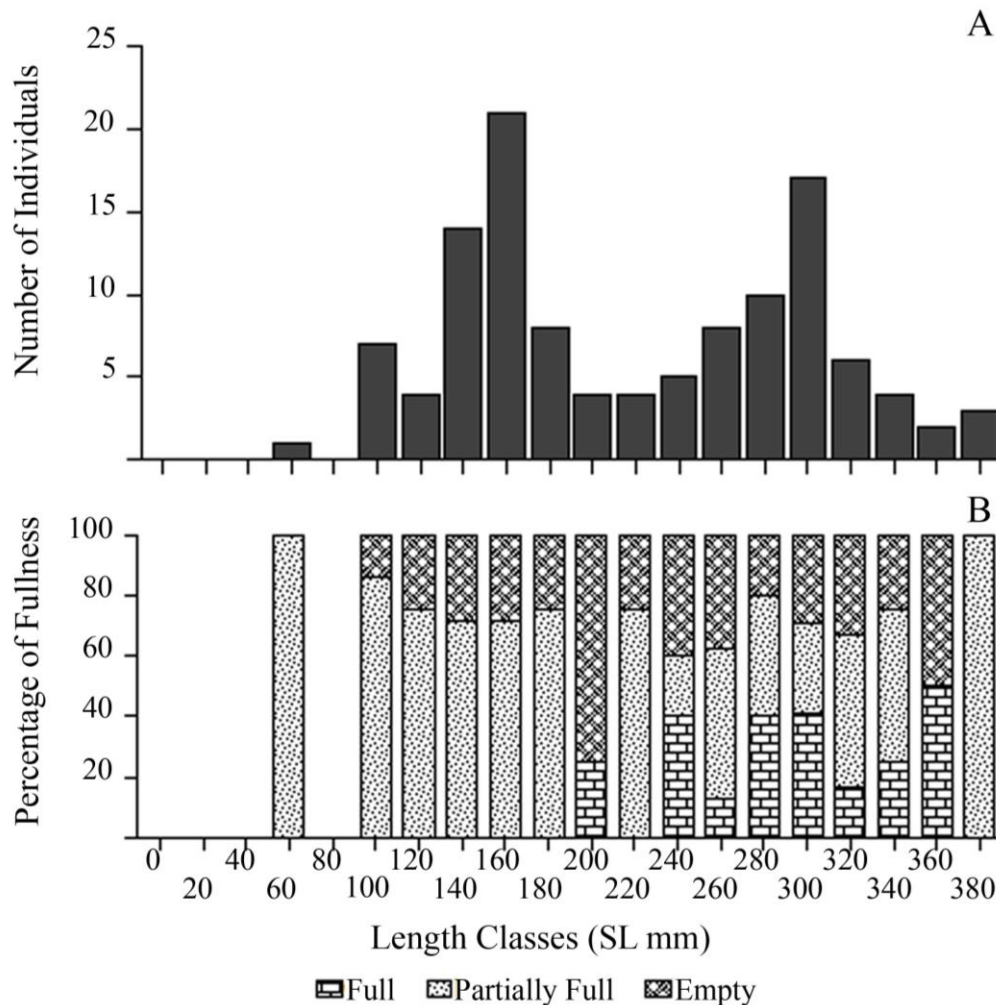


Figure 2. a) Size distribution of *Odontesthes bonariensis* individuals (n = 118) per length classes used for diet description, and b) Percentage of gut fullness degree of *Odontesthes bonariensis* (n = 118) per length classes.

A total of 21 different categories and eight different groups were identified, with three of these being responsible for 84.6% of the weight importance: teleosteans (%G = 48.8), crustaceans (%G = 21.1) and gastropod mollusks (%G = 14.7). The remaining preys (15.4%) included bivalve mollusks, insects, organic matter remains, plant remains, sand grains, and unidentifiable prey remains (Table 1).

Unidentified fish was the most important prey in weight and frequency of occurrence (47.0% and 15.2% respectively). Also recorded in this group were small fish identified by means of their bone structures as belonging to family Engraulidae, but with low representation in weight and frequency. Eggs and scales were also present in the diet of *Odontesthes bonariensis*, but in small quantities.

Crustaceans, responsible for 21.1% of the weight importance, were the most frequent prey in the diet of *O. bonariensis*, and the tanaidaceans were the most important in terms of weight (18.6%) and occurrence (5.4%). Isopods, shrimp fragments and the freshwater shrimp *Macrobrachium borelli* were important in frequency of occurrence, but not in weight percentage.

The gastropod mollusk prey item, represented mainly by *Heleobia* sp., was responsible for 14.7% of the weight and was the fourth prey group in terms of occurrence (12.7%), following the insect group, which represented 18.2% of the registered occurrences.

Based on dominance index, it was possible to identify six dominant prey groups: unidentified fish, gastropod *Heleobia* sp., coleopteran fragments,

bivalve mollusk *Corbicula fluminea*, plant remains and unidentified tanaidaceans (Fig. 3). These preys were responsible for describing the feeding strategy utilized by this species in the studied environment.

Table 1. Prey encountered in the diet of *Odontesthes bonariensis*. %G = gravimetric percentage (weight), %FO = percentage of frequency of occurrence and %FO_{adj} = percentage of adjusted frequency of occurrence.

PREY ITEMS	%G	%FO	%FO _{adj}
Gastropoda			
<i>Heleobia</i> sp.	14.7	31.0	12.7
Bivalvia			
<i>Corbicula fluminea</i>	2.7	16.7	6.9
<i>Neocorbicula limosa</i>	0.5	7.1	2.9
<i>Diplodon</i> sp.	-	1.2	0.5
Crustacea			
Isopoda	0.6	15.5	6.4
<i>Macrobrachium borelli</i>	1.4	11.9	4.9
<i>Palaeomonetes argentinus</i>	0.2	6.0	2.5
Shrimp fragments	0.2	11.9	4.9
Tanaidacea	18.6	13.1	5.4
Insecta			
Diptera	0.1	4.8	2.0
Coleoptera	3.9	19.0	7.8
Hymenoptera	0.1	1.2	0.5
Hemiptera	-	1.2	0.5
Larvae	-	6.0	2.5
Insect fragments	0.1	11.9	4.9
Teleostean			
Engraulidae	1.5	2.4	1.0
Fish eggs	0.1	1.2	0.5
Scales	0.3	8.3	3.4
Unidentified Fish	47.0	36.9	15.2
Remains			
Organic matter	0.7	8.3	3.4
Plants	6.5	16.7	6.9
Others	-	7.1	2.9
-	-	-	-
Sand Grains	0.6	3.6	1.5

Frequency and importance in weight

Frequency

< 0.1%

-

-

-

Analysis of the buco-pharyngeal structure of *O. bonariensis* showed that this species presents thin and numerous gill rakers (Fig. 4), characteristic of filter feeder species.

However, when the structures of the

superior (Fig. 5a) and inferior (Fig. 5b) pharyngeal teeth plates were analyzed, it was observed that they presented different formats, from thin and pointy to thick and rounded, which could be an indication of adaptation for preying on different types of prey.

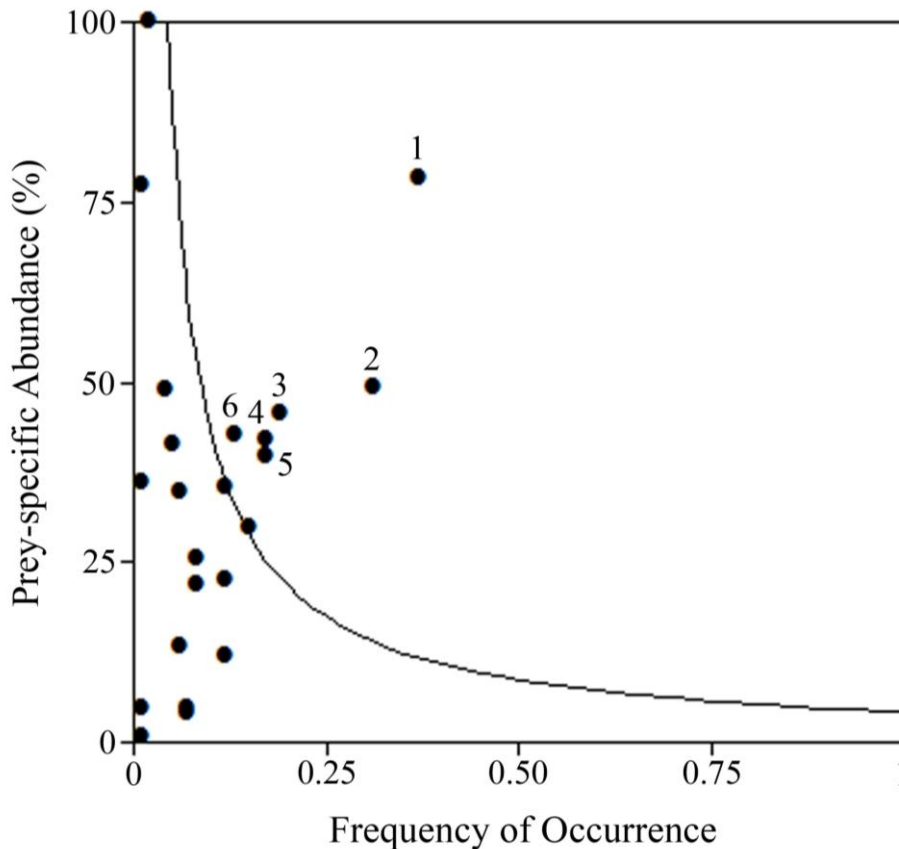


Figure 3. Graphic representation of feeding strategy of *Odontesthes bonariensis*. Isoline represents the level of dominance (Isoline = 4.35). The dominant prey items in the diet are: 1) Unidentified fishes; 2) *Heleobia* sp.; 3) Coleoptera; 4) plant remains; 5) *Corbicula fluminea* and 6) Tanaidacea.

Discussion

The silverside *Odontesthes bonariensis* that inhabits the Mirim Lagoon is an essentially carnivore species, which feeds mainly on fish, crustaceans and gastropod mollusks. This diet may be directly related to their buco-pharyngeal structure, with thick and rounded pharyngeal teeth, functioning for grinding prey with hard carapaces, such as crustaceans and mollusks.

The preference for fish, crustaceans and gastropod mollusks observed in the present study differs from early observations by Ringuélet (1942) and Ringuélet *et al.* (1980), who found for this species a diet composed mainly of planktonic crustaceans (copepods and cladocerans), in addition to small quantities of plant-originated prey, in Argentina.

A recent study have identified as dominant preys for this species microcrustaceans (cladocera and copepods), as well as insects, scales and organic detritus (Cassemiro *et al.* 2003). This study partially agrees with the results obtained in the past by the

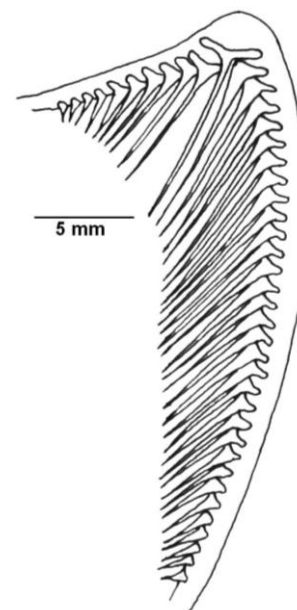


Figure 4. Drawing of the first left branchial arch of *Odontesthes bonariensis*, showing the thin, long and numerous gill rakers.

Argentinean researchers as well as those obtained in the present study, where fish, crustaceans and mollusks were the main representatives of this species' diet. This evidence can be corroborated by Piedras & Pouey's studies (2005), who identified benthonic invertebrates (bivalves and gastropods) as the species' main prey type in the Mirim and Mangueira lagoons.

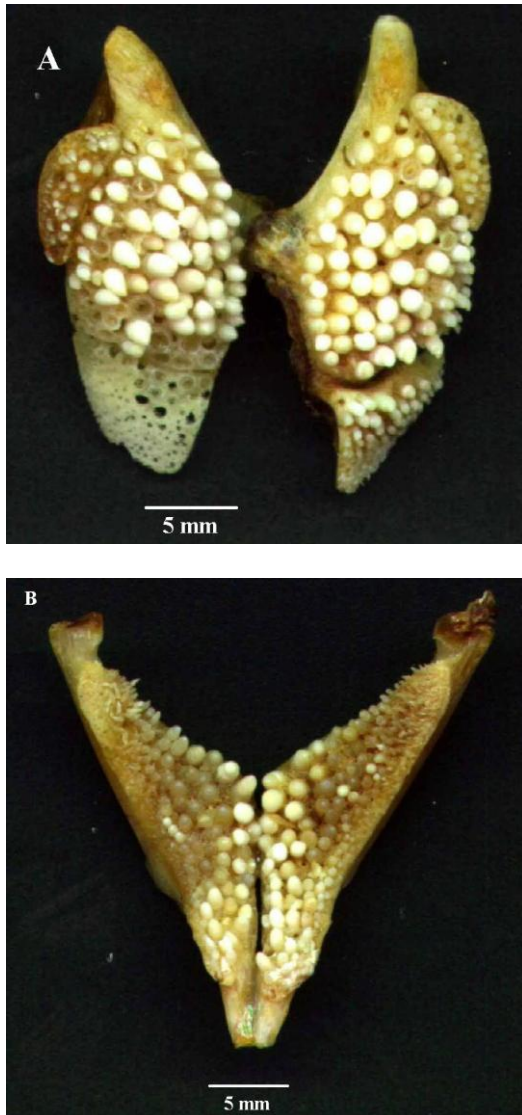


Figure 5. Structure of *O. bonariensis* pharyngeal teeth: a) superior pharyngeal teeth plates b) inferior pharyngeal teeth plates, showing the varied forms of pharyngeal teeth.

However, in an artificial pond for aquaculture, Piedras *et al.* (2006) observed that crustaceans and insects were the main prey present in the digestive tracts of the studied specimens. It should be considered that culture (tanks or dams) specimens are allocated in an environment with

spatial and feeding restrictions, with the type of prey varying according to environmental availability.

Studies performed in the Mar Chiquita Lagoon, Argentina, identified *O. bonariensis* as a zoophagous species, feeding on fish, gastropod mollusks and insects (Sagretti & Bistoni 2001). Such data is very similar to the ones obtained in this work, even if for environments with completely different characteristics. Based on the information obtained in this study, it can be affirmed that *O. bonariensis* is a carnivore species and has a high capacity for taking advantage of prey availability in the environment.

Odontesthes bonariensis presented an opportunistic feeding strategy and this diet opportunism is indicated mainly by the diversity of dominant prey. Specimens in the population preyed on different types of prey, and each food category was consumed by a small part of the population. According to Amundsen *et al.* (1996), this indicates that the species has preference for a determined type of prey; however, it also presents high trophic plasticity and capacity of exploration of more available prey in the environment at a particular moment.

One aspect considered important in fish biology is the feeding of the species (Wootton 1990). Studies on trophic ecology are nowadays the main instrument for improving the knowledge on the dynamics of aquatic ecosystems, since they provide information on the trophic relations among different fish species, and among these species and the organisms that constitute their potential food. This work complements the knowledge on the trophic biology of *O. bonariensis*, in an environment where trophic webs are still poorly studied.

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