Neotropical Ichthyology, 1(2):127-131, 2003

Diet and trophic ecomorphology of the silverside, *Odontesthes bonariensis*, of the Salto Caxias reservoir, rio Iguaçu, Paraná, Brazil

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This study aims to analyze the diet and trophic ecomorphology of *Odontesthes bonariensis*, relating these features with species' abundance in the natural environment and in the Salto Caxias reservoir (at Iguaçu river) after the reservoir's formation. The samples were carried out before (from March 1997 to February 1998- pre) and after (from October 1998 to February 2001 – post 1 and 2) the damming. The stomach contents of 218 individuals were analyzed by occurrence and volumetric methods. *O. bonariensis*' diet is based on insects, scales, plants and detritus. Microcrustaceans (Cladocera and Copepoda) were the main items, allowing the characterization of the species as zooplanktivore. The species has a superior position and protractible mouth, with small teeth, creating a serrated pattern, uniformly lined side by side. There are many gill rakers, that are long and close together (typical of filtering fishes); the stomach is ill defined and the intestine is short. There was a gradual increase of *O. bonariensis*' abundance during the period of field study, mainly after the second year of damming. This fact seems to be closely related with the high abundance and availability of zooplankton in the dammed environment, and also with the ability of the species to exploit this resource.

Este estudo teve como objetivo analisar a dieta e ecomorfologia trófica de *Odontesthes bonariensis*, relacionando estes aspectos à abundância da espécie, no ambiente natural e após a formação do reservatório de Salto Caxias, Rio Iguaçu. As coletas foram realizadas antes (de março de 1997 a fevereiro de 1998 - pré-represamento) e após o represamento (de outubro de 1998 a fevereiro de 2001- pós 1 e 2) e os conteúdos estomacais de 218 exemplares foram analisados pelos métodos de ocorrência e volumétrico. A dieta baseou-se em insetos, escamas, vegetais e detritos, sendo que microcrustáceos (Cladocera e Copepoda) foram dominantes, permitindo caracterizar a espécie como zooplanctívora. A espécie possui boca superior e protátil com dentes pequenos, dispostos em fileiras, conferindo-lhes um aspecto serrilhado. Os rastros branquiais são numerosos, longos e próximos entre si (típico de peixe filtrador), o estômago é pouco definido e seu intestino curto. Houve um incremento gradativo na abundância de *O. bonariensis*, durante o período de coletas, principalmente no segundo ano após o represamento. Este fato parece estar estreitamente relacionado com a elevada abundância e disponibilidade de zooplâncton no ambiente represado e a capacidade da espécie em explorar este recurso.

Key words: Atherinidae, feeding, planktivory, morphology, freshwater.

Introduction

The construction of Salto Caxias UHE, in October 1998, has created the fifth and last reservoir of a rank of four other reservoirs upstream of the rio Iguaçu (Júlio Júnior *et al*., 1997). Studies about the fish fauna began one year before dam closure and extended two years more (Project-UEM/Nupélia/COPEL).

These studies estimated that fish fauna in this environment compose almost 80% of the endemic species, and *Odontesthes bonariensis* is one of the eight introduced species, although its introduction to the rio Iguaçu is not well documented. It is an indigenous species of the Argentine and South extreme Brazil (Bemvenuti, 1990), and it has been introduced in some reservoirs (Quirós & Boveri, 1999) due to its good adaptation to lentic ecosystems with medium and high productivity. Moreover, it represents high fishing

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resource for sports and commercial fishing (Scasso & Campos, 1999). Bemvenuti (2002) points out that other Atherinidae species are also used in also used in aquiculture and so, suggests more detailed biological studies about this taxonomic group.of *O. bonariensis*.

In recently formed reservoirs, many species, at least temporarily, change their food habits, except those that have strong morphologic adaptations (such as specialist species) or those whose preferential food resources increase or remain constant. Studies in Salto Caxias reservoir, before and after impoundment, estimated that at least 30% of the species changed its diets (Delariva, 2002).

The few studies about natural feeding of *O. bonariensis* report its omnivory feeding habit (Ringuelet, 1942) or its zooplanktivory facultative habit (Ringuelet, 1967). Ontogenetic shift diet was reported by Piedras *et al.*, (1987) and Bemvenuti (1990), which showed that juvenile specimens eat zooplankton and adult specimens are insectivores or piscivores.

In this study, we analyzed some of the *O. bonariensis*' biological features, such as natural feeding, trophic morphology and abundance during the formation of Salto Caxias reservoir. In order to establish their feeding habit in the recently created environment, we take into account the relationship between diet and trophic morphology. We also discuss if these factors had been influenced by the abundance of the species at this reservoir.

Study Area. The studied area is located in the influence area of Salto Caxias reservoir (25° 32' S and 53° 30' W; 25° 35' S and 53° 06' W), at the Iguaçu river, Southwest of the Paraná state, between municipal districts of Capitão Leônidas Marques and Nova Prata do Iguaçu. This reservoir is located about 180 km upstream of the Iguaçu waterfalls and 100 km downstream of the Salto Osório reservoir (Fig.1).

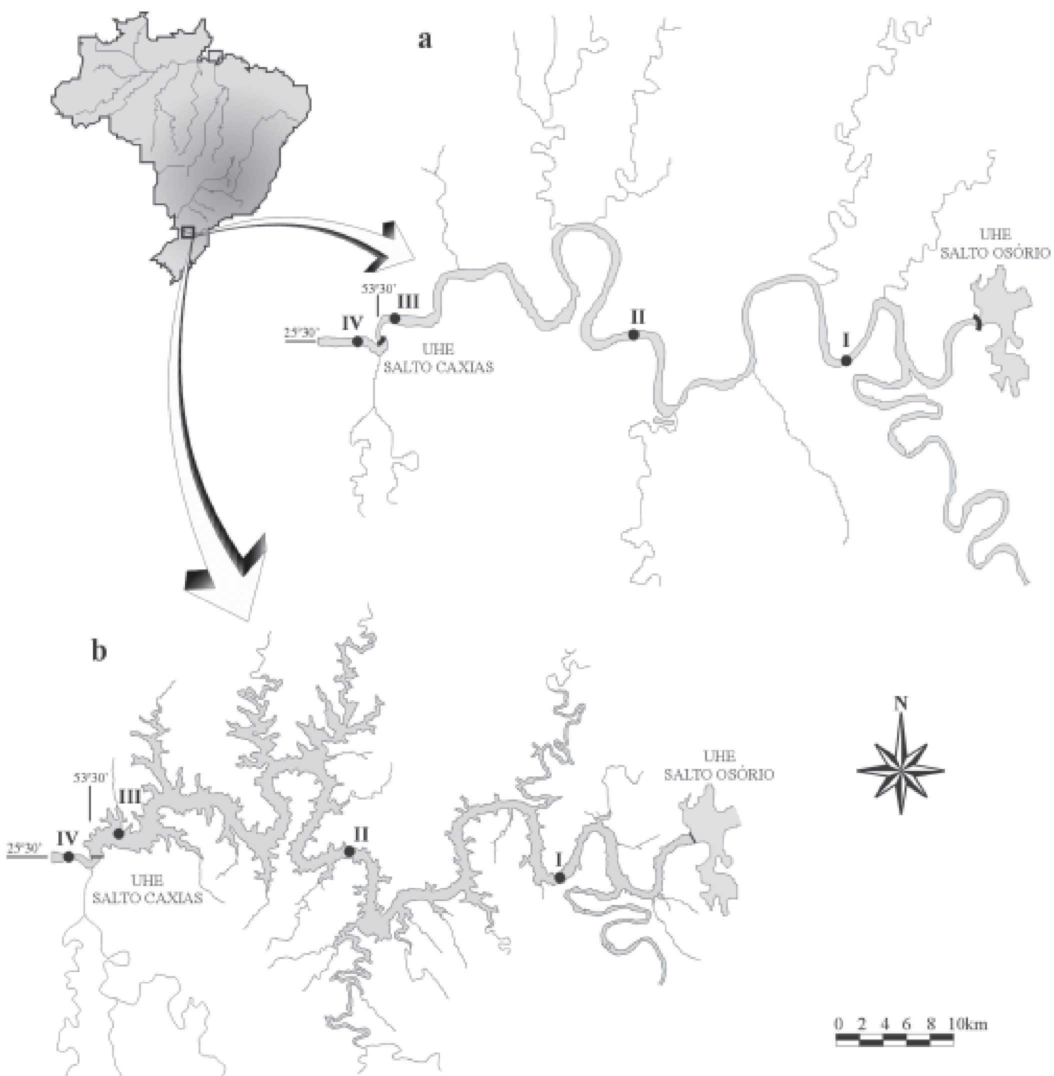

Fig. 1. Map of the studied area. Iguaçu river (a) and Salto Caxias reservoir (b).

Material and Methods

Different sampling sites were chosen along the reservoir, distributed in: I- downstream of the UHE Salto Osório; II- Porto Vorá; III- upstream of the dam; IV- downstream of the UHE Salto Caxias. Eleven more sites located in small rivers near the dam were sampled (Fig. 1).

Samples were taken using three batteries of 15 gillnets (2.4 to 14.0 cm) left for 24 hours. Fish were removed in the morning (8:00h), evening (16:00h) and at night (22:00h). In the pre-impoundment period the samples were taken from March 1997 to February 1998 (in order to calculate the species' abundance) and the post-impoundment period, from November 1998 to January 2000 (post 1) and March 2000 to February 2001 (post 2).

The specimens captured were measured and weighed. The digestive tract was excised and fixed in 4% formaldehyde. The stomach contents of 218 specimens, with standard length varying from 6.0 cm to 27.0 cm (mean = 17.3 cm), including juvenile and adult specimens, were analyzed by frequency of occurrence and volumetric methods. Volume of each food item was determined using graduated test tubes and a counting chamber for items whose volume was lower than 0.1ml (Hellawel & Abel, 1971).

Dates of stomach content analysis were graphically represented according to Costello (1990). The method consists of scatter plot of volume values in the y axis and occurrence values in the x axis. Points located near 100% of occurrence and 1% of volume show that the predator consumed different preys in low quantity, a hypothetical example of a trophic generalist species; on the other hand, points located near 1% of occurrence and 100% of volume show that the predator is a specialist for a given prey.

Voucher specimens are deposited at the ichthyological collection of the Center of Research in Limnology, Ichtyology and Aquiculture (Nupélia): NUP 1610 (06 ex.), Salto Caxias reservoir, Iguaçu river basin, Paraná state, Brazil, 2001, collected by Nupélia staff. Ten specimens of different sizes were taken at random for morphologic characterization. We drew and described the position and shape of mouth, gill rakers and digestive tract.

The species' abundance was estimated in terms of number of captures by unit of effort (CPUE). This measure is given by the number of specimens by 1000 m2 of net in 24 hours and taken by formula: CPUE = (C/E) x 1000 m2 / 24 hours, where: CPUE = Number of specimens by 1000 m2 of net / 24 hours; C = Number captured specimens; E = Total of effort (as m2 of net).

Results

Diet. The diet ranged among microcrustaceans, insects, scales, plants and detritus. However, Copepoda and Cladocera were the most important items, representing 82% of occurrence and 49% of the total volume and Cladocera 48% of occurrence and 15% of the total volume. The other items were all rare (Fig. 2).

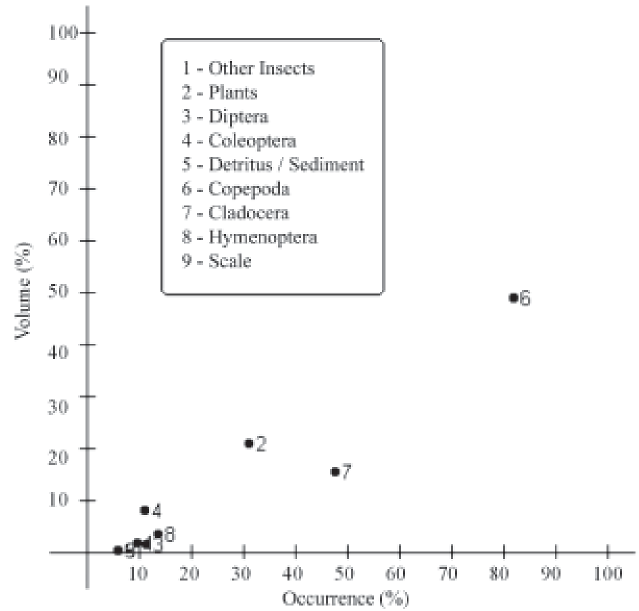

Fig. 2. Proportion of the food items in the diet of the *O. bonariensis* representing by Costello's method.

Trophic morphology. The mouth of this species shows superior position with reduced lips. The premaxillary is separated from the maxillary bone by thick and strong skin permitting wide protractibility to this organ. The teeth are small, similar among themselves and with uniform distribution. There are three at four ranks of teeth in premaxillary and dentary bones, creating a serrated pattern (Fig. 3 a). The gill rakers (just at the first arch), numerous and comb-shaped prolonged structures, are close together (Fig. 3 b). The first portion of the digestive tract is a short esophagus. It is followed by a straight and ill defined stomach whose wall is thick, and continues to a short intestine (Fig. 3 c).

Capture. Dates of captures of *O. bonariensis* before and after damming showed considerable increase in abundance, mainly in the second year (post 2) after damming (Fig. 4).

Discussion

Odontesthes bonariensis had a zooplanktivore feeding habit at Salto Caxias reservoir (independently of the individuals class sizes), in partial agreement with other studies about this species in natural environments (Ringuelet, 1942; Hartz, 1997; Bemvenuti, 1990; 2002). Besides of the tendency in exploit zooplankton organisms, the dammed environment had certainly favored this strategy by the wide availability of this food supply. It's well known that the first years of damming are characterized by the high rates of primary productivity, which increase the biological productivity in other levels of the food web, such as the zooplankton organisms. It is generally attributed to the high levels of nutrients availability within impounded environments, a consequence of the organic matter that had been flooded (O'Brien, 1990).

Studies about the zooplankton communities carried out before and after the Salto Caxias damming showed a significant increase of these organisms in the environment (Serafim Júnior, 2002). Although some fish species fed on microcrustaceans, mainly during the second year of reservoir formation (pers. obs.), to *O. bonariensis* this was an almost exclusive food supply.

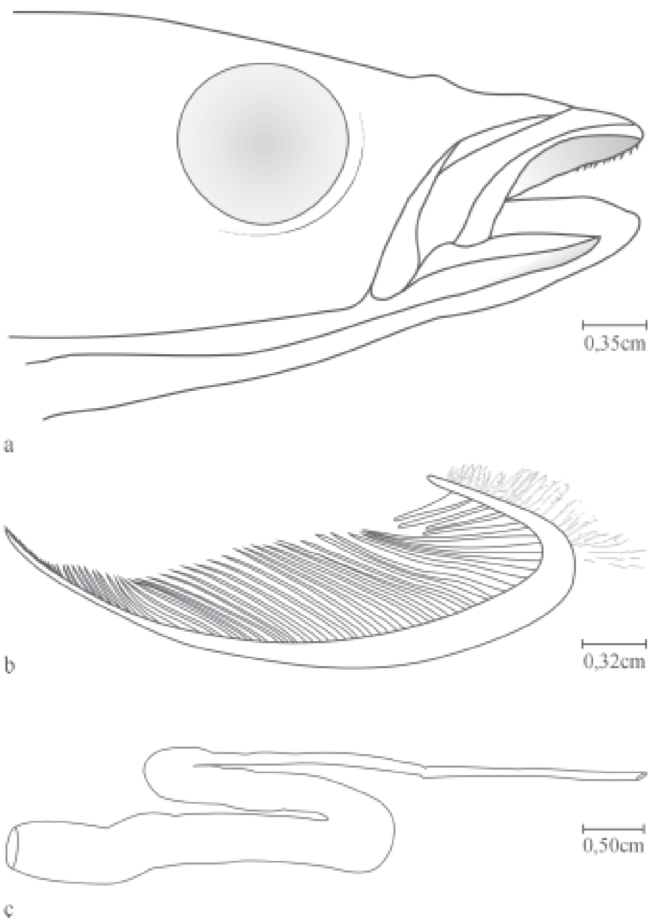

Fig. 3. a) Position and form of the mouth of *O. bonariensis;* **b)** left gill rackers; **c)** digestive tract**.**

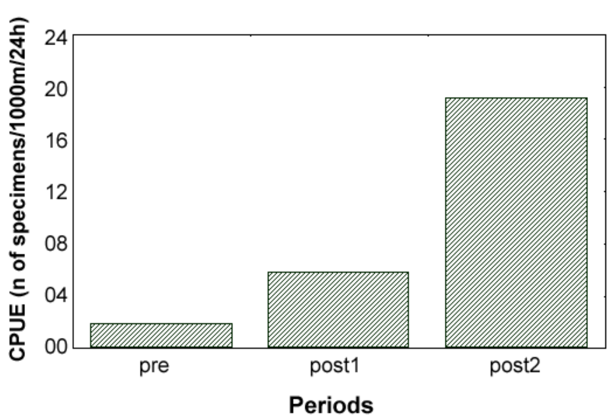

Fig. 4. *Odontesthes bonariensis* numerical abundance (CPUE), before and after the Salto Caxias damming.

Morphological patterns related to feeding markedly reflect the diet of a fish, mainly when it is a specialist species. The position and morphology of the mouth can indicate the depth in the water column where the fish is feeding; the gill rakers specify the size of the prey, while the form and length of the intestine point to the resource type.

Bemvenuti (1990), studying morphological patterns of two species of silverside, pointed out that to *Odontesthes* sp., as the mouth diameter increase, the individuals change the feeding habit from "sucker" to "grabber". Probably, this strategy could be similar to *O. bonariensis*'. However, in lentic environments, with a wide range of availability of microcrustaceans, it is possible that *O. bonariensis* could use both ways to capture their preys. The mouth and the big eye suggest that it is a particulate-feeder, making use of visual cues to seek and capture its prey (Gerking, 1994), whereas the patterns of gill rakers (similar to *Hypophthalmus edentatus*, a typical filtering fish from Paraná river) suggest feeding by filtration.

Some authors point out the ill defined morphology of *O. bonariensis'* digestive tract (De Buen, 1953, Bemvenuti, 1990; 2002), although Boschi & Fuster de Plaza (1959) think that this pattern is common among omnivores fish species. Conversely, the majority of fishes typically omnivores, such as *Pimelodus maculatus*, have this morphological patterns very conspicuous (Lolis & Andrian, 1996). These authors defined the stomach of *Pimelodus maculatus* as sack shaped, and according to them it is typical of omnivores and generalist carnivores. Again it is convenient to trace back to *H. edentatus*, whose digestive tract is very similar to *O. bonariensis'* (pers. obs.); this comparison could mean that a little-defined digestive tract it typical of zooplanktivore, rather than omnivore fishes.

An unavoidable effect of impoundment on the aquatic fauna is a shift in species composition and abundance, with extreme proliferation of some species and reduction, or even local extinction, of others (Agostinho *et al*., 1999). Many factors could influence fish colonization at the dammed environments, but food supply is one of the most important ones. Some fishes respond quickly to impoundment, whereas others respond only after years or decades, according to their trophic nature (Agostinho *et al*., op. cit.).

The shift in the population size (i.e. number of individuals) after the damming was well-marked during the samples, and this could indicate that, in spite of an initial stabilization process, the species had found favorable conditions for the adaptation in the lentic environments. Although this increment had been real for the silverside during the studied period, an increase of fishing effort in the second year after the damming, might had been responsible for the largest contribution of the species in that time. However, we attributed the increase of the population size as a function of the large abundance of its preferred food resource and its capacity (morphological adaptation) to exploit this available food supply. We also highlight that this species is already reproducing in the dammed environment.

Similar facts were observed in the Itaipu reservoir regarding *H. edentatus*, whose capture was rare before damming, and became one of the species more exploited in the commercial fishing after the damming (Agostinho *et al.*, 1994).

We conclude that the above mentioned patterns about the diet were closely related with the population size of *O. bonariensis* after the damming. Although in that time it had presented a restricted diet, as a function of the high abundance of zooplankton, other authors pointed out the *O. bonariensis* ability to exploit another resource in the environment such as insects, mollusks, crustaceans, other invertebrates and fishes. Hence, it could be expected that as the food supply decreases, *O. bonariensis* changes, at least partially, its diet, not necessarily reducing the population size, since it is known that it could also change feeding habits according to the availability of each food resource.

Acknowledgements

Our research programs on trophic ecology and ecomorphology have been continuously supported by Nupélia/UEM, Companhia de Energia Elétrica do Paraná (COPEL) and Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) in terms of field study financial support and personal grants (CNPq procs. 350538/02-6 to NSH, 370922/02-6 to FASC and 101379/02 to TFLVBR). We are also grateful to Eric Dibble (Mississipi State University) for reviewing the English manuscript.

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Received August 15, 2003
Accepted November 23, 2003