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A N I N T E R N A T I O N A L J O U R N A L

Feeding and Trophic Ecomorphology of *Satanoperca pappaterra* (Pisces, Cichlidae) in the Manso Reservoir, Mato Grosso State, Brazil

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ABSTRACT

The aim of this work was to evaluate the relationship between diet and features of the trophic ecomorphology of Satanoperca pappaterra (Heckel, 1840) in an impacted environment. Samples were collected from March 2000 to February 2003 in Manso Reservoir, Cuiabá River, Mato Grosso State. Analysis of 93 stomachs contents showed that food resources associated with the substrate, such as plant remains, detritus, fish scales and Chironomidae larvae, dominated the diet. Consequently this species was characterized as a detritivorous-invertivorous. However, individuals collected in 2003 showed a greater selection of benthic organisms in relation to previous periods. Morphological structures such as position of the mouth, form of the lips, gill rakers and pharyngeal teeth, in addition to the length of the intestine, showed specializations correlated with the diet. However, as long as the food was associated with the substrate, it seemed to be selected according to its abundance in the environment.

Key words: Cichlidae, diet, morphology, freshwater

INTRODUCTION

Analysis of stomach contents and particular traces give insights on the feeding ecology of a species, since these peculiarities suggest how a fish is able to feed (Fugi et al., 2001). According to Wootton (1990), analysis of some morphological aspects, such as form and position of the mouth and the teeth, gill rakers, form and size of the stomach and intestine can determine how and what an animal eats. Kullander (2003) found that for cichlids, a considerable variation existed in the form of the dentigerous plates and the teeth, which showed specialization in the diet.

The family Cichlidae includes a large number of genera and species and is widely distributed in North and South America, in addition to other continents (Kullander, 2003). *Satanoperca pappaterra* (Heckel, 1840), belonging to this family, was known as *Geophagus pappaterra* until the revision of Kullander (1986, *apud* Kullander and Ferreira, 1988). This species is common in inland waters of Brazil, Bolivia and Paraguay; however, its biology is not very well known. Kullander and Ferreira (1988) studied cichlids of the Amazon and described biological aspects of some species of *Satanoperca*. As regards the species studied here, information is quite limited. Therefore, investigations of the feeding of this

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species should fill in a gap for cichlids of South America.

Natural feeding data and morphological features of *S. pappaterra* are presented here in order to answer the following question: a) what is the degree of trophic specialization of this species? b) are there alterations in the diet corresponding with environmental changes?

MATERIAL AND METHODS

Manso Reservoir is located in Mato Grosso State ($14^0$32'-$15^0$40'S/$54^0$40'-$55^0$55'W) near to Chapada dos Guimarães National Park. The reservoir was formed in November 1999. It comprises an area of 427 km^2 at its maximum level (SONDOTÉCNICA/ELETRONORTE, 1999). Seven sampling sites were established inside Manso Reservoir (MM-1, MM-2, MM-3, CA-2, CA-3, QU, PA) (Fig. 1). Fishes were sampled using three batteries of six gillnets (2.4, 3, 4, 5, 6 and 7 cm) set for 24 hours. Samplings were conducted monthly or quarterly from March 2000 to February 2003.

Individuals captured were measured (standard length, cm) and weighed (total weight, g). The digestive tract was excised and fixed in 10% formalin. Voucher individuals were deposited at the ichthyological collection of the Center of Research in Limnology, Ichthyology and Aquaculture (Nupélia): NUP 871 (13 individuals), NUP 2185 (13 individuals), Manso Reservoir, Mato Grosso State, Brazil, collected by Nupélia staff. Stomach contents of 93 individuals, with standard length varying from 5.3 cm to 14.0 cm (mean= 9.04 cm), were analyzed according to frequency of occurrence and volumetric methods. Volume of the food items was determined using graduated cylinders and a counting chamber (Hellawel and Abel, 1971). Data are presented as Feeding Index (IA_i) values (Kawakami and Vazzoler, 1980): $IA_i=100\ F_i.V_i\ /.\sum\ (.F_i.V_i)$, where F = Frequency of occurrence of item *i* in the diet (%);V = Volume of item *i* in the diet (%). Ten individuals of different sizes were taken at random for morphological characterization.

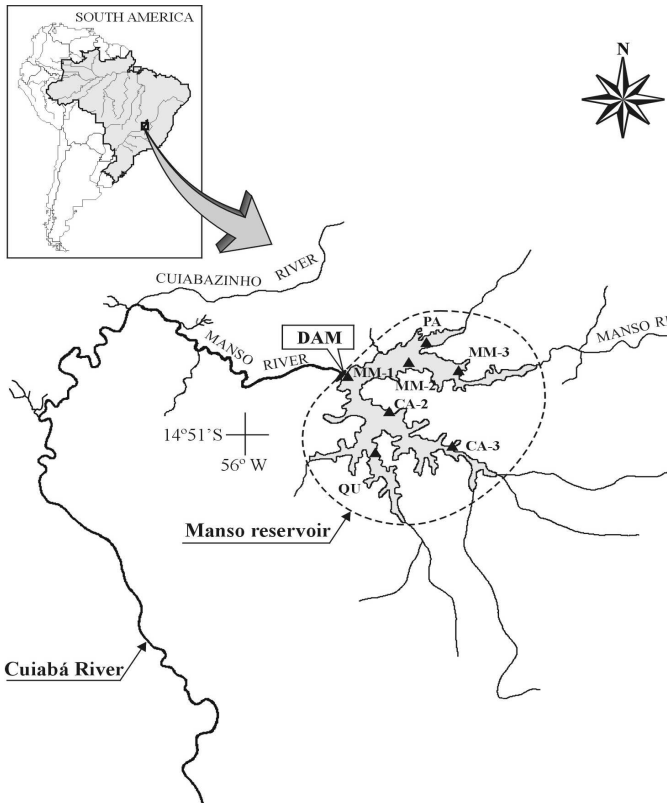

Figure 1 - Study area showing sampling locations. Dashed line indicates the area of Manso Reservoir.

RESULTS

Overall diet

In the stomach contents of S. pappaterra, 13 food items of different origins were recorded. Plant remains (30.5% of the Feeding Index -IAi), detritus/sediment (30.6%), scales (19.2%) and Chironomidae (7.9%) predominated (Fig.2).

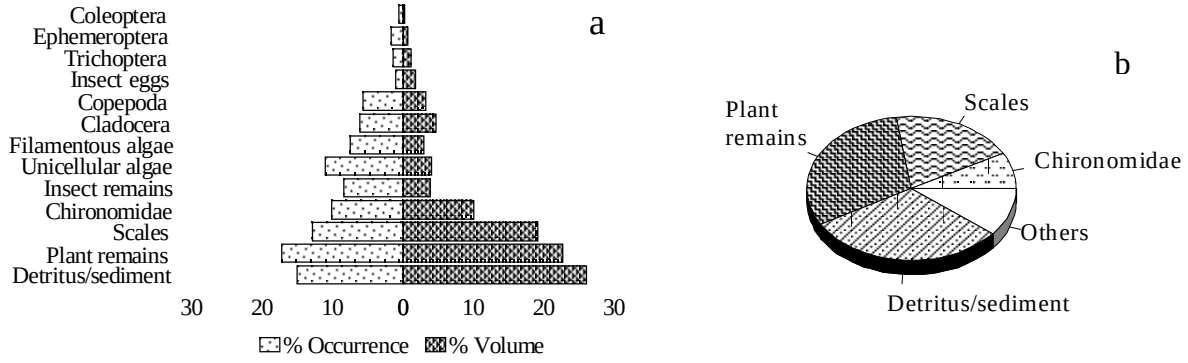

Figure 2 - a) Occurrence (%) and Volume (%), **b**) Feeding Index (% IAi) of the food items consumed by *Satanoperca pappaterra* in Manso Reservoir, Mato Grosso State.

Temporal variations in the diet

Plant remains, detritus/sediment, fish scales and benthic organisms were consumed throughout the study period. However, from 2000 to 2002 these organisms presented low IAi values. An increase in consumption of Chironomidae larvae was observed in 2003, whereas detritus presented the opposite tendency, with lower values in this year (Table I).

Trophic morphology

The relatively small mouth of this species is positioned subterminally, with a narrow gape and developed lips (Fig. 3a). In the premaxillary and dentary, the teeth are simple and conical, distributed in one or two rows. The superior pharyngeal tooth plate is roundish, whereas the inferior plate is triangulate. Both possess different sized teeth, with small simple and conical teeth at the external edges, larger teeth with three or four cusps internally (Fig. 3b). The gill rakers are soft, short and form oblique folds. The rakers of the four arches are similar and the "folds" fit into one another when the arches are close together (Fig. 3c). The stomach is sac-like and very small, and is positioned laterally to the intestine, similar to an appendix. The intestine is relatively long (Fig. 3d).

DISCUSSION

The filling of Manso Reservoir, which was initially rapid, lasted one year. This period was considered extremely critical for fish (Agostinho et al., 1999), in all vital aspects. In this period, feeding was often jeopardized due to alterations in resource abundance.

Satanoperca pappaterra was characterized as detritivorous-invertivorous independently of the body length of the individuals and during all study period. The species consumed large quantities of detritus (a mixture of plant remains and sand) in the first three years and started to select more benthic organisms, mainly Chironomidae larvae, only in the fourth year. The high consumption of detritus and plant remains in the beginning of reservoir formation could be explained by the high availability of these resources which were submerged with the filling of the reservoir.

Table 1 - Occurrence (%O), Volume (%V) and Feeding Index (% IAi), of the food items consumed by *Satanoperca pappaterra* in Manso Reservoir, Mato Grosso State. Shaded values indicate the main food items.

	2000			2001			2002			2003		
ITEMS	**% O**	**% V**	**% IAi**	**% O**	**% V**	**% IAi**	**% O**	**% V**	**% IAi**	**% O**	**% V**	**% IAi**
INSECT												
Chironomidae	10.63	8.28	6.48	9.80	8.18	5.93	8.15	7.04	4.76	14.28	20.94	21.89
Coleoptera	2.12	0.57	0.09	-	-	-	0.54	0.17	0.01	-	-	-
Ephemeroptera	1.06	0.06	0.01	0.98	0.45	0.03	1.63	1.06	0.14	3.89	0.66	0.19
Trichoptera												
Eggs	-	-	-	1.96	0.52	0.07	1.08	3.71	0.33	1.30	1.42	0.13
Remain	5.31	1.87	0.73	8.82	3.66	2.39	9.23	4.73	3.62	9.09	4.17	2.77
CRUSTACEAN												
Cladocera	9.57	12.15	8.56	4.90	2.48	0.73	5.98	1.88	0.93	3.89	4.39	1.25
Copepoda	8.51	7.31	4.58	3.92	1.67	0.48	5.43	2.74	1.23	5.19	1.54	0.58
FISH												
Scales	12.76	18.37	17.27	9.80	13.96	10.12	12.5	23.20	24.10	16.89	8.82	23.27
PLANT												
Unicellular algae	8.51	2.66	1.67	14.70	3.61	3.93	11.95	5.64	5.60	6.49	2.64	1.25
Filamentous algae	7.44	1.45	0.79	9.80	2.30	1.67	9.23	4.95	3.80	9.09	3.22	2.14
Remains	15.95	20.07	23.58	17.64	22.46	29.32	17.39	21.21	30.64	16.89	28.12	34.77
DETRITUS												
Detritus/sediment	18.08	27.20	36.26	15.69	38.78	45.03	14.13	20.90	24.53	1.69	13.69	11.71
Number of stomachs		21			17			40			15	

Generally Chironomidae larvae are well adapted to be the first colonizers of newly flooded areas Davies (1976) and endured the low oxygen concentrations that were likely to occur in new impoundments, under a considerable range of conditions (Baxter, 1977). Although these organisms were probably already present in the substrate, starting from the first months of reservoir closure, it was probable that to save energy, the species used the more accessible resource of plant remains and detritus. On the other hand, Cladocera and Copepoda were predated mainly in the first year (2000). It's well known that the first years of damming are characterized by high rates of primary productivity, supporting the development of microcrustaceans and increasing biological productivity in other levels of the food web as well.

The presence of detritus in the stomach clearly indicates that the species feeds near the substrate, which can be verified by the subterminal mouth and by the developed lips that are used to search in the mud. Casatti et al. (2003) characterized this species as predominantly algivorous, suggesting higher fidelity to the mode of obtaining food than to the type of food. For *S. lilith* of the Amazon, Kullander and Ferreira (1988) attributed a benthophagous (i.e. invertivorous) habit by the fact that grains of sand and aquatic invertebrates were the main items recorded in the stomach contents; whereas *S. jurupari* fed predominantly on plant remains (fruits, seeds and leaves). Therefore, according to the authors, this species should not feed near the bottom. Although *S. pappaterra* presented a large quantity of plant matter in the stomachs, which could corroborate the data obtained for *S. jurupari* of the Amazon, it should be emphasized that these contents were composed of decomposing plant remains. The high frequency and abundance of scales in the stomachs did not indicate that they were preyed, only that they were taken with the mouth in the substrate during foraging, which was common for several species (Kullander and Ferreira, 1988; Hahn et al., 1997).

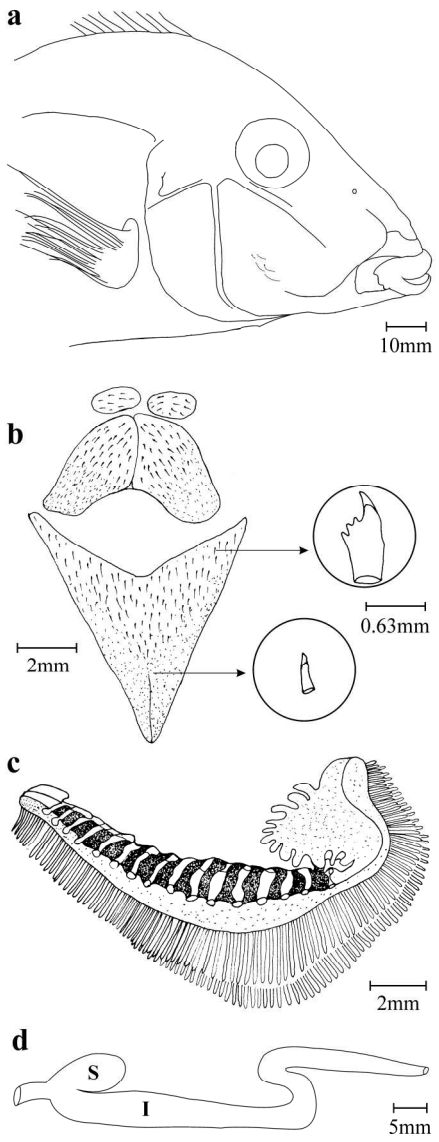

Figure 3 - Morphological characteristics of *S. pappaterra.* a) mouth, b) superior and lower pharyngeal tooth plate and teeth, c) first gill raker arch d) digestive tract, S= stomach and I= intestine.

Satanoperca pappaterra showed specializations correlated with the diet. The subterminal mouth allowed the fish to search in the substrate while supported by the caudal peduncle as observed by Casatti et al. (2003) in sub-aquatic investigations. The form and aspect of the gill rakers seem suitable for the retention of small organisms and detritus. However, Reis (1997), studying cichlids with different feeding habits (Batata Lake, Pará State, Brazil), apparently did not find marked differences among the species in relation to these structures. Casatti et al. (2003) observed that during foraging, *S. pappaterra* expelled unpalatable items through the mouth and opercles; however, in our study, grains of sand were quite abundant in the stomach. Studies on morphological relationships as regards the type of diet of bottom feeder fish such as *Loricariichthys platymetopon* and *Iheringichthys labrosus* (Fugi et al., 2001) showed that the gill rakers of these species were very similar to those of *S. pappaterra*. The small stomach of this species should be associated with the presence of pharyngeal plates, which grind ingested material before it reaches the stomach, performing the mechanical role of this organ, as suggested by Angelescu and Gneri (1949) for detritivorous fishes. The intestine seems to have an intermediate size when compared to carnivorous fish, which possess a short intestine, and detritivorous fish, which possess a very long intestine (Fryer and Iles, 1972). Fugi et al. (2001) reported intermediate intestinal lengths for *L. platymetopon* that also fed on large detritus particles and a certain amount of benthic organisms.

Although *S. pappaterra* was characterized as a detritivorous-invertivorous in this study, this did not appear to be its usual feeding habit. The conditions to which the species was exposed (during the filling of the reservoir) favored alterations in its diet. Despite the species presenting trophic adaptations, they do not restrict the intake of certain types of food. The type of diet seems to be more related to availability and abundance of resources than to any other factor, as long as the food is near the substrate.

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RESUMO

O objetivo deste estudo foi descrever e avaliar as relações entre dieta e traços da ecomorfologia

trófica de *Satanoperca pappaterra* (Heckel, 1840) em ambiente impactado. As coletas foram realizadas no reservatório de Manso, MT., entre março/2000 a fevereiro/2003. A análise de 93 estômagos, mostrou que recursos alimentares associados ao substrato, tais como restos vegetais, detritos, escamas e larvas de Chironomidae, predominaram na dieta, caracterizando esta espécie como detritívora-invertívora. Entretanto, indivíduos coletados em 2003 mostraram maior seleção de organismos bentônicos em relação aos períodos anteriores. As estruturas morfológicas, como posição da boca, forma dos lábios, rastros branquiais e dentes faríngeos, além do comprimento do intestino mostram um certo grau de especialização ao tipo de dieta. No entanto, o alimento, desde que associado ao substrato, parece ser selecionado de acordo com sua abundância no ambiente.

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