Biological aspects of *Schizodon nasutus* Kner, 1858 (Characiformes, Anostomidae) in the low Sorocaba river basin, São Paulo state, Brazil

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Abstract

Four biological aspects of *Schizodon nasutus* in the low Sorocaba river basin, São Paulo, Brazil were analysed. These were accomplished during the year seasons. The fish diet and the feeding activity were investigated by studying the repletion index, which showed no significant differences between seasons. The food items analysed by frequency of occurrence and dominance showed a predominance of vegetable items in the diet. The reproduction, analysed by using the gonadosomatic index, indicated that the reproductive period occurs during the summer period when temperatures are higher and rainfalls are more intense. The amount of accumulated fat and condition factor varied according to reproduction, especially for females.

Keywords: feeding, reproduction, condition factor, seasonality.

Aspectos da biologia de *Schizodon nasutus* Kner, 1858 (Characiformes, Anostomidae) no trecho inferior da bacia do rio Sorocaba, estado de São Paulo, Brasil

Resumo

Foram analisados quatro aspectos da biologia de *Schizodon nasutus* no trecho inferior da bacia do rio Sorocaba, estado de São Paulo, Brasil. Esses aspectos foram abordados durante as estações do ano. Na dieta da espécie, a atividade alimentar averiguada pelo índice de repleção estomacal não mostrou diferença significativa entre as estações. Os itens alimentares analisados pela frequência de ocorrência e dominância mostraram a predominância de itens de origem vegetal na dieta. A reprodução, analisada pela relação gonadossomática, indicou que o período reprodutivo ocorre durante o verão, quando há aumento de temperatura da água e das chuvas. A quantidade de gordura acumulada e o fator de condição variaram de acordo com a reprodução, principalmente para as fêmeas.

Palavras-chave: alimentação, reprodução, fator de condição, sazonalidade.

1. Introduction

The Anostomidae family is composed of approximately 110 species, restricted to South America (Santos, 1982), which show omnivorous alimentary habits (Andrian et al., 1994), though predominantly herbivorous (Britski, 1988; Gerking, 1994). *Schizodon nasutus* Kner, 1858, presents a small and subterminal mouth, which indicates it feeds on small-sized items and is able to get its food in middle or deep waters. Their general morphology indicates that they may be classified as good swimmers whose external aspect is typical of migratory fish (Teixeira and Bennemann, 2007), found in lagoons and rivers (Hahn et al., 2004).

In neotropical rivers, the alimentary activity investigations, fat development, and fish reproduction reveal that these factors are, in a general way, dependent on the hydrologic cycle. Therefore, it is important to consider both hydrological and biological factors, which coordinate such relations with the studied habitat (Bennemann et al., 1996).

Vazzoler (1996) mentions that the condition factor is an important indicator of the level of well-being in fish, and its value indicates recent nutritional conditions and/or reservoir expenses in cyclic activities, making it possible to comprehend relations with environmental conditions and behavioural aspects of a considered species. The condition factor might indicate the reproductive period, alimentary changes period, and fat accumulation (Gomiero and Braga, 2003, 2005, 2006), as well as seasonal changes in environmental conditions (Braga et al., 1985).

The biology of fish species in the lower Sorocaba river region is still poorly known. In addition, not much is known about the biology of *S. nasutus* populations living in the southeast region rivers, since the majority of

studies performed in this region were done so in modified environments, such as reservoirs. So far, there is no study specifically related to the biology of this species in this fluvial system.

The objective of this study is to describe biological aspects during the seasonal cycle of the species *S. nasutus* in the lower Sorocaba river basin analysing four biological factors: diet, reproduction, fat accumulated and condition factor.

2. Material and Methods

2.1. Study area

The Sorocaba river basin is located in São Paulo state, in a subarea known as the superior medium Tietê. The Sorocaba River represents the main river in this subsystem. The collection station (Figure 1) is located in the low Sorocaba part (23° 08' 59" S and 47° 49' 08" W; 23° 17' 39" S and 47° 46' 32" W; 23° 19' 41" S and 47° 46' 50" W). In the region, three important tributaries flow into the Sorocaba river: the Sarapui, Tatuí and Guarapó rivers, besides, a number of small streams and marginal lagoons contribute to the enlargement of the environmental variability (Villares Junior and Goitein, 2006) and are not heavily polluted (Smith, 2003).

2.2. Sampling

Fish were caught using distinct gill nets with meshes measuring 3.0; 4.0; 5.0; 6.0; 7.0; 8.0 cm between opposite knots. The sampling was performed from April 2004 to March 2006. The samples were gathered every month in three collection sites (23° 08' 59" S and 47° 49' 08" W; 23° 17' 39" S and 47° 46' 32" W; 23° 19' 41" S and 47° 46' 50"). The fishing effort was performed in a 150 m^2 area and totalled 24 samplings. After catching, the fishes were kept on ice and kept in a freezer until handling.

Water temperatures and rainfall data were also obtained during the sampling period, along with historical data, in order to study possible relationships among the biological aspects. The seasons defined as follows: autumn (March, April and May), winter (June, July and August), spring (September, October and November) and summer (December, January and February).

The pooled data represented two years of collecting in each season. For this study 118 individuals were collected, from which 85 were females and 33 males. During the manipulation the following data were obtained: Standard length (mm); total weight (g), stomach contents weight (g), sex (F = female, M = male), and gonads weight.

2.3. Data analysis

Diet

To analyse feeding activity, the Repletion Index (RI) was adopted, which consists of the relation between the mass of gut contents and total mass of the fish (Hyslop, 1980).

To study the indirect effects of food intake, the percentage of fat stored inside the visceral cavity (AF) was visual estimation (1 = without fat; 2 = with fat and 3 = full of fat).

The alimentary items found in the guts were analysed using the Frequency of Occurrence (Fi): relative percentage

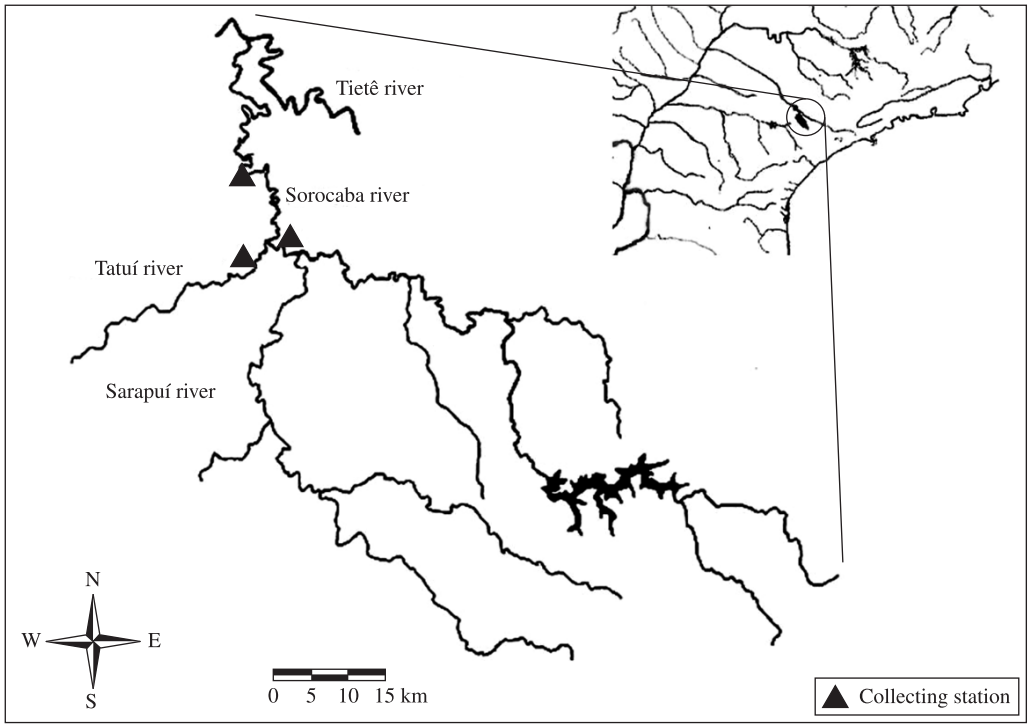

Figure 1. Map showing the location of Sorocaba river Basin and the location of the study area with collecting station.

of number of guts containing a given taxonomical group of prey compared to the total number of guts containing food in a given month (Hyslop, 1980). The stomach contents were observed by use of a stereomicroscope. The food components were identified to the lowest possible taxon level.

In order to determine the importance of each alimentary item, the methodology proposed by Bennemann et al. (2006) was adopted, proposing the use of the dominance of the alimentary item in combination to Costello`s (1990) graphic methods. The dominance is given as a percentage, which a particular food item represents as the most important of each stomach, according to the total number of samples analysed. In the graphical method the values of dominance are represented on the Y axis and the frequency of occurrence on the X axis. As a multivariate approach to determine the similarity patterns in the diet, the Morisita-Horn index (Krebs, 1998) was used, and a similarity food matrix was reduced by the use of a cluster analysis. For this statistic analysis, the software Statistica 7.1 (Stasoft, 2005) was used.

Reproduction

Analyses of reproduction was made using the Gonadossomatic Index (GSI) for which the ratio of gonad mass for total fish mass was multiplied by 100 (Vazzoler, 1996). This index was calculated separately for male and female individuals.

Condition factor

The condition factor was determined by applying the methodology proposed by Le Cren (1951): $Kn = W/aL^b$. The relative condition factor (Kn) was computed to compare fish condition of males and females between seasons. As it did not reveal normal distributions, the values of RI, Kn were compared using Kruskal-Wallis test (5%), with the subsequent analysis by the comparison method of Dunn. For this statistical analysis, the software Bio Stat 5.0 (Ayres et al., 2007) was used.

3. Results

Abiotic factors. The temperatures and rainfall data showed two distinct periods for the Sorocaba river basin. High temperatures and rainfall occurred from September to March (spring and summer), and low temperatures and rainfall from April to August (late autumn and winter) (Figure 2).

3.1. Diet

A number of 103 stomachs of *S. nasutus* was analysed, which showed no significant difference ($H = 4.1812$, $p = 0.2425$) in feeding activity between the seasons (Figure 3). The lowest (median = 0.0134; interquartilic amplitude = 0.0071) and highest (median = 0.0220; interquartilic amplitude = 0.0126) rates of food consumption were observed in winter and summer respectively.

A higher percentage of individuals with large amounts of stored fat (AF = 3) was observed in three seasons. The exception occurred during the autumn, when the opposite situation was observed (Figure 4). Spring was the season when the greatest number of individuals with high percentage of fat accumulated appeared.

It was possible to observe that the diet composition consists mainly of vegetal material. Nine food items were identified as food categories: Poaceae (grasses), vegetal fibers, algae, roots, seeds, leaves of dicotiledones, Oligochaeta (worms), Diptera larvae and detritus (Table 1).

Analyses of diet showed different items consumed during the seasons (Table 1). During the summer a higher occurrence of items of animal origin was observed, Oligochaeta (worms) and Diptera larvae, while during winter only plant items occurred (Figure 5).

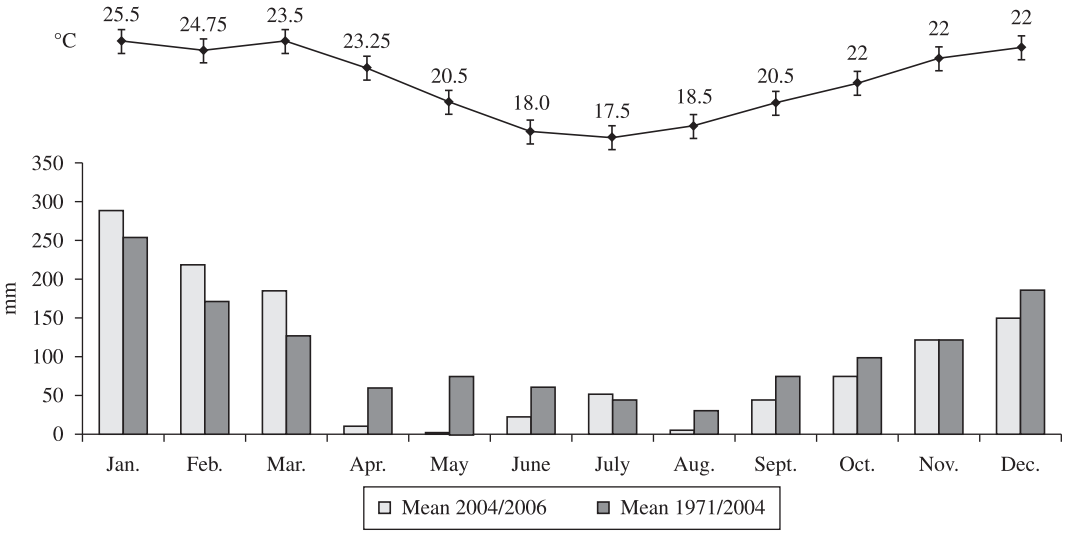

Figure 2. Monthly variation of rainfall (mm) and average water temperature (°C) during the capture period and historical mean in low Sorocaba river basin region.

Table 1. Alimentary items of *Schizodon nasutus* in the low Sorocaba river basin. Fi(%) = frequency of occurrence; d = number of stomach with certain item dominant; %D = dominance.

Alimentary item	Autumn			Winter			Spring			Summer		
	Fi(%)	d	%D	Fi(%)	d	%D	Fi(%)	d	%D	Fi(%)	d	%D
Poaceae	87.5	22	68.75	73.33	14	46.67	71.4	13	62	100	9	45
Vegetable fibres	37.5	-	-	60	12	40	28.5	-	-	-	-	-
Algae	37.5	6	18.75	40	4	13.33	85.7	6	28.5	22.2	-	-
Roots	56.25	4	12.5	40	-	-	38	-	-	11.5	-	-
Seeds	6.25	-	-	-	-	-	19	2	9.5	-	-	-
Leaves of dicotiledones	56.25	-	-	-	-	-	28.5	-	-	33.3	4	20
Oligochaeta (worms)	-	-	-	-	-	-	9	-	-	80.2	7	35
Diptera larvae	6.25	-	-	-	-	-	9	-	-	11.5	-	-
Sediment	6.25	-	-	-	-	-	-	-	-	11.5	-	-
Total	-	32	100	-	30	100	-	21	100	-	20	100

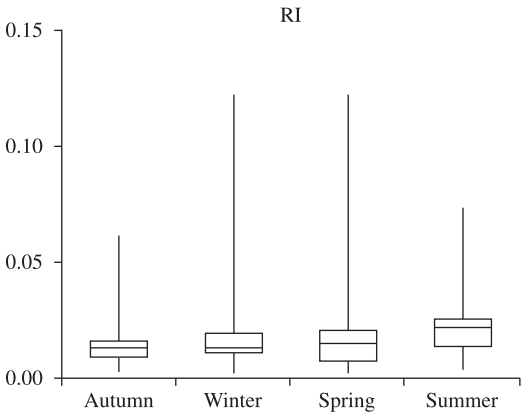

Figure 3. Median and interquartilic amplitude of repletion index of *Schizodon nasutus* in low Sorocaba river basin.

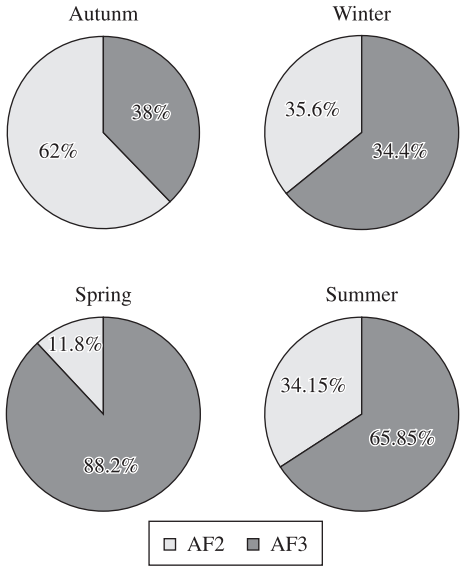

Figure 4. Fat stored accumulation percentage (AF) of *Schizodon nasutus* in low Sorocaba river basin.

A higher similarity for the diet of autumn and spring was detected, with greater dominance of Poaceae (grasses) and algae.

3.2. Reproduction

Analyses of gonadosomatic index (GSI) showed the highest values to be registered during summer. For males, the median values varied from 0.122 (interquartilic amplitude of 0.1461) in autumn, to 1.3196 (interquartilic amplitude of 0.1884) in the summer. The highest median values were registered for females, varying from 0.782 (interquartilic amplitude of 0.3952) to 4.235 (interquartilic amplitude of 10.179) in autumn and summer respectively (Figure 6).

The values of the relative condition were significantly different (H = 20,5036; p = 0.0001) for females. Such as all other factors, the highest values of relative condition factor were observed during summer (Figure 7). The lowest ones were observed in autumn. Significant differences were observed between autumn and spring, between autumn and summer and between winter and summer (Table 2) for females. For males the only difference was observed between autumn and spring.

4. Discussion

In flooding areas, fish alimentary dynamics is influenced by hydrological variations to which these environments are subjected (Hahn et al., 1997). The awareness of alimentary sources used by fish may lead to some data about habitat, food availability in the environment, and even some behaviour aspects. In the low Sorocaba River basin two different periods were observed. Smith (1999) pointed out a higher rainfall index in January and February and the low one in June and July for this region.

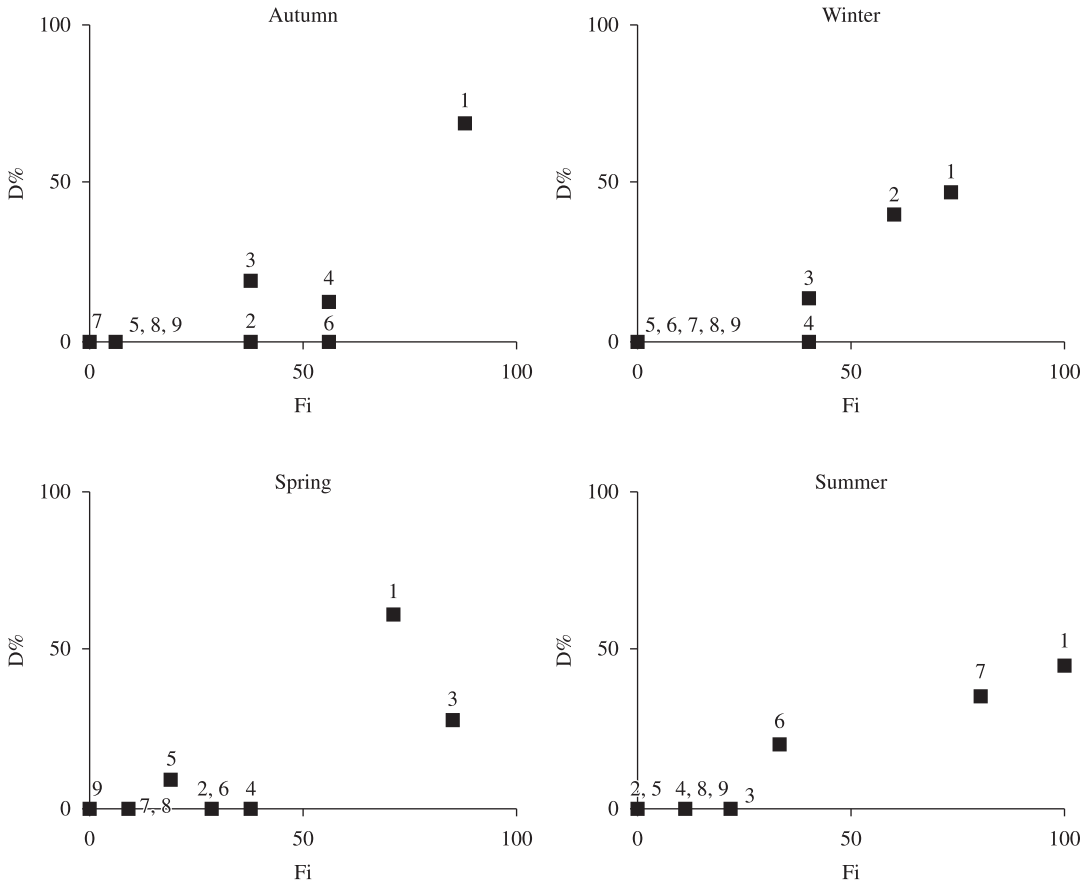

Figure 5. Graphic representation of the weight and dominance (D%) in function of the frequency of occurrence (Fi) of the alimentary items of *Schizodon nasutus* in low Sorocaba river basin. 1 = Poaceae (grass), 2 = vegetable fibres, 3 = Algae, 4 = roots, 5 = seeds, 6 = leaves of dicotiledones, 7 = Oligochaeta (worms), 8 = Diptera larvae, 9 = sediment.

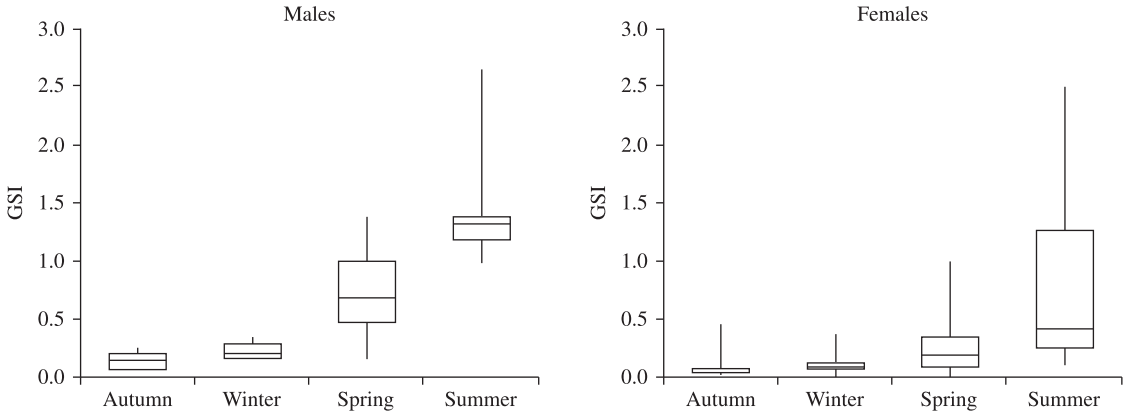

Figure 6. Similarity patterns (cluster analysis) in the seasonal diet composition of *Schizodon nasutus* in low Sorocaba river basin.

The feeding activity of some fish may suffer variations due to several environmental factors, which can differ according to the species and environmental quality (Hahn et al., 1997). The present study, however, showed constant feeding activity during the year. Mourgués-Schurter and Kishibe (1997) observed that *S. nasutus* feeds abundantly during the whole period, and there occurred no variation associated with the reproduction period. On the other hand, Santos (1982) associated high food intake in low waters as a critical behaviour to the reproductive

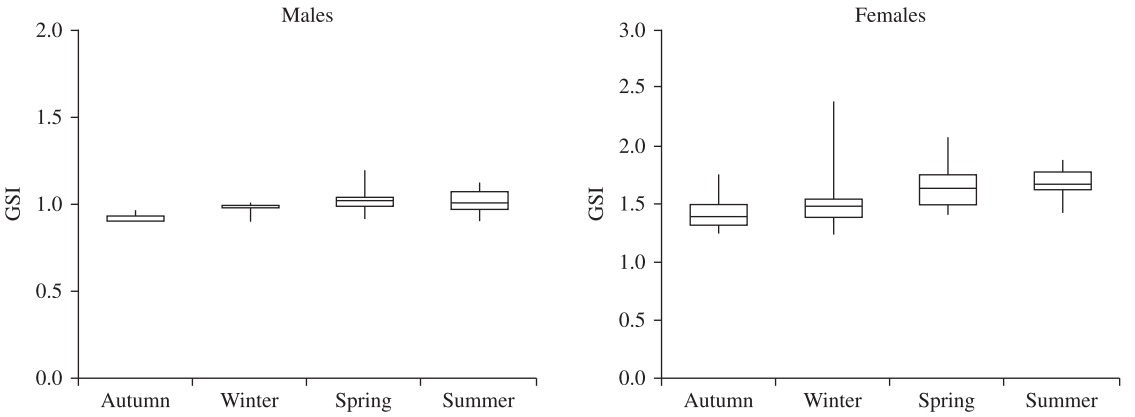

Figure 7. Median and interquartilic amplitude of the gonadossomatic index (GSI) of *Schizodon nasutus* in low Sorocaba river basin.

Table 2. Index comparison by Dunn's method (p = 0.05) between seasons for relative condition factor (Kn).

Season	Kn males (p)	Kn females (p)
Autumn/Winter	ns	ns
Autumn/Spring	>0.05	>0.05
Autumn/Summer	ns	>0.05
Winter/Spring	ns	ns
Winter/Summer	ns	>0.05
Spring/Summer	ns	ns

period, suggesting that variations in feeding activity seem to be more related to gonad development rather than to variation of feeding sources.

The examination of percentage of fat stored in the visceral cavity showed no differences between winter, spring and summer with a greater number of individuals accumulating fat. On the other hand, during autumn a higher percentage of individuals with little fat accumulation was observed. So, this means a populational variation, instead of one perceived in all the individuals. Godinho (1994) points out that the development of fat has a connection to reproduction, not to the variations in the water level. Bennemann et al. (1996) mentions that higher alimentary activity and fat accumulation occurs in the preceding period to the rainy one, when spawning happens. The larger number of individuals showing smaller amounts of fat during the autumn may be related to a high consumption of energy expended during the reproductive period. This may permit one to consider the existence of a relationship between the expenses of fat with reproduction.

In the low Sorocaba river basin, it was possible to observe that the diet composition of *S. nasutus* consists mainly of vegetal material. Several authors describe the gender *Schizodon* as an herbivorous one (Santos, 1982; Bennemann et al., 1996, 2000, 2006; Meschiatti, 1995; Ferretti et al., 1996; Resende, 2000; Marcal-Simabuku and Peret, 2002; Pompeu and Godinho, 2003; Pereira et al., 2004; Teixeira and Bennemann, 2007). The item Poaceae (grass) was the most significant one in the whole period observed, since it presented the highest frequencies and dominance, reflecting the availability of this alimentary item, because they are usually found in abundance on the margins of Sorocaba river, being even more accessible during the rainy period. In the low water period, some alimentary items (vegetal fibres, roots and seeds) were also found as the most frequent ones. Live vascular plants, represented by aerial, submerse or floating species are more commonly present in plain streams or flooded areas (Uieda and Motta, 2007). The analysis of dominance showed that, besides grass and vegetal fibres, algae are also significant items during the low water period. This fact can be justified by the availability of this alimentary item during this period. The lack of rain makes the river waters more transparent for a longer time, also enabling algae proliferation, and so this item becomes more abundant and accessible.

During summer, besides Poaceae, which were present within all stomach contents, dicotyledonous leaves and Oligochaeta were also frequently there. In this rainy period, fish food presents mainly an allochthonous origin, mainly from the forests or the marginal vegetation, becoming accessible and abundant (Bennemann et al., 1996). Seasonal flooding in some environments permits the available space to be increased, leading to the rise of a more diversified feeding composition, such as the floodplain (Lowe-McConnell, 1999). Zavala-Camin (1996) assumes that, in nature, herbivorous fish must complement their diet with animal protein, justifying the high rates of ingestion of worms and dipteran larvae. Changes in hydrological conditions affect not only the quantity but also the quality of available food for the fish (Junk, 1980). Differences in food abundance between the dry and rainy seasons affect the diets of tropical fish communities directly (Pompeu and Godinho, 2003) according to the food availability (Hahn et al., 1997).

Studies of reproductive timing and how the environment influences this timing are of great importance to understand the ecology of any species, especially in seasonally variable

environments (Vlaming, 1972). In the low Sorocaba river, it can be said that the reproductive period of this species happens in the rainy season with the highest water temperatures, in accordance with the observations of Welcomme (1979), Ferreira and Godinho (1990), Bennemann et al. (1996), Vazzoler (1996) and Vazzoler et al. (1997). The reproductive period may be seen as a result of biotic and abiotic stimuli, which influence the development and maturation of ovaries, and oocyte ovulation (Stacey, 1984).

The highest values of the relative condition factor during the rainy season coincide with a higher gonadossomatic index. This shows that in the low Sorocaba River basin, the reproductive period exerts a strong influence on the variation of the relative condition factor, confirming similar observations for other species (Barbieri and Verani, 1987; Ferreira and Godinho, 1990; Gomiero and Braga 2005; Santos et al., 2006; Villares Junior et al., 2007). During the reproductive period, gonads take over a lot of volume and mass in the visceral cavity, thus influencing the condition factor. Added to the percentage of accumulated fat, this explains the more elevated value of the relative condition factor in spring and summer. For the males, the smallest mass and testicle volume in the visceral cavity did not influence the relative condition factor, which did not reveal significant differences between summer and the other seasons. The low condition factor in the autumn coincides with the shrinking of the ovaries and the period of the year in which a higher percentage of individuals present little accumulated fat, probably resulting from the consumption of these reserves during reproduction. The condition factor and amount of accumulated fat follow the rhythm of the reproductive process. A gradual reduction of the condition factor happens just at the time when reduction of accumulated fat occurs, when reproductive intensity is very low. The later increase of the amount of accumulated fat and condition factor suggest a preparation for a new reproductive system (Braga and Gennari Filho, 1990).

In the lower part of the Sorocaba River basin, *Schizodon nasutus* showed a predominant herbivorous food intake and showed no significant difference for the feeding activity between the seasons. Reproduction occurs during the summer, when higher precipitation levels and water temperatures occur, and this strongly influences the amount of accumulated fat and condition factor.

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