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Food partitioning between sympatric species of *Serrapinnus* (Osteichthyes, Cheirodontinae) in a tropical stream

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ABSTRACT. This study investigated the feeding habits of *Serrapinnus microdon* and *S. calliurus* and possible seasonal differences (rainy and dry seasons) in the utilization of food. The fish were collected monthly in Cancela stream, in the basin of the Manso/Cuiabá rivers in the State of Mato Grosso, from March 2003 to February 2004. Both species preferentially consumed resources of autochthonous origin, independently of the season. The diet of *S. microdon* was basically composed by immature forms of aquatic insects, with Chironomidae and Ephemeroptera predominating during the entire study period, thus showing a restricted diet (Ba = 0.27 in the rainy season, and 0.29 in the dry season). For *S. calliurus*, aquatic insects (especially Ephemeroptera) were equally important, but algae and detritus were also prominent depending on the season, showing a less specialized diet (Ba = 0.44 in the rainy season, and Ba = 0.48 in the dry season). Both fish species presented a benthivorous feeding habit; however, everything indicates that they live together without competition, because the food on which they depend is widely available. *Serrapinnus calliurus* was susceptible to seasonal changes in the availability of food resources.

Keywords: *Serrapinnus*, diet, coexistence, stream.

RESUMO. Partilha de recursos alimentares por espécies simpátricas de *Serrapinnus* (Osteichthyes, Cheirodontinae) em um riacho tropical. Este estudo teve por objetivo investigar o hábito alimentar de *Serrapinnus microdon* e *S. calliurus* e possíveis diferenças sazonais (estações de chuva e seca) na utilização do alimento. Os peixes foram coletados mensalmente no riacho Cancela, bacia dos rios Manso/Cuiabá, Estado do Mato Grosso, entre março de 2003 e fevereiro de 2004. Ambas as espécies consumiram preferencialmente recursos de origem autóctone, independente da estação considerada. A dieta de *S. microdon* foi composta essencialmente por formas imaturas de insetos aquáticos, detacando-se Chironomidae e Ephemeroptera durante todo o período de estudos, apresentando, assim, uma dieta restrita (*Ba* = 0,27 na chuva e 0,29 na seca). Para *S. calliurus* inseto aquático (especialmente Ephemeroptera) foi igualmente importante, mas destacaram-se também algas e detrito, dependendo da estação considerada, apresentando dieta menos especializada (*Ba* = 0,44 na chuva e *Ba* = 0,48 na seca). Ambas apresentaram hábito alimentar bentívoro, porém, tudo indica que convivam sem competição, uma vez que o alimento do qual dependem é amplamente disponível. *Serrapinnus calliurus* mostrou-se mais susceptível às alterações sazonais na disponibilidade dos recursos alimentares.

Palavras-chave: *Serrapinnus*, dieta, coexistência, riacho.

Introduction

In Brazil, the available information on the food of stream fish is sparse compared to fish in other environments such as rivers and reservoirs (ESTEVES; ARANHA, 1999). According to Luiz et al. (1998), the strategic importance of streams as water source for urban and rural supply, and the need for preservation of the fauna peculiar to these small water bodies, strengthens the interest in this type of study.

Considering that the different types of biotopes used by fish populations can be directly related to the energy input (MITTELBACH, 1981; GARMAN, 1991), in stream environments, the particulate organic matter and material of terrestrial origin represent a large contribution as a source of nutrients (VANNOTE et al., 1980) and can therefore influence the feeding of the fish. The ichthyofauna of streams lives with considerable temporal and spatial variation in the food supply (POWER, 1983),and the availability of food depends on various factors such as streamflow, channel morphology, hydrological period, and physical and chemical attributes, as well as biotic interactions.

Therefore, studying the ichthyofauna and its ecology aspects assist the understanding of these small and fragile ecosystems. It must be emphasized that studies on feeding contribute greatly for the understanding of the dynamics of these water bodies. Brown (1995) noted that sympatric species differ in their attributes, such as the use of microhabitats, trophic structures, and body size. Thus, such differences would act to avoid interspecific competition for food, allowing the species coexistence.

Serrapinnus microdon (Eigenmann, 1915) and *Serrapinnus calliurus* (Boulenger, 1900) belong to the family Characidae and the subfamily Cheirodontinae, which is composed by very small-bodied species of fish. These two species do not exceed 4 cm in maximum length, and are popularly known in Brazil as lambaris or piabinhas. The species travel over short distances and do not show parental care of the young. They live in the freshwater benthopelagic habitat, demonstrating high resilience, with a minimum population doubling time lower than 15 months (MALABARBA, 2003). Both are found in the Paraguay River basin, but only *S. calliurus* occurs in the basins of the Paraná and Uruguay rivers (MALABARBA, 2003).

Considering the hypothesis that sympatric, phylogenetically related species differ in the use of food resources in order to avoid competition, the objective of this study was to investigate the feeding habits of *Serrapinnus microdon* and *S. calliurus*, and seasonal differences (rainy and dry seasons) in the utilization of food.

Material and methods

Sampling was carried out in Cancela stream, located in the basin of the Manso/Cuiabá rivers, in the State of Mato Grosso. This stream is a tributary of the Cuiabá river (Figure 1). The riparian vegetation is partially impacted by human activities, and the upper hillsides are dominated by pastures and areas of subsistence crops.

The fish were collected monthly from March 2003 through February 2004, by means of a fish electroshocker, which produces an electric field in the water current passing between two submerged electrodes (UIEDA; CASTRO, 1999). The apparatus functions with the aid of a 220 V generator, coupled to a high-voltage transformer with a current converter (1.5 KW, 200, 300, and 500 volts, 1A) equipped with a cable with an outlet to two dip-net and a metal ring (cathode and anode). The area sampled was measured, and a net to block the fishes with a mesh size of 1 cm knot-to-knot was installed at the lower limit of the section (UEM, 2000). The captures were carried out in the direction from downstream to upstream.

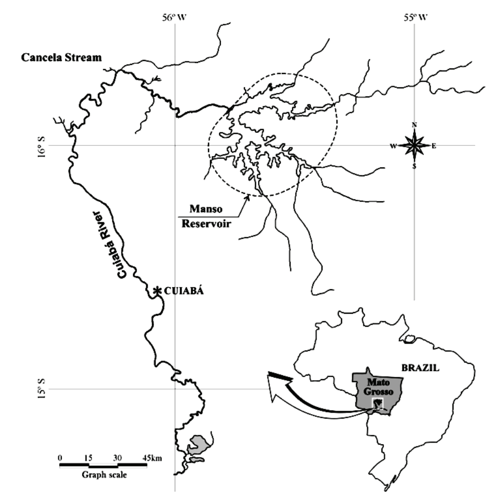

Figure 1. Study area with the location of Cancela Stream (Mato Grosso State, Brazil).

Each specimen was measured (standard length, cm), weighed (total weight, g), and eviscerated; stomachs containing food were fixed in 4% formol. Voucher specimens for the fish caught and utilized in this study are deposited in the collection of fishes of the Núcleo de Pesquisas em Limnologia, Ictiologia e Aquicultura (NUPÉLIA/UEM): *S. microdon* (NUP 966) and *S. calliurus* (NUP 967).

All the analyses were conducted regarding seasonal variations. The analysis of the local variations in hydrological levels (provided by ANA, Agência Nacional das Águas) served as the basis to distinguish the rainy and dry seasons. The rainy months were considered to be those in which rain fell within 10 days prior to the samplings, because the stream can remain full for several days after a rain. Based on this criterion, January, February, March, October, November, and December corresponded to the rainy season, and April, May, June, July, August, and September to the dry season.

The stomachs were opened and their contents were analyzed under stereoscopic and compound optical microscopes. The food items were identified as the source: autochthonous, allochthonous, and indeterminate (detritus and insect remains), and at lower taxonomic levels by means of specific identification keys.

To assess the quality and quantity of food consumed by the fish, the methods volumetric (%V) and frequency of occurrence (%O) were used (HYSLOP, 1980), and the values for each food item were represented by the Graphic Index of Costello (1990).

In order to demonstrate the relative level of specialization in the diet of the species, the Trophic Niche Breadth (dietary breadth) was estimated based on the volume of the food items, using the standardized Levins' Index, which ranges from 0, when a species consumed only one type of food, to 1, when a species consumed all the food items similarly. This is given by the formula of Hurlbert (1978):

$$B_i = [(\sum_j P^2_{ij})^{-1} - 1] (n - 1)^{-1}$$

where:

B_i = amplitude of the standardized trophic niche; P_{ij} = proportion of food item j in the diet of species i; n = total number of food items.

The food overlap between the species was estimated by the Index of Pianka (1973) with the data for volume of the food items, and ranges from 0 (no overlap) to 1 (total overlap), and is given by the formula:

$$O_{jk} = \frac{\sum_i^n p_{ij} p_{ik}}{\sqrt{\sum_i^n p_{ij}^2 \sum_i^n p_{ik}^2}}$$

where:

O_{jk} = Pianka's measure of food overlap between species j and species k; p_{ij} = proportion of food item i in the total of items utilized by species j; p_{ik} = proportion of food item i in the total of items used by species k; n = total number of items.

The results for interspecific overlap were arbitrarily considered as: high (> 0.6), intermediate (0.4 – 0.6), or low (< 0.4) (GROSSMAN, 1986). To evaluate the significance of Pianka's index, a null model was used. In the null model, the proportions of the volume of the observed food items were randomized 10,000 times, and for each randomization a Pianka's index was calculated. In this manner, the statistical significance was determined through comparison of the observed overlap with the null distribution, considering that an observed value higher than 95% of the simulated value indicates a significant overlap at the level of $\alpha < 0.05$. For the calculation of the null model, the EcoSim program was used (GOTELLI; ENTSMINGER, 2006).

Results

A total of 199 stomach contents of *S. microdon*, and 178 of *S. calliurus* were analyzed. In relation to the food sources seasonally consumed by both species, items of autochthonous origin predominated, in both the rainy and dry seasons. However, the consumption of allochthonous resources was slightly greater in the rainy season, for both species, and indeterminate resources were always consumed in important quantities, especially in the dry season (Figure 2).

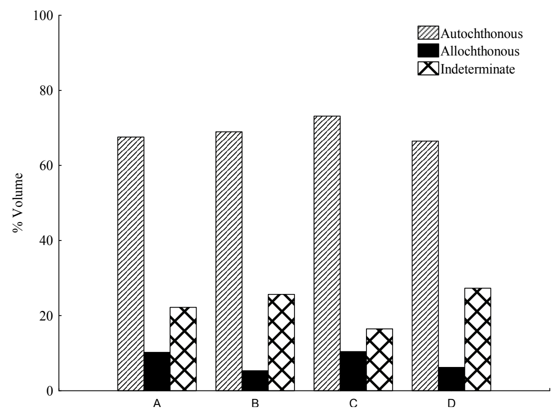

Figure 2. Volume (%V) of the food resources (autochthonous, allochthonous, and of indeterminate origin) consumed by *Serrapinnus microdon* and *S. calliurus* in the Cancela stream, Manso/Cuiabá river basin (State of Mato Grosso). (A = *S. microdon* - rainy season; B = *S. microdon* - dry season; C = *S. calliurus* - rainy season; D = *S. calliurus* - dry season).

Aquatic insects were the dominant food of *S. microdon*, with high values of occurrence and volume, independently of season. Algae were also recorded with high occurrence in the stomachs of individuals collected in the rainy season, whereas the other resources (grouped in the lower left quadrant of the graph) had little importance (Figure 3).

These results indicate that this species can be considered a trophic specialist, characterized by the benthivorous feeding habit, because the items recorded in its stomach contents are part of the benthic fauna. The restricted diet is confirmed by the low values of niche breadth (Ba = 0.27 and 0.29, in the rainy and dry seasons, respectively) (Figure 5).

Aquatic insects were prominent in volume in the diet of individuals of *S. calliurus* in the dry season, although algae and detritus contributed with high occurrence values. Algae, followed in importance by detritus, characterized the diet in the dry season. The remaining resources (grouped in the lower left quadrant of the graph) were unimportant (Figure 4). In relation to its congener, *S. calliurus* showed a less specialized diet (*Ba* = 0.44 in the rainy season, and

Ba = 0.48 in the dry season; Figure 5), although it had also been characterized as benthivore due to its consumption of different types of resources from the benthos.

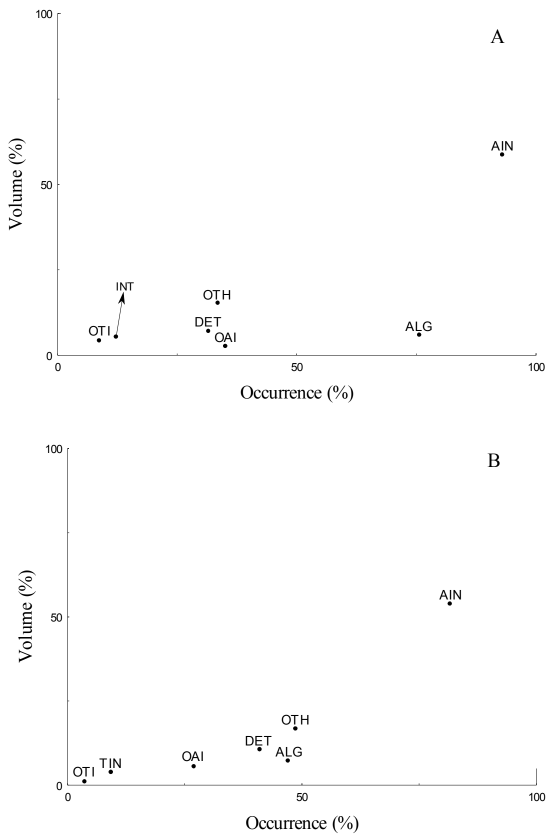

Figure 3. Feeding strategy of *Serrapinnus microdon* from Cancela stream, Manso/Cuiabá river basin (State of Mato Grosso). (A) rainy season, (B) dry season. AIN = aquatic insects; OAI = other aquatic invertebrates; ALG = algae; TIN = terrestrial insects; OTI = other terrestrial invertebrates; DET = detritus; OTH = other items.

In the diet of *S. microdon*, independently of the season, immature forms of Chironomidae predominated (%F rainy season = 80.7 and %F dry season = 69.0; %V rainy season = 29.4 and %V dry season = 26.4), and immature forms of Ephemeroptera represented the second-highest volumetric frequency (%V rainy season = 23.90 and %V dry season = 21.59). In addition to these items, Chlorophyceae algae (%F = 61.40) were predominant in the rainy season (Table 1).

In the diet of *S. calliurus*, detritus predominated in occurrence in both seasons (%F = 79.7 rainy season and %F = 84.2 dry season), whereas Chlorophyceae algae were a major component in the rainy season (%F = 56.25) and Bacillariophyceae in the dry season (%F = 72.81). However, the highest volume values were recorded for Ephemeroptera (%V = 29.75) in the rainy season, and for detritus (%V = 28.16) followed by Bacillariophyceae (%V= 15.98) and Ephemeroptera (%V = 15.15) in the dry season (Table 1).

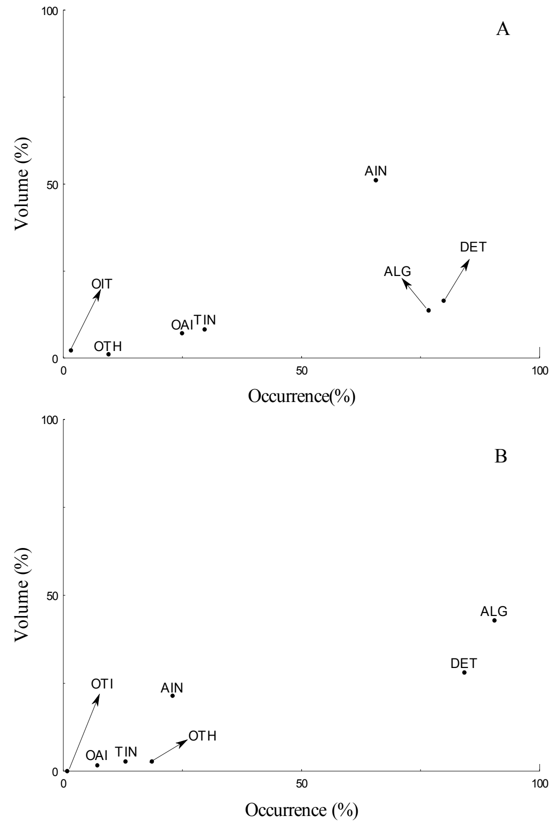

Figure 4. Feeding strategy of *Serrapinnus calliurus* from Cancela stream, Manso/Cuiabá river basin (State of Mato Grosso). (A) rainy season, (B) dry season. AIN = aquatic insects; OAI = other aquatic invertebrates; ALG = algae; TIN = terrestrial insects; OTI = other terrestrial invertebrates; DET = detritus; OTH = other items.

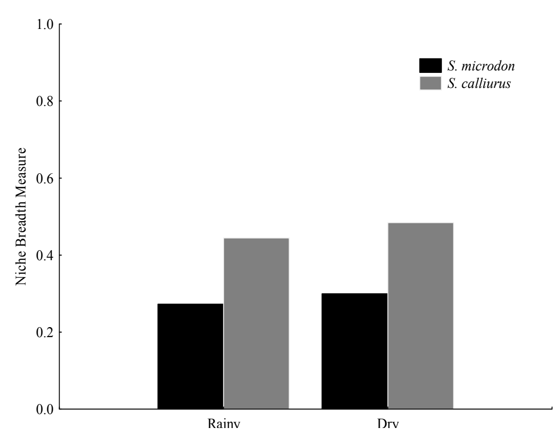

Figure 5. Trophic niche breadth of *Serrapinnus microdon* and *S. calliurus* from Cancela stream, Manso/Cuiabá river basin (State of Mato Grosso), during the rainy and dry seasons.

The values of feeding overlap varied from intermediate in the dry ($O_{jk} = 0.53$) to elevated in the rainy season ($O_{jk} = 0.82$), and the latter value was significant ($p < 0.05$).

Table 1. Diet composition of *Serrapinnus microdon* and *S. calliurus* in Cancela stream, Manso/Cuiabá river basin (State of Mato Grosso), during the rainy and dry seasons. %V = volumetric frequency of the food items; %O = occurrence frequency of the food items. OAI = other aquatic invertebrates; OTI = other terrestrial invertebrates.

	Serrapinnus microdon				*Serrapinnus calliurus*			
	Rainy		Dry		Rainy		Dry	
Food items	%V	%O	%V	%O	%V	%O	%V	%O
Autochthonous								
Chironomidae	29.41	80.70	26.44	69.01	11.64	43.75	4.43	10.53
Ceratopogonidae	1.51	10.52	1.05	4.93				
Diptera	2.90	15.78	2.40	10.56	10.01	26.56	1.61	2.63
Ephemeroptera	23.90	42.10	21.59	26.05	29.75	32.81	15.15	12.28
Trichoptera	0.07	1.75	0.73	3.52				
Odonata			1.09	2.81				
Annelida					4.01	7.81		
Nematoda	0.70	12.28	0.27	4.22				
Cladocera	0.44	12.28	4.22	19.01				
Copepoda	1.58	17.54	1.16	10.56				
Scales	0.18	3.50	1.75	9.85	0.86	9.38	2.60	18.42
Chlorophyceae	3.54	61.40	4.63	34.50	8.83	56.25	9.51	45.61
Cyanophyceae	1.39	26.31	1.24	11.26	1.83	35.94	11.78	47.37
Bacillariophyceae	0.89	26.31	1.36	24.64	2.00	40.63	15.98	72.81
Desmidia					1.15	25.00	5.65	41.23
OAI	1.51	15.78	1.36	7.74	3.04	18.75	1.92	7.02
Allochthonous								
Diptera	1.89	5.26	1.63	4.22				
Trichoptera	3.66	8.77	2.29	4.93				
Insect remains	14.73	33.33	14.82	40.84	8.41	29.69	2.98	13.16
OTI	4.49	8.77	1.36	3.52	2.01	1.56	0.23	0.88
Indeterminate								
Detritus/insect remains	7.11	31.57	10.52	40.84	16.47	79.69	28.16	84.21
Number of stomachs	57		142		64		114	

Discussion

Autochthonous resources comprised the largest share of the diets of *S. microdon* and *S. calliurus*, although the literature highlights the importance of allochthonous material for the feeding of stream fishes (SABINO; CASTRO, 1989; HENRY et al., 1994; SABINO; ZUANON, 1998; LOWE-McCONNELL, 1999; CASTRO, 1999). The autochthonous and indeterminate resources, when summed up, exceeded in importance those of allochthonous origin, showing that both species depend almost exclusively on the resources offered by the environment. Nevertheless, Gordon (1993) suggested that the input of allochthonous material may have an indirect importance in the diet of the fish, since leaves, branches, tree trunks, and the arrangement of rocks can create microhabitats that support immature forms of insects and other organisms that constitute the base of the autochthonous food resource for the fish. In addition, one must take into account that both species are benthopelagic (MALABARBA, 2003), and their diets, as analyzed in this study, indicate a preference for the benthic region as a foraging site. The preferential use of autochthonous food by stream fishes was also established by Casatti (2002), in São Carlos stream, São Paulo State, where the ichthyofauna consumed 70% of this resource.

The food spectrum suggests that both species studied can be considered benthivorous. However, *S. microdon* was more selective than its congener, because of the consumption of insect larvae selected from the substrate and because of the small quantity of detritus in its stomach contents. It is also worth noting that *S. microdon* showed greater constancy in the use of food, with a distinct seasonal variation, which may also reflect a constancy in food availability, or a plasticity of the species in the search for food in more favorable locations, in periods in which a resource becomes scarcer, as commented by Esteves and Aranha (1999). The seasonality effects have been described for diverse communities of stream fishes (DEUS; PETRERE JÚNIOR., 2003; LITTLE et al., 1998), and in fact, the rainfall regime in the Neotropical region is the main factor affecting the structure of the substrate, altering the dynamics of the trophic resources in diverse tropical rivers and streams (LOBÓN-CERVIÁ; BENNEMANN, 2000; MAZZONI; LOBÓN-CERVIÁ, 2000). For *S. calliurus*, these effects appear to have greater influence, because the species varied its diet seasonally and probably used the food that was most available at a particular season and location.

Chironomidae and Ephemeroptera were the most important items of animal origin in the diet of *S. microdon*, regardless of season, whereas for *S. calliurus* these insects were more important during rainy season. In addition to these insects, algae (Chlorophyceae) occurred in high frequency in the stomach contents of both species in the rainy season; and for *S. calliurus,* Bacillariophyceae was also frequent in the dry season, suggesting that these algae were more available at these year periods or also that this species might show a preference for this type of resource. In a study done with *Serrapinnus notomelas* associated with aquatic macrophytes in Rosana Reservoir, São Paulo State, Casatti et al. (2003) attributed an algivorous habit to this species, whereas Pelicice and Agostinho (2006), working in the same environment, considered the species to be herbivorous because they verified higher plants and algae in its stomach contents. On the upper Paraná river floodplain, *S. notomelas* was also characterized as algivorous (HAHN; LOUREIRO-CRIPPA, 2006).

Although Lowe-McConnell (1964) postulated that it is during the dry season that the highest values of dietary overlap occur, because the fish become concentrated in small areas where they share the available resources (especially bottom detritus), in this study the two species overlapped their diets more in the rainy season. Similarly, Zaret and Rand (1971) demonstrated significant values of food overlap in the rainy season, for eight pairs of species from a fish community in a stream in Panama. Therefore, there appears to be no pattern in the degree of dietary overlap between pairs of species. According to Mol (1995), phylogenetically related species tend to be ecologically similar in many respects, so that their coexistence is more difficult to explain. However, trophic segregation has been described as the most important mechanism of resource partitioning in fish assemblages (ROSS, 1986). Since both species of *Serrapinnus* exploit benthic organisms and also use detritus as a food resource, everything indicates that both of them live together stably, without apparent competition, because the type of food on which they depend is amply available. Fugi et al. (1996) commented that benthic invertebrates constitute a source of food for more than half the fish biomass in South America, and according to Zavala-Camin (1996), the insect larvae constitute the food category that is most utilized by the ichthyofauna.

Conclusion

The coexistence of the two species of *Serrapinnus* appears to be determined by the abundance of food resources. However, more refined studies, such as for example of feeding rhythm (different feeding times) or even trophic morphology (shape of teeth, gill rakers), which were not addressed in this study, may eventually indicate that these species present some kind of trophic segregation.

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