

Comparative feeding ecology of four syntopic *Hypostomus* species in a Brazilian southeastern river

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Abstract

Though their broad distribution in most Brazilian rivers, scarce studies concerning ecological interactions on *Hypostomus* species are available. This study observes the diet, the trophic interactions and some morphological aspects of four syntopic species of *Hypostomus*. These fishes were studied at the superior part of the Corumbataí river, at São Paulo state, southeastern Brazil. Analyses focused feeding patterns, their amplitude and whether there happens some food items overlap among the species. Fish were caught using cast nets at some points of the river. Species were chosen according to their local abundance and, so there were four main species: *H. albopunctatus*, *H. ancistroides*, *H. regani* and *H. strigaticeps*. Nine food items were found: sediments, fungi, diatoms, green algae, *Tecamoeba*, vegetal debris and invertebrates. There were not significant differences for the feeding pattern among the four *Hypostomus* species. The feeding niche amplitude has been larger for *H. albopunctatus* influenced by a larger amount of vegetal debris and invertebrates. Elevated niche overlap was found to happen among the species and also for their trophic morphology. Results may suggest that there is a similar pattern in food taken between four species of *Hypostomus* analyzed since all consume similar environmental resources and have similar anatomical features. However, a different intake insect larvae and plant material in *H. albopunctatus* diet indicate differences in local and how this species may be exploring their food compared to the others.

Keywords: Corumbataí river, niche breadth, niche overlap, macrohabitat.

Ecologia alimentar comparativa de quatro espécies simpátricas de *Hypostomus* em um rio do sudoeste brasileiro

Resumo

Apesar de sua grande distribuição em todos rios brasileiros, poucos estudos estão disponíveis sobre as interações ecológicas do gênero *Hypostomus*. Neste estudo nós examinamos a dieta, as interações tróficas e a morfologia de quatro espécies sintópicas de *Hypostomus* sp. no trecho superior do rio Corumbataí, estado de São Paulo no sudeste do Brasil. As análises focaram o padrão alimentar, a amplitude e sobreposição de nicho alimentar e a correlação entre a dieta com características da morfologia. A captura dos exemplares foi realizada com o uso de redes de arremesso (tarrafa) ao longo do leito do rio. O critério adotado para a escolha baseou-se nas espécies de maior abundância no local, chegando a quatro espécies principais: *H. albopunctatus*, *H. ancistroides*, *H. regani* e *H. strigaticeps*. Foram encontrados nove itens alimentares: sedimento grosso e fino, hifas de fungos, diatomáceas, algas verdes, algas azuis, *Tecamoeba*, restos de material vegetal e invertebrados, não havendo diferenças significativas no padrão alimentar entre as quatro espécies de *Hypostomus*. A amplitude de nicho alimentar foi maior para *H. albopunctatus* influenciada por um maior consumo de material vegetal e invertebrados. Foram encontrados altos valores de sobreposição de nicho alimentar além de uma similaridade entre a dieta e a morfologia trófica entre as espécies consideradas. Os resultados sugerem que exista um padrão semelhante na tomada de alimento entre as quatro espécies de *Hypostomus* analisadas, uma vez que, todas consomem recursos alimentares semelhantes e possuem características anatômicas semelhantes. No entanto, uma ingestão diferenciada de larvas de insetos e material vegetal na dieta de *H. albopunctatus* indicam diferenças nos locais e na forma como esta espécie pode estar explorando o seu alimento em comparação com as demais.

Palavras-chave: rio Corumbataí, amplitude de nicho, sobreposição de nicho, macrohabitat.

1. Introduction

For ecological purposes it is important to evaluate which environmental conditions present limitations to communities (Cetra et al., 2011). According Rivas (1964) the term syntopic to be used in reference to two or more related species which occupy the same locality (macrohabitat). A diet analysis may reveal important information about the trophic dynamics and resource partitioning among fish species (Ross, 1986). The resource utilization patterns constitute a fundamental mark of the ecological systems (Winemiller and Pianka, 1990), in which the food resources partitioning among coexistent species plays a more important role than that described even for the habitat partitioning inside aquatic environments (Schoener, 1974; Ross, 1986). Such a division may occur both in an intraspecific level as in an interspecific one (Gerking, 1994), and is seen as one the basic causes of population and community structurations (Tofoli et al., 2010). On the other hand, coexisting species may present a niche division based on spatial or temporal scales (Correa et al., 2011). Mechanisms of living and interactions among species remain as a central theme for the populations ecology and niche differences have been evoked as fundamental to keep biodiversity in distinct scales (Leibold and McPeck, 2006).

An elevated trophic plasticity may permit fishes to fit their feeding habits to fluctuations of food availability (Balassa et al., 2004). The two stochastic processes and the abundance of some kinds of food may reduce an intraspecific competition, which may permit a better coexistence of species in a same place (Dias and Fialho, 2011; Uieda and Pinto, 2011). The species which are phylogenetically related may display ecologic similarities in diverse aspects; so, in this way, feeding data may subsidies factors that segregate sympatric species, and may inform some single ecologic questions, such as competition and food resource partitioning (Tofoli et al., 2010).

Other factors such as the trophic morphology, the use of distinct microhabitats, activity periods and feeding strategies may minimize overlapping effects (Casatti, 2002; Brazil-Sousa et al., 2009; Cetra et al., 2011). The use of morphologic attributes may reflect an integration of a broad variety of ecosystem influences to the organisms which live inside those systems, mainly for aquatic organisms and are suited to define morphologic and ecologic similar patterns (Winston, 1995). Such morphologic variations may have favored the coexistence of fish groups in diverse regions where they live. This may be due to spatial and temporal differences of their distributions, which may appear as distinct adaptations for the habitat placement and resource exploration, which may minimize some kinds of competition (Lagler et al., 1977). In fact, the relationship between diet, body form and taxonomic aspects is commonly predicted for different levels in a community, which may adjust morphologic and ecologic configurations (Winston, 1995). Catella and Petrere Júnior (1998) believe that body form and feeding habits may reflect the general characteristics of the chemical and physical factors of the environment.

The Loricariidae represents a large group of fishes found primarily in freshwater ecosystems of the Neotropical Region (Nelson, 1994), and are known to constitute the world's most diverse family of catfishes. They are represented by six subfamilies, about 90 genera and a few more than 680 described species (Menezes et al., 2007). Individuals of this family present morphologic differences, such as dermal plates, mouth presenting sucking ventral lips, with were certainly important role for the evolutionary success of the Loricariidae (Schaefer and Lauder, 1986; Schaefer and Stewart, 1993). The Loricariidae display typical benthonic habits, living permanently near to the bottom where they use to grasp substrate algae or search for invertebrates (Britski et al., 1999). Notwithstanding this fact, ecologic studies concerning loricariids are important to better understand their singular radiation, and also to figure out the dynamics of nutritional patterns in distinct tropical systems (Flecker et al., 2002; Nonogaki et al., 2007).

Hypostomus represents the most diverse genus within this family (Weber, 2003; Hollanda Carvalho et al., 2010; Borba et al., 2013). The species of this genus live frequently in rapid flowing rivers and display a benthonic habit near to stony bottoms (Garavello and Garavello, 2004). Another aspect to distinguish *Hypostomus* from other Loricariidae is its distinguished ability to breathe atmospheric air. Their stomach walls are plenty of vessels which permit them to gas changing from the blood to the stomach internal space, when they swallow directly air from the surface (Armbruster, 1998). According to Val and Almeida-Val (1995), they may be classified as species to present an accessory breathing, and present this behavior specially when hypoxic conditions are happening.

There are relatively few feeding studies related to species of this genus. In spite of their large distribution in almost all Brazilian rivers there are important gaps in the comprehension of their ecologic interactions and also on morphological feeding aspects. Therefore, such ecological attributes should be better known to evaluate how they may explore feeding resources (Garavello and Garavello, 2004). In the present study we examine diet and trophic interactions of four sympatric species of *Hypostomus* from Corumbataí river in the São Paulo state in the southwestern of the Brazil. The analysis focuses in niche breadth, niche overlap between species and correlation of the diet with morphological features.

2. Material and Methods

The Corumbataí river basin is inserted in the Medium Tietê Peripheric Depression of the São Paulo State, at the northeastern portion of the sedimentary Paraná basin (Cetra, 2005), in which the Corumbataí is one of the most important affluent of the Piracicaba river. Collections were made monthly from June 2002 to May 2003. The collection site (22° 12' 47" S and 47° 37' 40" W) locate near to an urban area of Corumbataí, at 25km from the water spring (Figure 1). This river place locates up to the waste deposit coming from Corumbataí, which maintains the

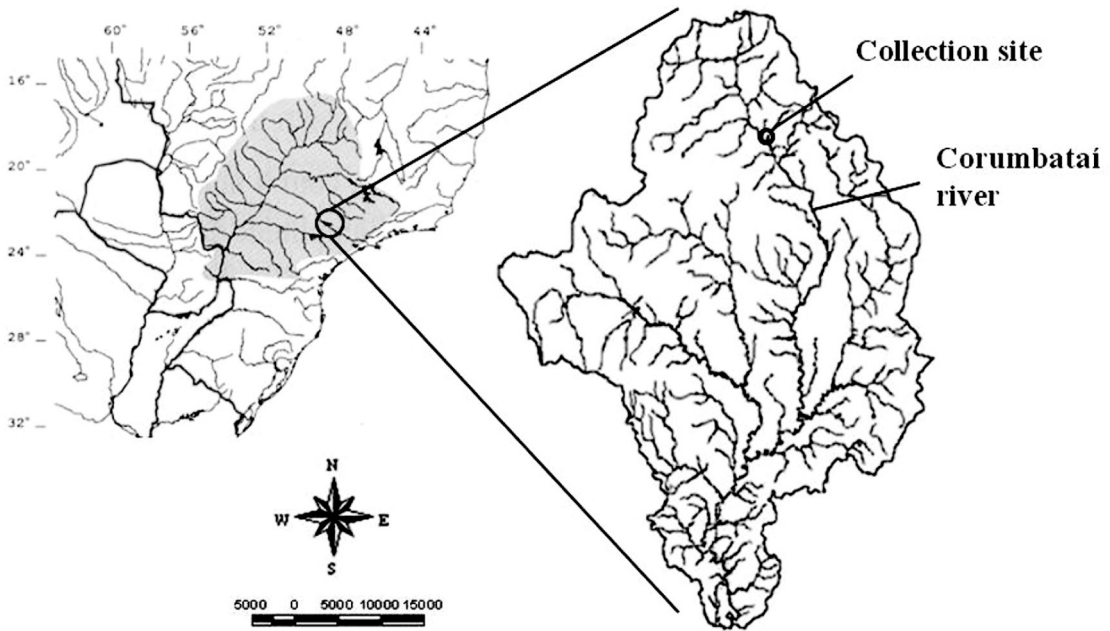


Figure 1. Partial map of South America showing the Alto Paraná river basin and location of Corumbataí river basin with localization of the collection site.

water condition almost unchanged (Lima Júnior, 2004; Cardone et al., 2006).

For the collections of specimens of *Hypostomus* sp. the employment of cast nets was used. This device measures 2 meters height and 1.2, 2.0 and 3.5 cm between the opposite meshes. It is a well suited method, as such fish use to move slowly. The caught individuals were separated in boxes containing ice, to be analyzed at the Zoology Department of UNESP - Rio Claro, SP. Identifications were based on Zoology Museum Prof. Heraldo Bristki and confirmed using Graça and Pavanelli (2007). So, four main species were identified: *H. albopunctatus* (Regan, 1908), *H. ancistroides* (Ihering, 1911), *H. regani* (Ihering, 1905) and *H. strigaticeps* (Regan, 1908). These were the most common species found in the system.

The diet analysis was made using stomach contents from the anterior third part of the gut, including the stomach, which contains normally the less digested material. The whole material for analysis was introduced in a graduated cylinder containing 70% ethanol filled until 50 mL. From the homogenized contents standardized sub-samples were disposed on lamina for identification and counting of food items, which were identified to the lowest possible taxonomic level. The food importance based on those analyses was established based on the volumetric method (Hyslop, 1980). For the evaluation of the similarity of feeding patterns among the species a comparison of the volumetric frequencies was made by the one-way test ANOSIM (5%) using the software PAST 2.15 (Hammer et al., 2001).

The volumetric proportions of respective data for each food item were joined for the calculation of the niche amplitude and feeding overlap. The niche amplitude has been calculated following the Lewis Index (Krebs, 1999), by using the Formula 1:

$$B = 1 / \left(\sum_{i=1}^n P_i^2 \right) \quad (1)$$

where: B represents the niche breadth, P_i the volumetric proportion of the food item i compounding the diet and n is the total number of food items of the diet.

The diet similarity was calculated based on the niche overlap index of Pianka (1974) Formula 2:

$$O_{jk} = \frac{\sum_{i=1}^n P_{ij} P_{ik}}{\sqrt{\sum_{i=1}^n P_{ij}^2 \sum_{i=1}^n P_{ik}^2}} \quad (2)$$

where: O_{jk} is niche overlap between species j and k , P_{ij} is the proportion of the resource i used by species j and P_{ik} is the proportion of resource i used by species k and n is the total number of resources categories.

There were measured nine morphologic attributes related to feeding: intestine length, jaw size, mouth width, head length, head height, body height, eye diameter, teeth number and gill rakers number. By using these morphometric data it was possible to build matrices using the Euclidian distance and a Mantel test of correlation was used to verify the distance of the morphology with the similar use of feeding resources.

3. Results

A total number of 582 individuals was collected for this analysis, with the great majority being represented by *H. strigaticeps*. Within the stomach contents of the four armored catfishes were found nine food categories: coarse sediment, fine sediment mixed with organic matter, fungi hifa, diatom algae (*Navicula*, *Pimularia*, *Nitzschia*, *Melosira* and *Synedra*), green algae (*Closterium*, *Cosmarium*, *Ankistrodesmus*, *Micrasterias*, *Scenedesmus*, *Oedogonium* and *Clorela*), blue algae (*Oscillatoria* and *Lyngbia*), *Tecamoeba* shells; vegetal remains (parts of autochthonous and alochthonous plants) and invertebrates. The ANOSIM test did not reveal significant differences for the feeding pattern of individuals belonging to the four species during the period ($R = 1.167$, $p > 0.05$).

The niche amplitude analyses for the four *Hypostomus* species showed the index to be larger for *H. albopunctatus* (Table 1) influenced by a higher consumption of plant material and invertebrate parts (Table 2).

During this period the Index of Pianka analyses presented niche high values of overlapping (up to 0.50) among those species, as the higher observed overlapping values occurred between *H. regani* and *H. strigaticeps* and between *H. ancistroides* and *H. strigaticeps*. The lowest overlapping value was, otherwise, observed between *H. albopunctatus* and *H. ancistroides* (Table 3).

The comparison result among the trophic similarity matrices and the trophic morphology, the Mantel test, indicated the existence of an interspecific significant correlation ($r = 0.6532$; $p < 0.05$) among the diets and the morphometric attributes (Table 4) related to the feeding of the four *Hypostomus* species.

Table 1. Niche breadth of four species of *Hypostomus* from Corumbá river.

	n	B
<i>H. albopunctatus</i>	28	5.1203
<i>H. regani</i>	29	4.5475
<i>H. ancistroides</i>	21	3.7481
<i>H. strigaticeps</i>	504	3.9463

n = numbers of individuals; B = niche breadth.

4. Discussion

The four studied species show that their food items are predominantly constituted by particulate organic material, and may suggest that all of them can be classified as detritivores. A similar pattern has been discussed to occur by Uieda (1984); Arcifa and Meschiatti (1993); Castro and Caramaschi (2003); Hahn et al. (2004); Casatti et al. (2005); Brandão-Gonçalves et al. (2010); Mazzoni et al. (2010); Silva et al. (2012), as an elevated consume of sediment and alloctonous and autochthonous organic matter mainly of vegetal material predominated. Instead of this, Delariva and Agostinho (2001) found a more varied diet, which could be classified as omnivore. This may reveal the existence of a relative plasticity for the feeding behavior of *Hypostomus* species (Buck and Sazima, 1995). Most species of this genus, however, do not use to select their food, by ingesting what is more available when they grasp the substrate (Delariva and Agostinho, 2001), which depends on ingesting a relative great amount of items to get a satisfactory energetic amount.

The lithologic constitution of the river may be related to this elevated consume of sediment, as the Corumbá river uses to get an consistent deposition of sediment (Viadana, 1993). In an association to this fact, loricariids use to grasp the substrate, which contains the organic matter mixed to the sediment. In the South American systems there happens a clear dominance of fish species, which use to ingest a great amount of sediments and play the role of the basic consumers (Bowen, 1983; Fugi, 1993; Gerking, 1994). Detritivory is known to be a common feeding habit for Loricariidae species and relates to a morphologic adaptation of their digestive system, such as the mouth form and position and the length of the intestine, as well (Agostinho et al., 1997; Hahn et al., 1997). Their general aspect permits them to dwell and explore benthonic microhabitats, by grazing on the algae and the associated microfauna (Garavello and Garavello, 2004). Iliophagy is a similar way of feeding upon the substrate, but is commonly accepted for only some species, such as the Prochilodontidae and Curimatidae species, which use to ingest sediment to absorb the organic material from them. So, in spite of ingesting sediments, Loricariidae differ from other substrate feeders in neotropical waters.

Table 2. Volumetric percentage of food items of the four *Hypostomus* species from Corumbá river.

	<i>H. albopunctatus</i>	<i>H. regani</i>	<i>H. ancistroides</i>	<i>H. strigaticeps</i>
thick sediment	22.35	21.44	22.49	25.13
fine sediment	24.86	35.12	3.059	39.66
Diatoms	11.11	17.00	16.08	11.95
Hypphae	9.20	11.06	10.65	11.89
green algae	2.87	4.62	5.74	4.95
<i>Tecamoebas</i>	1.91	2.01	6.74	4.64
plant material	25.09	8.38	7.69	1.31
invertebrates	2.59	0.00	0.00	0.05
blue algae	0.00	0.36	0.00	0.40

In any case, such as iliophagous species, the Loricariidae also constitute and important part of the trophic web in these systems (Alvin and Peret, 2004), in respect of the whole fish fauna.

By statistically comparing the food items volumetric frequencies added to the elevated values for the feeding niche overlapping it may be observed homogeneity related to the whole consummation of food organisms. Some fish display definite diets in result of their anatomic and physiologic adaptations. On the other hand, the feeding efficiency may regard the subtle differences among species when they, in fact, exist. Fish relative sizes may also play some role to these aspects, but could not be perceived by these results. Loricariidae are known by their highly specialized way of living in rapid water streams, presenting depressed bodies, staying almost immobilized and using their suctional discs around their mouths (Casatti and Castro, 2006; Ferreira, 2007).

The ingestion of *Tecamoeba* may also be related to a sediment swallowing, as such organisms use to be associated to such kind of sediment. This grazing and grasping of the substrate confirms that such species find their food on or inside the substrate (Ross, 1986). So, a similar resource may be available and partitioned by several species, though they may be able to explore other ones, as well (Hahn et al., 2004; Merona and Rankin-de-Merona, 2004; Novakowski et al., 2008).

Overlapping measurements may determine the resources segregation degree among the species, but may also furnish a descriptive measure of the population's organization (Correa et al., 2011). The higher abundance of *H. strigaticeps* in this system may also be another fact to explain the similarity between the diets of the *Hypostomus* species, in the high Corumbataí, as one may think that

there may not exist any system, which should permit the abundance of several species belonging to a same genus, presenting such overlapping diets. This may suggest that some species may display a better ability in relation to the other ones by performing a broader distribution in a same area.

Though the existence of an elevated diet similarity among the species, a peculiarity presented by *H. albopunctatus*, which ingested more insects and vegetal material, represented mainly by dipterans (Simuliidae), which use to occur in rapid streams fixed to rocks (Borror and Delong, 1964) very near to the margins (personal observation). This species may differ from the other ones by using its feeding site in distinct places, which is common to happen (Cabral, 2000). Distinct microhabitats may permit an easier coexistence between species (Declerky et al., 2002). In places where food overlapping uses to occur kinds of food and space may be recognized as the main axes as similar foods may occur in distinct microhabitats. Food and space are recognized as the main axes of resources to a niche division in vertebrates (Schoener, 1974), however Chase and Leibold (2003) state that related species living in a same community may present some type of differentiation (temporal or spatial) for the occupation of microhabitats. Some cases of spatial segregation of fishes presenting high overlapping indices for their feeding may occur as a consequence of historical differences between them in innate ability for habitat use and the absence of a species in a microhabitat (Edds et al., 2002). Differences of feeding tactics may lead during the evolutionary history of the species to a reduction of the effect for alimentary overlapping (Sabino and Correa e Castro, 1990). By considering that species belonging to a same genus use to show similarities in their general characters, Mazzone et al. (2012) suppose that other characteristics which were not measured or perceived in this study may help to explain this feeding patterns and species coexistence.

The significant correlation between these similarities, both to the diets and the morphologic aspects, may play a particular role when such species are compared to the other ones belonging to the community (Labropoulou and Eleftheriou, 1997). So, these species do not present distinct specializations for their diets and trophic morphology. However, the higher abundance of *H. strigaticeps* suggest

Table 3. Niche overlap feeding (O_{jk}) between pair of four *Hypostomus* species from Corumbataí river.

	O_{jk}
<i>H. albopunctatus</i> × <i>H. regani</i>	0.7778
<i>H. albopunctatus</i> × <i>H. ancistroides</i>	0.5983
<i>H. albopunctatus</i> × <i>H. strigaticeps</i>	0.7073
<i>H. regani</i> × <i>H. strigaticeps</i>	0.9700
<i>H. ancistroides</i> × <i>H. strigaticeps</i>	0.9740

Table 4. Median values of the nine morphological attributes of four *Hypostomus* species from Corumbataí river.

morphological attributes	<i>H. albopunctatus</i>	<i>H. regani</i>	<i>H. ancistroides</i>	<i>H. strigaticeps</i>
jaw length	0.65	0.50	0.80	0.96
intestine length	127.10	169.85	193.80	187.5
mouth length	2.65	1.50	1.90	2.31
body height	2.75	1.80	2.20	2.1
head length	4.75	2.85	3.80	3.6
eye diameter	0.55	0.40	0.80	0.60
head height	2.1	1.60	1.80	1.80
number of teeth	43	32	65	83
number of gill rakers	65	43	60	59

that this specie may display a better ability in relation to the other ones by performing a broader distribution in a same area and a different intake insect larvae and plant material in *H. albopunctatus* diet indicate differences in local and how this species may be exploring their food compared to the others species of *Hypostomus* in this lotic system.

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