Prey selection by two benthic fish species in a Mato Grosso stream, Rio de Janeiro, Brazil

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Abstract: Key to understand predator choice is the relationship between predator and prey abundance. There are few studies related to prey selection and availability. Such an approach is still current, because the ability to predict aspects of the diet in response to changes in prey availability is one of the major problems of trophic ecology. The general objective of this study was to evaluate prey selection by two species (*Characidium* cf. *vidali* and *Pimelodella lateristriga*) of the Mato Grosso stream, in Saquarema, Rio de Janeiro, Brazil. Benthos and fishes were collected in June, July and September of 2006 and January and February of 2007. Fish were collected with electric fishing techniques and benthos with a surber net. Densities of benthic organisms were expressed as the number of individuals per/m^2. After sampling, the invertebrates were fixed in 90% ethanol, and, in the laboratory, were identified to the lowest taxonomical level. Approximately, seventy individuals from each species were selected randomly in each month. Fishes were fixed in 10% formalin in the field and transferred to 70º GL ethanol in the laboratory. Fishes had their stomachs removed for subsequent analysis. Fish diet was described according to the numeric frequency method. The Manly Electivity Index was applied in order to verify prey selection. The most abundant families in both benthos and diet of both fish species were the same, indicating that these species consume mainly most abundant prey in the environment. We concluded that prey selection occurs even for preys that had small abundance in the environment. However, it is the availability of the macroinvertebrate resources that determines the major composition of items in diet of fish, demonstrating that the abundance is the factor that most influences the choice of prey. Rev. Biol. Trop. 59 (4): 1697-1706. Epub 2011 December 01.

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The acquisition of food by fish is a process that usually involves search, detection, capture and ingestion (Keenleyside 1979, Dunbrack & Dill 1983, Gerking 1994, Sih & Christensen 2001, Warburton 2003), in which the time spent searching and the respective energy expenditure should be compensated by the energy contained in the prey (Dill 1983, Gerking 1994). The predator decision in select prey is related to abundance or size and is directly correlated to the amount of food in its stomach and its nutritional needs (Keenleyside 1979, Dill 1983).

One of the major limitations for fish during foraging is spatio-temporal environmental heterogeneity, and the appropriate predator decision will depend on the local situation. Nonetheless, some environmental characteristics are rhythmic and, thus, already internally predicted by the fish, but others are stochastic and unpredictable. Examples of these latter include local food availability, type of territory and risk of predation in a giving location (Dill 1983). Regarding stream-dwelling fish feeding behavior, it is assumed that many predators are generalist and feed upon organisms present in the water column, including those that fall from the riparian vegetation to the water surface, but others are specialized benthic predators (*e.g.* Aranha *et al.* 2000, Barreto & Aranha 2006, Gomiero & Braga 2008). However, these generalizations have been made based mainly on feeding studies in temperate areas, with species such as *Salmo trutta* (brown trout) and *Oncorhynchus mykiss* (rainbow trout) (Gregory *et al.* 2007). Nowadays there are some studies on the topic on tropical areas (*e.g.* Costa 1987, Esteves & Lobón-Cerviá 2001, Barreto & Aranha 2006, Mazzoni & Costa 2007) that detected the same pattern.

Carnivorous guild is represented by a high number of fishes in most aquatic systems. One example is *Salmo trutta* that is a typical visual predator who select prey according to size and abundance in the environment (Rincón & Lobón-Cerviá 1999). Morphological (Gatz 1979) and behavioral characteristics are the main constraints directly involved in the predator decision of prey species (Sazima 1986), reflecting the variability of feeding strategies used by fish (Keenleyside 1979). In any case, predators choose their prey in order to minimize energy expenditure in the search and capture of food and maximize the amount of energy available from prey consumption. Factors such as size, morphology and prey behavior influence this cost-benefit relationship (Stephens & Krebs 1986).

Key to understand predator choice is the relationship between predator and prey abundance. Some models, based on fish from the temperate region, support the optimal foraging theory modeling the relationship between prey abundance and foraging time (Werner & Hall 1974); others discuss additional factors acting in prey choice as size (Gill 2003). The basic predation model (Emlen 1966, MacArthur & Pianka 1966) shows that the predator focuses only on the most profitable prey and, when their abundance decreases, they feed without selectivity, using many different prey types (Gill 2003).

Many issues related to resource partitioning and habitat use by fish from neotropical streams are widely discussed (Sabino & Castro 1990, Rezende *et al.* 2010) but there are few studies related to prey selection and availability (Rezende & Mazzoni 2006, Pinto & Uieda 2007, Carvalho 2008), while in the temperate region several studies, based on empirical data, have discussed prey selectivity (Mittelbach 1981, Cooper *et al.* 1985, Rincón & Lobón-Cerviá 1999). According to Sih & Christensen (2001), such an approach is still current, because the ability to predict aspects of the diet in response to changes in prey availability is one of the major problems of trophic ecology. The majority of studies on neotropical fishes describes some level of segregation across the aforementioned three major axes (Ross 1986): trophic (Esteves & Lobón-Cerviá 2001, Deus & Petrere 2003, Novakowski *et al.* 2008), spatial (Esteves & Lobón-Cerviá 2001, Benneman *et al.* 2005) and temporal (Lobón-Cerviá & Benneman 2000). It has also been shown that when the overlap along one axis is high, then segregation along the other axes is present (Lobón-Cerviá & Benneman 2000, Esteves & Lobón-Cerviá 2001, Benneman *et al.* 2005).

The optimal foraging theory started with models from Emlen (1966) and MacArthur & Pianka (1966) and it was known as a theory with Schoener (1971). According to this theory we approached prey choice (Gill 2003) and hypothesize that fish predators choose prey regardless of their abundance. The objective of the present study was to evaluate the prey selection by two insectivorous stream benthic fishes (Rezende 2009, Mazzoni *et al.* 2010) *Characidium* cf. *vidali* Travassos 1967, family Crenuchidae and *Pimelodella lateristriga* (Lichtenstein 1823) family Heptapteridae from Mato Grosso stream.

MATERIALS AND METHODS

Study site: The Serra do Mar, along the central and Southern Coast of Brazil, is formed by a complex net of streams rising up into its high altitudes, flowing through the Atlantic Rainforest, towards the Atlantic Ocean. The Atlantic Rainforest is the second largest tropical rainforest, after the Amazonian Hyalea. During recent decades, however, this vast region has been deforested and is nowadays reduced to 5% of its original distribution (Por 1992). However, the Atlantic Rainforest is considered one of the most important hotspots in the world regarding conservation priorities (Myers *et al*. 2000).

For the purpose of this study we selected the Mato Grosso stream, a typical Serra do Mar stream, located at the Eastern Coast of Brazil, distant approximately 70km from Rio de Janeiro city (Serra do Mar, 22º55'S - 42º35'W). From its sources, at about 800m above sea level, the stream drains a 30km^2 drainage area over the Northwestern areas of the Saquarema municipality (Rio de Janeiro) and leads into the Saquarema lagoon system. The 250m long sampling section selected for this study is located at the uppermost reaches of the stream (22º53'13.7" S - 42º39'44.4" W). This sampling section is characterized by abundant riparian vegetation and a substratum composed of rock, gravel, pebble and sand, along five succession of riffle, run and pool habitats. To prevent sampling-induced perturbations, the sampling section was divided into sub-sections as follows: the uppermost 50m sub-section was used for benthic macro-invertebrates sampling and 50m below that sub-section the fishes were collected at a 150m long sub-section.

The Mato Grosso stream fish assemblage in the selected site was composed of five species, of which three, *Astyanax taeniatus* (Jenyns 1842), *Characidium* cf. *vidali* and *Pimelodella lateristriga*, were abundant and only a few, scattered individuals of *Rhamdia quelen* (Quoy & Gaimard 1824) and *Phalloceros harpagos* Lucinda (2008) were recorded during the study period. We selected the two benthic most abundant species.

Voucher specimens were deposited at the Ichthyologic Collections of the Laboratório de Ictiologia da Universidade do Tocantins: *Phalloceros harpagos* (UNT 6771 to 6765) and the Museu Nacional do Rio de Janeiro: *Astyanax taeniatus* (MNRJ 29949 to 29954; 29962 to 29964; 29986 to 29988; 29990; 299994; 30000; 30003; 30005; 30006; 30011; 30016; 30018; 30027), *Characidium* cf. *vidali* (MNRJ 29955, 29959, 29967, 29969 to 29971, 29989, 29992, 29997, 30004, 30007, 30009, 30012, 30015, 30017, 30021, 30024), *Pimelodella lateristriga* (MNRJ 29965, 29972, 29995, 30019, 30020, 30022), *Rhamdia quelen* (MNRJ 29991).

Sampling and data analysis: Benthos and fishes were collected in 10-11 of June, 15-16 of July and 20-21 of September of 2006 and 9-10 January and 13-14 February of 2007. Fish were collected with electric fishing techniques (Mazzoni *et al*. 2000, Rezende *et al*. 2010). Approximately 70 individuals were chosen randomly from each species were selected randomly in each month during all day (morning, afternoon and night), totalizing 323 specimens of *Characidium* cf. *vidali* and 358 *Pimelodella lateristriga*. Fishes were collected and sacrificed according to Brazilian environmental laws (Brazilian government permission IBAMA/MMA 02022.002475/2006-10, authorization number 118/2006-DIFAP/IBAMA). All individuals collected were analyzed. Benthos was collected with a surber net (20x20cm, mesh size of 250μm) with a 250μm mesh screen sampling was conducted during the morning between 8-10a.m. On each sampling occasion, we collected 10 benthos samples for each type of substrate (rock, sand and leaf litter), totaling 150 samples at the end of the five sampling days. Densities of benthic organisms are expressed as the number of individuals per/m^2 (area of the Surber frame).

After sampling, the invertebrates were fixed in 90% ethanol and, in the laboratory, were identified to the lowest taxonomical level (Carvalho 1989, 1992, Carvalho *et al*. 2001, Olifiers *et al*. 2004, Salles *et al*. 2004, Borror & Delong 2005, Pes *et al*. 2005, Passos *et al*. 2007) and counted. Fishes were fixed in 10% formalin in the field and transferred to 70ºGL ethanol in the laboratory. Fishes had their stomachs removed for subsequent analysis and stomach items were identified and counted. Fish diet was described according to the numeric method (Hyslop 1980) that was expressed as frequencies and percentage frequencies.

The Manly´s α Electivity Index (Manly *et al*. 1993) was applied in order to verify prey selection. This index was chosen because the prey consumed by the species was very low when compared to the environment prey (benthos).

$$\alpha_i = \frac{r_i}{n_i}\left(\frac{1}{\Sigma(r_j / n_j)}\right)$$

where:

α_i = Manly's α (preference index) for prey type i

r_i, r_j = Proportion of prey i or j in the diet (i and j = 1,2,3 …, m)

ni, nj = Proportion of prey type i or j in the environment

When selective feeding does not occur, $\alpha_i = 1/m$ (m = number of prey types possible).

If α_i is greater than ($1/m$), then prey species i is preferred in the diet. Conversely, if α_i is less than ($1/m$), prey species i is avoided (Krebs 1989). The preys that were on the environment and were not found on diet were considered avoided (Manly *et al*. 1993).

According to Lechowicz (1982), an electivity index is not robust when analyzing rare prey, because the low values compromise the analysis. Thus, we excluded preys items whose numeric proportions were less than 1% of the total proportion. This way, we analyzed the electivity data discarding the rare prey and the prey available in the environment but no verified in the diet. We considered that the latter were rejected by the fishes and they are not useful in the electivity analysis (Lechowicz 1982).

RESULTS

Benthic fauna: A total of 9 825 individuals of 28 families were sampled in the benthos. Simuliidae, Chironomidae (families of Diptera) and Baetidae (family of Ephemeroptera) were the most abundant prey types (Table 1).

Diet composition: We collected 323 specimens of *Characidium* cf. *vidali* and 358 *Pimelodella lateristriga* were analyzed. *Characidium* cf. *vidali* consumed a total of 245 prey insects (total number of insects) and *Pimelodella lateristriga* consumed 276 preys items (total number of insects). *Pimelodella lateristriga* presented the most diverse prey consumption, totaling 33 different prey types while *Characidium* cf. *vidali* consumed 19 types of prey.

Prey more abundant in the diet of both species were Simuliidae (70.75% and 30.81%), Chironomidae (7.78% and 13.58%) and Baetidae (7.83% and 13.35%) The item Baetidae was the second more abundant in *Characidium* cf. *vidali* diet and Chironomidae was the second more abundant for *Pimelodella lateristriga* (Table 2).

Prey selection: According to α Manly's Preference Index *Pimelodella lateristriga* preferred Baetidae, Hydropsychidae and Leptoceridae while *Characidium* cf. *vidali* selected Simuliidae, Baetidae, Leptohyphidae and Leptophlebiidae. Despite being the second most abundant family in the benthos Simuliidae was not a preferred prey for both species. However Simuliidae was more abundant in the benthos and preferred only in the diet of *Characidium* cf. *vidali* (Table 3).

DISCUSSION

Characidium cf. *vidali* and *Pimelodella lateristriga* belong to the insectivorous guild (Rezende 2009, Mazzoni *et al*. 2010) that preyed mainly on benthic organisms.

TABLE 1
Total density (ind.m^{-2}) and relative density (%) of benthos organisms during the five sampling months (150 samples) in the Mato Grosso stream, Saquarema, Brazil

	Total density	Density (%)
Ephemeroptera		
Baetidae	75.78	8.99
Leptohyphidae	8.74	1.03
Leptophlebiidae	21.78	2.58
Odonata		
Anisoptera	2.11	0.25
Zygoptera	0.57	0.07
Plecoptera		
Gripopterygidae	3.38	0.40
Perlidae	12.05	1.43
Trichoptera		
Philopotamidae	0.79	0.09
Leptoceridae	14	1.66
Hydropsychidae	12.38	1.46
Hydroptilidae	3.44	0.40
Helicopsychidae	0.56	0.06
Calamoceratidae	0.85	0.10
Hydrobiosidae	0.39	0.04
Glossosomatidae	0.04	0.00
Lepidoptera		
Pyralidae	0.44	0.05
Coleoptera		
Elmidae larvae	50.26	5.96
Elmidae adult	27.11	3.22
Diptera		
Ceratopogonidae	1.14	0.14
Chironomidae	194.76	23.10
Simuliidae	406.93	48.27
Empididae	2.05	0.24
Tipulidae	0.42	0.05
Dixidae	0.17	0.02
Psychodidae	0.04	0.01
Hemiptera		
Veliidae	0.22	0.03
Decapoda		
Palaemonidae (*Macrobrachium* spp.)	1.62	0.19
Trichodactylidae (*Trichodactylus* sp.)	0.57	0.07
Total density of individuals (ind.m^{-2})	843	100
Total number of individuals	9 825	
Total number of samples	150	

Considering *Characidium* cf. *vidali* diet, the prey with highest numeric frequency were Simuliidae, Baetidae and Chironomidae. These three families are described in the literature as benthic organisms associated mainly to rocky substrate or leaf litter (Merritt & Cummins 1996). Species of the *Characidium* genus are benthic predators with sit-and-wait behavior (Sazima 1986, Sabino & Castro 1990). *Pimelodella lateristriga*, is also classified as a benthic predator, foraging aquatic insects along the substrate (Casatti *et al*. 2001, Mazzoni *et al*. 2010), consuming the same preferential prey as *Characidium* cf. *vidali*. *Pimelodella lateristriga* also use diversified micro-habitats, but with the predominance of sandy substrate, and presents foraging habit of substrate speculation, with use of the sensory function of the cephalic barbels to capture prey. This behavior is common between heptapterid catfish as *Imparfinis mirini*, *Phenacorhamdia tenebrosa*, *Pimelodella* aff. *gracilis* (Casatti *et al*. 2001). Patterns of feeding activity and feeding tactics differed markedly among the two species. In Mato Grosso stream the two benthic species showed consistent diet patterns of feeding activity. *Characidium* fed more intensively during the day, *Pimelodella* exhibited the opposite pattern with maximum feeding intensity at night (Rezende 2009, Mazzoni *et al*. 2010).

The most abundant families in both benthos and fishes diet were the same, indicating that these species consume the most abundant prey in the environment. Relations are described in the literature, in which fish predators influence the densities of macroinvertebrates, which probably does not occur in the Mato Grosso stream, due to the dominance of Simuliidae, Chironomidae and Baetidae. In a review about experiments in streams, Wooster (1998) suggests that vertebrate predators have a moderate effect on prey density (invertebrates), while invertebrate predators have a stronger effect on the prey density (invertebrates). This occurs because vertebrate predators are able to forage a higher diversity of prey than invertebrate predators.

TABLE 2

Numeric frequency and percentage numeric frequency of prey item consumed by *Characidium* cf. *vidali* (323 individuals) and *Pimelodella lateristriga* (358 individuals) during the five sampling months in the Mato Grosso stream, Saquarema, Brazil

	Characidium cf. *vidali vidali*		*Pimelodella lateristriga*	
	Total	%	Total	%
Ephemeroptera				
Baetidae	5.83	7.83	6.61	13.35
Leptohyphidae	2.11	2.83		
Leptophlebiidae	1.93	2.59	0.95	1.92
Ephemeroptera nymphae			0.04	0.08
Odonata				
Anisoptera			0.58	1.17
Zygoptera	0.02	0.03	0.04	0.08
Odonata unidentified	0.33	0.44		
Plecoptera				
Gripopterygidae	0.03	0.04	0.56	1.13
Perlidae			0.41	0.83
Megaloptera				
Corydalidae			0.05	0.10
Trichoptera				
Philopotamidae	0.50	0.67	1.26	2.55
Leptoceridae	0.47	0.63	2.96	5.98
Hydropsychidae	0.43	0.58	1.52	3.07
Hydroptilidae	0.89	1.20	0.98	1.98
Helicopsychidae			0.56	1.13
Lepidoptera				
Pyralidae	1.44	1.93	1.56	3.15
Coleoptera				
Elmidae larvae	1.15	1.54	1.85	3.74
Elmidae adult	0.47	0.63	0.55	1.11
Psephenidae			0.05	0.10
Diptera				
Ceratopogonidae	0.01	0.01	0.10	0.20
Chironomidae	5.79	7.78	6.72	13.58
Simuliidae	52.68	70.75	15.25	30.81
Empididae	0.32	0.43	3.14	6.34
Tipulidae	0.01	0.01	0.26	0.53
Muscidae			0.48	0.97
Terrestrial Insects				
Lepidoptera			0.03	0.06
Hymenoptera Formicidae	0.05	0.07	0.75	1.52
Hemiptera			0.25	0.51
Diptera			0.02	0.04
Araneae			0.04	0.08
Acari			0.02	0.04
Blattodae			0.02	0.04
Other items				
Oligochaeta			1.35	2.73
Osteichthyes			0.02	0.04
Seed (vegetal matter)			0.52	1.05

TABLE 3
Manly's α electivity index calculated for prey with proportions higher than 1% in the diet of *Characidium* cf. *vidali* and *Pimelodella lateristriga* considering the five samplings of the Mato Grosso stream, Saquarema, Brazil

	Characidium cf. *vidali*	*Pimelodella lateristriga*
Baetidae	0.11	0.13
Leptohyphidae	0.36	
Leptophlebiidae	0.13	0.07
Perlidae		0.05
Hydropsychidae	0.05	0.19
Leptoceridae	0.05	0.34
Elmidae adult	0.02	0.03
Elmidae larvae	0.03	0.05
Chironomidae	0.04	0.05
Simuliidae	0.18	0.05

Prey with α values >0.1 were considered preferred.

Other studies indicate that predators have little or no effect on benthic prey (Allan 1983). Cooper *et al*. (1990) argue that streams, due to the fact that they are closed systems, present very different results regarding predation, differing from terrestrial systems. One of the reasons is that some variables, such as current speed, act on organism distribution, affecting the relative importance of prey, in a way that other ecological relationships become more decisive regarding invertebrate densities, instead of predation by vertebrates (fish) (Cooper *et al*. 1990). The effects of fish foraging on invertebrates may also affect the densities, through indirect factors. Grazing and detritivorous fish have great impact on the communities of benthic invertebrates, through depletion or alteration of abiotic conditions (substrate scraping) (Flecker 1992, Gelwick *et al*. 1997). These indirect factors may be more important than the direct effects of predation (Flecker 1992).

In Mato Grosso stream Chironomidae was the second more abundant on benthos but was not a preferred prey for both species. Simuliidae was more abundant in the benthos and preferred only by *Characidium* cf. *vidali*. Pinto & Uieda (2007) studying a stream in the Atlantic Rainforest, observed that, in most cases of high selectivity by fish species, the insects presented a low frequency in the benthos. The low abundance of rare prey in the environment may affect the analysis of these indices, causing a false impression of a selected item (Lechowicz 1982, Manly *et al*. 1993). In the Mato Grosso stream, we decided to analyze the electivity data discarding the rare prey and the prey available in the environment but no verified in the diet. We considered that the latter were rejected by the fishes and they are not useful in the electivity analysis (Lechowicz 1982). These indices consider that food that occurs in higher proportions in the diet when compared to the environment is considered preferential, unlike the food that presents low occurrence in the diet and high occurrence in the environment (sensu Lechowicz 1982).

Pimelodella lateristriga selected Baetidae, Hydropsychidae and Leptoceridae contrasting with another study in Atlantic Rainforest stream where Pinto & Uieda (2007) described that a heptapterid catfish preferred Lepidoptera and Diptera prey. Also this study Pinto & Uieda (2007) described that *Characidium zebra* selected Plecoptera, differing from the Mato Grosso stream, where *Characidium* cf. *vidali* selected Diptera and Ephemeroptera. According to Carvalho (2008) plasticity in fish diet in Amazonian streams is related to the availability abundant prey. This author also argues that the ratio of high abundance of preys in the environment versus consumption of fishes represents a form of optimum foraging.

We conclude that in the Mato Grosso stream the fish species mainly consume the prey with the highest abundance in the environment. There is preference of non-abundant prey, demonstrating a feeding preference of the fish species for some food items. However, it is the availability of macroinvertebrate resources that determines the item composition in the diet of the two fish species, demonstrating that the factor influences the choice of prey the most is prey abundance.

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RESUMEN

Existen muy pocos estudios relacionados con la selección y disponibilidad de las presas por parte de sus depredadores. Actualmente, este enfoque se mantiene, debido a que uno de los principales problemas de la ecología trófica es la capacidad de predecir los aspectos de los hábitos alimentarios en respuesta a los cambios en la disponibilidad de las presas. El objetivo general de este estudio fue evaluar la seleccion de las presas en dos especies (*Characidium* cf. *vidali* y *Pimelodella lateristriga*) del arroyo Mato Grosso en Saquarema, Rio de Janeiro. Se recolectaron bentos y peces en junio, Julio y septiembre 2006 y en enero y febrero 2007. Los peces fueron recolectados con técnicas de pesca eléctrica y los del bentos con una red surber. La densidad de los organismos bentónicos se expresó como el número de individuos por m^2. Luego del muestreo, los invertebrados se fijaron en 90% de etanol y se identificaron con el nivel taxonómico más bajo. Los peces fueron fijados con 10% de formalina en el campo y transferidos a etanol 70º GL en el laboratorio. Los estómagos de los peces fueron extirpados para su posterior análisis. Las familias más abundantes del bentos y las dietas de los peces fueron las mismas, lo que indica que estas especies consumen principalmente la presa más abundante en el ambiente. Se concluye que la selección de la presa se produce incluso para aquellas presas con una abundancia pequeña en el entorno. Sin embargo, es la disponibilidad de los recursos de los macroinvertebrados la que determina la mayor composición en términos de la dieta de los peces, demostrando que la abundancia es el factor que se ve más influenciado por la elección de presas.

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