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Scientific Note

Feeding ecology of the leaf fish *Monocirrhus polyacanthus* (Perciformes: Polycentridae) in a *terra firme* stream in the Brazilian Amazon

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Monocirrhus polyacanthus (Polycentridae) is a remarkable leaf-mimicking fish that inhabits streams, lake and river margins along the Amazon basin. Despite its obvious predatory habits and being frequently present in the international aquarium trade, little is known about its diet under natural conditions. We examined 35 specimens of leaf fish (28.5-82.0 mm SL), of which 19 had food the stomach. Thirty-three preys were found in the stomach contents, 19 of which were measured (2.0-33.0 mm total length). Up to five preys were found in the stomach contents of a single leaf fish specimen. The diet of the leaf fish was constituted by fish (63.15% FO, n = 12) and invertebrates (36.3% FO, n = 4); fish and invertebrate preys occurred together in three stomachs (15.8% FO). Of the 33 prey found in the stomachs, 21 were fish and 12 invertebrates. Among the consumed prey fishes, Characiformes and Perciformes represented 76.1% and 14.2% respectively. Characidae was the most commonly recorded prey family, followed by Lebiasinidae. Invertebrates were represented by shrimps (Decapoda) and insects (Coleoptera, Hymenoptera, Ephemeroptera and Odonata). There was a positive relation between the size of the leaf fish specimens and of its consumed preys. The combination of leaf fish's visually effective body camouflage and the reduced activity of the characids at crepuscular hours probably allow the capture of such fast moving preys. The coiled position of the fishes found in the stomach of *M. polyacanthus* possibly allowed the accommodation of more than one prey simultaneously, which seems to be important for predators that consume proportionally large preys that are captured only occasionally.

Monocirrhus polyacanthus (Polycentridae) é uma espécie de peixe cuja aparência e hábitos mimetizam uma folha morta à deriva, e que habita igarapés e margens de rios e lagos da bacia Amazônica. A despeito de seu reconhecido comportamento predatório e do fato de ser frequentemente explorada no comércio internacional de peixes ornamentais, pouco se conhece sobre sua dieta em condições naturais. Nós examinamos 35 exemplares de peixe-folha (28,5-82,0 mm CP), dos quais 19 continham presas no estômago. Trinta e três presas foram encontradas, das quais foi possível estabelecer o comprimento total de 19 delas (2,0-33,0 mm CT). Até cinco presas foram encontradas no estômago de um único exemplar. A dieta dos peixes-folha foi constituída por peixes (n = 12; 63,15% FO) e invertebrados (n = 4; 21,05% FO); peixes e invertebrados ocorreram juntos em três estômagos examinados (15,8% FO). Das 33 presas encontradas nos estômagos analisados, 21 foram peixes e 12 invertebrados. Dentre os peixes consumidos, Characiformes e Perciformes representaram 76,1% e 14,2%, respectivamente. Characidae foi a família de presas mais comum, seguida de Lebiasinidae. Invertebrados (presas) foram representados por camarões (Decapoda) e insetos (Coleoptera, Hymenoptera, Ephemeroptera e Odonata). Constatou-se uma relação positiva entre o tamanho do predador e da presa. A combinação da camuflagem corporal do peixe-folha, a baixa atividade dos caracídeos nos horários de crepúsculo e a eficiência do mecanismo de captura de presas por sucção, provavelmente possibilitam a captura de presas ágeis e de hábitos nectônicos. A posição encurvada dos peixes nos estômagos dos exemplares de *M. polyacanthus* possivelmente facilita a acomodação simultânea de mais de uma presa no estômago, o que deve ser especialmente importante para predadores que consomem presas grandes e apenas ocasionalmente.

Key words: Diet, Feeding behavior, Piscivory, Camouflage.

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The family Polycentridae is known for its remarkable morphological specialization associated to predatory behavior (Liem, 1970). The family is represented by two species in the Amazon basin, including the leaf fish *Monocirrhus polyacanthus* Heckel, 1840, which is widely distributed in rivers and lakes of the region (Britz & Kullander, 2003), mostly in upland (henceforth *terra firme*) streams.

The leaf fish is a small-sized species that reaches up to 80 mm in standard length (SL), and presents distinct morphological characteristics, such as the absence of a lateral line, a large and protractile mouth, a petiole-like filament in the lower jaw, and a laterally compressed body, strongly resembling a dead leaf in format and color pattern (Nelson, 1994) (Fig. 1).

Fig. 1. A freshly collected leaf fish *Monocirrhus polyacanthus*. Photo by F. P. Mendonça.

Although present throughout the Amazon basin and frequently exploited by the ornamental fish trade, the leaf fish is apparently not as locally abundant as several other species commonly encountered in the same habitat (Gutiérrez, 2003). Such low abundance results in its rarity in fish collections and may explain the scarcity of information about its natural history and diet. Most of the available information on its feeding behavior refers to captive specimens maintained under aquarium conditions (Liem, 1970; Barros & Higuchi, 2007).

During a survey of the fish fauna of the Amanã Sustainable Development Reserve (RDSA) conducted in 2002 and 2003, 49 specimens of *M. polyacanthus* were collected with hand nets close to the riparian vegetation, and amidst aquatic macrophytes, and with fine-meshed seine nets in shallow stream margins of Baré stream, a terra firme tributary of Amanã Lake. Those specimens gave us the opportunity to study the diet of *M. polyacanthus* in that area, so aiming to contribute to a better understanding of the feeding habits of this remarkable, leaf-mimicking fish species.

The Amanã Reserve is a 2,35 million ha conservation unit located between the basins of the black water Negro River and the white water Japurá and Solimões Rivers (1º30'-3º05'S 62º50'-65º00'W), in the Amazonas State, Brazil.

All collected leaf fish specimens were immediately preserved in 10% formalin, later transferred to 70% ethanol, and measured (SL, mm). The abdominal cavities of 35 specimens were opened to determine the sex, and the presence of food in the stomach. The stomachs were then dissected and examined under a stereoscopic microscope. The position of the preys in the stomachs was verified and registered. Prey items were identified to the lowest taxonomic level possible, quantified (N), and measured (fish: SL, mm; invertebrates: total length, TL, mm) whenever possible. The importance of each prey taxon was calculated based on its frequency of occurrence (FO%) in relation to the number of stomachs with food (Hyslop, 1980). The relative contribution of fish preys were also expressed as frequency by numbers (FN%), calculated as the number of preys in each category (taxonomical order and family) in relation to the total number of fishes found in the stomachs. A linear regression was employed to investigate the relation between the paired size of the leaf fish specimens and its preys. Unfortunately, the dissected specimens were discarded after analyzed, but the accurate collecting locality of the studied sample warrants the possibility of further taxonomic confirmation of the species identity if needed.

The size of the collected specimens of *M. polyacanthus* averaged 67.2 ± 15.2 mm (N = 49). It was possible to determine the sex of 22 specimens, of which 10 were males (50.2 ± 13.1 mm SL, ranging 32.3 to 73.1 mm) and 12 were females (52.3 ± 12.8 mm SL; 31-82 mm). Thirty-three preys were found in the 19 stomachs of *M. polyacanthus* that contained food. Fish were the only prey type encountered in the stomach contents of 12 specimens (63.15% FO), while invertebrates only were present in four other stomachs (21.05% FO); both fish and invertebrates were found in the digestory tracts of three specimens (15.8% FO). Only two prey fishes were found in an advanced state of digestion and could not be adequately identified.

Of the 33 preys found in the stomachs of *M. polyacanthus*, 21 were fish and 12 were invertebrates. Characiformes (16) and Perciformes (3) represented 76.1% FN and 14.2% FN of the preys respectively. Among the Characiformes, Characidae was the most commonly recorded prey family (62.5% FN; n = 10), followed by Lebiasinidae (37.5% FN; n = 6). Both families were represented by three species each: *Hemigrammus analis*, *H. belottii* and *Hemigrammus* sp. (Characidae); and *Nannostomus eques*, *N. unifasciatus* and *N. trifasciatus* (Lebiasinidae). Perciformes were not identified to species level due to the advanced state of digestion of these preys (Table 1).

Invertebrates were represented by 12 specimens of crustaceans (Decapoda and Conchostraca) and insect remains (Coleoptera, Hymenoptera and larvae of Ephemeroptera and Odonata, Table 1).

Most preys found in the stomachs of leaf fish specimens were swallowed whole, despite their proportionally large

Table 1. Preys consumed by the leaf fish *Monocirrhus polyacanthus*. Number of stomachs with food = 19; number of preys = 33 (n.i. = not identified).

Prey type	Order	Family	Taxon	N
Fish	Characiformes	Characidae	*Hemigrammus analis*	4
			Hemigrammus belottii	2
			Hemigrammus sp.	1
			n.i.	3
		Lebiasinidae	*Nannostomus eques*	3
			Nannostomus unifasciatus	2
			Nannostomus trifasciatus	1
	Perciformes	Cichlidae	n.i.	3
	Fish remains			2
Invertebrates	Decapoda	Palaemonidae	*Euryrhynchus* sp.	1
			Palaemonetes sp.	1
	Conchostraca		Conchostraca n.i.	1
			Crustacean n.i.	1
	Ephemeroptera			4
	Hymenoptera			1
	Coleoptera			1
	Odonata			2

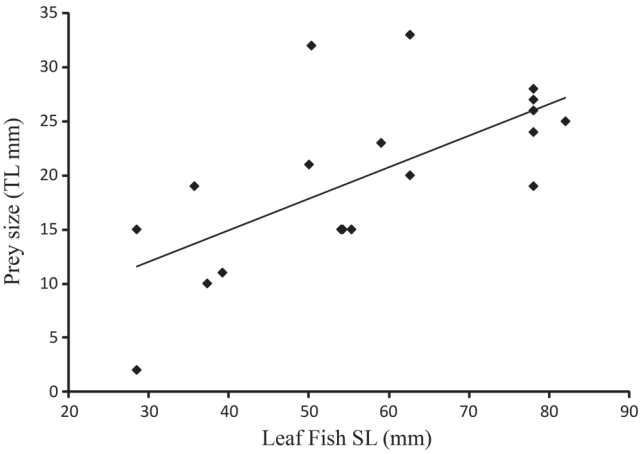

Fig. 3. Prey size (total length, in mm) in relation to predator's size (standard length, in mm) for specimens of the leaf fish *Monocirrhus polyacanthus* ($r^2 = 0.44$, $F = 13.24$, $p = 0.002$, Number of measured preys = 19).

dimensions when compared to the predator's size. Large sized prey fish were occasionally found occupying the whole space from the lower portion of the esophagus to the end of stomach, especially when the gut was filled with more than one prey. In these cases the large prey fishes were found in a coiled ("U"-shaped) position with head and tail directed to the head of the predator.

Invertebrates were mostly found in the guts of small specimens of *M. polyacanthus* (between 28.5 and 54.2 mm SL), whereas fish constituted the only prey of the larger leaf fish specimens (Fig. 2). Of the 33 preys consumed by the leaf fishes, only 19 were found whole and accurately measured. Fish and invertebrate preys ranged 11.0-33.0 mm SL and 2.0-15.0 mm TL respectively. Mean prey size corresponded to 34.9% of the predator size (n = 19). There was a positive relation between the sizes of the leaf fish specimens and the consumed preys ($r^2 = 0.44$, $F = 13.24$, $p = 0.002$, $N = 19$) (Fig. 3).

Fishes usually use camouflage to avoid the detection by visually oriented predators, by presenting color patterns that resemble their surroundings (*e.g.* Sazima *et al.*, 2006). However, camouflage and mimicry are not employed just as a defensive strategy, but also as an aggressive tactic. The leaf fish *Monocirrhus polyacanthus* typically lives in small *terra firme* streams, and presents a general body morphology, color pattern, and swimming behavior that remarkably resemble a soaked dead leaf slowly drifting in the water current (Liem, 1970; Britz & Kullander, 2003), which are probably used to facilitate predation. Moreover, the highly protrusible mouth of the leaf fish (which may correspond to 60% of the head length when fully expanded; *cf.* Waltzek & Wainwright, 2003) may allow an efficient strike after slowly approaching the prey.

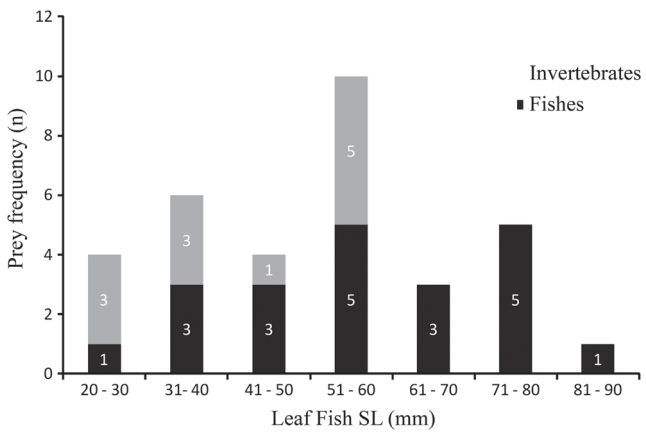

Fig. 2. Proportion of preys (fish and invertebrates) recorded in the stomach of the leaf fish *Monocirrhus polyacanthus*, by predator size classes (Number of stomachs with food = 19).

Our results confirm that *M. polyacanthus* is a predator species that feeds mostly on small fish, as reported by Liem (1970) and Gutiérrez (2003), and invertebrates (insects and crustaceans). The higher abundance of prey fishes of the families Characidae and Lebiasinidae in the stomachs of the leaf fish specimens is probably related to microhabitat sharing (the shallow margins of small streams, rivers, and lakes) by predators and preys. Fishes of the family Characidae, mainly represented in our study by species of the genus *Hemigrammus*, are commonly found moving constantly in shoals along the shallow streams during daytime (our personal observations). Considering the slow moving habits of the leaf fish, it is improbable that such characid preys are consumed under those conditions. Nevertheless, diurnal fishes like the above mentioned characids assume a lethargic state during twilight and night time, when individuals approach to the stream margins in search of protection against large fish predators (Zuanon & Ferreira, 2008). It is possible that the combination of a visually effective body camouflage by the leaf fish at twilight and the reduced activity of characids at crepuscular hours enhance the effectiveness of the capture of such fast-moving preys. On the other hand, the lebiasinids, represented by species of the genus *Nannostomus*, are slow

moving fishes that join in small shoals close to the water surface at shallow margins of streams and rivers during the day. These small fish presents a color pattern composed by one or more longitudinal dark stripes (Weitzmann & Cobb, 1975; Weitzmann, 1978) that possibly help to camouflage them among the plant debris that commonly accumulates close to stream banks (our field observations). The dead leaf mimicking by *M. polyacanthus* probably is highly effective as a disguise among the plant debris accumulated close to the shore, which would allow an efficient capture of lebiasinid fishes during daylight hours.

The coiled position of the preys encountered in the stomach of *M. polyacanthus* has already been observed in the stomach of other fish-eating species, such as the catfishes *Phractocephalus hemioliopterus* (Pimelodidae) and *Denticetopsis macilenta* (Cetopsidae) (J. Zuanon, pers. obs.), in the ogre catfish *Asterophysus batrachus* (Auchenipteridae; Zuanon & Sazima, 2005), and the marine sardine *Chirocentrodon bleekerianus* (Pristigasteridae) (Sazima *et al*., 2004). This arrangement of the preys inside the stomach may maximize the use of space in the digestory tract, allowing the allocation of a higher number of preys, which seems to be especially important for predators that consume proportionally large preys that are captured only occasionally.

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