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Chironomidae as a food resource for *Leporinus amblyrhynchus* (Teleostei: Characiformes) and *Pimelodus maculatus* (Teleostei: Siluriformes) in a Brazilian reservoir

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Abstract
The objective of this study was to demonstrate the importance of chironomid (Diptera, Insecta) larvae as food resource for *Leporinus amblyrhynchus* Garavello & Britski, 1987 (Anostomidae, Characiformes) and *Pimelodus maculatus* Lacépède 1803 (Pimelodidae, Siluriformes) and to call attention for the importance of the trophic relation between fish and chironomids assemblages in Miranda reservoir in Araguari River (Minas Gerais State, Brazil), focusing on the influence of the dam on the structure and taxonomic composition of chironomid assemblage. A total of 318 stomach contents of *L. amblyrhynchus* and *P. maculatus* were checked of which 108 had chironomid larvae. The number of chironomid larvae observed in stomach contents was higher for *L. amblyrhynchus* (86.3%) than for *P. maculatus* (52.7%). The recorded taxonomic richness of chironomid larvae in the stomach contents, suggest that these two fish species invest considerable time and energy feeding on chironomid larvae, thus consisting an important food resource. The recorded data constitute important additional information on the biology of the two studied fish species.

Key words: Chironomidae, Fish diet, Dam impacts, Biodiversity.

Introduction

Dynesius & Nilsson (1994) pointed out that 77% of the total discharge of the 139 largest river systems in the northern hemisphere is affected by river channel fragmentation caused by dams, reservoirs, intercatchment dimensions, and irrigation. This fragmentation could profoundly affect biological populations over a substantial area of the world (Rosenberg et al., 2000).

Ecological interactions between biological populations in reservoirs can be assessed easily and are always a reflex of environmental conditions (physical and chemical limnological parameters must be evaluated) of hydrological alterations. These hydrological alterations are defined by Rosenberg et al. (2000) as any anthropogenic disruption in the magnitude of timing of a natural river flow. Large dams have proven to be primary destroyers of aquatic habitat, contributing substantially to the destruction of fisheries, the extinction of species, and the overall loss of the ecosystem services on which the human ecology depends (Postel, 1998). The impacts of large-scale hydrological alterations include habitat fragmentation within dammed rivers (e.g., Barbosa et al., 1999); downstream habitat changes, such as loss of floodplains, riparian zones, and adjacent wetlands, and deterioration and loss of river deltas and ocean estuaries (e.g., Rosenberg et al., 1997); deterioration of irrigated terrestrial environments and associated surface waters (e.g., McCully, 1996).

The most important features of a reservoir are the ones related to its morphometry, retention time (which depends on uses, hydrological cycle and flow requirements), thermal patterns of stratification and circulation, water level fluctuations, type and size of associated wetlands and the effects or/and relationship with the downstream ecosystem (Tundisi, 1993).

Within aquatic environments, numerous studies have considered fish and benthic invertebrate communities focusing on (1) the effects that one or few species from one community have on another community, (2) the changes in biomass and production across different communities, and (3) the changes in the diversity of different communities due to environmental conditions (Jackson & Harvey, 1993). Some recent studies (e.g., Pierce & Hinrichs, 1997) have shown that fish control the densities and biomass of some macroinvertebrate taxa, and production-consumption rates (top-down effects). These interactions can have strong negative effects on total biomass and density (Mittelbach, 1988), or indicate weak or variable effects (Johnson et al., 1996), while other studies show little or no effect at all (Hanson & Leggett, 1986). Insects play an important role in food chains of aquatic systems, and among Diptera the chironomid larvae are recognized as an important food item for many fishes (bottom-up effects) (Branco et al., 1997; Fernando, 1994; Hahn et al., 1998; Lobon-Cerviá & Bennemann, 2000). The fact that the lakes exhibit similar patterns based on their fish and benthic invertebrate

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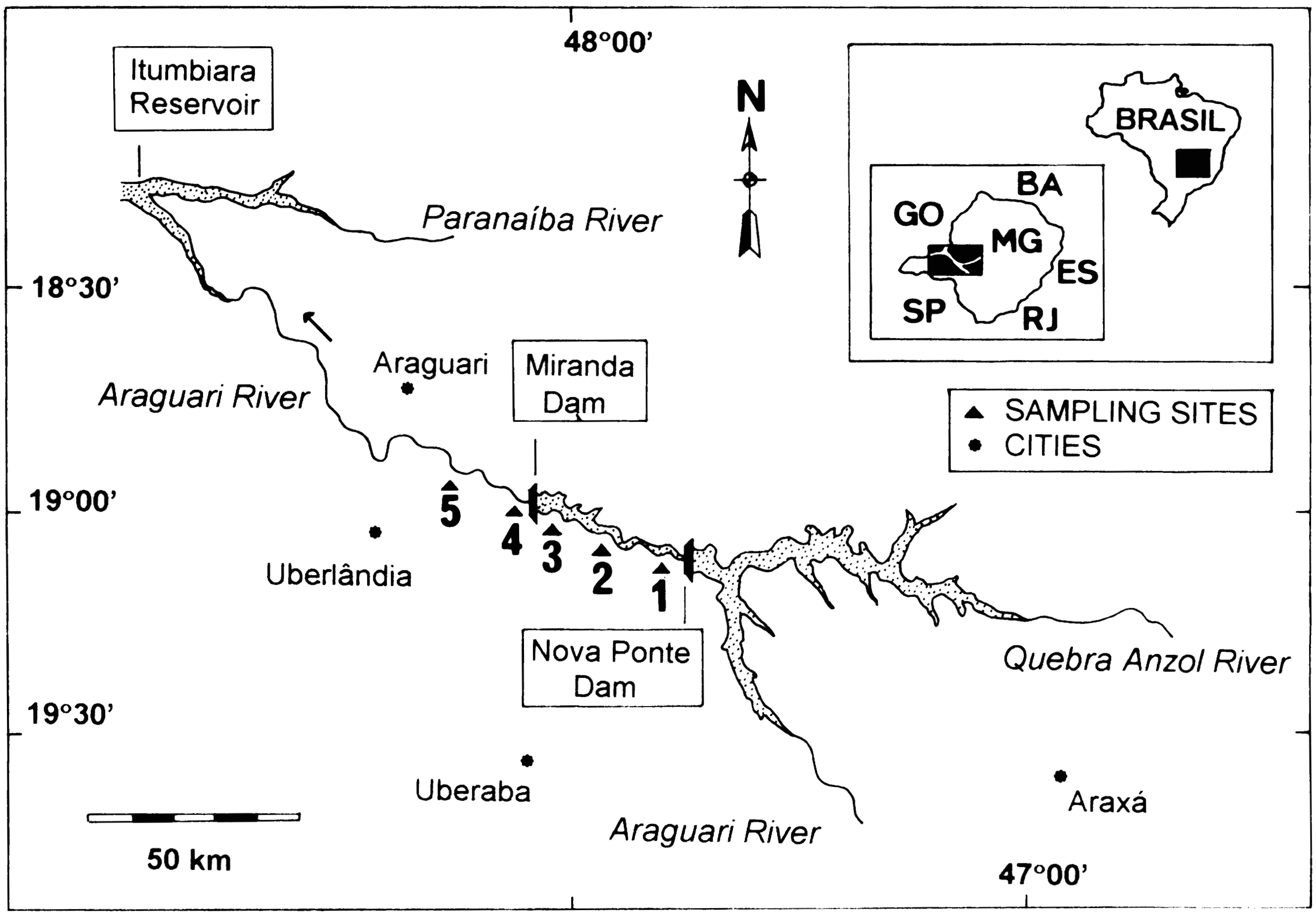

Figure 1 - Geographic location of Araguari river (Minas Gerais State, Brazil) with the indication of the study area and the location of the Miranda reservoir.

communities may not be surprising. Some invertebrate taxa may be limited in abundance due to direct predation by fish or show increased abundance due to reduced predation (Jackson & Harvey, 1993). The response of many benthic taxa may be species specific as shown by changes in size structure, of the invertebrate communities (Post & Cucin, 1984).

Given the role of benthic macroinvertebrates in the fish diet in different freshwater ecosystems, our objective was to demonstrate the importance of chironomid (Diptera, Insecta) larvae as food resource for *Leporinus amblyrhynchus* Garavello & Britski, 1987 (Anostomidae, Characiformes) and *Pimelodus maculatus* Lacépède 1803 (Pimelodidae, Siluriformes) and to call attention for the importance of the trophic relation between fish and chironomids assemblages in a Brazilian reservoir. We assumed that benthofagous fishes can find chironomids in a wide number of microhabitats, being much more efficient than the traditional benthic macroinvertebrates sampling efforts. Considering this, the stomach content of *L. amblyrhynchus* and *P. maculatus* were used as a tool to assess the chironomid diversity at Miranda reservoir in Araguari River, focusing on the influence of the dam on the structure and taxonomic composition of chironomid assemblage. Based on this, the following questions were proposed: (1) are the chironomid genera richness and Shannon diversity index, found in the stomach content, significantly different between the two fish species? (2) considering the rainy and dry seasons is there a significant difference between the feeding diets of the two fish species? (3) are there differences between the richness and diversity of chironomids up and downstream the reservoir for these species?

Study Area

The Araguari River is one of the main tributaries of Paranaíba river which forms, together with Grande River, the Paraná river basin (the second largest neotropical river catchment). This river basin is the tenth in discharge in the world and the fourth in drainage area (Agostinho et al., 1999). Approximately 70% of the Brazilian hydroelectric energy supply is produced by the power plants installed in the upper Paraná river basin (COMASE, 1994). More than 130 dams with height superior to 10 m were built in the upper Paraná river.

The region of Miranda reservoir is characterized by a tropical climate, with the dry period occurring from April to September and the rainy season from October through March,

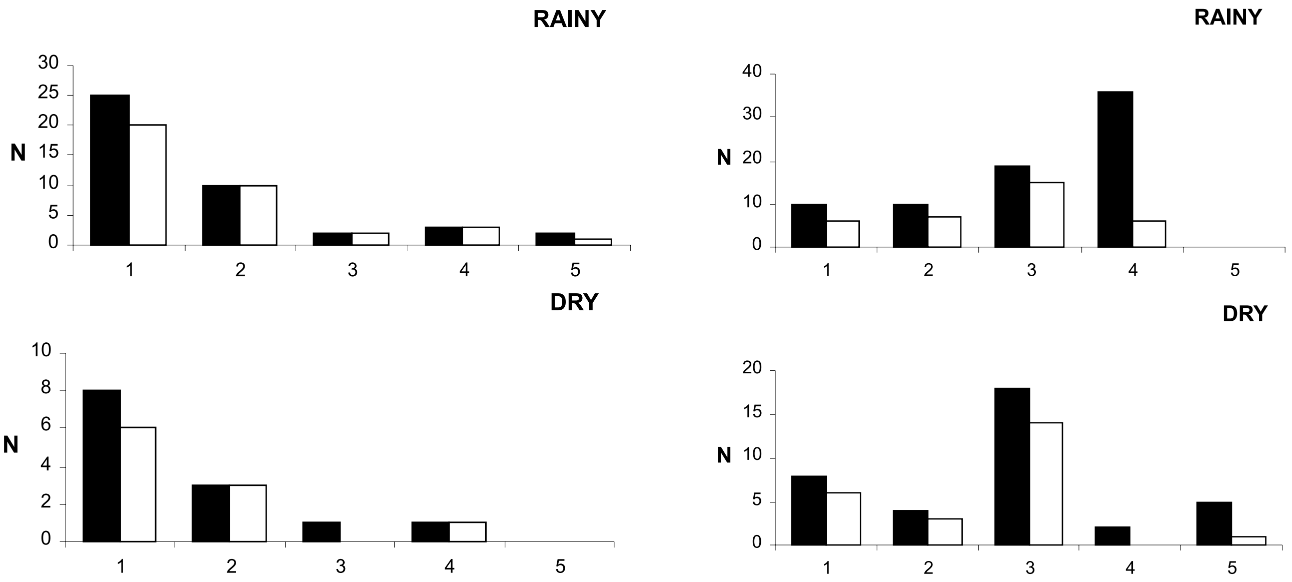

Fig. 2 - Number of collected fishes (black columns) of *Leporinus amblyrhynchus* and *Pimelodus maculatus* and number of stomach contents with chironomid larvae (white columns) during the rainy and dry seasons of 1998 in Miranda reservoir.

with a 1700 mm/year precipitation (Nimer, 1989). The region is located in an ecotone zone between savanna ("cerrado") and deciduous forest, mainly used for agricultural purposes (IBGE, 1992).

Miranda reservoir is located in the upper section of Araguari river, which is contiguous with Nova Ponte reservoir upstream (fig.1). Downstream, there is a stretch of 100 Km up to Itumbiara reservoir. The filling phase of Miranda reservoir began in August 1997. The reservoir shows a 80 m maximum depth and a 50.6 Km2 water surface. Before the filling phase, the mean turbidity was 75.0 NTU in the dry season (June through August) and 150.0 NTU in the rainy season (January through February). After the filling phase, the turbidity declined to 2.1 NTU and 7.9 NTU in the dry (July) and rainy (January and February) seasons, respectively. Table 1 presents some of the abiotic parameters measured during the dry and rainy sampling periods.

Material and methods

Fish were collected in the rainy (November 1997 and January 1998) and the dry (May and August 1998) seasons in three sampling stations in Miranda reservoir and in two sampling stations downstream the dam (Figure 1). Samplings were done from 5:00 pm to 7:00 am (14 hours long), using gillnets with 3-10 cm mesh size, 20 m long , and 1.6 m high. Collected fishes were preserved in 10% formalin solution, measured, and weighed in the laboratory. The fish specimens were deposited in the Fish Collection of the Laboratório de Ictiologia, Departamento de Zoologia, Instituto de Ciências Biológicas, Universidade Federal de Minas Gerais.

The stomach was cut apart and the content separated and diluted in 1 or 2 ml of water according to stomach repletion. Chironomid larvae and head capsules were sorted under a stereomicroscope. The identification at genus level was done under microscope using a 10% lactofenol solution. The identified specimens were deposited in the Reference Collection of Benthic Macroinvertebrates of the Institute of Biological Sciences, Universidade Federal de Minas Gerais. The number of chironomid larvae (N), richness index at genus level (R), Shannon-Wiener diversity index (H´) and Shannon evenness (E) were calculated as proposed by Magurran (1988). The statistical significance between the chironomid diversity in the stomach contents in temporal and spatial scales were tested using a t-Student test. The level of statistical significance was $p < 0,05$.

Results

Of the 105 fish species occurring in Araguari river during the 1986-2000 sampling period before and after the dam construction, ten species were exotic. In Miranda reservoir, 49 fish species were persistently captured at the study sites, of which one was exotic (*Tilapia* sp.). During the studied period, *P. maculatus* was the second and the fifth most abundant species in the reservoir and downstream, respectively, while *L. amblyrhynchus* was, respectively, the eighth and tenth most abundant species. Size ranges of 9.7-34.0 cm Standard Length (SL) for *P. maculatus* and 9.5-16.6 cm SL for *L. amblyrhynchus* included juvenile and adult individuals. In the rainy season the mean length size and mean weight for *P. maculatus* was higher (24.3 cm LS and 344.1 g) than in the dry season (18.1 cm SL and 155.9 g). Also *L. amblyrhynchus* specimens showed mean length sizes and weight higher in the rainy season (13.2 cm SL and 44.0 g) than in the dry season (12.4 cm SL and 36.9 g). Moreover, *P. maculatus* was in reproductive activity during November 1997 and January 1998 only, while *L. amblyrhynchus* was reproductivily active all over the hydrological year (see Vono *et. al.*, in press).

Downstream the Miranda dam, the river shows clear and well oxigenated waters (Table 1), with limnological characteristics similar to the reservoir upstream, and exhibiting lower

Table 1 - Abiotic parameters measured during the rainy and dry sampling periods in 1997-1998 in Araguari river, downstream the Miranda dam. (1, 2 and 3: sampling stations in Miranda reservoir; 4 and 5: sampling stations in Araguari river, downstream the dam; * data not obtained).

Parameters	Rainy					Dry				
	Sampling Stations									
	1	2	3	4	5	1	2	3	4	
Depth (m)	3.8	3.0	0.3	*	0.3	5.8	2.6	0.3	*	0.3
Temperature (^{o}C)	28.0	27.5	26.5	*	24.0	22.0	22.5	21.0	*	23.0
Dissolved Oxygen (% sat.)	84.0	80.0	39.0	*	89.0	41.0	63.0	92.0	*	105.0
pH	7.4	7.0	6.2	*	6.6	6.8	6.7	6.4	*	6.9
Electric conductivity (mS/cm)	25.0	18.0	28.0	*	27.6	43.0	22.0	4.1	*	23.4
Turbidity (NTU)	3.2	3.2	8.77	*	2.6	6.2	6.2	3.29	*	2.5
Color (mgPt/L)	1.5	3.0	3.0	*	1.0	2.0	4.0	4.0	*	1.0

Table 2 - Occurence of chironomid larvae in the stomach content of *L. amblyrhynchus* and *P. maculatus* in and downstream Miranda reservoir.

Taxa	*L. amblyrhynchus*	*P. maculatus*
Orthocladiinae		
Cricotopus	X	X
Tanypodinae		
Ablabesmyia	X	X
Labrundinia	X	
Tanypus		X
Chironominae		
Asheum	X	X
Beardius	X	
Chironomus	X	X
Cladopelma	X	X
Cryptochironomus	X	X
Dicrotendipes	X	
Fissimentum	X	X
Goeldichironomus	X	X
Harnischia	X	X
Nimbocera	X	X
Parachironomus	X	
Phaenopsectra		X
Polypedilum	X	X
Pseudochironomus		X
Rheotanytarsus	X	X
Saetheria	X	
Tanytarsini *genera varia*	X	X

Table 3 - Number of chironomid larvae (N), richness at genus level (R), Shannon-Wiener diversity index (H´) and Shannon evennes of chironomid larvae in the stomach content of *L. amblyrhynchus* and *P. maculatus*, in and downstream Miranda reservoir, during the rainy and the dry seasons. (1, 2 and 3: sampling stations in Miranda reservoir; 4 and 5: sampling stations in Araguari river, downstream the dam).

Fishes	**Periods**	**Stations**	**N**	**R**	**H' Shannon**	**Eveness**
L. amblyrhunchus	Rainy	1	142	9	1.6	0.7
		2	175	15	1.7	0.6
		3	5	4	1.3	1.0
		4	18	5	1.5	0.9
		5	31	2	0.2	0.3
	Dry	1	31	6	1.2	0.7
		2	62	7	1.2	0.6
		3	0	0	0	0
		4	4	2	0.6	0.8
		5	0	0	0	0
P. maculatus	Rainy	1	79	9	1.2	0.5
		2	49	6	0.6	0.3
		3	1028	13	0.5	0.2
		4	18	3	0.7	0.6
		5	0	0	0	0
	Dry	1	11	5	1.3	0.8
		2	19	4	1.1	0.8
		3	576	11	1.5	0.6
		4	0	0	0	0
		5	2	2	0.7	1

turbidity than the levels characteristic of the period before the construction of the dam. This better water quality may be related to the water intake position of the Miranda reservoir (18 m depth), and to the low oxigenated values of the bottom waters (1.9 to 3.2 mg/L at 58 m depth).

Because of the abundance of chironomids in their stomach contents, *L. amblyrhynchus* and *P. maculatus* were more closely examined. Both species showed higher percentage of chironomids in their stomach contents in the rainy season than in the dry season ($p<0.05$). Moreover, a high numbers of fishes were collect in the rainy season (Figure 2). Both species were more abundant at sampling stations 1, 2 and 3, in the Miranda reservoir.

A total of 165 stomach contents of *L. amblyrhynchus* (55 specimens) and *P. maculatus* (110 specimens) were analyzed and 108 had chironomid larvae. The number of stomach contents with chironomid larvae was higher for *L. amblyrhynchus* (86.3%) than for *P. maculatus* (52.7%).

The taxonomic composition of chironomid genera was similar for both fish (Table 2). Shannon diversity indices of chironomid genera found in the stomach contents of *L. amblyrhynchus* and *P. maculatus* showed no significant difference ($t_{(18,\ 0.05)}$=0.636; p=0.532), as well as the richness indices of chironomid genera in *L. amblyrhynchus* ($t_{(8,\ 0.05)}$=1.460; p=0.182) and in *P. maculatus* (Table 3). Comparing the rainy and dry seasons there were no significant difference in *L. amblyrhynchus* ($t_{(8,\ 0.05)}$=1.723; p=0.123) and in *P. maculatus* ($t_{(8,\ 0.05)}$=-0.976; p=0.357) stomach contents.

Comparing the up and downstream sampling stations, no significant difference was found in the richness ($t_{(8,\ 0.05)}$=1,699; p=0.127) and Shannon diversity indices ($t_{(8,\ 0.05)}$=1,453; p=0.184) concerning the diet of *L. amblyrhynchus*. On the other hand, richness ($t_{(7,\ 0.05)}$=4,111; $p<0.01$) and Shannon diversity index ($t_{(8,\ 0.05)}$=2,643; p=0.029) were significantly different when comparing up and downstream *P. maculatus* diets.

Chironomus and *Asheum* larvae were the most common chironomid genera observed in *L. amblyrhynchus´* diet in Miranda reservoir in rainy season. However, Tanytarsini *genera varia* larvae were dominant in its diet downstream the reservoir (sampling stations 4 and 5). In the reservoir, during the dry season, *Ablabesmyia* and *Chironomus* were the main items in sampling station 2 while downstream chironomids were rare in *L. amblyrhynchus* stomach contents.

According to the frequency of occurrence, the most frequently chironomid genera found in the stomach content of *P. maculatus* in Miranda reservoir during the rainy season were Ablabesmyia, *Chironomus* and *Polypedilum*, while in the dry season were *Ablabesmyia*, *Asheum* and *Chironomus*. In station

4, chironomids were not abundant in *P. maculatus* stomach contents, except for the presence of *Polypedilum* during the rainy season.

Discussion

Lobón-Cerviá & Bennemann (2000) pointed out that *P. maculatus* living on Rio Tibagi (Paraná State, Brazil) fed at all trophic levels, exhibiting a broad flexibility to ingest practically all organisms available at the site. A similar feeding pattern was found by Abujanra et al. (1999) for *P. ortmanni* in Segredo reservoir and nearby areas in south Brazil. These authors assumed that these species have specific feeding tactics in each specific environment or season, depending on the availability of feeding resources.

Pimelodus maculatus is more abundant at the bottom and its cavernous mouth allows whole preys to be swallowed (Braga, 2000). Lobón-Cerviá & Bennemann (2000) pointed out that while *P. maculatus* is foraging close to or along the bottom, it feeds on benthic macroinvertebrates (e.g., Mollusca, Diptera (larvae and pupae) and Ephemeroptera nymphs). A preliminary assessment of benthic macroinvertebrates diversity using an Eckman-Birge (225 cm^2) dredge in triplicates, found only 25% of the chironomid genera diversity found in the stomach of *P. maculatus* and *L. amblyrhynchus*. This suggests that the analysis of the stomach content of these two fish species is an efficient tool to assess the chironomid larvae diversity in Miranda reservoir and downstream.

Most of the chironomid genera found in the stomach content of *L. amblyrhynchus* and *P. maculatus* living in the Miranda reservoir are frequently found in mesotrophic and eutrophic ecosystems. *Asheum*, *Chironomus*, Crypto*Chironomus*, Goeldi*Chironomus*, *Polypedilum* and *PseudoChironomus* are suggested by Marques *et al.* (1999) and Callisto et al. (2001) as indicators of eutrophic conditions in Brazilian freshwater ecosystems. Most fishes are opportunistic in their feeding and chironomids may be taken only when they are relatively abundant (Armitage, 1995). In Miranda reservoir, "red chironomids" were dominant food item of *L. amblyrhynchus* and *P. maculatus*. The non-significant differences between the presence of chironomid genera in the stomach content of both fish suggest that these species invest similar effort in chironomids capture, probably occupying a close alimentary niche in the benthic food chain. Although, the obtained data shows that the chironomid availability as a food resource is the same up and downstream the dam, reflected by *L. amblyrhynchus* stomach content, it was observed that *P. maculatus* feed differently in the two sections.

A general shift to smaller taxa, reduced biomass, and increased rates of production is to be expected when an increase predation by fish occurs (top-down effect). However, paucity of data hampers any predictions about changes of benthic community structure in response to the fish community.

Ali (1995) pointed out that chironomid larvae and pupae comprised a significant part of the diet of a variety of both juvenile and adult fish, including several sunfish, catfish, carp, mosquito fish and *Tilapia*. Furthermore, Ali, (1995) and Lobón-Cerviá & Bennemann (2000) showed that midge larvae and pupae comprised 40-70% by volume and 40-80% by wet weight, of the total food contents of benthophagous fishes.

It was suggested by Armitage (1995) that the preference of bottom-feeding fish for chironomid larvae and pupae as food source is related to its high energy content (percentage mean values: moisture content 86, protein 48 to 55, lipid 14, carbohydrate 23, chitin 4, ash 9; with an utilizable energy of 4.1 to 6.1 Kcal g^{-1}. The relatively high protein content, high digestibility (73.6%) and the apparent function as a growth promoter in fish diets, make chironomid larvae a rich energy source for many fishes (De la Noüe & Choubert, 1985).

In this study we are assuming that *P. maculatus* and *L. amblyrhynchus* are the major species having chironomid as common items in their diets. Moreover, the recorded taxonomic richness of chironomid larvae in the stomach contents, suggest that these two fish species invest considerable time and energy feeding on chironomid larvae, thus consisting an important food resource.

In conclusion, the recorded data constitute important additional information on the biology of the two studied fish species. The observed differences between chironomid larvae diversity found up and downstream Miranda dam corroborate the use of fish stomach content analysis as an important tool to assess the diversity of benthic macroinvertebrate, specially chironomids. Furthermore, future studies should include benthic samples as well as fish stomach content analysis. Moreover, it provides further information to be used by decision makers to improve financial investments in the efforts of fish species management in the river channel fragmented areas by dam constructions. We suggest that this approach is of paramount importance for preserving the remnant freshwater biodiversity.

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