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Biological and ecological characteristics of *Roestes molossus* (Teleostei: Cynodontidae), a night hunting characiform fish from upper Madeira River, Brazil

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During fish samplings carried out between 2004 and 2005 in tributaries draining the rapids stretch of Madeira River in Brazilian Amazon, we captured 72 specimens of *Roestes molossus*, a rare and poorly known cynodontid species. These specimens comprised 1.17 % of the total catches with gillnets (out of 175 species), the smallest measuring 114 mm SL and the largest 198 mm SL. Males were smaller than females, which predominated in the higher length classes. Sex-ratio was roughly 1 : 1, and ripe females occurred in December, during the rising water period. *Roestes molossus* fed on small fishes, insects and shrimps, which live associated to submerged litter banks. The tributaries of the Madeira River rapids zone are important habitats in the life cycle of *R. molossus*. However, the absence of small-sized specimens in our samples indicates that the first development phases occur in other places or microhabitats not sampled in our study.

Introduction

The genus *Roestes* includes three species: *R. molossus* from the Madeira and Juruá rivers; *R. ogilviei* from Essequibo, Negro and upper Amazonas rivers; and *R. itupiranga* from Tocantins River basin. Recent phylogenetic studies have shown that *Roestes* and *Gilbertolus* constitute the subfamily Roestinae, the sister group of the Cynodontinae in the family Cynodontidae (Menezes, 1974; Menezes & Lucena, 1998; Lucena & Menezes, 1998; Toledo-Piza, 2003).

Most of the information available for Cynodontids or dog-fishes consists of systematic and taxonomic aspects, with very few data about their habitat or biology (Toledo-Piza, 2003). Based on anatomical characteristics (e.g. the shape and position of the mouth) and few (if any) information on the biology of the species of *Roestes*, Géry (1977: 311) suggested that these fishes would be adapted to live near the water surface. The scarcity of published information about *Roestes* apparently reflects the insignificant number of specimens captured so far (few specimens in museum collections worldwide). During 2004 and 2005 we carried out an ichthyofaunal survey on

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Madeira River in a stretch of about 300 km upstream of Porto Velho, Rondônia, Brasil. The collecting yielded a high number of *R. molossus* specimens, which give us the opportunity to study some aspects of the demography, feeding biology and reproduction of this species, revealing interesting characteristics of its natural history.

Material and methods

Study area. The Madeira River basin is probably the most geographically complex among the tributaries of the Amazonas River, and the rapids stretch upstream from Porto Velho represents an assortment of special habitats in that basin (Goulding, 1979). The abrupt transition of the Central Brazil's plateau to the sedimentary Amazon lowlands results in a sequence of 19 rapids in that stretch of the Madeira River, where Jirau, Teotônio and Santo Antonio Falls stand out. That stretch of the Madeira River upstream from the Santo Antonio Falls up to the city of Guajará-Mirim is known as "Alto Estrutural Guajará-Mirim-Porto Velho" (Souza-Filho et al., 1999). The drainage includes waters from the Mamoré and Beni Rivers, which drain the Bolivian Andes, and from the Madre de Dios River, which drains the Peruvian Andes and flows into the Beni River (McClain et al., 1995).

A portion of 228 km of the upper Madeira River was investigated in this study (Fig. 1). Collecting was conducted in the confluence of Madeira River with ten of its main tributaries. The Madeira River channel in that stretch is narrow and up to 80 m deep, with water velocities of up to 2.5 $m \cdot s^{-1}$. The shores of the Madeira River are made of mud and sand beaches during the dry season, with steep banks up to 30 m high in some places. Rock outcrops are present along the whole stretch, with large boulders emerging in the rapids zones.

The rising water starts in November, with a short peak between February and March and the falling water period occurring between May and October. Annual river level variation between dry and flood seasons ranges 11-13 m, with discharges varying between 2.3-47.2 $m^3 \cdot s^{-1}$ for the period between 1967 and 2005 (data from Furnas Centrais Elétricas). The mean air temperature in Porto Velho is about 25.2 °C (20.9-31.1 °C), with a mean relative humidity of about 85 % (81-89 %).

In the studied stretch the Madeira River receives the contribution of tributaries with chemical characteristics and dynamics typical of small streams and submitted to drastic seasonal changes in discharge (Table 1). Three of these tributaries are located between Jirau and Santo Antonio Falls, including the Jaciparaná River, the largest of them. The substrate in the Jaciparaná is constituted by sandy stretches interspersed by large litter banks deposited in slow-flowing places, with water characteristics typical of the tributaries draining that area.

Fish sampling. Six bimonthly collecting were carried out between April 2004 and February 2005 in 10 sampling stations located in the confluence of the Madeira River with its main tributaries in that stretch (upstream limit: Igarapé do Arara, 10°00'45.3"S 65°19'6.2"W; downstream limit: Igarapé Belmont, 8°38'27.1"S 63°50'58.6"W; Fig. 1). A set of 13 gill nets (30, 40, 50, 60, 70, 80, 90, 100, 120, 140, 160, 180 and 200 mm mesh size, measured between opposite knots) was exposed to 24-hour cycles and checked at 4 h intervals. The experimental fishing was complemented by sampling with a seine net (0.5 mm mesh size) in beaches and shallow marginal habitats in the Madeira River, in order to allow the capture of small sized specimens not caught by the gill nets.

Biological data. Samples of *Roestes molossus* were obtained in April, June, August, October and December 2004. The following information was gathered from each captured specimen: (i) standard length (SL), with an accuracy of 0.1 mm; (ii) total weight (Wt); and (iii) macroscopic de-

Table 1. Limnological parameters of upper Madeira River and its tributaries.

limnological parameters	Madeira River	tributaries
Conductivity ($\mu S \cdot cm^{-1}$)	70.5 (7.2-127.4)	14.6 (4.1-40.5)
pH	6.5 (5.4-7.3)	5.6 (4.8-6.4)
Dissolved oxygen ($mg \cdot l^{-1}$)	7.5 (3.6-17.1)	5.2 (0.8-9.7)
Water temperature (°C)	27.3 (25.2-30.2)	26.4 (23.2-29.3)

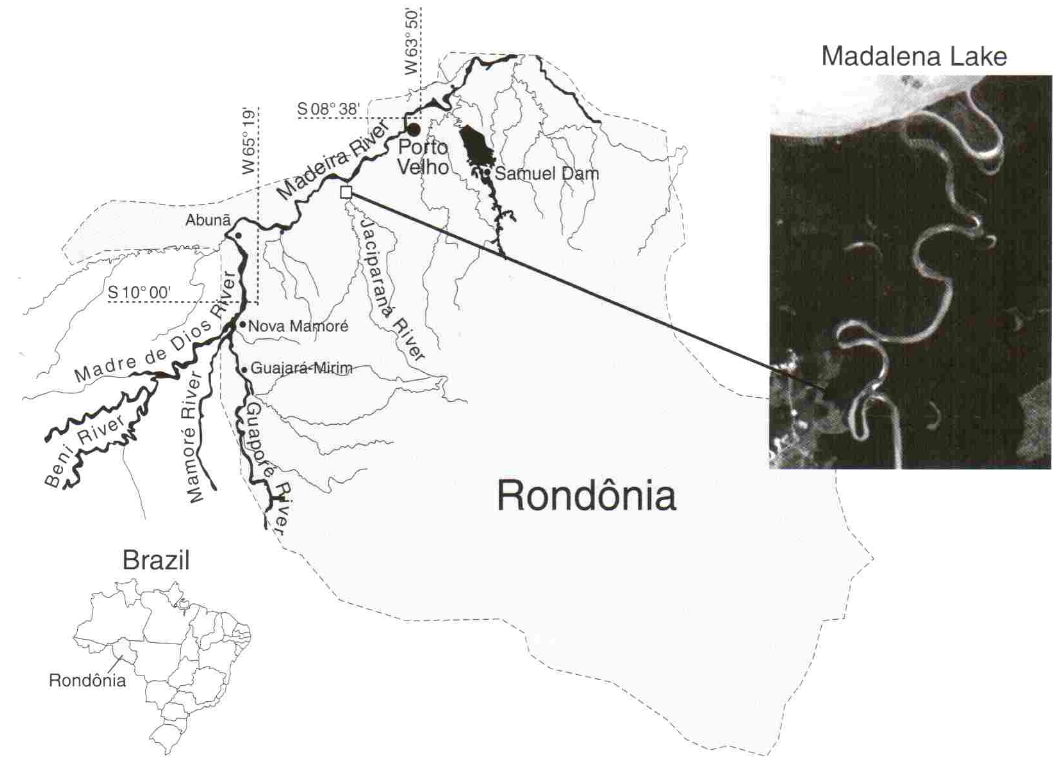

Fig. 1. Map of upper Madeira River upstream of Porto Velho in Brazil, showing the limits of the sampled stretch (indicated by coordinates).

termination of the sex and gonadal development, based on a scale modified from Vazzoler (1996): immature, early maturation, advanced maturation, spawning, spent, and resting. Gonad tissue samples were collected and preserved in Alfac for a later confirmation of the macroscopic determination of sex and maturation phases.

Stomachs with repletion different from zero were preserved in 10 % formalin solution, latter washed and transferred to 70 % ethanol. The stomach contents were analyzed using a stereomicroscope. Food items were identified, counted whenever possible, and quantified according to the relative volume (%) occupied by each food type (visually estimated, considering the total volume in the stomach as 100%).

Voucher specimens were preserved in 10 % formalin, subsequently transferred to 70 % ethanol and deposited in the reference collection of the Universidade Federal de Rondônia (UNIR 0006), Museu de Zoologia da Universidade de São Paulo (MZUSP 89683) and the Instituto Nacional de Pesquisas da Amazônia (INPA 28442).

Data analyses. Length-frequency. Standard-length data are presented by sex using descriptive statistics (mean, median, minimum and maximum values). The mean SL difference between the sexes was compared with Student's *t* test (Zar, 1999). Individual data (SL) were grouped in 10 mm classes, and the relative frequencies were presented by sex. In function of the small sample size obtained in certain months we refrained to employ statistical tests for these data.

Sex-ratio. Relative frequencies (%) of females and males were compared for the whole sample. To verify if the observed proportions differed from the expected ratio of 1:1, a G test with the Yates correction was used (Zar, 1999).

Length-weight relationship. The relation of SL and Wt was estimated for the total captured specimens, and the isometrics of the angular coefficient *b* was tested for the whole sample and by sex (Le Cren, 1951).

Food spectrum. Food items were grouped in three main categories: fishes, insects and shrimps. The relative participation of these food categories in the diet was analyzed by the Frequency of Occurrence method (FO% = number of times that a food category occurs in the stomach contents, compared to the total number of stomachs with food) and relative volume (VO% = ratio between the estimated volume of each food type and the total volume of food in the stomachs) (Hyslop, 1980).

Reproductive period. The delimiting of the reproduction season was inferred from the occurrence of specimens in "advanced maturation", "in reproduction", and "spawned" in the samples.

Results

Roestes molossus was caught only in the confluence of the tributaries with the main river, never in the Madeira River itself. The 72 specimens of *R. molossus* represented 1.17 % of the total fish collected and 0.92 % of the total biomass obtained during the experimental fishing. Most of the specimens (83 %) were collected in the tributaries situated between Jirau and Teotônio Falls, especially in Jaciparaná River (Fig. 1). No specimens were captured downstream from Teotônio Falls or in the 114 seine net samples obtained along the shallow margins of the Madeira River and its tributaries. Most of the analyzed specimens were captured in places where the substratum was predominantly composed of submerged leaf litter banks.

The size of the specimens ranged between 114-198 mm SL (mean = 160 ± 19.16 S.D.), and adult specimens varied between 130-173 mm SL for males and 141-198 mm SL for females. Mean SL values differed between sexes (males: 150 mm; females = 169 mm; $t_{0.05} = 5.026$; $P < 0.01$). Among the few immature specimens collected, males (N = 2) measured 132 and 138 mm, and females (N = 4) measured 134, 138, 145 and 157 mm; two additional immature specimens (114 and 141 mm) could not be sexed. The smallest mature male and female in the samples measured 130 and 141 mm SL respectively.

The overall length-frequency distribution revealed a bimodal pattern, where the first mode was composed mainly by male specimens and the second one by female specimens (Fig. 2). The proportion of adults males and females was roughly 1:1 (34 females : 24 males, $G_{0.05} = 1.4$).

The angular coefficient (b) of the length-weight relationship was higher than 3.0 for females, indicating a positive allometric growth ($t_{0.05} = 2.75$), whereas males showed isometric growth ($t_{0.05} = 2.10$). So, there was sexual dimorphism in the length-weight relationship ($t_{0.05} = 4.99$) and the equation that explains this relation is $Wt = 0.000003917419 * SL^{3.336}$ for females ($r^2 = 0.955$; $P < 0.01$), and $Wt = 0.000003647539 * SL^{3.351}$ for males ($r^2 = 0.946$; $P < 0.01$).

Specimens in advanced gonad maturation and spawning were registered in December, during the rising water period. The only examined ripe gonad of a female *R. molossus* corresponded to 4.65 % of its total body weight.

Roestes molossus specimens with food in the stomach were collected only at dawn and night (Fig. 3). The diet of *R. molossus* (N = 28) consisted of small fishes (74 %), insects (52 %) and shrimps (22 %), which corresponded to 61.3 %, 26.5 % and 12.2 % of the food volume inside the stomachs respectively (Table 2). Small heptapterid catfish (*Gladioglanis* sp.; about 3 cm SL) corresponded to 84 % (67 out of 80) of the identified prey fish in the stomach contents of *R. molossus*.

Table 2. Frequency of occurrence (FO%) and relative volume (VO%) of major food items in the diet of *Roestes molossus* (n = 28) from upper Madeira River. *Includes *Moenkhausia* sp. and other unidentified Tetragonopterinae species.

Food item	FO(%)	VO(%)
Insects (total)	51.9	26.5
Ephemeroptera (Baetidae)	22.2	8.1
Coleoptera (Elmidae)	3.7	0.2
Diptera (Chironomidae)	14.8	5.1
Odonata (unidentified)	18.5	7.2
Insetcs remains	14.8	5.9
Crustaceans (Palaemonidae shrimps)	22.2	12.2
Fishes	74.1	61.3
Characiformes		
Anostomidae (*Pseudanos* sp.)	3.6	3.6
Characidae*	11.1	5.5
Curimatidae	6.5	6.5
Hemiodontidae (*Hemiodus* sp.)	5.4	5.4
Siluriformes		
Auchenipteridae	3.6	3.6
Heptapteridae (*Gladioglanis* sp.)	20.9	20.9
Gymnotiformes (unidentified)	5.8	5.8
Perciformes		
Cichlidae	4.2	4.2
Gobiidae (*Microphilypnus* sp.)	1.4	1.4
Fish remains	4.2	4.2

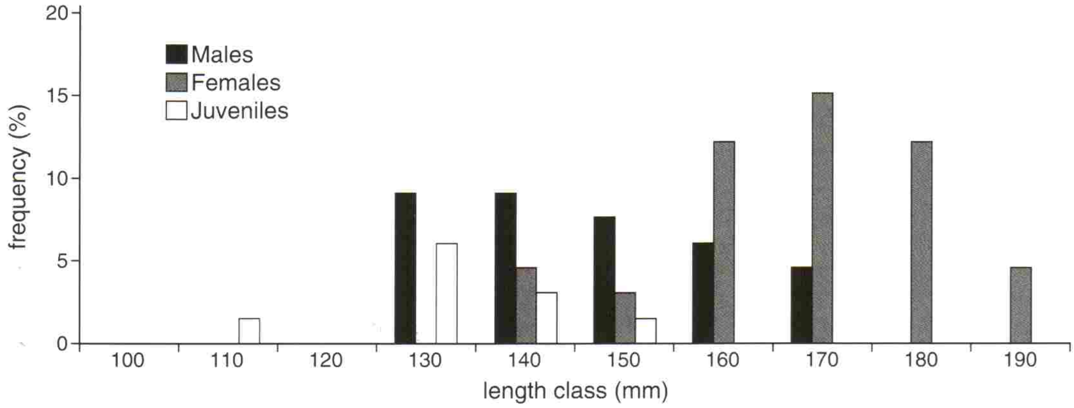

Fig. 2. Length-frequency distribution of juveniles (n=8), males (n=24) and females (n=34) of *Roestes molossus* from upper Madeira River in Brazil.

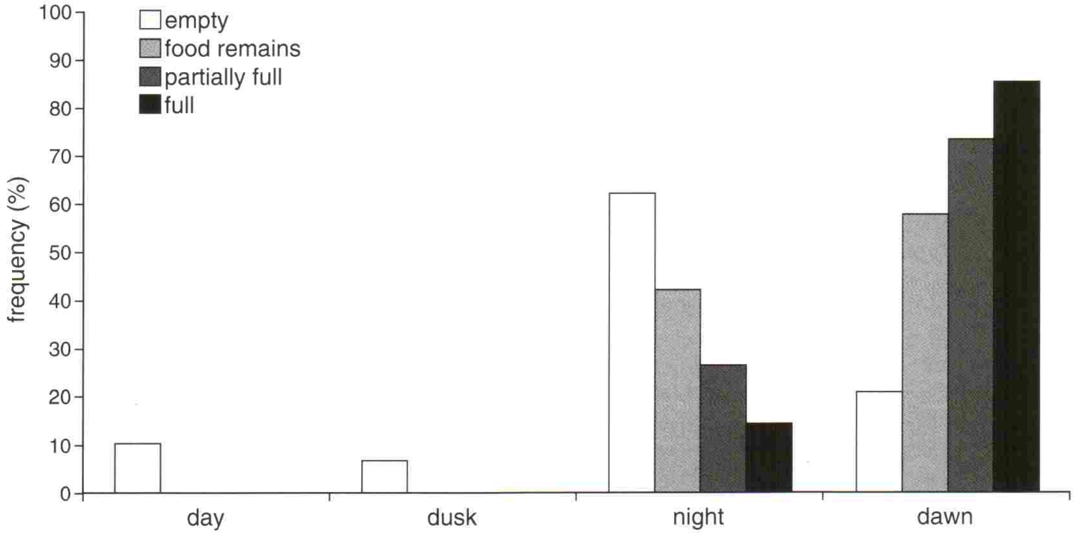

Fig. 3. Daily variation in frequency of stomach repletion categories of *Roestes molossus* (n=68) in upper Madeira River in Brazil.

Discussion

The samples collected by gill nets were composed mainly of adult fish, with only eight immature specimens. There was a high proportion of captures of a single fish (70.8 %), which indicates that *R. molossus* usually lives alone and groups infrequently. Two or more specimens were only captured together during the rising waters, which coincides with the reproductive period.

Our findings of larger females of *R. molossus* lead to three hypotheses: (1) females would have a higher growth rate; (2) females would have a lower mortality rate or; (3) protandric hermaphroditism. Sexual dimorphism in size seems to be one of the most common phenotypic expressions that indicate the sharing of resources between the sexes (Nikolsky, 1963), and have been commonly observed among fishes (Erlandsson & Ribbink, 1997; Lowe McConnell, 1999; Chellappa et al., 2003; Mazzoni & Silva, 2006). Preliminary data on scale ring patterns (not shown) and the results of the length-weight relationship suggest that the first hypothesis does not apply to this case, but the other two remain to be investigated.

Characiform fishes commonly show differences in sex-ratio along the species life cycle resulting from differences in mortality and growth rates, or just due to the biased captures during the reproductive period (Vazzoler, 1996). Nevertheless, *R. molossus* did not show the same pattern, bearing in mind the small sample obtained. Freshwater fishes in other river systems in Brazil showed deviation in the sex-ratio only during the reproductive period, maintaining the sex-ratio values around 1:1 in the other life cycle phases. Such examples include the pacu *Mylossoma duriventre* (Characidae) and the jaraquis *Semaprochilodus* spp. (Prochilodontidae) in the Central Amazon (Vazzoler et al., 1989).

Roestes molossus seems to be a total spawning species, but the scarcity of mature gonads in the samples does not allow corroborating this hypothesis. The apparently small aggregation of males and females during the reproductive period at Madalena Lake in the Jaciparaná River (as inferred from the gillnet catch rates) may have resulted from short distance migrations, which constitute a behavioral pattern compatible with the restricted geographic distribution registered for that species (Toledo-Piza, 2003).

The spawning period of *R. molossus* coincides with the beginning of the rising water in the Madeira River (December), as generally observed for Amazonian floodplain fishes (Lowe McConnell, 1999). The absence of specimens in our captures during the subsequent flood period (January to March) indicates that the fish move to spawn in a different place and stay there after spawning or disperse in the narrow floodplain of the Madeira River during the resting period.

The feeding activity of fishes is adjusted to the period of food abundance, which corresponds to the low water period for most of the carnivorous-piscivorous species due to the increased prey density (Junk, 1985; Goulding, 1989; Winemiller & Kelso-Winemiller, 2003). In fact, the examined specimens of *R. molossus* showed higher feeding activity and accumulation of fat deposits between April and August, during the falling water period (data not shown). Apparently, *R. molossus* goes through periods of food scarcity during the peak of the drought and flood, when the energetic needs of these fishes must be supplied by the fat reserves accumulated previously.

Madalena Lake, in the lower Jaciparaná River, was the place where most of the specimens of *R. molossus* with full stomachs were captured. The lake shore substratum is composed mostly by submerged litter banks, forming dense layer of dead leaves (up to 25 cm deep), which becomes exposed during the falling waters along the lake shore (pers. obs.). These litter banks constitute the habitat of most of the preys eaten by *R. molossus*, mainly small heptapterid catfishes (*Gladioglanis* sp.), detritivorous curimatids, dwarf cichlids, minute gobiids (*Microphilypnus* sp.), palaemonid shrimps and dragonfly larvae (Odonata). The high consumption of the catfish *Gladioglanis* sp. (67 specimens in five stomachs; up to 23 specimens on a single stomach contents) indicates a very specialized diet, based on the consumption of leaf litter dwelling fishes. This indicates that the higher feeding activity of *R. molossus* during the falling and rising water periods may be related to the availability of proper foraging grounds, when compared to the peaks of flood and drought.

The diel variation in the stomach repletion of *R. molossus* indicates that this fish forages mainly at dawn and during the night. These characteristics (foraging in the submerged litter banks and predominantly nocturnal activity) constitute an apparently unique condition among the Cynodontidae, and an uncommon condition among Characiformes in general (Lowe McConnell, 1999). Trahiras (Erythrinidae) are the main characiform fishes that forage during the dark and closely associated to the substratum in Amazon, by ambushing its prey (Sabino & Zuanon, 1998; Lowe McConnell, 1999; Castro 1999). Some species of piranhas are also known to forage occasionally at dawn and early night in western Brazil when there is enough light, although it doesn't seem to represent a very frequent or important behavior for the feeding of these fishes (Sazima & Machado, 1990). Moreover, differently from erythrinids and *R. molossus*, piranhas forage mostly at mid water and do not include leaf litter dwelling animals among their main prey (per. obs.).

The large and straight forward eyes and the upturned mouth of *R. molossus* seem to constitute an inadequate set of morphological characteristics for a night hunting predator that forages close to the bottom. Nevertheless, the predominance of leaf litter dwelling preys in its diet indicates that *R. molossus* forages in a head-down position, with the body leaned around 45° degrees. We surmise that this fish forages by slowly moving close to the submerged litter banks, scanning the substra-

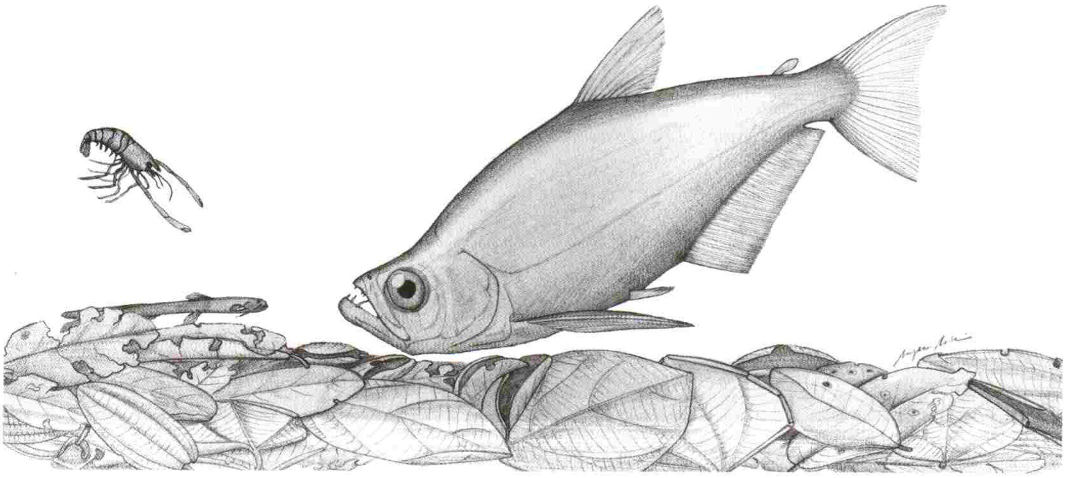

Fig. 4. Hypothetical representation of *Roestes molossus* foraging posture, based on information gathered from collecting habitat and predominant preys habitat. Note body orientation and close proximity to substrate (drawing by A. Midori).

tum in search of preys that are caught with its strong canine teeth (Fig. 4). Underwater observations in its natural habitat, as well as behavioral studies in captivity are needed to verify this hypothesis.

The Brazilian government is planning to construct two hydroelectric dams at the Madeira River headwater area (Santo Antonio and Jirau dams). These impoundments will possibly cause several environmental modifications including changes on the local flood pulse dynamics, water depth, dissolved oxygen, light penetration, and biological energy sources (Fearnside, 2006). Furthermore, these alterations will simplify the physical structure of the river's natural waterways with the loss of shallow banks and riffles, and by modifying the lower course of the small tributaries of the Madeira River in that area. *Roestes molossus* main habitat (Madalena Lake in Jaci-paraná River), located between the two planned dams, may be strongly altered which may result in negative consequences for the species in that area. Thus, studies focusing on distribution, biological cycles and habitat use by *R. molossus* are strongly needed and urgent.

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