Biology and ecomorphology of stream fishes from the rio Mogi-Guaçu basin, Southeastern Brazil

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The córrego Paulicéia is a direct tributary of the rio Mogi-Guaçu, located in Santa Rita do Passa Quatro, State of São Paulo, Southeastern Brazil. This stream runs inside a savannah-like (cerrado) environment and it associated vegetation. Biological and ecomorphological aspects of its fish community were studied in three stretches of the stream, denominated herein as the upper, middle and lower courses. The fish fauna recorded in this study consisted of 15 species, belonging to five orders and nine families, based in a total of 715 collected individuals representing 1,450 kg of biomass. The most important abiotic factors related to the occurrence and distribution of the fish fauna were the substrate, current speed, and presence or absence of riparian vegetation. The analysis of 336 stomach contents of 13 species demonstrated that 65% of food items are autochthonous, 32% allochthonous, and 3% are of unknown origin. Four alimentary guilds could be identified, based on the predominant food items: omnivores with tendency to insectivory - *Astyanax paranae*, *A. fasciatus* and *Piabina argentea*; larvivores - *Corydoras difluviatilis*, *Cetopsorhamdia iheringi*, *Phenacorhamdia tenebrosa*, *Characidium gomesi*, *Eigenmannia virescens*, and *Rhamdia quelen*; periphyton feeders - *Hisonotus* sp., *Hypostomus ancistroides* and *Synbranchus marmoratus*; and piscivore - *Hoplias malabaricus*. Reproductions data are presented for *Astyanax altiparanae* and *Hisontus* sp. Three ecomorphological groups could be established, based on swimming, feeding, and microhabitat strategies: nektonic (*A. fasciatus*, *A. paranae*, *Bryconamericus stramineus*, *P. argentea*, *H. malabaricus* and *Phallotorynus jucundus*), benthic (*C. gomesi*, *P. tenebrosa*, *C. iheringi*, *R. quelen*, *C. difluviatilis*, *H. ancistroides* and *Hisonotus* sp.), and necktobenthic (*E. virescens* and *S. marmoratus*).

O córrego Paulicéia é um afluente direto do rio Mogi-Guaçu, situado no município de Santa Rita do Passa Quatro, Estado de São Paulo, correndo dentro de um gradiente de fisionomias de cerrado e formações associadas. Aspectos da biologia e ecomorfologia de sua comunidade de peixes foram estudados para três trechos do córrego Paulicéia, aqui denominados de superior, médio e inferior. Durante o período de estudo foram coletadas 15 espécies de peixes pertencentes a cinco ordens e nove famílias, num total de 715 indivíduos coletados e 1.450 kg de biomassa. Os fatores ambientais de maior importância na ocorrência e distribuição dos peixes deste córrego foram o tipo de substrato, a velocidade da corrente, e a presença ou ausência de vegetação ripária submersa. A análise de 336 estômagos pertencentes a 13 espécies mostrou que 65% dos itens alimentares consumidos são autóctones, 32% alóctones e 3% são de origem desconhecida. Quatro guildas alimentares puderam ser definidas com base nos itens alimentares predominantes: onívoros com tendência a insetivoria - *Astyanax paranae*, *A. fasciatus* e *Piabina argentea*; larvófagos - *Corydoras difluviatilis*, *Cetopsorhamdia iheringi*, *Phenacorhamdia tenebrosa*, *Characidium gomesi*, *Eigenmannia virescens* e *Rhamdia quelen*; perifitívoros - *Hisonotus* sp., *Hypostomus ancistroides* e *Synbranchus marmoratus*; e piscívoro - *Hoplias malabaricus*. Dados sobre reprodução são fornecidos para *Astyanax altiparanae* e *Hisonotus* sp. Três agrupamentos ecomorfológicos foram estabelecidos de acordo com o tipo de natação, estratégia alimentar e micro-hábitat ocupado: nectônicos (*A. fasciatus*, *A. paranae*, *Bryconamericus stramineus*, *P. argentea*, *H. malabaricus* e *Phallotorynus jucundus*), bentônicos (*C. gomesi*, *P. tenebrosa*, *C. iheringi*, *R. quelen*, *C. difluviatilis*, *H. ancistroides* e *Hisonotus* sp.), e nectobentônicos (*E. virescens* e *S. marmoratus*).

Key words: Ichthyofauna, Trophic ecology, Reproduction, Upper Paraná basin, Cerrado Biome.

Introduction

The diversified neotropical continental ichthyofauna consists of about 4,500 described species (Reis *et al*., 2003). In the upper rio Paraná basin the ichthyofauna is composed of about 170 species distributed in 22 families. In the upper rio Paraná basin, headwater streams are inhabited primarily by small-sized species usually with restricted distribution, with little or any com-

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mercial value, and largely dependent of the riparian vegetation for feeding, reproduction and shelter (Castro & Menezes, 1998).

Unfortunately, in the last decades, the fish fauna associated with headwaters and streams has been drastically affected by anthropogenic activities. Alterations in chemical, physical and biological properties of these lotic systems have resulted in several changes in the distribution and structure of its fish assemblages (Agostinho *et al.*, 1995; Maret *et al.*, 1997). Among Brazilian biomes, the Cerrado (with a savana-like vegetation) is one of the most reduced in terms of original area, being mostly restricted to areas under permanent conservation policy, such as the area in which the Paulicéia stream is located.

In this paper qualitative and quantitative data of the ichthyofauna of the Paulicéia stream were collected and analyzed according to a longitudinal gradient, including data concerning diet feeding, behavior, gonadal analysis and ecomorphology. The goal of this study is contribute to the knowledge of the fish fauna of the heavily impacted ecosystem of the Brazilian Cerrado biome.

Study site. This study was conducted in the Paulicéia stream, a direct tributary of Mogi-Guaçu River in the upper rio Paraná basin. The Paulicéia stream is located in the municipality area Santa Rita do Passa Quatro, State of São Paulo, Brazil (Fig. 1), and has approximately 15 km in length, draining an area of native cerrado vegetation located inside a protected environmental area named "Pé-de-Gigante". The general climate is sub-tropical, with the rainy season occurring during the summer months (September to April) and the dry season occurring during the winter months (May to August) (Nimer, 1989). The mean annual temperature of the region varies between 18 and 24.5 °C (Nimer, 1989), and the mean annual rainfall is approximately 1,300 mm (Pivello *et al.*, 1999).

Field work was accomplished in three stretches of 70 meters each along the Paulicéia stream (Figs. 1-2), named as upper, middle, and lower stretches. The upper and the middle stretches have more similar physiographical and physicochemical characteristics compared to the lower stretch (see Table 1).

Material and Methods

Field work was undertaken monthly (October 2000 to September 2001) in two consecutive days. Data were taken in a standardized way during all study period. In the first day, data of air and water temperature (ºC), pH, conductivity, dissolved O₂, horizontal transparency of the water, current velocity, and discharge were taken. Four trap nets were distributed equidistantly in each studied stretch, baited with bread and bovine liver. These baits were kept within cotton bags so as not to disturb the gut analysis. In the next morning (second day), the trap nets were removed and the entrapped fishes were fixed. In each 70 m of the studied stretches, block nets (5 mm-mesh) were installed to avoid escape. In the upper and middle stretches, fishing was performed by two collectors using metal hoop nets (70 cm in diameter and 2.5 mm-mesh), usually close to riparian vegetation for approximately 40 min-
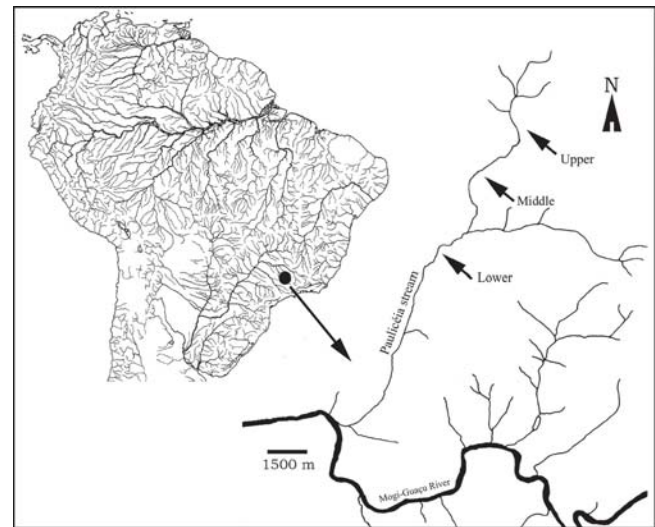
Fig. 1. Location of the study area in the Paulicéia stream, Mogi-Guaçu River basin, State of São Paulo, Brazil; upper (21º38'45.8"S 47º38'06"W), middle (21º39'23"S 47º38'34"W) and lower (21º40'58.1"S 47º39'26.3"W) stretches.

Table 1. Environmental data obtained for the three studied stretches of the Paulicéia stream. Minimum and maximum values of discharge represent the dry season and rainy season, respectively. * - average.

Data	Upper	Middle	Lower
Width (m)*	1.30-2.80	1.10-2.25	2.61-4.08
Depth (m)*	0.06-0.80	0.07-0.71	0.05-0.51
Current velocity (m/s)*	0.08-0.11	0.08-0.15	0.17-0.25
Air temperature (ºC)	21.2-32.3	20.1-30.3	22.0-30.9
Water temperature (ºC)	18.0-25.4	19.7-24.1	19.4-24.0
pH*	7.3	7.6	7.7
Dissolved O₂ (mg/l)*	8.7	8.5	10.5
conductivity (μ.S.cm^{-1})	3-6	3-6	11-25
horizontal transparency of the water (m)	2.10- 5.0	1.53-2.81	0.43-0.87
Discharge (m³/s)	0.05-0.08	0.05-0.08	0.19-0.25
Riparian vegetation	Cerrado biome	Cerrado biome and eucalyptus	Cerrado biome and sugar cane
Substrate	Fine sand and granules	Fine sand and granules	basaltic rocks
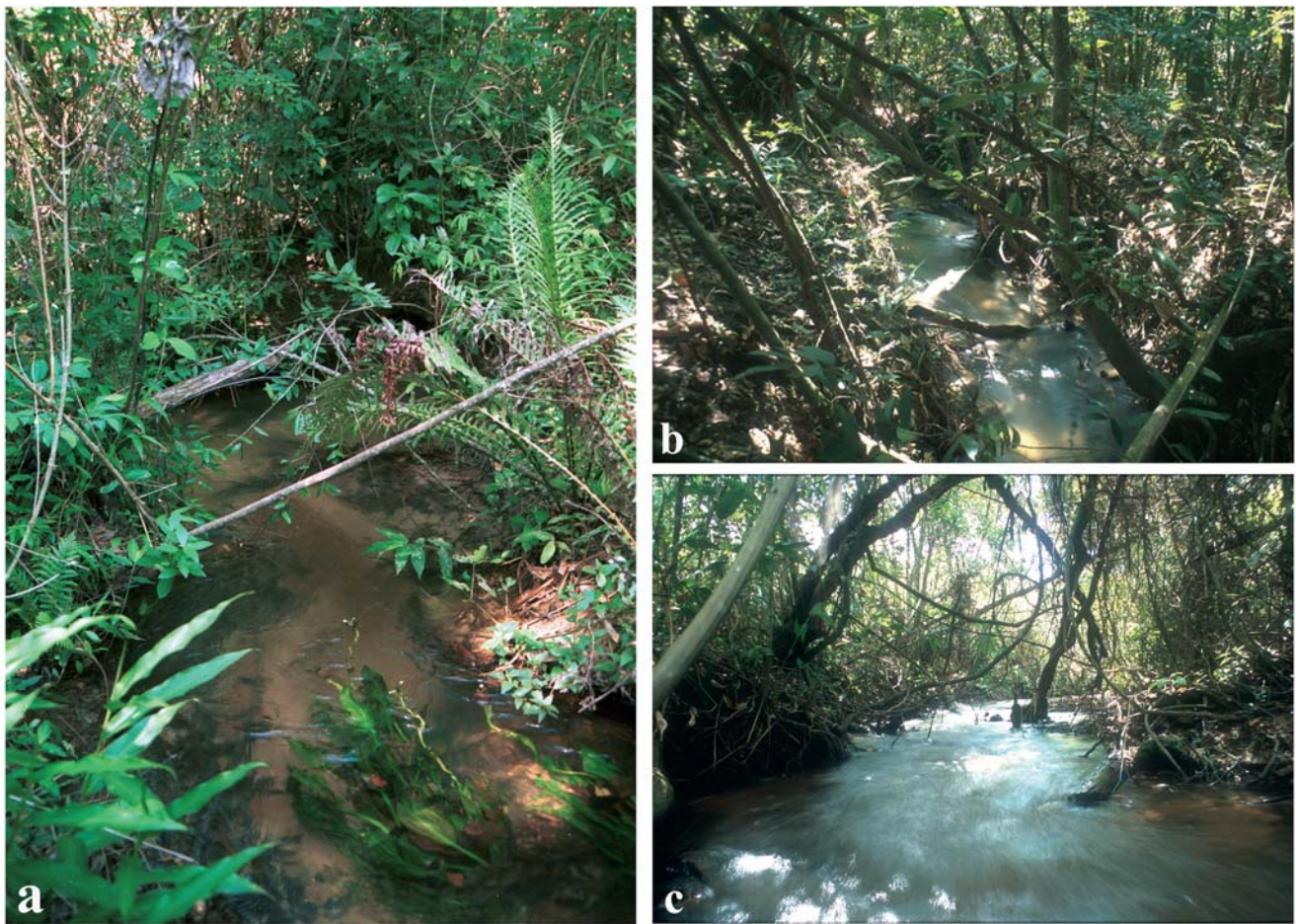
Fig. 2. General view of the three studied stretches in the Paulicéia stream, Mogi-Guaçu River basin; a) upper stretch, b) middle stretch and c) lower stretch.

utes. In the lower stretch, the hoop nets were substituted for one seine (2 m long, 1.5 m high and 2.5 mm-mesh).

To verify the efficiency of the fishing methods used during this study, a different methodology was employed in the three studied stretches during the last day of field work. This methodology consist of three electrofishing passes, combined with two passes with a seine and one pass with metal hoop nets (see Castro *et al.*, 2003, for a detailed explanation of this methodology).

Species richness was estimated through ICE (Incidence-based Coverage Estimator; Lee & Chao, 1994), which calculates the correction factor using the incidence of rare species (frequency of occurrence). ICE was processed using the EstimateS program (Colwell, 1997). Shannon-Wiener (H'), Evenness (E') and Simpson (S') diversity indexes were also applied to each one of the studied communities, and the Jaccard Similarity Index was used to compare the three communities. These analyses were performed using the BIO~DAP program (Magurran, 1988). Constancy (c) was calculated after the frequency of each species was recorded, being the relationship expressed as percent by the formula c= (p x 100)/ P, where "p" was the number of samples containing the species in question, and "P" was the total number of collections

(Dajoz, 1983). Species present in more than 50% of the collection were considered residents, species present in 25 to 50% of the collection were considered accessory, and species present in fewer than 25% of the collection were considered accidental.

All the collected fishes were deposited in the fish collection of the Laboratório de Ictiologia de Ribeirão Preto, Universidade de São Paulo (LIRP 3050-3161).

Diet. The stomach content of all species was analyzed, except for *Bryconamericus stramineus* and *Phallotorynus jucundus*, because only one specimen of these genera was sampled. The utilized methods were frequency of occurrence (Bowen, 1992) and percent composition (Hynes, 1950). In cases where stomachs were not discernible, only the anterior portion of the gut was analyzed. The food items were grouped in broad taxonomic or ecological categories according to their origins: aquatic insects, fishes (including fish scales), algae, annelids, thecamoebas; and crustaceans were considered autochthonous; whereas terrestrial insects, vascular plants and organic matter were considered allochthonous. The similarity between the diets was calculated using the software PC-ORD 4 version (McCune & Mefford, 1999), using the Bray-

Curtis coefficient (Valentin, 1995). The Morisita index was used to calculate the overlap alimentary index. Values e" 0.58 were considered significant (Linton *et al.*, 1981). The test of Incidence Rate was used to compare diets among species that occurred in two stretches or more, employing the software BioEstat 2.0 (Ayres & Ayres Jr., 2000) in which the *p* value is considered significant when smaller than 0.01.

Reproduction. The gonads were extracted and examined using a stereomicroscope for macroscopic identification. Four gonadal stages were identified: immature, maturing, mature, and empty (see Vazzoler, 1996).

The gonadal analyses were intended to determine the first sexual maturation length (L_{50}), the maturity stages, sexual proportion [being considered significant value for the chi-square (χ^2) test above of 3.84] and the reproductive period for females and males (see Vazzoler, 1996 for methodology).

Ecomorphology. For the ecomorphological analyses 10 adult specimens of each species were selected whenever possible. Twenty corporal measurements were taken, following Beaumord & Petrere (1994): a) standard length; b) maximum width; c) maximum body height; d) medium line height; e) head length; f) head height; g) height of the medium line of the eyes; h) mouth width; i) mouth height; j) angle of the mouth; k) pectoral fin length; l) pectoral fin width; m) caudal fin height; n) caudal peduncle length; o) caudal peduncle width; p) caudal peduncle height; q) area of the body (Mahon, 1984); r) dorsal-fin area; s) pectoral-fin area; t) caudal-fin area. All of these measurements were done with calipers and the fin areas were calculated using their contours on metric paper.

From these measurements, 16 ecomorphological attributes were calculated, and their interpretation followed Gatz (1979), Mahon (1984), Watson & Balon (1984), Balon *et al*. (1986), Winemiller (1991) and Beaumord & Petrere (1994): a) compression index (CI); b) relative depth (RD); c) relative caudal peduncle length (RPL); d) caudal peduncle compression Index (IPC); e) index of ventral flattening (IVF); f) relative area of the dorsal fin (RAD); g) relative area of the pectoral fin (RAP); h) pectoral fin aspect ratio (PAR); i) relative area of caudal fin (RAC); j) caudal fin aspect ratio of (CAR); k) relative head length (RHL); l) eyes position (EP); m) relative mouth width (RMW); n) relative mouth height (RMH); o) ratio of the mouth configuration (RMC); and p) mouth Orientation (MO).

Principal Component Analysis (PCA) using variance/covariance matrix containing the arithmetic average of the 16 attributes for the 15 studied species was used to allow the analyses and interpretation of the morphological variation. In the Tukey Test performed in the GraphPad InStat 3.01 version, each attribute was separately calculated and compared for each one of the three groups established with PCA; the attribute was considered significant when p< 0.05. The Ward's method, with the Person coefficient (Valentin, 1995), was used to join the species according to ecological similarity. Both analyses were done in PC-ORD version 4 (McCune & Mefford, 1999).

Species that are active swimmers were defined as nek-

tonic; species that swim close the bottom were defined as benthic, and species that usually live at mid-water, but that feed and shelter in the substrates, were defined as nektobenthic (Lincoln *et al*., 1995).

Results

Ichthyofauna. Seven hundred and fifteen fish specimens, belonging to five orders, nine families, 14 genera and 15 species were collected (Fig. 3). Among the collected species, 40% were characiforms, 39% siluriforms, 7% cyprinodontiforms, 7% gymnotiforms and 7% synbranchiforms.

Astyanax paranae and *Hisonotus* sp. were the most abundant species, representing 85% of the collected specimens. These two species were residents in the three studied stretches, being more abundant in the upper stretch. In the upper stretch, most of the species were residents (50%), in the lower stretch most species were accidental (50%), and in the middle stretch the percentages of resident, accessory and accidental species were the same (33.4%) (Table 2). The highest difference between the observed and the estimated richness occurred in the lower stretch where 12 species were collected and 15 species were estimated (Table 2).

The upper and the middle stretches presented a very similar fish fauna, sharing 67% of its species, although the lower stretch shares only 27% of its species with the upper and the middle stretch. In the lower stretch there were seven additional species, and *Hisonotus* sp. was the more abundant species (Table 2). Lower diversity occurred in the upper and the middle stretch, with dominance of just a few species, but in the lower stretch a higher diversity and lower dominance occurred (Table 2). The largest indexes of Shannon-Wiener and evenness obtained were in the lower stretch (1.81 and 0.73, respectively), and the largest value of the Simpson index obtained was in the upper stretch (0.435). The largest similarity obtained was in the upper and middle stretches (0.500).

With the electrofishing methodology, no new occurrence was registered in the upper stretch. *Synbranchus marmoratus* and *P. tenebrosa* was the new occurrence in the middle and lower stretches, respectively. Furthermore, species that were previously considered accessory and accidental in the lower stretch were collected in abundance.

Diet and food overlap. The stomach contents of 336 specimens were examined; 65% of all items found were autochthonous, 32% were allochthonous and 3% were items that could not be identified. Among the autochthonous items, the most representative were Diptera (mainly Chironomidae larvae), Trichoptera larvae, green algae (mainly *Mesotaenium*, *Spirogyra* and *Oedogonium*), blue algae (mainly *Oscillatoria*, *Anabaena* and *Raphidiopsis*), and diatoms (mainly *Navicula*, *Spirogyra*, *Tabellaria* and *Gomphoneis*). Among the allochthonous ones, the most representative items were terrestrial insects (mainly Coleoptera, adults of Diptera and Hy-
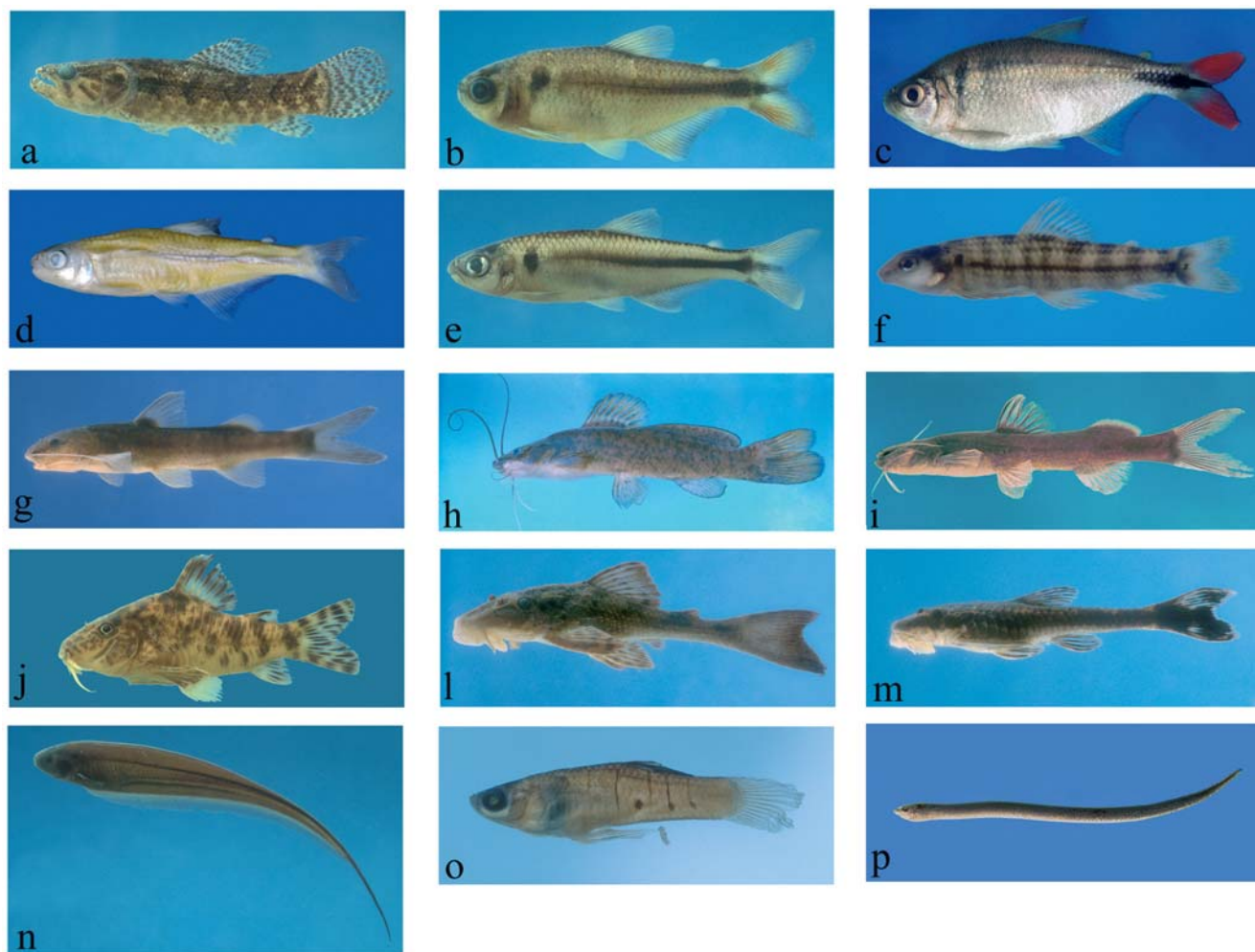
Fig. 3. Representative specimens of the collected species: a) *H. malabaricus* (LIRP 3077; 101.8 mm SL); b) *A. paranae* (LIRP 3093; 47.4 mm SL); c) *A. fasciatus* (LIRP 3161; 48.3 mm SL); d) *B. stramineus* (LIRP 3157; 45.3 mm SL); e) *P. argentea* (LIRP 3121; 55.2 mm SL); f) *C. gomesi* (LIRP 3138; 32.1 mm SL); g) *C. iheringi* (LIRP 3127; 36.0 mm SL); h) *R. quelen* (LIRP 3151; 88.9 mm SL); i) *P. tenebrosa* (LIRP 3160; 37.3 mm SL); j) *C. difluviatilis* (LIRP 3056; 44.0 mm SL); l) *H. ancistroides* (LIRP 3122; 37.4 mm SL); m) *Hisonotus* sp. (LIRP 3092; 30.4 mm SL); n) *E. virescens* (LIRP 3080; 119.8 mm SL); o) *P. jucundus* (LIRP 3063; 19.8 mm SL) and p) *S. marmoratus* (LIRP 3097; 137.1 mm SL).

menoptera). No significant differences were observed in the diets with respect to the seasons, nor among the same species in different stretches.

Figure 4 shows the percent composition of the gut contents of the fish species grouped in broad taxonomic or ecological categories. Based on similarity of the predominant food items, fish species were grouped into the flowing feeding categories (Fig. 5):

a) Omnivores with tendency to insectivory: These species represented 20% of the species sampled in the Paulicéia stream that eat 60% of allochthonous items (Diptera [Chironomidae], Hymenoptera [Formicidae], Coleoptera, Hemiptera, Isoptera, Pseudoptera, arachnids and vascular plants) and 40% of autochthonous items (Dipterans larvae [Chironomidae and Culicidae], Lepidoptera larvae, Odonata larvae, Ephemeroptera nymphs, Plecoptera, Collembola, Co-

leoptera, Hemiptera, fishes or fish scales, crustaceans, annelids, aschelminthes, and filamentous algae).

b) Larvivores: These species represented 40% of the species sampled in the Paulicéia stream that eat 85% of autochthonous items (Dipterans larvae [Chironomidae and Culicidae], Lepidoptera larvae, Ephemeroptera Trichoptera, Odonata larvae, Collembola, Plecoptera Coleoptera, thecamoebas, nematods and algae) and 15 % of the food of allochthonous items (Coleoptera and Orthoptera).

c) Periphitivores: These species represented 20% of the species sampled in the Paulicéia stream; all of these consumed items were allochthonous: Cyanophyceae (*Oscillatoria*, *Anabaena* and *Raphidiopsis*), Chlorophyceae (*Mesotaenium*, *Oedogonium*, *Spirogyra* and *Chlorella*), Bacillariophyceae (*Tabellaria*, *Navicula*, *Synedra*, *Bacillaria*, *Gomphonema*, *Gomphoneis* and *Amphora*), Eugnophyceae

(*Phacus* and *Trachelomonas*), Zygnemaphyceae (*Closterium*, *Micrasterias* and *Cosmarium*), filamentous algae, zooplancton (Cladocera and Copepoda), sand and periderm of aquatic plants. In the stomach of *S. marmoratus* aquatic dipterans were also found (Chironomidae) (see Fig. 4).

d) Piscivore: Only one piscivore species was found in the Paulicéia stream. Its stomach contained only fishes and scales of *A. paranae*.
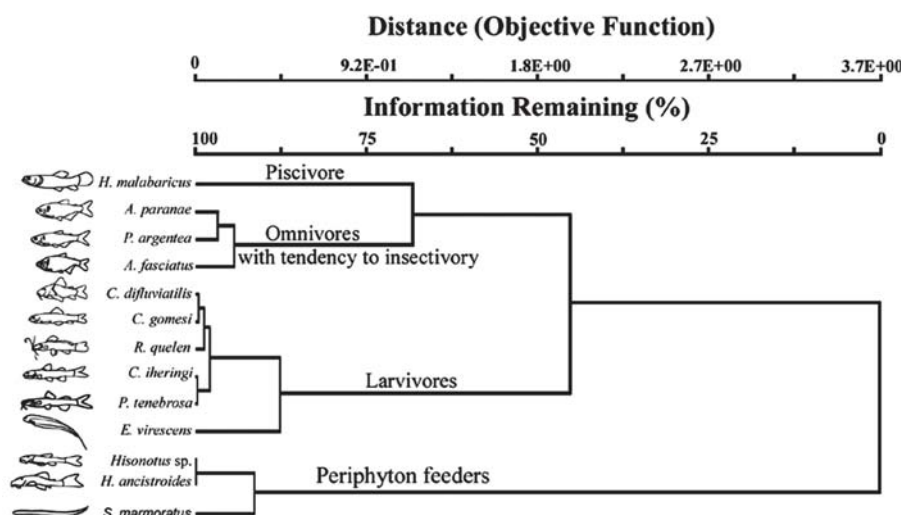
Significant feeding overlap was found between 31 pairs of species (see Table 3). In the upper stretch there was food overlap between *E. virescens* and *C. difluviatilis*, and between *E. virescens* and *A. paranae*. In the middle stretch there was food overlap between *C. iheringi*, *C. difluviatilis* and *E. virescens*; between *A. paranae* and *E. virescens*; and between *Hisonotus* sp. and *S. marmoratus*. In the lower stretch there was food over-

lap between *C. difluviatilis*, *P. tenebrosa*, *P. argentea*, *C. gomesi* and *R. quelen*; between *A. paranae*, *A. fasciatus* and *P. argentea*; and between *H. ancitroides* and *Hisonotus* sp.

Reproductive behavior. The gonads of 564 specimens, representing the totality of the sampled specimens in the Paulicéia stream were analyzed. During the study period, 67% of the species (*A. fasciatus*, *A. paranae*, *P. argentea*, *C. difluviatilis*, *E. virescens*, *C. iheringi*, *Hisonotus* sp., *H. ancistroides*, *P. tenebrosa* and *C. gomesi*) presented gonads in maturation or mature, without young individuals. The remaining 33% (*A. paranae*, *A. fasciatus*, *E. virescens* *Hisonotus* sp. and *H. ancistroides*) presented both sexually mature and young individuals. Only for *A. paranae* and *Hisonotus* sp. was a detailed study on the reproductive behavior possible, because
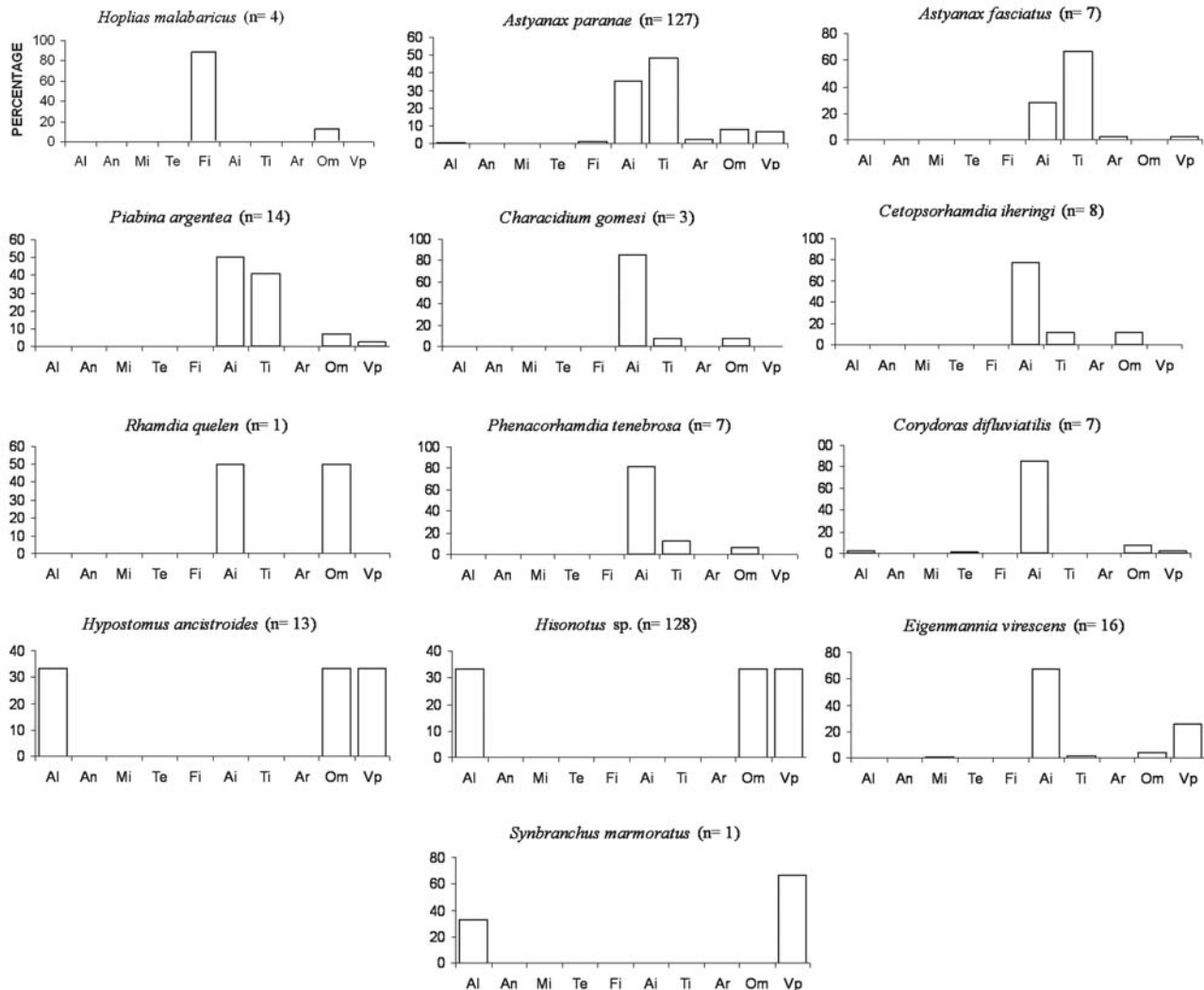
Fig. 4. Percent composition of the gut contents of the fish species with the food items grouped in the following broad categories: the autochthonous - Al = algae, An = anelideos, Mi = micro-crustaceans, Te = thecamoebas, Fi = fishes and fish scales, Ai = aquatic insects; and the allochthonous - Ti = terrestrial insects, Ar = Arachnidae, Om = organic matter and Vp = debris of vascular plants.

Distance (Objective Function)

0	9.2E-01	1.8E+00	2.7E+00	3.7E+00

Information Remaining (%)

100	75	50	25	0

H. malabaricus — Piscivore

A. paranae
P. argentea — Omnivores
A. fasciatus — with tendency to insectivory

C. difluviatilis
C. gomesi
R. quelen
C. iheringi — Larvivores
P. tenebrosa
E. virescens

Hisonotus sp.
H. ancistroides — Periphyton feeders

S. marmoratus

Fig. 5. Similarity dendrogram between 13 fish species from Paulicéia stream based on percent composition of diet.

Table 2. Fish species collected in each studied stretch of the Paulicéia stream, during the wet and dry season. SL = range of standard length (mm), N = number of specimens, BM = biomass and ICE = Incidence-based coverage estimator (± standard error). ([1]) resident species; ([2]) accessory species; ([3]) accidental species.

Species	Wet season			Dry season		
	SL	N	BM	SL	N	BM
Upper stretch (6 species, ICE = 6)						
Hoplias malabaricus [3]	101.8	01	20.0	92.8-206.3	02	127.5
Astyanax paranae [1]	14.4-77.2	94	345.5	15.8-73.5	133	408.5
Corydoras difluviatilis [2]	17.9-40.0	01	0.5	13.9	04	10.5
Hisonotus sp. [1]	13.2-33.6	104	20.5	15.8-33.6	74	24.5
Eigenmannia virescens [1]	12.5-187.7	11	25.5	19.8-119.2	06	5.5
Phallotorynus jucundus [3]	19.8	01	0.5	-	-	-
Middle stretch (6 species, ICE = 8 ± 1.4)						
Astyanax paranae [1]	24.4-62.7	39	92.5	34.7-71.6	32	101.0
Cetopsorhamdia iheringi	66.9	01	5.5	46.2-61.6	03	7.5
Corydoras difluviatilis [3]	-	-	-	35.1-35.9	02	4.0
Hisonotus sp. [1]	14.8-31.0	31	9.0	13.2-31.6	24	7.5
Eigenmannia virescens [2]	52.2-102.0	02	2.0	90.1-99.5	02	2.5
Synbranchus marmoratus [3]	-	-	-	137.1	01	2.5
Lower stretch (12 species, ICE = 15 ± 2.1)						
Hoplias malabaricus [3]	59.4	01	4.5	-	-	-
Astyanax paranae [1]	22.6-59.2	03	8.5	27.0-35.6	05	2.5
Astyanax fasciatus [2]	28.3-58.5	03	5.0	69.3-71.4	02	58.0
Bryconamericus stramineus [3]	-	-	-	58.8-61.2	02	7.0
Piabina argentea [1]	55.0-58.0			47.8-64.2	07	26.0
Characidium gomesi [2]	32.1	01	0.5	43.6-57.2	03	6.5
Cetopsorhamdia iheringi [2]	19.8-42.0	04	2.5	43.8-65.7	08	21.0
Rhamdia quelen [3]	-	-	-	88.9	01	11.0
Phenacorhamdia tenebrosa [3]	-	-	-	37.8-55.3	10	20.0
Corydoras difluviatilis [3]	18.8-25.1	03	1.0	-	-	-
Hypostomus ancistroides [3]	16.4-58.8	18	20.5	23.7-48.9	06	9.0
Hisonotus sp. [1]	21.3-32.3	59	21.5	22.6-30.3	11	4.0
Total	-	377	585.5	-	338	866.5

these two species were very abundant during the whole study period.

Two hundred and two specimens of *A. paranae* were analyzed, being 90 females and 164 males. The sex ratio proportion found in this study was 1.8:1 (male: female) which was significantly different from the expected value 1:1 ($\chi^2 = 9$). Immature individuals, in maturation and maturity were found throughout the year (Fig. 6). Individuals with emptied gonads were sampled in January to March and in October (Fig. 6). The size at first maturation (SL_{50}) differed between males

and females, being the size range between 30-35 mm for males and 35-40 mm for females. The smallest mature female had 36.5 mm and was sampled in August, and the smallest mature male had 31.2 mm and was sampled in November. The size in which all of the individuals are capable of actively reproductive process (SL_{100}) is also different for males and females, being the size range between 40-45 mm for males and 45-50 mm for females. Among small sized individuals (15-50 mm) there was a predominance of males, while among the largest individuals (over 50-80 mm) there was a predominance of females (Fig. 7).

Two hundred and eighty-eight specimens of *Hisonotus* sp. were analyzed, being 148 females and 140 males. The sex ratio presented no significant differences with the expected 1:1 proportion ($\chi^2 = 0.04$). Immature individuals were observed basically throughout the year, except in the months May, June and August (Fig. 8). Individuals in maturation and maturity were found throughout the year (Fig. 8). Individuals with emptied gonads were sampled in January to March (Fig. 8). The size at first maturation (SL_{50}) differed between males and females, with a size range of 15-17.5 mm for males and 20-22.5 mm for females. The smallest mature female had 15.8 mm and was sampled in April, and the smallest mature male had 17.5
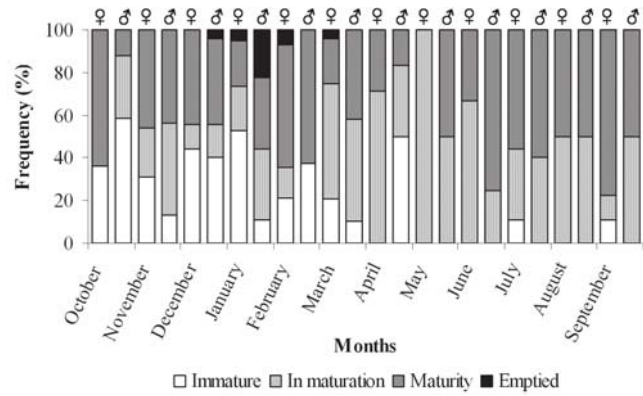
mm (sampled in December). The size in which all the individuals were capable of actively participating in the reproductive process (SL_{100}) was also different for males and females, with the size range between 22.5-25 mm for males and 25-27.5 mm for females. Among small sized individuals (12.5-25 mm), there was a predominance of males. On the other hand, between the largest individuals (25-35 mm) there was a predominance of females (Fig. 9). The females of *Hisonotus* sp. presented oocytes at different sizes during the "in maturation" and "maturation" stages. This is characteristic of species with asynchronic spawning (or multiple spawning), in which oocytes in different stages of development are found inside of the ovary and their elimination occurs when the oocytes are mature (*cf.* Vazoller, 1996). Usually, there were few mature oocytes close to the urogenital opening and many oocytes in initial stages of development in the anterior portion of the ovary (Fig. 10).

Ecomorphology. The average values of each one of the 16 ecomorphological attributes analyzed for all studied species are presented in Table 4. The first two axes of the PCA explained together 67.8% of the accumulated variance (Table 5).

Three ecomorphological groups were obtained: a) nek-
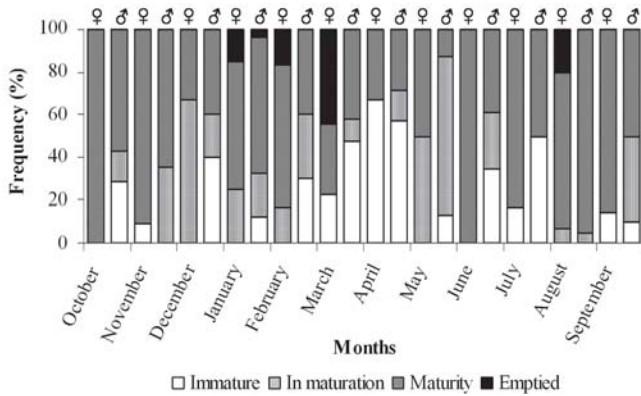
Fig. 6. Frequency of the reproductive stages found in each month to *A. paranae* in the Paulicéia stream.

Fig. 8. Frequency of the reproductive stages found in each month to *Hisonotus* sp. in the Paulicéia stream.
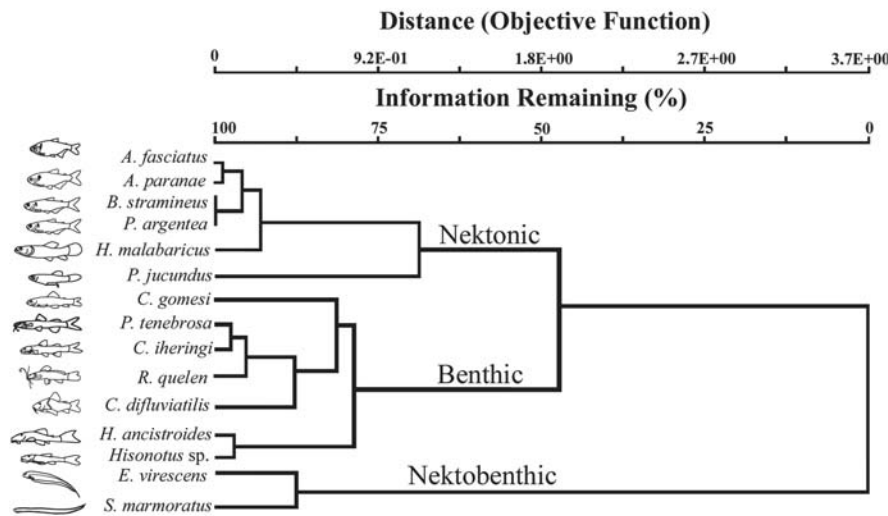

Fig. 7. Sexual proportion of males and females of *Astyanax paranae* for each size intervals of the standard length.

Fig. 9. Sexual proportion of males and females of *Hisonotus* sp. for each size intervals of the standard length.

Table 3. Food overlap between 31 pairs of fish species of the Paulicéia stream. Values were considered significant when ≥ 0.58. *Apar – A. paranae*; *Hmal – H. malabaricus*; *Cdif – C. difluviatilis*; *Smar – S. marmoratus*; *Hiso – Hisonotus* sp.; *Evir – E. virescens*; *Cihe – C. iheringi*; *Afas – A. fasciatus*; *Parg – P. argentea*; *Hanc – H. ancistroides*; *Cgom – C. gomesi* and *Rque – R. quelen*.

	Apar	*Hmal*	*Cdif*	*Smar*	*Hiso*	*Evir*	*Cihe*	*Afas*	*Parg*	*Hanc*	*Cgom*	*Rque*
Hmal	0.03											
Cdif	0.54	0.01										
Smar	0.10	0	0.03									
Hiso	0.14	0.07	0.07	**0.75**								
Evir	**0.59**	0	**0.89**	0.31	0.23							
Cihe	**0.68**	0.01	**0.94**	0	0.07	**0.92**						
Afas	**0.94**	0	0.36	0.03	0.02	0.37	0.50					
Parg	**0.96**	0.01	**0.71**	0.02	0.07	**0.74**	**0.84**	**0.87**				
Hanc	0.14	0.07	0.07	**0.75**	1	0.23	0.07	0.02	0.07			
Cgom	**0.61**	0.01	**0.96**	0	0.04	**0.91**	**0.99**	0.44	**0.79**	0.04		
Rque	0.49	0.09	**0.72**	0	0.39	**0.70**	**0.78**	0.27	**0.61**	0.39	**0.74**	
Pten	**0.67**	0.01	**0.95**	0	0.04	**0.91**	**0.99**	0.51	**0.83**	0.04	**0.99**	**0.74**

Table 4. Mean values of the 16 ecomorphological attributes calculated for the 15 fish species recorded at the Paulicéia stream. CI – Compression index; RD – Relative depth; RPL – Relative caudal peduncle length; IPC – Caudal peduncle compression index; IVF – Index of ventral flattening; RAD – Relative area of the dorsal fin; RAP – Relative area of the pectoral fin; PAR – Pectoral fin aspect ratio; RAC – Relative area of the caudal fin; CAR – Caudal fin aspect ratio; RHL – Relative head length; EP – Eyes position; RMW – Relative mouth width; RMH – Relative mouth length; RMC – Reason of the mouth configuration; MO – Mouth orientation and N – number of the examined specimens.

Species	CI	RD	RPL	IPC	IVF	RAD	RAP	PAR	RAC	CAR	RHL	EP	RMW	RMH	RMC	MO	N
H. malabaricus	1.70	0.22	0.17	11.27	0.95	0.17	0.10	1.73	0.34	0.33	0.33	0.46	0.11	0.10	0.94	0.63	2
A. paranae	2.59	0.34	0.17	6.37	1.47	0.12	0.09	2.13	0.24	0.44	0.26	0.42	0.09	0.09	0.97	0.90	10
A. fasciatus	3.14	0.34	0.14	6.80	1.51	0.15	0.12	1.82	0.26	0.65	0.24	0.41	0.07	0.07	1.02	0.90	4
B. stramineus	2.31	0.25	0.16	6.95	1.07	0.13	0.11	1.47	0.27	0.40	0.23	0.67	0.06	0.06	1.03	0.81	2
P. argentea	2.43	0.26	0.16	5.84	1.26	0.15	0.13	1.72	0.25	0.36	0.24	0.51	0.06	0.07	1.05	0.71	10
C. gomesi	1.76	0.22	0.22	6.28	0.93	0.26	0.24	2.33	0.26	0.17	0.23	0.45	0.04	0.05	1.22	0.71	3
C. iheringi	1.13	0.18	0.22	8.33	0.59	0.20	0.18	1.72	0.42	0.31	0.22	0.59	0.11	0.06	0.53	0.44	8
R. quelen	1.45	0.17	0.20	10.38	0.79	0.26	0.16	1.67	0.38	0.24	0.25	0.53	0.11	0.04	0.37	0.20	1
P. tenebrosa	1.13	0.14	0.21	8.02	0.73	0.24	0.14	1.31	0.38	0.25	0.20	0.61	0.08	0.04	0.57	0.47	8
C. difluviatilis	1.35	0.35	0.15	5.68	0.64	0.32	0.16	1.84	0.47	0.38	0.32	0.52	0.09	0.07	0.80	0.31	3
H. ancistroides	0.72	0.20	0.33	6.91	0.57	0.31	0.20	2.00	0.34	0.24	0.25	0.83	0.14	0.09	0.64	0.31	10
Hisonotus sp.	0.71	0.16	0.38	4.79	0.56	0.22	0.19	2.36	0.26	0.11	0.24	0.70	0.11	0.09	0.84	0.31	10
E. virescens	1.96	0.09	0.21	4.56	1.08	0.00	0.00	2.05	0.00	0.00	0.10	0.52	0.02	0.02	1.01	0.63	6
P. jucundus	2.00	0.21	0.00	6.75	1.33	0.23	0.04	5.00	0.36	0.14	0.27	0.50	0.05	0.05	0.90	0.60	1
S. marmoratus	1.17	0.04	0.00	2.00	0.88	0.00	0.00	0.00	0.00	0.00	0.11	0.80	0.02	0.01	0.50	0.40	1

Fig. 10. Female of *Hisonotus* sp. (32.8 mm SL) showing the different stages of the oocytes maturation inside the ovary.

tonic fishes, b) benthic fishes, and c) the nektobenthic fishes (Figs. 11-12). Three ecomorphological attributes contributed to distinguish nektonic from benthic fishes: compression index, index of ventral flattening, and mouth orientation. Only one attribute contributed to distinguish nektonic from nektobenthic fishes: the caudal fin aspect ratio. The relative head width permits to distinguish benthic from nektobenthic fishes. The same two attributes contributed to distinguish nektonic from benthic fishes, nektonic from nektobenthic fishes, and benthic from nektobenthic fishes: the relative area of the dorsal and pectoral fins. Four attributes contributed to distinguish benthic from nektobenthic fishes and nektonic from nektobenthic fishes: the relative depth, relative area of the caudal fin, relative head length, and relative mouth height (Table 5; Fig. 12).

Fig. 11. Dendrogram of the ecomorphological relationships for the 15 studied fish species.

Table 5. The correlation index values between each ecomorphological attribute and the correspondent axes, and the variance attracted for the two principal axes of PCA.

Attributes	Axes 1	Axes 2
Compression index (CI)	-0.240	0.946
Relative depth (RD)	-0.879	0.237
Relative caudal peduncle length (RPL)	0.394	-0.357
Caudal peduncle compression index (IPC)	-0.756	-0.076
Index of ventral flattening (IVF)	-0.164	0.889
Relative area of the dorsal fin (RAD)	0.931	-0.160
Relative area of the pectoral fin (RAP)	0.944	-0.026
Pectoral fin aspect ratio (PAR)	0.944	-0.26
Relative area of the caudal fin (RAC)	0.887	-0.032
Caudal fin aspect ratio (CAR)	0.600	0.626
Relative head length (RHL)	-0.929	-0.166
Eyes position (EP)	0.419	-0.631
Relative mouth width (RMW)	-0.739	-0.479
Relative mouth length (RMH)	-0.874	-0.115
Reason of the mouth configuration (RMC)	-0.278	0.597
Mouth orientation (MO)	-0.109	0.841
Total variation (%)	60.9	16.4

Discussion

Environmental factors. The water temperature did not varied in the three studied stretches, probably as a result of a thermal balance provided by tree shadows (Gregory *et al.*, 1992 *apud* Lima & Zakia, 2000). The dissolved oxygen variation also was low in the three studied stretch, probably in function of the thermal balance of the water, since oxygen solubility varies inversely with temperature. The high value of dissolved oxygen in the lower stretch is probably due to the action of the topographical steepness, small depth, rocky bottom, and higher current speed. Those factors can cause an increase in the water agitation, and consequently, a renewal of the interface water layer, increasing the gaseous exchanges.

The horizontal water transparency depends of the amount of suspended material. In none of the studied stretches there was seasonal variation of this characteristic, probably as a function of the presence of riparian vegetation that filters the sediments that would otherwise be discharged by the stream during the rainy season (Lima & Zakia, 2000).

Similar conductivity was found between the upper and middle stretches, but in the lower stretch there was an increase in conductivity values. This increase is probably related to the utilization of agricultural defensive practices in the sugar cane plantations, besides an increase of water volume due to a tributary, the Água Santa stream.

Ichthyofauna. The characiform and siluriform predominance found in the Paulicéia stream corroborates Lowe-McConnell's (1987) previous observation.

Uieda (1984) provided three explanations to justify the occurrence of accessory and accidental species: a) that these species are probably migratory, joining the local community at certain periods of the year; b) that these species present low population density; c) or that these species take shelter in places in which sampling is difficult, resulting in low sample frequencies. Due the applied collecting effort during the entire study period, I believe that the accessory and accidental species have a low population density.

Several accidental species were found in the lower stretch (*C. gomesi*, *C. iheringi*, *R. quelen*, *P. tenebrosa* and *H. ancistroides*) which can be explained by the lack of efficiency of the sampling methodology. When the electrofishing methodology was used in the lower stretch, almost all species that were first registered as accidental were captured in higher abundance, besides the new occurrence of *P. tenebrosa*. Probably, electrofishing was efficient in the lower stretch because 60% of the species that occur there were benthic, and the rocky bottom provides hiding places among the rocks impeding their capture. The methodology applied during the entire study period was appropriate in the upper and middle stretches; electrofishing did not show differences in number of specimens or species collected in these stretches.
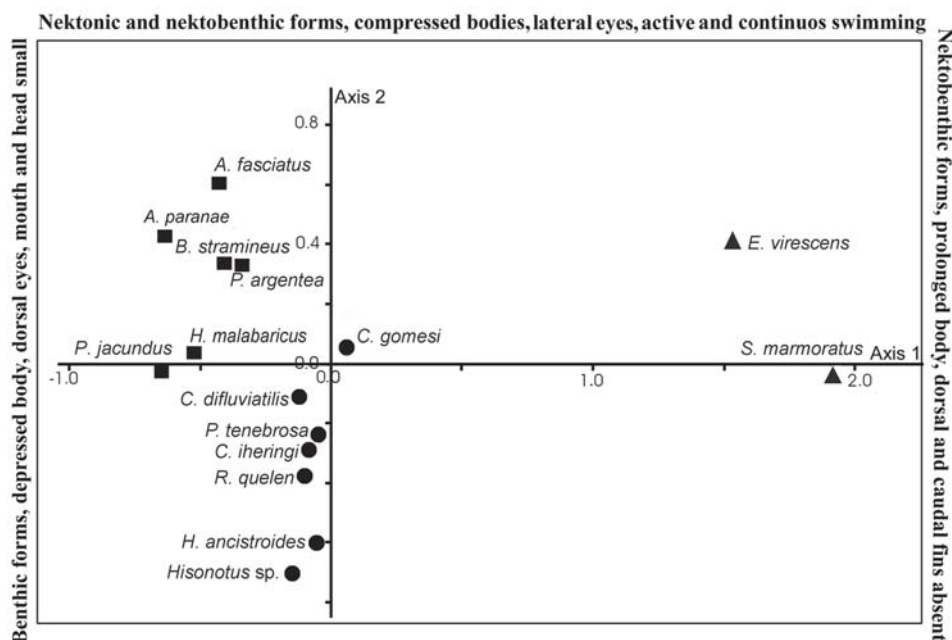
Fig. 12. Projection of the 15 studied species in the two first axes of the PCA; squares represent the nektonic species; circles the benthic and the triangles the nektobenthic.

The longitudinal distribution of the species is associated with several factors, that can act separately or together (Garutti, 1988). When the three studied stretches were compared, two different situations concerning substratum type (rocky or sandy), depth (shallow or deep), width (narrow or wide), current speed (slowly and fast), and riparian submerged vegetation (absence or presence), were found. I believe that the combination of these abiotic factors determines the occurrence and distribution of the fish fauna of the Paulicéia stream. For example, *Eigenmannia virescens* was considered a resident species in the upper stretch and accessory in the middle stretch. This species shelters within submerged vegetation (see Garutti, 1988 and Ferreira & Castro, 2005), which suggests that its absence in the lower stretch may be related to the absence of this kind of microhabitat.

The discharge in the lower stretch was three times larger than the value registered in the other two stretches. The occurrence and addition of species in the lower stretch corroborates Lowe-McConnell's (1999) observation in which the water level increase is a factor responsible for the expansion of the microhabitat, increasing food availability, spawning places, and areas that will serve as shelter, since six, six and 12 species were collected in the upper, middle, and lower stretches, respectively.

The fish fauna in the upper and middle stretches were very similar. However, the abundance in the middle stretch was smaller than the abundance in the upper stretch. In the middle stretch, the vegetation and submerged tree branches were not so abundant as in the upper stretch. The large heterogeneity in aquatic vegetation is an important factor in the determination of the species richness, because it increases the offer of refuge areas. The riparian vegetation is very important to nektonic species that use it as temporary shelter between displacements, and benthic species that use it for hiding (Caramaschi, 1986; pers. obs.).

Diet. The three omnivore species with a tendency for insectivory (*A. paranae*, *A. fasciatus* and *P. argentea*) belong to family Characidae. In general, characin species are omnivores, visually dependent to feed, showing high feeding plasticity, capturing prey both at the water column as well as in the substratum. There is a wide literature on the feeding habits in different environments corroborating the results presented herein for the genus *Astyanax* (*e.g.* Uieda *et al*., 1997; Esteves & Galetti, 1995; Esteves, 1996; Castro & Casatti, 1997) and for *P. argentea* (Godoy, 1975; Ferreira *et al*., 2002).

The majority of the studied species are larvivores. The importance of the aquatic insects for tropical stream fishes was reported by many authors. Previous studies concerned with the species studied herein or its congeners corroborate the results of the present study: see Obara & Mendes (1990), Aranha *et al*. (1993) and Castro & Casatti (1997) for *C. difluviatilis*; see, Casatti & Castro (1998) and Obara & Mendes (1990) for *C. iheringi*; see Uieda (1984), Costa (1987), Sabino & Castro (1990), Casatti & Castro (1998) and Aranha *et al*. (1998) for *C. gomesi*; see Knöppell (1970), Soares (1979), Obara & Mendes (1990) and Castro & Casatti (1997) for *E. virescens*; see Knöppel (1970), Soares (1979), Costa (1987), Castro & Casatti (1997), Casatti & Castro (1998) and Casatti *et al*. (2001) for *R. quelen*.

Algae are a common feeding item present in the diet of neotropical stream fishes. Especially for Loricariidae, algae

are the most important item (see Power, 1984 a, b; Lowe-McConnell, 1987; Buck & Sazima, 1995). The loricariids are morphologically specialized for scraping attached material from flat surfaces (Power, 1990). The digestion process in loricariids is facilitated by the elongate coiled intestine. Green algae and blue algae are found intact in their feces, while diatom tests are usually empty, suggesting that they are more easily digested by these species (Power, 1984). The diatoms were the most abundant item found in the guts of *Hisonotus* sp. and *H. ancitroides*, which is in accordance to the literature.

Synbranchus marmoratus is known as insectivorous species (see Mérigoux & Ponton, 1998; Meschiatti & Arcifa, 2002). In the present study this species was considered to feed on periphyton, probably because only one specimen was analyzed and the algae found in its stomach were probably ingested accidentally.

Hoplias malabaricus was the unique piscivorous species in the Paulicéia stream. Several authors studied its feeding behavior (Knöppel, 1970; Winemiller, 1989; Silva, 1993; Castro & Casatti, 1997), observing that young individuals feed on small crustaceans and insects while the adults are fish feeders.

Food overlap. The food overlap found among 40% of the species pair does not necessarily invoke the existence of competition. It could be a reflex of the availability of resources that are partitioned (Ross, 1986) or the employment of broad taxonomic categories for such analysis.

There was food overlap between *E. virescens* and *C. difluviatilis*, and between *E. virescens* and *A. paranae* in the upper stretch. However, these three species have distinct morphological features, which occupy different habitat and use different feeding strategies. *Eigenmannia virescens* is a nocturnal species, *A. paranae* and *C. difluviatilis* are both diurnal predators. *Astyanax paranae* is a nektonic species, actively swimming during the day at the water column in groups of three to seven individuals using "drift feeding" (*cf.* Grant & Noakes, 1987) and "surface picking" (*cf.* Sazima, 1986) as feeding strategies (Ferreira & Castro, 2005). *Corydoras difluviatilis* is a benthic species, which was observed always solitary or in couples practicing "the hunting by speculation" tactic (*cf.* Curio, 1976; Ferreira & Castro, 2005).

The food overlap in the middle stretch was between *C. iheringi*, *C. difluviatilis* and *E. virescens*, and between *Hisonotus* sp. and *S. marmoratus*. *Corydoras difluviatilis* is a diurnal species and also practices "the hunting by speculation" tactic (*cf.* Curio, 1976; see Ferreira & Castro, 2005). *Eigenmannia virescens* and *C. iheringi* have nocturnal habits and practice "substratum speculation". However, these two species presented low population densities during the study period (four specimens for both). The food overlap found between *Hisonotus* sp. and *S. marmoratus* was probably due to the fact that only one specimen of *S. marmoratus* was analyzed. Loricariids and *S. marmoratus* possess different spatial distributions and do not use the same tactics to obtain food (see Silva, 1993; Buck & Sazima, 1995).

In the lower stretch, *C. difluviatilis*, *P. tenebrosa*, *P. argentea*, *C. gomesi* and *R. quelen* also presented food overlap. However, these species present different feeding activity periods, spatial distribution and alimentary tactics. *Corydoras difluviatilis* and *C. gomesi* are diurnal and benthic species; however, *C. difluviatilis* was sampled in lentic waters with sandy bottoms, while *C. gomesi* was sampled from bottom rocks in area of stronger current. *Piabina argentea* is also a diurnal species, but a nektonic one. *Rhamdia quelen* and *P. tenebrosa* are nocturnal and benthic species (see Casatti *et al.*, 2001), however, *R. quelen* was sampled in lentic waters with sandy bottoms, while *P. tenebrosa* was sampled in bottom-rock areas of high current.

In the lower stretch also have food overlap between *Astyanax paranae*, *A. fasciatus* and *P. argentea*. These three characins species are diurnal, use similar feeding tactics and occupy similar micro habitats (see Uieda, 1984; Casatti & Castro, 1998; Casatti *et al.*, 2001). Analyzing in more detail the items ingested by these three species, I could observe differences among their diets. *Piabina argentea* presented a diet more diversified when compared to *Astyanax* species. The diets of *A. paranae* and *A. fasciatus* were similar; however, these species were represented by just a few individuals, decreasing the degree of food competition.

Hypostomus ancistroides and *Hisonotus* sp. were sympatric in the lower stretch and had a maximum food overlap. This is related to the feeding tactic used by loricariids to feed on periphyton. Probably algae are not a limited food resource in the Paulicéia stream and the preference for certain types of micro habitats probably minimizes the competition for food (Buck & Sazima, 1995; Uieda *et al.*, 1997).

Reproduction. The simple presence of females that are mature or in maturation does not mean that a species is reproducing in the Paulicéia stream. If environmental conditions are not favorable, the oocytes can be absorbed and spawning will not be executed, or spawning can occur but the eggs and embryos will not survive. The simple presence of young individuals as a sign of reproduction in certain places should also be carefully analyzed because recruitment can occur from adjacent areas (Suzuki & Agostinho, 1997).

The reproductive success of a species can be indicated by the presence of females with signs of recent spawning together with juvenile individuals in a same region (Suzuki & Agostinho, 1997). At the study site, only *A. paranae*, *A. fasciatus* and *Hisonotus* sp. complete the reproductive cycle in Paulicéia stream. I believe that such place is a favorable environment for the development of complete ontogenetic stages only for *A. paranae* and *Hisonotus* sp. These species do not accomplish extensive migrations and they occur only in small streams. According to Nomura (1975) and Agostinho *et al.* (1995), *A. fasciatus* lives in rivers, realizing migrations and presenting total spawning. The spawn of the larger-sized migratory fishes occur in small streams during the rainy season and the eggs flow for great distance; where they reach flooded areas with favorable conditions for survived (Suzuki

& Agostinho, 1997). For such reasons, I believe that *A. fasciatus* probably swim up the Paulicéia stream to spawn, as it is a direct tributary of the Mogi-Guaçu River and this species was only sampled in the lower stretch studied.

The results indicate that *A. paranae* and *Hisonotus* sp. reproduce throughout the whole year in the Paulicéia stream. Barbieri (1992 a, b) and Veregue & Orsi (2003) corroborate the present study with respect to *A. paranae*. This prolonged reproductive season may be explained as an important strategy to assure the survival in a stochastic environment, because headwaters are not stable as rivers, and their physiography can be changed by erosive actions (Garutti, 1988). This phenomenon causes massive loss of eggs, larvae or juveniles by heavy rain, with sand accumulation on the bottom, suspended material, and more accumulation of predators at headwaters.

In the present study, the expected sexual proportion 1:1 was observed only for *Hisonotus* sp. No other Hypoptopomatinae species has presently been studied, except for *Pseudotothyris obtusa* from southeastern Brazil. This species have a proportion of four females to one male (Takeuti *et al*., 1999).

The proportion among females and males of *A. paranae* found in the Paulicéia stream corroborates the studies of Barbieri (1992 a, b) in the Fazzari stream, São Paulo State. Barbieri (1992 a, b) also observed that the females are larger than the males and that the adult individuals are ready for reproduction during the whole year. However, Veregue & Orsi (2003), also studying *A. paranae* in Marrecas stream (Tibagi basin, Paraná State), found a prevalence of males during the studied period. This difference in the sexual proportion can be explained in two ways: by inadequate methodology (the mesh of sieves and hoop nets may be too big, allowing the escape of males that are smaller than females), or by environmental pressures that can alter this proportion of males and females, either positively or negatively (Nikolsky, 1969).

The great size of the mature females of *A. paranae* and *Hisonotus* sp. compared to males when reaching the first sexual maturation is probably a reproductive strategy of this species. It should be an advantage for females to be larger than males because they could produce more oocytes. Besides, I also believe that the males are smaller than females because their energy investment for reproduction is lower and they lack parental care.

In spite of several studies on reproductive aspects of neotropical fish have been developed in the last years, the volume of available information is still quite reduced when compared to the number of existing species, and this type of study is restricted to species with some commercial interest. It is important to point out that information on the reproductive period and life cycle are of great value for the understanding of the importance of small streams in the ecology of larger rivers (Garutti, 1988).

Ecomorphology. The goal of an ecomorphological study is to understand the interaction between the morphology of organisms and their ecology (Norton *et al*., 1995).

The ecomorphological attributes of each species may reflect important aspects of their ecology and can be used as indicators of theirs life habits or adaptations to different habitats. The attributes related to swimming, feeding and habitat were the most important for the distribution of the studied species in the ecomorphological analysis.

a) Nektonic: In this group are included the mid-water swimmers, with adaptive characters to weak to moderate current environments. Small-sized characins present morphological characters related on continuous swimming, such as, compressed bodies, lateral eyes and small pectorals fins. *Piabina argentea* and *B. stramineus* presented high values in the pectoral fin ratios when compared to species of *Astyanax*. This attribute is related to their capacity to travel long distances (Keast & Webb, 1966 *apud* Mahon, 1984) and to habitats of fast waters. *Piabina argentea* and *B. stramineus* were sampled only in the lower stretch where the water velocity is three times larger than in the upper stretch. The small-sized characin species are omnivorous in the Paulicéia stream and they possess subdorsal mouth. Except for *P. jucundus* and *H. malabaricus*, the other nektonic species presented high values of caudal fin ratios, indicating active and continuous swimming (Balon *et al*., 1986). There is a vast literature about the preference of the poecilids and erythrinids for lentic habitats.

The analyzed specimens of *H. malabaricus* presented high values in head length, width and height relative to the mouth, suggesting that they feed on items that are relatively big. *Hoplias malabaricus* practice "sit-and-wait predation" strategies to obtain food (*cf.* Sazima, 1986). Usually they stay immobile in marginal areas in which prey is captured in fast spurts, starting initially from a state of immobility. This species can explore all of the water column to capture prey. I observed this species in the half water column, in rest close to the margin in the upper stretch of Paulicéia stream.

b) Benthic: In this group are fishes with a morphology related to life close to the bottom, typical of riffles. With exception of *C. difluviatilis* and *Hisonotus* sp., the other species were sampled only in the lower riffle stretch. In general, this group presents a high caudal peduncle, depressed body, dorsal eyes and large pectoral and caudal fins. *Characidium gomesi* has a fusiform body, wide pectoral fins, high caudal peduncle, low indexes of ventral flattening, and a small dorsal fin, characteristics that are fundamental to live in a fast water habitat (Balon *et al*., 1986). Besides, the individuals of this species present small and narrow mouths, suggesting microphagous habits, which were verified in the diet analysis.

Heptapterinae comprise catfishes with slender bodies, sensorial barbells and dorsal eyes, characters that facilitate the exploration of small spaces among the bottom rocks, where they probably feed on aquatic insect larvae. *Rhamdia quelen* is different than the other heptapterines for presenting a caudal peduncle that is extremely high, indicating little capacity to accomplish maneuvers (Balon *et al*., 1986). It also present high values in the relative head length and relative mouth height and width, suggesting the ingestion of big prey items.

In the present study, only a single specimen of *Rhamdia* was collected, having in its stomach only small aquatic insect larvae; however, several studies show the occurrence of larger items in their diet (fishes for example).

Corydoras difluviatilis was collected in the three studied stretches of the Paulicéia stream. Callichthyidae are benthic fishes with typical characteristics as sensorial barbells, eyes dorsolaterally located, high body and large caudal fin that increases their capacity for vertical displacements (Balon *et al.*, 1986). This species also presents a short caudal peduncle, which is related to life in lentic habitats, a slightly dorsoventrally flattened body and wide pectoral fins, allowing these benthic species to remain motionless on the substratum (Balon *et al.*, 1986). *Corydoras difluviatilis* also possesses a small and subterminal mouth, suggesting that it feeds on small bottom prey, which in fact was observed during the underwater observations (Ferreira & Castro, 2005) and in the diet study.

The two species of Loricariidae are morphologically specialized for life in riffles. They possess ventral lips modified as adhesive organs, depressed body, eyes dorsally located, long caudal peduncle, and relatively large pectorals and caudal fins. *Hisonotus* sp. and *H. ancistroides* forage on the surface of rocks and submerged leaves and logs (see Casatti *et al.*, 2001; Ferreira & Castro, 2005).

c) Nektobenthic: In this group are two species phylogenetically distant but that present similar morphological characters (a example of ecomorphological convergence). These two species present elongated bodies, lack dorsal and caudal fins, and their pectoral fins are reduced. These features decrease their capacity to actively swim allowing them to live only in lentic waters. Usually, they are captured among the riparian vegetation, where they remain stationary. The relative head length, and the width and height of their mouth are low, indicating theirs preference for small food items, which was verified in the diet analysis.

The ecomorlogical analysis corroborates the underwater observations, as well as natural history data from the literature. The development of this type of study is very important for understanding the niches occupied by stream fishes in the Neotropical region (Ueda, 1995).

General considerations. The substratum type, current speed, and the presence or absence of submerged marginal vegetation are environmental factors of great importance in constraining the occurrence and distribution of the ichthyofauna of the Paulicéia stream. The riparian vegetation is also very important as food or prey habitat for the studied fish species. Alterations in the riparian vegetation will certainly result in a negative impact for the biotic integrity of a stream. São Paulo is probably the most degraded state of Brazil and there are few studies on the dynamics of fish communities that inhabit the Upper Paraná River streams. Studies like this are useful for future work about evaluation and recovery of degraded areas.

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