Structure and feeding of a stream fish assemblage in Southeastern Brazil: evidence of low seasonal influences

Estrutura e alimentação de uma comunidade de peixes em um riacho no sudeste do Brasil: evidências de baixa influência sazonal

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Abstract: Aim: The present study was developed in a deforested stream located in a region that exhibits marked seasonality with the purpose to investigate whether ecological descriptors of the quantitative structure (i.e., composition, abundance, biomass, species richness, diversity) and feeding of fishes do change between the dry and wet periods. **Methods:** Sampling was conducted bimonthly from April 2004 to February 2005 by using a standardized effort with electrofishing equipment and environmental variables measurements. **Results:** We collected 713 fishes belonging to 23 species. The most abundant species were *Gymnotus carapo* (24.0%) and *Poecilia reticulata* (23.8%). Species richness, abundance, and biomass showed to be higher in the wet period, but these differences were not significant and did not influence the multivariate pattern of the assemblage (ANOSIM, R = 0.148). Nevertheless, average dissimilarity between community structure in the dry and wet periods was 52.7%, mainly due to the differential contribution of *P. reticulata*, notably more abundant in the wet season, under quasi-hypoxic water conditions. Examination of 333 gastric contents of 12 species evidenced that food variety was higher in the dry period. Of these species, 67% (*Astyanax altiparanae*, *Astyanax fasciatus*, *Geophagus brasiliensis*, *Gymnotus carapo*, *Hypostomus ancistroides*, *Phalloceros harpagos*, *Poecilia reticulata*, and *Rhamdia quelen*) kept the diet throughout the year, being classified in the same trophic groups in both periods, and detritus was the most important item for half of them, followed by aquatic insects. Overall, no significant differences in the community's diet between periods were registered (ANOSIM, R = –0.04). **Conclusions:** This relative constancy suggests a quite regular availability of resources (mainly shelters in submerged marginal grasses and detritus) along the year.

Keywords: pasture, Upper Paraná, temporal variation, detritus.

Resumo: Objetivo: O presente estudo foi desenvolvido em um riacho desflorestado localizado em uma região que exibe marcada sazonalidade com o propósito de investigar se descritores ecológicos da estrutura da comunidade (i.e., composição, abundância, biomassa, riqueza de espécies, diversidade) e alimentação dos peixes variam entre os períodos seco e chuvoso. **Métodos:** As amostragens foram realizadas bimestralmente de abril de 2004 a fevereiro de 2005, empregando-se um esforço padronizado com equipamento de pesca elétrica e medidas de variáveis do ambiente. **Resultados:** Foram coletados 713 exemplares de peixes, pertencentes a 23 espécies. As espécies mais abundantes foram *Gymnotus carapo* (24,0%) e *Poecilia reticulata* (23,8 %). Riqueza de espécies, abundância e biomassa foram mais elevadas no período chuvoso do que no seco, porém essas diferenças não foram significativas e não influenciaram o padrão multivariado da estrutura da ictiofauna (ANOSIM, R = 0,148). Apesar disso, a dissimilaridade média entre os períodos foi de 52,7%, principalmente devido à contribuição diferencial de *P. reticulata*, notavelmente mais abundante no período chuvoso, em condições quase hipóxicas. O exame de 333 conteúdos gástricos de 12 espécies mostrou que a variedade de itens alimentares foi maior no período seco. Destas espécies, 67% (*Astyanax altiparanae*, *Astyanax fasciatus*, *Geophagus brasiliensis*, *Gymnotus carapo*, *Hypostomus ancistroides*, *Phalloceros harpagos*, *Poecilia reticulata* e *Rhamdia quelen*) mantiveram a dieta ao longo do ano, sendo classificadas nos mesmos grupos tróficos em ambos os períodos e detrito foi o item mais importante para metade delas, seguido por insetos aquáticos. No geral, não foram registradas alterações significativas na dieta da comunidade entre os períodos (ANOSIM, R = –0,04). **Conclusões:** Esta relativa constância sugere uma disponibilidade regular dos recursos (principalmente abrigos entre gramíneas marginais submersas e detrito) ao longo do ano.

Palavras-chave: pastagem, Alto Paraná, variação temporal, detrito.

1. Introduction

Seasonality, hydrological regime (Horwitz, 1978; Poff and Allan, 1995), habitat diversity on several scales (Gorman and Karr, 1978; Angermeier and Karr, 1984; Schlosser, 1982), and predation (Glasser, 1979; Schlosser, 1987) are all ecological factors that commonly influence stream fish communities. The magnitude of such influence is often constrained to topography, geomorphology, and other hydraulic descriptors, which, in turn, determine a set of important structural features for composition and abundance of fish species in streams, such as width, depth, discharge, and substrate (see studies of Angermeier and Schlosser, 1989; Súarez, 2008).

Variations in seasonality and physical habitat structure may explain not only the quantitative structure of the stream fish fauna (Galacatos et al., 2004; Fialho et al., 2007), but also the trophic structure and food networks (Winemiller, 1990; Winemiller and Jepsen, 1998). Seasonal changes in feeding between dry and wet seasons may (Prejs and Prejs, 1987; Deus and Petrere-Jr., 2003) or not (Esteves and Lobón-Cerviá, 2001; Novakowski et al., 2008) occur, meaning that there is no general pattern of seasonal change within trophic guilds and no agreement about the seasonal effects on the organization of fish assemblages (Novakowski et al., 2008), reinforcing the need of more ecological studies on this issue.

During seasonal flooding, small tropical rivers often show less expansion than larger rivers; this factor together with the poor connection of surrounding floodplain and anthropogenic disturbance may force fishes to rely more on habitats within the main channel (Rayner et al., 2008), suggesting less seasonal variation in several ecological attributes of the community. Anthropogenic disturbance is marked in the northwestern region of São Paulo state, in where only 4% of native vegetation remains (SMA/IF, 2005), which makes this region as one of the most degraded in the state (Casatti et al., 2008) and of high priority for ecological studies. Despite the extensive ongoing deforestation in tropical areas, little information concerning its impacts on fish assemblages in streams or even on the processes structuring these assemblages exists (Esteves et al., 2008). The present study was developed in a deforested stream located in a region that presents marked seasonality but it not exhibits a pattern of flooding pulses. Our purpose was to investigate whether ecological descriptors of the quantitative structure (i.e., composition, abundance, biomass, species richness, diversity) and feeding of fishes do change between dry and wet periods.

2. Material and Methods

2.1. Study area

The study region is located in the northwestern portion of the Planalto Ocidental Paulista, Brazil, in the Rio Turvo-Grande basin, which was, up to the end of sampling period (February 2005), mostly used for live-stock grazing. Due to this, grasslands occupied more than 60% of the area (Silva et al., 2007). It is now mainly used for sugar cane crops. Climate is hot tropical (Nimer, 1989) with the beginning of the rainy season (September to March) shown to be variable year to year (Rossa-Feres and Jim, 2001). The rainy season receives 85% of annual rainfall, while cold and dry season (April-August) receives only 15% of annual rainfall, ranging from 1100 to 1250 mm (±225 mm) (Barcha and Arid, 1971).

Field work was carried out in an 75 m third order stretch of the Córrego da Felicidade (20° 45' S and 49° 20' W, Figure 1), a low gradient stream that is a tributary of the Rio Preto, the main river that drains the urban area of the São José do Rio Preto city. The selected stretch shows sandy bottom and is located 6 km downstream from the spring and 7 km upstream from the Rio Preto main channel, in such a way that the sampling stretch is not subjected to seasonal flooding influences from the Rio Preto. Predominant marginal vegetation includes Cyperaceae (*Eleocharis elagans* (Kunth)), Poaceae (*Brachiaria* sp., *Echinochloa* sp.), and Typhaceae (*Typha* sp.), all occasionally submerged.

Sampling was conducted bimonthly from April/04 to February/05, totaling three samples in the dry (April, June, August/04, corresponding to Dry 1, Dry 2, and Dry 3) and three in the wet period (October and December/04, February/05, corresponding to Wet 1, Wet 2, and Wet 3). Average monthly rainfall and air temperature was obtained from the Centro de Informações Agrometeorológicas. In each collection five physico-chemical descriptors of water were measured in the field with Horiba® electronic equipment: dissolved oxygen, conductivity, pH, turbidity, and temperature. Differences between dry and wet periods in relation to the environmental descriptors were investigated using univariate tests (T-test, 0.05 of significance level).

Fishing effort was standardized across all samplings with the stretch blocked up and downstream by 5 mm-mesh stop nets and then submitted to two electric fishing passes for a total of 40-50 minutes. Electrofishing equipment consisted of a stationary generator of alternate current (220 V, 50-60 Hz, 3.4-4.1 A, 1000 W), as detailed by Castro et al. (2003). Fish were fixed in 10% formalin, and after 48 hours were transferred to 70% ethanol. Fish were identified by species, counted, and weighed. All specimens were deposited at the fish collection of the Departamento de Zoologia e Botânica da Universidade Estadual Paulista (DZSJRP), São José do Rio Preto, São Paulo, Brazil.

To evaluate the inventory representativeness, a Coleman's curve was calculated along with the ICE (Incidence Coverage Estimator, Lee and Chao, 1994) and the ACE (Abundance Coverage Estimator, Lee and Chao, 1994) estimators of richness using the software EstimateS 7.0 (Cowell, 2004). Alpha diversity was evaluated by

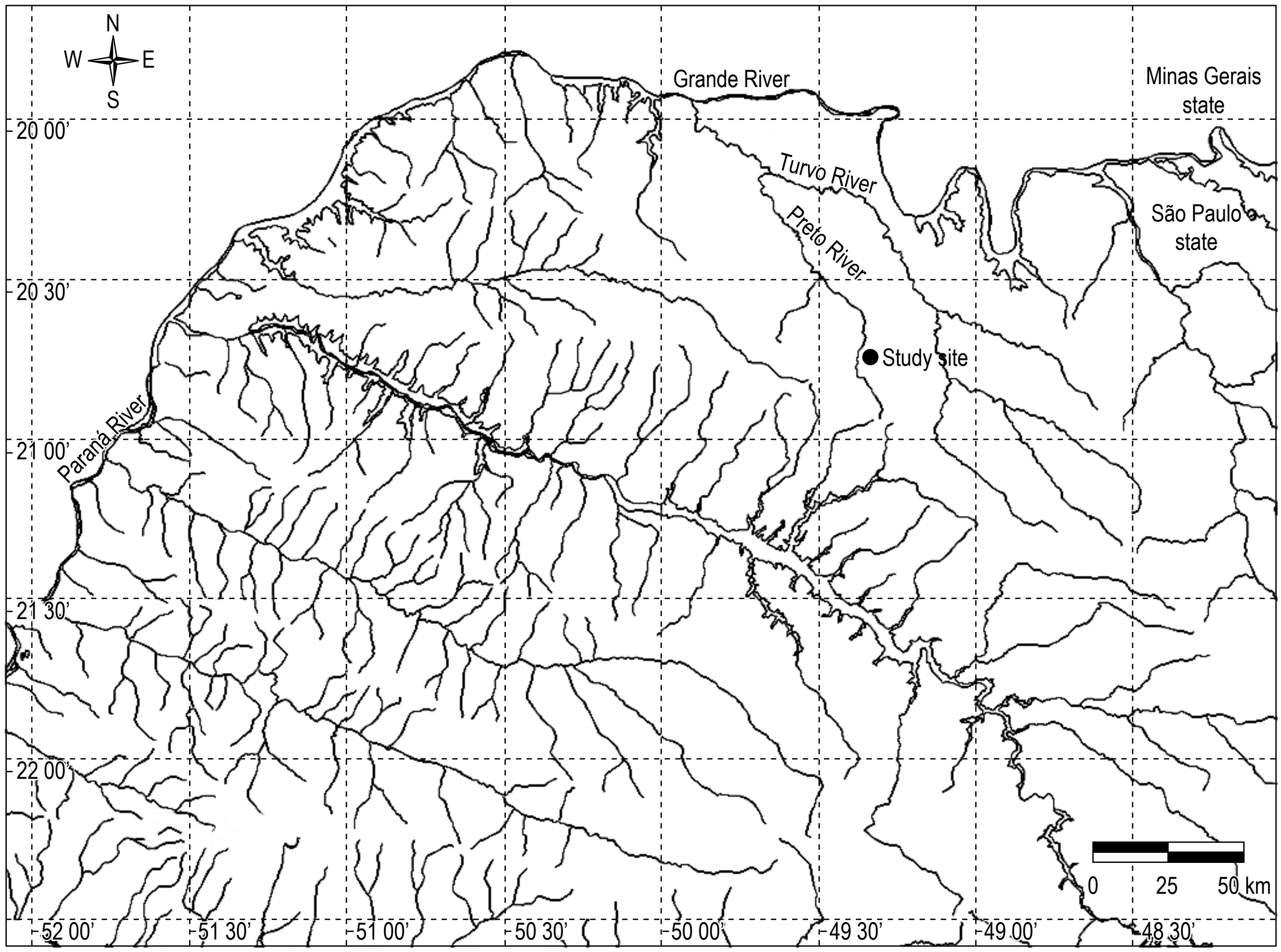

Figure 1. Location of the study site in the northwestern region of the São Paulo state, Upper Rio Paraná basin.

Shannon-Wiener index with base 10 logarithm (Magurran, 2004). Univariate comparisons were investigated using T-test (0.05 of significance level).

An exploratory ordination technique (NMDS - non-metric multidimensional scaling analysis) was employed to evaluate the qualitative (taxonomic composition) and quantitative (species abundance) similarities between the dry and wet periods. The Jaccard coefficient was computed for composition and the Bray-Curtis similarity index for abundance. Calculations, after log(x+1) data transformation, were performed by using the Primer 6 (Clarke and Gorley, 2006) software, after specifying 25 random re-starts. Using the same software, a similarity analysis (ANOSIM) was performed to test the null hypothesis that there are no assemblage differences between dry and wet groups of samples specified by the levels of a single factor (seasonality). According to procedures described by Clarke and Gorley (2006), the output of the analysis is the value of R; if it is close to zero the null hypothesis is accepted. To highlight the species principally responsible for determining the sample ordination between the dry and wet periods (factors) a species similarity analysis was conducted using the SIMPER routine in the Primer 6 software. SIMPER procedures decompose average Bray-Curtis dissimilarities between all pairs of samples into percentages from each species, listing the species in decreasing order of such contributions, being an especially interesting method to interpret differences when they have been show to exist after ANOSIM procedures (Clarke and Gorley, 2006).

Diet was evaluated for the 12 resident species (i.e., those present in more than 50% of the samples) and the number of specimens selected for feeding analysis ranged from seven to 15, according to the abundance of species per sample (with exception of *Hoplosternum littorale* and *Tilapia rendalli*, which were resident, but represented by only a few specimens along the sampled period). After gastric contents removal, food items were identified with the view to achieve the most detailed taxonomic resolution. Detritus was defined as the combination of animal and vegetal coarse matter of unknown origin (Uieda and Motta, 2007), discriminated from fine particulate organic matter by having size larger than 1 μm (Allan, 1995). Frequency of occurrence, dominance, and percentage composition (Hynes, 1950) were calculated for each item. The most important feeding items were determined using Bennemann's et al. (2006) method, an adaptation of Costello's (1990) method, in which dominance of each item – instead of item weight as proposed by Costello (1990) – is used in combination with its frequency of occurrence; items with highest frequencies and dominances are assumed to be more important for species diet, and, hence, used to classify species into trophic groups.

To identify multivariate patterns in the feeding of community a second NMDS ordination was carried using the percentage composition data for each item. This analysis was followed by ANOSIM using the Primer 6 software, according to procedures mentioned before, in order to test the null hypothesis that diet is similar in both dry and wet periods.

3. Results

Rainfall throughout the year, dissolved oxygen, pH, turbidity, and water temperature exhibited significant variation between the dry and wet periods (Table 1). A total of 713 specimens of fish, belonging to six orders, 9 families, 20 genera, and 23 species (Table 2), making a total biomass of 7.5 kg, were recorded. Orders Siluriformes and Characiformes made up 56.5% of the set of species; Cyprinodontiformes and Gymnotiformes made up 53.4% of the overall abundance. The most abundant species were *Gymnotus carapo* (24.0%) and *Poecilia reticulata* (23.8%); those with higher biomass were *Gymnotus carapo* (29.6%) and *Tilapia rendalli* (20.2%). Estimates of species richness indicated ten more species to the ACE and six more species to the ICE (Figure 2). Overall species richness, abundance, and biomass showed to be higher in the wet period than in the dry, whereas diversity was shown to be similar across periods (Table 2), but these differences were not statistically significant (T-test for independent samples, $p_{richness} = 0.37$, $p_{abundance} = 0.30$, $p_{biomass} = 0.13$, $p_{diversity} = 0.94$).

Ordination analysis with NMDS revealed a tendency to segregation of dry and wet groups of samples both in composition and abundance (Figure 3a,b), but differences in the multivariate structure of the abundance matrix were not significative when considering the factor season (ANOSIM, R = 0.148, significance level of sample statistic = 40%). The few observed differences between the dry and wet periods were due to the differential contribution of *Poecilia reticulata* and *Gymnotus carapo* (Table 3).

Examination of 333 gastric contents (149 from the dry period and 184 from the wet) of 12 species evidenced that food variety was higher in the dry period (Tables 4-5). Of these species, 67% (*Astyanax altiparanae*, *Astyanax fasciatus*, *Geophagus brasiliensis*, *Gymnotus carapo*, *Hypostomus ancistroides*, *Phalloceros harpagos*, *Poecilia reticulata*, and *Rhamdia quelen*) kept the diet throughout the year, being classified in the same trophic groups in both periods, and detritus was the most important item for half of them, followed by aquatic insects (Tables 4-5, Figure 4). In fact, NMDS (Figure 3) and ANOSIM analyses revealed no significant differences in the community's diet between periods (R = –0.04, significance level of sample statistic = 83.8%). Considering overall abundance and biomass of these 12 species, in the dry period omnivores and detritivores dominated in abundance (27 and 24%, respectively) and insectivores/detritivores and detritivores in biomass (57 and 23%, respectively). In the wet period, detritivores and insectivores/detritivores dominated in abundance (61 and 22%, respectively) and biomass (37 and 38%, respectively).

4. Discussion

Values of pH and turbidity were higher in the wet than in the dry period, which are consequences, among several factors, of particles (ions, sediment) inputs under rainfall conditions. In contrast, dissolved oxygen exhibited lower concentrations during the wet period, with similar results already registered in water courses close to the studied area

Table 1. Environmental descriptors evaluated in the Córrego Felicidade, southeastern Brazil, during the dry and wet periods.

Descriptors	Dry 1	Dry 2	Dry 3	Wet 1	Wet 2	Wet 3
Average rainfall (mm)*	76.1	57.0	0	95.2	160.0	80.9
Average air temperature (°C)	25.3	20.1	23.0	24.4	26.9	27.9
Dissolved oxygen ($mg.L^{-1}$)**	6.65	6.5	5.65	2.22	3.07	2.7
Conductivity ($\mu S.cm^{-1}$)	69	64	60	76	54	64
pH**	7.23	7.17	7.38	5.93	6.38	6.32
Turbidity (NTU)**	4	5	5	10	14	10
Current ($cm.s^{-1}$)	45	38	25	36	23	15
Water temperature (°C)**	23.8	18.6	19.9	24	27.5	27.8
Width (m)	2.3	2.5	2.2	1.6	2	2.2
Depth (cm)	75	72	72	50	76	80

*Statistically significant when compared all months of the dry (March to September) and wet (October to February) periods (T-test for Independent Samples, $p < 0.05$).

**Statistically significant difference between the dry and wet periods (T-test for Independent Samples, $p < 0.05$).

Table 2. Taxonomic classification (according to Buckup et al., 2007), abbreviations, species abundance, and ichthyofauna structure descriptors in the dry and wet periods.

Orders, families, and species	Abbreviations	Dry	Wet
Characiformes			
Characidae			
Astyanax altiparanae Garutti and Britski, 2000	Astalt	20	26
Astyanax fasciatus (Cuvier, 1819)	Astfas	6	27
Oligosarcus pintoi Campos, 1945	Olipin	13	22
Piabina argentea Reinhardt, 1867	Piaarg	26	5
Serrasalmus marginatus Valenciennes, 1836	Sermar	0	1
Erythrinidae			
Hoplias malabaricus (Bloch, 1794)	Hopmal	3	4
Siluriformes			
Callichthyidae			
Aspidoras fuscoguttatus Nijssen and Isbrücker, 1976	Aspfus	0	1
Callichthys callichthys (Linnaeus, 1758)	Calcal	1	0
Corydoras aeneus (Gill, 1858)	Coraen	9	17
Hoplosternum littorale (Hancock, 1828)	Hoplit	1	3
Loricariidae			
Hypostomus ancistroides (Ihering, 1911)	Hypanc	16	29
Hypostomus sp.	Hypsp	9	0
Heptapteridae			
Rhamdia quelen (Quoy and Gaimard, 1824)	Rhaque	12	8
Gymnotiformes			
Gymnotidae			
Gymnotus carapo Linnaeus, 1758	Gymcar	84	87
Gymnotus inaequilabiatus (Valenciennes, 1839)	Gymina	0	1
Cyprinodontiformes			
Poeciliidae			
Phalloceros harpagos Lucinda, 2008	Phahar	9	30
Poecilia reticulata Peters, 1859	Poeret	13	157
Synbranchiformes			
Synbranchidae			
Synbranchus marmoratus Bloch, 1795	Synmar	0	1
Perciformes			
Cichlidae			
Cichlasoma paranaense Kullander, 1983	Cicpar	0	1
Crenicichla britskii Kullander, 1982	Crebri	0	3
Geophagus brasiliensis (Quoy and Gaimard, 1824)	Geobra	18	41
Oreochromis niloticus (Linnaeus, 1758)	Orenil	2	0
Tilapia rendalli (Boulenger, 1897)	Tilren	1	6
Species richness		17	20
Abundance		243	470
Biomass (g)		2,160.4	5,377.9
Shannon-Wiener diversity index (decits)		0.98	0.94

(Branco and Necchi-Jr., 1997; Ferreira and Casatti, 2006a). Our results seems to correspond to literature data which assumes that low dissolved oxygen values in wet period are related with the greater solubility of this gas in higher temperatures (Allan, 1995), the expansion of flooded grasses in marginal areas that increases respiration rates (Pusey and Arthington, 2003) and, as consequence, higher decomposition rates (Allan, 1995).

In contrast to the specific dominance of the orders Siluriformes and Characiformes, that usually represent the pattern in undisturbed streams of the Upper Rio Paraná basin (Uieda, 1984; Garutti, 1988; Castro et al., 2003), abundance data revealed the rarity of catfishes and the importance of Gymnotiformes and Cyprinodontiformes. In fact, the highest abundance of the cyprinodontiform *Poecilia reticulata* in the wet period are congruent with the

Table 3. Comparison between species contributions to fish assemblage structure in the dry and wet period samples.

Species	Average abundance[a]		Average dissimilarity[b]	Contribution[c] (%)
	Dry	Wet		
Poecilia reticulata	4.3	52.3	15.84 ± 0.96	30.0
Gymnotus carapo	28.0	29.0	8.56 ± 1.27	16.2
Geophagus brasiliensis	6.0	13.7	3.54 ± 1.61	6.7
Astyanax fasciatus	2.0	8.7	3.49 ± 0.94	6.6
Piabina argentea	8.7	1.7	3.45 ± 1.26	6.5
Phalloceros harpagos	3.0	10.0	3.15 ± 1.50	6.0
Hypostomus ancistroides	5.3	9.7	2.23 ± 0.95	5.6
Astyanax altiparanae	6.7	9.0	1.94 ± 1.25	4.2

[a] Contribution of each species to the average dissimilarity between groups.

[b] Average dissimilarity between groups ± standard deviation.

[c] Percentage of contribution of each species (>3.0%) for the dissimilarity between groups.

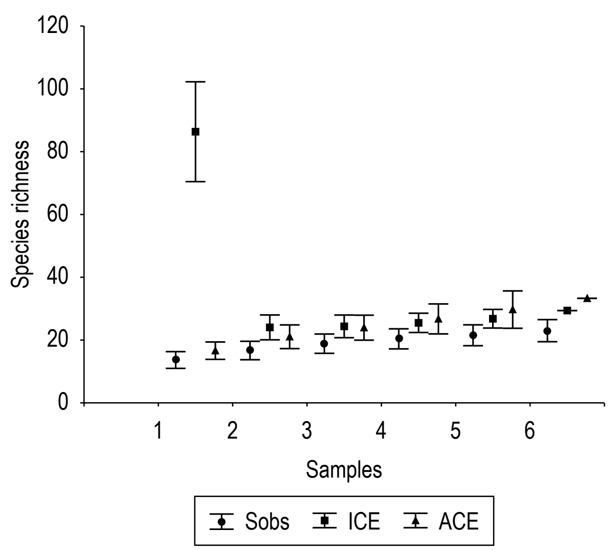

Figure 2. Accumulation curve of the observed number of species and curve of estimated number of species derived from ACE (Abundance Coverage Estimator) and ICE (Incidence Coverage Estimator) by 50 randomizations against cumulative samples.

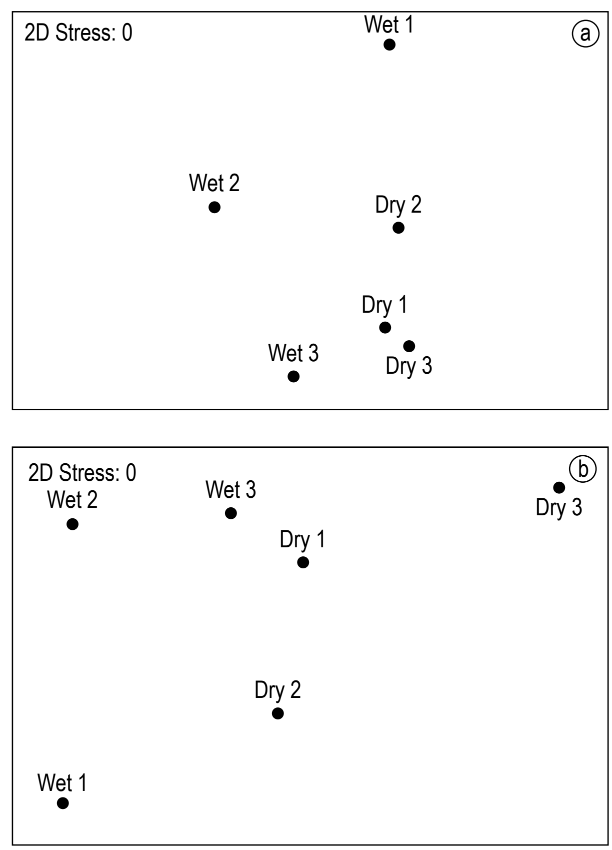

Figure 3. Two-dimensional plot of six samples from dry and wet periods, showing the ordination resulting from the NMDS based on a Jaccard coefficient. a,b) Bray-Curtis coefficient of similarity. Stress value indicates an excellent representation with no prospect of data misinterpretation (Clarke and Warwick, 2001).

lowest values of dissolved oxygen, mirroring the great ability of this species to live in hypoxic environments (Kramer and Mehegan, 1981) and its dominance is indicative of possible anthropogenic environmental impacts (Kennard et al., 2005; Cunico et al., 2006).

The estimate of species richness based on abundance indicates the probable occurrence of ten more species, highlighting the fact that 12 species fitted the rare species definition according to the ACE algorithm, i.e. species with abundance between 1 and 10 individuals (Santos, 2003). By contrast, six more species were estimated by ICE, probably reflecting the local migration of individuals belonging to species which are typical of deeper waters that, in the wet period, reached the studied stretch from the Rio Preto, like *Cichlasoma paranaense*, *Crenicichla britskii*, *Serrasalmus marginatus*, *Hoplias malabaricus*, *Gymnotus inaequilabiatus*, *Synbranchus marmoratus*, and *Tilapia rendalli*. These species were also responsible for changes in species composition between seasonal periods, suggesting the existence of a local dynamic of specimens' movements between the Córrego da Felicidade and the Rio Preto (see similar cases of local movements in Smith and Kraft, 2005;

Table 4. Frequency of occurrence (FO, %) and dominance (D, %) of food items of the fish species in the Córrego Felicidade, during the dry period. For species names see Table 2. Bold numbers indicate the most important items. OMNI, omnivores; DETR, detritivores; INSET, insetivores; CARN, carnivore.

	Astalt		*Astfas*		*Coraen*		*Geobra*		*Gymcar*		*Hopmal*		*Hypanc*		*Olipin*		*Phahar*		*Piaarg*		*Poeret*		*Rhaque*	
N/Nempty	15/0		6/0		9/0		15/0		15/0		3/0		15/1		13/0		9/0		25/0		12/0		12/0	
Items	FO	D	FO	D	FO	D	FO	D	FO	D	FO	D	FO	D	FO	D	FO	D	FO	D	FO	D	FO	D
Autochthonous																								
Algae	6.7	-	**66.7**	**33.3**	11.1	-	26.7	-	-	-	-	-	7.1	-	-	-	11.1	-	-	-	16.7	-	-	-
Testate amoeba	-	-	-	-	66.7	-	13.3	-	-	-	-	-	7.1	-	-	-	-	-	8.0	-	-	-	-	-
Nemathelmintes	-	-	-	-	-	-	-	-	6.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gastropoda	6.7	-	-	-	-	-	**60.0**	**33.3**	-	-	-	-	-	-	15.4	-	-	-	16.0	-	-	-	16.7	-
Bivalvia	-	-	-	-	-	-	-	-	6.7	-	-	-	-	-	-	-	-	-	4.0	-	-	-	-	-
Crustacea	-	-	-	-	22.2	-	-	-	-	-	-	-	-	-	-	-	-	-	4.0	-	-	-	-	-
Ephemeroptera nymphs	-	-	66.7	16.7	-	-	46.7	6.7	33.3	-	33.3	33.3	-	-	38.5	23.1	11.1	-	80.0	12.0	8.3	8.3	50.0	8.3
Odonata nymphs	-	-	16.7	-	-	-	6.7	-	40.0	13.3	-	-	-	-	7.7	7.7	-	-	-	-	-	-	-	-
Hemiptera	-	-	16.7	-	77.8	-	53.3	-	20.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Trichoptera larvae	13.3	-	16.7	-	22.2	-	40.0	-	33.3	6.7	-	-	-	-	7.7	-	-	-	12.0	-	-	-	58.3	25.0
Coleoptera larvae	6.7	-	16.7	-	-	-	13.3	-	40.0	6.7	-	-	-	-	-	-	-	-	40.0	-	-	-	-	-
Ceratopogonidae larvae	6.7	6.7	50.0	-	66.7	22.2	60.0	-	26.7	-	-	-	-	-	30.8	-	22.2	-	72.0	4.0	8.3	-	25.0	8.3
Simuliidae larvae	-	-	66.7	-	22.2	-	13.3	-	-	-	-	-	-	-	46.2	-	11.1	-	32.0	-	-	-	-	-
Chironomidae larvae	-	-	-	-	-	-	-	-	6.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Diptera larvae	13.3	-	-	-	-	-	20.0	-	33.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Diptera pupae	-	-	100.0	-	22.2	-	46.7	-	6.7	-	-	-	-	-	38.5	-	-	-	36.0	-	-	-	33.3	-
Aquatic insect debris	**46.7**	26.7	**100.0**	**33.3**	22.2	-	66.7	-	**66.7**	**26.7**	-	-	-	-	**76.9**	**53.8**	33.3	22.2	**100.0**	**12.0**	50.0	8.3	**91.7**	**25.0**
Aquatic Acari	-	-	-	-	-	-	13.3	-	-	-	-	-	-	-	-	-	11.1	-	-	-	-	-	-	-
Fish	-	-	-	-	-	-	-	-	-	-	33.3	33.3	-	-	-	-	-	-	-	-	-	-	-	-
Allochthonous																								
Vegetal debris	**93.3**	66.7	**100.0**	16.7	77.8	77.8	-	-	-	-	-	-	64.3	7.1	69.2	-	11.1	-	**96**	**16**	100	-	-	-
Araneae	-	-	-	-	-	-	6.7	-	46.7	-	-	-	-	-	15.4	-	-	-	-	-	-	-	-	-
Hymenoptera	6.7	-	-	-	-	-	6.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Odonata	-	-	-	-	11.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Coleoptera	6.7	-	-	-	-	-	13.3	6.7	13.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Formicidae	13.3	-	-	-	-	-	6.7	-	6.7	-	-	-	-	-	-	-	-	-	4.0	-	-	-	-	-
Adult Diptera	26.7	-	16.7	-	-	-	-	-	13.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Terrestrial insect debris	-	-	-	-	-	-	6.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Unknown origin																								
Detritus	-	-	33.3	-	11.1	-	**93.3**	**53.3**	**100.0**	**46.7**	33.3	33.3	**100.0**	**92.9**	92.3	15.4	**100.0**	**77.8**	**64.0**	**56.0**	**91.7**	**83.3**	**91.7**	**33.3**
Fine organic matter	-	-	-	-	88.9	-	6.7	-	-	-	-	-	-	-	-	-	11.1	-	-	-	-	-	-	-
Trophic classification	OMNI		OMNI		OMNI		DETR		INSET/DETR		CARN		DETR		INSET		DETR		OMNI		DETR		INSET/ DETR	

Table 5. Frequency of occurrence (FO, %) and dominance (D, %) of food items of the fish species in the Córrego Felicidade, during the wet period. For species names see Table 2. Bold numbers indicate the most important items. OMNI, omnivores; HERB, herbivores; INSET, insetivores; DETR, detritivores; PISC, piscivore.

	Astalt		*Astfas*		*Coraen*		*Geobra*		*Gymcar*		*Hopmal*		*Hypanc*		*Olipin*		*Phahar*		*Piaarg*		*Poeret*		*Rhaque*	
N / N empty	15/0		24/0		17/0		15/0		15/0		4/3		15/0		17/0		21/0		5/0		18/0		18/0	
Items	FO	D	FO	D	FO	D	FO	D	FO	D	FO	D	FO	D	FO	D	FO	D	FO	D	FO	D	FO	D
Autochthonous																								
Algae	6.7	6.7	**83.3**	**33.3**	-	-	13.3	-	-	-	100.0	-	26.7	-	11.8	-	14.3	4.8	-	-	-	-	-	-
Testate amoeba	-	-	-	-	41.2	-	6.7	-	-	-	-	-	6.7	-	-	-	-	-	-	-	-	-	-	-
Nemathelmintes	-	-	16.7	-	17.6	-	13.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gastropoda	-	-	-	-	-	-	40.0	40.0	20.0	-	-	-	-	-	5.9	5.9	-	-	-	-	-	-	12.5	12.5
Bivalvia	-	-	-	-	11.8	5.9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ephemeroptera nymph	-	-	25.0	4.2	29.4	-	66.7	6.7	-	-	-	-	-	-	29.4	17.6	4.8	-	20.0	-	22.2	16.7	12.5	-
Odonata nymph	-	-	-	-	-	-	-	-	40.0	6.7	-	-	-	-	11.8	11.8	-	-	-	-	-	-	-	-
Hemiptera	-	-	-	-	5.9	-	-	-	-	-	-	-	-	-	11.8	-	-	-	-	-	-	-	-	-
Trichoptera larvae	6.7	-	16.7	-	5.9	-	40.0	6.7	40.0	-	-	-	-	-	-	-	-	-	20.0	-	-	-	12.5	-
Coleoptera larvae	6.7	-	12.5	-	-	-	20.0	-	20.0	-	-	-	-	-	-	-	-	-	20.0	-	-	-	-	-
Ceratopogonidae larvae	26.7	-	37.5	-	76.5	5.9	80.0	-	26.7	6.7	-	-	6.7	-	11.8	-	23.8	9.5	**100.0**	**60.0**	33.3	5.6	25.0	-
Simuliidae larvae	-	-	4.2	-	5.9	-	6.7	-	-	-	-	-	-	-	17.6	5.9	-	-	-	-	-	-	-	-
Diptera larvae	-	-	-	-	-	-	6.7	-	6.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Diptera pupae	6.7	-	33.3	-	5.9	-	40.0	-	6.7	-	-	-	-	-	17.6	5.9	4.8	4.8	80.0	-	-	-	-	-
Aquatic insect debris	**20.0**	**20.0**	**66.7**	**16.7**	11.8	-	53.3	-	**73.3**	**46.7**	-	-	-	-	88.2	5.9	23.8	14.3	100.0	-	27.8	5.6	**62.5**	**25.0**
Aquatic Acari	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.9	5.9	-	-	-	-	5.6	-	-	
Fish	-	-	-	-	-	-	-	-	-	-	**100.0**	**100.0**	-	-	-	-	-	-	-	-	-	-	-	
Allochthonous																								
Vegetal debris	**100.0**	**73.3**	**95.8**	45.8	94.1	88.2	-	-	-	-	-	-	33.3	-	-	-	-	-	80	-	-	-	-	-
Hymenoptera	6.7	-	-	-	-	-	6.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Odonata	-	-	-	-	-	-	-	-	13.3	-	-	-	-	-	5.9	5.9	-	-	-	-	-	-	-	-
Coleoptera	-	-	8.3	-	-	-	13.3	-	26.7	20	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Formicidae	13.3	-	4.2	-	5.9	-	-	-	13.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Diptera	-	-	-	-	5.9	-	-	-	-	-	-	-	-	-	5.9	5.9	-	-	-	-	-	-	-	-
Terrestrial insect debris	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.9	5.9	-	-	-	-	-	-	-	-
Unkown origin																								
Detritus	-	-	-	-	58.8	-	**100.0**	**46.7**	**86.7**	**20.0**	-	-	**100.0**	**100.0**	**88.2**	**23.5**	**100.0**	**66.7**	**100.0**	**40.0**	**77.8**	**72.2**	**100**	**62.5**
Trophic classification	OMNI		OMNI		HERB		DETR		INSET/ DETR		PISC		DETR		DETR		DETR		INSET/ DETR		DETR		INSET/ DETR	

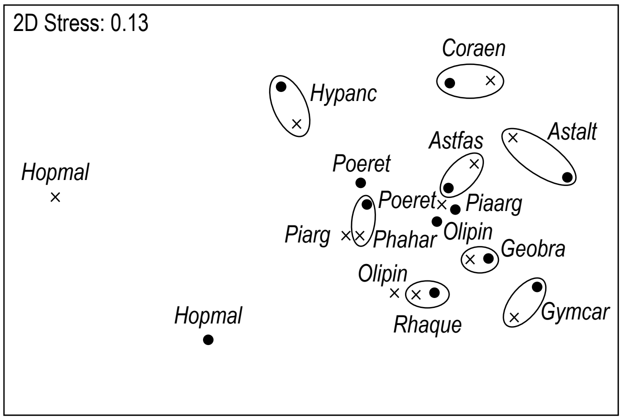

Figure 4. Two-dimensional plot of 12 species' diet from dry (black circles) and wet (crosses) periods, showing the ordination resulting from the NMDS based on the Bray-Curtis coefficient of similarity. See Table 2 for species names. Stress value indicates a good representation with no real prospect of a misleading interpretation (Clarke and Warwick, 2001).

Thomas and Hayes, 2006). Notably, Rio Preto received (and still receives) all the sewage from a city of approximately 380,000 inhabitants (IPT, 2007) and the Córrego da Felicidade could be a less polluted alternative used by upriver migrating fish during the wet period. Currently, even the studied stream is receiving sewage from new urban districts around it.

Overall, the species richness, abundance, and biomass were higher during the wet period and these findings are in agreement with previous studies in the Neotropical region (Garutti, 1988; Mazzoni and Lobón-Cerviá, 2000; Casatti, 2005; Ferreira and Casatti, 2006a). This increase is common and usually explained by the intensification of the reproductive period along with the recruitment of individuals from adjacent areas (Lowe-McConnell, 1999) and may also reflect fish preference for expanded habitats which would provide refuge against predators (Angermeier and Karr, 1984). Multivariate patterns on abundance, however, did not demonstrate differences between periods, indicating a weak effect of the seasonality in the assemblage structure. In fact, strong seasonal variation on the stream fish assemblage structure was detected in some studies (Medeiros and Maltchik, 2001, in the semiarid region; Galacatos et al., 2004, in Ecuadorian Amazon; Langeani et al., 2005, and Fialho et al., 2007, in Upper Rio Paraná) but in others not (Bührnheim and Cox-Fernandes, 2001, in Amazonian streams; Súarez, 2008, in Upper Rio Paraná streams). In a seasonal lowland stream in the pampean plain, for example, floods and droughts are common events, being expected high seasonal variation of the fish assemblage attributes, but actually the number and relative abundance of fish species was relatively constant throughout the year (Almirón et al., 2000). Even in a coastal stream commonly affected by spates, fish richness and density assessed along the year did not show influence of these events, except when considering some species separately (Esteves and Lobón-Cerviá, 2001). These examples reveal that more ecological investigations are needed to better understand this dynamic in streams of Neotropical region, using refined scales and confined to similar ecoregions.

Proliferation of pasture grasses at the banks in the studied site was noteworthy, especially during the wet period, although the quantification of grasses was not the main objective of this study. Pasture grasses lead to several changes in the aquatic habitats (i.e., physical structure, water quality, trophic web structure, see Pusey and Arthington, 2003 and authors therein) that cause impacts on fish fauna. In the studied stream, grass dominance on the banks is a favorable condition to *Poecilia reticulata* and *Gymnotus carapo*, which were the most important species contributing to the (few) dissimilarity between dry and wet groups of samples. Individuals of *Poecilia reticulata* are active during the daytime, swim close to the water surface in small marginal ponds among grass roots and leaves whereas individuals of *Gymnotus carapo* were seen to have nocturnal activity and, during the daytime, remain motionless among submerged roots of marginal vegetation (observations *in loco*). Thus, the architecture created by roots and leaves of marginal pasture grasses are of fundamental importance to species selection in streams, and would contribute to provide structural complexity to stream habitat (Collier et al., 1999), but, when dominant, grasses may render negative consequences to the aquatic biota, for instance, habitat diversity reduction, secondary production depression, and flow channelization (Pusey and Arthington, 2003).

Besides providing microhabitat for some species, the structure formed by submerged roots probably also promotes the accumulation of organic debris, which was mirrored in the fishes' diet as detritus. Its origin is unknown, but a considerable fraction of it may be associated with the greater primary productivity, typical of pasture streams (Burcham, 1988; Esteves et al., 2008). Importance of detritus in fish feeding is documented to several localities and species, often associated to some level of degradation (Oliveira and Bennemann, 2005; Ferreira and Casatti, 2006b). In the present study, the contribution of this food item to the fishes' diet was remarkable, especially in species that were known to typically feed on invertebrates, like *Gymnotus carapo* (Saul, 1975; Ferreira and Casatti, 2006b) and *Rhamdia quelen* (Casatti, 2002; Gomiero et al., 2007).

No pattern of seasonal use of feeding resources was confirmed. This tendency of low seasonal changes in fish feeding was documented in mountain streams that supposedly would suffer high hydrological variation year round (Esteves and Lobón-Cerviá, 2001, Esteves et al., 2008). We believe that at the studied site fishes are consuming the most abundant item at the time – detritus – which explains the lack of seasonality in their diet and the dominance of few guilds. Our results agree with the statement of Esteves et al. (2008), that the predominance of a few feeding guilds seems to reflect the presence of a pre-selected species group which adapted to consume the most abundant resources in a site.

Nutritionally, the relevance of detritus is questionable (Bowen, 1984), but it was consumed by individuals of species with different foraging behavior, in agreement with the fact that tropical fishes have high trophic adaptability in response to environmental variation (Hahn et al., 2004). To illustrate this plasticity, in preserved streams *Phalloceros harpagos* (= *Phalloceros caudimaculatus*), *Hypostomus ancistroides*, and *Geophagus brasiliensis* have their diets based on aquatic insects, periphyton, and a mixture of vegetal/animal items, respectively (Uieda et al., 1997; Casatti, 2002; Mazzoni and Lobón-Cerviá, 2000, respectively), but they can be essentially detritivorous in urban (Oliveira and Bennemann, 2005) and pasture streams (Ferreira and Casatti, 2006b). Finally, the importance of detritus is reinforced when considered the abundance and biomass percentages of the fishes that are maintained by this resource in the Córrego da Felicidade, contrasting with clear water and more preserved streams in which terrestrial insects (Esteves and Lobón-Cerviá, 2001) or periphyton (Uieda et al., 1997; Casatti, 2002) seem to provide an important forage base for fish.

Despite the species richness, abundance, and biomass increased in the wet period, these changes were not strong enough to show a remarkable effect of seasonality in the multivariate pattern of the assemblage structure. Neither diet has shown significative seasonal changes, with several fish species maintaining their trophic classification along the time and using detritus as the main food item. In synthesis, these results suggest a quite regular availability of resources at the studied site along the year, given by the presence of shelters among submerged marginal grasses which facilitates detritus accumulation.

Acknowledgements

We thank colleagues of the Laboratório de Ictiologia IBILCE-UNESP for their help during field work, Fabrício B. Teresa and anonymous reviewers for helpful suggestions on the manuscript, Departamento de Zoologia e Botânica IBILCE-UNESP for facilities; IBAMA for collecting license (001/2003), David R. Mercer for language revision, "BIOTA/FAPESP Program" (www.biota.org/br) of the Fundação de Amparo à Pesquisa do Estado de São Paulo and Conselho Nacional de Desenvolvimento Científico e Tecnológico for financial support.

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Received: 13 February 2009
Accepted: 20 March 2009