

# Benthic macroinvertebrate assemblages structure in two headwater streams, south-eastern Brazil

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**ABSTRACT.** From December 2003 to September 2004, benthic macroinvertebrates (BM), fishes, water and sediment were collected quarterly at six stations in two streams of the upper São Francisco River basin, south-eastern Brazil. We evaluated the ecological conditions, habitat diversity, water quality, composition and structure of BM communities, as well as the food habits of the local fish fauna. By applying a protocol for rapid characterization of ecological conditions and habitat diversity, three of the sampled localities were classified as “pristine” while the others stations were considered “altered”. A well oxygenated water with near neutral pH and low electric conductivity ( $< 0.01$  mS/cm) and nutrient concentrations ( $< 0.08$  mg/l total P and  $< 0.90$  mg/l total N) was found for both streams. Sediment analysis revealed the dominance of medium, fine and very fine sand fractions in all sampled areas. The organic matter content in the sediment was higher in the lotic and well preserved area. We found 45 BM taxa, and Chironomidae (68%), Oligochaeta (10%) and Elmidae (8.5%) showed the highest abundances. From the stomach contents analysis of 13 fish species, 26 BM taxa were found, including four that were not collected in the sediment samples, being Chironomidae the dominant group ( $> 60\%$ ). Our results show that human activities such as forest clearing, agriculture and cattle rising have altered the habitat diversity in freshwater ecosystems in a process that affects the aquatic biota and thus the food availability to the fish fauna. The results also highlight the importance of the fish stomach contents analysis as a complementary tool in BM inventories. **KEY WORDS.** Bioindicators; ecological conditions; human activities; stomach contents; water quality.

**RESUMO.** Estrutura das assembléias de macroinvertebrados bentônicos em dois córregos de cabeceira no sudeste do Brasil. Entre dezembro de 2003 e setembro de 2004, macroinvertebrados bentônicos (MB) e peixes foram capturados e amostras de água e sedimento foram coletadas trimestralmente em seis pontos de dois córregos de cabeceira da bacia do rio São Francisco. Foram avaliadas as condições ecológicas, diversidade de habitats, qualidade da água, composição e estrutura das comunidades de MB, bem como sua ocorrência na dieta da ictiofauna local. Três trechos amostrados foram classificados como “naturais” e os demais como “alterados”. As águas mostraram-se bem oxigenadas, com pH próximo ao neutro, com condutividade elétrica ( $< 0,01$  mS/cm) e concentrações de nutrientes reduzidas ( $< 0,08$  mg/l P-total e  $< 0,90$  mg/l N-total). Houve predominância das frações de areia média, fina e muito fina no sedimento em todos os trechos, e o teor de matéria orgânica foi maior no trecho lótico melhor preservado. Foram encontrados 45 taxa de MB, sendo Chironomidae (68%), Oligochaeta (10%) e Elmidae (8,5%) os mais abundantes. Na análise do conteúdo estomacal de 13 espécies de peixes, obteve-se 26 taxa de MB, quatro destes não encontrados no sedimento, com predomínio de Chironomidae ( $> 60\%$ ). Os resultados sugerem que atividades humanas como desmatamento, agricultura e extração de areia têm alterado a diversidade de habitats em ecossistemas aquáticos de água doce, em um processo que afeta a biota aquática e consequentemente a disponibilidade de alimento para a ictiofauna. Foi evidenciada também a importância da análise do conteúdo estomacal de peixes como ferramenta complementar em inventários da fauna de MB. **PALAVRAS-CHAVE.** Atividades antrópicas; bioindicadores; conteúdo estomacal; condições ecológicas; qualidade de água.

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Rivers are open dynamic ecosystems whose physic, chemical and biotic characteristics are influenced by anthropic activi-

ties taking place in their drainage basin (VANNOTE *et al.* 1980, ALLAN 1995). Forest clearance and silting are among the main

processes that affect the environmental quality of drainage basins, favouring the homogenization of the river bed and causing the reduction of habitat diversity and available microhabitats (CALLISTO *et al.* 2005, MORENO & CALLISTO 2006). These factors can affect the communities of aquatic organisms leading to loss of diversity and species extinction (DUDGEON 1996, PRIMACK & RODRIGUES 2001). Thus, studies on biological communities, associated to the evaluation of habitat diversity and measurements of abiotic parameters, provide a broad picture about land use and occupation and its effects over freshwater ecosystems (JACKSON & HARVEY 1993, POMPEU *et al.* 2005, CASATTI *et al.* 2006).

Brazilian large rivers and reservoirs had been studied more frequently because of their economic importance for fisheries and power production (ESTEVEZ & ARANHA 1999). Nevertheless, small-sized rivers and streams share several species with larger ones, being important sites for the reproduction and growth of many aquatic species, especially fishes (BUCKUP 1999).

In small rivers surrounded with gallery forests, the deposit of fallen leaves, twigs and trunks on the river bed, provides food and shelter for benthic organisms (GONÇALVES *et al.* 2006a, b). The ability of these organisms to transform vegetal matter and detritus into animal tissues is important for the aquatic food web (VANNOTE *et al.* 1980, MCCAFFERTY 1981, ALLAN 1995, GRAÇA 2001). Several benthic macroinvertebrates (BM) taxa, mainly Diptera, are important food items in the diet of the fish fauna (PREJS & PREJS 1987, ABELHA *et al.* 2001, WILLIAMS *et al.* 2003, POUILLY *et al.* 2004).

Previous fish studies at the Araguari River basin (Minas Gerais) (CALLISTO *et al.* 2002b), and Manso Reservoir (Mato Grosso) (GALINA & HAHN 2004), suggest that stomach contents analysis can be used as a tool to evaluate the taxonomic composition and the spatial and temporal distribution of benthic communities, being complementary to biodiversity inventories. Thus, the study of BM communities can be complemented by fish stomach content analysis, especially when information about food availability in the environment is included (ANDRIAN *et al.* 1994, DEUS & PETRERE-JUNIOR 2003).

The aim of this study was to evaluate the structure of BM assemblages in two streams in the upper region of the São Francisco River (SFR) basin, South-eastern Brazil. In order to do so, we evaluated the ecological conditions and habitat diversity, as well as the quality of the water of the two streams. We also estimated the composition and structure of BM communities and analysed its occurrence on the stomachs of the fish fauna.

## MATERIALS AND METHODS

### Study area

The SFR has 2,900 Km long, draining an extension of 645,000 km<sup>2</sup>. This river drains six Brazilian states, covering 7.6% of the country area. From its headwaters to mouth, the river runs through several Brazilian biomes such as the Cerrado (Brazilian Savanna), the Caatinga (Brazilian drylands) and the Atlantic Forest, also draining some island and shoreline ecosystems (GODINHO & GODINHO 2003).

The Bagaço stream (10 Km long) is an affluent of the Coelhos stream (20 km long), a sub-basin of the Pará river (300 Km long) which is one of the most important tributaries at the right margin of the SFR. Thus, both streams are tributaries of 4<sup>th</sup> and 3<sup>rd</sup> order respectively, of the upper SFR basin.

Two sampling stations for data collection were delimited at the Bagaço (1A and 1B) and four at the Coelhos stream (2A, 2B, 3A and 3B). The sampling stations 3A and 3B were located downstream the confluence of the two water bodies (Fig. 1).

Station 1A (20°06'917"S, 44°39'921"W): without any vegetal covering, with margins covered by aquatic macrophytes and large areas of still or calm water, being surrounded by pastures and cattle farms.

Station 1B (20°05'483"S, 44°39'801"W): margins are protected by well preserved gallery forest. The surroundings are mainly pastures and there is an area cleared for sand extraction at the right margin.

Station 2A (20°08'086"S, 44°41'192"W): gallery forest remains only in the left margin. The stream has areas of still waters intermingled with rapids and is surrounded by pastures and agriculture farms. It also receives the domestic waste produced by a small upstream village.

Station 2B (20°05'859"S, 44°40'429"W): margins are protected by gallery forest but the surroundings are being heavily cleared for coal production and pasture formation.

Station 3A (20°03'636"S, 44°40'245"W): the gallery forest is degraded because of fishing activities and cattle browsing. Pastures at the left margin and agriculture farms at the right margin constitute the surrounding area.

Station 3B (20°01'515"S, 44°40'470"W): gallery forest is preserved at the right margin while there are pastures at the left margin. The area is submitted to intensive fishery and agriculture farms are located in its surroundings.

### Sampling and data analysis

Water, sediment and fishes were collected quarterly from December 2003 to September 2004 at every sampling station in order to evaluate water quality, BM communities and fish food items. BM data was analysed in a spatial (among stations) and seasonal (among dry – June and September, and rainy – December and March – periods) approach. The biological indexes of water quality were analysed only in a temporal basis. Fish stomach contents were also determined as complement of BM inventory.

### Ecological conditions and habitat diversity

For the characterization of ecological conditions and habitat diversity in the two water courses, we applied the protocol for the rapid characterization of ecological conditions and habitat diversity proposed by CALLISTO *et al.* (2002a), where a value is obtained by adding partial values given to each of the parameters independently. The scores indicate the degree of preservation of the sampling stations as follows: 0-40 points, "impacted"; 41-60 points, "altered"; over 61, "pristine".

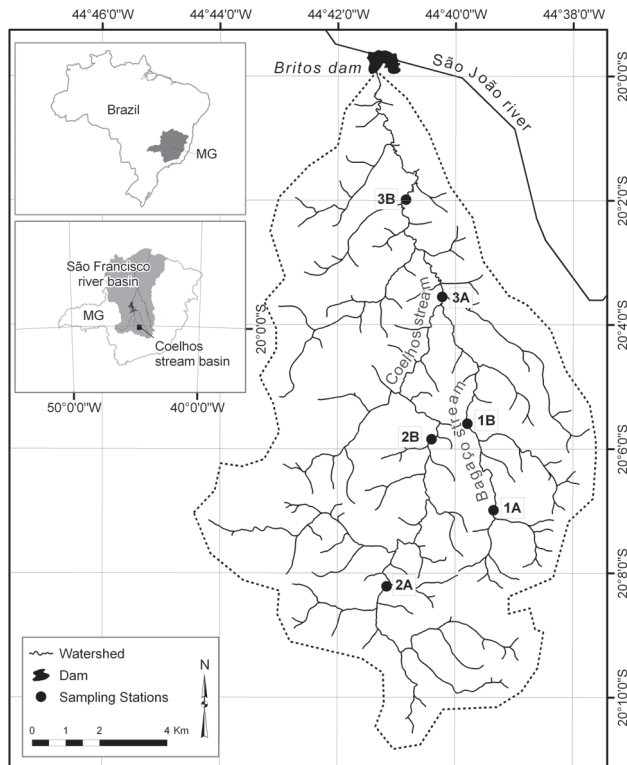


Figure 1. Map of Bagaçó and Coelhos streams with sampling stations, São Francisco river basin, Minas Gerais.

### Abiotic parameters in the water and sediment

The variables pH, electrical conductivity and turbidity were measured in the water column using a portable multiprobe (Horiba, model U-10). Water samples were collected and preserved for laboratory analyses. Following the AMERICAN WATER WORKS ASSOCIATION (1999), the concentration of dissolved oxygen was quantified by Winkler's method, total phosphorus was quantified by SM 4500 P colorimetry, acid digestion and ascorbic acid reaction and total nitrogen was quantified by SM 4500 N C colorimetry and persulphate reaction method.

Sediment samples collected using a Van Veen type dredge were used to determine the granulometric composition (SUGUIO 1973, modified by CALLISTO & ESTEVES 1996) and the levels of organic matter (gravimetry).

### Microbiological indicators of water quality

To evaluate water quality for balneability and potability, total and fecal coliforms concentrations were determined by the multiple tube methodology and the density of heterotrophic bacteria was determined by the pour-plate method (AMERICAN WATER WORKS ASSOCIATION 1999).

### Benthic macroinvertebrates

Using a Van Veen dredge (area = 0,045 m<sup>2</sup>), three sediment samples were collected in each sampling station for the

analysis of the BM community. The samples were washed in 1.00 and 0.50 mm mesh sieves and the BM were retrieved by observation under a stereoscopic microscope. Identification keys in PÉREZ (1988), EPLER (1995), and MERRITT & CUMMINS (1998) were used for taxonomic identification and the specimens were deposited in the BM reference collection of the Instituto de Ciências Biológicas of the Universidade Federal de Minas Gerais.

In order to characterize the structure of BM communities the Shannon diversity index and the Pielou equitability index were calculated following MAGURRAN (2004). Additionally, the density of organisms (ind/m<sup>2</sup>) was estimated and their relative abundance (% ind/m<sup>2</sup>) was calculated. The biological indexes of water quality BMWP (Biomonitoring Working Party, adapted by JUNQUEIRA & CAMPOS 1998) and ASPT (Average Score Per Taxa, JOHNSON *et al.* 1993) were also calculated.

### Fish food items

Fifty square meters of gill nets with mesh sizes ranging from three to eight cm between opposing knots (exposed in the water column for 12 hours, since six p.m. to six a.m.) were used for fish collection at each sampling station. Sieves and seine nets were also utilized in order to maximize the number species collected. From 1396 specimens of 29 fish species we analyzed 271 stomach contents of 13 species that: (a) potentially eat BM; (b) N > 3. Fish species that do not reach these assumptions were not considered in this study. At the field, a ventral incision was made to the captured specimens that were then fixed in a 10% formalin solution. At the laboratory, the biometric measurements were made (Standard length & Weight) and the identification key of BRITSKI *et al.* (1988) was used for taxonomic identification. Some unidentified fishes were sent to Museu de Ciências e Tecnologia of Pontifícia Universidade Católica de Rio Grande do Sul for taxonomic identification. Stomachs were removed and stored in a 70% alcohol solution.

The stomachs were dissected and the food items found were separated. The BM found were identified using the same keys mentioned above and quantified using the volumetric and occurrence methods proposed by HYSLOP (1980). By using these two methods combined it was possible to estimate, for the species with N > 3, the Feeding Index (Ali) proposed by KAWAKAMI & VAZZOLER (1980):  $Ali = (Fi.Vi)/\sum Fi.Vi$ , where, (Ali) Feeding index of the i<sup>th</sup> item; (Fi) frequency of occurrence of the i<sup>th</sup> item; (Vi) volume of the i<sup>th</sup> item.

### Fish stomach analysis for BM inventory

To evaluate the contribution of the analysis of stomach contents to the characterization of the fauna of BM, the taxonomic inventory obtained by this method and the one obtained by sediment analysis were compared using the Jaccard similarity index (qualitative), following MAGURRAN (2004).

### Statistical analysis

Biotic and abiotic data approved in the normality test (Kolmogorov-Smirnov) were submitted to a parametric statistical analysis using a two-way analysis of variance (ANOVA),

while data that did not displayed normality were submitted to a generalized non-linear statistical analysis (main effects ANOVA) with Poisson distribution. Software packages Sigmastat 2.03 (ACCESS SOFTEK 1995) and Statistica 7.0 (STATSOFT 2004) were used for the analyses.

## RESULTS

### Ecological conditions and diversity of habitats

Stations 1B, 2A and 2B were classified as “pristine” while sampling stations 1A, 3A and 3B were considered “altered”. The main parameters of the rapid protocol that affected the results were the presence/absence of gallery forest, the land use in the surroundings and the diversity of habitats and microhabitats (Tab. I).

### Abiotic parameters in the water and in the sediment

In all sampled stations the water was well oxygenated, with near neutral pH and low electrical conductivity and nutrient concentrations. The highest turbidity values were found at sampling stations 2A, 2B, 3A and 3B, with the maximum value re-

corded at 3B. The evaluation of the sediments granulometric composition showed a predominance of medium, fine and very fine sand fractions in all the sampled stations. The highest levels of organic matter in the sediment were measured at 1B (Tab. II).

There were significant differences between dry and rainy periods for the parameters pH ( $F_{(1,5)} = 5.720$ ;  $p < 0.05$ ), water temperature ( $F_{(1,5)} = 7.6$ ;  $p < 0.05$ ), and for the fine grain granulometric fraction at the 1A station ( $F_{(1,5)} = 3.538$ ;  $p < 0.05$ ). For all the other parameters, no spatial or seasonal significant differences were found.

### Microbiological indicators of water quality

The highest values of total and fecal coliforms were found at 1A, 2A, 2B and 3A sampling stations (> 3000 colonies/100ml). The bacterial density was over 2000 UFC up to 500 ml in all sampled stations (Tab. II). No significant differences were found between stations or periods.

### Benthic macroinvertebrates

We collected 9,786 specimens belonging to 45 different taxa. Of these, three belong to the Phylum Mollusca (Planorbidae,

Table I. Characterization of streams ecological conditions and habitat diversity of the São Francisco river basin, Minas Gerais, from December 2003 to September 2004, using Rapid Protocol by CALLISTO *et al.* (2002).

Parameters	Bagaço stream		Coelhos stream			
	1 <sup>a</sup>	1B	2A	2B	3A	3B
Type of edge occupation	Grazing fields	Natural vegetation	Grazing fields	Natural vegetation	Grazing fields	Grazing fields
Erosion	Moderate	Absent	Moderate	Moderate	Moderate	Moderate
Anthropic alterations	Domestic alterations	Absent	Domestic alterations	Domestic alterations	Domestic alterations	Domestic alterations
Vegetal covering	Absent	All	Partial	All	All	Partial
Type of sediment	Mud and sand	Rocks and gravel	Mud and sand	Mud and sand	Mud and sand	Mud and sand
Mud deposition	> 75%	< 25%	< 25%	< 25%	< 25%	< 25%
Instream cover	10 - 30% of diversified habitats	> 50% diversified habitats	30-50% diversified habitats	> 50% diversified habitats	30-50% diversified habitats	30-50% diversified habitats
Channel alteration	40-70 %	Absent	40-70 %	Absent or minimum	Absent or minimum	Absent or minimum
Protective stream bank vegetation	< 50%	70-80%	< 50%	70-80%	50-70%	50-70%
Bank stability	Stable	Moderately stable 5-30% eroded	Moderately unstable 30-60% eroded	Moderately stable 5-30% eroded	Moderately stable 5-30% eroded	Moderately stable 5-30% eroded
Riparian vegetation zone width	< 6 meters	12-17 meters	< 6 meters	6-12 meters	< 6meters	Moderately stable 5-30% eroded
Presence of aquatic vegetation	Presence of macrophytes	Small macrophytes along the river bed	Absent	Small macrophytes along the river bed	Small macrophytes along the river bed	Small macrophytes along the river bed
Scores	44	82	68	67	59	59
Classification	Modified	Natural	Natural	Natural	Modified	Modified

Table II. Quarterly samplings of water, sediment and microbiological parameters in Bagaço and Coelhos streams, São Francisco river basin, from December 2003 to September 2004. (EC) Electric conductivity, (TP) total phosphorus, (TN) total nitrogen, (O<sub>2</sub>) dissolved oxygen, (T) turbidity, (WT) water temperature, (TC) total coliform, (FC) fecal coliform, (BD) bacterial density, (VCS) very coarse sand, (CS) coarse sand, (MS) medium sand, (FS) fine sand, (VFS) very fine sand, (ST+C) Silt and clay, (OM) organic matter.

Sampling locals	EC (mS/cm)	TP (mg/l)	TN (mg/l)	O <sub>2</sub> (mg/l)	T (UT)	pH	WT (°C)	TC	FC	BD	VCS (%)	CS (%)	MS (%)	FS (%)	VFS (%)	ST+C (%)	OM (%)
<b>1A</b>																	
Mean	0.06	0.02	0.21	7.65	44.75	6.92	21.25	5537.00	3046.67	2873.67	16.51	9.07	17.61	33.28	20.46	3.06	2.92
SD	0.02	0.01	0.14	0.11	39.49	0.18	1.82	7400.88	4209.77	2572.39	19.88	8.03	8.33	19.27	14.70	4.60	2.64
Maximum	0.10	0.04	0.35	7.80	113.00	7.12	23.20	16001.00	9000.00	6501.00	48.92	20.68	29.79	61.73	40.36	11.03	7.33
Minimum	0.04	0.01	0.05	7.50	18.00	6.67	18.30	110.00	30.00	820.00	0.22	0.91	9.59	8.03	1.31	0.23	0.33
<b>1B</b>																	
Mean	0.05	0.03	0.51	7.70	61.50	7.11	21.00	633.33	183.33	2933.67	2.79	6.09	25.92	37.69	24.54	2.98	6.04
SD	0.02	0.01	0.28	0.14	35.81	0.15	2.42	188.56	90.31	2522.82	2.32	3.14	11.63	5.24	17.88	2.48	7.48
Maximum	0.08	0.05	0.80	7.90	100.00	7.33	23.50	900.00	300.00	6501.00	5.65	8.48	38.00	43.84	52.83	5.98	19.00
Minimum	0.03	0.02	0.10	7.50	3.00	6.92	17.00	500.00	80.00	1100.00	0.00	0.74	8.70	31.75	8.88	0.43	1.50
<b>2A</b>																	
Mean	0.03	0.04	0.43	8.03	85.50	6.95	21.55	6033.67	5733.67	3733.67	4.68	9.25	24.20	37.87	22.56	1.43	4.08
SD	0.01	0.02	0.28	0.17	31.12	0.26	2.41	7062.26	7264.23	2007.67	5.95	8.32	11.40	12.46	12.19	1.40	1.84
Maximum	0.06	0.07	0.80	8.20	114.00	7.40	24.30	16001.00	16001.00	6501.00	14.72	21.86	37.37	55.44	35.56	3.83	6.00
Minimum	0.02	0.01	0.01	7.80	36.00	6.75	17.70	500.00	300.00	1800.00	0.23	0.50	7.75	20.27	10.36	0.47	1.33
<b>2B</b>																	
Mean	0.04	0.03	0.49	8.10	93.75	6.89	21.53	5733.67	5470.33	3233.67	5.13	12.13	35.02	28.76	18.09	0.87	1.67
SD	0.01	0.02	0.28	0.28	54.93	0.10	2.30	7264.23	7446.36	2323.30	2.71	2.98	2.12	1.83	3.41	0.39	1.07
Maximum	0.05	0.07	0.90	8.50	150.00	7.05	23.80	16001.00	16001.00	6501.00	9.39	16.01	37.36	31.75	23.50	1.32	3.50
Minimum	0.02	0.01	0.10	7.90	10.00	6.80	17.70	300.00	170.00	1300.00	1.90	8.17	32.24	26.76	15.01	0.25	0.83
<b>3A</b>																	
Mean	0.04	0.04	0.30	7.68	84.25	6.90	20.85	6033.67	5476.67	3200.33	4.22	5.56	27.36	35.16	24.36	3.35	2.50
SD	0.01	0.02	0.25	0.08	47.47	0.27	2.56	7062.26	7441.44	2362.67	5.63	3.11	9.68	2.75	5.41	1.88	1.36
Maximum	0.06	0.07	0.65	7.80	154.00	7.35	23.10	16001.00	16000.00	6501.00	13.84	9.97	37.03	37.44	33.60	6.61	4.83
Minimum	0.02	0.02	0.05	7.60	20.00	6.66	16.50	500.00	130.00	1100.00	0.24	2.61	16.38	30.55	20.42	2.21	1.50
<b>3B</b>																	
Mean	0.04	0.04	0.41	7.68	88.25	6.90	20.85	1133.33	246.67	2853.67	8.94	15.21	26.64	15.98	28.75	4.48	4.17
SD	0.01	0.02	0.19	0.08	55.94	0.36	2.65	895.67	179.32	2675.09	11.10	7.33	12.85	2.91	23.56	4.50	2.89
Maximum	0.06	0.08	0.60	7.80	170.00	7.50	22.90	2400.00	500.00	6501.00	27.96	24.77	47.93	19.66	57.11	11.40	8.50
Minimum	0.02	0.02	0.09	7.60	12.00	6.60	16.30	500.00	110.00	160.00	0.59	5.52	15.53	12.64	2.64	0.06	1.00

Physidae and Bivalvia), two to the Phylum Annelida (Oligochaeta and Hirudinea) and 40 to the Phylum Arthropoda, distributed among Crustacea, Arachnida and Insecta. The nine orders and 37 families of insects were: Plecoptera (Perlidae), Diptera (Ceratopogonidae, Chironomidae, Psychodidae, Simuliidae, Stratiomyidae, Dolichopodidae, Empididae, Tabanidae, Tipulidae), Coleoptera (Elmidae, Scirtidae, Ptilodactylidae, Dryopidae, Dysticidae, Gyrinidae, Hydrophilidae), Ephemeroptera (Polymitarcyidae, Baetidae, Leptophlebiidae, Leptohyphidae), Odonata (Libellulidae, Coenagrionidae, Gomphidae), Trichoptera (Leptoceridae, Hydroptilidae, Polycentropodidae, Calamoceratidae, Odontoceridae, Hydropsychidae), Heteroptera (Belostomatidae, Corixidae, Notonectidae, Naucoridae, Pleidae, Veliidae), Lepidoptera (Pylalidae) and Collembola. Chironomidae, Oligochaeta and Elmidae were the most abundant taxa during both rainy (66, 15 and 8%) and dry (70, 7 and 9%) periods.

More taxa were registered for the rainy (38 taxa) than for the dry period (32 taxa). The highest richness values were observed at 2B for rainy and at 3B for dry period (both with 22 taxa). The lowest values were found at 1A during the rainy period (11 taxa) and at 2A during the dry one (9 taxa).

The diversity values were low at all the sampled stations ( $H' = < 2$ ) with the highest value found at 2B ( $H' = 1.9$ ) during the rainy period, and the lowest at 2A ( $H' = 0.6$ ) during the dry one (Tab. III).

By applying the BMWP and ASPT biological indexes it was possible to determine water quality during the rainy period as "satisfactory" at 1A, "good" at 1B, 2A, 3A and 3B, and "optimum" at 2B. During the dry period, the quality of the water was considered "satisfactory" at 1A and 2A, "good" at 2B and 3A and "optimum" at 1B and 3B (Tab. III).

The BM density was significant both between stations ( $W_{(1;5)} = 45,166$ ;  $p < 0.05$ ) and sampling periods ( $W_{(1;5)} = 5,325$ ;  $p < 0.05$ ) (Tabs IV and V), with the highest values found at 1B during the dry period. The taxonomic richness was significant only between sampling stations 1A and 1B ( $W_{(1;5)} = 22.44$ ;  $p < 0.05$ ) (Tabs IV and V).

### Fish food items

From 271 collected specimens, 244 – belonging to 11 families and 13 species – showed some kind of alimentary item

Table III. Density, richness, evenness, diversity, BMWP and ASPT values from benthic macroinvertebrates community and protocol for rapid characterization of ecological conditions for each sampling local, by season, from December 2003 to September 2004, in Bagaço and Coelhos streams, São Francisco river basin, Minas Gerais.

Sampled season	Density (ind/m <sup>2</sup> )	Richness (n° taxa)	Evenness	Shannon index (H')	BMWP	ASPT
<b>Rainy</b>						
1A	3,063.6	11	0.6	1.3	46.0	4.2
1B	33,078.0	17	0.6	1.5	74.0	4.4
2A	16,694.4	18	0.5	1.2	75.0	4.2
2B	18,958.8	22	0.8	1.9	117.0	5.3
3A	16,671.0	17	0.6	1.3	84.0	4.9
3B	16,783.2	15	0.6	1.4	82.0	5.5
<b>Dry</b>						
1A	2,997.0	13	0.7	1.5	49.0	3.8
1B	22,621.8	19	0.8	1.6	96.0	5.1
2A	24,353.4	9	0.9	0.6	37.0	4.1
2B	19,269.6	16	0.7	1.6	80.0	5.0
3A	28,749.0	14	1.0	1.4	63.0	4.5
3B	22,777.2	22	0.7	1.8	99.0	4.5

in their stomach and were analysed. Three species fed mainly on fish: *Hoplias lacerdae* Miranda Ribeiro, 1908, *Hoplias malabaricus* (Bloch, 1794) (Erythrinidae) and *Salminus hilarii* Valenciennes, 1850 (Characidae); two ingested terrestrial plants: *Astyanax* sp. Baird and Girard, 1854 (Characidae) and *Leporinus reinhardti* Lütken, 1875 (Anostomidae); four fed on sediments: *Hypostomus wuchereri* (Günther, 1864) (Loricariidae), *Cyphocharax gilbert* (Quoy and Gaimard, 1824) (Curimatidae), *Geophagus brasilienses* (Quoy and Gaimard, 1824) (Cichlidae) and *Callichthys callichthys* (Linnaeus, 1758) (Callichthyidae); and four used aquatic invertebrates and sediment as main food items: *Gymnotus carapo* Linnaeus, 1758 (Gymnotidae), *Rhamdia quelen* (Quoy and Gaimard, 1824), *Pimelodella vittata* (Lutken, 1874) (Heptapteridae) and *Eigenmannia virescens* (Valenciennes, 1842) (Sternopygidae) (Tab. VI).

Table IV. Statistical tests for density and richness among sampled stations, from December 2003 to September 2004, in Bagaço and Coelhos streams, São Francisco river basin, Minas Gerais.

Parameters	Sampling stations						DF	W	p
	1A	1B	2A	2B	3A	3B			
N	10	12	12	12	12	12	5	45,266	< 0.05
Density									
Mean	606.1	6,497.2	3,420.7	3,185.7	3,792.5	3,296.7			
sd	605.1	7,418.5	4,684.6	3,401.2	3,553.1	2,989.2			
N	10	12	12	12	12	12	5	22.440	< 0.05
Richness									
Mean	4.3	8.3	5.1	7.8	7.6	7.7			
sd	2.6	3.3	3.6	3.0	1.9	3.8			

Table V. Statistical tests for density and richness among sampling periods, Dry and Rainy, from December 2003 to September 2004, in Bagaço and Coelhos streams, São Francisco river basin, Minas Gerais.

Parameters		Rainy	Dry	DF	W	p
Density	N	34	36			
	Mean	3,098.2	3,973.2	1	5,325	< 0.05
	sd	3,491.4	5,326.4			
Richness	N	34	36			
	Mean	6.6	7.2	1	1,453	> 0.05
	sd	3.4	3.3			

### Fish stomach analysis for BM inventory

In total, 26 MB taxa were found in the stomach contents of the fishes (17 during the rainy period and 24 during the dry period), being 22 of them also found in the sediment samples, Chironomidae was the dominant group found during both periods (> 60%). Four taxa were exclusively found in the stomach contents (Curculionidae-Coleoptera; Caenidae-Ephemeroptera; Belostomidae-Heteroptera; and Corydalidae-Megaloptera). Similarity of 45% was observed between the number of taxa found by the analysis of the sediments and stomach contents.

## DISCUSSION

The use of the protocol for the rapid characterization of ecological conditions and habitat diversity evidenced the great influence that anthropic impacts in the surroundings have over the sampling stations. Forest clearance, silting, cattle raising and pasture formation, among others, favoured the homogenization of the bed of both water courses, reducing habitat and microhabitat diversity and thus affecting the biotic compartment of these ecosystems (DOBSON 1994, DUDGEON 1996, PRIMACK & RODRIGUES 2001, AGUIAR *et al.* 2002, CALLISTO *et al.* 2002a, BOYERO & BOSCH 2004, CASSATI *et al.* 2006). The areas with the lowest scores in the characterization protocol also scored low values for the biological indexes of water quality (BMWP and ASPT), as well as low richness and equitability values for benthic organisms. The physical and chemical conditions were homogeneous in relation to the sampled stations during the rainy and the dry periods, suggesting that the same human impacts influence water quality in the studied sub-basins.

The presence of gallery forests is important for the preservation of the margins since it prevents the carriage of sediments to the water courses, as evidenced by the increase in the proportion of the fine sand fraction at the local without any gallery forest coverage (1A) during the rainy season. On the other hand, the local with a well preserved gallery forest (1B), showed lower levels of total and faecal coliforms and a greater proportion of organic matter in the sediments.

Based on the water usage by local riverine inhabitants, both

water courses are considered to belong to Class II (CONAMA resolution number 357/05), appropriate for human consumption after conventional treatment. However, the values of total and fecal coliforms found during this study are above the established limits for this class (2500 colonies/100ml) at sampling stations 1A, 2A, 2B and 3A, while bacterial density values are above the limits (2000 UFC up to 500ml) in all the studied stations.

Vegetal materials as fruits, seeds and other parts of higher plants were the main items in the diet of *Astyanax* sp. and *L. reinhardti*, however, aquatic invertebrates and detritus were also found in their stomach contents. Similar results were found in other Brazilian localities such as Lobo Reservoir (BARBOSA & MATSUMURA-TUNDISI 1984); São João River basin in Rio de Janeiro State (BIZERRIL 1996); Caconde lagoon in Rio Grande do Sul State (HARTZ *et al.* 1996); upper SFR (ALVIM & PERET 2004); Atalho stream in Itatinga, São Paulo State (MOTA & UJEDA 2004); and Tibagi River in Paraná State (LOBÓN-CERVIÁ & BENNEMANN 2000, BENNEMANN *et al.* 2005). For *Leporinus* Agassiz, 1829, vegetal matter and invertebrates (ANDRIAN *et al.* 1994, MESCHIATTI 1995, HAHN *et al.* 1998, BENNEMANN *et al.* 2005) as well as insects (DURÃES *et al.* 2001, LUZ *et al.* 2001) are frequently registered as food in the literature. CALLISTO *et al.* (2002b) found 86% of Chironomidae larvae in the stomach contents of *Leporinus amblyrhynchus* Garavello & Britski, 1987 at the Miranda Reservoir in the Araguari River basin.

Fish was utilized by *H. lacerdae*, *H. malabaricus* and *S. hilarii* who also feed on aquatic invertebrates, as registered by other studies carried out at the SFR (POMPEU & GODINHO 2003) and the Segredo Reservoir (Paraná) (LOUREIRO & HAHN 1996) for *H. malabaricus*; at SFR (ALVIM & PERET 2004) for *Salminus* Agassiz, 1829.

*Geophagus brasiliensis* (Quoy & Gaimard, 1824) fed mainly on sediments, although aquatic invertebrates and terrestrial plants were also found in the stomach contents. BRITSKI *et al.* (1988) suggest that Cichlidae ingest sediment that is selected later in the oral cavity. Other authors considered this species omnivorous (SABINO & CASTRO 1990, BIZERRIL 1996). *Cyphocharax gilbert* fed upon sediment but small quantities of terrestrial plants and aquatic invertebrates were also observed in its diet, in agreement with MÉRIGOUX & PONTON (1998) for French Guiana curimatids species. Curimatids are considered detritivorous (BOWEN 1984, GERKING 1994). *Hypostomus wuchereri* fed on algae and sediments (POMPEU & GODINHO 2003, ALVIM & PERET 2004). Loricariidae scratch the substrate in search of their food (BRITSKI *et al.* 1988, GARAVELLO & GARAVELLO 2004). Thus, the occurrence of benthic organism in their stomach contents is common. The food items of *P. vitatta* (Lutken, 1874), *R. quelen*, *G. carapo* and *E. virescens* was mainly constituted by benthic invertebrates as described by MÉRIGOUX & PONTON (1998).

The broad variety of BM (26 taxa) among the food items ingested by the studied fish could be related to ontogenetic and individual variations of the species (ESTEVES & ARANHA 1999), to seasonal fluctuations in food availability (PREJS & PREJS 1987, ABELHA *et al.* 2001) and to human activities carried out in the

Table VI. Occurrence frequency (F), volume (V) and feeding index (IAi) of food items consumed by fish species sampled quarterly in Bagaço and Coelhos streams, São Francisco river basin, from December 2003 to September 2004. (SL) Standard length in cm, (FI) fish, (TI) terrestrial invertebrates, (AI) aquatic invertebrates, (TP) terrestrial plants, (SD) sediment, (AL) algae, (N) number of analysed fish, (ES) empty stomachs, (\*) values below than 0.01.

Fish species	SL range	Parameters	Food resources					
			FI	TI	AI	TP	SD	AL
<i>Astyanax</i> sp.	7.8-9.8	V (%)		4.55	13.460	80.55	0.91	0.530
N = 105		F (%)		2.56	27.350	64.10	4.27	1.710
ES = 15		Ali		*	0.070	0.93	*	*
<i>Callichthys callichthys</i>	8.4-9.0	V (%)			27.370		72.62	0.010
N = 8		F (%)			46.670		46.67	6.670
ES = 0		Ali			0.270		0.73	*
<i>Cyphocharax gilbert</i>	9.6-12.5	V (%)			5.220	16.40	78.38	
N = 13		F (%)			8.330	37.50	54.17	
ES = 0		Ali			*	0.13	0.87	
<i>Eigenmannia virescens</i>	12.5-14.0	V (%)			65.360	0.32	34.32	
N = 12		F (%)			50.000	4.55	45.45	
ES = 0		Ali			0.680	*	0.32	
<i>Geophagus brasiliensis</i>	8.1-12.0	V (%)			8.670	10.56	80.77	
N = 18		F (%)			34.290	20.00	45.71	
ES = 0		Ali			0.070	0.05	0.88	
<i>Gymnotus carapo</i>	16.2-22.0	V (%)			27.350	5.60	67.06	
N = 5		F (%)			45.450	18.18	36.36	
ES = 1		Ali			0.330	0.03	0.65	
<i>Hoplias lacerdae</i>	21.0-35.0	V (%)	97.970		1.530	0.14	0.36	
N = 19		F (%)	50.000		25.000	6.25	18.75	
ES = 3		Ali	0.991		*	*	*	
<i>Hoplias malabaricus</i>	15.0-20.0	V (%)	0.990		0.020			
N = 11		F (%)	40.000		60.000			
ES = 2		Ali	0.970		0.030			
<i>Hypostomus wuchereri</i>	9.4-12.3	V (%)					42.98	57.300
N = 13		F (%)					52.94	47.060
ES = 0		Ali					0.46	0.542
<i>Leporinus reinhardti</i>	17.5-21.0	V (%)			7.400	69.17	23.43	
N = 12		F (%)			40.000	30.00	30.00	
ES = 0		Ali			0.10	0.68	0.23	
<i>Pimelodella vittata</i>	8.0-9.0	V (%)	2.360		61.020	3.15	33.07	0.390
N = 5		F (%)	8.330		41.670	8.33	33.33	8.330
ES = 0		Ali	*		0.690	*	0.30	*
<i>Rhamdia quelen</i>	16.0-23.0	V (%)	31.930		43.710	1.57	22.79	
N = 17		F (%)	26.670		43.330	10.00	20.00	
ES = 6		Ali	0.270		0.590	*	0.14	
<i>Salminus hilarii</i>	17.5-22.3	V (%)	74.690		10.370		14.94	
N = 6		F (%)	66.670		16.670		16.67	
ES = 0		Ali	0.920		0.032		0.05	



surroundings of the studied areas. DEUS & PETRERE-JUNIOR (2003) suggest that during the rainy season in tropical regions, fishes tend to be more generalists due to the increase in the variety of available items and also to the reduction of visibility which reduces their capacity to detect their usual prey.

According to WILLIAMS *et al.* (2003), some fish species show feeding preferences for special benthic organisms, independent of their abundance and presence in the sediment. Seasonality and human activities affect the density and richness of BM communities (BISPO & OLIVEIRA 1998, CALLISTO *et al.* 2005), a fact that can justify the feeding plasticity common of freshwater fishes (ABELHA *et al.* 2001).

The importance of BM as an autochthonous food resource for fishes in rivers and streams is well documented in the literature (PREJS & PREJS 1987, LOBON-CERVIÁ & BENNEMANN 2000, ABELHA *et al.* 2001, ABES *et al.* 2001, CALLISTO *et al.* 2002b, CASATTI 2002, WILLIAMS *et al.* 2003, POUILLY *et al.* 2004).

The BM taxa found in the sediment (45) and the ones found by the analyses of stomach contents (26) showed a median similarity (45%), evidencing the relationship between the BM available in the sediment compartment and the diet of the fish assemblages. Four of the observed taxa were only found in the stomach contents, complementing the benthic inventory of the studied freshwater systems, and reinforcing the statements by CALLISTO *et al.* (2002b), RUSSO *et al.* (2002) and GALINA & HAHN (2004), which suggest that these analyses can contribute to the evaluation of the composition and distribution of BM communities.

Despite the low number of fish studied, the analysis of the stomach contents showed that the use of more than one methodology to access benthic diversity is efficient, enriching the inventory of BM from two headwater streams in the upper SFR basin.

The simultaneous study of different biological communities and their interactions, together with the evaluation of ecological conditions, habitat diversity and abiotic parameters of the water and the sediment, provided an integrate picture on the influence of anthropic activities over drainage basins and their consequences for energy flow and nutrient cycles in freshwater ecosystems.

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