

Ephemeroptera, Plecoptera and Trichoptera assemblages in two Atlantic Rainforest streams, Southeastern Brazil

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ABSTRACT. Assemblages of Ephemeroptera, Plecoptera and Trichoptera (EPT) of rocky substrates were studied in two streams of the Intervales State Park. Monthly collections with a Surber sampler (10 random sampling units, 1 m²) were carried out from September 1999 to September 2000 and quarterly from December 2000 to September 2001 in the Bocaina and Água Comprida Streams. The EPT fauna in the Bocaina Stream was more diversified and more abundant than in the Água Comprida Stream. The EPT fauna was quite different in the two streams both in composition as in functional aspects. The results of this study indicate that there was not a clear seasonal pattern in the temporal variation of density.

KEY WORDS. Aquatic insects; diversity; EPT; lotic environments.

RESUMO. Comunidades de Ephemeroptera, Plecoptera e Trichoptera em dois ribeirões de Mata Atlântica do Sudeste do Brasil. Comunidades de Ephemeroptera, Plecoptera e Trichoptera (EPT) em substrato rochoso foram estudadas em dois riachos do Parque Estadual Intervales. Coletas com um amostrador de Surber (10 subamostras aleatórias, 1 m²) foram feitas mensalmente de setembro de 1999 a setembro de 2000 e trimestralmente de dezembro de 2000 a setembro de 2001 nos Ribeirões Bocaina e Água Comprida. A fauna de EPT do Ribeirão Bocaina foi mais diversificada e mais abundante do que a do Ribeirão Água Comprida. A fauna de EPT foi bastante diferente entre os dois riachos, tanto do ponto de vista da composição faunística quanto do ponto de vista funcional. Os resultados indicaram que não houve um padrão sazonal claro da variação temporal da densidade.

PALAVRAS-CHAVE. Ambientes lóticos; diversidade; EPT; insetos aquáticos.

Aquatic insects are important elements in the ecological dynamics of lotic environments. In recent years, the interest in the study of these insects has grown mainly due to their utilization in environmental monitoring, since many of them are sensitive to environmental disturbances (ROSENBERG & RESH 1993, NAVAS-PEREIRA & HENRIQUE 1996). Among the aquatic insects of low and medium order streams in mountainous regions, Ephemeroptera, Plecoptera and Trichoptera (EPT) are usually abundant and highly diversified. In Brazil, studies on the EPT fauna have intensified from the late nineties on, improving the knowledge about them (FROEHLICH & OLIVEIRA 1997, OLIVEIRA & FROEHLICH 1997a, OLIVEIRA *et al.* 1997, BISPO & OLIVEIRA 1998, DINIZ-FILHO *et al.* 1998, BISPO *et al.* 2001). MARCHANT *et al.* (1995) suggest that as the EPT fauna represents well the ecological patterns of all the macroinvertebrate community, the studies could be centered in these orders.

As benthic organisms present, on the whole, low mobility, in this way, local conditions, such as degree of canopy cover, declivity, hydraulics, environmental heterogeneity, frequency

of disturbances, may be very important in structuring their communities (BISPO & OLIVEIRA 1998, DINIZ-FILHO *et al.* 1998, BISPO *et al.* 2004). Keeping this in mind, the aim of this study was to investigate the structure of EPT assemblages in two streams with differences in declivity, heterogeneity and canopy cover. In addition, the temporal variation of density in the two streams was also investigated.

MATERIAL AND METHODS

Study area

This study was carried out in two streams of the Intervales State Park. The Park is located in the Serra de Paranapiacaba, South of the State of São Paulo, and includes areas of the municipalities of Ribeirão Grande, Eldorado, Guapiara, Iporanga and Sete Barras. The Park is situated at latitudes 24°12'-24°25'S and 48°03'-48°30'W. Its area is approximately 380 km² and it represents one of the last well-preserved areas of the Atlantic Forest. Altitudes vary from 70 to 1000 m. The highest ridges define the watershed between the Ribeira de Iguape River catch-

ment in the direction of the coast and the Paranapanema River catchment flowing inland. As concerns the hydrological classification, within the Park the rivers vary from first to 5th order. It rains along all the year and this promotes high air humidity.

Collection and identification

This study was carried out in the Bocaina Stream (Station 1: 24°16'13"S and 48°27'09"W) and the Água Comprida Stream (Station 2: 24°17'38"S and 48°25'04"W). The Bocaina Stream is 2nd order, with a dense canopy cover, presence of riffles and pools, and common litter accumulations. The Água Comprida Stream is 3rd order, with a partially open canopy cover, with a high declivity and the consequent higher water speed, pools are scarce. In this study, the classification of stream order of STRAHLER (1957) was followed. During collections, the following environmental factors were registered: air and water temperatures (°C, alcohol thermometer), water speed (m/s, floater method), discharge (m³/s, according to the methodology described in LIND 1979), electric conductivity (µS/cm), hydrogenionic potential (pH), water turbidity (NTU) and dissolved oxygen (mg/l), the last four measured with portable meters. The characterization of the two stations is presented in table I. Precipitation data were obtained in the "Departamento de Águas e Energia Elétrica" of the State of São Paulo (DAEE).

Each of the two streams was sampled monthly from September 1999 to September 2000. From December 2000 to September 2001 quarterly samplings were carried out. In each of the collections, 10 random sampling units were collected in riffles with rocky bottom with a Surber sampler, totalling 1 m².

The Ephemeroptera, Plecoptera and Trichoptera immatures were sorted out and identified to genus. For this, the following keys were used: DOMÍNGUEZ *et al.* (1992) for Ephemeroptera, BENEDETTO (1974) and FROELICH (1984) for Plecoptera, and ANGRISANO (1995) and WIGGINS (1998) for Trichoptera. The EPT genera were included in the functional feeding categories proposed by CUMMINS & KLUG (1979) using data from the literature (MERRITT & CUMMINS 1996, WIGGINS 1998, POLEGATTO & FROELICH 2003) and observations in the field. The

trophic functional categories considered were collectors, scrapers, shredders and predators.

Data analysis

Diversity was evaluated using the Shannon-Wiener Diversity Index ($H' = -\sum p_i \ln p_i$) and Pielou Evenness Index ($E = H'/\ln S$), where $p_i = n_i/N$, n_i abundance of the taxon i , N total abundance and S richness. In the case of the Shannon-Wiener index, a t test was made using the Hutcheson method (MAGURANN 1989) to compare the diversity between the two streams. Additionally, richness was evaluated by rarefaction curves (HULBERT 1971, SIMBERLOFF 1972) using a Monte Carlo permutation method. To estimate the number of taxa for k individuals, k individuals were randomly withdrawn from the sample and the observed number of taxa was registered. That procedure was repeated 1000 times. The procedures were carried out using the Ecosim 5 simulation program (GOTELLI & ENTSMINGER 2000).

The logarithmized abundance matrix [$\log(x + 1)$] was submitted to the Detrended Correspondence Analysis (DCA) ordering the observations (months) and the variables (taxa). DCA was carried out using the PC-ORD 4.0 program (McCUNE & MEFFORD 1999).

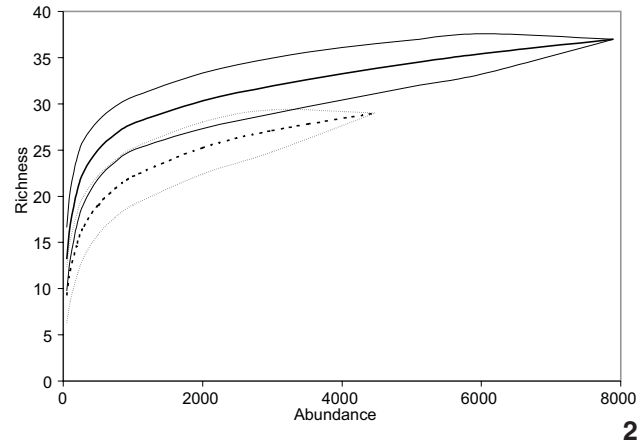
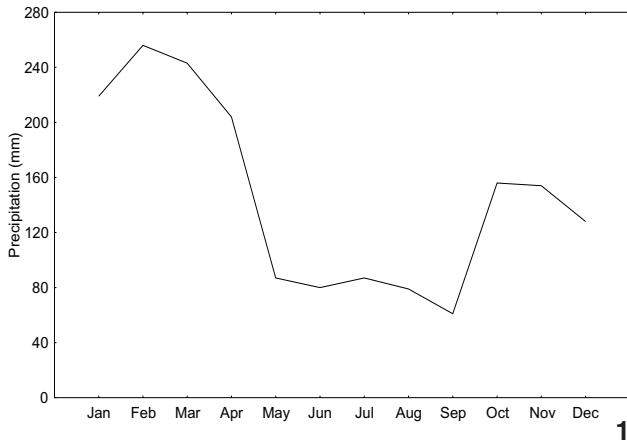
The logarithmized matrix was also used to calculate a similarity matrix among the samples (Q mode), using the Morisita-Horn Index (HORN 1966, KREBS 1999). Visualization of that matrix was obtained through an agglomerative cluster analysis (ROMESBURG 1984). UPGMA was used to obtain the dendrogram (KREBS 1999). The dendrogram distortion was evaluated by the cophenetic correlation coefficient (ROMESBURG 1984). That coefficient was obtained correlating the original similarity matrix with the matrix obtained from the dendrogram; $r \geq 0.8$ is considered a good value (Rohlf 2000). The cluster analysis was carried out using the NTSYS 2.1 program (Rohlf 2000).

RESULTS

Figure 1 shows the average monthly precipitation (mm) from 1990 to 2001 for the Intervalas State Park. Historically, the data show that lower precipitations occurred between May

Table I. Mean and standard deviation (SD) of abiotic factors of the Bocaina and Água Comprida streams recorded monthly from Setember 1999 to Setember 2000 and quarterly from December 2000 to June 2001, Intervalas State Park, São Paulo.

Abiotic factors	Bocaina Stream		Água Comprida Stream	
	Mean	SD	Mean	SD
Air Temperature (°C)	15.810	3.680	17.580	3.290
Water Temperature (°C)	17.300	4.320	19.350	3.270
Water Velocity (m/s)	0.326	0.080	0.524	0.161
Discharge (m ³ /s)	0.194	0.168	0.343	0.176
pH	7.840	0.430	8.030	0.340
Electrical Conductivity (µS/cm)	113.250	24.990	148.910	16.280
Dissolved Oxigen (mg/l)	8.360	1.090	8.310	1.320
Water Turbidity (NTU)	4.550	3.440	7.560	6.420



Figures 1-2. (1) Average monthly rainfall from 1990 to 2001 in the Intervales State Park; (2) rarefaction curves of immatures of genera of Ephemeroptera, Plecoptera and Trichoptera collected monthly from September 1999 to September 2000 and quarterly from December 2000 to September 2001 in Bocaina and Água Comprida Streams, Intervales State Park, São Paulo. Bocaina Stream (continuous line); Água Comprida Stream (dashed line).

and September, and that the rainiest month is February. These data also show that rainfall in the less rainy months was approximately 50mm. Precipitation data referring to the period of the study were unavailable.

Table II lists the total EPT taxa collected monthly from September 1999 to September 2000 and quarterly from December 2000 to September 2001 in the Bocaina and Água Comprida Streams. The EPT fauna in the Bocaina Stream was more diversified and abundant than in the Água Comprida Stream (Tab. II). The Shannon-Wiener diversity and Pielou equitability indices were higher in the Bocaina Stream ($H' = 2.35$, $E = 0.65$) than in the Água Comprida Stream ($H' = 1.84$, $E = 0.55$). In the case of the Shannon-Wiener diversity index, there was a significant difference between the values obtained for the two streams (Hutcheson t test, $p < 0.05$). The rarefaction curves for the two streams estimating richness through standardized abundance data are presented in figure 2. The Bocaina Stream has a higher richness than the Água Comprida Stream. The richness standardized for 4000 collected individuals was 33.25 taxa (30.40-36.10, 95% confidence interval) for the Bocaina Stream and 28.46 taxa (27.11-29.82, 95% confidence interval) for the Água Comprida Stream.

Figure 3 shows the ordination of the samples according to DCA. There was a clear separation between the Bocaina Stream and the Água Comprida Stream faunas. We can observe that, according to DCA I (87.6% of the total variance), the samples with higher scores were those collected in the Água Comprida Stream (Fig. 3). *Caenis*, *Camelobaetidius*, *Gr. Traverhyphes*, *Xiphocentron*, *Gripopteryx*, *Farrodes*, *Baetodes*, *Chimarra*, *Grumicha*, *Cloedes* and *Leptonema* reached their optima in the Água Comprida Stream. On the other hand, *Barypenthus*, *Macrogynoplax*, *Polyplectropus*, *Tricorythodes*, *Campylocia*, *Kempnyia*, *Hagenulopsis*, *Nectopsyche*, *Grumichella*,

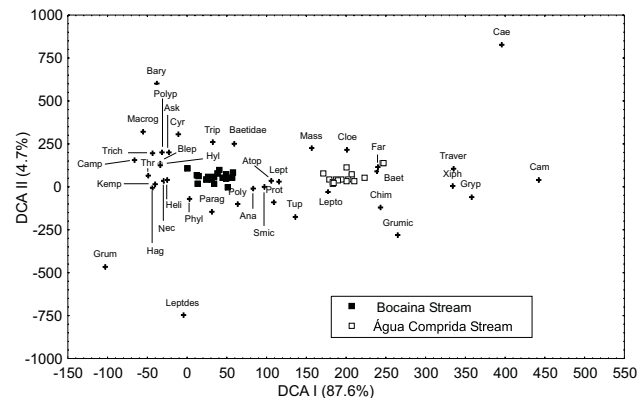


Figure 3. Scores of Detrended Correspondence Analysis (DCA) for samples and EPT taxa collected monthly from September 1999 to September 2000 and quarterly from December 2000 to September 2001 in Bocaina and Água Comprida Streams, Intervales State Park, São Paulo. Abbreviations table II.

Leptohyphodes, *Helicopsyche*, *Thraulodes*, *Cyrnellus*, *Askola*, *Blepharopus*, *Hylister* and *Phylloicus* reached their optima in the Bocaina Stream. The dendrogram (Fig. 4) representing the cluster analysis also confirms the clear separation between the faunas of the two streams.

The proportion of each functional feeding category for the two studied streams is presented in figure 5. In this figure, for the taxa belonging to more than one category, only the main alimentary behaviour was considered. In the Bocaina Stream, the scrapers category was dominant (49.35%), followed by the collectors (25.57%), shredders (16.36%) and predators (8.72%). In the Água Comprida Stream, the dominant category was the collectors (51.81%) followed by the scrapers (45.76%) with a

Table II. Numbers of immatures of genera of Ephemeroptera, Plecoptera and Trichoptera collected monthly from September 1999 to September 2000 and quarterly from December 2000 to September 2001 in Bocaina and Água Comprida Streams, Intervales State Park, São Paulo.

Genera	Abbreviations	Bocaina	Comprida	Total	Feeding Category
<i>Leptohyphes</i> Eaton, 1882	Lept	243	150	393	CR
<i>Gr.Traverhyphes</i> Molineri, 2001	Traver	32	895	927	C
<i>Tricorythodes</i> Ulmer, 1920	Trich	3	0	3	C
<i>Leptohyphodes</i> Ulmer, 1920	Leptdes	2	0	2	C
<i>Thraulodes</i> Ulmer, 1920	Thr	1359	0	1359	R,C
<i>Hylister</i> Domínguez & Flowers, 1989	Hyl	333	3	336	C
<i>Hagenulopsis</i> Ulmer, 1919	Hag	292	1	293	C
<i>Farrodos</i> Peters, 1971	Far	38	158	196	R,C
<i>Massartella</i> Lestage, 1930	Mass	22	30	52	R,C
<i>Askola</i> Peters, 1969	Ask	1	0	1	R,C
<i>Baetodes</i> Needham & Murphy, 1924	Baet	108	1805	1913	R
<i>Cloeodes</i> Traver, 1938	Cloe	48	109	157	C
<i>Camelobaetidius</i> Demoulin, 1966	Cam	0	3	3	C
Others Baetidae	Baetidae	49	15	64	C
<i>Caenis</i> Stephens, 1835	Cae	0	1	1	C
<i>Campylocia</i> Needham & Murphy, 1924	Camp	104	0	104	F
<i>Anacroneuria</i> Klapálek, 1909	Ana	422	84	506	P
<i>Kempnyia</i> Klapálek, 1914	Kemp	218	1	219	P
<i>Macrogynoplax</i> Enderlein, 1909	Macro	11	0	11	P
<i>Tupiperla</i> Froehlich, 1969	Tup	7	8	15	C
<i>Gripopteryx</i> Pictet, 1841	Grip	2	33	35	CR
<i>Paragripopteryx</i> Enderlein, 1909	Parag	64	11	75	CF
<i>Leptonema</i> Guérin, 1843	Lepto	246	798	1044	CP
<i>Smicridea</i> McLachlan, 1871	Smic	533	240	773	C
<i>Blepharopus</i> Kolenati, 1859	Blep	114	1	115	C
<i>Phylloicus</i> Müller, 1880	Phyl	69	5	74	F
<i>Nectopsyche</i> Müller, 1879	Nec	1102	3	1105	F
<i>Triplectides</i> Kolenati, 1859	Trip	15	2	17	F
<i>Grumichela</i> Müller, 1879	Grum	1	0	1	CR
<i>Helicopsyche</i> Siebold, 1856	Heli	2337	39	2376	R
<i>Chimarra</i> Stephens, 1829	Chim	12	36	48	C
<i>Polycentropus</i> Curtis, 1835	Poly	3	1	4	CP
<i>Polyplectropus</i> Ulmer, 1905	Polyp	31	0	31	C
<i>Cyrnellus</i> Banks, 1913	Cyr	1	0	1	C
<i>Atopsyche</i> Banks, 1905	Atop	37	14	51	P
<i>Protoptilinae</i> Ross, 1956	Prot	29	18	47	R
<i>Xiphocentron</i> Brauer, 1870	Xiph	1	12	13	C
<i>Grumicha</i> Müller, 1879	Grumic	1	4	5	C
<i>Barypenthus</i> Burmeister, 1839	Bary	1	0	1	P
Ephemeroptera Total	-	2634	3170	5804	
Plecoptera Total	-	724	137	861	
Trichoptera Total	-	4533	1173	5706	
Grand Total	-	7891	4480	12371	

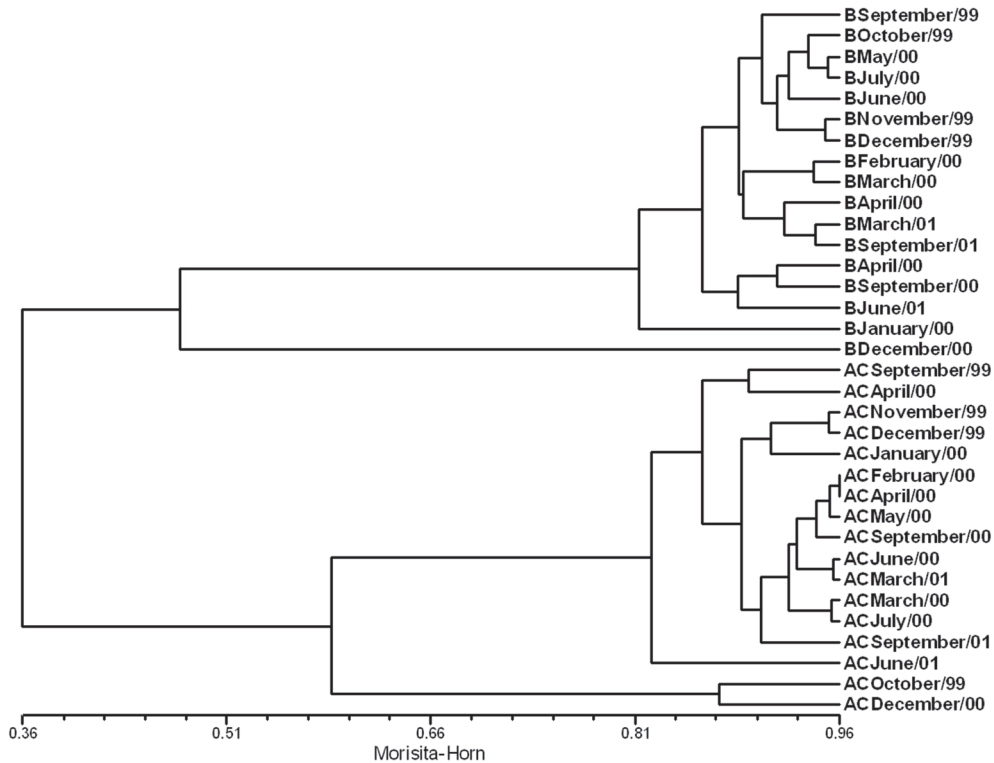
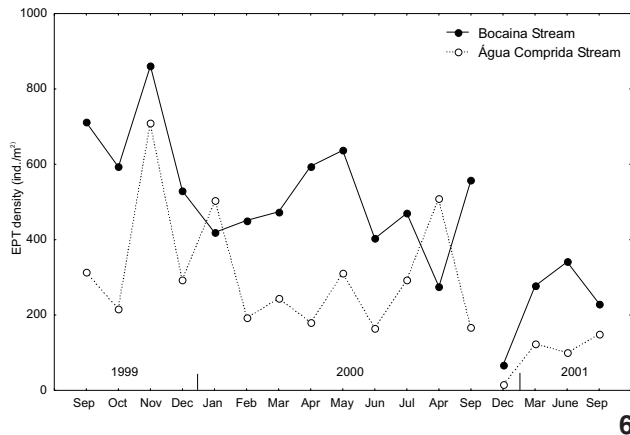
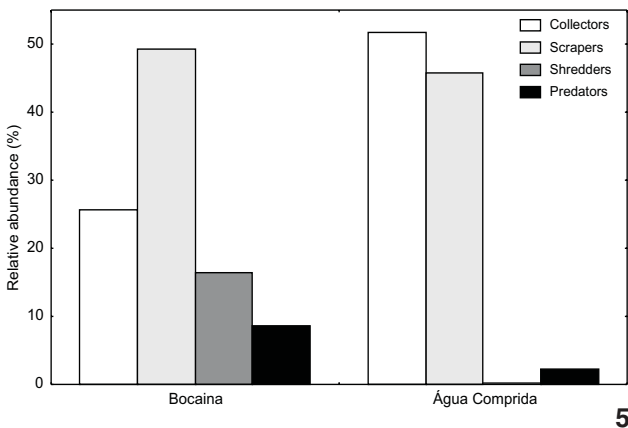


Figure 4. Dendrogram showing the similarity (Morisita-Horn) among EPT samples collected monthly from September 1999 to September 2000 and quarterly from December 2000 to September 2001 in Bocaina and Água Comprida Streams, Intervales State Park, São Paulo. Linkage: UPGMA. Cophenetic correlation coefficient (0,929). B, Bocaina Stream; A, Água Comprida Stream.



Figures 5-6. (5) Relative abundances (%) of the functional feeding categories and (6) temporal variation in density of EPT collected monthly from September 1999 to September 2000 and quarterly from December 2000 to September 2001 in Bocaina and Água Comprida Streams, Intervales State Park, São Paulo.

quite low percentage of predators (2.21%) and shredders (0.22%).

Figure 6 shows the temporal variation of the EPT density for the two streams. In the Bocaina Stream, density peaks were observed in November (1999), May (2000) and September

(2000), while in the Água Comprida Stream the density peaks occurred in November (1999), January (2000) and August (2000). These results indicate that there was not a clear seasonal pattern in temporal variation of the EPT density.

DISCUSSION

Ecological theory and empirical data have shown that environmental heterogeneity determines the taxon diversity in different communities. In that sense, a higher diversity of food resources (VANNOOTE *et al.* 1980), a higher daily variation of temperature (VANNOOTE *et al.* 1980) and a higher hydraulic variability (STATZNER & HIGLER 1986) are some of the environmental heterogeneity sources that have constantly been mentioned as possible determinant factors of diversity as concerns aquatic organisms in lotic environments. Heterogeneous environments allow that a greater number of taxa manages to coexist in a given site. The data of this study indicate that environmental heterogeneity can be an explanation for the greater diversity of taxa registered in the Bocaina Stream. The higher environmental variability of the Bocaina Stream is promoted by good retention of litter between the rocks and the presence of riffles alternating with pools. On the other hand, the Água Comprida Stream has higher declivity and higher water speed, making it a highly erosive stream with low litter retention and in the studied stretch consisting almost only of riffles, making it a less variable environment than the Bocaina Stream.

The differences between the two streams were not reflected only in diversity but also in the composition of the fauna. The EPT community in the Bocaina Stream was formed by taxa that use rocky substrates or accumulations of litter retained by the rocks. Although the collections were made only in rocky substrate, taxa commonly associated with litter accumulations as *Macrogynoplax*, *Campylocia*, *Nectopsyche* and *Phylloicus* occurred preferentially in that stream. In the case of the Água Comprida Stream, the fauna had structured itself in a highly erosive environment.

The functional dynamics of the lotic environments influences directly the aquatic insect fauna, as it is related to the quality and availability of the food resources. Thus, in environments where the input of allochthonous energy in the form of coarse organic matter is predominant it is expected that shredders should have a greater importance. In sites where autochthonous energy inputs are important, scrapers should have greater importance. In general, collectors are always important for the functional dynamics of the stream, however the degree of their importance increases with increases in allochthonous energy inputs in the form of fine organic matter. The results of this study show that from the functional point of view the EPT communities have structured themselves in a different form in the two studied streams. In Bocaina Stream, where possibly there is a greater diversity of energy inputs (autochthonous and allochthonous) the functional categories were better equidistributed. In the the Água Comprida Stream, the collectors and scrapers were the dominant functional categories and the shredders are practically non-existent. That can be a reflection of the possible predominant autochthonous energy sources and of the low capacity of the studied stretch to retain allochthonous material due to the high speed of the water.

The temporal variation in the aquatic insect density can be determined by several factors, among them those related to the seasonal environmental changes, the capacity of recolonization after disturbance events, and life cycle characteristics among others. This study has not shown a clear seasonal pattern in the temporal variation in density; this result disagrees with other studies made in tropical regions in which abundance decreases in the rainy season were clearly observed (BOON *et al.* 1986, FLECKER & FEIFAREK 1994, DUDGEON 1996, 1997, OLIVEIRA & FROELICH 1997b, BISPO *et al.* 2004). These decreases can be related to environmental disturbances provoked by rain in certain periods of the year or by diminution of organism aggregation, due to rising of the water level in rainy periods. In this study, several falls in density were observed, and these falls cannot be explained by the rain seasonality, since the more rainy periods (January, February and March) in that region did not present lower densities when compared to the historically less rainy periods (May to September). The variations in density could be attributed to other possible factors as redistributions among patches, peaks of recruitment of immatures and peaks of adult emergence. The results of this paper showed that the different environmental conditions of the two studied streams determined differences in EPT diversity, faunistic composition and functional structure. On the other hand, it indicated that there was no clear seasonal pattern in the temporal variation of density.

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