

Macroinvertebrates associated with bryophyta in a first-order Atlantic Forest stream

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ABSTRACT. This study describes the composition and structure of the benthic community associated with bryophytes in a first-order stream, located in a biological reserve of the Atlantic Forest, during two seasons. During three months of the dry season of 2007 and three months of the rainy season of 2008, samples of bryophytes attached to stones were collected randomly, along a 100 m stream reach. The structure of the community was analyzed through the mean density of individuals, Shannon's diversity index, Pielou's evenness, family richness, dominance index, and the percentage of Ephemeroptera, Plecoptera and Trichoptera (% EPT). Chironomidae larvae were dominant in the two periods of study, followed by Ceratopogonidae in the rainy season, and Naididae in the dry season. The orders EPT contributed 14 families. The results showed that bryophytes constitute suitable habitat which is able to shelter an abundant and diversified benthic fauna in a small extension of the stream. This habitat provides refuge during spates, and thus minimizes downstream transport of the macroinvertebrate fauna.

KEY WORDS. Aquatic insects; lotic systems; tropical region.

Forested streams generally present high spatial heterogeneity in terms of microhabitats, water flow conditions, and existing food quality, factors that favor high diversity (BEISEL *et al.* 1998, SURIANO & FONSECA-GESSNER 2004). In streams, stability of substrates usually varies and may affect the benthic fauna during spates, being one of the main factors, which determine species composition and abundance (KIKUCHI & UIEDA 1998). Among the substrates available in streams, bryophytes constitute a distinctive habitat for colonization by different groups of invertebrates, since they accumulate organic detritus, provide substrates for algal colonization and refuge against the water current and potential predators (GALDEAN *et al.* 2001, TURETSKY 2003).

Studies carried out in temperate regions highlight the high richness and abundance of families of invertebrates associated with bryophytes (DEACON *et al.* 2001, ANDREW *et al.* 2003, HABDJIA 2004, HEINO 2005, HEINO & VIRTANEN 2006). According to SUREN (1991), the architecture and thickness of bryophyte patches play an important role in retention of particulate organic matter, favoring the colonization of various groups of invertebrates, whose composition change along the seasons of the year due to changes in the water flow conditions (HABDJIA *et al.* 2004). In Brazil, information regarding composition, diversity and abundance of macroinvertebrates associated with

these plants is still very scarce in the literature. Studies conducted in the state of São Paulo by GORNI & ALVES (2007) examined the occurrence of Naididae (Oligochaeta) in patches of moss adhered to rock substrates in the rapids of the Jacaré Pepira River. GALDEAN *et al.* (2001) studied the benthic fauna of streams at Serra do Cipó National Park (southeastern Brazil) and observed that moss patches constituted an important substrate for invertebrates. COSTA & MELO (2008), in a study carried out in the State Park of Intervales (São Paulo), evaluated the diversity of macroinvertebrates in three streams and four microhabitats, including mosses at the air-water interface, and attested that differences among these microhabitats were higher than among stream sites, demonstrating the importance of the variety of habitats for the maintenance of biodiversity in streams.

The present study describes the composition and structure of the benthic community associated with bryophytes in a first-order stream, located in a biological reserve of the Atlantic Forest in southeastern Brazil, during two seasons.

MATERIAL AND METHODS

The study was conducted in the Municipal Biological Reserve of Poço D'Anta, a fragment of the Atlantic Forest in secondary succession stage. The Reserve is located in the urban area

in the city of Juiz de Fora, southeastern Brazil (21°44'23"-21°45'52"S and 43°18'29"-43°19'10"W). It comprises an area of 277 ha, which shelters rich vegetation and animal species diversity, as well as springs and streams (SOUSA 2008).

The studied site is a first order stream located between the coordinates 21°44'36"-21°44'31"S and 43°18'51"-43°18'53"W, and at the altitude of 850 m. It is a narrow and shallow stream with a predominantly sandy bottom and large numbers of fallen leaves and branches. The streambed also includes stones of different sizes, many of them partly covered by bryophytes.

Sampling was obtained monthly during two seasons. The first sampling occurred in the dry and cold season, in the period of July and September of 2007 (austral winter). The second sampling occurred in the rainy and warm season, during January and March of 2008 (summer) (Fig. 1).

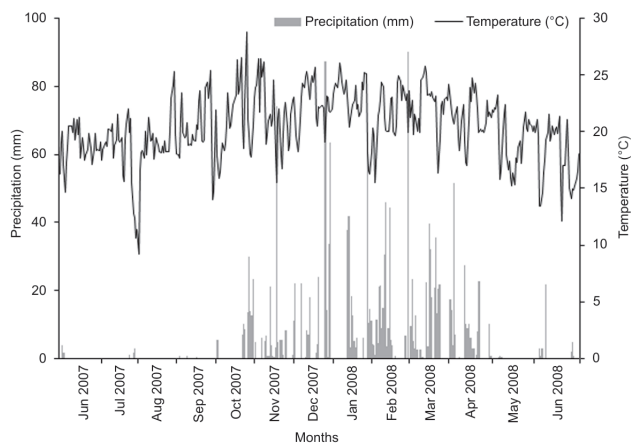


Figure 1. Monthly precipitation and average air temperature from June 2007 to June 2008 in Juiz de Fora, Brazil. The bars indicate precipitation and the line temperature. Source: Laboratório de Climatologia e Análise Ambiental, Universidade Federal de Juiz de Fora, Brazil.

Samples of bryophytes attached to stones (25-50 cm diameter) protruding water surface were removed using a blade. Bryophytes were located 1-2 cm above water surface. However, in the rainy season, due to the high water level bryophytes were visibly more humid than in the dry season. In each month, two pots of 200 mL were filled with bryophytes from patches haphazardly selected. Two moss families, Pilotrichaceae Kindb, 1899 and Hypnaceae Schimp, 1856, and one hepatic family, Geocalyceae H. Klinggr., 1858, were represented in the bryophyte samples.

All collections were carried out in a 100 m stream reach. The material collected was immediately fixed in formaldehyde solution 4%. In the laboratory, samples were washed in a sieve

with a 0.21 mm mesh size and sorted in a stereoscopic microscope. All organisms were preserved in 70° GL ethanol. Aquatic insects were identified at family level based on studies of McCafferty (1981), Merritt & Cummins (1984), Fernández & Domínguez (2001), Pes *et al.* (2005), and Costa *et al.* (2006). Oligochaeta were identified according to Brinkhurst & Marchese (1989).

In order to characterize the studied stream site, water temperature, pH, conductivity, and the dissolved oxygen were registered during the collections using a multi-sensor (Horiba U10). Mean flow velocity was obtained using the fluctuating method (Martinelli & Krusche 2007). We carried out three measurements during each sampling date for each environmental variable. The dry mass of bryophyte material was obtained after drying at 60°C for 48 hours.

For each sample, numerical density of each family collected (number of individuals per gram of dry mass, DM), Shannon's diversity index and Pielou's evenness were calculated according to Magurran (2004). Data were averaged for each period. The family richness and the percentage of Ephemeroptera, Plecoptera and Trichoptera (% EPT) per period were also calculated. The dominance index (DI) was obtained for each taxon, through the equation $DI = Q \cdot 100 \cdot F / \sum Q$ (Kownacki 1971), where Q is the average number of individuals present in all the samples; $\sum Q$ is the total of the average quantity of all the specimens, and F the frequency of each species, when $DI > 10$ (dominant), $1 < DI < 10$ (subdominant) and $DI < 1$ (adominant).

The Wilcoxon rank-sum test was used to detect whether there were significant differences ($p < 0.05$) in the Shannon's diversity, family richness, mean density of individuals, and in the % EPT between the dry and the rainy seasons. The analyses were conducted using the statistical program BioEstat 5.0 (free version).

Linear regression analysis was used to test the relationship between the response variables mean density of individuals and richness, and the predictor variable flow velocity in the two seasons (BioEstat 5.0). For this analysis, species richness, density and velocity were transformed ($\log [x+1]$).

RESULTS

The reach of the studied stream presented transparent and well-oxygenated water, with low conductivity, and slightly acid water (Tab. I). The monthly average rainfall in the rainy season was higher than in the dry season, thus leading to a significant increase of the flow velocity in the rainy season ($Z = 2.93$, $n = 6$, $p = 0.003$) (Tab. I).

A total of 1314 individuals distributed in 24 families were obtained in the dry season. In the rainy season, 2699 individuals and 38 families were obtained. Two families were dominant ($DI > 10$) during the dry season (Chironomidae and Naididae), and two during the rainy season (Chironomidae and Ceratopogonidae) (Tab. II).

Table I. Characterization of the studied stream, located in the Poço D'Anta Municipal Biological Reserve, during the dry and the rainy season.

	Mean and standard deviation	
	Dry season	Rainy season
Air temperature (°C)	19.06 ± 1.20	21.93 ± 0.30
Water temperature (°C)	16.13 ± 2.25	19.16 ± 0.28
Water speed (m/s)	0.07 ± 0.11	0.39 ± 0.40
Water depth (cm)	4.53 ± 0.97	6.73 ± 0.75
pH	6.51 ± 0.39	6.25 ± 0.25
Conductivity (µS/cm)	14.50 ± 0.07	17.00 ± 0.01
Dissolved oxygen (mg/L)*	10.03 ± 0.42	–
Precipitation (mm)	4.33 ± 3.07	316.00 ± 13.57

* The values for the dissolved oxygen were registered only in the dry season.

During the rainy season, a significant increase in the mean density of individuals ($Z = 1.99$, $n = 6$, $p = 0.04$) and in the family richness ($Z = 2.02$, $n = 6$, $p = 0.04$) was observed. However, the Shannon's diversity index did not differ between the seasons ($Z = 0.10$, $n = 6$, $p = 0.9$). The orders Ephemeroptera, Plecoptera and Trichoptera (EPT) presented together relative density significantly higher during the rainy season than during the dry season ($Z = 2.20$, $n = 6$, $p = 0.02$) (Tab. III).

The results of the linear regression analysis indicated that density of macroinvertebrates was affected positively by flow velocity ($R^2 = 0.64$, $F_{1,4} = 7.35$, $p = 0.05$) (Fig. 2). However, there was no relationship between family richness and flow velocity ($R^2 = 0.03$, $F_{1,4} = 0.12$, $p = 0.74$) (Fig. 3).

DISCUSSION

The results obtained indicated that bryophytes harbor more macroinvertebrates during the period of higher precipitation and flow velocity. This is the opposite pattern found in previous studies in the Neotropical region dealing with rocky substrates (FLECKER & FEIFARECK 1994).

Results obtained for other kinds of substrates in streams usually show a decrease in the number of organisms during high flow, mainly in unstable substrates as sand and gravel (AMORIM *et al.* 2004, ABÍLIO *et al.* 2007, ABURAYA & CALLIL 2007). Although no data on density at other substrates are available, it is possible that bryophytes acted as refuge areas against high flow during the rainy season. This possibility is reinforced by results obtained by HADJIA *et al.* (2004) that found the density of macroinvertebrates in bryophytes increased non linearly with increases in current velocity, and this result was associated with an accumulation of large amounts of ultrathin particulate organic matter. As suggested by CALLISTO *et al.* (2001), during the rainy season, macroinvertebrates can colonize new habitats if

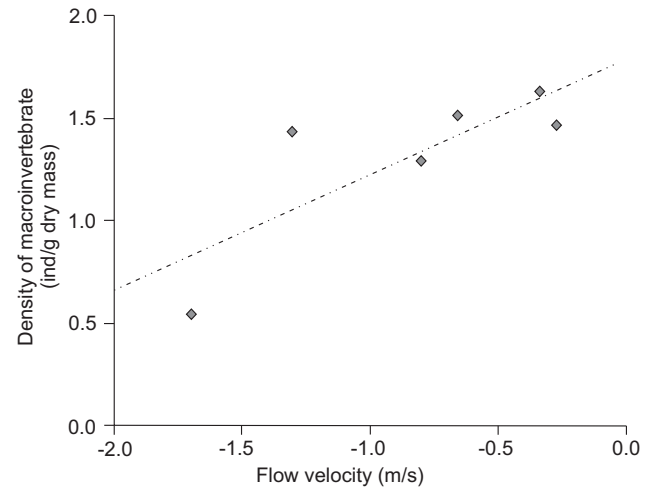


Figure 2. Effect of flow velocity on mean density of individuals (ind./g dry mass) inhabiting stream bryophytes in the Poço D'Anta Biological Reserve. The axes are in logarithmic scale.

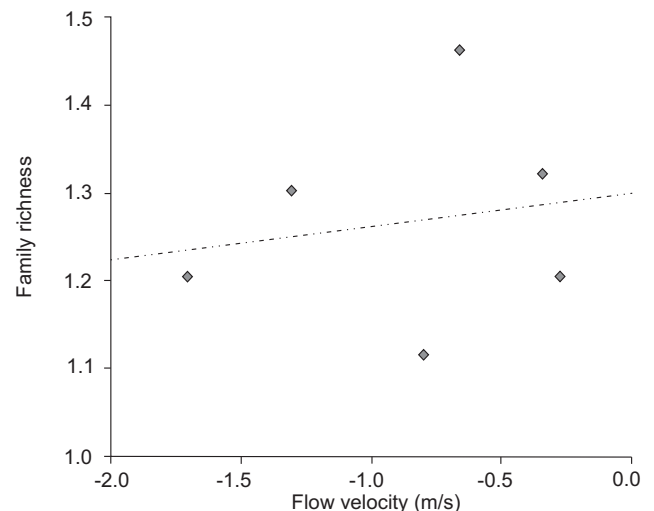


Figure 3. Effect of flow velocity on family richness of the fauna inhabiting stream bryophytes in the Poço D'Anta Biological Reserve. The axes are in logarithmic scale.

they offer high protection and shelter against the high flow, and this seems to be the case for stream bryophytes.

Chironomidae was dominant in the two seasons, followed by Ceratopogonidae in the rainy season, and Naididae in the dry season. Differences in the dominance of some taxa may occur due to changes in the water flow and associated retention of organic particles, which in turn may favor some functional groups (CRISCI-BISPO *et al.* 2007). Chironomidae larvae include species of most functional feeding groups, and thus are able to colonize several habitat types (ROQUE *et al.* 2007). Besides, they

Table II. Mean density of individuals (ind/g dry mass) and dominance index (DI) of the macroinvertebrate fauna in stream bryophytes in the Poço D'Anta Biological Reserve, during the dry and the rainy season. Dominant ($DI > 10$) = DO, subdominant ($1 < DI < 10$) = SD and adominant ($DI < 1$) = AD.

Order	Family	Dry season		Rainy season	
		ind/g dry mass	DI	ind/g dry mass	DI
Diptera	Chironomidae	20.41	DO	41.05	DO
	Ceratopogonidae	2.02	SD	14.38	DO
	Dolichopodidae	0.23	AD	0.43	AD
	Dixidae	–	–	0.02	AD
	Empididae	–	–	0.05	AD
	Muscidae	–	–	0.23	AD
	Tabanidae	0.05	AD	0.10	AD
	Tipulidae	1.56	SD	1.26	SD
	Simuliidae	0.02	AD	0.15	AD
	Stratiomyidae	0.10	AD	0.03	AD
	Trichoptera	Anomalopsychidae	0.12	AD	0.97
Calamoceratidae		–	–	0.05	AD
Helicopsychidae		–	–	0.15	AD
Hydropsychidae		0.22	AD	0.44	AD
Hydroptilidae		0.43	AD	1.15	SD
Odontoceratidae		0.02	AD	0.15	AD
Philopotamidae		–	–	0.21	AD
Polycentropodidae		–	–	0.15	AD
Ephemeroptera	Xiphocentronidae	–	–	0.13	AD
	Baetidae	0.02	AD	0.28	AD
	Caenidae	–	–	0.05	AD
Plecoptera	Leptophlebiidae	–	–	0.03	AD
	Gripopterygidae	–	–	0.08	AD
Hemiptera	Perlidae	0.02	AD	0.23	AD
	Hebridae	0.02	AD	–	–
	Mesoveliidae	0.05	AD	0.05	AD
Coleoptera	Veliidae	0.12	AD	0.13	AD
	Amphizoidae	–	–	0.03	AD
	Curculionidae	–	–	0.03	AD
	Elmidae	0.28	AD	0.44	AD
	Hydraenidae	0.02	AD	0.03	AD
	Hydrophilidae	0.07	AD	0.08	AD
	Psephenidae	0.02	AD	–	–
Lepidoptera	Scirtidae	–	–	0.13	AD
	Pyrilidae	0.07	AD	–	–
Odonata	Calopterygidae	–	–	0.03	AD
	Coenagrionidae	–	–	0.05	AD
Megaloptera	Corydalidae	–	–	0.03	AD
Oligochaeta	Megadrilli	0.05	AD	–	–
	Enchytraeidae	0.76	SD	1.85	SD
	Naididae	6.48	DO	4.03	DO
	Tubificidae	0.41	AD	0.54	AD

Table III. Family richness, %Ephemeroptera+Plecoptera+Trichoptera (EPT), mean values for Shannon's diversity, Pielou's evenness, and density of individuals associated to stream bryophytes in the Poço D'Anta Municipal Biological Reserve, during the dry and the rainy season.

	Dry season	Rainy season
Family richness	24	38
% EPT	2.58	5.89
Pielou's evenness	0.49 ± 0.17	0.42 ± 0.15
Shannon's diversity	1.37 ± 0.43	1.32 ± 0.57
Mean density (ind./g bryophyte dry mass)	33.69 ± 2.66	69.20 ± 4.24

are considered efficient colonizers (CALLISTO *et al.* 2001), what probably leads to the high abundance of this family of bryophytes.

Naididae was the most common family of Oligochaeta. They are predominantly free swimmers (VERDONSCHOT 1982), what may have favored the utilization of the bryophytes as habitat by these invertebrates. Naididae was the only family representing Oligochaeta in samples of bryophytes collected in rocky substrates of rapids by GORNI & ALVES (2007). This family was also one of the most abundant in the study carried out by SUREN (1993) in a stream in New Zealand.

Some Ceratopogonidae species are predators and feed on aquatic insect eggs. Others feed on periphyton or are omnivorous (MCCAFFERTY & PROVONSHA 1983). In a tropical stream, these larvae were classified by MOTTA & UIEDA (2004) as detritivorous in the rainy season, but were mostly restricted to feed on periphyton in the dry season, indicating the broad flexibility of these insects in terms of feeding habits. In addition, the larvae of this group are less selective in choosing substrate (FIDELIS *et al.* 2008), and these factors may have favored colonization of bryophytes by these invertebrates during the rainy season.

Immature individuals of Ephemeroptera, Plecoptera and Trichoptera were represented by 14 families, indicating the importance of these insects in the composition of the benthic fauna in the bryophyte samples. Studies carried out in temperate regions also show a high contribution of EPT families to the composition of the macroinvertebrate fauna inhabiting stream bryophytes (SUREN 1993, HADJA *et al.* 2004, KORSU 2004). Among the families found by these authors, Baetidae, Hydropsychidae, Hydroptilidae, Philopotamidae, and Polycentropodidae were also present in this study.

The results indicate that bryophytes attached to stones provide suitable habitat to shelter an abundant and diversified fauna of benthic macroinvertebrates even in a small extension of stream. In addition, bryophytes in streams are likely to act as refuge areas for benthic invertebrates during the period of increase in water flow.

ACKNOWLEDGMENTS

We would like to thank CNPq for the undergraduate fellowship to Marcos Vinícius Dias da Silva that allowed the conduction of this work. FAPEMIG provided financial support (Process CRA – APQ-01285-08). We would also like to thank Andréa Pereira L. Ponzó, of the Botany Department (ICB/UFJF) for the identification of the bryophyte families.

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Submitted: 03.V.2010; Accepted: 27.II.2011.

Editorial responsibility: Adriano S. Melo