Forested streams generally present high spatial heterogeneity in terms of microhabitats, water flow conditions, and existing food quality, factors that favor high diversity (B EISEL 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, HARDYA 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 (HARDYA 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 Naïdidae (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, 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).

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 

\[ DI = \frac{Q.100}{H} \]  

where Q is the average number of individuals present in all the samples; ΣQ 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).
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 \(\text{(EPT)}\) 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 & Fiefareck 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, Aburana & Callie 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 Hardia 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 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         | AD |
|            | Calamoceratidae          | –          | –            | 0.05         | AD |
|            | Helicopsychida           | –          | –            | 0.15         | AD |
|            | Hydropsychida            | 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 |
|            | Xiphocentronidae         | –          | –            | 0.13         | AD |
| Ephemeroptera| Baetidae               | 0.02       | AD           | 0.28         | AD |
|            | Caenidae                 | –          | –            | 0.05         | AD |
|            | Leptophlebiidae          | –          | –            | 0.03         | AD |
| Plecoptera  | Gribopterygidae          | –          | –            | 0.08         | AD |
|            | Perlidae                 | 0.02       | AD           | 0.23         | AD |
| Hemiptera   | Hebridae                 | 0.02       | AD           | –            | – |
|            | Mesoveliidae             | 0.05       | AD           | 0.05         | AD |
|            | Velidae                  | 0.12       | AD           | 0.13         | AD |
| Coleoptera  | 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           | –            | – |
|            | Scirtidae                | –          | –            | 0.13         | AD |
| Lepidoptera | Pyralidae                | 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 |
Macroinvertebrates associated with bryophyta in a first-order Atlantic Forest stream

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 |

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