

# Biomonitoring of benthic macroinvertebrates in the middle Doce River watershed.

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## **ABSTRACT: Biomonitoring of benthic macroinvertebrates in the middle Doce River watershed.**

The aim of this study was to assess the benthic macroinvertebrate communities in seven lotic and four lentic ecosystems in the middle Doce River watershed (MG, Brazil) during the rainy and dry periods of 2000-2001. A total of 110 sediment samples were collected in the lakes, and 153 in the rivers. Sediment organic matter contents and granulometric composition analysis were also done. Shannon-Wiener diversity and Pielou evenness indices were calculated and the U-test of Mann-Whitney was used to evaluate whether there were differences on density (ind.m<sup>-2</sup>) and taxonomic richness values between the studied periods. In the rivers, sediment granulometric composition presented a mixture of particles and fractions. Lake sediments were organic and showed high percentages of silt and clay. A total of 49 taxa was found in lotic ecosystems and the highest density was found in 2001 (> 30,000 ind.m<sup>-2</sup>). The lowest values of taxa richness were found in Piracicaba and Ipanema Rivers (6 and 2 taxa, respectively). Total density of macroinvertebrates was different between rainy and dry seasons in 2001 ( $p < 0.005$ ). Evenness index values were high and diversity values were low ( $H' < 0.7$ ). In the lakes, 31 invertebrate taxa were found and the highest density was found in the dry period of 2001 (2,500 ind.m<sup>-2</sup>). Carioca Lake showed high density and taxa richness in all sampling periods (> 750 ind.m<sup>-2</sup> and > 6 taxa). Significant differences were found on densities and on taxa richness between rainy and dry seasons in 2000 and 2001 ( $p < 0.005$ ). Thus, benthic macroinvertebrate communities can be used as a tool in the assessment of water quality and freshwater ecosystem health.

**Key-words:** benthic macroinvertebrates, water quality bioindicators, family-level identification, Doce River watershed.

## **RESUMO: Biomonitoramento de macroinvertebrados bentônicos na bacia do médio rio Doce.**

O objetivo deste estudo foi avaliar as comunidades de macroinvertebrados bentônicos em sete ecossistemas lóticos e quatro lênticos na bacia do médio rio Doce (MG, Brasil) durante os períodos de chuvas e seca de 2000-2001. Um total de 110 amostras de sedimento foi coletado nos lagos e 153 nos rios. Os teores de matéria orgânica e a composição granulométrica dos sedimentos também foram analisados. Os índices de diversidade de Shannon-Wiener e equidade de Pielou foram calculados e utilizou-se o teste U de Mann-Whitney para verificar se haviam diferenças na densidade (ind.m<sup>-2</sup>) e na riqueza taxonômica entre os períodos estudados. Nos rios, a composição granulométrica do sedimento apresentou uma mistura de frações granulométricas. Os sedimentos dos lagos foram orgânicos e apresentaram altas porcentagens de silte e argila. Um total de 49 taxa foi encontrado nos ecossistemas lóticos e a maior densidade foi encontrada em 2001 (> 30.000 ind.m<sup>-2</sup>). Os menores valores de riqueza taxonômica foram encontrados nos rios Piracicaba e Ipanema (6 e 2 taxa, respectivamente). A densidade total de macroinvertebrados foi diferente entre as estações chuvosa e seca em 2001 ( $p < 0,005$ ). Os valores de equidade foram altos e os de diversidade foram baixos ( $H' < 0,7$ ). Nos lagos foram encontrados 31 taxa de invertebrados e o maior valor de densidade foi encontrado no período de

seca de 2001 (2.500 ind.m<sup>2</sup>). A lagoa Carioca apresentou elevada densidade e riqueza taxonômica em todos períodos amostrados ( $> 750$  ind.m<sup>2</sup> e  $> 6$  taxa). Diferenças significativas foram encontradas nos valores de densidade e riqueza taxonômica entre os períodos de chuvas e seca em 2000 e 2001 ( $p < 0,005$ ). Portanto, a comunidade de macroinvertebrados bentônicos pode ser usada como ferramenta na avaliação da qualidade da água e saúde dos ecossistemas aquáticos.

**Palavras-chaves:** macroinvertebrados bentônicos, bioindicadores de qualidade de água, identificação em nível de famílias, bacia do rio Doce.

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## Introduction

The ecological study of freshwater ecosystems must consider their landscape surroundings, taking account the spatial arrangement of ecosystems and large scale processes linking them. Water quality is directly influenced by predominating uses of the land and resources within the watershed. These uses are necessary elements to assess the existing relationships between aquatic and terrestrial ecosystems. The quality and quantity of terrestrial inputs are determinant factors for the ongoing processes within the aquatic ecosystem. The concept of the watershed as the study unit has been used as a tool for the definition of environmental politics, conservation and management (Tundisi & Barbosa, 1995).

Aquatic macroinvertebrates are an important component of freshwater communities. The benthic species diversity is controlled by productivity, habitat heterogeneity and biotic interactions (Townsend, 1989). In general, invertebrates have a clumped distribution, which is assumed to be related with the mosaic of interchanging conditions in the substratum, flow conditions and depth (Townsend, 1989; Graça et al., 2004). Some physical and chemical features directly affect taxonomic composition and community structure. Habitat characterization is of prime importance to the knowledge of benthic macroinvertebrates distribution (Beisel et al., 2000). According to Graça et al. (2004), factors that regulate macroinvertebrates distribution and richness are substratum particle size, substratum stability, substratum organic matter contents, habitat spatial heterogeneity and sediment grain size.

Benthic macroinvertebrates are widely used as water quality bioindicators due their long life period in the bottom of freshwaters. Biological assessments are being developed worldwide evaluating changes in genetic composition of specific populations, bioaccumulation of toxins and related occurrence of morphological deformities, changes in community composition and ecosystem functioning (Marques & Barbosa, 2001). An ideal Environmental Biomonitoring Program is the one that integrates physical, chemical and biological measurements, resulting in a physicochemical characterization of the watershed and an ecological study of the bioindicators of water quality. The use of these organisms as bioindicators is based on a simple feature: when submitted to adverse conditions, the organisms become adapted or die. Therefore, the organisms that live in a determined ecosystem are adapted to the environmental conditions present on it and then must indicate the preservation level of natural conditions or changes caused by the emission of pollutants (Hynes, 1974).

Biological communities are related with ecological features (e.g., chemical, physical, and biological characteristics), integrating effects from different stressors, and therefore providing a broad measure of combined impacts. Changes in species composition, dominance of pollution tolerant species, and frequency of deformity occurrences on larval head capsules are some of the commonly used features in these types of evaluations (Marques et al., 1999). Amongst the human impacts, eutrophication can determine a shift in the benthic organisms and a gradual replacement of species can be observed (Marques et al., 2003). Long term monitoring

efforts can provide a suitable description of the temporal variation in water and sediment physico-chemical factors and benthic communities composition.

The middle Doce River watershed can be considered as an example of the most important Brazilian environmental problems (De Paula et al., 1997). In this region can be observed the deforestation of Atlantic Forest and the development of economical activities that produce important environmental impacts (e.g., mining, steel processing, cellulose industry, gold-mining, reforestation projects with *Eucalyptus* spp. and intense human occupation) (Barbosa et al., 1997). Meanwhile, Brazilian Long Term Ecological Research (LTER) studies have been developed in order to assess the water quality and aquatic biodiversity (Mayrink et al., 2002; Barbosa et al., 2004). These studies are of great importance for assessing the ecological consequences of social-economic activities in this region. Essential elements to the definition of politics and proposes on conservation, recuperation and management of the involved ecosystems are some expected consequences of the LTER studies (Barbosa et al., 1997).

The aim of this paper was to assess the benthic communities in seven lotic and four lentic ecosystems in the middle Doce River watershed (MG, Brazil) during the rainy and dry periods of 2000-2001. We assume that this information will contribute to the understanding of the main determining factors on benthic macroinvertebrate communities distribution, structure and diversity in this site of the Brazilian LTER Program.

## Study Area

The Doce River watershed is one of the most important basins in southeastern Brazil (83,000 km<sup>2</sup>; 3.1 million inhabitants; 37.3 inhabitants.km<sup>-2</sup>) representing an important segment of the economy recently developed (Mayrink et al., 2002). This region also includes the Rio Doce State Park (c. 36,000 ha), which is the largest remnant of the Atlantic Forest in the State of Minas Gerais and one of the few places in Brazil where natural lakes (considering the geomorphologic origin) can be found. The climate is characterized by two well-defined seasons: a dry (from April to September) and a rainy (from October to March) seasons (Marques & Barbosa, 2001).

The studied ecosystems are located on seven sub-basins (Caraça Stream, Santa Bárbara River, Peixe River, Severo Stream, Piracicaba River, Ipanema River and Doce River) of the middle Doce River watershed (De Paula et al., 1997). The geographical coordinates of the study sites are presented in Tab. 1. Two natural lakes (Dom Helvécio and Carioca) located inside the Rio Doce State Park (19°29'24" - 19°48'18" S; 42°32'01" - 42°38'30" W) and two lakes in the surroundings of the park: Amarela (19°50'27" S e 42°36'56" W) and Águas Claras (19°49'01" S; 42°35'47" W) were also investigated.

Table 1: Geographical coordinates of studied lotic sites in the middle Doce River basin.

<b>Sub-basins</b>	<b>Geographical coordinates of studied lotic sites</b>
Caraça Stream	20°06'00" S - 43°29'09" W
Santa Bárbara River	19°50'01" S - 43°21'14" W
Peixe River	19°44'35" S - 43°01'16" W
Severo Stream	19°36'57" S - 42°50'50" W
Piracicaba River	19°29'25" S - 42°31'08" W
Ipanema River	19°28'14" S - 42°32'01" W
Doce River	19°19'12" S - 42°21'52" W

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## Material and methods

Two sampling campaigns were conducted in the rainy periods and 2 in the dry periods. Sampling campaigns always occurred on January-April (rainy periods) and July-September (dry periods) on both lotic and lentic ecosystems. Pluviometric data of the study area were obtained on SIMGE website (Meteorology and Aquatic Resources System of Minas Gerais – [www.singe.mg.gov.br](http://www.singe.mg.gov.br)).

Sediment samples were collected in the marginal region of the lakes (totalizing 30 in the rainy period and 40 in the dry period in 2000 and, 20 in both periods, in 2001) using a corer sampler (0.050 m<sup>2</sup>). In the rivers, samples were collected in the marginal region and, in the center of the riverbank (totalizing 33 and 43 in the rainy and dry periods in 2000 and, respectively, 34 and 43 in 2001) using a Petersen dredge (0.0375m<sup>2</sup>). A Surber sampler (30 x 30 cm, 250 mm mesh size) was used in Caraça and Santa Bárbara streams due the characteristic rocky substrate. Samples were immediately fixed in 5% formalin. After, they were washed through 2.00, 1.00 and 0.50 mm mesh sieves and the macroinvertebrates were sorted and identified under a stereomicroscope (40x). The organisms were preserved in 70% ethanol and deposited in the Benthic Macroinvertebrate Reference Collection of the Institute of Biological Sciences, Federal University of Minas Gerais. During the sampling campaigns, one sediment sample was collected in each studied ecosystem for granulometric composition analysis (Suguio, 1973). Organic matter content of sediment was determined by ashing previously dried samples in an oven at 550°C for 4 hours.

In order to evaluate the structure of benthic macroinvertebrate communities, Shannon-Wiener diversity and Pielou evenness were calculated according to Magurran (1991). Organisms density (individuals.m<sup>-2</sup>) and taxonomic richness, represented as the total number of taxa found in each ecosystem per sampling period, were estimated. To evaluate whether there were differences on density and taxonomic richness between rainy and dry periods, the non-parametric U-test of Mann-Whitney was used (Statistica Software 6.0).

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## Results

As a result of the intense dynamism, the granulometric composition of river sediments was typically sandy with the prevalence of coarse and medium sand fractions probably due to riverbank erosion and margin deforestation (Fig. 1). In Caraça Stream it was not possible to collect sediment for granulometric analysis in all sampling campaigns. Lake sediments were organic and showed high percentages of silt and clay fractions on their granulometric composition, typical of lentic ecosystems with intense sedimentation process (Fig. 2).

A total of 49 taxa was found in lotic ecosystems during the studied period (Tab. II). In 2000, 26 taxa were found in rainy and 27 in dry periods, meanwhile in 2001 an increase on the number of taxa was observed (30 and 28, respectively in rainy and dry periods). Oligochaeta was very abundant in all sampling stations, except in Caraça Stream (dry period of 2000 and rainy period of 2001). Helicopsychidae, Hydrobiosidae and Odontoceridae (Trichoptera) were found only in Caraça Stream. Chironomids were also very abundant during all studied period and the highest densities were found in Piracicaba and Doce River, reaching over 30,000 ind.m<sup>-2</sup> in the dry period of 2001 (Fig. 3). In most of the sampling stations, the highest density values were found in 2001. Taxa richness was low in almost all sampling stations and the lowest values were found in Piracicaba and Ipanema Rivers. There were no differences in the taxa richness between rainy and dry seasons both in 2000 (U = 634; p > 0.05) and in 2001 (U= 621.5; p > 0.05). Total density of macroinvertebrates was different between rainy and dry seasons only in 2001 (U = 416.5; p < 0.005). Although the high density values, Pielou Evenness indices were high, probably due to the presence of few taxa in each

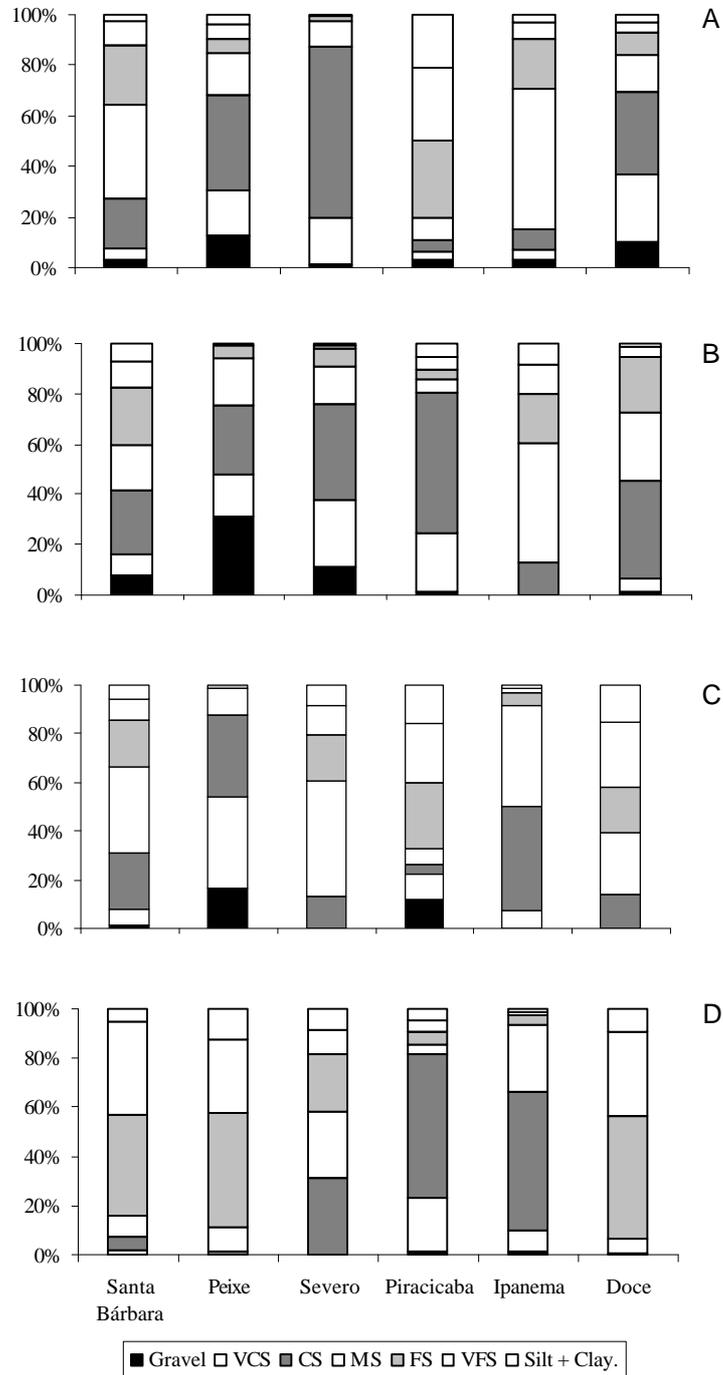


Figure 1: Granulometric composition of river sediments of the middle Doce River basin, during the rainy (A, C) and dry (B, D) seasons of 2000-2001. Gravel (2.000 mm), VCS = very coarse sand (1.000 mm), CS = coarse sand (0.500 mm), MS = medium sand (0.250 mm), FS = fine sand (0.125 mm), VFS = very fine sand (0.063 mm), Silt + Clay ( $\leq$  0.063 mm).

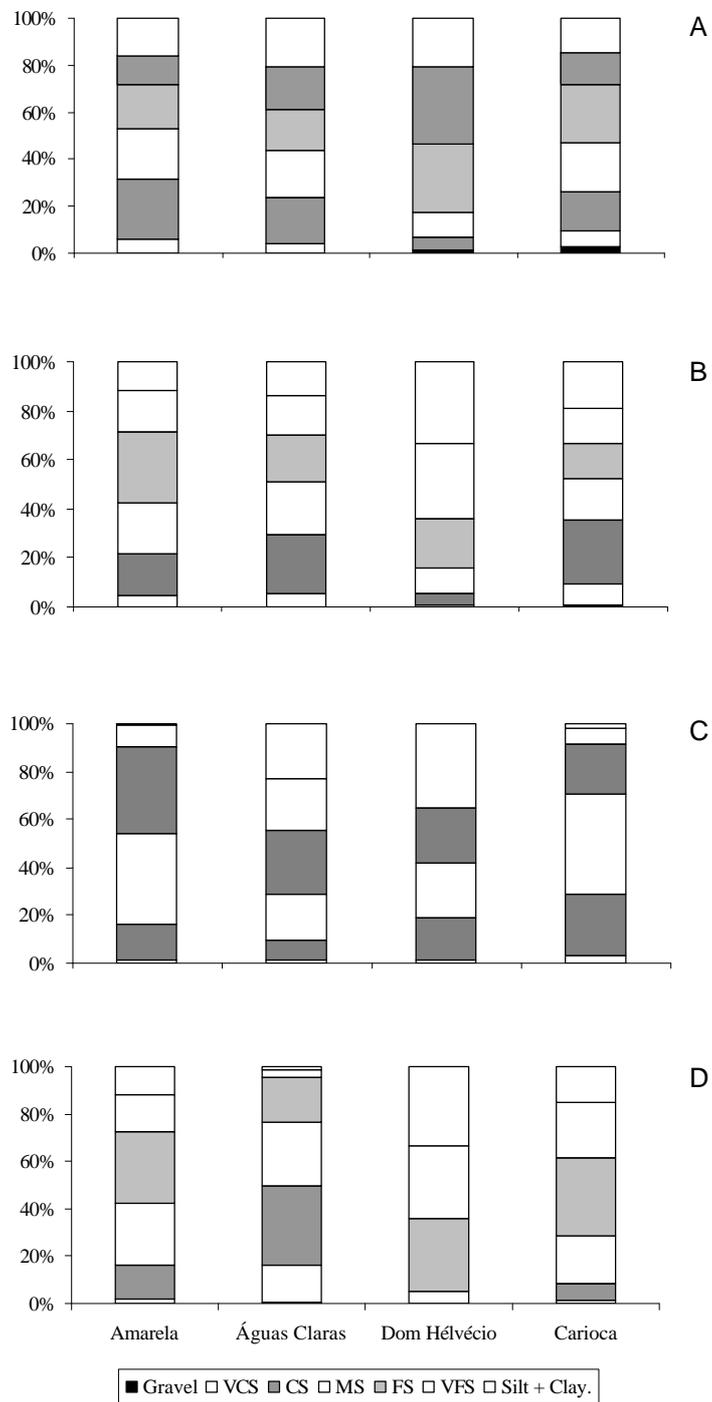


Figure 2: Granulometric composition of lake sediments of the middle Doce River basin, during the rainy (A, C) and dry (B, D) seasons of 2000-2001. Gravel (2.000 mm), VCS = very coarse sand (1.000 mm), CS = coarse sand (0.500 mm), MS = medium sand (0.250 mm), FS = fine sand (0.125 mm), VFS = very fine sand (0.063 mm), Silt + Clay ( $\leq$  0.063 mm).

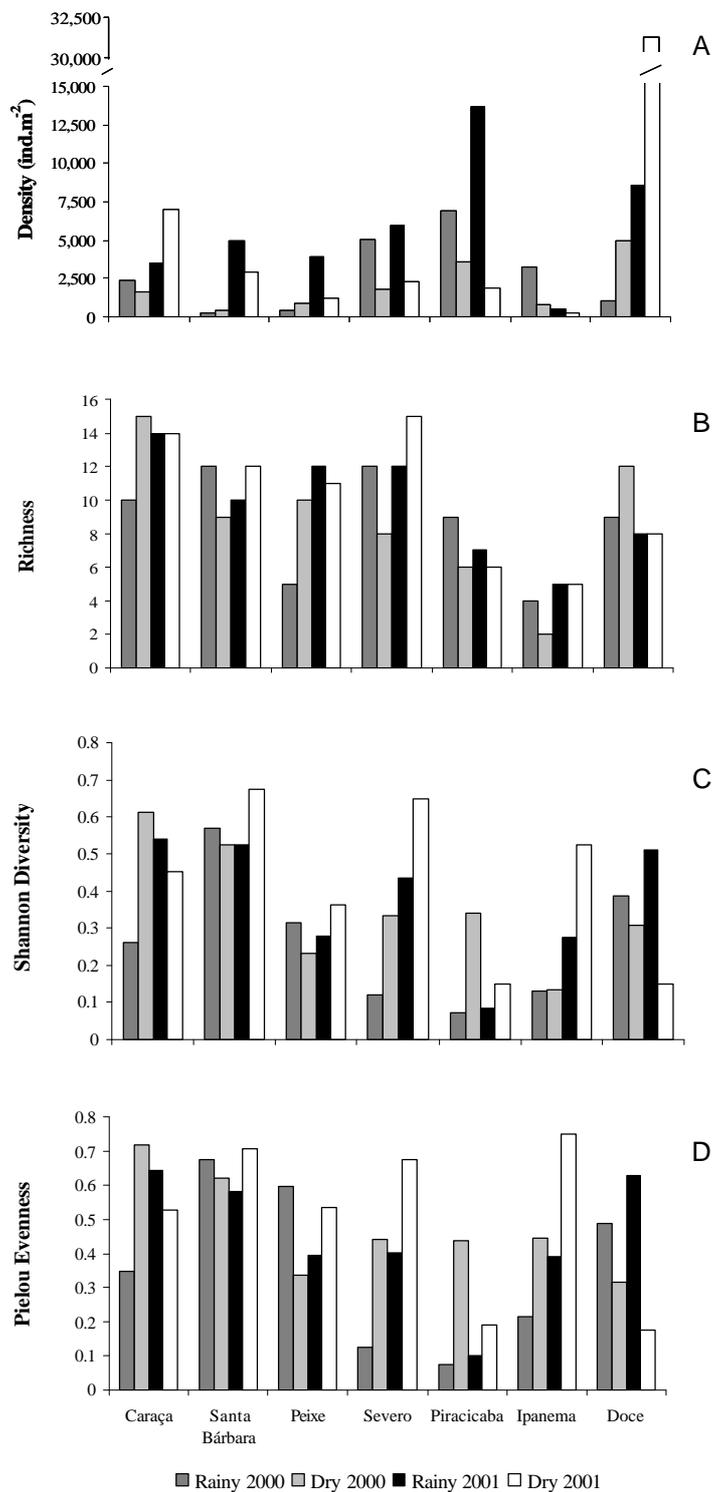


Figure 3: Density (ind.m<sup>-2</sup>), richness (number of taxa), Shannon-Wiener diversity and Pielou evenness indexes of benthic macroinvertebrates in the lotic ecosystems of the middle Doce River basin, during the rainy and dry seasons of 2000-2001.

Table II: Taxonomical composition and abundance of benthic macroinvertebrates in the lotic ecosystems of the middle Doce River basin, during the rainy (R) and dry (D) seasons of 2000-2001

	Caraça			Sta-Bárbara			Peixe			Severo			Piracicaba			Ipanema			Doce					
	2000	2001	R	2000	2001	R	2000	2001	R	2000	2001	R	2000	2001	R	2000	2001	R	2000	2001	R	2000	2001	
<b>Insecta</b>																								
<b>Diptera</b>																								
Ceratopogonidae	**		*	*	***	*	***	*	**	**	***									*	*	**	*	*
Chaoboridae			*			*																		
Chironomidae	***	***	***	**	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***
Culicidae	***	***	***	***	***	***	***	***	***	***	***	*												
Dolichopodidae																								
Empididae						*																		
Psychodidae	*					*					*						*		*	*	*	*	*	*
Simuliidae	***	**	**	**	**	*	*	*	*	*	*													
Stratiomyidae																								
Tipulidae	*				***					**	**	**	*	*	*	*	*	*	*	*	*	*	*	*
<b>Odonata</b>																								
Calopterigidae										*														
Coenagrionidae						*				*														
Gomphidae	**		*	*	**	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Libellulidae					*	*				*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
<b>Coleoptera</b>																								
Dytiscidae	**	**	**	**	**	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Elmidae	***	***	***	*	**	***	**	**	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Hydrophilidae										*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Psephenidae																								
<b>Trichoptera</b>																								
Helicopsychidae	**	**	***	***	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Hydrobiosidae	**	**	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Hydropsychidae	**	**	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Hydroptilidae	**	***	**	**	**	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Leptoceridae	**	***	**	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Odontoceridae	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Polycentropodidae						*																		

Table II: Cont.

	Caraça		Sta.Bárbara		Peixe		Severo		Piracicaba		Ipanema		Doce	
	2000	2001	2000	2001	2000	2001	2000	2001	2000	2001	2000	2001	2000	2001
<b>Ephemeroptera</b>														
Baetidae	***	**	***	***	*	**	**	*	**	**	*	*	*	*
Caenidae						*								
Euthyplociidae									*					
Leptohyphidae		*		**			*	**		**			**	**
Leptophlebiidae	**	*	**	*	*		*		*		*		*	*
<b>Heteroptera</b>														
Belostomatidae	*							*						
Corixidae														
Gerridae							*							
Naucoridac	***	***	*	*			*		*				*	*
Nepidae							*							
Notonectidae	**						*							
Velidae							*							
<b>Lepidoptera</b>														
Pyralidae	*	**	**						*					
<b>Collembola</b>														
<b>Oligochaeta</b>	**	***	***	***	***	***	***	***	***	***	***	***	***	***
<b>Hirudinea</b>														
<b>Bivalvia</b>				*	***	***	*	**	*	**	*	*	***	***
<b>Gastropoda</b>														
Hydrobiidae														***
Planorbidae											*			*
Thiaridae							*	*	**	***	**	**	***	***
<b>Hidracarina</b>	**	**	**	*	*	*	*	*	*	*	*	*	*	*
<b>Ostracoda</b>														*
<b>Decapoda</b>													**	**
<b>Nematoda</b>							*	*	*	*	*	*	***	***

\*rare: 1-10 ind.m<sup>-2</sup>; \*\*abundant: 11-100 ind.m<sup>-2</sup>; \*\*\*very abundant: >101 ind.m<sup>-2</sup>.

sampling station (e.g., only two up to five taxa in Ipanema River). Shannon-Wiener diversity indexes were low during the study. Peixe, Piracicaba, Ipanema and Doce Rivers showed the lowest H' values ( $\leq 0.5$ ).

A total of 31 invertebrate taxa was found in studied lakes. Chironomids were abundant, except in Amarela Lake (rainy period of 2000) and Águas Claras Lake (dry period of 2001) where Oligochaeta and Thiaridae predominated (Tab. III).

Table III: Taxonomical composition and abundance of benthic macroinvertebrates in the lentic ecosystems of the middle Doce River basin, during the rainy (R) and dry (D) seasons of 2000-2001.

Streams/Rivers	Amarela		Águas Claras				Dom Helvécio				Carioca			
	Year		2000		2001		2000		2001		2000		2001	
	R	D	R	D	R	D	R	D	R	D	R	D	R	D
<b>Insecta</b>														
<b>Diptera</b>														
Ceratopogonidae									*	**		*	*	
Chaoboridae		**			**				*	**			*	
Chironomidae	***	**	***	**	***	**		*	***	**	***	***	***	***
Dolichopodidae														*
Psychodidae				*										
Tabanidae				*										*
Tipulidae				*										**
<b>Odonata</b>														
Coenagrionidae				*					*	*		*		
Gomphidae													*	*
Libellulidae					*				*		**	*	**	**
<b>Coleoptera</b>														
Dryopidae										*				
Dytiscidae				**		*	*							**
Hydrophilidae				*										
Noteridae														**
Scirtidae				**										
<b>Trichoptera</b>														
Calamoceratidae														**
Hydroptilidae										*		*		
Leptoceridae														**
Polycentropodidae														*
<b>Ephemeroptera</b>														
Baetidae		*		**					*	**				*
Caenidae				*							**		***	**
Leptohyphidae									*		*	**		
Leptophlebiidae										*	**	**		
<b>Heteroptera</b>														
Corixidae														**
Nepidae													*	
Notonectidae				**										
Oligochaeta	*	*	***	**	*	*	***	*	*	***		***	***	***
<b>Hirudinea</b>														
<b>Gastropoda</b>														
Thiaridae			***	***	***	***	***			**	***		*	
Decapoda		*	*		*				**	**				
<b>Nematoda</b>														
											*			

\*rare: 1-10 ind.m<sup>-2</sup>; \*\*abundant: 11-100 ind.m<sup>-2</sup>; \*\*\*very abundant: >101 ind.m<sup>-2</sup>.

The highest density values were found in the dry periods (Fig. 4). In the dry period of 2001, the highest density, richness and Shannon-Wiener indexes were found in Amarela, Dom Helvécio and Carioca Lakes. Nonetheless, in Águas Claras Lake were found high densities but the lowest richness and diversity indexes in the same period. Benthic macroinvertebrates in Carioca Lake showed high density and taxa richness in all sampling periods. Significant differences were found on density and on taxa richness between rainy and dry seasons in 2000 (respectively,  $U = 261.5$ ;  $p < 0.005$  and  $U = 285$ ;  $p < 0.005$ ) and in 2001 (respectively,  $U = 120$ ;  $p < 0.05$  and  $U = 60$ ;  $p < 0.005$ ). The exotic mollusk species *Mellanoides tuberculata* (Thiaridae) was found in high densities in Águas Claras Lake along the studied period and, in Dom Helvécio and Amarela Lakes during 2001 sampling periods.

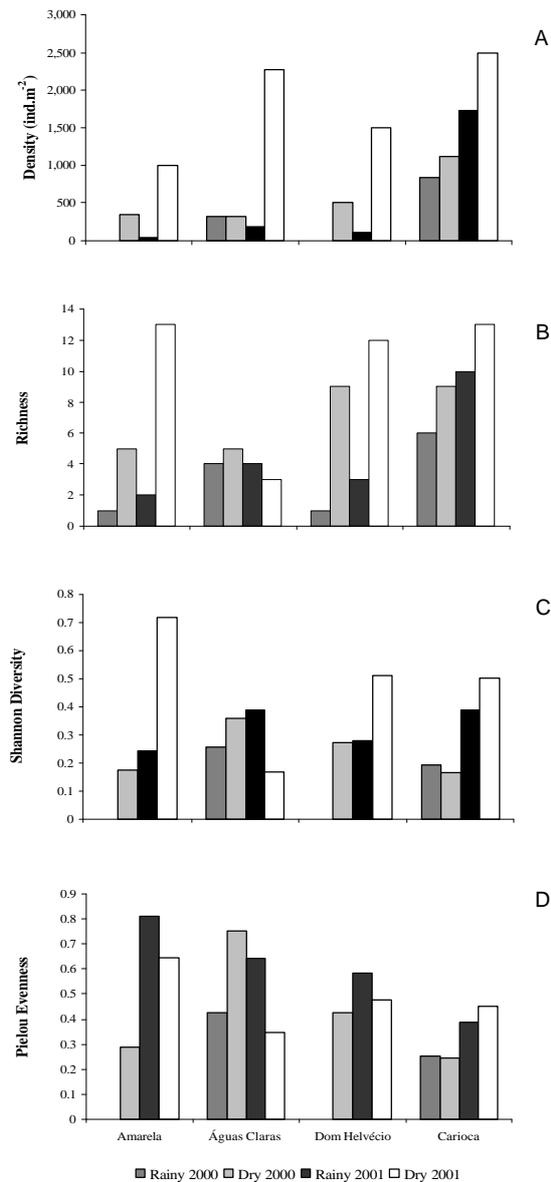


Figure 4: Density (ind.m<sup>-2</sup>), richness (number of taxa), Shannon-Wiener diversity and Pielou evenness indexes of benthic macroinvertebrates in the lentic ecosystems of the middle Doce River basin, during the rainy and dry seasons of 2000-2001.

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## Discussion

Along this two-year study, we did not identify a pattern between the assessed community attributes (diversity and taxa richness indexes) and temporal distribution of the benthic fauna in the sub-basins of the middle Doce River watershed. These results contrast what have been found in similar environments with gravel substrates, where low density and taxa richness values are found in rainy periods (Callisto & Goulart, 2005). However, we observed a clear pattern of the benthic fauna distribution with regard to rainy and dry periods in the lakes.

The differences found on the density values between rainy and dry periods can be explained by temporal changes that occur on the water level and flux affecting some abiotic parameters such as temperature, dissolved oxygen and nutrients availability (De Paula et al., 1997; Barbosa et al., 1997). In spite of the macroinvertebrates response to environmental factors, changes on abundance and taxonomic richness of this community between periods can also be a consequence of biological factors (e.g., predation risk, temporal changes on macrophyte community during growth period and trophic resources availability) that vary along the year. Allan & Flecker (1993) proposed six factors as being of critical importance in lotic environments: habitat loss and degradation, the spread of exotic species, over-exploitation, secondary extinctions, chemical and organic pollution, and climate change. Among them, chemical and organic pollution are of a prime importance in Doce River watershed, due to land use and human influences.

The higher values of density and taxonomic richness found in the rivers, comparing with the lakes, are probably related with the high number of available habitats in lotic ecosystems (Nessimian, 1996). Beisel et al. (2000) pointed out intense relationships between macroinvertebrate assemblages and substrate heterogeneity. In a heterogeneous environment, habitats produce high ecological niches diversity, what influences positively the benthic diversity (Callisto et al., 2004). Richness measures are frequently included in multimetric systems (Roy et al. 2003). Perhaps, due to taxonomic difficulties with the typical Chironomidae and Oligochaeta fauna in the lentic benthos, taxa richness is more frequently used for the assessment of disturbance effects in streams and rivers than in stagnant waters (Resh & McElvay, 1993).

The input of organic matter into rivers modifies the bottom substrate characteristics. Sedimented particles of organic matter form patches that are dependent of the instream hydraulic conditions. Because fine organic particles have hydrological properties similar to silt, food quantity is rarely a limiting factor in silt-bottom habitats. As stated by Brabec et al. (2004), the reach-scale geomorphic and chemical parameters are related to catchment land cover, as also observed in the Doce River sub-basins. Roy et al. (2003) and Brabec et al. (2004) pointed out that effects of organic pollution and eutrophication on stream benthic fauna are linked to each other by organic matter and nutrients transformation processes.

Numerous indices are commonly used on biomonitoring and they may provide useful ecosystem management tools to rapidly assess possible detrimental effects of habitat alteration and ecosystem pollution. If perturbation conditions are present for a period of time sufficient to induce detrimental effects at a population level, it becomes possible to evaluate changes in the community structure by using measures such as diversity and community structure indexes (Norris & Georges, 1993). In the present study, we used density and taxa richness to assess water quality and its impact on benthic macroinvertebrate communities because they are seen as a useful way to condense complex data (Norris & Georges, 1993).

The sampling stations placed in Piracicaba and Ipanema Rivers showed low taxonomic richness, high abundance of one or two taxa over the rest of them and organisms belonged to tolerant groups to bad water quality (e.g., red chironomids and oligochaets) (Callisto et al., 2004). The Piracicaba sub-basin is strongly affected by human activities and, only in 1992, received 80,000 m<sup>3</sup> of non-treated effluents. Moreover, the demographic density of this sub-basin is more than four times higher

than the average of Minas Gerais State (124 and 27.4 hab.km<sup>2</sup>, respectively) (Barbosa et al., 1997).

Santa Bárbara River, Caraça and Severo Streams suffer lower intensity of human impacts and are sufficiently stables to maintain a well utilization of their resources by natural biota (Barbosa et al., 1997), since the high values of taxonomic richness found, when compared with the other studied systems. In addition, the Santa Bárbara and Severo sediments are composed by several fractions, increasing habitat diversity and the colonization by benthic macroinvertebrates, as also observed by Cota et al. (2002), in a study of the water quality of the Doce River middle reach using an adaptation of the Biological Monitoring Working Party Score System index. Excluding Caraça Stream (that showed natural conditions), all sampling stations present altered to strongly impacted conditions.

The Carioca Lake, located inside the Rio Doce State Park, presents its margins with well preserved natural vegetation. Thus, higher values of taxonomic richness and diversity indexes were found on this lake, when compared with the Águas Claras Lake, which is rounded by Eucalyptus plantations. Some authors have suggested that Eucalyptus plantations contribute with a fraction of allochthonous carbon of low nutritional quality comparing with the Atlantic Forest, which leaves are more easily decomposed (Callisto et al., 2002).

In the lentic ecosystems, invertebrate taxonomic diversity is probably related with the presence of aquatic macrophytes. Callisto et al. (1996) suggested that vegetable surfaces are important substrates for the development of the periphytic community, that becomes the main food source for macroinvertebrates. The marginal region receives also larger quantities of allochthonous organic matter in the rainy periods, increasing the availability of resources to the benthic community and providing new colonization opportunities (Callisto et al., 2002).

Long term sampling efforts to evaluate water quality in European watersheds and the intercalibration of used methods and validate Environmental Quality Criteria are necessary (Sandin & Hering, 2004). Unpredicted floods can cause disturbance in stream ecosystem structure. In Doce River watershed, high water discharges and velocities wash the riverbed, remove the organisms and, increase levels of nutrients and organic matter in the streams and rivers (Barbosa et al., 2004; Petrucio & Barbosa, 2004). In addition, the high density on the rainy period of 2001 in almost all lotic ecosystems may be due to the drift effect (Callisto & Goulart, 2005).

The high density of Chironomidae and Oligochaeta found in almost all sampling stations is a consequence of the bad water quality of the majority of the middle Doce River aquatic ecosystems (Barbosa et al., 1997; Marques et al., 1999; Marques & Barbosa, 2001; Cota et al., 2002; Mayrink et al., 2002). Chironomids are one of the highest invertebrate diverse groups. Unfortunately, this taxon is both the last well described and most difficult to identify (Allan & Fleker, 1993). According to Fagundes & Shimizu (1997) some chironomid genera (mainly Chironomus) predominate, together with Oligochaeta and Hirudinea, in environments with high inputs of organic sewage, low dissolved oxygen levels and high N and P concentrations in the water and sediment.

Elmidae (Coleoptera) and Baetidae (Ephemeroptera) showed wide distribution along the Doce River middle reach, being present in many sampling stations. Goulart & Callisto (2003) suggested these taxa as tolerant to some level of environmental contamination, caused by inputs of domestic untreated sewage. Galdean et al. (2000), studying altitudinal streams at Serra do Cipó (MG), pointed out Simuliidae (Diptera) as filter-feedings of fine particulate organic matter (FPOM), characteristic of rapid reaches, attached to mosses and aquatic macrophytes. This distribution pattern can be associated with the high densities of organisms during the rainy season in a rocky bed and an intense water flux of Caraça Stream.

No plecopterans in the studied reaches suggests that these organisms, indicators of good water quality, are not tolerating the waters of the middle Doce River. Moreover, the low diversity of habitats affected the distribution of this taxon. Galdean et al. (2000), Goulart & Callisto (2003) and Callisto & Goulart (2005) working

in streams that showed high substrate heterogeneity, found wide distributions of Plecoptera in others localities of Minas Gerais State.

According to Guerold (2000), family-level identification may exert a great influence on most biological indices. He found that underestimation rose with increasing water quality. When low determination levels were used, communities living in stressed streams appeared to be less altered than they really were. The lack of species-level information decrease sensitivity and reduce the ability of a study to detect the magnitude of changes (Hughes, 1978).

The use of higher taxonomic levels might be an advantage to reduce bias created by environmental heterogeneity (such as seasonal changes) and stochastic events, which may mask the effects of human activities (Warwick, 1988; Reece et al., 2001). Some studies on species-level supported the conclusions made based on family-level, or that higher taxonomic levels are sensitive enough to detect environmental impacts (Reece et al., 2001). Zamora-Muñoz & Alba-Tercedor (1996), for example, assumed that family-level identification was adequate to monitoring water quality in Spanish streams.

The purpose of our study was simply to detect the impact of a perturbation on macroinvertebrate communities, and thus we assumed that determination to family-level was useful. If the goal is going to be the assessment of community and population changes (and it is probably desirable), lower taxonomic determinations will be imperatively needed. On the other hand, a benefit-cost balance must be consider, due to the increasing need for rapid and low-cost methods to assess water quality and the necessity of much time for the determination to low taxonomic levels by (rare) specialists.

The use of benthic macroinvertebrate communities is a useful tool in the assessment of water quality and freshwater ecosystem health. According to Barbosa et al. (2001) and Galdean et al. (2000), the taxonomic composition and community structure also offer important information for these assessments, starting from the biological knowledge of nutritional requirements, utilization of available trophic resources and relationships with the diversity of available habitats.

The taxonomic richness values of benthic macroinvertebrates found in the first two years of Brazilian LTER Program are lower than those found during the period of 1993-1995 in this same region using the same sampling efforts (Barbosa et al., 1997). This fact may suggest some changes in the structure of benthic communities that are probably associated with the continuous degradation process of the middle Doce River sub-basins.

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