Environ Monit Assess (2009) 157:305–318
DOI 10.1007/s10661-008-0536-7

Benthic communities of streams related to different land uses in a hydrographic basin in southern Brazil

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Received: 4 March 2008 / Accepted: 11 September 2008 / Published online: 9 October 2008

Abstract Different land uses affect the characteristics of a hydrographic basin, reflected in the river water quality, and consequently affecting the aquatic biota. The benthic community closely reflects the alterations caused by different human activities. In this study, the effects of different land uses were evaluated by analysis of the benthic community structure in streams with urban, agricultural and pasturage influences, as well as areas in better-conserved regions. The abiotic parameters showed distinct seasonal variability, which did not occur with the benthic organisms. A degradation gradient was observed among the study sites, in the headwaters–agriculture–pasture–urban direction. By the CCA its possible to observe that the density of organisms tended to increase along this gradient, whereas richness, diversity, evenness, and EPT families decreased. The most intense effects of land use on the benthic community composition, richness, and diversity were observed in urban areas ($F_{1,4} = 16.0$, $p = 0.01$; $F_{1,4} = 8.97$, $p = 0.04$; respectively). In conclusion a trend in the benthic community is observed in to predict alterations caused for the different land uses, mainly, when the source point pollution, as the case of urban area.

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Keywords Bioindicators · Biomonitoring · Benthic macroinvertebrates · Environmental quality · Water quality

Introduction

Different land uses affect the characteristics of a hydrographic basin, reflected in hydrological characteristics, substratum availability and water quality of the rivers thus impacting the aquatic biota. Residues generated by human activities and launching in hydric bodies caused an expressive decrease in the native species (Smith and Lamp 2008). Human activities provide the residues discharged into the watercourses, causing changes in the dissolved-oxygen concentration, increase in organic matter and nutrient concentrations, and altering electrical conductivity and pH (Zalidis et al. 2002; Moreno et al. 2006; Macgregor and Warren 2006).

The occurrence and distribution of the benthic macroinvertebrates in aquatic ecosystems depend on innumerable factors, such as: hydrological characteristics (Braccia and Voshell 2006), substrate type (Buss et al. 2004), availability of habitats (Stewart et al. 2000), physical and chemical characteristics of the water (Buss et al. 2002; Silveira et al. 2006), nutrient (Niyogi et al. 2007), metal concentrations (Rhea et al. 2006), riparian vegetation removal (Roy et al. 2003), hydroelectric production (Camargo and Voelz 1998), and biological interactions (Tomanova et al. 2006), among others. Several investigators have used benthic macroinvertebrates as indicators of different land uses in different hydrographic basins. In these studies, the macroinvertebrate communities revealed as good bioindicators of urban (Bunn et al. 1999; Roy et al. 2003), agricultural (Niyogi et al. 2007; Molozzi et al. 2007), and pasture use (Braccia and Voshell 2006), as well as impacts of different land use intensities were shown (Stewart et al. 2000).

The effects caused by pollution sources provoke alterations in the benthic communities. In general way occurs a reduction in the abundance and in the number of sensible species, and an increase in the abundance of tolerant organisms to the pollution (Megan et al. 2007). Metrics that reflect the biological diversity and population size can be used in the evaluation of water quality (Bacey and Spurlock 2007). Hepp and Restello (2007) commented that density, species richness, diversity, and evenness of the macroinvertebrate community are efficient parameters to measure the water quality, making possible a soundly based analysis of the environmental conditions. Aquatic communities associates with urban and pasture regions are characterized by diversity and complexity trophic low (Dauer et al. 2000). The biological interactions between the organisms and the environment, mainly in respect to the functional feeding groups, are also important for the dynamics of macroinvertebrate communities (Tomanova et al. 2006). Currently, the use of macroinvertebrates is accepted as a measure of evaluation point and non-point impacts in hydric bodies (Karr and Chu 2000).

In South of Brazil, the intensive practical of pasture, agriculture and urban activities provoke the degradation of great extensions of hydric bodies, either for the removal of the riparian vegetation, wetlands draining or for the launching of chemical residues, being necessary urgent measures of hydric bodies restoration. The use of bioindicators organisms still is incipient in Brazil, especially in the Neotropical region, becoming important the accomplishment of studies that showed the knowledge of ecological standards for aquatic ecosystems making possible the implantation of biomonitoring programs (Roque et al. 2003). However, in Neotropical region of the Brazil, few studies have dealt with understanding of the benthic community behavior in relation to the different land uses in a particular hydrographic basin. The objective of this study was to evaluate the benthic macroinvertebrate community structure in the River Jacutinga hydrographic basin in relation to the different land uses in this basin, testing the hypothesis that the benthic community will go to answer in differentiated way to the impacts caused for the pasture, agriculture and urban activities in comparison the regions with absence of anthropogenic disturbances.

Materials and methods

Study sites

The study area is situated in the Alto Uruguai region in northern Rio Grande do Sul, in Jacutinga (Southern Brazil). The total area of the region is 179 km^2 (27°40′52″ and 27°53′07″ S; 52°38′48″ and 52°27′23″ W) (Fig. 1). The mean altitude of the area is 650 m. The climate is subtropical, with temperatures ranging from 0°C to 38°C, with annual mean of 18°C and mean annual precipitation of 2,300 mm (Scariot and Zanin 2005). The local economy is based almost entirely on farming (about 55% of the basin area), with soy culture in the summer and wheat culture in the winter as well as pastures (about 30% of the area) for the creation of dairy and beef cattle (Scariot and Zanin 2005). The hydrographic basin of the Jacutinga River has an area of approximately 56.6 km^2, only about 5% of which is still covered by native vegetation. The hydrographic basin have stretches of first to third order, with

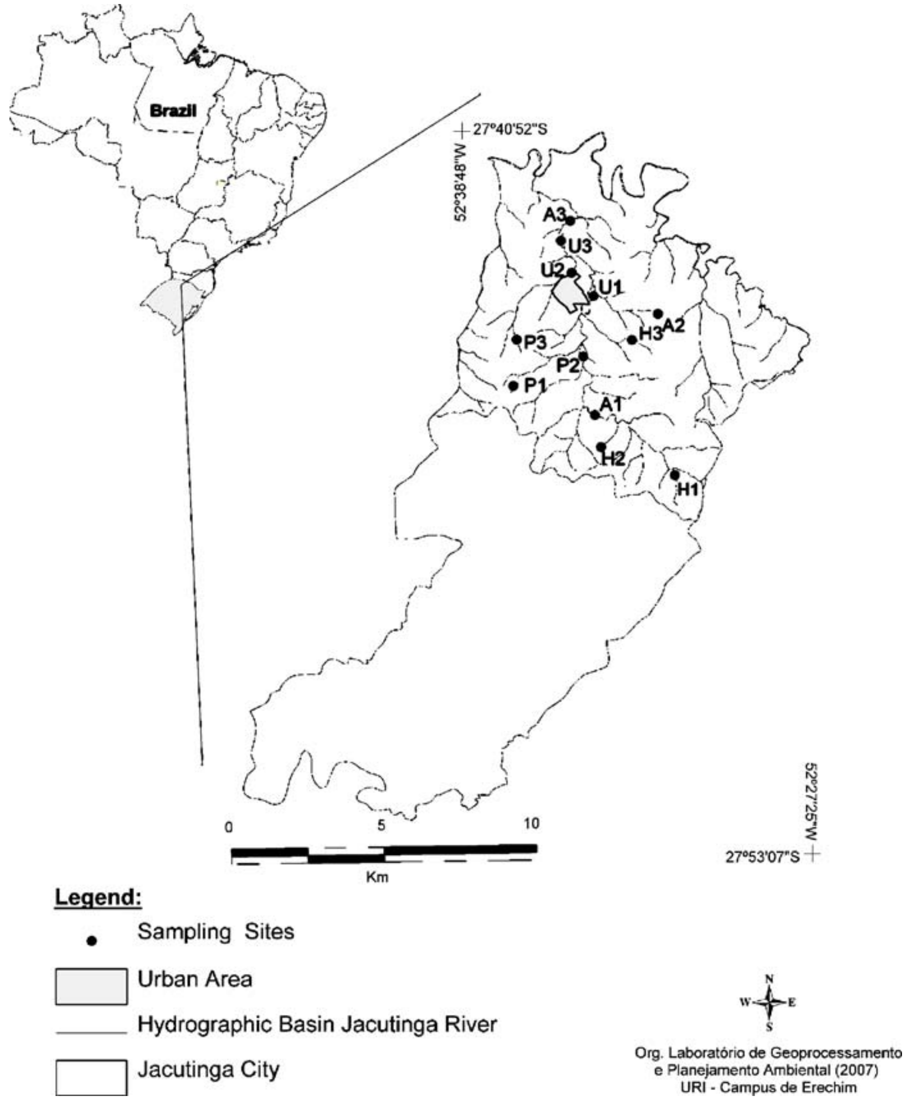

Fig. 1 Location of the hydrographic basin of the Jacutinga River (Jacutinga, RS) and distribution of the sampling sites

depth that oscillates between the 0.05 and 0.40 m and the annual flow oscillating between 1.58 and 2.70 $m^{-3}\ s^{-1}$.

Benthic macroinvertebrates

Samples were collected in the summer (January) and winter (July) of 2004 at 12 sites in the hydrographic basin. The stretches classification in accordance with the land use was defined by the analysis of topographical map and satellite images (Landsat-7 ETM 2002) and later observations in field. In the stretches, it was considered land use the locals with more than 70% of covering land proposed. The locations of the sites were chosen to reflect different land uses. For each land use, three sampling sites were defined considering the morphological homogeneity of the sites: headwaters, agriculture, pastures, or urban areas (Table 1, Fig. 1). The benthic macroinvertebrates were collected with a Surber sampler, with a 0.1 m^2 area and 250 μm mesh net. At each sampling site, 10 pseudo-replicates were collected, with different types of substrates (e.g. stones, litter, sand), totaling 1 m^2 in area for the site. The material was fixed in the field with 10% formalin and taken to the laboratory, washed in 2.0; 1.0; 0.5 and 0.25 mm meshes

Table 1 Morphological characteristics of the sampling sites in the hydrographic basin of Jacutinga River (Jacutinga, RS, South Brazil)

Sampling sites	Land use	Geographic coordinates (UTM)	Altitude (m)	Depth (m) (summer–winter)	Flow (m s^{-1}) (summer–winter)
H1	Headwaters	0350750/6927177	635	0.28–0.21	0.50–0.41
H2	Headwaters	0349570/6926168	764	0.06–0.05	0.29–0.52
H3	Headwaters	0348912/6931095	545	0.09–0.26	0.25–0.28
A1	Agriculture	0349496/6927772	596	0.14–0.14	0.84–0.51
A2	Agriculture	0351284/6931219	619	0.05–0.06	0.11–0.17
A3	Agriculture	0348208/6933828	554	0.25–0.27	0.90–0.88
P1	Pasture	0346917/6929128	657	0.05–0.05	0.53–0.47
P2	Pasture	0349242/6929111	576	0.16–0.12	0.75–0.90
P3	Pasture	0346460/6930311	641	0.03–0.08	0.38–0.48
U1	Urban	0348919/6931450	543	0.24–0.33	0.86–0.95
U2	Urban	0664630/6898581	639	0.09–0.13	0.74–0.48
U3	Urban	0348995/6932855	547	0.17–0.19	0.70–0.62

sieves. The specimens were later identified to the family level by means of Merritt and Cummins (1996), Bond-Buckup and Buckup (1999), Fernandez and Domingues (2001), Veitenheimer-Mendes and Silva (2004), and Costa et al. (2006). The organisms were identified following the recommendations of Dolédec et al. (2000), Melo (2005), and Corbi and Trivinho-Strixino (2006). The identified material was preserved in 80% ethanol and deposited in the Collection of Benthic Invertebrates of the Regional Museum of Alto Uruguai, Universidade Regional Integrada do Alto Uruguai e das Missões—Campus de Erechim.

Environmental variables

In the field, water temperature (°C) and dissolved oxygen (mg L^{-1}) were measured with YSI-55 Oximeter, electrical conductivity (μS cm^{-1}) with conductometer and pH with a JENCO pH meter. In the laboratory, the water samples were analyzed for several physical, chemical, and microbiological parameters: turbidity (NTU) with turbidimeter Policontrol AP2000, BOD (mg L^{-1}) by incubation of samples at 20°C for 5 days and titration Winkler method; ammonium ion (mg L^{-1}) with Nessler method and spectrophotometer lecture 630 nm, nitrite ion (mg L^{-1}) with *N*-(1-naphthyl)-ethylene-diamine dihydrocloride and lecture 543 nm, and total phosphorus concentrations (mg L^{-1}) with ascorbic acid reaction and lecture 880 nm by the spectrophotometric method; calcium (mg L^{-1}) and magnesium concentrations (mg L^{-1}) by atomic absorption spectrophotometer; and thermotolerant coliforms by incubation of the samples in VRB Agar at 44.5°C for 48 h. The methods used are in accordance with Standard Methods (APHA 1998).

Data analysis

To analyze the benthic community, the total density of organisms (ind m^{-2}), density of Chironomidae, density of Ephemeroptera, Plecoptera and Trichoptera (EPT) organisms, number of EPT families, and taxonomic richness, represented by the number of identified families, were estimated. Shannon's diversity index and Pielou's evenness index (Magurran 2004) were calculated. To evaluate the difference among density, taxonomic richness, diversity Shannon's, and Evensess and the different land uses, as well as the seasonal variations in macroinvertebrate communities, an ANOVA was used ($p < 0.05$) (Gotelli and Ellison 2004). To evaluate the benthic fauna variability in relation to the seasons (temporal) and among the locals with different land use (spatial) it was utilized a multivariate analyze of variance (MANOVA; Pillar and Orloci 1996). A grouping analysis was performed by the UPGMA technique, using the Bray–Curtis coefficient for the evaluation of the similarity between the sampling sites and the different land uses. To evaluate the variation of macroinvertebrates community explained for the environmental variables studied, it was applied the canonical correspondence analysis (CCA). For this analyze the values of the organisms density, Chironomidae density, EPT density, EPT families, taxonomic richness, Shannon's diversity and evenness was utilized. An analysis was made with the mean values of the abiotic parameters measured, and also one with the values of organism density, normalized by logarithmic transformation [$y = \log(x + 1)$]. The statistical analyses were conducted using Software R (R Development Core Team 2006) and MVSP 3.1 (Kovach Computing Services 2000).

Results

Environmental variables

Grouping the data of the studied areas and evaluating the seasonal variation, water temperature ($F_{1,22} = 62.9$; $p = 0.0001$), turbidity ($F_{1,22} = 9.72$; $p = 0.005$), pH ($F_{1,22} = 11.8$; $p = 0.002$), total phosphorus ($F_{1,22} = 5.62$; $p = 0.02$), calcium ($F_{1,22} = 12.78$; $p = 0.002$), and magnesium ($F_{1,22} = 5.86$; $p = 0.02$) showed significant differences between summer and winter. The other parameters were similar in the two seasons ($p > 0.05$). The water temperature, pH, and phosphorus were higher in summer. Turbidity, calcium, and magnesium showed higher mean values in winter (Table 2).

The electrical conductivity, with mean values lower than 90 μS cm^{-1}, increased from the headwaters toward the estuary. The DO was always higher than 5 mg L^{-1}. Conductivity behaved inversely, with the lowest concentrations recorded in the urban perimeter (5.26 ± 2.46 mg L^{-1}). The BOD and thermotolerant coliforms increased near the urban perimeter; however, contamination by these microorganisms occurred in all the locations studied. Only nitrite and ammonia concentrations showed significant differences ($F_{3,20} = 3.83$; $p = 0.02$ and $F_{3,20} = 4.29$; $p = 0.01$ respectively), when analyzed on the spatial scale, considering the different land uses. The mean values for these parameters were the highest in urban, pasture, and agricultural areas (Table 2).

Table 2 Average values and standard deviation of the abiotic parameters measured in the Hydrographic Basin of Jacutinga River (Jacutinga, RS) at sites with different land uses in summer and winter of 2004

Parameters	Land uses							
	Headwater		Agriculture		Pasture		Urban	
	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter
Temperature (°C)	21.24 ± 2.33	15.78 ± 2.02	20.94 ± 0.86	16.62 ± 0.94	22.33 ± 1.54	17.13 ± 0.95	23.51 ± 1.60	17.72 ± 1.51
Conductivity	56.32 ± 16.31	56.82 ± 14.14	51.82 ± 13.35	57.30 ± 12.71	61.08 ± 20.96	58.66 ± 9.28	64.52 ± 20.00	70.83 ± 3.39
Turbidity (NTU)	4.67 ± 1.71	6.36 ± 2.35	6.93 ± 0.88	8.25 ± 3.31	5.98 ± 1.21	13.20 ± 4.21	6.48 ± 0.68	10.34 ± 1.24
pH	7.57 ± 0.30	6.85 ± 0.43	7.19 ± 0.53	6.85 ± 0.87	7.31 ± 0.34	6.51 ± 0.21	6.91 ± 0.27	6.04 ± 0.24
DO (mg L^{-1})	9.15 ± 1.56	8.70 ± 0.53	8.16 ± 1.76	6.93 ± 3.34	7.37 ± 1.07	7.40 ± 1.90	7.85 ± 0.16	5.26 ± 2.46
BOD (mg L^{-1})	4.80 ± 1.85	5.72 ± 2.25	4.44 ± 0.95	8.81 ± 9.54	3.79 ± 1.13	3.39 ± 1.56	5.00 ± 1.05	14.36 ± 9.36
Nitrite (mg L^{-1})	0.134 ± 0.032	0.200 ± 0.041	0.228 ± 0.089	0.262 ± 0.135	0.241 ± 0.083	0.306 ± 0.068	0.533 ± 0.558	0.516 ± 0.124
Ammonium (mg L^{-1})	0.000 ± 0.000	0.039 ± 0.015	0.007 ± 0.009	0.035 ± 0.032	0.013 ± 0.022	0.023 ± 0.026	0.068 ± 0.047	0.080 ± 0.061
Phosphorous (mg L^{-1})	0.130 ± 0.116	0.008 ± 0.001	0.184 ± 0.045	0.007 ± 0.001	0.122 ± 0.094	0.008 ± 0.003	0.456 ± 0.640	0.008 ± 0.003
Calcium (mg L^{-1})	4.893 ± 1.436	6.243 ± 1.602	4.563 ± 0.562	6.870 ± 1.710	5.254 ± 1.876	6.530 ± 1.025	5.434 ± 1.287	7.979 ± 0.813
Magnesium (mg L^{-1})	3.172 ± 0.812	3.802 ± 1.002	3.041 ± 0.475	4.029 ± 1.462	3.554 ± 1.157	4.440 ± 1.258	3.387 ± 0.667	4.486 ± 1.003
Coliforms (logUFC mL^{-1})	1.27 ± 1.01	1.68 ± 1.55	1.81 ± 1.50	1.89 ± 0.55	1.15 ± 0.93	2.50 ± 0.88	3.01 ± 1.11	2.86 ± 0.55

For the cluster analysis, it was possible to observe the formation of groups in regard to seasonal particularities. One group was constituted by the sites of the four study areas, in summer; another group was formed by the headwaters, agriculture, and pasture sites in winter. The urban sites were isolated in winter (Fig. 2). In both sampling periods, the headwater and agricultural sites were similar; and urban and pasture sites were more similar to each other.

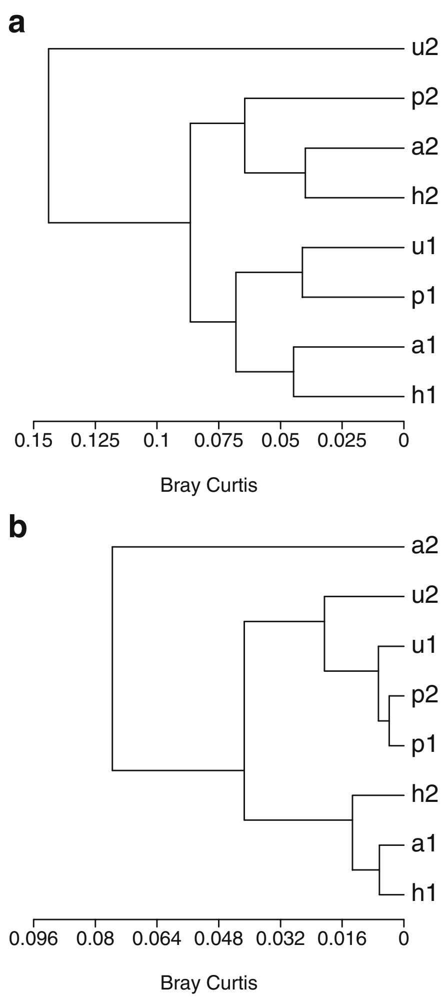

Fig. 2 Dendrograms based on abiotic variables (**a**) and macroinvertebrate densities (**b**) measured in areas with different land uses in the hydrographic basin of the Jacutinga River (Jacutinga, RS), using Bray–Curtis index of similarity. *h* headwaters, *a* agriculture, *p* pastures, *u* urban, 1 summer, 2 winter

Benthic macroinvertebrates

During the study period, a total of 22,285 organisms were collected: 12,251 in summer and 10,034 in winter. Chironomidae, Simuliidae (Diptera) and Baetidae (Ephemeroptera) were the most abundant families. Chironomidae were the most frequent in the sites from the urban perimeter. Simuliidae were more common in the headwater sites, and Baetidae in pasture areas (Table 3). In total, 42 macroinvertebrate families were identified, representing Oligochaeta, Hyrudinea, Gastropoda, Bivalvia, Crustacea, and Insecta. The MANOVA showed a variation between the benthic macroinvertebrates composition in summer and winter of 2004 ($p = 0.004$) and among the different land uses ($p = 0.02$). The fauna composition between headwaters and pastures in comparison to the urban areas were more significantly different ($p = 0.009$ and 0.02, respectively).

The macroinvertebrate density did not differ significantly between different land uses ($F_{3,20} = 2.39$; $p = 0.09$). However, density was the highest in the sampling sites located near the urban perimeter (Fig. 3). Taxonomic richness, represented by the number of families, and diversity were the greatest in the headwater areas and the lowest in the urban perimeter. No significant difference was observed between different land uses in regard to taxonomic richness ($F_{3,20} = 2.59$; $p = 0.08$), diversity ($F_{3,20} = 2.55$; $p = 0.08$), and evenness ($F_{3,20} = 1.63$; $p = 0.21$). However, there was a significant difference in taxonomic richness during the summer, when only urban and headwater sites were compared ($F_{1,4} = 16.0$; $p = 0.01$), as well as in the diversity of these same sites in the winter ($F_{1,4} = 8.97$; $p = 0.04$) (Fig. 3). The sampling sites located in agricultural and pasture areas showed similar values of taxonomic richness, diversity, and evenness. Macroinvertebrate density was the lowest in the agricultural areas. The number of Ephemeroptera, Plecoptera, and Trichoptera (EPT) families decreased along the headwater–agricultural–pasture–urban gradient, however without significant differences ($p > 0.05$). There was a difference between the seasons ($F_{1,22} = 4.63$; $p = 0.04$); the number of families collected was the lowest in winter (Fig. 3).

Table 3 Values of absolute densities (ind m^{-2}) of benthic macroinvertebrates collected in the hydrographic basin of Jacutinga River (Jacutinga, RS) at sites with different land uses in summer (S) and winter (W) of 2004

Family	Land uses							
	Headwater		Agriculture		Pasture		Urban	
	S	W	S	W	S	W	S	W
Lumbriculidae	1	61	14	25	6	18	125	269
Naididae		1			1			15
Tubificidae				2	2	4	4	34
Erpobdellidae		1	3		1			152
Hirudinidae		10	4	1				141
Glossiphonidae			4	1	6			20
Ancylidae					1	6		287
Bithyniidae						2		
Lymnaeidae	4	2		150	2	4		
Physidae								3
Planorbidae	1	1				19		3
Viviparidae	12	14	11		23	289	4	1
Corbiculidae	2	9	8	55	92	287		
Aeglidae	13	35	14	13	38	9	4	2
Hypogastruridae	1		1	3	7			40
Isotomidae		4				36		
Poduridae	2							
Elmidae	164	305	115	78	73	129	69	14
Hidrophillidae	6							
Psephenidae	62	27	4	1	1			
Chironomidae	752	726	845	395	1,127	2,160	2,378	2,013
Empididae	16		4		4	4	13	
Simuliidae	359	84	534	107	1,130	147	813	18
Tabanidae	2	7	9	15	2			
Tipulidae	5		3	7		1	6	
Baetidae	163	168	283	107	427	582	183	108
Caenidae	29	30	25	15	10	268	2	1
Leptophlebiidae	118	63	179	3	305	5	360	
Leptohyphidae	5	5	17	21	14	11	7	
Corydalidae	2	2	4	1	2	2	3	1
Coenagrionidae	30	33	5	5	9	22		3
Calopterygidae		2						
Cordulidae		7				2		
Gomphidae		3	1		1			
Lestidae	9							
Libellulidae	1							
Perlidae	2	3						
Hidrobiosidae	3							
Hydroptilidae	20	2	100	8	33	11	4	1
Hydropsychidae	367	33	78	18	112	96	202	48
Leptoceridae	11	5		1	1			
Philopotamidae	25	22	67	17	50	31	75	1

The cluster analysis for the density data indicated the formation of three distinct groups (Fig. 2) as a function of different land uses. The sites located in the headwater and agricultural areas (summer) formed one group; the sites in pastures and urban areas formed another group; and a final group was formed by the agricultural area in winter, which was isolated from the other

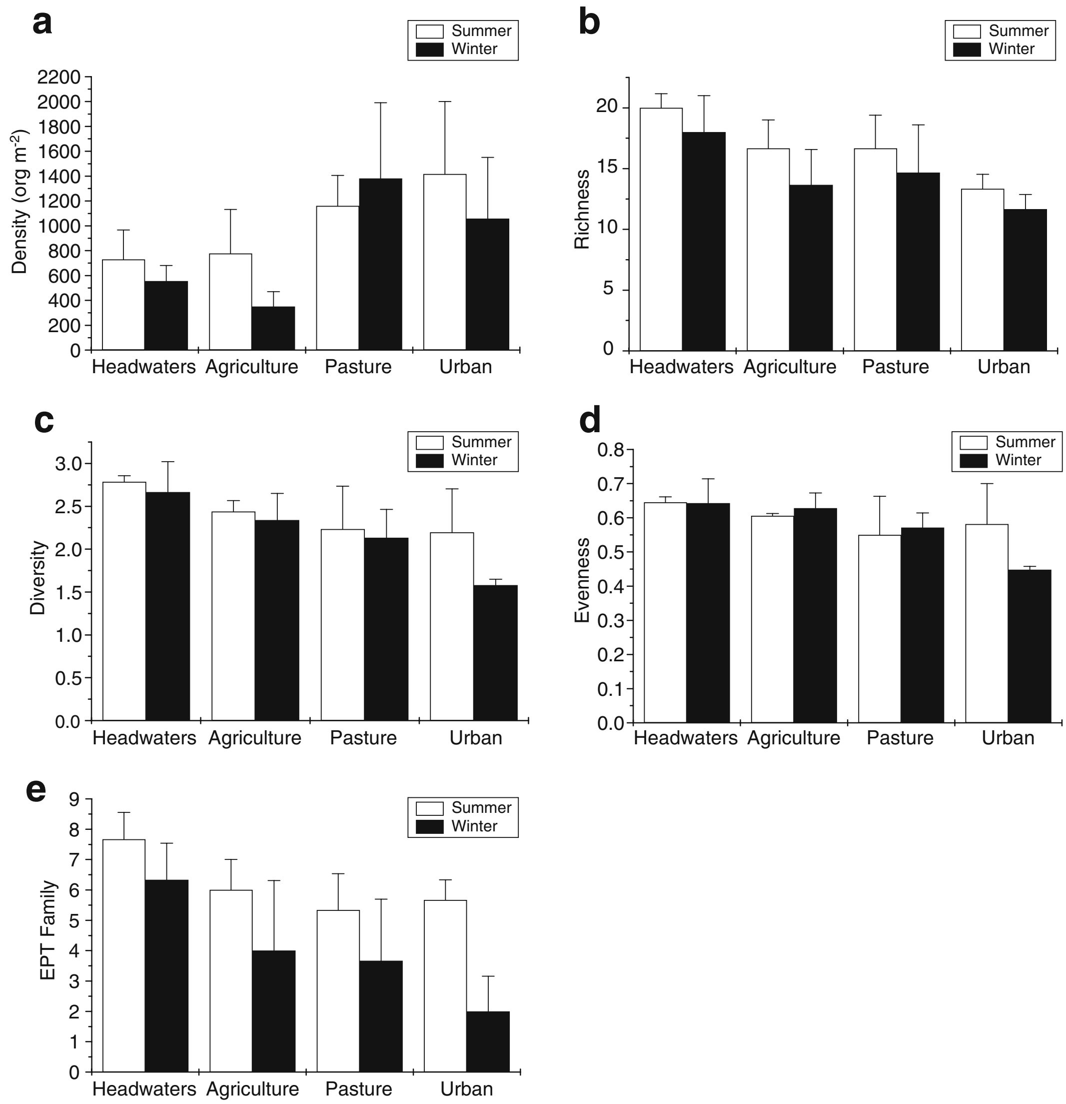

Fig. 3 Average values and standard deviation of density (ind m^{-2}) (**a**), taxonomic richness (**b**), Shannon's diversity index (**c**), evenness (**d**), and EPT families (**e**) collected in areas with different land uses in the hydrographic basin of Jacutinga River (Jacutinga, RS) in summer and winter of 2004

sites. The pasture areas, in both sampling periods, showed the greatest similarity.

The explanation of the first two axes determined by CCA was 52.2% of the data variation. The first axis explained 51.6%, while the second axis explained only 4.6% of the variation (Table 4). The eigenvalues for the first two axes was 0.123 and 0.011, respectively (Table 4). Organisms density, EPT density, number of EPT families, taxonomic richness, Shannon's diversity and evenness showed positive correlation with the first axis as well as pH, DO and phosphorus and the sites situated in headwaters. The Chironomidae density and the others environmental variables showed negative correlation with the first axis, either the sites situated in pasture and urban areas, mainly (Fig. 4). Turbidity, ammonia concentration, and thermotolerants coliforms was the variables that most affects the benthic community.

Table 4 Summary of canonical correspondence analyses (CCA): eigenvalues, variance percentage, species–environment correlations for the first two axes, and total inertia

	Axes 1	Axes 2
Eigenvalues	0.123	0.011
Percentage	51.591	4.596
Species–environment correlations	0.769	0.616
Total inertia	0.133	

Discussion

The ecological conditions of the streams are strong related to the terrestrial landscape. The anthropic modifications that occur in the hydrographic basin are concentrated in the removal of the vegetation that amongst other causes provoke modifications in the land geologic structure, facilitating the nutrients input to the hydric body (Vondracek et al. 2005). The physical and chemical characteristics of the water are directly affected by different land uses, in addition to the climatic and geological conditions of a region (Stewart et al. 2000; Moreno et al. 2006).

The land use showed important correlation with the environmental variables. Temperature, conductivity, and turbidity have negative correlation with natural areas, being positively correlated with the increase of urban, industrial, and agriculture residues (Stewart et al. 2000). Urban residues are rich in organic matter, which causes chemical and biochemical reactions that result in high oxygen consumption and a decrease in pH, and consequently increases in the nutrient content and BOD, showing toxicity that affects the biota (Allan 1995; Brigante and Espínola 2003; Ometto et al. 2004; Salomoni et al. 2007). In this study, we observed highest concentration of ammonia ion and nitrite in locals near for the urban perimeter. The increase in electrical conductivity at the sites near the urban perimeter. Bacey and Spurlock (2007) commented that the conductivity have a negative correlation with the benthic community composition, showing that the number of EPT families decrease significantly with the increment of this variable values. This results corroborates with this study, where its possible to observe by the CCA a negative correlation with number of EPT families and exists a negative correlation with the others biological metrics analyzed (except for the Chironomidae density).

The observed seasonal patterns point to the activities occurring throughout the basin during the year. The proximity of the sites located in headwaters and agricultural areas indicates the physical and chemical similarity between these areas. The Jacutinga River basin changes little in relief, which favors mechanized agriculture (Scariot and Zanin 2005). However, the isolation of the urban site in winter can be attributed to the higher BOD in this season, which contributed to a greater difference of this location in relation to the others (Table 1).

The modifications in the environmental characteristics provoked by the land uses cause negative effects about of 60% in the macroinvertebrates community (Vondracek et al. 2005). The benthic community reflected the different land uses in the Jacutinga River basin. Although not statistically significant, but the trend in the decrease in taxonomic richness, diversity, evenness and sensible organisms (EPT) in the studied locations was evident. However, the composition of the benthic community revealed influenced by the land uses. The stretches in the urban perimeter had presented significant differences when compared with headwaters and pastures areas. In accordance with Smith and Lamp (2008) the urbanization reduce the habitats richness and consequently the aquatic insects richness and the unique species in streams of small order (<3rd to order), as it is the case of urban stretches in Jacutinga River. In these places, occurs an increase of more tolerant organisms (Molozzi et al. 2007). Bacey and Spurlock (2007) had observed alterations in the benthic community, mainly Plecoptera, in urban and agricultural regions, as in this study, where Perlidae was only registered in headwaters areas. Buss et al. (2002) comment that a degradation gradient contributes for the reduction of taxonomic richness and to the exclusion of intolerants species to the pollution. The absence of riparian vegetation, for example, affects drainage conditions, leads to greater input of sediments and toxic substances into the watercourse, and reduces the entrance of allochthonous plant material (Stewart et al. 2000; Rios and Bailey 2006). The riparian vegetation is basic for the maintenance of the flu-

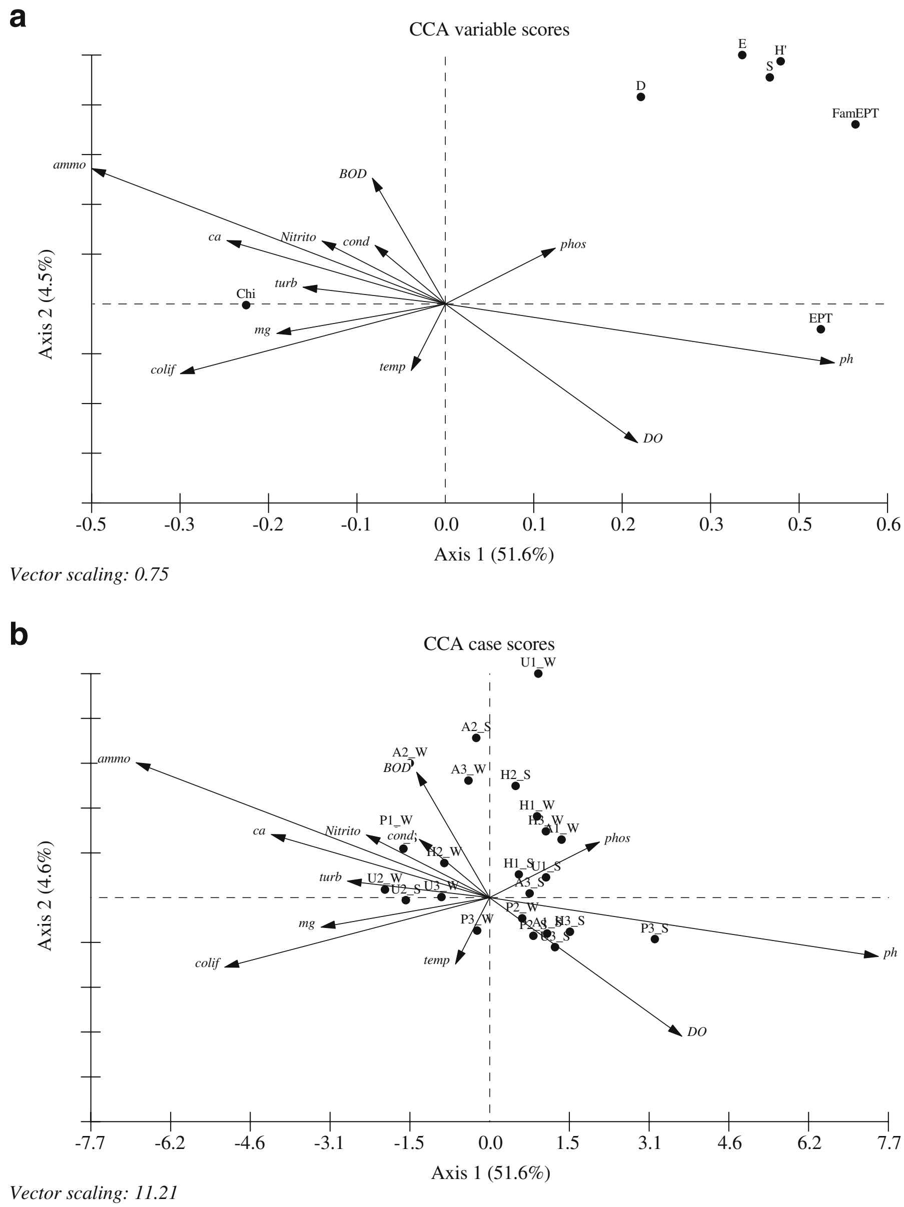

Fig. 4 Ordination diagram based in biological and environmental variables (**a**) in the 12 sites of sample (**b**) in the Jacuting River hydrographic basin. Biotic variables: *D* density, *S* richness, *H′* Shannon diversity, *E* evenness, *Chi* Chironomidae density, *FamEPT* EPT families; abiotic variables: *temp* water temperature, *cond* conductivity, *turb* turbidity, *ph* pH, DO, *ammo* ammonia, *Nitrito* nitrite, *phos* phosphorus, *colif* coliforms, *ca* calcium, *mg* magnesium; sampling sites: *H* headwaters, *A* agriculture, *P* pastures, *U* urban, *S* summer, *W* winter

vial structure. Places with vegetation possess EPT insects abundance high superior than the pasture areas (Nessimian et al. 2008). In rice culture areas the reduction of taxonomic richness, in special EPT, is caused by the removal of the vegetation that facilitates the sediments input and habitats homogeneity (Molozzi et al. 2007). Areas with riparian vegetation were important to the nutrients retention and transformation (Niyogi et al. 2007) and they were associated to the increase in the organism richness (Roque et al. 2003; Molozzi et al. 2007).

The site with the smallest human impact (headwaters) contained the lowest organism density, and the highest taxonomic richness, diversity, and evenness. Hepp and Restello (2007) commented that this community pattern is common in areas with differentiated land uses in a hydrographic basin. In other hand modifications in the water physical and chemical characteristics (e.g. conductivity and turbidity increment, DO and pH reduction), become more easy the occurrence of tolerant organisms. This results in increase in density and in reduction in species richness and consequently lead to decrease in diversity and evenness of the community, which serves as a good indicator of impacts in a drainage basin. According to Lenat and Crawford (1994), places with vegetation present greater densities of Diptera and Trichoptera, however, in urban and agricultural regions, the density of Diptera increases in three times more.

The differences observed between richness and diversity at the headwater sites and the urban perimeter are explained, probably, by the increase in the input of organic matter and nutrients, causing a reduction of DO and consequent reduction of macroinvertebrate diversity (Roy et al. 2003). Roque et al. (2003) noted that there is a spatial difference in macroinvertebrate distribution between locations with riparian vegetation and other types of land use. Benthic macroinvertebrate communities in streams in forested areas are richer and less abundant than in streams in areas with other land uses characteristic of human activities. Macroinvertebrate diversity also decreases significantly in watercourses near locations with intense human activity (Ometto et al. 2004).

Most of the families were present in all the sites in the hydrographic basin, with the Chironomidae predominating. Some genera of this family, especially *Chironomus*, can easily tolerate adverse conditions, resulting mainly from high organic-matter input (Marques et al. 1999). In places with the highest concentration of organic matter, the dominance of Chironomidae is evident, because of this opportunism (Kleine and Trivinho-Strixino 2005). Buckup et al. (2007) observed a similar situation of Chironomidae predominance in an area with environmental stress caused by effluents from a small city. Members of Elmidae (Coleoptera) were present at all the sites in summer, together with Simuliidae and Hydropsychidae (Trichoptera). This heterogeneity in distribution can be explained by the differences in the abiotic components, among the sampling sites and periods (Ramirez and Pringle 2001; Buss et al. 2004). The characteristic locations for the impact of the organic residues (urban and pastures) showed the greatest densities of Chironomidae, Hyrudinidae, Tubificidae, and Ancylidae.

Insects of the orders Ephemeroptera, Plecoptera, and Trichoptera (EPT) are useful indicators of good water quality (Bueno et al. 2003; Buckup et al. 2007), because of their great sensitivity to environmental impacts (Rosemberg and Resh 1993). In this study, the number of EPT families decreased at sites with the highest impact (agricultural, pastures, and urban), possibly because of the higher nutrient concentrations, conductivity and turbidity, and lower DO. Niyogi et al. (2007), in streams in New Zealand, observed a decrease in the richness of EPT in locations with higher nutrient concentrations and fine-particle concentrations, associated with pasture areas. Lenat and Crawford (1994) described a reduction of the fauna of less-tolerant organisms (EPT) in agricultural regions of the USA. Buss et al. (2002) observed a similar response in a study in southeastern Brazil. Roy et al. (2003), evaluating the urban impact on benthic fauna in the USA, observed a significant reduction in the EPT richness in streams with urban influence. Lenat and Crawford (1994) cite that in urban areas the EPT fauna reduces in about 80%. On the other hand, at locations in headwater areas, the EPT fauna was the richest, due to the presence of riparian vegetation and habitat diversity. Stretches with greater vegetal covering provoke an increment of EPT richness and other *taxa* sensible to the disturbances. Rios and Bailey (2006). According to Locke et al. (2006) the EPT density is high in tributaries with high vegetal covering. The occurrence of Perlidae and Leptophlebiidae is strongly associated with these locations (Buckup et al. 2007), corroborating their low tolerance for adverse situations.

Point sources of pollution (e.g. urban and industrial) generally present greaters effect on the aquatic community than the no-point sources (e.g. pasture and agriculture) (Locke et al. 2006). According to Megan et al. (2007) studies have demonstrated that macroinvertebrate are very sensible to the immediate impacts caused by point sources. This corroborates the results of this study, where the urban effect had been very significant, causing alterations in the structure and composition of the benthic fauna. The Jacutinga city possess less than 2,000 inhabitants, however, the absence of sewer systems treatment and the launching in the hydric body result in modifications in the ecological quality of the hydrographic basin.

Collectors, mainly represented by Chironomidae and Simuliidae, were always the most abundant. Their capacity for adaptation to disturbed locations contributes to their predominance in the community (Silveira et al. 2006). Predators and filterers showed similar distributions in the locations with different land uses. Scrapers were the least frequent FFG, sometimes even nonexistent. Similar situations were reported by Tomanova et al. (2006) and Buss et al. (2002), where collectors and filterers were the most abundant. Because the urban perimeter is located in the region of the basin estuary, the size of suspended particles was lowest, contributing to the highest frequency of collectors, corroborating Buss et al. (2002). Ometto et al. (2004) noted that the presence of scrapers is associated with rocky substrates, which support primary producers, thus constituting a resource for these organisms. The absence of shredders throughout the hydrographic basin calls attention to the poor state of conservation of the riparian vegetation. In the majority of the localities studied, with rare exceptions, the vegetation is limited to small shrubs and a few trees, not more than 3 m high. In studies in southeastern Brazil, the authors attributed the low percentage of shredders to the non-availability of allochthonous material, caused by vegetation removal (Buss et al. 2002; Silveira et al. 2006).

In conclusion a trend in the benthic community is observed in to predict alterations caused for the different land uses, mainly, when the source point pollution, as the case of urban area. Sample sites located near the urban perimeter showed significant changes in macroinvertebrate density, due to predominance of tolerant species. The CCA demonstrated negative correlation among taxonomic richness, diversity, evenness, EPT density and richness with environmental variables that indicated disturbances (e.g. conductivity, turbidity, nitrite and ammonia). This showed that exist a similarity among information from biological communities, independent of the region that they are (e.g. tropical and subtropical).

Acknowledgements The authors are especially grateful to the valuable comments and suggestions provided by Dr. Marcos Callisto (Instituto de Biologia da Universidade Federal de Minas Gerais), Dra. Edélti Albertoni (Fundação Universidade do Rio Grande), and Dr. Adriano Sanches Melo (Universidade Federal do Rio Grande do Sul). And to the Universidade Regional Integrada do Alto Uruguai e das Missões—Campus de Erechim for the financial support.

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