Distribution of benthic macroinvertebrates in Subtropical streams (Rio Grande do Sul, Brazil)

Distribuição de macroinvertebrados bentônicos em riachos Subtropicais (Rio Grande do Sul, Brasil)

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Abstract: Aim: The aim of this study was to evaluate the spatial and seasonal distribution of the benthic macroinvertebrates community in streams in the north region of Rio Grande do Sul State; **Methods:** The samplings were carried out in nine streams, in annual seasons. The organisms were collected with a Surber sampler (250 µm mesh; area: 0.1 m²). Environmental variables were measured to verify influences in the benthic community using a Canonical Correspondence Analysis. To evaluate the differences among communities, density, richness, diversity and evenness an ANOVA was used. To compare benthic fauna composition a MANOVA was used; **Results:** The environmental variables showed significant differences among the streams; however the seasons not differ. The density of organisms was significantly different among the streams and the diversity was different among the seasons. Richness and evenness not showed spatial-seasonal differences. The canonical correspondence analysis explained 67.4% of the data total variability. The main variables that influenced the benthic community were the nutrients contents, pH, electric conductivity and substrate organic matter; **Conclusions:** Streams with riparian vegetation and lower contents of dissolved nutrients showed higher richness of intolerant organisms to pollution. The results suggest that the distribution of benthic macroinvertebrates in the studies region was mainly related to anthropic activities developed in the catchment.

Keywords: environmental quality, lotic environmental, spatial distribution, seasonal distribution.

Resumo: Objetivo: O objetivo deste estudo foi avaliar a distribuição espacial e temporal da comunidade de macro-invertebrados bentônicos em riachos da região norte do Rio Grande do Sul; **Métodos:** As coletas foram realizadas em nove riachos, com periodicidade trimestral, compreendendo as quatro estações anuais. Os organismos foram amostrados com um coletor Surber (malha: 250 µm; área: 0,1 m²). Variáveis ambientais foram mensuradas para verificar possíveis influências sobre a comunidade bentônica, utilizadando uma Analise de Correspondência Canônica. Para avaliar diferenças entre a densidade, a riqueza, a diversidade e a equitabilidade, utilizou-se uma ANOVA. Para comparar a composição da fauna bentônica foi utilizada uma MANOVA; **Resultados:** A densidade de organismos foi significativamente diferente entre os riachos, enquanto que a diversidade foi significativamente diferente entre as estações do ano. Riqueza e equitabilidade não apresentaram diferenças significativas entre os riachos e entre as estações do ano. A análise de correspondência canônica explicou 67,4% da variabilidade total dos dados. As principais variáveis que influenciaram a comunidade bentônica foram os teores de matéria orgânica no substrato e nutrientes; **Conclusões:** Riachos com vegetação ripária e baixos teores de nutrientes dissolvidos apresentaram maior riqueza de organismos intolerantes à poluição. Os resultados sugerem que a distribuição dos macroinvertebrados bentônicos na região estudada está ligada principalmente a atividades antrópicas desenvolvidas na área de drenagem.

Palavra-chave: qualidade ambiental, ambiente lótico, distribuição espacial, distribuição temporal.

1. Introduction

Benthic macroinvertebrates are an important component of aquatic communities; they have large distribution, being found in the sediment, in accumulated leaves, associates with macrophytes, between the rocks and therefore they interact with the environmental conditions (Moretti and Callisto, 2005; Würdig et al., 2007). These communities showed different distributions in the space and time that vary in accordance with the morphology and the water physical-chemical conditions (Pereira and De Luca, 2003; Silveira et al., 2006). In such a way, the benthic organisms are sensible to the habitat characteristics and substratum (Buss et al., 2004), water temperature (Camargo and Voelz, 1998), pH (Sandin and Johnson, 2004), electric conductivity (Buss et al., 2002), sedimentation (Smith and Lamp, 2008) and riparian vegetation (Silveira et al., 2006).

Anthropogenic activities in the hydrographic basin can cause the removal of marginal vegetation, decrease of the food availability and causing changes in the water quality (Biasi et al., 2008). These cause the extinction of the *taxa* intolerant, decreasing the richness and increasing dominant *taxa* (Smith and Lamp, 2008). According to Buss et al. (2004), streams physical factors create specific habitat conditions that offer food and shelter for aquatic biota. Streams affected by urban and agricultural activities showed changes that influence the quality and availability of resources and the ecological integrity, making alterations in the structure and composition of the benthic community (Buss et al., 2002; Hepp and Santos, 2009).

Few studies of spatial and seasonal distribution of the benthic macroinvertebrates community in streams in the north of Rio Grande do Sul were made. Studies on spatial and seasonal scale were carried out in lentic environments (Cenzano and Würdig, 2006) and in humid areas (Maltchik et al., 2006). In streams, studies were carried out involving functional feeding groups (Hepp and Santos, 2005; Ayres-Peres et al., 2006), community composition and structure (Bueno et al., 2003; Buckup et al., 2007; Biasi et al., 2008), macrophytes associated fauna (Albertoni et al., 2005), use of the benthic community in indices of quality (Pereira and De Luca 2003; König et al., 2008) and the influence of land uses (Hepp and Restello, 2007; Hepp and Santos, 2009). However, studies in hydrographic basins scale about the organisms distribution are scarce.

Thus, the aim of this study was to evaluate the distribution of the benthic macroinvertebrates community in streams located in Alto Uruguai region of the Rio Grande do Sul (spatial scale) in different periods of the year (temporal scale). This study wants to answer the following questions: (i) Does the benthic macroinvertebrate fauna composition and structure vary among the streams and/or seasons? (ii) What environmental variables does influence in the distribution of these communities?

2. Material and Methods

2.1. Study area

The study was carried out in Erechim (27° 37' 54" S and 52° 16' 52" W) situated in the north of Rio Grande do Sul, in the Alto Uruguai region. The region of municipality presents an area of 425.86 km^2. Erechim town are 768 m a.s.l.; the region presents subtropical climate with annual average temperature of 18.7 °C and pluviosity ranges from 1750 to 2000 mm (Rampazzo, 2003). The vegetation was Mixed Rain Forest and Semideciduos Subtropical Forest and the ground are characterized by basaltic origin (Cassol and Piran, 1975; Rampazzo, 2003).

For the study, sampling sites were selected, distributed in hydrographical basins with different land uses. Sites 1, 2, 3 and 4 are in streams of first order and are characterized by the absence of anthropogenic impacts, with forested edges and composed substratum by leaves and rocks. Sites 5, 6, 8 and 9 are in streams of third order, except site 5 that is of second order. These sites are located in an agricultural matrix and receive influence from the predominant activities. The vegetal covering is partially absent and the predominant substrata are mud and rock. Site 7 is distinct from the others (fourth order), is located near to a barrage of water reservoir, showed removal of riparian vegetation and mud predominance. The distribution of the sampling sites was shown in Figure 1.

2.2. Data collection

Collects were carried out in all the seasons of the year, beginning in September/06 (spring) to July/07 (winter). Five sub-samplings of macroinvertebrates were carried out in each site distributed random in 15 m intervals stretch. The organisms were collected using a Surber sampler with 250 µm mesh size and 0.1 m^2 area (Merritt and Cummins, 1996). The collected biological material was fixed in loco with 5% formalin, taken to the laboratory and washed in sieves to remove the organisms. The organisms were identified until the less possible taxonomic level, using identification keys of Merritt and Cummins (1996), Fernández and Domínguez (2001), Salles et al. (2004) and Costa et al. (2006).

Water samples were collected for the measurement of the following physical-chemical variables: electric conductivity and total dissolved solids (potenciometric method), turbidity (nephelometric method), ammonia (Nessler method), total phosphorous (ascorbic acid method) organic matter content (gravimetrical method) and biochemical oxygen demand (Winkler method with incubation of 20 °C per 5 days). The water temperature was determined with an oximeter (YSI55), the flow was measured by the product between the speed (measured with fluxometer) and the stretch area previously defined for the sampling, pH determined by potenciometric method and dissolved oxygen using an

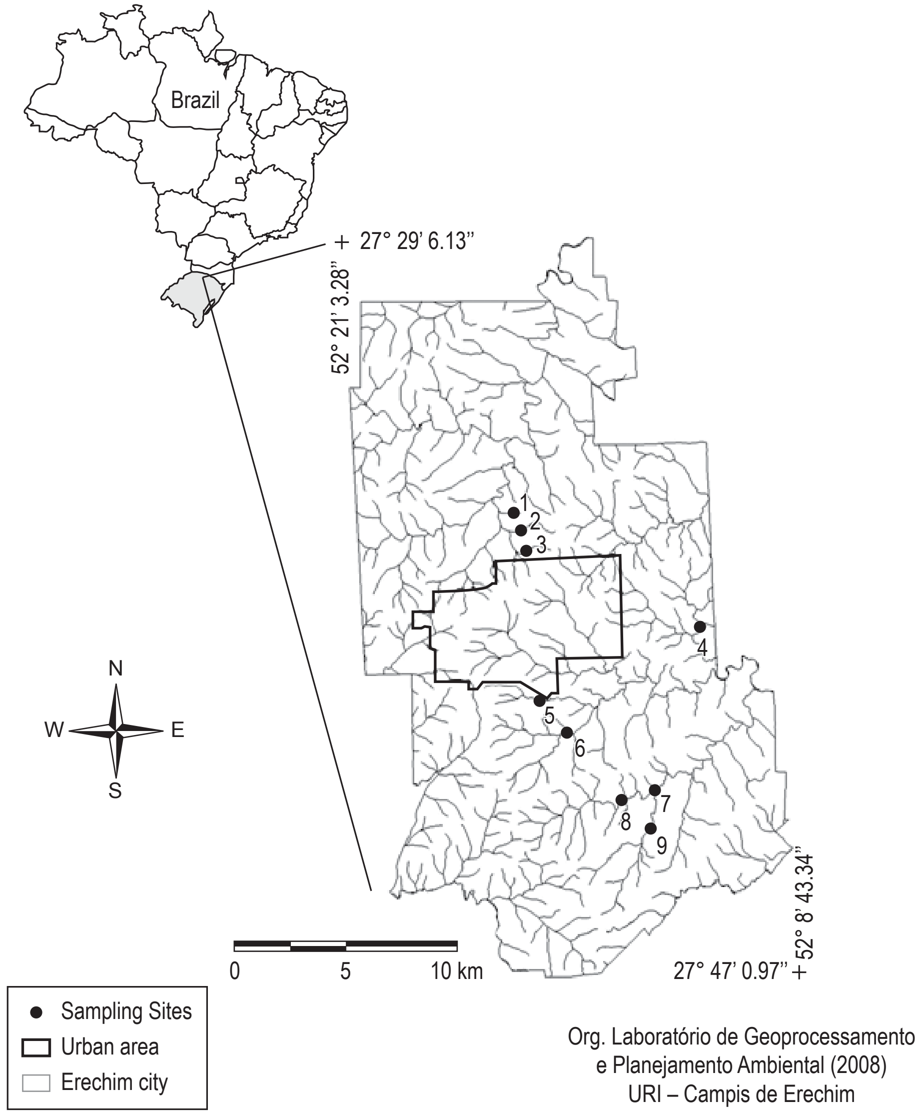

Figure 1. Sampling sites distribution of Erechim city and localization (Rio Grande do Sul, Brazil).

oxygen sensor (YSI55). The methods for the analyses of the variables are described in APHA (1998).

2.3. Data analyses

For the data evaluation, organisms density (ind.m^{-2}) and taxonomic richness were estimated. The indices of Shannon diversity and Pielou evenness were calculated (Magurran, 2004). The biological metrics variability between sampling sites and the seasons of the year was evaluated by the application an ANOVA one way (Gotelli and Elisson, 2004). The benthic community composition and the environmental variables were tested with a multivariate analysis of variance (MANOVA) using randomization tests (Pillar and Orlóci, 1996). The influence of the environmental variables on the benthic community distribution was tested with a Canonical Correspondence Analysis. For normalization, data of the biological matrix were transformed into log (x + 1).

3. Results

The environmental variables showed significant variability between the streams (MANOVA, SS = 3.94, p = 0.001) and without variations between the seasons of the year. The variables pH and dissolved oxygen not oscillated between the sampling sites. The pH values were near to 7 (6.12 and 7.07). Dissolved oxygen showed an average of 7.58 mg.L^{-1}. The nutrients ammonia and total phosphorous presented average values of 0.025 and 0.075 mg.L^{-1}, respectively. The organic matter percentage in the sediment was similar among the sampling sites, with exception of site 3, which presented a high value (59.8%) in relation to the others sites. The values of environmental variables are presented in Table 1.

The density of the community presented spatial differences (ANOVA, $F_{1,8}$ = 2.36, p < 0.001; Table 2). However, seasonally the density was similar (ANOVA, $F_{1,3}$ = 2.36,

Table 1. Average values (minimum-maximum) of environmental variables (n = 4), in the sampling sites located in Erechim - Rio Grande do Sul, 2006 and 2007.

Variables	P1	P2	P3	P4	P5	P6	P7	P8	P9
Average widht (m)	1.28 (0.60-2.20)	1.16 (0.70-1.40)	0.95 (0.45-1.90)	4.12 (3.90-4.40)	5.7 (5.20-6.50)	4.55 (4.20-4.60)	6.26 (2.58-4.45)	3.39 (2.10-2.85)	2.61 5.60-7.47)
Average depth (m)	0.06 (0.01-0.09)	0.09 (0.03-0.12)	0.06 (0.04-0.07)	0.13 (0.06-0.25)	0.10 (0.07-0.13)	0.11 (0.08-0.15)	0.22 (0.07-0.38)	0.18 (0.09-0.14)	0.12 (0.16-0.32)
Flow	0.020 (0.001-0.04)	0.017 (0.006-0.03)	0.013 (0-0.04)	1.383 (0.02-4.97)	0.204 (0.12-0.33)	0.292 (0.24-0.37)	0.580 (0.07-0.68)	0.263 (0.06-1.05)	0.372 (0.22-0.97)
Temperature (ºC)	18.10 (15.90-20.50)	18.18 (15.70-20.60)	17.57 (16.10-18.90)	18.30 (16.00-20.10)	18.60 (16.20-21.60)	18.27 (15.60-20.90)	18.65 (12.90-28.80)	20.34 (15.80-21.10)	19.22 (13.30-22.30)
Electric conductivity ($\mu S.cm^{-1}$)	69.04 (55.07-80.30)	70.27 (61.70-75.37)	51.13 (48.63-55.87)	70.42 (60.73-87.93)	38.92 (33.83-45.30)	46.80 (38.37-60.10)	68.12 (56.37-77.20)	65.79 (68.50-94.80)	79.48 (57.33-79.43)
Turbidity (NTU)	2.95 (2.77-3.16)	3.12 (1.19-6.40)	5.63 (1.72-8.67)	5.13 (2.51-10.5)	4.92 (3.76-6.56)	7.61 (5.29-9.87)	8.04 (4.49-6.89)	5.31 (5.80-8.46)	6.54 (5.70-13.20)
TDS ($mg.L^{-1}$)	47.89 (27.70-3.33)	48.26 (20.68-37.73)	34.15 (23.2-64.67)	38.79 (30.4-58.0)	23.51 (16.97-8.75)	32.76 (19.20-7.33)	34.34 (28.17-8.67)	37.95 (34.53-2.67)	53.61 (28.77-0.67)
pH	6.49 (5.74-7.31)	6.12 (5.34-6.94)	6.13 (5.60-6.58)	6.36 (5.91-7.07)	7.00 (5.86-8.19)	6.96 (5.92-7.65)	7.07 (4.76-7.49)	6.28 (5.04-7.88)	6.72 (6.51-7.83)
Dissolved oxigen ($mg.L^{-1}$)	7.19 (6.41-7.96)	7.53 (7.14-8.07)	7.62 (7.16-8.48)	7.46 (6.82-8.30)	7.51 (6.91-8.46)	7.59 (7.06-8.45)	7.37 (6.53-9.16)	7.89 (6.87-8.76)	7.99 (6.30-8.70)
Biochemical demand oxigen ($mg.L^{-1}$)	0.45 (0.34-0.61)	0.89 (0.48-1.17)	1.15 (0.78-1.86)	0.95 (0.53-1.41)	0.99 (0.35-1.52)	1.16 (0.64-1.68)	1.13 (0.77-2.41)	1.89 (0.98-2.86)	2.11 (0.41-1.61)
Amonniun ($mg.L^{-1}$)	0.012 (0.00-0.03)	0.023 (0.00-0.03)	0.023 (0.00-0.03)	0.022 (0.00-0.05)	0.024 (0.00-0.05)	0.026 (0.00-0.05)	0.037 (0.00-0.05)	0.028 (0.00-0.06)	0.035 (0.00-0.057)
Total Phosphorous ($mg.L^{-1}$)	0.057 (0.00-0.09)	0.059 (0.00-0.13)	0.064 (0.00-0.11)	0.076 (0.00-0.166)	0.065 (0.00-0.13)	0.212 (0.00-0.74)	0.056 (0.00-0.095)	0.042 (0.00-0.09)	0.040 (0.00-0.11)
Organic matter sediment (%)	10.42 (9.37-11.34)	12.72 (9.37-11.22)	59.82 (9.50-92.82)	14.92 (9.61-19.85)	15.64 (12.18-19.0)	10.07 (9.21-12.11)	11.32 (11.18-5.17)	12.44 (9.07-13.79)	11.10 (9.27-15.38)

Table 2. Total Density (ind.m^{-2}), *taxa* richness (number of *taxa*), Shannon diversity and Pielou Evenness indexes of benthic macroinvertebrates in streams in Erechim – Rio Grande do Sul, during the spring (Sp), summer (S), autumn (A) and winter (W) of 2006 and 2007.

	P1	P2	P3	P4	P5	P6	P7	P8	P9
Density (ind.m^{-2})	Sp	902	1210	2690	6334	4106	12610	3726	9616
	S	1442	2366	9792	2448	1872	9298	2244	3834
	A	816	934	2904	2352	1634	8338	1488	3130
	W	1314	894	1696	1514	2426	4974	814	2446
Taxa richness	Sp	30	31	26	25	21	25	27	31
	S	26	38	26	26	24	23	27	20
	A	23	24	27	23	22	21	27	20
	W	31	23	23	27	23	23	26	23
Shannon diversity	Sp	3.920	3.306	2.938	2.581	2.136	2.664	2.660	2.355
	S	3.255	4.031	2.681	3.308	3.141	2.584	3.308	2.865
	A	0.992	1.025	1.012	0.993	0.870	0.824	0.909	0.834
	W	0.935	1.005	1.049	0.913	0.777	0.869	1.086	0.907
Evenness	Sp	0.807	0.674	0.633	0.556	0.486	0.574	0.560	0.475
	S	0.693	0.768	0.577	0.704	0.685	0.571	0.696	0.663
	A	0.728	0.743	0.707	0.729	0.648	0.623	0.635	0.631
	W	0.627	0.749	0.770	0.645	0.571	0.638	0.768	0.666

$p = 0.07$; Table 2). The total richness was of 58 *taxa* during the study period, not presenting spatial-seasonal differences ($p > 0.05$). Among the seasons, differences with Shannon diversity occurred (ANOVA, $F_{1,3} = 38.04$, $p < 0.001$). In Summer and Spring seasons, higher average of Shannon diversity were recorded (3.131 and 2.806, respectively) in relation to Autumn and Winter. Spatially, the diversity showed no significant difference ($p > 0.05$). In relation to evenness the values were similar between the sites and seasons ($p > 0.05$; Table 2).

The macroinvertebrates community composition showed seasonal (MANOVA, SS = 5.03, $p = 0.04$) and spatial differences (MANOVA, SS = 1.74 $p = 0.001$). The Chironomidae *taxa* (Diptera) occurred in elevated density in all the seasons, being the higher value registered in the spring season (17,150 ind.m^{-2}). Elmidae (Coleoptera), Baetidae (Ephemeroptera), Hydropsychidae (Trichoptera) families occurred in all sampling sites. Perlidae and Gripopterygidae (Plecoptera) had not been found only in site 7 (Table 3).

According to the canonical correspondence analysis among the sampling sites and environmental variable, two first axes explained 67.4% of total variability of the data. Axis 1 explained 44.4% and axis 2 explained others 23% of the data variability (Figure 2). Axis 1 presented positive correlation with the communities of the sites 1, 2 and 3 and negative correlation with sites 5, 6 and 8. Sampling sites 4, 7 and 9 presented a strong positive correlation with axis 2. For the environmental variables, it was possible to observe that the organic matter in the sediment presented positive correlation with axis 1, whereas turbidity, pH, ammonia, total phosphorous, temperature and BOD presented negative correlation with this axis. Flow (m^3.s^{-1}), conductivity and total dissolved solid presented positive correlation with axis 2.

4. Discussion

In this study, the environmental variables presented differences among the sampling sites. However, no variations between the seasons of the year were recorded. This suggests an anthropogenic influence on the water quality of streams. According to Leunda et al. (2009) oscillations in the water physical-chemical characteristics are important when the benthic fauna is evaluated. In work carried out in Rio Grande do Sul state, Pereira and De Luca (2003) observed that the physical-chemical variables were spatially different. This variability was related with the presence of anthropogenic impacts (Bacey and Spurlock, 2007; Hepp and Santos, 2009), with the riparian vegetation presence (Beauger et al., 2006), and sites morphologic characteristics (Silveira et al., 2006). The high values of nutrients as the total phosphorous, verified in site 6, can be attributed to the domestic and industrial pollution source (Bahar et al., 2008) and to the agricultural practice (Kyriakeas and Watzin, 2006). The organic matter was higher in site 3 probably due the vegetal covering on the streambed and in the edges of the stream. The input of organic matter is responsible for the modification of morphologic aspects of the stream substratum influencing in the community characteristics (Hagen et al., 2006).

The density of organisms varied among the sites but not among the seasons. The variations in the density of organisms among the places can be a result of anthropogenic activities developed in the regions around the drainage

Table 3. Average (standard deviation) organisms density in streams in Erechim, Rio Grande do Sul State, 2006 and 2007.

Taxa	Sites								
	P1	P2	P3	P4	P5	P6	P7	P8	P9
Platyelminthes									
Turbellaria	15.0 (16.7)	12.0 (13.5)	1.5 (1.0)	16.0 (15.4)	3.5 (3.0)	89.0 (29.2)	1.0 (0.0)	14.0 (13.5)	80.0 (47.6)
Annelida									
Hyrudinea	0.0 (0.0)	1.5 (3.0)	0.0 (0.0)	8.5 (17.0)	0.0 (0.0)	0.0 (0.0)	1.0 (2.3)	1.5 (1.9)	0.0 (0.0)
Oligochaeta	43.0 (21.6)	17.5 (10.7)	119.0 (56.8)	40.0 (50.8)	90.0 (128.5)	129.5 (217.9)	1.0 (1.1)	10.0 (8.1)	23.5 (44.3)
Mollusca									
Bivalve	104.0 (73.6)	14.50 (12.4)	179.0 (180.7)	90.5 (127.3)	44.0 (25.9)	49.5 (47.3)	22.0 (43.9)	5.0 (3.4)	0.5 (1.0)
Gastropoda	34.5 (27.9)	12.0 (12.5)	3.5 (1.9)	6.5 (5.0)	1.0 (2.0)	216.5 (25.3)	10.0 (9.4)	10.0 (6.3)	8.0 (7.1)
Crustacea									
Aeglidae	0.0 (0.0)	1.0 (1.1)	0.0 (0.0)	2.5 (2.51)	2.5 (2.5)	0.5 (1.0)	0.0 (0.0)	3.0 (3.4)	0.0 (0.0)
Hyalellidae	1.0 (1.1)	1.5 (3.0)	1132.5 (1848.89)	1.0 (2.0)	0.0 (0.0)	0.0 (0.0)	29.0 (57.1)	10.5 (13.6)	0.0 (0.0)
Aranae	1.0 (2.0)	1.5 (1.9)	2.0 (2.3)	0.5 (1.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.5 (1.0)	1.0 (2.0)
Acari	4.0 (3.2)	26.0 (33.0)	23.0 (30.1)	2.5 (3.0)	0.5 (1.0)	10.5 (18.4)	2.0 (2.3)	8.0 (4.3)	25.5 (29.94)
Insecta									
Collembola	3.5 (5.7)	1.0 (1.15)	0.5 (1)	36.5 (71.67)	16.5 (26.4)	2.0 (4.0)	0.0 (0.0)	4.0 (6.7)	73.5 (124.4)
Coleoptera									
Dytiscidae	0.0 (0.0)	0.0 (0.0)	1.0 (2.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Elateridae	0.5 (1.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Elmidae	13.0 (37.8)	168.5 (92.0)	443.5 (249.1)	287.5 (113.9)	82.0 (38.2)	992.0 (291.7)	59.0 (55.5)	130.5 (33.5)	424.5 (83.0)
Coleoptera									
Gyrinidae	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	1.0 (2.0)	0.0 (0.0)	0.0 (0.0)	0.5 (0.0)	0.0 (0.0)	0.0 (0.0)
Hydrophillidae	7.5 (8.6)	3.0 (6.0)	3.0 (6.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	4.0 (5.0)	2.0 (4.0)	0.0 (0.0)
Lampyridae	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.5 (1.0)	0.0 (0.0)
Noteridae	1.0 (2.0)	0.5 (1.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Psephenidae	8.5 (6.8)	22.5 (30.3)	76.5 (21.0)	11.5 (11.8)	3.0 (4.7)	0.0 (0.0)	1.0 (0.0)	6.5 (6.8)	17.5 (7.0)
Diptera									
Ceratopogonidae	9.0 (6.2)	9.0 (6.21)	35.5 (26.0)	24.5 (28.5)	4.5 (2.5)	42.0 (23.6)	0.0 (0.0)	2.0 (2.3)	4.0 (3.6)
Chironomidae	340 (212.3)	285.5 (104.8)	984.0 (899.5)	896.0 (1456.2)	944.0 (764.3)	1061.5 (806.1)	816.5 (1269.1)	459 (230.5)	1951.5 (2314.1)
Culicidae	0.0 (0.0)	0.0 (0.0)	37.0 (68.6)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Dolichopodidae	0.5 (1.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.5 (1.0)
Empididae	1.0 (1.1)	2.5 (3.0)	1.5 (1.91)	0.5 (1.0)	5.0 (6.6)	2.5 (2.51)	1.5 (1.1)	3.5 (5.7)	5.0 (4.1)

Table 3. Continued...

Taxa	Sites								
	P1	P2	P3	P4	P5	P6	P7	P8	P9
Psychodidae	2.5 (2.5)	2.0 (1.63)	0.0 (0.0)	0.5 (1.0)	34.0 (48.3)	0.5 (1.0)	0.0 (0.0)	0.5 (1)	1.5 (3.0)
Simuliidae	34 (45.1)	99.5 (81.5)	28.0 (33.2)	40.5 (57.7)	709.0 (516.3)	3755.5 (1717.8)	6.0 (5.7)	400.0 (602.6)	367.0 (358.3)
Stratiomyidae	1.5 (1.9)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Tabanidae	1.0 (2.0)	3.5 (7.0)	0.0 (0.0)	1.0 (2.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Tipulidae	6.0 (3.6)	8.0 (6.9)	16.5 (14.2)	6.5 (5.5)	3.5 (3.0)	2.0 (2.82)	0.0 (0.0)	7.0 (5.2)	0.0 (0.0)
Ephemeroptera									
Baetidae	82.0 (18.2)	84.0 (59.0)	284.5 (235.4)	678.0 (522.8)	164.5 (63.1)	896.0 (324.1)	414.0 (458.6)	465.5 (406.8)	755.5 (264.3)
Caenidae	32.0 (48.4)	73.0 (135.3)	147.0 (292.6)	14.0 (26.6)	7.0 (10.3)	0.5 (1.0)	397.5 (894.8)	11.0 (16.7)	5.5 (11.0)
Leptohyphidae	6.0 (5.1)	91.0 (114.5)	0.0 (0.0)	23.0 (28.3)	72.5 (21.4)	239.0 (139.0)	28.5 (31.0)	90.5 (41.0)	95.5 (25.9)
Leptophlebiidae	100.5 (90.2)	112.5 (78.5)	440.5 (483.9)	258.0 (108.5)	14.5 (13.8)	58.0 (22.6)	3.0 (3.4)	40.5 (15.1)	59.5 (26.2)
Lepidoptera	0.5 (1.0)	0.5 (1.0)	0.0 (0.0)	0.5 (1.0)	0.5 (1.0)	8.0 (4.32)	0.0 (0.0)	3.5 (4.4)	0.5 (1.0)
Megaloptera									
Corydalidae	0.5 (1.0)	1.0 (2.0)	0.0 (0.0)	2.0 (1.63)	4.0 (5.4)	14.0 (10.8)	0.0 (0.0)	1.0 (2.0)	8.5 (13.1)
Odonata									
Ashnidae	0.0 (0.0)	0.0 (0.0)	1.5 (3.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0 (0)	0.0 (0.0)
Coenagrionidae	23.5 (9.9)	36.0 (52.0)	12.0 (14.2)	44.5 (25.0)	35.5 (14.8)	43.5 (22.1)	4.0 (3.0)	32.5 (16.5)	29.0 (18.8)
Cordulidae	0.0 (0.0)	0.0 (0)	0.0 (0.0)	0.5 (1.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Gomphidae	0.0 (0.0)	0.0 (0.0)	1.0 (2.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.5 (1.1)	4.5 (9.0)	0.0 (0.0)
Lestidae	0.5 (1.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.5 (0.0)	0.0 (0.0)	0.5 (1.0)
Libellulidae	6.0 (7.1)	26.5 (53.0)	1.0 (1.1)	0.5 (1.0)	0.5 (1.0)	0.0 (0.0)	6.5 (2.3)	0.5 (1.0)	2.5 (2.5)
Plecoptera									
Gripopterygidae	1.0 (2.0)	9.0 (12.9)	27.0 (33.8)	30.5 (46.4)	9.0 (9.3)	46.0 (48.9)	0.0 (0.0)	22 (37.6)	2.0 (2.3)
Perlidae	49.5 (18.2)	64.0 (22.8)	157.5 (95.6)	125 (53.7)	16.0 (8.3)	112.0 (42.1)	0.0 (0.0)	6.0 (3.6)	4.5 (5.2)
Trichoptera									
Calamoceratidae	7.5 (8.6)	9.5 (19.0)	12.5 (4.43)	0.0 (0.0)	1.0 (2.0)	1.0 (2.0)	1.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Glossosomatidae	0.0 (0.0)	1.5 (1.9)	0.0 (0.0)	3.0 (6.0)	0.0 (0.0)	0.5 (1.0)	0.0 (0.0)	25.0 (50)	5.0 (6.6)
Helicopsychidae	3.0 (3.4)	3.5 (4.1)	5.5 (7.5)	1.0 (1.1)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.5 (1.0)	0.5 (1.0)
Hydrobiosidae	0.0 (0.0)	5.0 (6.6)	0.0 (0.0)	5.5 (11.0)	0.0 (0.0)	0.0 (0.0)	1.5 (0.0)	0.0 (0.0)	3.5 (7.0)
Hydropsychidae	28.0 (29.7)	103.5 (41.9)	15.5 (13.7)	350.5 (234.5)	208.5 (47.0)	896.5 (599.3)	11.0 (5.0)	208.5 (143.2)	502.0 (322.2)

Table 3. Continued...

Taxa	Sites								
	P1	P2	P3	P4	P5	P6	P7	P8	P9
Hydroptilidae	3.0 (3.8)	5.0 (5.2)	7.5 (13.6)	24.5 (28.3)	17.5 (16.8)	42.5 (19.5)	24.0 (13.3)	37.0 (24.7)	256.0 (323.5)
Leptoceridae	3.5 (7)	1.0 (2.0)	1.0 (2.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (00)	0.0 (0.0)
Odontoceridae	9.5 (8.2)	3.0 (4.7)	33.5 (20.7)	0.5 (1.0)	4.0 (8.0)	2.0 (1.6)	15.5 (7.5)	13.5 (11.8)	16.5 (18.6)
Philopotamidae	0.5 (1.0)	14.0 (13.6)	1.0 (2.0)	33.0 (48.7)	10.5 (7.7)	92 (47.6)	44.0 (58.3)	20.5 (13.6)	17.0 (12.2)
Sericostomatidae	0.0 (0.0)	1.0 (2.0)	0.0 (0.0)	47.5 (75.1)	0.0 (0.0)	0.0 (0.0)	0.5 (0.0)	0.0 (0.0)	8.5 (14.4)
Hemiptera									
Veliidae	4.5 (6.4)	12.0 (22.6)	33.0 (31.4)	0.5 (1.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Belostomatidae	0.0 (0.0)	0.0 (0.0)	0.0 (0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	6.5 (13.0)	0.0 (0.0)
Corixidae	0.0 (0.0)	1.0 (2.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Gerridae	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.5 (1.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	1.0 (2.0)	0.0 (0.0)
Naucoridae	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	1.0 (2.0)	1.0 (2.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Pleidae	0.0 (0.0)	0.5 (1.0)	1.5 (3.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)

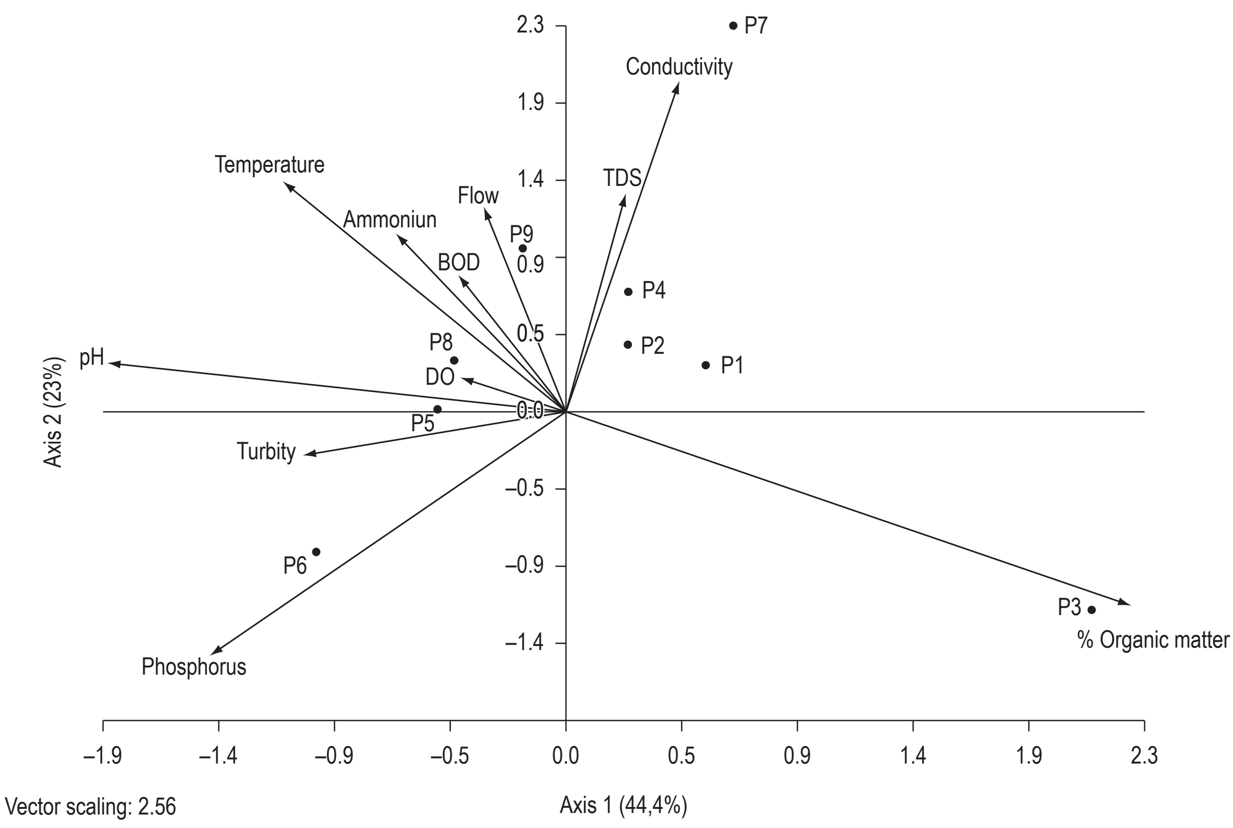

Figure 2. Canonical Correspondence Analysis among the sites and the environmental variables in Erechim - Rio Grande do Sul in 2006 and 2007. TDS: total dissolved solid; BOD: biochemical oxygen demand; DO: dissolved oxygen.

basin (Hepp and Santos, 2009). These activities contribute for increase of the tolerant organisms. The taxonomic richness not presented spatial-seasonal differences. Moretti and Callisto (2005) observed a similar result in a study carried out in Minas Gerais. A total of 58 *taxa* was recorded; the same number was found by Ayres-Peres et al. (2006) in work carried out in the central region of Rio Grande do Sul state. Other studies carried out in the Rio Grande do Sul that evaluated the structure and composition of the benthic community, showed inferior number of taxonomic richness (Bueno et al. 2003; Pereira and De Luca, 2003; Buckup et al., 2007) than that found in this study.

The Shannon diversity index showed differences among the seasons and not among the sites. This index was superior in spring and summer. In works in the Center-West and Southeast of Brazil, the values of diversity were superior in the dry season, what corroborates the present study (Moretti and Callisto, 2005; Silveira et al., 2006). Spatial differences for this metric had not occurred; however, sites 1 and 2 presented the highest average values of diversity, what can be attributed to the environmental integrity of the streams. These data corroborate Hepp and Santos (2009) in work carried out in the north region of the Rio Grande do Sul state, which verified higher diversity values in preserved streams with the presence of riparian vegetation.

The Chironomidae family was the most abundant due the great potential of adaptation and the opportunist profile (Kleine and Trivinho-Strixino, 2005). These data corroborate with many works carried out in the country, which showed the predominance of these organisms (Moretti and Callisto, 2005; Buckup et al., 2007; Molozzi et al., 2007; Corbi and Trivinho-Strixino, 2008). According to Biasi et al. (2008) one of the factors that increase the Ephemeroptera, Plecoptera and Trichoptera (EPT) richness in small order streams is the availability of habitats. The sites that presented higher EPT richness (sites 1 and 2) are the ones that showed greater availability of shelter and food probably due the marginal vegetation in these streams. Baetidae and Hydropsychidae, families found in all sites, can be considered tolerant to the adverse conditions what cause an increment in its population in relation to other *taxa* (Buss et al., 2002; Buss and Salles, 2007; Biasi et al., 2008).

The canonical correspondence analysis demonstrated that the organic matter in sediments was an important variable for site 3, as well as conductivity and total dissolved solids for sites 4 and 7. The positive correlation of site 3 and the organic matter with axis 1, probably occurred because this site is situated in place where occurs great input of allochthonous vegetation, increasing consequently the values of organic matter and influencing the macroinvertebrates distribution (Hagen et al., 2006). In site 3 the predominance of Hyalellidae occurred; this organism is a shredders organism that assists in the foliar material degradation (Merritt and Cummins, 1996). Site 6 is situated in an agricultural matrix what can increase the values of total phosphorous, related directly with the pesticides and herbicides in the hydric bodies (Kyriakeas and Watzin, 2006). The majority of the explanations for the variations in the macroinvertebrates community composition are associated to the fluctuations in the water chemical and physical variable (Sandin and Johnson, 2004).

In conclusion, the results of this study showed that the richness of benthic macroinvertebrates in the region was similar and superior to others studies carried out in Brazil and Rio Grande do Sul, respectively. Seasonal variations were not clear using richness and density. However, Shannon diversity showed seasonal differences and density showed spatial differences. The integrity of the sampling sites was an important factor for the fauna composition. The main environmental variables that influenced the benthic fauna were associated to the presence of riparian vegetation (organic matter in the sediment) and to the absence of anthropogenic activities. The results of this work suggest that new studies are necessary relating the landscape attributes in the data analyses. The drainage area characteristics are very important and, influenced of the water quality and aquatic biota.

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