Benthic macroinvertebrates and the quality of the hydric resources in Maratá Creek basin (Rio Grande do Sul, Brazil).

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ABSTRACT: Benthic macroinvertebrates and the quality of the hydric resources of the Maratá Creek basin (Rio Grande do Sul, Brazil). The current study was performed as a monitoring study of the surface hydric resources of the Maratá stream, Caí river basin, Rio Grande do Sul State, Brazil to evaluate the relationship between indexes and indicators of water quality and the density, richness and diversity of benthic macroinvertebrates. Water and benthic macroinvertebrate samples were collected at four different sampling stations, using a Surber sampler. The average velocity and the streamflow were also measured. Through multivariate analysis, similarity matrices between sample units were obtained based upon the values of: 1) the traditional indicators of water quality; 3) the Aquatic Life Protection Index; 3) the Trophic State Index; 4) the Essential Parameters of Aquatic Life Preservation Index; 5) the density of macroinvertebrates; 6) the Margalef Richness Index; 7) the Simpson Diversity Index; 8) the Shannon-Wiener Diversity Index; 9) the Streamflow and 10) the Average river velocity. The matrices were then submitted to a randomization test, in order to identify the spatial and temporal variation of the indexes and indicators. Correlations between the indexes and indicators matrices were tested using the Mantel and randomization test. The water quality indicators and the CETESB indexes showed no spatial but temporal variations, being mostly affected by the hydrological cycle. The flow and the indicators of water quality presented positive correlations, because the water quality decreased towards the river mouth. The density, richness and diversity of the macroinvertebrate families showed no correlation with the indicators of water quality and with the CETESB indexes. Other factors, such as the physical features of the fluvial environment, affected the structure of the macroinvertebrate community.
Key-words: Environmental indexes, water quality, benthic macroinvertebrates.

RESUMO: Macroinvertebrados bentônicos e a qualidade dos recursos hídricos na sub-bacia do arroio Maratá (Rio Grande do Sul, Brasil). Com o objetivo de testar a relação entre índices de qualidade de água e a densidade, riqueza e diversidade de macroinvertebrados bentônicos, foi realizado o monitoramento dos recursos hídricos superficiais do arroio Maratá, bacia do rio Caí, RS, no ano hidrológico de 2001. Em quatro estações foram obtidas amostras de água e de macroinvertebrados bentônicos, utilizando-se amostrador tipo Surber. Foram medidas também a velocidade média e a vazão da água. Por meio de análise multivariada foram obtidas as seguintes matrizes de semelhança entre unidades amostrais a partir dos valores de: 1) indicadores tradicionais de qualidade da água; 2) Índice de Proteção da Vida Aquática; 3) Índice do Estado Trófico; 4) Índice de Parâmetros Mínimos para a Preservação da Vida Aquática da Companhia Estadual de Tecnologia em Saneamento Ambiental (CETESB); 5) Densidade de Macroinvertebrados; 6) Índice de Riqueza de Margalef, 7) Índice de Diversidade de Simpson; 8) Índice de Diversidade Shannon-Wiener; 9) vazão e 10) velocidade média da água. As matrizes foram submetidas a testes de aleatorização para testar a variação espacial e temporal dos índices e indicadores. A correlação entre matrizes de índices e indicadores foi testada por meio do teste de Mantel, seguido de aleatorização. Os indicadores de qualidade da água e os índices da CETESB não variaram espacialmente, mas, temporalmente, sofrendo influência do ciclo hidrológico. A vazão e alguns indicadores de qualidade da água apresentaram correlações significativas, em função da qualidade da água decrescente em direção à foz. Nenhuma correlação significativa entre a riqueza e a diversidade de macroinvertebrados e os

indicadores de qualidade da água e os índices da CETESB foi encontrada, o que sugere que outros fatores, tais como as características físicas do ambiente fluvial, influenciam a estrutura da comunidade de macroinvertebrados.
Palavras-chave: índices ambientais, qualidade da água, macroinvertebrados bentônicos.

Introdution

Indexes are tools to assess environmental quality. An Index is a means devised to reduce a large quantity of data down to its simplest form, retaining essential meaning for the questions that are being asked of the data (Ott, 1978).

Several indexes were developed in order to evaluate the quality of surface water resources, based, mainly, on physical, chemical and biological water characteristics, such as the National Sanitation Foundation (NSF-WQI), Horton, Harkins, Pratti and Simpson Water Quality Indexes. Ott (1978) and Peláez-Rodriguez et al. (2000) reviewed the most utilized indexes. The NSF-WQI, based on physical, chemical and microbiological water parameters for water supply, is the most communly employed index in the world. In Brazil, the index was applied over the last ten years in several river basins in São Paulo, Mato Grosso do Sul, Rio Grande do Sul, Santa Catarina, Minas Gerais and Rio de Janeiro States (COMITESINOS, 1990), and also for the Caí River basin (Ribeiro et al., 1999), the urban sub-basin of Cria creek (Almeida, 1999) and the rural sub-basins of the Cará (Weirich et al. 2002) and Maratá (Pereira, 2002) brooks. This index has been used to assess the quality of water for consumption; but no for the evaluation of the environmental quality of water resources.

In 1998, CETESB (Companhia de Tecnologia e Saneamento Ambiental) proposed the Index of Aquatic Life Protection (IVA), which compost the following sub-indexes IPMCA (Index of Minimum Parameters for the Preservation of Aquatic Life) and Carlson's IET (Trophic State index), modified by Toledo Jr. (1983) for subtropical environments. The IVA was based on indicators related to the maintenance of aquatic life and has been used annually to monitor surface waters in the State of São Paulo. In Rio Grande do Sul State, De Luca et al. (2001) used the CETESB indexes to evaluate water quality in the basin of Itaquirinchim creek and found predominantly fair and bad quality classes, due to the high levels of phosphate and heavy metals.

Benthic macroinvertebrates play an important role in the metabolism of aquatic ecosystems (Allan, 1995). Therefore, any environmental changes affect the structure (density, richness and diversity) or the functional organization of the macroinvertebrate community. Diversity and species richness of benthic communities and environmental quality studies were published in Europe, Asia and America (Afonso, 1992; Kulinska et al., 1992; Sinha & Das, 1993) and reviewed (Bollman & Marques, 2000; 2001).

Far little is known about the relationship between the CETESB indexes and the structure of aquatic communities. The present study aimed to apply the CETESB indexes and test their relationships with the density, richness and diversity of benthic macroinvertebrates in the sub-basin of Maratá creek, in the Caí river basin, Rio Grande do Sul, during the hydrologic period of 2001.

Material and methods

The Maratá creek is a tributary on the right bank of the Caí river, that flows into the Lake Guaíba, close to Porto Alegre, Brazil (Fig.1). The headwater of Maratá Creek is located at a 540 m altitude, on a basalt floor, in the morphological unit of Encosta da Serra. Maratá Creek flows towards the Depressão Central in the unit of Terra de Coxilhas, from the sandstone hills of the Botucatu and Rosário do Sul formations to the unit of Várzeas Aluviais, where it discharges into the Caí river at a 5 m altitude, after a 47.4 km distance of the headwater. According to Moreno (1961), the climate in the region is Virginian subtropical of the Cfa II2b (altitude ‹400 m) types, with annual mean temperatures of ‹19 ºC and a maximum of ›25 ºC during the warmest month of the year.

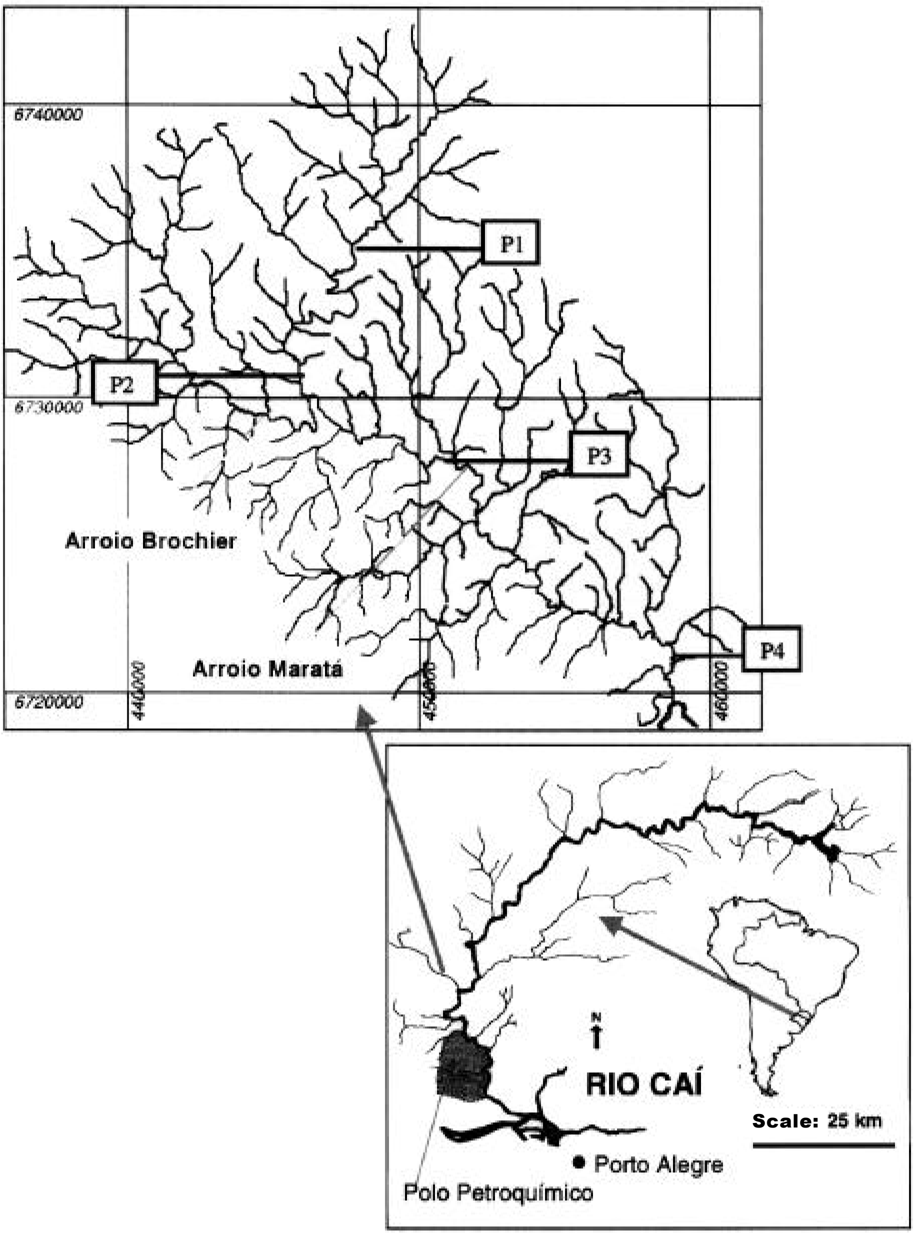

Figure 1: Sampling points in the sub-basin of Maratá Creek, Rio Grande do Sul State, Brazil (adaptation of FEPAM, 1997 and Volkmer-Ribeiro et al., 1984).

Based on physiographic aspects and land use in the Maratá Creek basin (Pereira, 2002), four sampling stations were chosen: P1, located in the morphological unit of Encosta da Serra (altitude of 120 m; 67°30'00" S and 44°59'00" W), in a rural area with good plant cover of forests interspersed by crops and grazing areas, upstream from the urban center of the municipality of Maratá; P2, subjected to discharges of domestic sewage (5,000 people), located in a transition zone between morphological units of Encosta da Serra and Terras de Coxilhas (altitude: 31m; 67°30'00" S and 44°59'00" W); P3, located in Terras de Coxilhas (altitude: 29 m; 67°27'00" S and 45°12'00" W) in a rural area predominantly covered with forests; P4, located in the Várzeas Fluviais unit (altitude: 6m; 67°21'00" S and 45°85'00" W), in a rural area covered by forests interspersed by citrus crops and grazing areas, close to the creek mouth into Caí River. The P1, P3 and P4 sampling stations present banks covered by cilliary forest.

Water samplings were performed at 20 cm depth in the rainy (January and May) and dry (August and November) periods of 2001 for the physical, chemical and microbiological indicators of water quality (Tab. I). Water average velocity was measured in a transversal known section, using a current meter. Using a Surber sampler (area: 0.009 m²) according to APHA (1998), marginal collections of benthic macroinvertebrates were performed in depositional areas with 60 cm maximum depth (five replications at each station). The following microhabitats were sampled: 1) boulder-coble; 2) gravel; 3) sand; 4) silt-clay and 5) litter. In order to remove the sediment, the material contained in the sampler area was slowly collected with the help of a spatula, so as to avoid loss of organisms. The sediment collected was, then, transferred to plastic bags and fixed with a 4% formaldehyde solution. The benthic material was screened (washed in a 500 mm mesh, identified and quantified under a stereomicroscope), conserved in 70% alcohol, and identified at family level according to Doledéc et al. (2000), using literature as contained in Pereira (2002).

Table I: Analytical methods for physical, chemical and microbiological indicators of water quality.

Indicators	Units	Method
pH		Potentiometric
Temperature	(°C)	Thermometer
Turbidity	(UNT)	Nephelometric
Total Dissolved Solids	(mg/L)	Gravimetry
Biochemical Oxygen Demand (BOD_5)	(mg/L O_2)	Winkler
Orthophosphates	(mg/L PO_4^{-3})	Ion Chromatography
Dissolved Oxygen (DO)	(mg/L O_2)	Winkler
Nitrate	(mg/L NO_3^-)	Íon Chromatography
Cupper	(mg/L Cu^{++})	Atomic Absorption
Mercury	(mg/L Hg^+)	Atomic Absorption – cold vapor
Fecal Coliforms	(MPN/100mL)	Chromogenic Substrate

Water quality was evaluated by means of the Indexes of Aquatic Life Protection (IVA), Trophic State Index (IET) and Minimum Parameters for the Preservation of Aquatic Life (IPMCA) from CETESB. The Margalef Richness and Simpson and Shannon-Wiener Diversity Indexes were obtained based on the density of families of benthic macroinvertebrates, using Quanta software (Brower et al., 1997). The values of each water quality indicator were tested, regarding temporal and spatial scales, by randomization ($p<0.05$; 1,000 and 10,000 permutations).

Euclidean distance was employed to obtain the following dissimilarity matrices between sampling units using: 1) traditional indicators of water quality (centralized and normalized values); 3) Aquatic Life Protection Index; 3) Trophic State Index; 4) Essential Parameters of Aquatic Life Preservation Index; 5) density of macroinvertebrates (square root transformation of data); 6) Margalef Richness Index; 7) Simpson Diversity Index; 8) Shannon-Wiener Diversity Index; 9) Streamflow and 10) Average velocity.

Each matrix was tested for temporal and local variations ($p<0.05$; 1,000 and 10,000 permutations) by randomization. All matrices were also tested for correlation according to Mantel, which was submitted to a randomization test ($p<0.05$; 1,000 and 10,000 permutations). All statistical procedures were performed using Multiv software (Pillar, 1998).

Results

The highest streamflow was found in May and the lowest in August of 2001 (Tab. II). Also, the mercury concentrations in P4 were significantly different ($p<0.05$) from those found in P1 and P2. Some significant temporal variations ($p<0.05$) of the water quality

Table II: Values of average velocity, streamflow and physical, chemical and microbiological indicators of water quality, in the Maratá creek, Rio Grande do Sul State, Brazil (hidrologic year of 2001). Average velocity (V); Streamflow (Q); Biochemical Oxygen Demand (BOD_5); Dissolved Oxygen (DO); Total Dissolved Solids (TDS); Fecal Coliforms (FC).

Stations		V (m/s)	Q (m^3/s)	pH	Turbidity (UNT)	BOD_5 (mg/L)	NO_3^- (mg/L)	PO_4^{-3} (mg/L)	DO (%)	TDS (mg/L)	FC (MPN/ 100mL)	Hg (µg/L)
P1		0.47	0.62	7.4	17	0.83	1.50	0.491	102.9	93	1,230	0.4
P2	January	0.51	1.10	7.4	19	3.85	1.76	0.536	104.5	55	2,419	0.4
P3		0.60	2.45	7.1	31	0.52	1.32	0.482	85.1	59	1,986	0.1
P4		0.48	3.49	7.3	43	5.82	1.57	0.449	90.1	58	1,624	2.7
P1		0.77	1.58	7.5	11	0.97	0.76	0.028	99.0	25	740	0.2
P2	May	0.81	2.17	7.4	13	2.50	0.84	0.107	95.0	16	1,990	0.4
P3		0.68	5.66	7.2	19	1.03	0.77	0.057	74.5	60	410	0.6
P4		0.60	7.53	7.1	27	2.90	0.67	0.159	70.5	60	860	0.4
P1		0.15	0.19	7.5	3	0.16	0.01	0.040	97.0	49	1,100	0.2
P2	August	0.08	0.19	7.1	4	0.87	0.01	0.014	92.5	57	3,680	0.2
P3		0.80	1.07	7.2	7	0.31	0.45	0.038	101.0	59	1,580	0.2
P4 A		0.29	1.70	7.3	12	0.94	1.25	0.010	98.0	50	1,200	0.1
P1		0.34	0.55	7.8	33	1.78	6.94	0.410	90.0	37	6,630	0.1
P2	November	0.19	0.73	7.5	82	1.39	7.49	0.540	83.0	45	12,500	0.1
P3		0.62	2.32	7.3	37	1.35	3.56	0.010	104.0	36	6,050	0.1
P4		0.47	3.81	7.4	44	1.39	2.45	0.560	94.0	37	4,620	3.8

indicators were found (Tab. II). Turbidity, which showed difference between the months of November and August, while BOD_5 presented different values between the months of January and August (Tab. II). In addition, the orthophosphate values of January differed from May, as well as the ones of August were different compared to those of November (Tab. II). Fecal coliforms and nitrates showed significant differences in the values of November compared to all other months (Jan/May/Aug) (Tab. II). The randomization performed, after the matrix of physical, chemical and microbiological water quality indicators (Tab. II) present no significant differences between sampling stations, but presented significant differences ($p<0.05$) between rainy and dry seasons.

The IVA showed low water quality in 62.5% of the samples and good quality in 18.75% (Tab. III). The IET showed hypereutrophic waters for 44% of the samples and eutrophic for 31%. The IPMCA values corresponded to the good quality in 56% of the samples and regular in 44%. None of the indexes (Tab. III) presented significant differences between sampling stations, but significant differences ($p<0.005$) were found between the seasons.

Table III: Values and quality classes of Trophic State Index (IET), of Minimum Parameters for the Preservation of Aquatic Life Index (IPMCA) and Aquatic Life Protection Index (IVA), in the Maratá creek, Rio Grande do Sul State, Brazil (hidrologic year of 2001).

	Stations	IPMCA		IET		IVA	
P1		2	regular	4	hipereutrophic	6.4	bad
P2	January	2	regular	4	hipereutrophic	6.4	bad
P3		1	good	4	hipereutrophic	5.2	bad
P4		2	regular	4	hipereutrophic	6.4	bad
P1		1	good	2	mesotrophic	3.2	good
P2	May	2	regular	3	eutrophic	5.4	bad
P3		2	regular	3	eutrophic	5.4	bad
P4		2	regular	3	eutrophic	5.4	bad
P1		1	good	3	eutrophic	4.2	regular
P2	August	1	good	2	mesotrophic	3.2	good
P3		1	good	3	eutrophic	4.2	regular
P4		1	good	2	mesotrophic	3.2	good
P1		1	good	4	hipereutrophic	5.2	bad
P2	November	1	good	4	hipereutrophic	5.2	bad
P3		1	good	1	oligotrophic	2.2	excellent
P4		2	regular	4	hipereutrophic	6.4	bad

The benthic macroinvertebrates corresponded to 56 families of in the Maratá creek sub-basin (Tab. IV). The total number of individuals was highest at station P1 and decreased towards the river mouth. The following families predominated in density of individuals: Baetidae, Hydropsychidae, Leptophlebiidae and Perlidae (P1 station), Elmidae (P1 and P2 stations), Tipulidae (P2 station), Hydrobiidae (P3 and P4 stations), Chironomidae (all sampling stations). No significant differences of densities at the family level were found between the months but P1 station was different from the other stations ($p=0.004$).

Among the temporal variation of richness and diversity, maximum Margalef's richness indexes can be observed at P1 station, except for the August (P2 station) and November (P3 station) (Fig. 2). The Simpson diversity, equitability values and maximum diversity were higher at P1 station (Fig.3). The maximum values of richness and diversity in P1 station, was significantly different from P4 station as to the Margalef ($p=0.0064$) and Simpson ($p=0.022$) values. The Shannon-Wiener diversity, maximum diversity and equitability values, were also higher at P1 station (Fig. 4). No significant differences were found between the sampling stations. Randomization showed significant differences between May and November, for the Shannon-Wiener diversity values ($p=0.04$).

The Mantel test (Tab.V) showed the following significant correlations: IVA with water quality indicators ($r=-0.44$; $p=0.01$); IPMCA with water quality indicators ($r=0.33$; $p=0.002$).

Table IV: Density (ind./m²) of benthic macroinvertebrates (family level) in the Maratá Creek, Rio Grande do Sul State, Brazil (hidrologic year 2001). Mean ($\bar{X}$) and Standard Deviation (SD) values.

Táxons		**P1**		**P2**		**P3**		**P4**	
		$\bar{X}$	**SD**	$\bar{X}$	**SD**	$\bar{X}$	**SD**	$\bar{X}$	**SD**
ANNELIDA									
Clitellata									
Hyrudinae	Hyrudinae fam.1	0	0	3	5	0	0	0	0
Oligochaeta	Naididae	81	76	39	33	42	29	44	71
MOLLUSCA									
Gastropoda									
Mesogastropoda	Hydrobiidae	47	56	6	6	1,017	917	72	68
	Chilinidae	0	0	0	0	0	0	8	9
	Planorbidae	0	0	3	5	3	5	0	0
Bivalvia									
Veneroida	Corbiculidae	0	0	14	18	139	183	19	28
CRUSTACEA									
Malacostraca									
Amphipoda	Hyalellidae	0	0	0	0	0	0	8	14
Isopoda	Cymothoidae	0	0	0	0	3	5	0	0
Decapoda	Paleonomidae	0	0	0	0	22	14	3	5
	Aeglidae	11	19	11	19	31	30	3	5
	Trichodactylidae	0	0	0	0	6	10	0	0
ARTHROPODA									
Insecta									
Collembola	Isotomidae	6	6	22	38	0	0	3	5
Ephemeroptera	Baetidae	744	512	386	624	31	47	3	5
	Caenidae	6	10	122	212	8	9	0	0
	Leptophlebiida	836	1,120	47	76	56	68	0	0
	Leptohyphidae	267	234	28	29	0	0	0	0
Odonata	Gomphidae	25	21	17	18	0	0	8	5
	Coenagrionidae	0	0	0	0	3	5	0	0
	Libelullidae	3	5	3	5	0	0	0	0
Plecoptera	Gripopterygida	11	19	8	14	0	0	0	0
	Perlidae	419	593	3	5	67	73	3	5
Hemiptera	Naucoridae	8	5	3	5	0	0	0	0
	Nototecnidae	0	0	0	0	3	5	3	5
	Hemiptera	3	5	0	0	0	0	0	0
Megaloptera	Corydalidae	25	43	0	0	0	0	0	0
Trichoptera	Hydropsychida	936	1,443	3	5	25	32	0	0
	Glossosomatid	572	687	0	0	0	0	0	0
	Hydroptilidae	458	495	0	0	0	0	0	0
	Odontoceridae	25	25	31	53	6	10	8	14
	Leptoceridae	225	204	100	91	3	5	3	5
	Calamoceratida	3	5	6	6	6	10	0	0
Lepdoptera	Pyralidae	158	230	0	0	0	0	0	0
Coleoptera	Gyrinidae	3	5	0	0	6	6	0	0
	Noteridae	0	0	0	0	0	0	0	0
	Hydrophilidae	3	5	3	5	0	0	3	5
	Elmidae	1,444	1,187	114	87	58	49	3	5
	Psephenidae	36	38	0	0	0	0	0	0
Diptera	Tipulidae	492	335	53	91	6	6	3	5
	Ptychopteridae	3	5	0	0	0	0	0	0
	Chaoboridae	14	24	0	0	0	0	0	0
	Simuliidae	25	32	0	0	6	10	0	0
	Chironomidae	2,289	1,228	1,931	3,197	92	115	786	885
	Ceratopogonid	6	10	0	0	8	14	0	0
	Tanyderidae	0	0	0	0	0	0	6	10
	Empididae	3	5	3	5	0	0	0	0
	Sciomyzidae	0	0	0	0	3	5	0	0
	Total	9,186	7,139	2,956	3,987	1,642	1,041	989	940

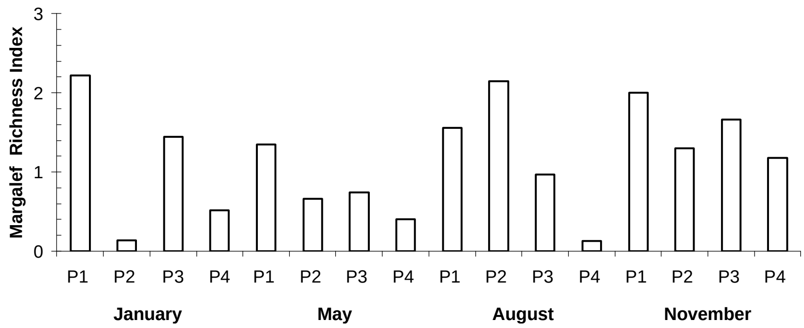

Figure 2: Richness of benthic macroinvertebrate in the sub-basin of Maratá Creek, Rio Grande do Sul State, Brazil (hidrologic year of 2001).

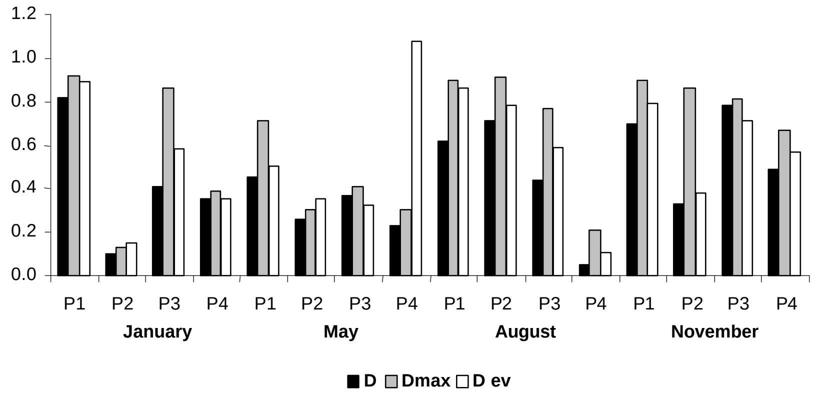

Figure 3: Diversity of benthic macroinvertebrate in the sub-basin of Maratá Creek, Rio Grande do Sul State, Brazil (hidrologic year of 2001): Simpson Diversity (D), Simpson Maximum Diversity (Dmax.) and Simpson Equitability (D ev).

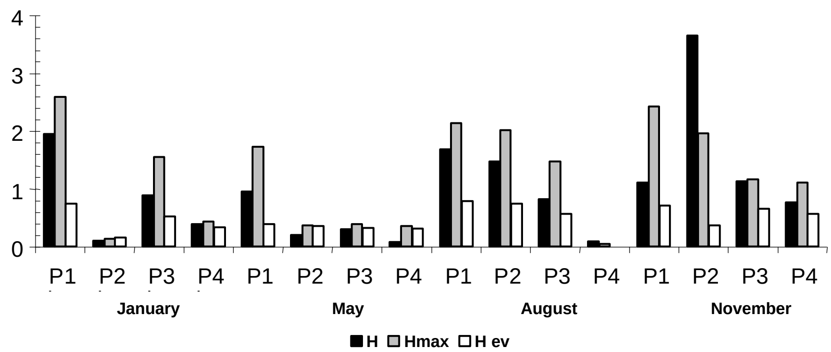

Figure 4: Diversity of benthic macroinvertebrate in the sub-basin of Maratá Creek, Rio Grande do Sul State, Brazil (hidrologic year of 2001): Shannon-Wiener Diversity (H), Shannon-Wiener Maximum Diversity (Hmax.) and Shannon-Wiener Equitability (H ev).

Table V: Correlation between matrices (Mantel) and probability ($p<0.005$*) obtained by randomization (10,000 permutations): Physical, chemical and microbiological indicators of water quality (IWQ); Aquatic Life Protection Index (IVA); Trophic State Index (IET) and Minimum Parameters for the Preservation of Aquatic Life Index (IPMCA); density of macroinvertebrate, family level (D); Margalef Richness Index (Mar); Simpson (Simp) and Shannon-Wiener (Shann) Diversity Index; streamflow (Q) and average river velocity (V).

	IWQ	IVA	IET	IPMCA	D	Mar	Simp	Shann	Q	V
IWQ	0.000	0.0001*	0.724*	0.002*	0.149*	0.507*	0.424*	0.044*	0.002*	0.202*
IVA	-0.449	0.000	0.044*	0.122*	0.873*	0.158*	0.263*	0.080*	0.071*	0.536*
IET	-0.035	0.206	0.000	0.453*	0.767*	0.792*	0.083*	0.865*	0.366*	0.245*
IPMCA	0.337	-0.154	0.079	0.000	0.192*	0.804*	0.628*	0.231*	0.003*	0.092*
D	-0.148	0.062	-0.017	-0.030	0.000	0.755*	0.038*	0.692*	0.404*	0.512*
Mar	-0.071	0.150	-0.029	0.025	-0.132	0.000	0.327*	0.193*	0.561*	0.658*
Simp	0.082	-0.121	-0.171	0.048	-0.033	-0.101	0.000	0.163*	0.598*	0.181*
Shann	-0.209	0.183	-0.016	-0.119	0.211	-0.131	-0.142	0.000	0.122*	0.660*
Q	0.319	-0.184	-0.097	0.292	-0.036	0.061	-0.056	-0.154	0.000	0.844*
V	0.130	-0.063	-0.118	0.171	-0.067	-0.045	-0.135	-0.046	0.021	0.000

Discussion

The hydrologic year of 2001 presented atypical behavior: the highest water level was found in autumn, not in winter, and the lowest level was found in winter, not in summer. The BOD was higher in summer when the bacterial decomposition processes are more intense. The nutrients and the fecal coliforms were higher in spring, which may be attributed to a concentration effect during the long dry period.

Similar values of pH were found in Cará creek by Weirich et al. (2002). The turbidity values in Maratá creek were similar to those found by Almeida (1999), in Cria creek and by Weirich et al. (2002) in Cará creek, and can be atributed to water erosion of marginal banks (P2). Maratá creek presented lower BOD_5 values and higher values of orthophosphates and nitrates when compared with the values of Cria Creek (Almeida, 1999). Mercury has already been found in Caí river, since mercury salts are compost of fertilizers and are present in some agricultural fungicides. Non-point sources of contamination, especially the agricultural from citrus culture, are probably the main source of contamination in this sub-basin.

Physical, chemical and microbiological indicators, and the indexes present no significant spatial variation. Thus, the domestic wastewater discharges did not significantly change the water quality in Maratá creek, and that the self-purification capacity of the waterbody was not surpassed. The water quality indicators presented a significant temporal variation. In November, the values were was significantly different from the others (high fecal coliforms, nitrates, mercury and turbidity values, Tab. II).

The negative correlation between IVA and the traditional water quality indicators showed a discrepance. The bad water quality, when IVA is considered, was due to high phosphate content and of the high levels of mercury in the Maratá Creek waters. Rodrigues et al. (2000) found predominantly low quality water in two sub-basins of the Jacaré Guaçu river basin of São Paulo State and was, also due to phosphate concentration. Low water quality was also found by De Luca et al. (2001) in the Itaquirichim creek, due to heavy metals, which resulted in the minimum IPMCA and IVA values. The positive correlation between the IPMCA and water quality indicators is an indication of the spatial and temporal variations of the water quality parameters.

The density, richness and diversity of benthic macroinvertebrates present no correlation with water flow, with the water quality and with the CETESB indexes. Harding et al. (1999) did not find significant variations in the structure of the benthic macrointervetebrate community (Margalef index) along the Pomahaka river, in an agricultural area in Australia. The species composition was different in the upper region of this river in which the Ephemeroptera, Plecoptera and Trichoptera (EPT) dominated, as compared to the lower region, in which the Mollusca and Chironomidae predominated. A similar pattern was found in the Maratá Creek: the EPT group prevailed in the rocky (basaltic) region of Encosta da Serra (P1 station) while the Hydrobiidae and Chironomidae predominated in the sandstone regions of the Terras de Coxilhas and flat and depositional region of Várzeas Fluviais. Junqueira (1995) found a similar distribution of macroinvertebrates and substrate gradient in the Sinos River, of the Lake Guaíba basin of Rio Grande do Sul State.

The Margalef Richness and Simpson Diversity Indexes were correlated to morphometric factors of river. The minimum values were observed in areas modified by marginal erosion (P2) and with depositional areas poor in microhabitats (P4). The Shannon-Wiener diversity and maximum diversity of Shannon-Wiener indexes found by Junqueira (1995) in the Sinos River, are higher than those found in Maratá creek. According to Wilhm & Dorris (1968), Shannon-Wiener diversity values ›3 correspond to non-polluted waters, between 1 and 3 to moderately polluted waters and ‹1 to polluted waters. These scales were used for biological monitoring of Chinese (Das & Sinha, 1993) and Portuguese (Afonso, 1992) rivers, but they are not valid for the Maratá Creek (Tab. V). The significant differences between May and November, regarding Shannon-Wiener diversity, may be attributed to the life cycle of the different groups of organisms and to the sudden, atypical climate variations in the hydrologic year of 2001. The evaluation performed in the Maratá creek sub-basin did not identify sites of heavy contamination, even close to the township of Maratá, where the domestic sewage is discharged. Most of the sources of contamination are non-point and agricultural, as shown by Pereira (2002). The temporal and spatial variations of water quality were due to the natural variations of the hydrologic period studied and to the streamflow gradient. Positive correlation between the water quality indicators and streamflow, shows a continuum of quality, whith a reduction towards the river mouth of Maratá creek. A similar gradient was found by Feijoó et al. (1999), in tributary creeks of Luján river, on the Pampean plain of Argentina.

The evaluation of Maratá creek's environmental quality did not show any relationship between the environmental indexes and the benthic macroinvertebrate communities. Such conclusion should not invalidate the use of indexes and macroinvertebrates in the evaluation of the ecological integrity of aquatic ecosystems. A wider data series may reveal spatial and temporal patterns that not were identified in the hydrologic year of 2001.

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