A POLYETHYLENETHEREPHTHALATE (PET) DEVICE FOR SAMPLING FRESHWATER BENTHIC MACROINVERTEBRATES

VOLKMER-RIBEIRO, C.,[1] GUADAGNIN, D. L.,[2] DE ROSA-BARBOSA, R.,[3] SILVA, M. M.,[3] DRÜGG-HAHN, S.,[3] LOPES-PITONI, V. L.,[3] GASTAL, H. A. de O.,[3] BARROS, M. P.[3] and DEMAMAN, L. V.[4]

[1]Museu de Ciências Naturais da Fundação Zoobotânica do Rio Grande do Sul, C.P. 1188, CEP 90001-970, Porto Alegre, RS, Brazil, Research Fellow of CNPq, Brazil

[2]Laboratório de Ecologia e Conservação de Ecossistemas Aquáticos, Universidade do Vale do Rio dos Sinos, Av. Unisinos, 950, Centro 2, CEP 93020-000, São Leopoldo, RS, Brazil

[3]Museu de Ciências Naturais da Fundação Zoobotânica do Rio Grande do Sul, C.P. 1188, CEP 90001-970, Porto Alegre, RS, Brazil

[4]Assessoria de Gestão de Pessoas, Segurança e Meio Ambiente, Companhia Petroquímica do Sul, COPESUL, BR 386, Rod. Tabaí/Canoas, km 419, Pólo Petroquímico, CEP 95853-000, Triunfo, RS, Brazil

Correspondence to: Cecilia Volkmer Ribeiro, Museu de Ciências Naturais da Fundação Zoobotânica do Rio Grande do Sul, C.P. 1188, CEP 90001-970, Porto Alegre, Rio Grande do Sul, Brazil, e-mail: cvolkmer@fzb.org.br

Received January 13, 2003 – Accepted May 22, 2003 – Distributed August 31, 2004

(With 4 figures)

ABSTRACT

A new device to sample freshwater benthic macroinvertebrates was used in a low and sandy stretch of a Brazilian sub-tropical river (the River Caí, Triunfo, RS) and in one of its small tributaries, Bom Jardim brook (*Arroio Bom Jardim*). In this study, the effectiveness of this device, a PET sampler, was tested at different sites in the river and the brook throughout the four seasons between 2001-2002. Comparisons were made by PCA and ANOVA, both employing a bootstrap procedure based on similarity matrices. The PET sampler proved to be a reliable tool for detection of seasonal and spatial differences in richness, total abundance of organisms, and Shannon´s diversity index in both river and brook and is therefore recommended for use in the monitoring of macroinvertebrate communities in this system.

Key words: PET artificial sampler, lotic, benthic macroinvertebrates.

RESUMO

Um dispositivo de Polietiltereftalato (PET) para amostragem de macroinvertebrados bênticos de água doce

Foi utilizado novo dispositivo para amostragem de macroinvertebrados bênticos de água doce num segmento do curso inferior arenoso de um rio brasileiro subtropical (Rio Caí, Triunfo, RS) e de seu pequeno tributário, Arroio Bom Jardim. Neste estudo, a efetividade do amostrador PET foi testada em locais diferentes do rio e do arroio e ao longo das quatro estações do ano, entre 2001-2002. Foram realizadas comparações por PCA e ANOVA, ambos empregando um procedimento "bootstrap" com base em matrizes de similaridade. O amostrador PET é confiável para detecção de diferenças sazonais e espaciais de riqueza, abundância total de organismos e diversidade de Shannon no rio e no arroio, sendo, portanto, recomendável para o monitoramento de comunidades de macroinvertebrados nesse sistema.

Palavras-chave: amostrador artificial PET, ambiente lótico, macroinvertebrados bênticos.

INTRODUCTION

Water quality monitoring by means of biological indicators has been widely used to verify tendencies towards temporal or spatial alterations (Cairns *et al.,* 1993). The parameters normally used are the abundance of organisms as well as indexes of richness and diversity of the species obtained from surveys of macroinvertebrate fauna (Magurran, 1988; Pontasch *et al.,* 1989; Zmarzly *et al.,* 1994; Arocena, 1996; Veijola *et al.,* 1996), although there is no consensus about which sampling methodologies and indicators are the most suitable for use in different situations (Magurran, 1988; Cairns *et al.*, 1993; Chessman, 1995). In order to overcome surveying problems, particularly with regard to standardization and replication of methodologies, an array of artificial substrates to be colonized by benthic organisms has been proposed and used, particularly in the United States (Rosemberg & Resh, 1982).

Water quality monitoring using macroinvertebrate benthic fauna began in 1997 in the lower course of the River Caí and the Bom Jardim brook, in an area influenced by the *Pólo Petroquímico do Sul* (the Southern Petrochemical Complex), municipality of Triunfo, RS. The roots of the water jacinth *Eichhornia azurea* (Sw). Kunth*,* found along the river banks, had been employed as natural samplers of that fauna (Volkmer-Ribeiro *et al.*, 1984), since dredging techniques had proved inefficient in that area, due to the irregular/sandy river bed. The increasing rarefaction of this macrophyte, noted in 2001-2002 and attributed to intensive commercial extraction of sand in the lower course of the river (FEPAM, 2001), showed a need to design and test an artificial substrate to serve as a basis for a standard method of sampling to be used henceforth both in the river and the brook. Artificial substrates are known to be selective, depending on the materials of which they are made and/or the sites in which they are placed (Rosemberg & Resh, 1993). Hard artificial substrates are usually colonized by sessile or small moving organisms which ultimately results in the exclusion of mud-burrowing or mud-feeding ones. As the area to be surveyed was mostly composed of soft substrate, particular consideration was given to this fact in designing the device. This study describes its construction and reports testing results.

MATERIAL AND METHODS

PET sampler assembling

Each sampler consists of two 2 l PET-type, disposable green bottles, sanded inside and out, with the bottoms removed and eliminated. The caps are retained on the bottle necks (Fig. 1A). The walls are then cut into 6 strips, starting from a circular line around the neck to the base. Each strip, measuring about 2 cm in width, is then cut transversally every 2 mm, resulting in a comb-like appearance (Fig. 1B). One bottle is then placed inside the other, with necks opposite, and both are wrapped in a small nylon net that has the opening fixed under the cap of one of the bottles (Fig. 1C and D). Prior to this procedure, a natural filling, consisting of a cellulose network that houses the seeds of the plant *Luffa cylindra* L. (Fig. 1E), is placed within the recipient formed by the juxtaposition of the two bottles (Fig. 2). Each filling is cut to the appropriate size for fitting inside the recipient. A metal weight of approximately 300 g is fixed to one neck (Fig. 1D). A nylon thread, about 3 m in length, is firmly attached at the other end. The sampler is made of green bottles as, once submerged, they are less conspicuous than transparent bottles, and less prone to the human depredation observed in the area.

Placing and recovering the PET sampler: the procedures

Samplers were placed in two areas (Fig. 3): at four sites in the River Caí (RC 1 – 29°55'49''/51°17'07''; RC 2 – 29°51'58''/51°21'52''; RC 3 – 29°49'16''/51°21'04''; RC 4 – 29°40'07''/51°25'41'') and at three sites in the tributary (the Bom Jardim brook) which runs through the petrochemical plant (ABJ 1 – 29°50'12''/51°22'02''; ABJ 2 – 29°50'19''/51°23'42''; ABJ 3 – 29°50'16''/51°22'46''). Sampling was concentrated in spring and winter, since a previous study (Volkmer-Ribeiro *et al.*, 1984) had found that these were, respectively, the seasons of greater and lesser abundance and richness. To check this information, samples were also taken in summer and autumn at one site in the brook and another in the river.

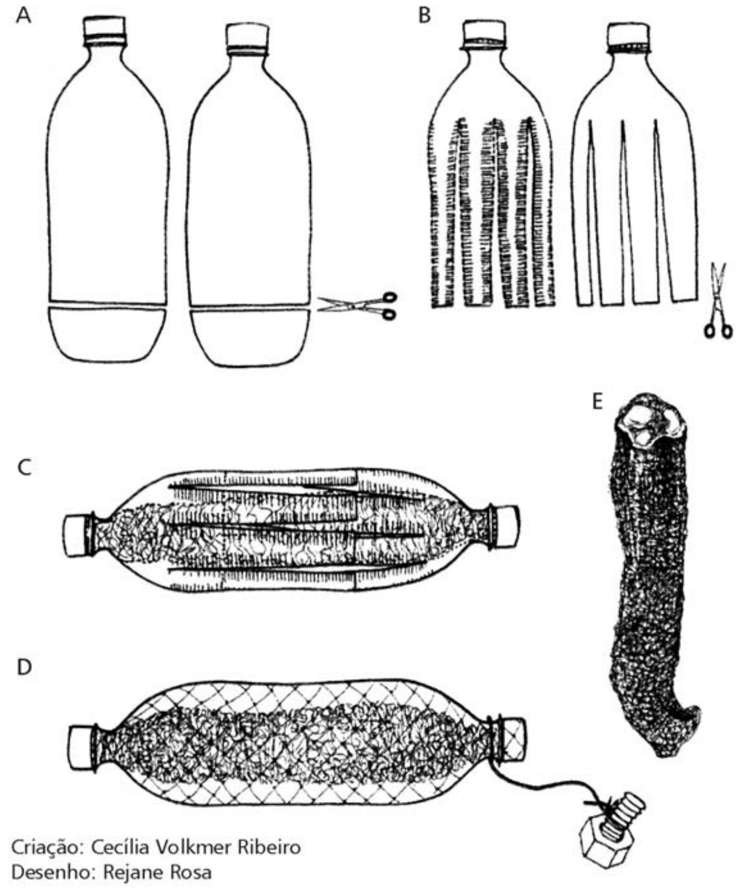

Fig. 1 — Illustration of the PET sampler assembly.

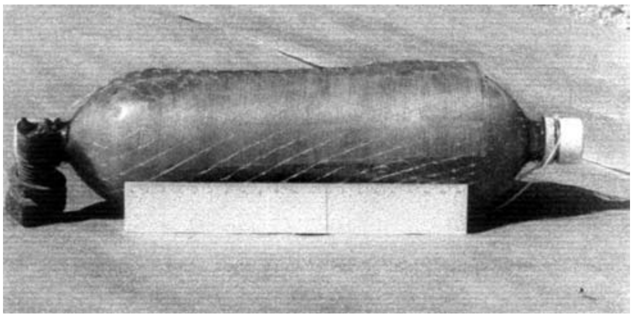

Fig. 2 — Photo of the assembled PET sampler.

Samplers were placed on the bank, holding one end of the nylon thread and throwing the sampler, then tying the thread to a trunk or a branch of riverside vegetation at water level. Care had to be taken to ensure that the sampler sink, resting horizontally on the river bed, at a depth not overly exposed during the dry season. Occupation of the sampler by sediment and fauna took place over the duration of its stay on the river bottom.

The time estimated for colonization of the artificial substrate was two months. Recovery was done by a researcher positioned in the water by the bank who, after releasing the nylon thread from the substrate to which it was tied, used it to locate the sampler without displacing it. Once located, the device was maneuvered, without raising it, into a plastic bag placed on the river bottom. As soon as the sampler was bagged, it was sealed and lifted from the water.

Out of the river the bag was placed inside a plastic bucket, opened in order to fix the material with 5% formalin, closed again, and transported in the same bucket to the laboratory. The reason for placing the plastic bag in a bucket was to preserve the individual samples, in case the plastic bag leaked, after removal from the river. The contents of each bag, with its sampler, were inverted into a sieve lined with cotton and washed under running water, following which the bottles, as well as the nets and the vegetable fillings, were left to dry for subsequent examination of the attached fauna.

Data analysis

The temporal and spatial patterns in faunal composition and abundance found in the samplers were analyzed using Principal Component Analysis. A sampling unit was considered to be a group of five PET samplers recovered from each point, the data from which were totaled.

We calculated the classically-used parameters for the description of macroinvertebrate communities: abundance of organisms (total number of organisms, independent of taxonomic identity), species richness, and Shannon's Diversity index. The abundance data were previously transformed, using the logarithm ($\log(|x + 1|)$), in order to reduce the effect of the large number of organisms of some species. Differences between the sites were tested using Analysis of Variance, via randomization testing, calculating the sum of the squares (Qb) from a Euclidean distance similarity matrix. This procedure is recommended by Pillar & Orlóci (1996) as an alternative to the data normality requirements of traditional ANOVA. Block delineation, corresponding to the seasons of the year, and two factors (season of the year and areas) were adopted, in order to eliminate variation between the sites of each area from the analysis. The PET samplers obtained on each sampling occasion were taken as replicates. The relationship between the community's descriptive parameters was measured using Correlation Coefficient, with the significance assessed using randomization testing according to Pillar & Orlóci (1996).

The analyses were performed with a MULTIV version 2.1.1 (Pillar, 2000).

RESULTS

The samplers captured a total of 68 macroinvertebrate species, with 36 species common to both river and brook, 10 species found only in the brook, and 22 species found only in the river. The PET sampler also captured one species of small fish occurring in both river and brook. The sampling covered the most representative macroinvertebrate groups, from molluscs to crustaceans and insect larvae, plus sessile groups such as sponges and bryozoa, thereby proving the device successful in enclosure/colonization of mud/sand as well as in affording a hard substrate for fixation of sessile animals such as bryozoan and sponges. Gastropod, crustacean, and insect larvae were the groups with the highest richness, both in river and brook. Turbellaria, the gastropod *Heleobia piscium*, Oligochaeta, the crustaceans Cyclopidae sp. and Podocopida, Lepidoptera larvae, and Bryozoa were the invertebrates with the highest abundance in the river while, for the brook, the taxa were *Heleobia piscium*, Oligochaeta, Collembola sp.1, Lepidoptera sp.1, and Elmidae sp.1 (Tables 1 and 2).

TABLE 1
Benthic fauna sampled with the PET sampler in River Caí in autumn, winter, spring and summer.

Taxonomic list	Station 4	Station 4	Station 3	Station 2	Station 2	Station 1	Station 1	Station 1	Station 1
	Winter	Spring	Spring	Winter	Spring	Autumn	Winter	Spring	Summer
Turbellaria sp.	0	0	0	0	156	0	0	255	304
Nematoda sp.	0	6	11	0	5	0	0	0	0
Bivalvia sp.	0	0	0	0	0	4	0	0	0
Limnoperna fortunei (invasor bivalve)	0	0	1	0	8	0	0	4	7
Eupera klappenbachi	0	7	0	0	0	0	0	6	9
Psidium punctiferum	2	1	1	0	0	0	0	4	9
Gastropoda sp.	2	14	2	0	1	5	9	20	0
Heleobia piscium	2	21	0	63	216	162	0	147	261
Potamolithus sp.	0	0	66	0	0	0	0	0	0
Asolene spixi	0	1	0	0	0	0	0	0	0
Pomacea canaliculata	0	5	0	0	3	0	0	2	0
Gundlachia concentrica	2	102	1	0	5	0	0	1	24
Gundlachia moricandi	0	0	0	0	0	2	0	0	0
Antillorbis nordestensis	1	0	0	0	78	0	0	9	1
Drepanotrema anatinum	0	0	0	0	0	0	0	1	0
Hirudinea sp.	0	61	24	0	33	0	0	2	0
Oligochaeta sp.	0	217	184	0	560	0	0	260	83
Fritzianira exul (Isopoda)	0	0	0	1	0	0	0	0	0
Hyalella curvispina (Amphipoda)	0	0	1	0	0	0	0	0	0
Trichodactylus panoplus (Decapoda)	0	0	13	1	8	6	0	17	19
Cladocera sp.	1	6	84	2	5	0	8	41	0
Chydoridae sp.	0	0	0	0	0	1	0	0	0
Ilyocryptus spinifer	0	0	0	0	0	1	0	4	9
Maxillopoda sp.1	0	0	0	0	0	0	15	0	0
Maxillopoda sp.2	0	0	0	0	0	0	6	0	0
Cyclopidae sp.	28	18	20	443	75	106	127	82	19
Diaptomidae sp.	0	0	0	0	0	29	0	0	0
Harpacticoida sp.	0	0	0	7	0	0	0	0	0
Podocopida sp.1	57	8	0	7	26	0	99	66	6
Podocopida sp.2	0	0	0	1	0	0	1	23	0
Chlamidotheca sp.	0	1	0	0	1	0	0	1	0
Cytheridella ilosrayi	0	0	0	0	0	0	0	23	37
Darwinulidae sp.	0	0	0	0	0	12	0	0	0
Ephemeroptera sp.	0	15	0	0	3	0	0	3	0
Caenidae sp.	0	1	0	0	0	0	0	0	0
Leptophlebiidae sp.1	0	0	0	1	0	0	0	0	0
Leptophlebiidae sp.2	0	0	1	0	0	0	0	0	0
Zygoptera sp.	0	0	0	0	0	0	0	0	1
Coenagrionidae sp.	0	0	0	0	0	1	0	0	0
Belostoma sp.	1	0	0	0	0	0	0	0	0
Mesoveliidae sp.	5	0	0	0	0	0	0	0	0
Gerridae sp.	0	0	0	1	0	0	0	0	0
Noteridae sp.1	1	0	0	10	1	3	0	1	0
Noteridae sp.2	0	0	1	0	0	0	1	0	0
Elmidae sp.1	0	0	0	0	0	0	0	0	1
Elmidae sp. 2	4	1	1	0	0	1	0	4	0
Gyrinidae sp.	0	0	0	0	0	0	0	1	0
Collembola sp.1	0	17	15	0	18	0	0	27	5
Collembola sp.2	0	0	0	0	0	0	0	0	1
Collembola sp.3	3	0	0	0	0	0	0	0	0
Lepidoptera sp.1	46	80	45	9	201	12	6	110	0
Lepidoptera sp. 2	0	2	0	0	0	0	0	0	0
Ceratopogonidae sp.	6	0	1	0	25	0	1	0	0
Acariformes sp.1	0	0	0	0	1	0	0	0	0
Theridiidae sp. (Aranae)	0	0	0	0	0	1	0	0	0
Amaurobiidae sp. (Aranae)	0	0	69	0	0	0	0	0	0
Bryozoa sp.	0	32	0	0	103	0	0	74	89
Synbranchus marmoratus (Pisces)	0	1	1	0	0	0	0	1	0

TABLE 2
Benthic fauna sampled with the PET samplers in the Bom Jardim stream in autumn, winter, spring and summer.

Taxonomic list	Station 1	Station 1	Station 2	Station 2	Station 2	Station 2	Station 3	Station 3
	Winter	Spring	Autumn	Winter	Spring	Summer	Winter	Spring
Heteromeyenia stepanowii	0	0	0	0	0	0	0	1
Trochospongilla paulula	0	0	0	0	0	0	0	1
Turbellaria sp.	0	0	0	0	3	0	0	5
Nematoda sp.	0	1	0	0	18	0	0	1
Eupera klappenbachi	0	4	0	0	0	1	0	0
Psidium punctiferum	0	10	8	4	7	0	1	2
Gastropoda sp.	37	2	3	0	0	0	1	1
Heleobia piscium	268	365	1	1	3	0	0	0
Gundlachia concentrica	9	27	4	0	22	0	0	11
Antillorbis nordestensis	7	11	0	0	5	0	0	5
Hirudinea sp.	0	32	0	0	4	2	0	5
Oligochaeta sp.	0	7	0	0	158	29	0	238
Fritzianira exul	1	0	0	0	0	0	0	0
Hyalella curvispina	0	3	1	0	0	0	0	0
Trichodactylus panoplus	2	3	2	4	1	2	0	1
Cladocera sp.	3	11	0	0	0	1	1	3
Ilyocryptus spinifer	0	0	0	0	3	0	0	9
Simocephalus sp.	0	0	0	0	0	1	0	0
Cyclopidae sp.	6	7	9	26	0	2	1	6
Podocopida sp.1	6	52	0	5	7	0	0	1
Podocopida sp.2	0	9	0	0	0	0	0	0
Chlamidotheca sp.	0	0	0	0	1	0	0	0
Cytheridella ilosrayi	18	12	0	0	0	4	0	0
Baetidae sp.	0	0	0	0	0	0	0	1
Caenidae sp.	0	0	0	4	0	0	0	1
Leptophlebiidae sp.1	0	0	0	0	0	0	0	9
Coenagrionidae sp.	0	0	1	0	0	0	0	0
Hemiptera sp.	0	0	2	0	0	0	0	0
Noteridae sp.1	0	0	0	0	0	0	0	0
Noteridae sp.2	0	0	0	1	0	1	0	0
Elmidae sp.1	0	1	29	62	22	20	5	7
Elmidae sp.2	0	0	0	0	1	0	0	0
Elmidae sp.3	0	0	0	0	0	0	0	1
Gyrinidae sp.	0	0	0	0	0	2	0	2
Hydrophilidae sp.	0	0	1	0	0	0	0	0
Collembola sp.1	0	9	0	0	16	48	0	66
Collembola sp.2	0	0	0	2	0	0	0	1
Collembola sp.3	0	0	1	0	0	0	0	0
Collembola sp.4	0	0	0	0	0	0	1	0
Lepidoptera sp.1	6	147	45	87	75	34	13	185
Lepidoptera sp. 2	0	2	0	0	4	86	0	1
Ceratopogonidae sp.	0	0	2	1	1	0	0	0
Psychodidae sp.	0	0	0	0	0	0	2	0
Acariformes sp.1	0	0	0	0	0	0	0	1
Acariformes sp.2	0	0	1	0	0	0	0	0
Bryozoa sp.	0	3	0	0	5	5	0	2
Heptapterus mustelinus (Pisces)	0	0	0	0	1	1	0	0

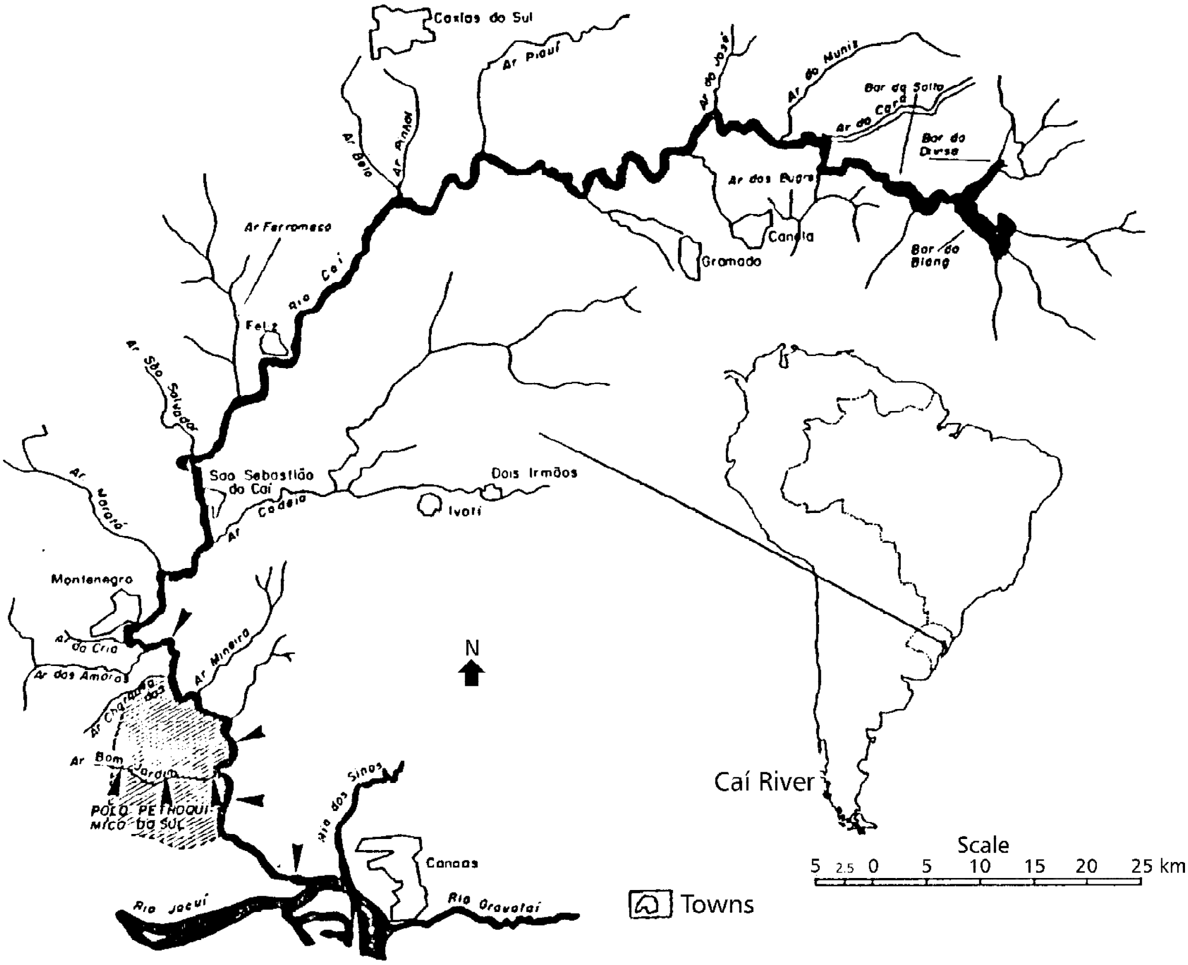

Fig. 3 — River Caí basin. The arrows from top to bottom (stations 4, 3, 2, 1) indicate the area of the river and the Bom Jardim brook (stations 3, 2, 1) where the PET sampling device was tested. Adapted from Volkmer-Ribeiro *et al.* (1984).

TABLE 3

Benthic macroinvertebrates in the River Caí and the Bom Jardim brook obtained in the artificial samplers, in the period 2001-2002. N = total number of organisms, S = species richness, H' = Shannon's diversity index.

	River Caí									Bom Jardim brook							
Station	4	4	3	2	2	1	1	1	1	1	1	2	2	2	2	3	3
Season	win	spr	spr	win	spr	aut	win	spr	sum	win	spr	aut	win	spr	sum	win	spr
N	161	617	542	546	1533	346	273	1189	885	363	718	110	197	357	239	25	567
S	15	22	20	12	23	16	10	28	18	11	21	15	11	20	16	8	27
H'	1.770	2.123	1.246	0.75	2.054	1.508	1.329	2.356	1.848	1.061	1.725	1.806	1.423	1.899	1.855	1.508	1.637

The richness, the diversity of species, and the abundance of organisms tended to be greater in spring and summer and in the River Caí location (Table 3). The three parameters were correlated, showing that the same patterns can be detected with any one of them (Table 4). Significant differences of richness, abundance, and diversity were detected between the seasons, but not between the two sampled areas (River Caí and Bom Jardim brook) (Table 5). A clear pattern of progressive reduction in the three community descriptors from spring to winter was detected, with significant differences found between the hotter and colder seasons (Table 6).

The ordination of the samples obtained with the PET samplers (Fig. 4) showed a greater variation, particularly apparent in the first axis, in composition and abundance between the seasons of the year. Spring and summer have similar compositions, different from those found in autumn and winter, which also tend to form a group. *Limnoperna fortunei,* Gastropoda sp*.*, *Heleobia piscium,* Nematoda sp., *Gundlachia concentrica,* Hirudinea sp*.*, Cyclopidae sp., Podocopida sp.1, Chlamidotheca sp., Darwinulidae sp., Noteridae sp.1, Noteridae sp.2, and Ceratopogonidae were the taxons that most influenced these patterns. There was great variation until the 13^{th} axis, although the first two explain 57.6% of total variance, suggesting the absence of a strong association between the species themselves or an area or a particular season of the year.

DISCUSSION

The characterization of macroinvetebrate communities is highly influenced by decisions about sampling design (Beisel *et al*., 1998; Larsen & Herlihy, 1998), parameters calculated (Solimini *et al*., 2000; Thompson & Townsend, 2000; Brown, 2001) and sampling devices employed (Bartsch *et al*., 1998). Several studies have pointed out that all methods of macroinvertebrate collection are selective (Muzaffar & Colbo, 2002; Humphries *et al.,* 1997). Choice of a device should be based on the specific objectives of a particular monitoring program and pilot studies measuring the efficiency of the selected device in pattern detection (Carter & Resh, 2001). The main aim in monitoring the structure of the macroinvertebrate community of the River Caí and the Bom Jardim brook, in the area influenced by the Southern Petrochemical Complex in Triunfo, RS, is the detection of fluctuations between years and sites. The detection of any reduction in abundance of organisms, species richness, or diversity is particularly important as it may indicate alterations occurring in environmental conditions (Magurran, 1988; Pontasch *et al.,* 1989; Cairns *et al.,* 1993). The PET sampler proved, first of all, capable of yielding a broad spectrum of macroinvertebrate benthic fauna and, second, to be sensitive in the detection of patterns and identification of differences between the seasons of the year and the two surveyed areas.

The use of artificial samplers is still open to debate. Some studies have found them efficient (Benoit *et al.,* 1998) but others have demonstrated that direct sampling captures a more diversified fauna (Casey & Kendall, 1997). The correlation between species richness, total abundance of organisms, and Shannon's index obtained with the PET sampler is an advantage not offered by every method. This property makes the new device suitable for use in different strategies of data analysis in river systems under study.

TABLE 4
Correlation between the species richness, Shannon-Wiener diversity index (H'), and abundance of organisms at sites on the River Caí and the Bom Jardim stream, in the period 2001-2002. The matrix shows the correlation value below the principal diagonal and the corresponding probabilities above the principal diagonal. H´ = Shannon diversity index.

	Abundance	Richness	H'
Abundance		0.001	0.001
Richness	0.74127		0.055
H'	0.71424	0.47373	

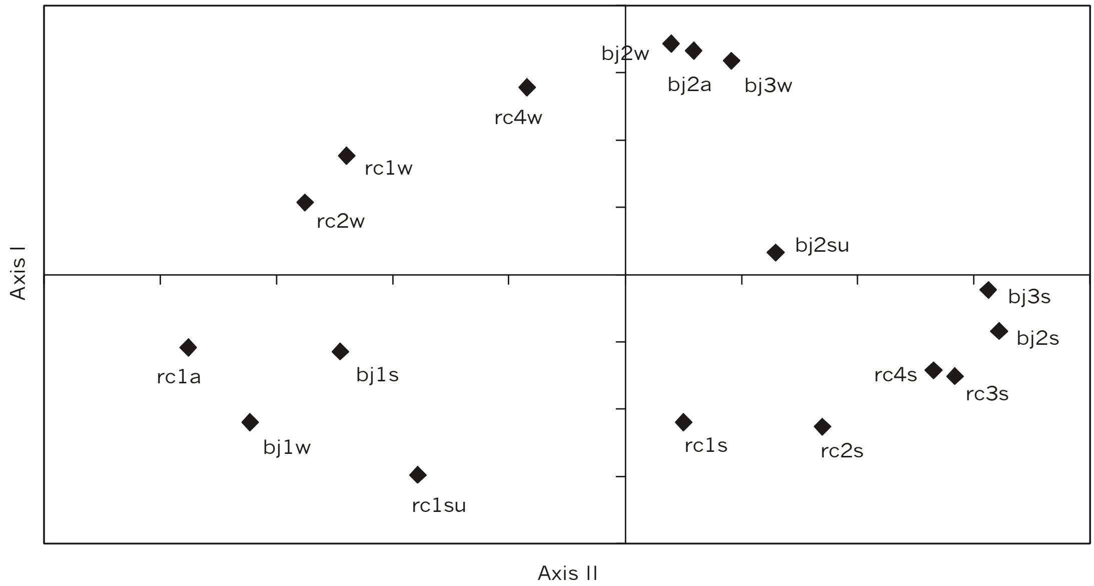

Fig. 4 — Dispersion diagram of the first two PCA axes of the macrobenthic samples from the River Caí (rc) and the Bom Jardim stream (bj) with PET samplers in the period 2001-2002. a = autumn, w = winter, s = spring, su = summer.

TABLE 5
Effect of the season of the year and type of environment on community parameters of macroinvertebrate fauna of the River Caí and the Bom Jardim brook in the period 2001-2002.

Parameter	Factor	Qb	P
Richness	Block (sampling site)	83.344	
	Season	590.72	0.001
	Environment	73.35	1.000
Abundance	Block (sampling site)	2.2743	
	Season	2.1842	0.001
	Environment	110.29	0.895
Shannon's index	Block (sampling site)	1.6839	
	Season	6.7064	0.001
	Environment	928.69	0.300

TABLE 6
Contrasts in the analysis of the effect of the season of the year on community parameters of macroinvertebrate fauna of the River Caí and the Bom Jardim stream in the period 2001-2002.

Contrast	Richness		Abundance		Shannon's index	
	Qb	P	Qb	P	Qb	P
Spring-summer	28.93	0.167	90.94	0.368	0.0146	0.827
Spring-autumn	126.23	0.004	958.27	0.001	0.4497	0.167
Spring-winter	567.77	0.001	1802.50	0.001	6.1951	0.001
Summer-autumn	22.05	0.271	294.91	0.084	0.1944	0.377
Summer-winter	120.00	0.006	382.70	0.028	2.4884	0.005
Autumn-winter	27.07	0.190	2.16	0.902	1.0763	0.060

The faunal composition sampled in the present case is comparable to that found in Volkmer-Ribeiro *et al.* (1984) in the same river and to that of the survey performed by Sampóns (1988) for similar antropically-modified lotic environments in the area around Buenos Aires. The patterns also compare to those found in the literature (Hynes, 1970; Whitton, 1975; Petts & Calow, 1996). The clear seasonal pattern found with the new sampler is characteristic of macroinvertebrate communities sampled using different methods and in different locations (Gratwicke, 1998), including in Brazilian systems (Melo & Froehlich, 2001). The fact that the River Caí system had previously been shown to present the maximum count for most taxons in spring (Volkmer-Ribeiro *et al.,* 1984) also reinforces the utility of the new sampler.

No clear difference in richness, abundance, and Shannon's index was found between the two areas sampled because the variation between the seasons of the year is of much greater importance. On the other hand, the variation in composition between these two areas was detected by the multivariate procedure, which reflects the differences in habitat preferences (Baptista *et al.,* 2001).

The introduction of the artificial sampler along the length of the River Caí under examination allowed, for the first time, a viable statistical comparison between the different sampling sites and periods of the year. This sampler also creates the possibility of standardization of sampling, which is advantageous for monitoring purposes, over long stretches of river systems where natural habitats vary (Rosemberg & Resh, 1982). The PET samplers represent a reliable, low-cost alternative for monitoring the macrobenthos of the studied river system. The technique is particularly promising in situations where the river characteristics inhibit the use of other techniques.

Acknowledgements – The authors are indebted to Erika Elena Buckup of MCN/FZB for the identification of the Arachnida morpho species, Rejane Rosa of MCN/FZB for the drawings in Fig. 1, George Rodrigues Cunha of MCN/FZB for help in field work, and an anonymous referee for valuable suggested and accepted improvements.

REFERENCES

AROCENA, R., 1996, La comunidad bentónica como indicadora de zonas de degradación y recuperación en el arroyo Toledo (Uruguay). *Ver. Biol. Trop., 44*: 659-671.

BAPTISTA, D. F., BUSS, D. F., DORVILLE, L. F. M. & NESSIMIAN, J. L., 2001, Diversity and habitat preference of aquatic insects along the longitudinal gradient of the Macae River basin, Rio de Janeiro, Brazil. *Braz. J. Biol.*, *61*(2): 249-258.

BARTSCH, L. A., RICHARDSON, W. B. & NAIMO, T. J., 1998, Sampling benthic macroinvertebrates in a large flood-plain river: considerations of study design, sample size, and cost. *Environ. Monitor. Assess.*, *52*(3): 425-439.

BEISEL, J. N., USSEGLIO, P. P., THOMAS, S. & MORETEAU, J. C., 1998, Effects of sampling on benthic macroinvertebrate assemblages in assessment of biological quality of running water. *Annales de Limnologie*, *34*(4): 445-454.

BENOIT, H. P., POST, J. R., PARKINSON, E. A. & JOHNSTON, N. T., 1998, Colonization by lentic macroinvertebrates: Evaluating colonization processes using artificial substrates and appraising applicability of the technique. *Can. J. Fisheries Aquatic Sci.*, *55*(11): 2425-2435.

BROWN, C. A., 2001, A comparison of several methods of assessing river condition using benthic macroinvertebrate assemblages. *Afr. J. Aquatic Sci.*, *26*(2): 135-147.

CAIRNS Jr. J., MCCORMICK, P. V. & NIEDERLEHNER, B. R., 1993, A proposed framework for developing indicators of ecosystem health. *Hydrobiologia, 263*: 1-44.

CARTER, J. L. & RESH, V. H., 2001, After site selection and before data analysis: sampling, sorting, and laboratory procedures used in stream benthic macroinvertebrate monitoring programs by USA state agencies. *J. North Am. Benthol. Soc.*, *20*(4): 658-682.

CASEY, R. J. & KENDALL, S. A., 1997, Sample number and colonization patterns of benthic macroinvertebrates and organic material on artificial and natural substrata. *J. Freshwater Ecol.*, *12*(4): 577-584.

CHESSMAN, B. C., 1995, Rapid assessment of rivers using macroinvertebrates: a procedure based on habitat-specific sampling, family level identification and a biotic index. *Austral. J. Ecol., 20:* 122-129.

FEPAM, 2001, *Avaliação ambiental da mineração de areia no Lago Guaíba e afluentes*. Porto Alegre, RS. 1 CD-ROM. Windows 3.1.

GRATWICKE-B., 1998, The effect of season on a biotic water quality index: a case study of the Yellow Jacket and Mazowe Rivers, Zimbabwe. *South. Afric. J. Aqu. Sci.*, *24*(1-2): 24-35.

HUMPHRIES, P., GROWNS, J. E., SERAFINI, L. G., HAWKING, J. H., CHICK, A. J. & P. S., 1997, Macroinvertebrate sampling methods for lowland Australian rivers. *Hydrobiologia*, *364*(2): 209-218.

HYNES, H. B. N., 1970*, The ecology of Running Waters*. University Press, Liverpool, 555p.

LARSEN, D. P. & HERLIHY, A. T., 1998, The dilemma of sampling streams for macroinvertebrate richness. *J. North Am. Benthol. Soc.*, *17*(3): 359-366.

MAGURRAN, A. E., 1988, *Ecological diversity and its measurement*. Princeton Univ. Press, Princeton, 179p.

MELO, A. S. & FROEHLICH, C. G., 2001, Macroinvertebrates in neotropical streams: Richness patterns along a catchment and assemblage structure between 2 seasons. *J. North Am. Benthol. Soc*., *20*(1): 1-16.

MUZAFFAR, S. B. & COLBO, M. H., 2002, The effects of sampling technique on the ecological characterization of shallow, benthic macroinvertebrate communities in two Newfoundland ponds. *Hydrobiologia*, *477*: 31-39.

PETTS, G. & CALOW, P. (eds.), 1996, *River biota: diversity and dynamics selected extracts from the rivers handbook.* Blackwell, Oxford, 257p.

PILLAR, V. D. & ORLÓCI, L., 1996, On randomization testing in vegetation science: multifactor comparisons of relevé groups. *Journal of Vegetation Science, 7*: 585-592.

PILLAR, V. D., 2000, *Multiv – Multivariate exploratory analysis, randomization testing and bootstrap resampling: user's Guide v.2.0.* Universidade Federal do Rio Grande do Sul, Porto Alegre.

PONTASCH, K. W., SMITH, E. P. & CAIRNS, J., 1989, Diversity indexes, community comparison indexes and canonical discriminant analysis: interpreting the results of multispecies toxicity tests. *Water Res., 23*: 1229-1238.

ROSEMBERG, D. N. & RESH, V. H., 1982, The use of artificial substrates in the study of freshwater benthic macroinvertebrates, pp. 175-235. *In*: J. Cairns (ed.), *Artificial substrates*. Ann Arbor Sci., Ann Arbor, MI.

ROSEMBERG, D. N. & RESH, V. H. (eds.), 1993, *Freshwater biomonitoring and benthic macroinvertebrates*. Chapman & Hall, New York, 488p.

SAMPÓNS, M. R., 1988, Zoobentos del río Arrecifes (Buenos Aires, Argentina) y sus principales tributarios. *Iheringia*, ser. Zool. Porto Alegre, *68*: 63-82.

SOLIMINI, A. G., GULIA, P., MONFRINOTTI, M. & CARCHINI, G., 2000, Performance of different biotic indices and sampling methods in assessing water quality in the lowland stretch of the Tiber River. *Hydrobiologia*, *422-423*: 197-208.

THOMPSON, R. M. & TOWNSEND, C. R., 2000, Is resolution the solution?: The effect of taxonomic resolution on the calculated properties of three stream food webs. *Freshwater Biol.*, *44*(3): 413-422.

VEIJOLA, H., MERILÄINEN, J. J. & MARTTILA, V., 1996, Sample size in the monitoring of benthic macrofauna in the profundal of lakes: evaluation of the precision of estimates. *Hydrobiologia, 322*: 301-315.

VOLKMER-RIBEIRO, C., MOTHES DE MORAIS, B., DE ROSA BARBOSA, R., MANSUR, M. C. D. & VEITENHEIMER-MENDES, I. L., 1984, Um estudo do bentos em raízes de *Eichhornia azurea* (Sw.) Kunt, do curso inferior de um rio Subtropical Sul-americano. *Revista Brasileira de Biologia*, Rio de Janeiro, *44*(2): 125-132.

WHITTON, B. A., 1975, *River ecology*. Blackwell, Oxford, (Studies in Ecology, 2) Scientific Publications, 725p.

ZMARZLY, D. L., STEBBINS, T. D., PASKO, D., DOUGLAS, R. M. & BARWICK, K. L., 1994, Spatial patterns and temporal succession in soft-bottom macroinvertebrate assemblages surrounding an ocean outfall on the southern San Diego shelf: relation to anthropogenic and natural events. *Mar. Biol., 118*: 293-307.