Suction sampler for collection of benthic macroinvertebrates in several continental aquatic environments: a comparative study with the Hess and Surber samplers.

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ABSTRACT: Suction sampler for collection of benthic macroinvertebrates in several continental aquatic environments: a comparative study with the Hess and Surber samplers. The difficulty of collecting benthic samples in turbulent, deep water, stony substrate and high flow rivers, is known. Thus, the aim of this article is to describe a Suction sampler, its operation, as well as demonstrate its efficiency for collecting benthic macroinvertebrates in several substrates of a river from large boulder to muddy substrate and in different water depths and current velocity. This sampler was developed and tested in the Tocantins River, in the influence area of the Luís Eduardo Magalhães hydroelectric power station during the phases: pre-filling, reservoir filling and reservoir. In this article, just the results of the pre-filling phase from the period of September 2000 until August 2001 are presented. The Suction sampler had a good performance comparing to Hess and Surber samplers and could be used in most varied conditions, also enabling comparisons between points with different characteristics and sampling periods.

Key-words: Suction sampler, benthic macroinvertebrates, benthic collecting.

RESUMO: Amostrador de sucção para coleta de macroinvertebrados bentônicos em ambientes aquáticos continentais diversos: um estudo comparativo com os amostradores Hess e Surber. A dificuldade de coletar amostras de bentos em rios caudalosos, profundos, rochosos e com alta correnteza é conhecida. Assim, este trabalho tem como objetivo descrever um amostrador tipo sucção, seu funcionamento, bem como demonstrar sua eficiência na coleta de macroinvertebrados bentônicos em um rio com leito heterogêneo, de bloco rochoso a substrato lodoso e profundidade da coluna d'água e velocidade da corrente variadas. Esse amostrador foi desenvolvido e testado no rio Tocantins, na área de influência da usina hidrelétrica Luis Eduardo Magalhães, nas fases de: pré-inundação, enchimento e represa, mas no presente trabalho somente os resultados da fase pré-inundação são apresentados, referentes ao período de setembro de 2000 a agosto de 2001. O amostrador de sucção teve desempenho bom em relação aos de Hess e de Suber, podendo ser usado nas mais variadas condições, e também, permitindo comparações entre pontos de diferentes características e períodos de amostragem.

Palavras-chave: amostrador de sucção, macroinvertebrados bentônicos, coleta de bentos.

Introduction

According to Rosenberg & Resh (1993), the benthic macroinvertebrates refer to organisms that inhabit the bottom substrates (sediments, debris, logs, macrophytes, filamentous algae, etc.). This community is formed by invertebrates of several taxonomic groups. These invertebrates inhabit aquatic habitats, from small ponds to great lakes, streams to great rivers. The quantitative sampling is hindered by the contagious distribution of the benthic macroinvertebrates and it requests a great number of samples to get a larger precision to estimate the abundance of the populations that participate in the community (Rosenberg & Resh, 1993). According to Brandimarte et al. (2004), the use of several sampler types in a same collection place would be necessary in wide explorations of a same aquatic system. However, that hinders comparisons among points in different places, considering the heterogeneity of bottom substrates and/or sampling periods, particularly the susceptible systems to the variations of water column depth. Therefore to ensure the possibility of comparisons among the samples, the sampler to be used should be equally effective in the most different habitat types (Brown et al., 1987). The comparison problems from the obtained results appear in several occasions when different sampling methods are used (Mackey, 1972).

Generally, the biggest difficulty is the choice of the equipment to guarantee the standardisation of the samples. The sampler should be efficient in obtaining samples. In other words, it should be able to penetrate in the substrate to collect the present invertebrates in the sediment. Also it should be able to have always the same superficial area as well as constant depth; not turning over the sediment and disturbing the organisms during the drop of the equipment. At last it should be able to avoid material losses during the closing and withdrawal of the sampler (Brandimarte et al., 2004).

The chosen sampling techniques depend on the physical characteristics of the investigated system (Downing, 1984) and on the aim of the research, taking into account the reality of available resources and the limitations of time imposed to the study (Weber, 1973).

The difficulty of collecting benthic samples in deep and torrential rivers and rocky bottom is known among the researchers. According to Brandimarte et al. (2004), the use of suction samplers allow population estimates with larger accuracy than grab samplers. Also they can be used in several types of substrates, from the rocky ones (gravel, pebble, flintstones, blocks) to the soft substrates (sand and mud).

Depending on the mechanism to be used the suction samplers can be classified in two types: suction to be accomplished by a water pump or by an air compressor (air-lift pump) (Drake & Elliott, 1982). The first type refers to the samplers that use the pumping water mechanism, frequently using a tube and the sediment is aspired through this. The second type includes the ones that use the under pressure air to elevate the sediment inside of the collecting net (Elliott et al., 1993). These authors subdivide the suction samplers in other categories, taking into account the need or not of divers during the collection and if it is a vacuum suction or through difference of a pressure between the air inside the equipment and in the water.

According to Rostron (2001) the suction samplers present the following advantages: i) depending on the model used the equipment can be totally portable and with an easy manipulation; ii) the technicians receive simple instructions about the use of the equipment; iii) the exact conditions of the habitat can be registered and information about the sediment and the biota can be obtained at the same place. In the case of the grab samplers, impact and loss occur frequently, since they are thrown in water several times; iv) these samplers can be thrown from a small boat, depending on the size and weight of the sampler; v) the sampling efficiency is high and it can be collected in different depths as well as several substrates, even in those ones which are difficult to collect by other ways.

In this context, the evaluated Suction sampler in this work try to maximise the standardisation of the samples and its efficiency in the collection of the fauna, considering the evaluation of the environmental changes as a result of the damming of the Tocantins River for hydroelectric power station construction (Dam Luís Eduardo Magalhães). In this article, only the results of the pre-filling phase have been discussed once the samplers used (Hess and Surber) to compare with the Suction sampler are inappropriate in the other phases (filling and reservoir) of the hydroelectric power station construction.

Therefore, this work aims to describe a Suction sampler, its operation in different habitats as well as to demonstrate its efficiency in the collecting the benthic macroinvertebrates in a river with different bed substrates (from large boulder to muddy substrate), different water depth and current velocity, comparing to the Surber and Hess samplers.

Material and methods

The work was accomplished in the Tocantins River, in the stretch denominated Medium Tocantins, with 250 km of extension. This stretch corresponds to the area of influence of the hydroelectric power station Luís Eduardo Magalhães. The

Tocantins River presents an annual flow average of 10.900m^3/s. The depth of the river in the sampled area in the pre-filling phase varied from 0.47m to 6.0m, and the current velocity from 2.09m/s to 17.08m/s.

Starting from the difficulties faced in the sampling of the benthic fauna in Tocantins River, the construction of a more efficient sampler was necessary to allow sampling during the whole process of the hydroelectric power station construction. An appropriated sampler that can be applied to the different substrates, as well as suitable to the changes of the substrate, water column depth and current velocity in different phases of the damming (pre-filling, filling and reservoir phases).

This sampler was developed and tested in the Tocantins River, in the influence area of the Luís Eduardo Magalhães hydroelectric power station during the phases: pre-filling, reservoir filling and reservoir. In this article, just the results of the collections made every other month in the pre-filling phase, during the period of September 2000 until August 2001 are presented; mainly data of the dry period.

Results about density (number of individuals per m^2) and richness (sum of the taxonomic groups) has been compared between three samplers (Suction, Hess and Surber) to evaluate the efficiency of the Suction sampler during pre-filling phase of the dam construction in the Tocantins River.

Description of the sampler

The body of the sampler (Fig. 1) consists of a metal square box (galvanised iron plates) with dimension 30 cm x 30 cm x 30 cm (height, width and depth) plus 10 cm on the width in each side for the addition of the weights. The box's lower part (D) is open and it is in contact with the bed of the river. The lateral sides of the box are totally closed. On the upper part a metal tube (inox) with 5 cm of diameter and 25 cm long penetrates the middle of the box. In the tube's upper extremity (A), outside of the box, a hose (plastic tube) of the water pump is placed to aspirate the sediment.

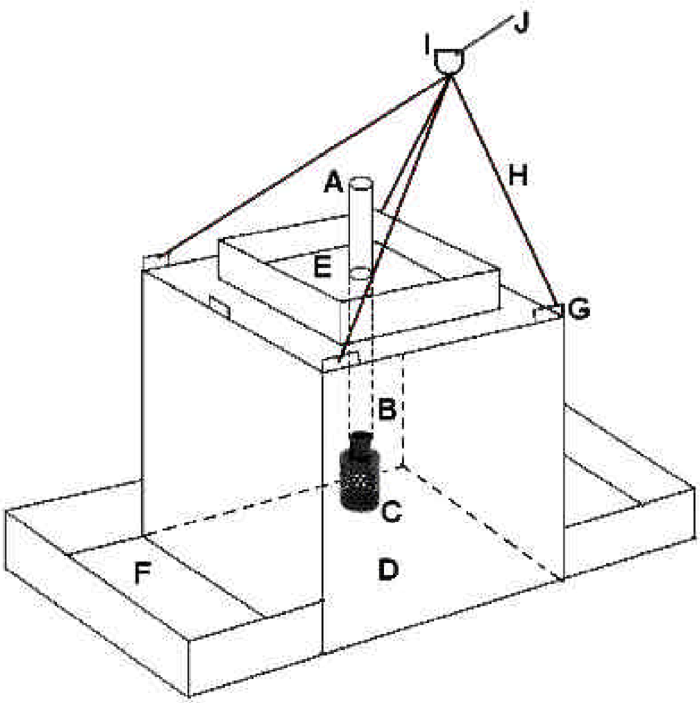

Figure 1: Three-dimensional view of the Suction sampler: (A and B) extremities of the tube; (C) filter; (D) lower part of the box; (E and F) ballasts installation places; (G) handle; (H) strings; (I) clamp and (J) steel cable.

In the tube's lower extremity (B), inside of the box, a plastic or metal filter is placed (C) with little holes of 1.0 cm of diameter (part of the pump). Like this it is possible to the invertebrates to pass through it and impeding big materials to be aspirated and damage the system. In each extremity of the box's upper part there is a handle to tide the strings (H) to a clamp (I) and to the steel cable (J) of the winch. Also ballasts are placed in the upper part (E) and on the sides (F) to give balance and weight;

allowing the equipment to go strait down and avoiding to be drifted by the river current.

Collection procedure

The Suction sampler presented in this work can be used for lotic and lentic environment, but the procedure differs in each one of these systems as it can be seeing next.

In rivers or in pre-filling phase, the boat prow is positioned against the current (Fig. 2). With the help of anchors and ballasts (A) in the collection point, the boat worker (B) should leave the boat motor in operation to guarantee that the sampler is thrown without being drifted by the current.

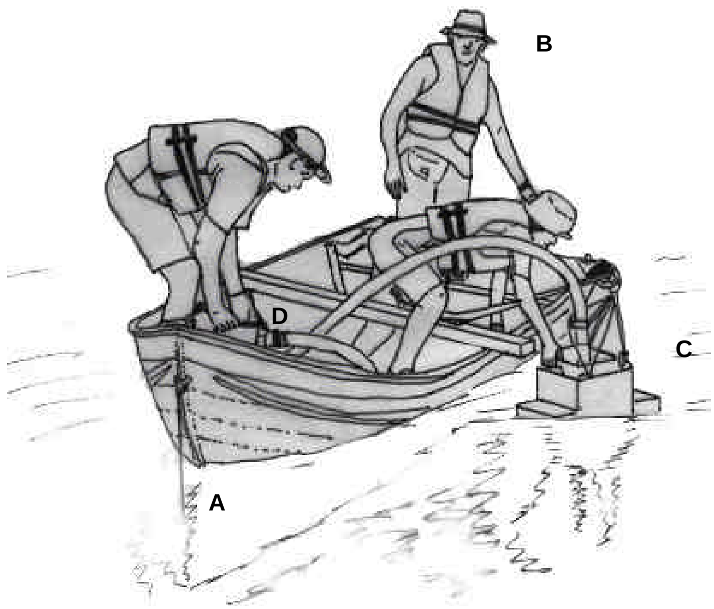

Figure 2: Collection procedure: (A) put the anchors and ballasts in the river; (B) the boat worker maintains the boat motor in operation; (C) put the sampler in the water and (D) fill the pump and the hose with water.

Also the ballasts put on the upper part and on the sides of the sampler help to maintain the sampler in the position. Afterwards the sampler is put into the water (C), the pump and the hose are filled with water (D). Than the pump is turned on and when the water comes out from the hose attached to the pump (E, Fig. 3), the drop of the equipment

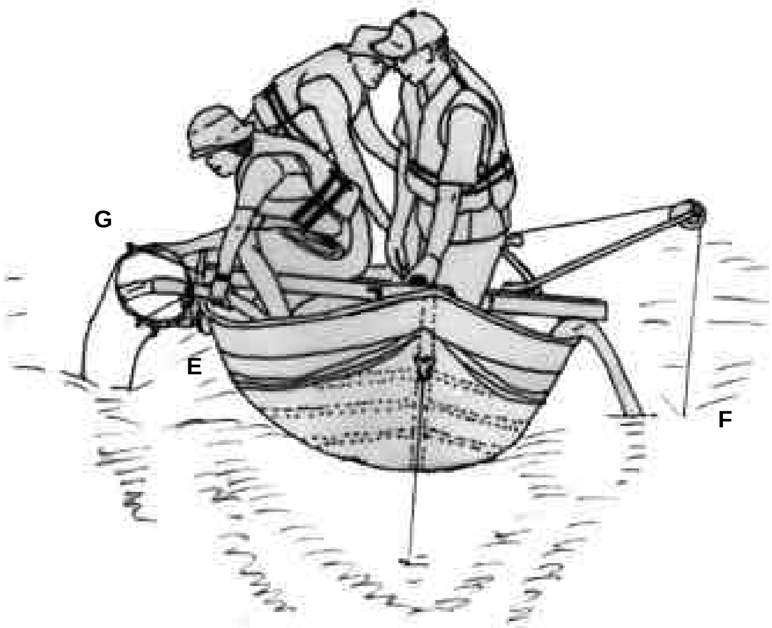

Figure 3: Collection procedure: (E) turn on the pump and the water comes out from the hose; (F) low the sampler with the winch and (G) put the collecting net in position.

in water can begin with aid of the winch to reach the bottom (F). The collecting net is positioned (G) to keep the material as the collected material starts to come out from the extremity of the hose. The pump and the hose should be fixed to the boat because the power of the motor makes then move. The aspirated material goes (Fig. 4) through the filter (A), through the hose (B), passing through the pump (C) and coming out from the other hose (D) where the collecting net is positioned (E). The hose entrance and the pump need to be always filled out with water to avoid the entrance of air that impedes the suction and the overload of the water pump. The length of the suction hose should be adjusted to the depth of the place.

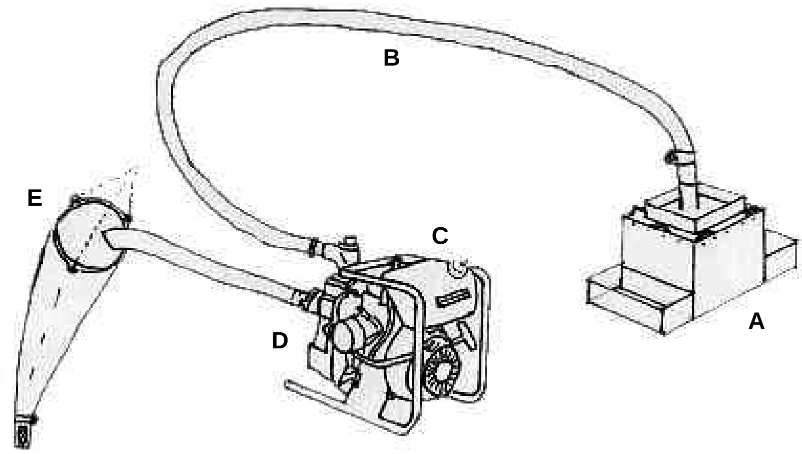

Figure 4: Disposition of the equipment parts in operation: (A) entrance of the material in the Suction sampler; (B) passage of the material through the hose; (C) passage of the material through the pump; (D) exit of the material from the hose and (E) collection of the material in the net.

In lentic environment or reservoir phase, if there is no current or if it is very slow there is no need to the boat worker to leave the motor in operation neither add ballasts in the sampler. The entrance hose should be filled with water before putting the sampler in aquatic environment. The fastest and efficient procedure to fill the hose with water in this phase is to be in the boat and hold an extremity of the hose inside of the water, leaving the other extremity in the water attached to a buoy. Than the boat is put in movement, making the water enter from one extremity of the hose and the air coming out from the other. With the hose full of water the equipment is set up and the collection can begin.

For the operation of the equipment it is necessary a boat with at least 5m of length, with outboard motor, winch and water pump. The winch to be used should cross over from one side of the boat to the other and should hold at least 50 kg of weight. It is a similar winch used in hydrometry. The water pump which will able the suction of the material is the two inches self-priming type with 3600 rpm gasoline motor. Another piece of hose (5 cm of diameter and the length of 1.50 m) will be connected to the water pump from where the aspirated material comes out. The pump should be on the bottom of the boat and the sampler should be fixed to a winch with a 0.5 cm thick steel cable; enabling the sampler to go up and down in the water. Than the collected material should go through the collecting net with mesh of 250 mm, enabling to remove the excess of water of the aspirated material.

That Suction sampler works in a similar way to the proposed by Brooks (1994) and operates under the same principle of the vacuum cleaner. According to Drake & Elliott (1982), the suction of the sample should last 30 seconds starting from the moment that the sampler reaches the bottom and it begins the remove of the material.

Analysis of the results

With the Suction, Hess and Surber samplers 159 samples were collected, corresponding to 54, 54, 51 samples respectively (the replicates already included in the values, on an average three replicates per sample). The density calculation was based on the works of Anaya (1997) and Brandimarte (1997), where the density of the taxonomic groups was determined

Table I: Average density (number of individuals per m²), standard error (±) and relative abundance (% of the total) of the benthic macroinvertebrates of the Tocantins River (pre-filling phase) collected with three different types of samplers.

Samplers / Taxa	Suction			Hess			Surber		
	Density	Standard Error	Relative Abundance	Density	Standard Error	Relative Abundance	Density	Standard Error	Relative Abundance
Diptera				1	1	0.01			
Chironomidae	4691	1408	34.86	3734	849	44.56	2735	578	59.46
Ceratopogonidae	381	102	3.01	88	12	0.97	14	6	0.30
Empididae	34	11	0.24	56	13	0.70	28	10	0.54
Simuliidae	47	20	0.30	109	33	1.48	29	13	0.65
Tipuliidae	0.4	0.3	0.01						
Trichoptera	1	0.4	0.01	15	5	0.20	10	3	0.23
Hydropsychidae	187	53	1.42	1114	150	12.26	1079	306	20.11
Philopotamidae	19	11	0.19	72	29	1.04	2	1	0.04
Hydroptilidae	221	98	1.48	124	29	1.51	63	13	1.21
Glossosomatidae	218	53	1.69	156	49	1.94	31	12	0.68
Leptoceridae	38	18	0.23	7	3	0.10	1	1	0.02
Helicopsychidae	21	9	0.17	7	3	0.07	8	3	0.20
Odontoceridae	10	4	0.08	8	2	0.09	1	1	0.03
Polycentropodidae							0.4	1	0.01
Plecoptera									
Perlidae	18	4	0.17	52	12	0.64	6	2	0.15
Ephemeroptera	15	4	0.12	16	4	0.20	10	3	0.19
Leptophlebiidae	423	137	3.17	639	94	7.48	173	15	3.53
Caenidae	8	4	0.05	1	1	0.01			
Polymitarcidae	30	10	0.21	21	6	0.27	2	1	0.06
Leptohyphidae	219	70	1.83	234	37	2.62	158	38	3.11
Baetidae	222	48	1.82	224	72	3.00	83	16	1.72
Oligoneuriidae							3	1	0.05
Odonata									
Gomphidae	4	2	0.04	1	1	0.01			
Libellulidae				5	2	0.07	1	1	0.03
Calopterygidae				1	2	0.01			
Coenagrionidae				1	1	0.01			
Hemiptera									
Naucoridae	4	1	0.03	4	2	0.04	1	1	0.02
Coleoptera				1	3	0.01	0.4	1	0.01
Elmidae	561	139	4.34	259	72	2.90	46	17	0.99
Hydrophiloidea				0.4	0.5	0.01	2	2	0.05
Psephenidae				0.4	0.5	0.01			
Lepidoptera	5	2	0.03	2	1	0.03			
Megaloptera									
Corydalidae				1	1	0.01			
Collembola	1	1	0.01						
Annelida									
Oligochaeta	5596	1986	42.46	1343	485	12.78	201	52	4.22
Hirudinea	3	1	0.02	3	2	0.03	1	1	0.01
Arachnida									
Hydracarina	210	77	1.47	184	73	2.08	15	5	0.28
Mollusca									
Pelecypoda	63	36	0.30	186	110	2.75	173	126	2.05
Gastropoda	64	46	0.21	7	6	0.07	3	2	0.04
Ancylidae				3	4	0.06	2	1	0.04
Platyhelminthes	1	1	0.01						
Total			100.00			100.00			100.00

using the cumulative value of the three replicates divided by the total area of the three replicates. Then to obtain the average density the density values were added and divided by the number of samples. The number of individuals per unit of area (m²) and standard error in each sampler has been analysed enabling to make a comparison. The Suction and the Surber samplers have the same area of 0.09 m² and Hess ones have an area of 0.07065 m².

The density and richness values were submitted to the variance analyses by the SAS Mixed procedure and to the Tukey test for average comparison. The Similarity Percentage or Renkonen Rate, according to Krebs (1989), was applied to the values of relative abundance.

Results

The samples obtained by the three samplers present significant differences regarding the density (F=3.54, P=0.0321) and the taxonomic richness (F=7.79, P=0.0040). The Suction sampler (average density of 9512 and average richness equal to 38) presents higher density and richness average than the Hess (average density equal to 9171 and average richness of 32) and the Surber (average density of 4986 and average richness equal to 28) but statistically the Suction sampler was only higher to Surber, at the level of 5%.

In the Table I the values of average density (number of individuals per m^2) and relative abundance (% of the total) of the taxa of the benthic invertebrates are presented. A predominance of similar taxonomic groups has been noticed in the three samplers, in other words, usually Chironomidae (Diptera), Hydropsychidae (Trichoptera), Leptophlebiidae, Leptohyphidae and Baetidae (Ephemeroptera), Elmidae (Coleoptera), Oligochaeta (Annelida) present a higher density and abundance.

Through Renkonen Rate the percentage is similar between the Suction and the Hess samplers (70.44%) and between the Hess and the Surber samplers (76.50%), but between the Suction sampler and the Surber one (56.75%), a smaller similarity percentage has been noticed in relation to the previous ones.

Discussion

The presentation of the results on new equipments and their performance varies a lot, as it can be seeing in the works of Aarefjord (1972); Mackey (1972); Boulton (1985); Brown et al. (1987) and Brooks (1994).

Considering the density average and taxonomic richness values, the Suction sampler presented better performance than the Hess and Surber samplers. Significant difference occurred only between the Suction sampler and the Surber one. Brooks (1994) used a suction sampler (electric pump) and noticed that this equipment was more efficient collecting more individuals and taxa compared with Surber. Boulton (1985) used also a suction sampler (manual operation) and it was able to capture more benthic macroinvertebrate individuals than with the Surber sampler although the differences in statistics terms were not significant. That same author didn't find significant difference in the number of taxa collected through the suction sampler and the Surber one, contrary to the results obtained in the present work in the Tocantins River, where statistically the density and the taxonomic richness were higher in samples collected by the Suction sampler than by Surber one.

Comparing the Hess sampler with the suction sampler (vacuum), Brown et al. (1987) concluded that quantitatively the suction equipment was more efficient, similar to the results obtained in the Tocantins River, despite of the Suction sampler had a higher density average than the Hess sampler these didn't show significant differences in density. The same happened with the taxonomic richness in which the Suction sampler presented higher richness value but it was significantly higher only to Surber sampler.

One of the advantage of the Suction sampler is the possibility to collect samples in different climatic periods even in rainy seasons when the rivers are subject to higher depths, whereas the other two (of Hess and of Surber) are able only to make collections in lotics systems with depths lower than 60 cm and 30 cm respectively.

Other advantages of the Suction sampler are: the possibility to collect also in of low current and lentic environment, as well as in any type of bottom substrate while the Hess and Surber samplers were designed for lotic systems specially for hard substrates.

The Suction sampler collected a variety of benthic macroinvertebrates and they were similar and larger than collected with the Hess and Surber samplers respectively. It collected also taxonomic groups with shelters (Odontoceridae, Hydroptilidae, Glossosomatidae, Helicopsychidae), shells (Pelecypoda and Gastropoda mollusks) and hooks (Simuliidae). According to Brown et al. (1987), the suction sampler can underestimate the organism's abundance with shelters or heavy shells groups. However, the results of this work demonstrated that the Suction sampler has been also efficient in the collection to these groups similar to the ones obtained by the Hess sampler, except for Pelecypoda. Insects like Corydalidae (Megaloptera) and Psephenidae (Coleoptera) live under stones or adhered to then respectively, were obtained only with the use of the Hess sampler and there was just one individual of each taxon. They were also not collected with Surber sampler therefore the non capture with the Suction sampler doesn't implicate in a failure of the equipment but most probably because of the low density of these groups.

The Suction, Hess and Surber samplers were used in the same area. But because of the depth limitations the last two samplers were used in shallow environment (cascade) in two occasions, but still in the same points of collection of the Suction sampler. This probably explains the higher similarity percentage between the Surber and Hess samplers and also between Suction and Hess Samplers and a lower percentage between Surber and the Suction sampler. This probably explains also a higher density of Hydropsychidae collected with the Hess and Surber samplers. These caddisflies are usually found in riffles and they make fixed net on the substrates like stones as shelter and filtration (Merritt & Cummins, 1996).

The Petersen sampler was used by Anaya (1997) and Brandimarte (1997) in the collection of benthic macroinvertebrates in São Paulo state rivers. Through these works it has been also acknowledged that the Petersen sampler was efficient in places with substrate composed of sand, gravel and a gravel/pebble mixture and it was very difficult to collect in places with river bed constituted of pebbles and larger rocks with rifts.

Collecting samples with Petersen grab in pebble/gravel or pebble/sand substrates are not easy and it is necessary to throw the grab sampler several times to obtain a small quantity of samples and standardise a fixed number of pebbles with certain diameter. The most common problem with this type of equipment in rocky substrate is the presence of stones and logs that hooks on jaws of the sampler impeding its closing. This collection procedure demands long time to obtain a representative sample. These problems could have been avoided with the Suction sampler.

Although Rostron (2001) mentioned that the suction samplers can be thrown starting from a small vessel, in this work a larger boat is recommended due to the weight of the equipment and accessories (ballasts and hose).

For the collection with the sampler presented in this work, the needs of a boat with motor, an experienced boat worker and assistants with specific training are decisive on the success of the sample collection. Although some authors mentioned that the sampler per suction has some disadvantages like high costs (for instance the air compressor) and the need of a deep water diver, the sampler developed for this work doesn't need such expensive equipment either needs a diver. Another advantage of this equipment is that in muddy sediment sampling one part of the sample is already washed during the use of the suction pump. Once the material kept in the collecting net has been already washed the sample processing time in the laboratory is reduced.

Although they are still few companies specialised in the production of sampling equipments in aquatic environment in Brazil, there is possibility to develop samplers according to the necessary specifications. The lack of specialised hand worker to the production and handling of these equipments demands the search for skilled technicians and training.

The Suction sampler had a good performance comparing to the Hess and Surber equipments in the collection of benthic macroinvertebrates samples in Tocantins River (in pre-filling phase), in which the substrate was predominantly rocky, considering the density and the taxonomic richness. This sampler was able to collect samples independent of the current velocity, water depth and the rocky substrate composition. This sampler was also important for the collections in the filling and reservoir phases; clearly showing the impact of the construction of a hydroelectric power station on the river's benthic community, which will be discussed in another article.

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Received: 12 December 2005
Accepted: 04 May 2006