ASSESSMENT OF BENTHIC MACROINVERTEBRATE HABITAT SUITABILITY IN A TROPICAL WATERSHED

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ABSTRACT

Urban land uses such as deforestation, mining, agriculture, logging and road construction, can cause stream sedimentation, modifying the morphology and depth of the river channel and diminishing the availability of physical habitats. Habitat requirements of benthic macroinvertebrates must be considered in a streamflow management strategy to maintain the biotic integrity. The aim of this study was to develop a benthic macroinvertebrate habitat suitability criteria based on velocity, depth and substrate type in a silted river and in three reference rivers, and to evaluate if the diversity and the community structure would differ between them. Three reference rivers from the das Velhas River basin were chosen (Cipó, Curimataí and Pardo Grande) in addition to a stretch at the main channel, which is severely damaged by urbanization and mining activities. Samplings were performed during the dry and rainy seasons along 500 meters in each river. In each sampling period, 25 sediment samples were collected using a Surber sampler to assess the benthic macroinvertebrate communities while other set of 25 samples was collected to evaluate the granulometric composition of the sediment. Some physical-chemical parameters (temperature, alkalinity, conductivity, pH, dissolved oxygen, turbidity, Total-Nitrogen and Total-Phosphorus) were measured to assess water quality. The habitat suitability criteria curves were developed for the main taxa found during the dry season: Chironomidae, Oligochaeta, Leptohyphidae, Philopotamidae and Baetidae. The Philopotamidae preferred higher speeds (0.48 m/s - 1.25 m/s). The only taxa that had preference for fine sediment were the Oligochaeta. The lowest percentage of filtering-collectors and the lowest Shannon-Wienner diversity indices were found in the silted river. The information obtained in this study can be used in river restoration projects in urban watersheds in South-America.

Keywords: Habitat suitability, benthic macroinvertebrate, sedimentation, habitat criteria curves, bioindicators.

INTRODUCTION

Anthropic activities like mining, agriculture and timber extraction can lead to an increasing deposit of particles on the river bed, which modifies the channel morphology and depth reducing its heterogeneity and thus, the availability of physical habitats for the biota, causing a subsequent biodiversity loss (Allan, 2004).

The method known as PHABSIM (*Physical Habitat Simulation System*) is based on the relationships between the river discharge and the physical habitats required by the several life stages of aquatic organisms (Stalnaker *et al*., 1995). The quality and adequacy of habitats for a given taxon can be predicted using preference curves (Persinger, 2003), which are needed for the application of the PHABSIM method. These curves can be used to establish the physical characteristics of the habitats found in aquatic ecosystems, including depth and substrate type, that allow the existence of aquatic species (Dakou *et al*., 2007).

The habitat requirements of benthic macroinvertebrates also have to be considered in streamflow evaluations for the maintenance of biotic integrity (Arend, 1999). As benthic macroinvertebrates are considerably less mobile than fishes, they have less tolerance to changes in the water volume and a reduced ability to colonize habitat-poor areas (Gore, 1989).

In this context, the present study intended to answer two main questions: i) which is the habitat suitability criteria of the main five benthic macroinvertebrate taxa found at the das Velhas River basin?, and ii) Is the benthic macroinvertebrate community structure in an impacted river with low habitat diversity different than the community structure found in reference rivers?

MATERIAL AND METHODS

Study sites

The das Velhas River basin is in the central region of the Minas Gerais State, with an area of 27,867.2km^2 that encompasses 51 municipalities and a 4.3 million population, of which 86% is found in the Belo Horizonte metropolitan area (IBGE, 2000). The main environmental problems of the basin are due to the discharge of solid industrial waste, urban and domestic wastes, erosion, forest clearance, irregular land divisions and illegal mining that take place in the upper river course, next to Belo Horizonte and Contagem, the major urban concentrations in the basin (Polignano *et al.*, 2001).

Four reaches belonging to the das Velhas River basin were studied: the Cipó River (18º 41’ 7.1’’ S, 43º 59’ 48.7’’ W), the Curimataí River (17º 59’ 33.3’’ S, 44º 10’ 48.2’’ W), the Pardo Grande River (18º 13’ 43.3’’ S, 44º 13’ 3.1’’ W) and the Rio Acima River (upper course of the das Velhas River) (20º 06’ 01.44’’ S, 43º 47’ 35.85’’ W) (Figure 1).

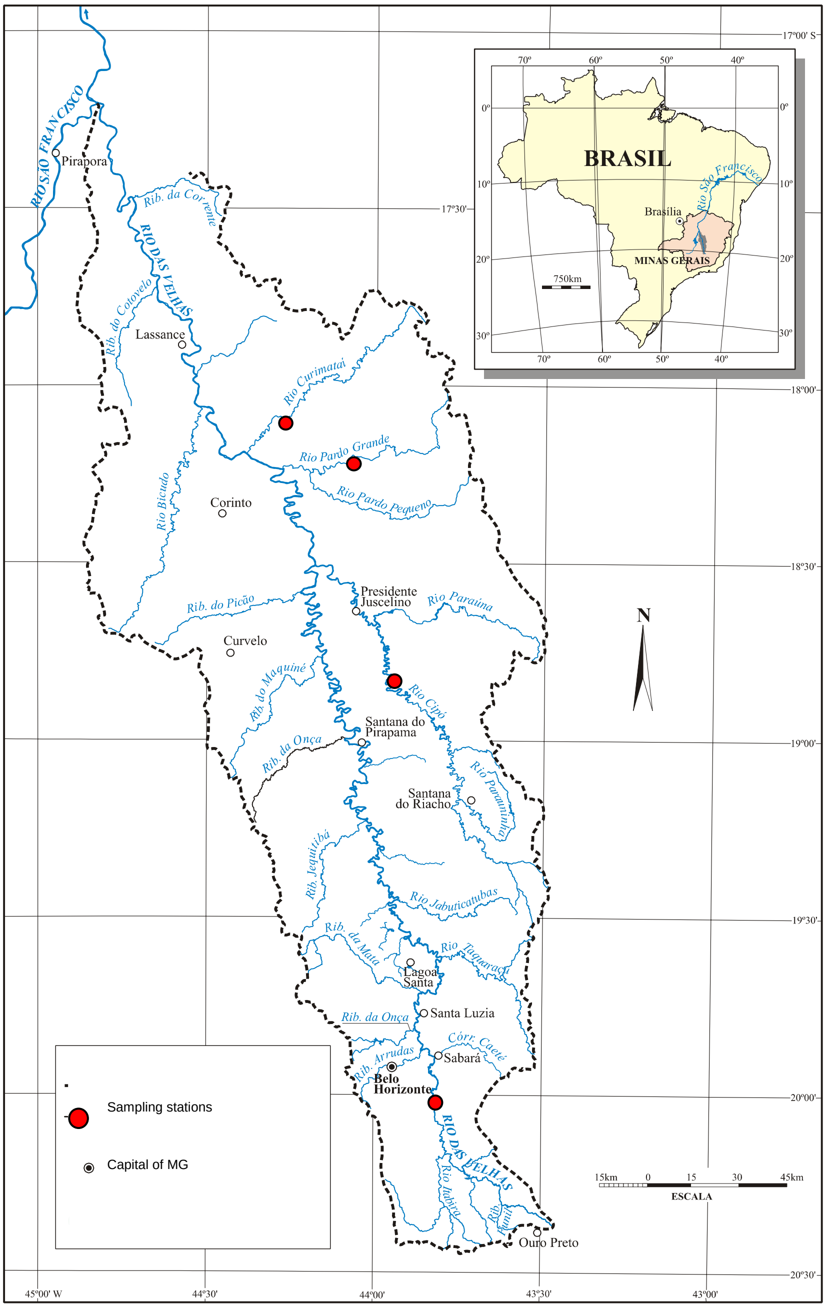


Figure 1. das Velhas River basin highlighting the studied areas: Cipó River, Curimataí River, Pardo Grande River and the upper course of the das Velhas River (Rio Acima), Brazil (Modified from Pompeu *et al*., 2005).

Methods

Sampling campaigns were carried out during the dry season (September 2007) and during the rainy season (March 2008). The Cipó, Pardo Grande and Curimataí Rivers were considered reference areas for the study of the benthic macroinvertebrate communities at the das Velhas River basin since they still present natural ecologic characteristics (Moreno & Callisto, 2004; Paz *et al*., 2008). In order to evaluate how much affected are the aquatic habitats at the Rio Acima River, the studied reach of it was compared with portions of the three reference riches. The sampling areas were chosen taking into account the mean long-term average flow and the geomorphology of the areas, in order to guarantee the validity of the comparison among the morphological structures found in each studied area.

The length of studied reaches is 500 meters. The sampling points were placed along of this length and were defined considering different hydraulic habitats characterized by varying depths, flow velocity and main substrate. In the dry season, 25 points were sampled in each reach. During the rainy season and due to the increase in water levels and current it was not possible to match the sampling effort of the dry season. Thus, along the 500 meter fragments nine points were sampled at the Curimataí River, 25 points at Rio Acima, 18 at Cipó and 25 at Pardo Grande.

The water quality in each sampling station was analyzed in order to complement the information obtained with the inventory of the benthic macroinvertebrate communities. Physical and chemical parameters as pH, conductivity, temperature, turbidity and total alkalinity were measured *in situ* using a YSI portable equipment. Water samples were collected for laboratory determination of nutrient contents (total N and total P) and for the quantification of dissolved oxygen (Winckler method).

A sediment sample was collected in each sampling station for granulometric analysis. For the granulometric composition classification the samples were processed following the methodology in Suguio (1973) modified by Callisto & Esteves (1996). The sediment categories considered were: silt and clay (<0.063mm), very fine sand (0.063mm), fine sand (0.25mm), medium sized sand (0.5mm), coarse sand (1mm), very coarse sand (2mm), gravel (4mm), pebbles (>16mm e <300mm) and stones (>300mm). The depths and flow speed (measured at 60% depth) were measured in each sampling station using a flow meter (Swofer, model 2100).

For the benthic macroinvertebrate inventory one sample was collected using a Surber sampler (0.09 m^2) in each sampling station, for a total of 100 samples collected in the dry season and 77 samples in the rainy season. The samples were washed in the field using sieves (0.5 mm mesh size), preserved in 70% alcohol and taken to the laboratory for identification using taxonomic keys (Péres, 1988; Merritt e Cummins, 1996). The structure of benthic macroinvertebrate communities was evaluated by calculating: organism density (individuals/ m^2), taxonomic richness, equitability, Shannon-Wienner diversity and functional trophic groups (Merritt & Cummins, 1996).

The habitat criteria curves were developed considering flow velocity, depth and substrate for the five main benthic macroinvertebrate taxa collected during the dry season. The habitat criteria curves were developed, and were based on the methodology used by Persinger (2003). The nonparametric tolerance limit approach uses nonparametric tolerance limits, confidence levels, and the total number of observations to pinpoint the range at which 50% of the observations are found, which corresponds to a suitability level of 1.0 or most suitable. The tolerance limits for the central 75% were used to establish the range of data with a suitability value of 0.5. The tolerance limits for the central 90% were used to establish the cut-off between suitable and unsuitable habitat and to the range of data between these two points was assigned a suitability value of 0.2. The range of data beyond the central 90% tolerance limit received a suitability value of zero and was considered unsuitable habitat.

RESULTS

The dissolved oxygen concentrations were lower at the Rio Acima River both during the dry and the rainy season (Table 1). Turbidity values higher than the turbidity meter scale (>500NTU) were found at the Curimataí and the Pardo Grande Rivers during the rainy season. These results could be explained by the rains registered at these regions the day before the sampling took place.

Table 1. Physical and chemical characterization of the sampling points in Rio Acima, Cipó, Curimataí and Pardo Grande reaches during the dry and rainy seasons.

Physical-chemical parameters	Rio Acima		Cipó		Curimataí		Pardo Grande	
	Dry	Rainy	Dry	Rainy	Dry	Rainy	Dry	Rainy
Temperature (ºC)	20,4	22,7	23,1	26	24,5	23,9	25,7	24,7
Condutivity (µS/cm)	72,1	111,4	126,5	8,51	60	74	137	9,0
pH	6,23	7,23	7	6,05	6,4	6,94	7,5	6,52
Turbity (NTU)	7,97	11,73	34	96	12	>500	13	>500
Dissolved oxigen (mg/L)	5,7	5,9	8,8	8,9	7,2	7,3	9,2	7,9
Total Alcalinityl(µEq/L)	320,4	137,5	801,4	252,4	308,4	294,1	1028	252,5
Total N (µg/L)	42	39	56	74	28	89	42	62
Total P (µg/L)	26	22	11	25	26	157	5	64

During the dry season 13.863 specimens distributed belonging to 45 taxa were collected (Table 2). Total density values ($F_{3.96}$ =5.4851, $p < 0.05$), taxonomic richness ($F_{3.96}$ =6.9207, $p < 0.05$), Pielou’s equitability ($F_{3.96}$ =10.1167, $p < 0.05$) and Shannon-Wienner diversity ($F_{3.96}$=10.116, $p < 0.05$) among the four reaches were significantly different. In the four reaches there was a dominance of gathering-collectors while shredders were the less abundant (Figure 2). The lowest percentage of filtering-collectors was found at the Rio Acima reach (2.93%).

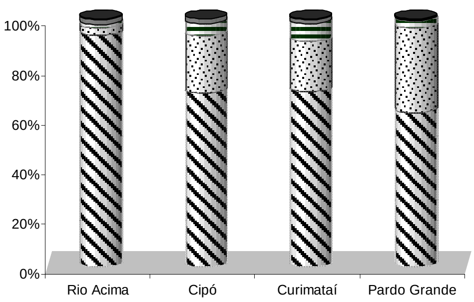
During the rainy season there were 958 specimens collected. There was a dominance of gathering-collectors in the sampled rivers with the exception of the Pardo Grande River where filtering-collectors were dominant during this season (Figure 2). Only gathering-collectors (87%) and predators (13%) were found at the Rio Acima reach.

During the dry season the five most representative taxa (present in more sampling points) were Chironomidae (48.39%), Oligochaeta (12.39%), Leptohyphidae (6.02%), Baetidae (5.34%) and Philopotamidae (5.30%). The habitat criteria curves were calculated for these families and for the Oligochaeta class (Figure 3).

Table 2. Dominance (%) of benthic macroinvertebrates collected at the das Velhas River basin in the Rio Acima, Cipó, Curimataí and Pardo Grande reaches during the dry season.

Taxa	Rio Acima	Cipó	Curimataí	Pardo Grande
Annelida				
Oligochaeta	25,62	0,61	6,21	0,78
Mollusca				
Gastropoda	0,00	1,78	1,09	0,03
Bivalve	2,74	10,17	8,87	1,98
Crustacea				
Hidracarina	0,00	0,05	0,00	0,03
Turbellaria				
Planariidae	0,00	0,00	0,39	0,00
Insecta				
Collembola	0,00	0,00	0,04	0,00
Ephemeroptera				
Baetidae	3,77	4,08	4,28	10,21
Leptophlebiidae	0,05	3,89	3,05	2,63
Leptohyphidae	0,37	2,11	15,75	10,63
Caenidae	0,00	0,66	0,32	0,03
Euthyplociidae	0,00	0,00	0,00	0,10
Polimitarcyidae	0,00	2,58	0,63	0,06
Odonata				
Libellulidae	0,03	0,38	0,56	0,39
Gomphidae	0,08	1,27	0,63	0,55
Calopterigydae	0,05	0,05	0,11	0,10
Coenagrionidae	0,00	0,28	0,39	0,26
Plecoptera				
Perlidae	0,00	0,94	0,49	0,03
Megaloptera				
Corydalidae	0,03	0,00	0,00	0,00
Hemiptera				
Belostomatidae	0,03	0,00	0,00	0,00
Gelastocoridae	0,00	0,05	0,00	0,00
Naucoridae	0,05	0,56	0,04	0,81
Notonectidae	0,00	0,14	0,04	0,00
Gerridae	0,00	0,00	0,04	0,00
Coleoptera				
Dytiscidae	0,00	0,00	0,53	0,00
Gyrinidae	0,00	0,05	0,00	0,03
Hydrophilidae	0,05	0,00	2,39	0,49
Elmidae	1,31	13,22	6,28	1,62
Staphylinidae	0,00	0,00	0,00	0,03
Psephenidae	0,00	0,00	0,07	0,00
Tricoptera				
Calamoceratidae	0,00	0,00	0,07	0,16
Glossosomatidae	1,45	0,00	0,21	0,03
Helicopsychidae	0,00	0,00	0,00	0,19
Hydropsychidae	0,07	1,69	4,49	3,24
Hydroptilidae	0,61	0,00	0,11	0,58
Leptoceridae	0,00	0,05	0,14	0,88
Hydrobiosidae	0,00	0,00	0,07	0,00
Odontoceridae	0,00	0,00	0,07	0,06
Philopotamidae	0,05	8,53	4,45	13,97
Polycentropodidae	0,00	0,05	0,14	0,06
Lepidoptera				
Pyralidae	0,00	0,09	0,28	0,10
Diptera				
Psychodidae	0,00	0,00	0,04	0,00
Ceratopogonidae	0,32	0,94	1,16	0,68
Chironomidae	62,79	42,94	34,30	37,44
Simuliidae	0,03	2,67	2,28	11,60
Tipulidae	0,00	0,14	0,00	0,00
Empididae	0,49	0,05	0,04	0,19
Richness	21	29	38	34
Shannon Diversity	1,1	2,1	2,3	2,1
Pielou Eveness	0,4	0,6	0,6	0,6
Density (ind/m2)	63656	23711	38224	31224

(A)



(B)

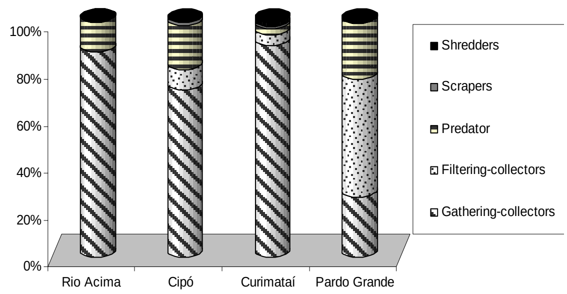


Figure 2. Percentages of the different functional trophic groups found at the Rio Acima, Cipó, Curimataí and Pardo Grande reaches during the dry (A) and rainy (B) seasons at the das Velhas River basin, Minas Gerais, Brazil.

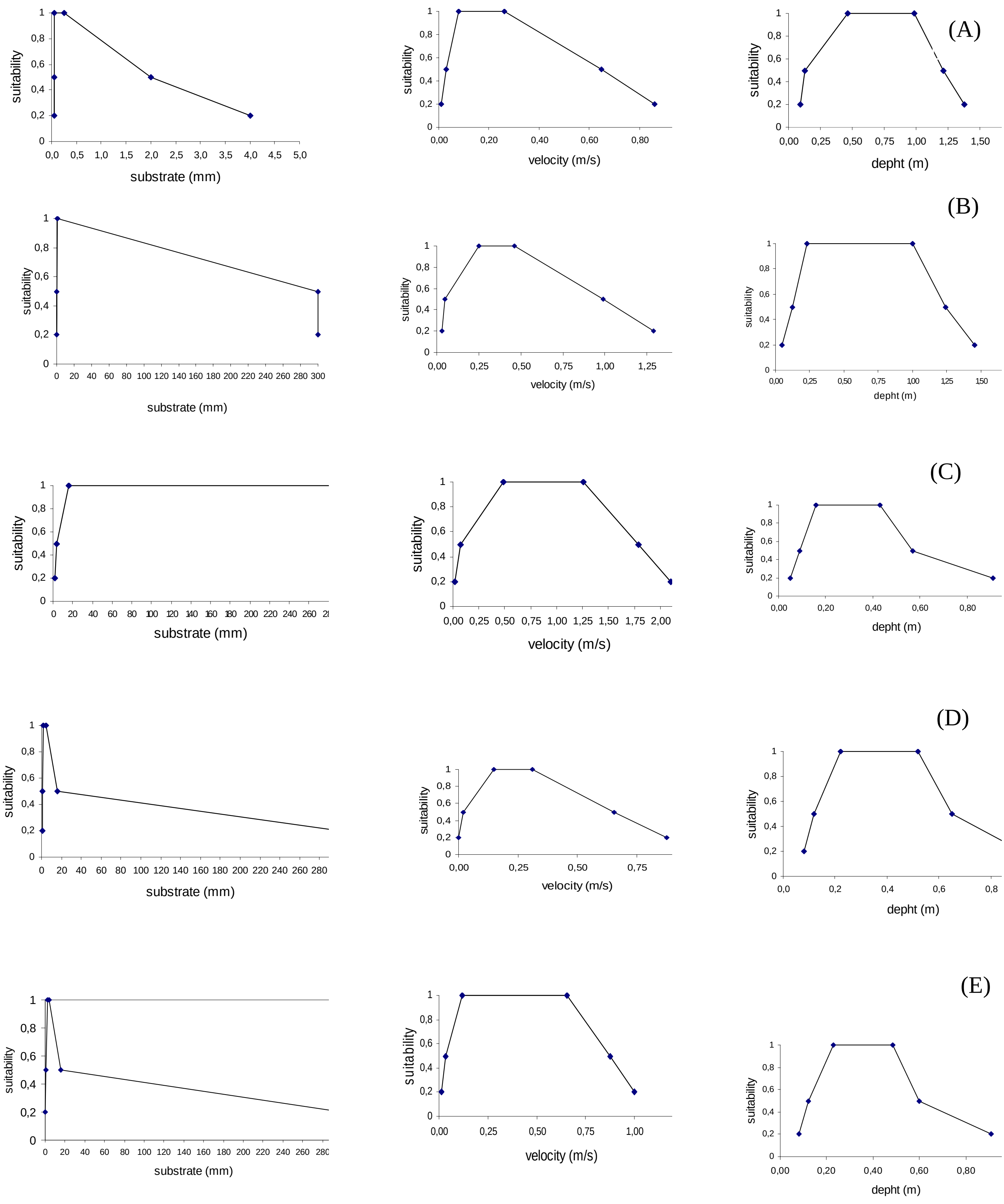


Figure 3. Substrate, velocity and depth preference curves for Oligochaeta (A), Chironomidae (B), Philopotamidae (C), Leptohyphidae (D) and Baetidae (E), developed based on data recorded during the dry season at the Rio Acima, Cipó, Curimataí and Pardo Grande reaches in the das Velhas River basin, Brazil.

DISCUSSION

The benthic macroinvertebrate fauna at the Rio Acima reach was characterized by a poor taxonomic richness and a poor diversity when compared to the fauna found at reference reaches. At this site there was a dominance of pollution tolerant organisms and others typical of impacted ecosystems as Chironomidae and Oligochaeta. The sediment homogenization caused by particle sedimentation on the river bed also affects the size of benthic macroinvertebrate populations causing habitat loss. The structure of the benthic community, according to functional trophic groups, at the Rio Acima reach was different than the structure found at the other rivers studied. The smaller proportions of filtering-collectors at the Rio Acima River can be explained by the effect of the suspended fine sediments that adhere to the gills of these organisms reducing the quantity and quality of the food obtained.

Among the taxa used for the preference analysis, the only organisms that had their optimal habitats associated with silt and clay and fine sand fractions are the Oligochaeta. The poorness of this substrate is probably due to the proximity between particles that reduces the capture of organic compound detritus and oxygen availability (Fenoglio *et al*., 2004). The Oligochaeta was the group that was less tolerant to greater speeds of water flow. Similar results were found by Jowett *et al*. (1991) that report the Oligochaeta preference for speeds near to 0 m/s. The slow water flow allows the accumulation of higher quantities of detritus, facilitating habitat colonization by animals that are typical of eutrophied environments (Fujita & Takeda, 2005).

Chironomidae were found in all kinds of substrates having its optimal habitat in a range of substrates between middle sized sand and pebbles. This broad range of substrate preferences displayed by the Chironomidae can be explained by their diverse feeding habits since they can act as predators, fine particulate organic matter collectors and also as shredders (Armintage *et al.*, 1994). Chironomidae larvae do not display exigencies regarding their ideal substrate for development (Goulart & Callisto, 2005), even being able to feed upon foliar detritus (Callisto *et al.*, 2007).

Leptohyphidae and Baetidae presented similar substrate preference curves that indicated their preference for particles sized between gravel and pebbles. The distribution and abundance of Ephemeroptera nymphs are mainly determined by temperature, substrate type and water quality (Goulart & Callisto, 2005). According to Galdean *et al*. (2001), in rivers where the river bed is covered by stones, gravel and sand, the macroinvertebrate diversity is high and presents high frequencies of Ephemeroptera and Trichoptera immature stages. These organisms are pollution sensitive and serve as bioindicators of high quality waters.

The family Philopotamidae was found in sampling stations where the substrate was coarse, ranging from very coarse sand (2 mm) to stones (300 mm) and displaying preferences for particles sized between pebbles (16 mm) and stones (300 mm). According to Galdean *et al*. (2001), stones and gravel are substrates that favour the occurrence of Philopotamidae species, corroborating the results of this study. The Philopotamidae are scrapers and feed upon periphyton and organic particles adhered to stones and pebbles, which favours their occurrence in these type of substrates (Merritt & Cummins, 1996).

Fenoglio *et al*. (2004) found a negative relationship between the abundance of gathering-collectors and water speed while they observed a positive relationship between the abundances of scrapers and filtering-collectors and water speed. In accordance with the data presented by Fenoglio *et al.* (2004) the Philopotamidae, characterized as scrapers, had its optimum habitats in higher water speeds than the ones preferred by the gathering-collectors.

CONCLUSIONS

As a part of a broad conceptual and analytical framework for addressing stream flow management issues called the Instream Flow Incremental Methodology (IFIM) (Stalnaker et al., 1995), the PHABSIM analyses the benthic macroinvertebrates preferences based on parameters like speed, depth and substrate type. However variables like temperature, pH, nutrient concentrations, as well as predation and competition effects, influence the habitat preference and should be also considered, mainly in Rivers as das Velhas River. In this context, the simulation of physical habitats will added efforts to water quality analysis and give support to river restoration projects. With the identification of the habitats preferred by the benthic fauna, restoration projects can be projected to include those habitats, consequently generating conditions that will favour the increase of the diversity of benthic macroinvertebrates in degraded rivers.

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