Community structure of aquatic insects (Ephemeroptera, Plecoptera, and Trichoptera) in Cerrado streams of Paraguay, Paraná, and São Francisco river basins

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Abstract: We evaluated qualitatively and quantitatively the community structure of aquatic insects (Ephemeroptera, Plecoptera, and Trichoptera) in 19 streams in areas of Cerrado in the Paraguay, Paraná, and São Francisco river basins. The number of genera and taxonomic composition were compared at spatial (at the hydrographic basins level) and conservation levels (more preserved and less preserved areas). The influence of spatial and environmental factors in richness and abundance was also evaluated. The geographical distribution of *Grumicha*, *Coryphorus*, and *Austrotinodes* was expanded. The highest Trichoptera richness was found in the São Francisco river basin ($F = 5{,}602$, $p = 0{,}004$) and a higher number of Ephemeroptera genera occurred in the relatively less preserved sites ($F = 6{,}835$, $p = 0{,}009$). The pattern of genera distribution was different among basins ($R = 0{,}0336$, $p = 0{,}001$), but it was similar among relatively less and more preserved areas ($R = -0{,}039$, $p = 0{,}737$). These findings can be explained by the low impact level in these streams and also by the taxonomic resolution used in this study. Latitude and instream diversity were the most important factors to explain the variation in genera richness and abundance ($p = 0.004$ and $p = 0.026$, respectively). Hence, the regional differences can be attributed to spatial influences, quantity or quality of habitats and the original distribution of taxa within each basin.
Keywords: *benthic macroinvertebrates, EPT, biomonitoring, conservation.*

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Resumo: Foi avaliada a estrutura quali e quantitativa da comunidade de Ephemeroptera, Plecoptera e Trichoptera (EPT) em 19 riachos em áreas de Cerrado nas bacias dos rios Paraguai (PG), Paraná (PN) e São Francisco (SF). O número de gêneros e a composição taxonômica foram comparados espacialmente (diferentes bacias hidrográficas) e quanto ao grau de conservação (áreas mais e menos preservadas). A influência de fatores espaciais e ambientais na riqueza e na abundancia também foi avaliada. Foi registrada a ampliação da área de ocorrência dos gêneros *Grumicha*, *Coryphorus* e *Austrotinodes*. A riqueza de Trichoptera foi superior na bacia do São Francisco ($F = 5{,}602$, $p = 0{,}004$) e a riqueza de Ephemeroptera foi maior em áreas relativamente menos preservadas ($F = 6{,}835$, $p = 0{,}009$). O padrão de distribuição dos gêneros diferiu entre as bacias hidrográficas ($R = 0{,}0336$, $p = 0{,}001$), mas foi igual entre áreas mais e menos preservadas ($R = -0{,}039$, $p = 0{,}737$), o que pode ser explicado em função do baixo grau de impacto existente entre os riachos estudados e/ou pelo grau de resolução taxonômica atingido no presente estudo. A latitude e, secundariamente, a diversidade interna do hábitat aquático foram os fatores que melhor explicaram a variação encontrada no número de gêneros e na abundância ($p = 0{,}004$ e $p = 0{,}026$, respectivamente). Assim, as diferenças regionais observadas puderam ser atribuídas às influências espaciais, à quantidade e qualidade de hábitats e à distribuição original dos táxons em cada bacia.
Palavras-chave: *macroinvertebrados bentônicos, EPT, biomonitoramento, conservação.*

Introduction

Benthic macroinvertebrates are important components of freshwater communities; they are widely distributed and occur in several substrate types in freshwater environments (Moretti & Callisto 2005). The distribution of benthic macroinvertebrates is influenced by the interaction between habits, physico-chemical variables, structural and hydrological characteristics, and by human activities (Resh & Rosenberg 1984, Merritt & Cummins 1984). Therefore, changes in water body characteristics, habitat, and environmental resources can strongly influence patterns of spatial and temporal distribution in benthic communities (Buss et al. 2002, 2004, Silveira et al. 2006).

Immature stages of ephemeropterans (mayflies), plecopterans (stoneflies), and trichopterans (caddisflies), which are commonly referred to as EPT, are widely distributed in streams (Hynes 1970, Allan 1995) and have proven to be good surrogates for representing the ecological characteristics of the whole freshwater community (Beauchard et al. 2003). Thus, the evaluation of EPT community structure can bring some fruitful insights on many aspects of stream ecology and also on the understanding of ecological processes at broad scales. In addition, ecological data on these insects provide valuable information for building and improving multimetric indices for biomonitoring (Karr 1991).

Several studies have shown a close relationship between macrobenthic communities and habitat components, as well as the implications of this relationship for biomonitoring (Arunachalam et al. 1991, Cairns & Pratt 1993, Kerans & Karr 1994, Galdean et al. 2000, Barbosa et al. 2001, Marques & Barbosa 2001, Callisto et al. 2004, Hodkinson & Jackson 2005, Silveira et al. 2006, Ayres-Peres et al. 2006, Milesi et al. 2009). However, studies conducted in pristine and protected areas in Brazil are rare, despite being fundamentally important for biodiversity management in these areas.

In this context, the aim of the present study was to investigate the diversity and composition of aquatic insects (Ephemeroptera, Plecoptera, and Trichoptera) in the Paraná, Paraguay and São Francisco basins, in streams submitted to different conservation status. We described and compared the variations in community structure among these Cerrado basins – which are submitted to different conservation status – and tested how environmental variables influence ecological attributes.

Materials and Methods

The Brazilian savanna, also known as "Cerrado", spans more than 2,000,000 km^2, formerly covering 23% of the country's surface (Ratter et al. 1997). It is a vegetation mosaic composed by different vegetation types (Sano & Almeida 1998), which harbor springs and major watersheds in Brazil (Padovesi-Fonseca 2006). We sampled 19 first and second orders streams (1:50.0000 scale, Strahler convention) near or within protected areas such as Serra da Bodoquena National Park, Emas National Park, and Serra da Canastra National Park, which belong to the upper portions of Paraguay, Paraná, and São Francisco river basins, respectively (Figure 1, Table 1).

Firstly, we defined streams conservation status based on the habitat physical integrity index (PHI, Barbour et al. 1999, adapted to headwaters of the Paraná river basin by Casatti et al. 2006) and the type of matrix that surrounded the stream. For that stream reaches were divided in 10 equidistant transects, in which habitat features such as width, depth, current velocity, flow, substrate composition were evaluated (according to Casatti et al. 2006). The phisico-chemical parameters (dissolved oxygen, turbidity, temperature and conductivity) were also obtained with Horiba® - U-10 model. Streams with the higher values of PHI and located within or close to conservation areas were considered the more preserved, whereas those with lower values of PHI and inserted in pasture areas or distant from protected areas were considered less preserved (Table 1).

Macroinvertebrates were sampled with a Surber net (0.09 m^2 area, 250 µm mesh) by washing the substrate within the sampler area for one minute. Six pseudoreplicates were taken in each main substrate type at each sampling site. The streams were sampled in September 2008 and in January 2009, with a total of 282 samples (102 in the Paraguay River basin, 90 in the Paraná, and 90 in the São Francisco). The material retained in the sampler was fixed in 10% formalin and later preserved in 70% ethanol. The specimens were sorted into taxonomic groups (orders or families) and specific keys were used for each group (Fernández & Domingues 2001, Costa et al. 2006, Mugnai et al. 2010). Specialists confirmed the identification of all specimens and overall genera distributions were obtained in the reference literature.

The number of genera in each order was compared using a covariance analysis (ANCOVA, Underwood 1997), with the abundance used as covariate and basins and conservation status as categorical independent variables. The abundance was transformed with natural logarithm (Zar 1999). ANCOVA was conducted in the software Statistica 6.0 (Statsoft 2004), and the comparison between groups were conducted by the least square means tool. The alfa level adopted in this analysis was 0.01.

To compare the community structure among basins we used a non-metric multidimensional scaling (nMDS) with clustering option. Complementarily, we conducted a similarity analysis (ANOSIM) to test whether species abundance was influenced by spatial variables (hydrographic basins) and conservation status (more and less protected areas). Species abundance was transformed using square root and the similarity matrix was extratected using the Bray Curtis coefficient. This analysis was conducted in the software Primer 6.0 (Clarke & Gorley 2001).

We performed a partial linear regression to evaluate the proportion of variation in genera richness and abundance (response variables) explained by predictor variables. This analysis estimates how much of the variation in a response variable that can be assigned exclusively to one set of factors, taking into account the effect another set (Legendre & Legendre 1998). Two sets of predictive variables were considered: spatial (latitude and longitude) and environmental (instream diversity, size, flow, and physical habitat integrity index "PHI"). Previously, we removed environmental variables with VIF (variance inflaction factor) higher than 10, since VIF $\geq$ 10 indicates high correlation among predictive variables (Quin & Keough 2002). This analysis was conducted in the software SAM v4.0 (Rangel et al. 2010).

Results

Overall, 2,728 specimens of aquatic insects were collected in 282 samples, belonging to 21 families and 62 genera (Appendix 1, 2 and 3). The percentage of insect orders was similar in the three basins, with the predominance of Ephemeroptera in all of them. The mayfly families Baetidae and Leptophlebiidae were also the most abundant in all basins, representing more than 80% of the material sampled. The genus *Americabaetis* was the most abundant in the Paraguay and São Francisco basins. The caddisfly Hydropsychidae was the most abundant family in the Paraná and São Francisco basins, whereas the Calamoceratidae was the most abundant family in the Paraguay basin. The Paraná basin had low abundances of all genera collected.

Plecoptera and Ephemerptera richness did not vary in the three basins, though São Francisco streams showed the highest Trichoptera

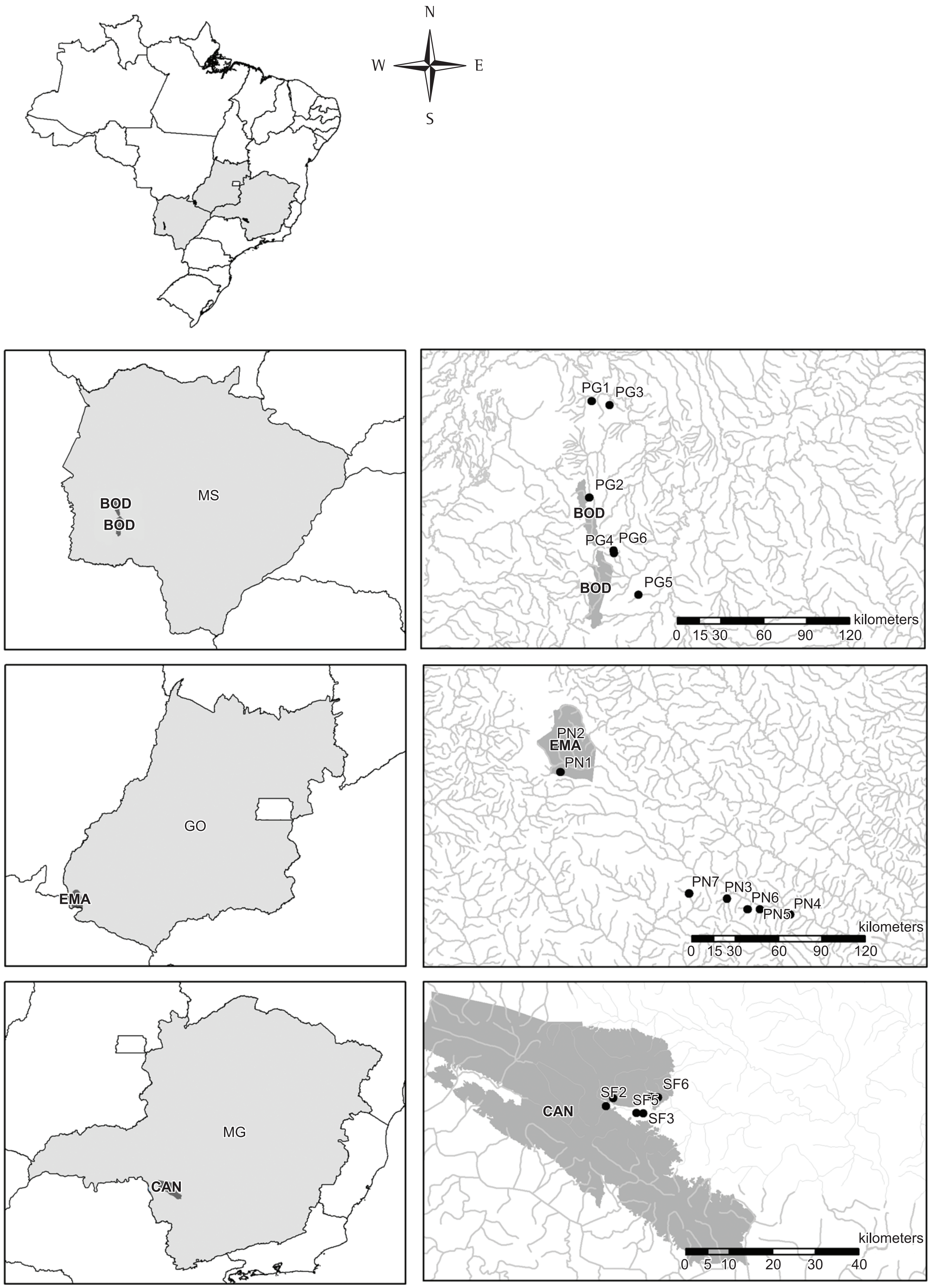

Figure 1. Stream reaches sampled in the Paraguay (PG), Paraná (PN), and São Francisco (SF) river basins, Brazil. BOD, Serra da Bodoquena National Park (MS State), MPE, Emas National Park (GO State), CAN, Serra da Canastra National Park (MG State).

genus richness. With regards to conservation status we did not find differences in Tricoptera and Plecoptera richness, though the less preserved areas presented higher richness of Ephemeroptera genera (Table 2). The pattern of genera distribution was significantly different among the three basins (R = 0.336, p = 0.001) (Figure 2), evidencing their distinct patterns of composition, but differences in status of conservation were not significant (R = –0.039, p = 0.737).

The regression model evidenced that genera richness was significantly explained by the set of predictive variables (Table 3). Nonetheless, the latitude explained most of the variation in genera

Table 1. Stream codes, location, surroundings, mean width (m), mean depth (m), and geographical coordinates of the sampling sites in the Paraguay (PG), Paraná (PN), and São Francisco (SF) river basins. MS = Mato Grosso do Sul State, MG = Minas Gerais State, NP = National Park.

Codes	Stream/city/State	Surroundings	Mean width (m)	Mean depth (cm)	Physical habitat integrity (PHI)	Geographical coordinates
PG1	Azul/Bodoquena/MS	NP Bodoquena	9.4	54.1	159	20° 45' 31,3" S 56° 45' 06,8" W
PG2	Santa Maria/Bodoquena/MS	NP Bodoquena	9.5	35	161	20° 41' 06,2" S 56° 46' 40,4" W
PG3	Taquaral/Bonito/MS	NP Bodoquena	6.4	32.2	177	20° 06' 13,7" S 56° 38' 00,3" W
PG4	Seco/Bonito/MS	Pasture	5.1	34.7	140	21° 02' 06,4" S 56° 36' 53,7" W
PG5	Mutum/Bonito/MS	Pasture	5.5	36	113	21° 18' 01,1" S 56° 26' 07,7"W
PG6	Olaria/Bonito/MS	Pasture	3	34	145	21° 01' 46,9"S 56° 36' 56,5" W
PN1	Glória/Chapadão do Céu/MS	NP Emas	1.1	35	158	18° 17' 49,6" S 52° 58' 33,2" W
PN2	Água Amarela/Chapadão do Céu/MS	NP Emas	1.1	44.5	165	18° 07' 57,7" S 53° 00' 33,0" W
PN3	Galheiros/Cassilândia/MS	Preservation area	2.7	49.7	145	19° 05' 11,9" S 51° 53' 06,2 W
PN4	Grande MS/Cassilândia/MS	Pasture	5.6	51.3	69	19° 11' 16,8" S 51° 28' 29,8" W
PN5	Ritinha/Cassilândia/MS	Pasture	4.5	35	59	19° 09' 48,6" S 51° 40' 09,6" W
PN6	Cedro/Cassilândia/MS	Pasture	2.5	50	87	19° 09' 11,8" S 51° 45' 00,7" W
PN7	Indaiazinho/Cassilândia/MS	Pasture	5.7	30.6	115	19° 03' 00,2" S 52° 08' 54,6" W
SF1	Luciano/São Roque de Minas/MG	NP Canastra	8.7	26.5	152	20° 18' 46,5" S 46° 31' 46,5" W
SF2	Cachoeirinha/São Roque de Minas/MG	Reserve	9.1	50	147	20° 19' 27,3" S 46° 32' 15,3" W
SF3	Grande MG/São Roque de Minas/MG	Reserve	6	26.9	147	20° 20' 25" S 46° 27' 56,2" W
SF4	Mandioca/São Roque de Minas/MG	Pasture	3.6	27.3	126	20° 18' 52,6" S 46° 26' 22,3" W
SF5	Cerrado/São Roque de Minas/MG	Pasture	4.3	34.5	131	20° 20' 00,0" S 46° 28' 30,6" W
SF6	Lavra/São Roque de Minas/MG	Pasture	8.8	27.6	137	20° 18' 36,1" S 46° 25' 59,6" W

Table 2. Results of ANCOVA for genera richness, with the abundance as a covariate, and river basin and status of conservation as the categorical independent variables. SS, sum of squares; DF, degree of freedom; F, statistical value; p, level of significance. Significant p values were marked with *.

Parameters	Plecoptera				Ephemeroptera				Trichoptera			
	SS	DF	F	p	SS	DF	F	p	SS	DF	F	p
Intercept	0.104	1	3.443	0.064	0.294	1	0.559	0.455	1.861	1	8.263	0.004*
Abundance	33.789	1	1117.913	0.000*	567.021	1	1075.679	0.000*	192.483	1	854.285	0.000*
Basin	0.024	2	0.411	0.663	0.658	2	0.625	0.536	2.524	2	5.602	0.004*
Status	0.0009	1	0.030	0.861	3.603	1	6.835	0.009*	0.019	1	0.086	0.768
Basin × status	0.0000	2	0.001	0.998	2.304	2	2.186	0.114	0.452	2	1.004	0.367
Error	8.312	275			144.960	275			61.961	275		

richness (p = 0.004) and abundance (p = 0.026). Additionally, 55% of the variation in the number of genera was explained by environmental variables (Table 3), among which instream diversity was the most important (p = 0.041).

Discussion

Biogeographic analyses for most tropical benthic macroinvertebrates are scarce, mainly due to taxonomic uncertainties and lack of regional studies. The percentage of insect orders and the dominance of the families Baetidae, Leptophlebiidae, and Helicopsychidae found herein followed the same general patterns of tropical streams (Jacobsen et al. 2008). Nevertheless, some families like Griptoterygidae, Glossosomatidae, Hydrobiosidae, Polycentropodidae, and Sericostomatidae occurred only in the São Francisco basin, whereas Coryphoridae, Polymitarcyidae, and Ecnomidae were restricted to the Paraguay basin. All members of these families occurred in low abundance, reinforcing their rarity.

The distribution of some genera was expanded. The genus *Grumicha*, only known from São Paulo and Santa Catarina states (Paprocki et al. 2004), now had their occurrence registered in the Minas Gerais State. The genera *Coryphorus* (known from Amapá and Pará states, Salles et al. 2004) and *Austrotinodes* (known from Amazonas, São Paulo, Minas Gerais, and Paraná states, Paprocki et al. 2004) were now recorded for Mato Grosso do Sul state, expanding the distribution of these genera.

The São Francisco basin, especially where the study was conducted, is characterized by streams with the predominance of runs and rapids, with a wide range of substrate types like gravel, little rocks and rocks as found by Casatti & Castro (1998). This kind of gravelly substrate is an important source of resources to several macroinvertebrates, including those of the order Trichoptera (Flecker & Allan 1984, Nolte et al. 1996, Kikuchi & Uieda 1998, Duan et al. 2008), what may explain the higher richness of this group in this basin. In the three investigated groups of aquatic insects, only the number of Ephemeroptera genera was associated to stream conservation status. The higher number of mayfly genera was registered in the less preserved area, contrasting with other studies (e.g., Kerans & Karr 1994, Compin & Céréghino 2003, Baptista et al. 2007). These studies, in general, were conducted with the aim to compare streams along a conservation gradient, differently of those herein studied. The increased number of Ephemeroptera genera in less preserved streams was probably reflected their great habitat heterogeneity, which is typical of low disturbance condictions, like the sites studied by us. Additionally, the results derived from ANOSIM showed that the community structure was similar, independently of the conservation status, reinforcing the similarity in community structure of aquatic insects.

The low physical alterations observed in the less preserved areas, such as the few exposed riverbanks, some fragmentation and siltation points, and pasture surrounding the riparian vegetation, contributed

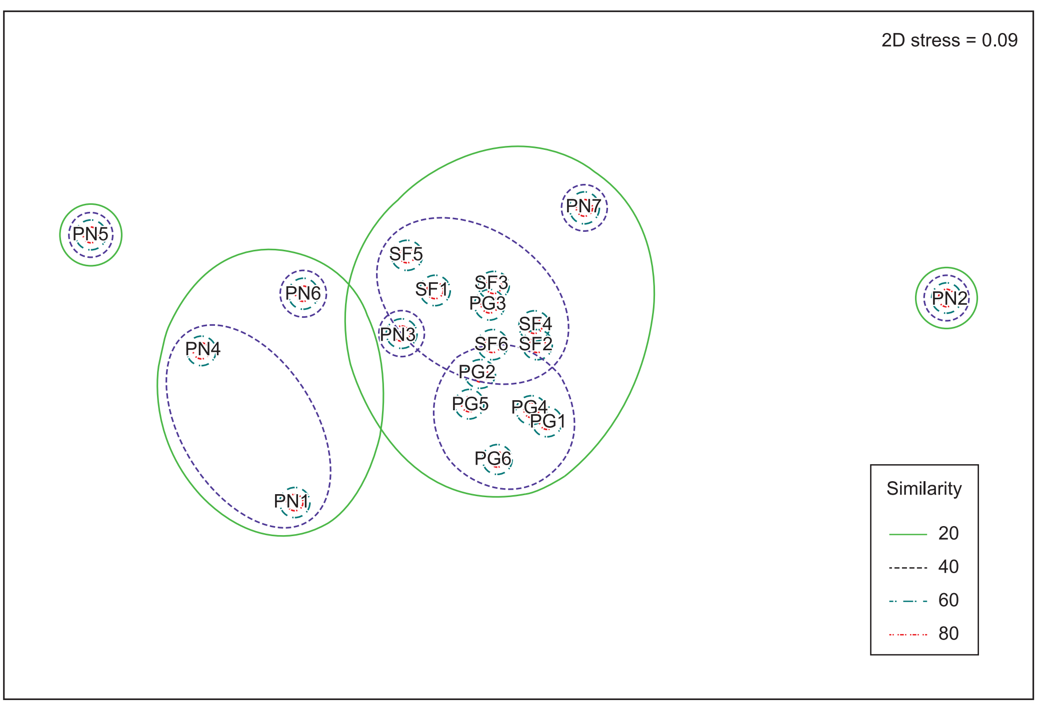

Figure 2. Two-dimensional projection of the axes from nMDS analysis, considering the abundance of genera and the groupings of more preserved transects (C) and less preserved (D) in the Paraguay (PG), Paraná (PN), and São Francisco (SF) river basins.

Table 3. Adjusted coefficient of determination (R^2), P-values, and variation in genera richness and abundance explained by each group of variables: (a) latitude and longitude, (b) instream diversity, size, flow, and physical habitat integrity index.

Response variables	n	R^2	*P*	Proportion of variation explained (R^2)			
				a	***b***	***a + b***	**Residual**
Number of genera	19	0.735	**<0.001**	0.658	0.548	0.809	0.191
Abundance	19	0.430	0.060	0.459	0.037	0.588	0.412

to an intermediate value for the physical habitat integrity index (see Table 1) and possibly provided a very diverse instream habitat, one of the most important structuring factor affecting community richness, like proved by the partial regression. In addition, all streams presented riparian forests, even the less preserved ones; this vegetation directly influences the community structure of aquatic insects, mainly by the input of nutrients and allochthonous energy (Gonçalves-Junior et al. 2006a, b, Jacobsen et al. 2008).

The physical habitat integrity index remains a useful tool for physical disturbance characterization in lotic environments (Barbour et al. 1999, Casatti et al. 2006) and consists of a breakthrough on how to quantify impacts in these environments. However, if the aim is to distinguish between sampling groups, only areas with extreme index values should be used. Considering the taxonomic resolution of this study, we concluded that less impacted areas, or with diffuse impacts, apparently did not influence the aquatic insect communities enough to allow distinguishing areas according to impact degree. An improved taxonomic resolution (Olsgard et al. 1998) and the inclusion of other groups in the analysis (Callisto et al. 2004, Hodkinson & Jackson 2005), along with the development of complete biotic indices (Baptista et al. 2007, Roche et al. 2010), could be other useful tools to discriminate between sites with different degrees of anthropogenic impacts.

In summary, community structure among river basins was significantly different, and latitude was identified as one of the most important factors that affect genus richness in these communities, reiforcing the influence of spatial attributes. Presumably, the geographic barriers separating the river basins prevent the migration of larvae and the distance between sampling sites probably limited a wide dispersion between areas; moreover, mayflies, stoneflies, and caddisflies have a short-lived winged adult stage and are not good dispersers (Sartori et al. 2000). Hence, the regional differences can be attributed to spatial influences, quantity or quality of habitats (Kay et al. 1999) and the original distribution of taxa within each basin (Jacobsen et al. 2008).

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Appendix

Appendix 1. List of Ephemeroptera, Plecoptera, and Trichoptera sampled in each of the six streams from the Paraguay River basin (PG 1-6). The geographical distribution of species marked with * was expanded.

Order/family	Taxa	PG1	PG2	PG3	PG4	PG5	PG6
Ephemeroptera							
Baetidae							
	Americabaetis	7	13	144	24	1	2
	Baetodes	0	0	3	42	0	0
	Camelobaetidius	5	5	1	2	1	0
	Cloeodes	0	0	0	0	0	3
	Cryptonympha	0	1	0	0	0	1
	Baetidae type 1	0	0	0	0	1	0
	Waltzoyphius	6	2	4	5	7	4
Leptohyphidae							
	Leptohyphes	2	2	1	4	3	0
	Macunahyphes	1	0	0	0	0	0
	Traverhyphes	38	1	11	47	35	0
	Tricorythodes	0	0	0	2	0	0
Caenidae							
	Caenis	3	1	0	6	3	8
	Cercobrachys	0	0	0	0	1	0
Leptophlebiidae							
	Farrodes	0	7	7	8	3	4
	Leptophlebiidae type 1	0	0	0	1	0	4
	Hagenulopsis	21	14	14	50	7	23
	Massartela	0	0	0	0	0	3
	Miroculis	2	4	0	15	4	19
	Simothraulopsis	1	0	0	0	0	0
	Terpides	39	0	0	48	2	5
	Thraulodes	114	0	0	20	1	6
	Ulmeritoides	1	1	0	132	3	31
	Ulmeritus	0	0	0	0	0	76
Coryphoridae							
	*Coryphorus**	0	0	0	0	1	0
Polymitarcyidae							
	Campsurus	0	0	0	0	1	0
Plecoptera							
Perlidae							
	Anacroneuria	4	4	1	6	3	2
	Macrogynoplax	0	0	0	1	0	2
Trichoptera							
Hydropsychidae							
	Hydropsychidae type 1	0	0	0	0	0	1
	Leptonema	2	1	4	0	0	1
	Macronema	0	1	7	0	0	0
	Smicridea	3	10	65	26	3	9
Policentropodidae							
	Cyrnellus	3	0	0	3	0	0
	Polycentropus	2	0	0	0	0	2
Philopotamidae							
	Chimarra	35	21	0	12	0	0
Odontoceridae							
	Barypenthus	4	0	0	0	0	0
	Marilia	0	1	0	0	0	3
Helicopsychidae							
	Helicopsyche	0	2	6	4	2	0

Appendix 1. Continued...

Order/family	Taxa	PG1	PG2	PG3	PG4	PG5	PG6
Trichoptera							
Leptoceridae							
	Nectopsyche	1	0	0	2	4	1
	Oecetis	0	0	6	2	0	1
	Triplectides	0	3	0	1	0	4
Calamoceratidae							
	Phylloicus	25	24	0	141	2	67
Ecnomidae							
	*Austrotinodes**	0	0	1	0	5	0
Hydroptilidae							
	Neotrichia	0	0	9	1	0	0
	Rhyacopsyche	0	0	0	0	0	1
Richness		22	20	16	26	22	26
Abundance		319	118	284	605	93	283

Appendix 2. List of Ephemeroptera, Plecoptera, and Trichoptera sampled in each of the seven streams from the Paraná River basin (PN 1-7).

Order/family	Genera	PN1	PN2	PN3	PN4	PN5	PN6	PN7
Ephemeroptera								
Baetidae								
	Americabaetis	0	0	1	1	1	2	0
	Apobaetis	0	0	0	0	0	1	1
	Aturbina	0	0	2	0	0	1	5
	Baetodes	0	0	3	0	0	0	4
	Camelobaetidius	0	0	0	0	0	0	6
	Baetidae type 2	0	0	6	1	1	0	0
	Waltzoyphius	0	0	4	0	0	0	8
	Zeluzia	0	0	1	0	0	3	0
Leptohyphidae								
	Macunahyphes	0	0	0	0	0	0	2
	Traverhyphes	0	0	0	0	0	1	0
	Tricorythopsis	0	0	0	0	0	0	7
Caenidae								
	Caenis	0	0	1	0	0	0	0
Leptophlebiidae								
	Farrodes	5	0	5	7	0	10	0
	Thraulodes	5	0	4	0	0	0	0
	Ulmeritus	0	0	4	0	0	0	0
Plecoptera								
Perlidae								
	Anacroneuria	0	0	5	0	0	0	0
	Macrogynoplax	0	2	0	0	0	0	1
Trichoptera								
Hydropsychidae								
	Leptonema	0	0	2	0	0	0	0
	Macronema	0	0	2	0	0	0	0
	Smicridea	0	0	5	0	0	1	27
Philopotamidae								
	Chimarra	0	0	0	0	0	1	0
Odontoceridae								
	Marilia	0	0	0	0	0	2	0
Helicopsychidae								
	Helicopsyche	0	0	0	0	0	0	3

Appendix 2. Continued...

Order/family	Genera	PN1	PN2	PN3	PN4	PN5	PN6	PN7
Trichoptera								
Leptoceridae								
	Grumichela	2	0	0	1	0	0	0
	Nectopsyche	1	0	0	0	0	0	0
	Oecetis	1	0	0	0	0	0	0
	Triplectides	1	0	0	0	0	0	0
Calamoceratidae								
	Phylloicus	1	0	0	0	0	0	0
Richness		7	1	14	4	2	9	10
Abundance		16	2	45	10	2	22	64

Appendix 3. List of Ephemeroptera, Plecoptera, and Trichoptera sampled in each of the six streams from the São Francisco River basin (SF 1-6). The geographical distribution of species marked with * was expanded.

Order/family	Genera	SF1	SF2	SF3	SF4	SF5	SF6
Ephemeroptera							
Baetidae							
	Americabaetis	1	0	39	88	35	10
	Apobaetis	0	0	0	12	8	0
	Aturbina	0	0	0	1	0	0
	Baetodes	7	5	13	5	3	4
	Camelobaetidius	0	1	1	3	0	10
	Cloeodes	0	0	0	9	0	0
	Cryptonympha	0	0	2	3	0	4
	Baetidae type 3	0	0	0	0	1	0
	Baetidae type 4	0	0	0	0	2	0
	Paracloeodes	0	0	0	0	0	7
	Tupiara	0	0	0	6	0	0
	Waltzoyphius	0	6	6	9	0	11
	Zelusia	0	0	0	2	1	0
Leptophlebiidae							
	Farrodes	3	4	3	51	5	23
	Hagenulopsis	6	21	0	12	1	8
	Hermanella	0	0	0	2	0	0
	Hylistes	3	2	0	0	0	0
	Massartela	0	0	0	0	0	1
	Miroculis	1	0	0	1	0	3
	Thraulodes	0	14	0	26	0	2
Leptohyphidae							
	Leptohyphes	19	28	9	11	1	3
	Traverhyphes	10	0	0	0	16	1
	Tricorythopsis	0	0	1	0	1	4
Ephemeridae							
	Haxagenia	0	0	0	0	0	1
Plecoptera							
Perlidae							
	Anacroneuria	1	4	8	13	0	9
	Kempnyia	0	0	2	5	0	0
	Macrogynoplax	0	0	1	2	0	0
Gripopterygidae							
	Paragripopteryx	0	0	0	0	2	0
	Tupiperla	0	0	0	0	2	0

Appendix 3. Continued...

Order/family	Genera	SF1	SF2	SF3	SF4	SF5	SF6
Trichoptera							
Hydropsychidae							
	Leptonema	2	8	4	2	1	4
	Macronema	0	0	1	7	0	0
	Macrostemum	0	0	1	1	0	0
	Smicridea	9	25	6	14	2	3
Leptoceridae							
	Atanatolica	0	0	0	1	0	0
	Amphoropsyche	0	0	0	0	0	1
	Nectopsyche	0	0	0	1	0	2
	Oecetis	0	0	0	0	0	4
Odontoceridae							
	Marilia	0	0	1	9	0	6
	Barypenthus	0	0	0	20	0	0
Calamoceratidae							
	Phylloicus	0	0	5	4	0	0
Sericostomatidae							
	*Grumicha**	1	2	0	2	0	5
Helicopsychidae							
	Helicopsyche	0	0	1	0	0	2
Hydrobiosidae							
	Atopsyche	0	0	0	4	0	0
Polycentropodidae							
	Cyrnellus	0	5	0	0	0	0
	Polyplectropus	0	25	0	6	0	1
Glossosomatidae							
	Mexitrichia	0	0	0	0	0	1
Philopotamidae							
	Chimarra	0	1	0	0	0	1
Hydroptilidae							
	Hydroptila	2	0	0	0	0	0
Richness		13	15	18	31	15	27
Abundance		65	151	104	332	81	131