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RESEARCH ARTICLE

# Structure of aquatic macroinvertebrate communities in streams of a sub-basin in the Pampa Biome, Southern Brazil

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## Abstract

The Piratinim River is located in the northwest of Rio Grande do Sul, and represents an important effluent from the Uruguay River, with streams located far from urbanized areas, in conditions similar to those of environmental integrity, but under the influence of agricultural activities. In this study, we aim at investigating the structure of the aquatic macroinvertebrate community in streams of the Piratinim river basin by observing both spatial and local scales. The sampling was carried out in six streams distributed in three regions (upper, middle and lower) of the basin, thus exploring its upstream, intermediate and downstream stretches, during spring and autumn. Macroinvertebrates were collected using aquatic dipnets and were identified at the family level; trophic-functional categories were established according to the classification adapted to the state of Paraná. The spatial and temporal variations of the groups and of the biotic attributes (density, richness, diversity and equitability) were subjected to Kruskal-Wallis non-parametric tests and *a posteriori* Dunn's tests. The abiotic variables were obtained to verify possible influence on the composition of the macroinvertebrate community, evaluated through a Canonical Correspondence Analysis. We sampled 11,564 macroinvertebrate individuals from 72 taxa, and found a predominance of the collector-filter trophic group. Abundance and richness were different between streams; the highest densities were found in the streams located in the upper region of the watershed (Chuní and Itú). The highest taxon richness was found in the lower region of the watershed (Guaracapa stream), and the lowest richness was found in the two streams



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for the intermediate region (Santana and Ximbocu). Diversity and equitability did not vary; temporal variations were not found. Canonical correspondence analysis explained 31.7% of the data variability. The main environmental variables that influenced macroinvertebrates distribution were temperature, electrical conductivity, dissolved oxygen, altitude and extension of the riparian forest. Seasonality and the longitudinal gradient along the basin represented determining factors for the structure and distribution of the macroinvertebrate community in the tributary streams of the Piratinim River.

**Keywords**
environmental descriptors, lotic environments, Piratinim watershed, river ecology, seasonal variations

## Introduction

One of the main goals of community ecology is to identify processes that influence the patterns of community structure along spatial and temporal scales. Patterns observed in communities at a particular scale are often the consequence of complex interactions among several processes occurring at multiplex scales (Dray et al. 2012). Many authors encourage broadening the spatial and temporal scales of studies to recognize the hierarchical organization of the ecological systems and effects of environmental heterogeneity at each scale (Leibold et al. 2004; Vellend 2010).

Rivers and streams are complex ecosystems with patchy environmental heterogeneity at multiple spatial and temporal scales (Ward et al. 2002; Winemiller et al. 2010). Several authors have proposed theoretical frameworks to integrate longitudinal (upstream-downstream), temporal dimensions of river ecosystems, incorporating geomorphological, hydrological, and ecological characteristics (Thorp et al. 2006; Humphries and McCann 2014). Change in community structure along the longitudinal dimension has been attributed to environmental gradients generated as stream order increases along the altitudinal gradient (Vannote et al. 1980) or by geomorphic patches at the landscape scale (Montgomery 1999). Variability in community structure along the temporal dimension generally is related to the seasonal variation in temperature and interannual pattern of river flow regimes (Winemiller et al. 2010).

Benthic macroinvertebrates are an important group of organisms which are found in sediment present beneath the water column and that act as key components in any aquatic ecosystem. Studying them is important because the macrobenthic organisms are known as indicators of anthropogenic stress due to their sedentary habitat. Furthermore, they maintain various levels of interaction between the community and environment (Bieger et al. 2010; Silveira-Manzotti et al. 2016; Brraich and Kaur 2017). The structure of the aquatic macroinvertebrate community provides precise and local information on recent events. They are the first causalities of any environmental change (Salvarrey et al. 2014; Siegloch et al. 2016). However, few investigators have analyzed simultaneously the processes influencing aquatic macroinvertebrates community structure at multiple scales in subtropical rivers and streams (Barbero et al. 2013).

Some studies indicate that aquatic macroinvertebrate communities show gradual changes in species richness and composition along the longitudinal dimension as not only the stream order and composition but also habitat complexity increase, giving rise to nested patterns composition or variations in macroinvertebrate functional groups (Pereira and De Luca 2003; Milesi et al. 2009; Baptista et al. 2014). In rivers with large longitudinal variation in climate, geology, substrate and relief, community assemblage generally shows strong discontinuities with high species turnover between adjacent sites (Bagatini et al. 2012; Barbero et al. 2013; Mc Conigley et al. 2017). In this sense we hypothesized that the structure of the aquatic macroinvertebrate community may vary both at the basin level and within the river. Seasonal variations of aquatic macroinvertebrate assemblage have been observed in both rivers and streams in works conducted at temperate, tropical and subtropical latitudes (Marshall et al. 2006; Johnson et al. 2012; Brraich and Kaur 2017; Martins et al. 2018). In this regard, we also expect differences in the structure of the community between autumn and spring seasons.

The present study was conducted in the Piratinim River basin, an important river in southern Brazil and the Pampa biome. The pampa biome occupies a large portion of South American territory, including part of Argentina, Uruguay, and the state of Rio Grande do Sul, Brazil (Capítulo et al. 2001). Typical native fields of this biome have been losing ground to cultivated crops, further altering land uses (Overbeck et al. 2007; De Oliveira et al. 2017), which reflect changes in watercourses. Specifically, the Piratinim River sub-basin is part of the Middle Uruguay River region and is little known in terms of scientific literature, especially with regard to the streams that make up its drainage network. In this scenario, the Piratinim River basin offers the possibility of understanding the structure of the aquatic macroinvertebrate community in environments far from urbanized areas, in conditions similar to those of environmental integrity, but under the influence of agricultural activities.

The samplings considered some of the main tributaries of Piratinim in its upper, middle and lower sections in two seasons of the year. The objective of our study was to apply a multiscale approach to identify the main factors leading the spatial and temporal changes in the structure of aquatic macroinvertebrates of Piratinim river basin, investigating: 1) How the structure and distribution of the macroinvertebrate community varies between basin regions, between streams and in different stretches of streams and 2) The relative importance of climatic seasonality.

## Methods

### Study area

This study was conducted in streams on the right bank of the Piratinim River sub-basin (Middle Uruguay River), located in the Northwest region of the state of Rio Grande do Sul, Brazil. The basin is located between the geographical coordinates 28°00' to 29°05'S and 54°05' to 56°00'W, covering the geomorphological province of the Southern Plateau. Its surface area is approximately 7,596.07 $km^2$, with approximate dimensions of 155 km in the East-West direction, and 40 km North-South (Sema 2009).

According to the Köppen global climate classification (Kuinchtner and Buriol 2001), the Piratinim watershed region is framed in the Cfa or subtropical type climate. On a regional scale, Rossato (2011) stratifies this classification. In the western part of the watershed, a very humid subtropical climate prevails, with cool winter and hot summer, and annual rainfall of 1700–1900 mm. In the eastern portion, there is a humid subtropical climate, with a longitudinal variation in average temperatures, and a rainfall of 1700–1800 mm per year. In the central area, there is a transition section between both climates.

The coverage area of the basin is inserted in the phytoecological region Steppe Savanna, within the Pampa biome, with natural and semi-natural remnants. In a small portion of its extension, there is an area of "Ecological Tension", which configures a transition with the Seasonal Deciduous Forest (Cordeiro and Hasenack 2009). Along the watershed region there are agricultural activities, especially soybean, corn and wheat plantations, as well as livestock areas in native grasslands and cultivated pastures.

In the studied region, spring is characterized by an increase in temperature and water volume in streams; autumn is characterized by a reduction in these two factors. These conditions were also observed during the study.

## Biotic and abiotic data sampling

Sampling was carried out in biweekly collections, during spring and autumn: from September to November 2017, and from May to June 2018, respectively. Collections were performed at 18 sampling points, distributed in six streams (Figure 1). The investigated area covers the three main regions (upper, middle and lower) of the watershed, and for each region, two streams were selected. Three stretches were sampled for each stream: upstream, intermediate and downstream. Sampling points were previously determined using geo-referenced satellite images in the Google Earth Pro browser (version 7.3.2.5491), see Suppl. material 1: Table S1, which contains the geographical coordinates and altitude of the localities. Our criteria while selecting areas were that all the points should be located in rural areas, without the direct influence of urban centers.

During field work, a 30–45 min sampling effort was applied to collect macroinvertebrates at each site. In order to determine the streams' width, a measuring tape was used. A multi-parameter meter (YSI Professional Plus) was used to measure abiotic parameters, such as water temperature (°C), pH, dissolved oxygen ($mg.l^{-1}$) and electrical conductivity ($\mu S.cm^{-1}$).

Macroinvertebrates were sampled using an aquatic dipnet (250 µm mesh), from downstream to upstream, in an extension of approximately 30 m. As recommended by Usepa (1997), we used a multi-habitat approach to cover all available biotopes in the watercourse, both rapid and slow stretches. The available sediments (sandy bottom, rocky sediments, aquatic vegetation) were driven into the dipnet with the aid of the researcher's feet, if necessary. During field survey, samples were placed in light colored trays and then pre-screened. Individuals

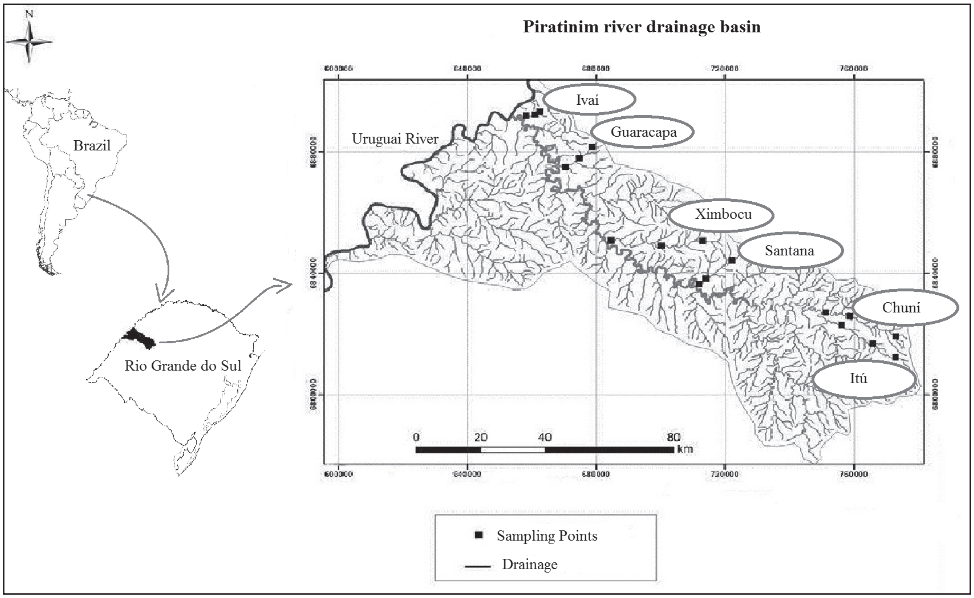


**Figure 1.** Distribution of aquatic invertebrates sampling points in streams from the Piratinim River watershed, in the state of Rio Grande do Sul, Brazil.

were separated from the substrate using fine-tipped forceps, stored in tubes containing 70% ethyl alcohol and identification labels, for later definitive screening and taxa identification.

In the laboratory, samples were analyzed using a stereomicroscope, at 45× magnification. Macroinvertebrates were identified, whenever possible, to the Family taxonomic level, using dichotomous and/or pictorial keys by McCafferty (1981), Merrit and Cummins (1984), Lopretto and Tell (1995), Fernández and Domínguez (2001), Pes et al. (2005), Benetti et al. (2006), Costa et al. (2006), Pereira et al. (2007), Mugnai et al. (2010), Segura et al. (2011), Hamada et al. (2014). Individuals were counted and stored in tubes containing 70% alcohol. The testimony material was deposited in the scientific and didactic collection of the Zoology laboratory from the Federal University of Fronteira Sul, *campus* Cerro Largo.

The trophic-functional groups were determined by the classifications of Cummins (1973), Cummins and Klug (1979), Merrit and Cummins (1996), Wallace and Webster (1996), as well as by the adaptation of these categories to the Atlantic Forest region, in the state do Paraná, developed by Cummins et al. (2005).

## Data analysis

To assess the structure of the macroinvertebrate community, data were transformed into log10 (x + 1), where "x" represents organism abundance in each family. We established a Frequency of Occurrence of at least 5% for the inclusion of taxa in the analysis, in order to exclude the influence of rare families.

We calculated the Shannon-Wiener diversity index (H') and equitability (E), as well as taxa richness (S) and organism density (ind.$m^{-2}$) (Magurran 2004). In addition, specimens were grouped into their respective trophic-functional groups: predators, scrapers, shredders, filtering-collectors and gathering-collectors (Cummins et al. 2005). All these dependent variables were submitted to the Kruskal-Wallis non-parametric test. In all cases, variations between streams (spatial) and seasons (temporal) were investigated. When statistical differences were identified, Dunn's *a posteriori* test was used. We used the software STATISTICA (version 7.0) for data analysis.

The abiotic factors used to test the relation with the biotic data included variables of temporal nature, such as: seasons (spring and autumn), included as 2 dichotomous binary variables and the days of sampling (Julian dates); limnological variables (water temperature, dissolved oxygen, electrical conductivity and pH) and spatial variables (streams width, altitude of sampling points and riparian forests width). Variables were measured through georeferenced satellite images in Google Earth Pro browser.

To verify the influence of environmental variables on macroinvertebrates distribution, a Canonical Correspondence Analysis (CCA) (Ter Braak 1986) was applied. Prior to the use of CCA, the forward-selection procedure was applied to reduce multicollinearity among the abiotic variables used. To test the significance of the relationship between taxa and environmental variables, as indicated by the CCA axes ($p<0.05$), we used a Monte Carlo test with 999 permutations. For the ordination analyzes, we used the PC-ORD software (version 5.0).

## Results

### Structure of the macroinvertebrate community

A total of 11,564 macroinvertebrate individuals were sampled in the six streams of the Piratinim watershed. Of these, 6,089 specimens were sampled during spring, and 5,475 during autumn. Among the sampled macroinvertebrates, there are aquatic and semi-aquatic species, distributed in 72 taxa from the phyla Platyhelminthes, Nematomorpha, Anellida, Mollusca and Arthropoda (see Suppl. material 2: Table S2). Insecta represented 89.38% of the total sampled individuals, which includes most of the sampled families: Coleoptera (12), Hemiptera (9), Diptera (9), Odonata (8) and Trichoptera (7), among others.

The most abundant taxa were Hydropsychidae (17.08%), Philopotamidae (15.46%) and Simuliidae (11.46%). Baetidae and Chironomidae were the most frequent families, occurring in all locations during the two sample seasons. Leptophlebiidae did not occur in only one location, Hydropsychidae in two, and Simuliidae in three. Eleven taxa were sampled exclusively at one point and one season, in low abundance.

Regarding the trophic-functional groups, the predator category had the highest taxonomic richness (N = 33), while shredders were represented only by 10 families. Considering abundance, the collectors-filters group (45.7%) predominated in the watershed, followed by gathering-collectors (26.6%), predators (17.3%), scrapers (8.5%) and shredders (1.9%) (see Suppl. material 2: Table S2).

When comparing all streams, the highest densities were found in the streams located in the highest region of the watershed: Chuní (3,312 ind.m$^{-2}$) and Itú (2,450 ind.m$^{-2}$) ($p < 0.05$). In the Guaracapa stream, located in the lower region of the watershed, the highest average taxon richness (24) was found. The lowest taxon richness was found in the two streams located in the intermediate region of the watershed, Santana and Ximbocu, with an average of 19 taxa ($p < 0.05$). Diversity and equitability showed no statistical difference between streams (Figure 2; $p > 0.05$).

Regarding trophic-functional groups, only the gathering-collectors group showed statistical difference when comparing streams (Figure 3; $p < 0.05$).

Temporally, there was no statistical difference in community attributes between the streams of the Piratinim River watershed (Figure 4; $p > 0.05$).

When comparing seasons, predators occurred in higher densities during autumn ($p<0.05$), whereas the gathering collectors had a higher density during spring. The other groups did not vary between seasons (Figure 5; $p < 0.05$).

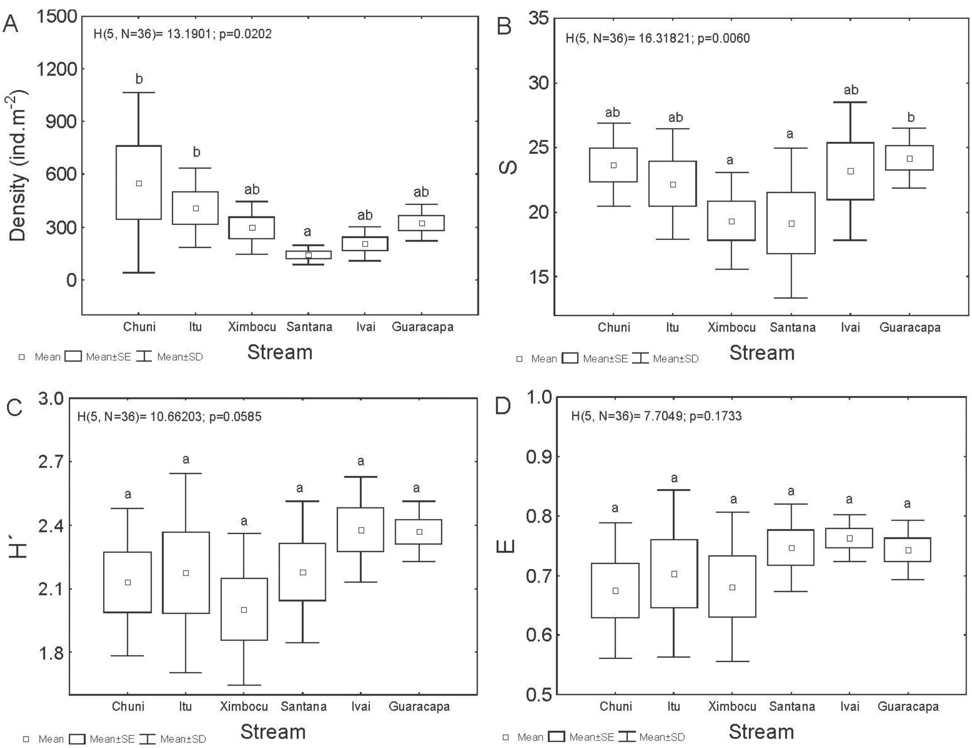


**Figure 2.** Biotic attributes: density (**A**), richness (**B**), Shannon-Wiener diversity index (**C**) and equitability (**D**) of macroinvertebrate communities in streams of the Piratinim River watershed, southern Brazil. Average values represented by equal letters do not differ statistically. ±SD = standard deviation; ±SE = standard error.

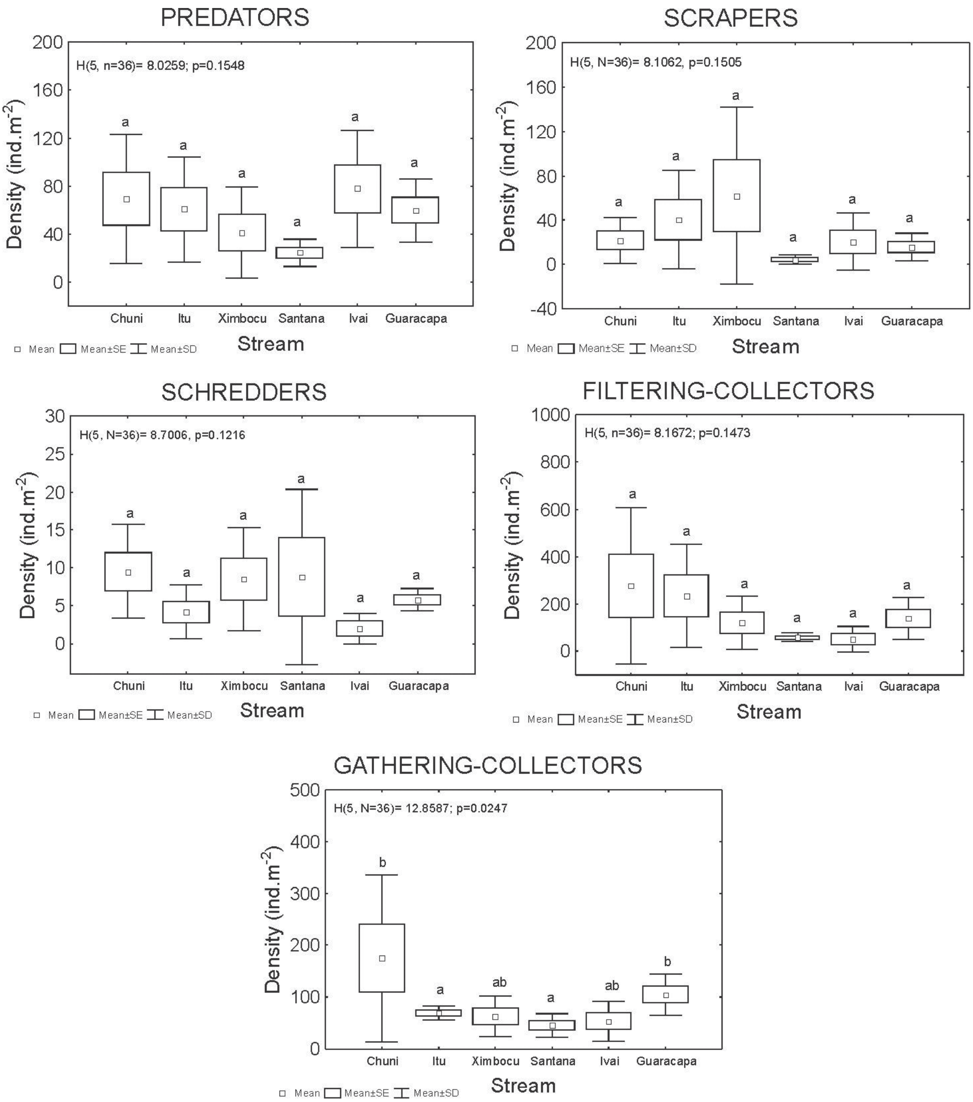


**Figure 3.** Density of trophic-functional groups of macroinvertebrate communities in streams of the Piratinim River watershed, southern Brazil. Average values represented by equal letters do not differ statistically. ±SD = standard deviation; ±SE = standard error.

## Association with abiotic parameters

The forward-selection procedure of CCA method indicated only six variables to be included in the analysis: altitude, stream width, riparian forest, temperature, electrical conductivity and dissolved oxygen. The physical-chemical parameters of the water and the environmental characteristics of the streams (except altitude) are presented in the Suppl. material 3: Table S3.

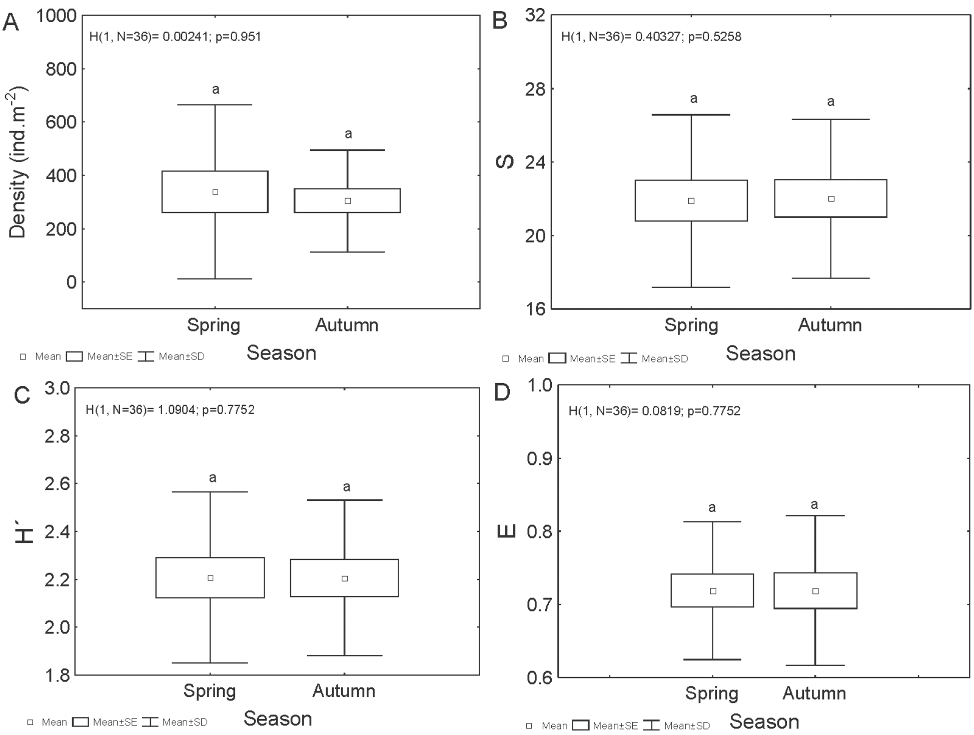


**Figure 4.** Biotic attributes: density (**A**), richness (**B**), Shannon-Wiener diversity index (**C**) and equitability (**D**) of the macroinvertebrate communities per season (spring and autumn) sampled in the Piratinim River watershed, southern Brazil. Average values represented by equal letters do not differ statistically. ±SD = standard deviation; ±SE = standard error.

**Table 1.** Result of the Canonical Correspondence Analysis (CCA) applied to the matrix of abiotic and macroinvertebrate data sampled in different streams of the Piratinim River basin, southern Brazil, during spring 2017 and autumn 2018 seasons. Monte Carlo test for the significance of the ordination first axis p<0.05 (n = 999 permutations). Values in bold were statistically significant (p<0.05).

| Total variance: 2,28 | | |
|---|---|---|
| **Environment characteristics** | **CCA1** | **CCA2** |
| Electric conductivity | **-0.48** | **0.42** |
| Dissolved oxygen | **0.59** | **0.40** |
| Altitude | -0.31 | **-0.48** |
| Riparian forest | 0.21 | **0.40** |
| Width | -0.27 | -0.21 |
| Temperature | **-0.76** | **-0.44** |
| % of explanation | 18.8 | 12.9 |
| Pearson's Species-Environment Correlation | **0.91** | **0.88** |

According to the Canonical Correspondence Analysis (CCA), the first two axes were significant ($p < 0.05$) and together explained 31.7% of the data variation. Axis 1 explained 18.8% and axis 2 explained 12.9% of the total variability. In addition, a significant correlation was observed between abiotic and biotic variables ($p < 0.05$; Table 1).

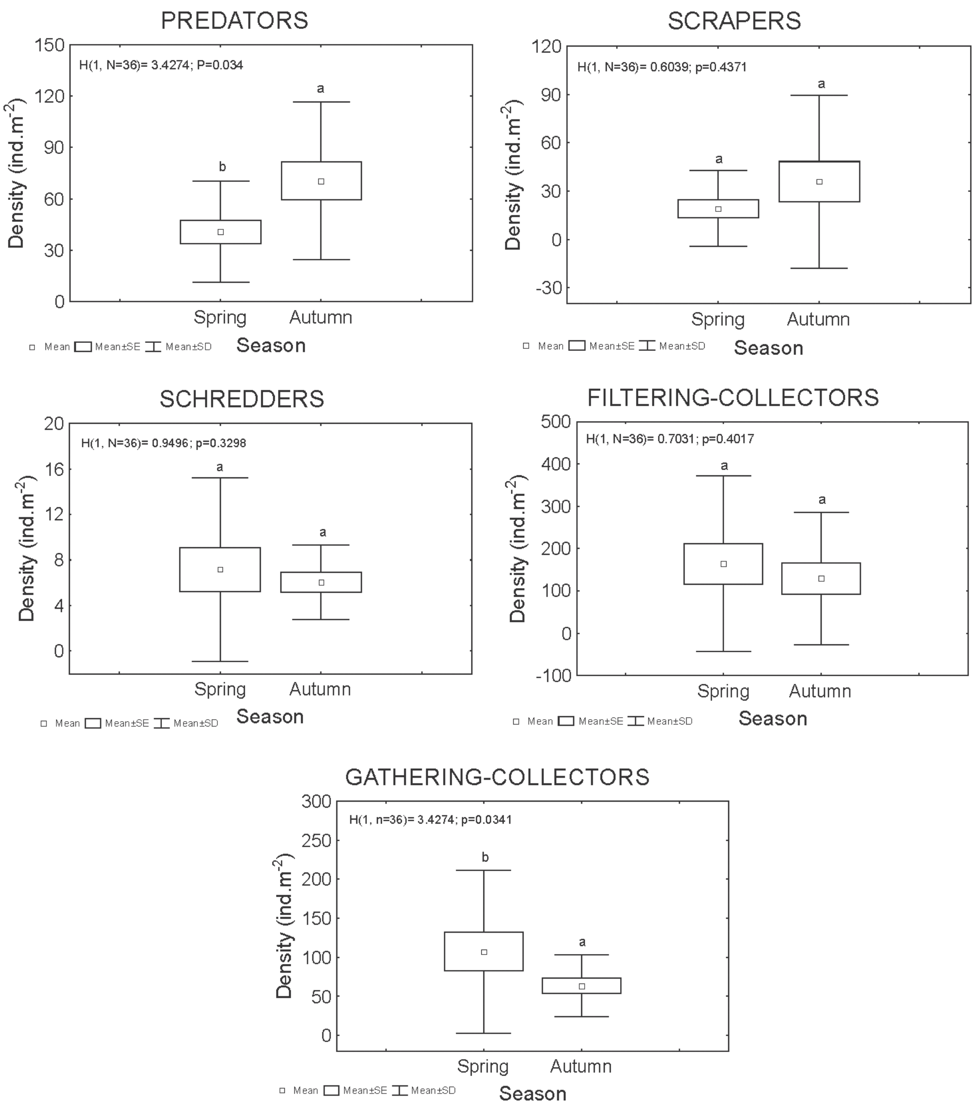


**Figure 5.** Abundance of trophic-functional groups of macroinvertebrate communities by season (spring and autumn), collected in the hydrographic basin of the Piratinim River, southern Brazil. Average values represented by equal letters do not differ statistically. ±SD = standard deviation; ±SE = standard error.

CCA1 was mainly influenced by temperature, which clearly separated samples made during different seasons in the plot, where autumn samples were grouped in the right side and spring samples in the left side. Electrical conductivity increased during the spring, and it is also related to the left side of the plot. Dissolved oxygen had the highest levels recorded during autumn, in the right side.

CCA 2 presented a spatial segregation between the sampling points located upstream and downstream of the basin, influenced by altitude and riparian forest. The

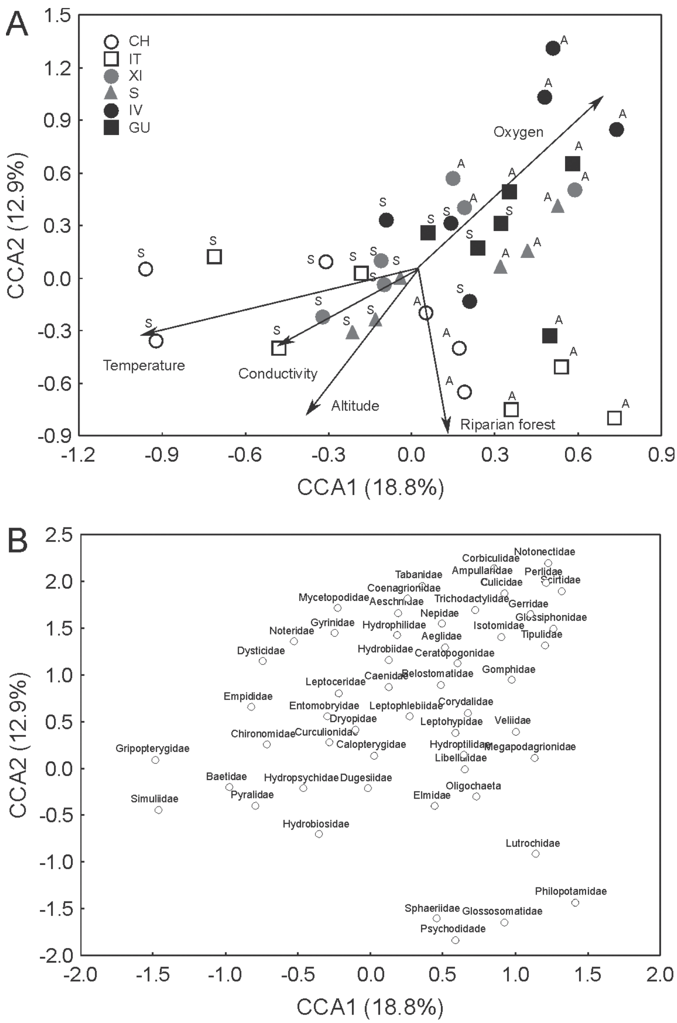


**Figure 6.** **A,B** Result of the Canonical Correspondence Analysis (CCA) applied to the matrix of abiotic data and families of macroinvertebrates sampled during the seasons of spring 2017 and autumn 2018, in the Piratinim River basin, southern Brazil. Streams: CH = Chuní; GU = Guaracapa; IT = Itú; IV = Ivaí; S = Santana and XI = Ximbocu.

points of the Chuní and Itú streams, located at the bottom of the plot, are characterized by a higher altitude and larger extension of riparian forest. The points of the Ivaí and Guaracapa streams, located at the top of the plot, are characterized by a lower altitude and reduced riparian forest (Figure 6A).

The right side of CCA1 plot was characterized by the presence of the families Lutrochidae ($r = 0.49$), Ceratopogonidae ($r = 0.57$), Gerridae ($r = 0.61$), Veliidae ($r = 0.53$), Corydalidae ($r = 0.60$), Libellulidae ($r = 0.55$) and Philopotamidae ($r = 0.59$). The left side, related to the increase in temperature and conductivity, mainly showed representatives of the families Chironomidae ($r = -0.48$), Simuliidae ($r = -0.59$), Baetidae (r = -0.66) and Hydropsychidae (r = -0.48). In CCA2, the lower side of the plot was mainly characterized by representatives of Hydrobiosidae (r = -0.62) and Baetidae (r = -0.41) (Figure 6B).

## Discussion

Studies in neotropical aquatic environments are mostly focused on areas affected by urbanism, mainly because these studies seek to investigate the themes of environmental degradation and public health through disease vectors, or because those environments are often located near the research institution (Cruz et al. 2016). In contrast, few studies have been carried out in more preserved environmental conditions, or environments that are influenced by other human activities, such as agriculture and livestock (Petesse and Petrere 2012).

In this study we covered a drainage basin with considerable variation in geomorphological conditions and landscape structure (Cordeiro and Hasenack 2009; Sema 2009). We find that there is a high diversity of macroinvertebrates, with significant variation in the community structure, that is, species' richness, abundance and composition. In addition, the results indicate that environmental (such as altitude, riparian forest and limnological characteristics) and seasonal factors (seasons) mostly explained the variation in organism distribution. The data obtained support the prediction that specific environmental conditions select different assemblies, but indicate that temporal aspects also play an important role.

We found a highly diverse macroinvertebrate fauna in the tributaries of the Piratinim River. Other studies carried out in southern Brazil indicated a lower taxa representativeness (Bueno et al. 2003; Pereira and De Luca 2003; Ayres-Peres et al. 2006; Strieder et al. 2006a; Buckup et al. 2007; Milesi et al. 2009 ; Biasi et al. 2010; Sobczack et al. 2013; Baptista et al. 2014; Salvarrey et al. 2014). The study conducted the closest to our study area was carried out in the Ibicuí River basin, west of Rio Grande do Sul, also within the Pampa biome (Baptista et al. 2014). These authors sampled more than 9,000 individuals, distributed in 26 aquatic insect families, in the evaluated streams. The richness found in the Piratinim River basin was higher, comprising 57 insect families.

Regarding the most abundant taxa, Hydropsychidae and Philopotamidae were the most representative (32.54% of the total sampled individuals). These taxa are grouped in the order Trichoptera, which is considered one of the most diverse insect Orders in lotic environments, with families widely distributed in temperate and tropical latitudes (Wallace and Merrit 1980; Dudgeon 1997). In this study, seven (7) families were sampled; Breda et al. (2018) found ten (10) families in streams in the northern region of Rio Grande do Sul, while Spies et al. (2006) recorded nine (09) families for the central region. Simuliidae (Diptera) was also representative for the Piratinim watershed. In general, this family is representative of well-oxygenated waters (Callisto et al. 2001), but some species have a wide tolerance range to environmental pollutants (Strieder et al. 2006b).

In the sampled tributaries, some insect families, such as Baetidae (Ephemeroptera) and Chironomidae (Diptera), were present in all collection locations. A similar result was obtained by Biasi et al. (2010), when studying streams in the northern region of Rio Grande do Sul for eight years, having observed the presence of the families Baetidae, Chironomidae and Hydropsychidae in all sampled locations.

Usually, Ephemeroptera are used as bioindicators of good water quality; however, Baetidae has a wide range of pollution tolerance, which can occur in areas under intermediate impact. Likewise, Chironomidae is an indicator of disrupted environments; however, some genera have higher tolerance to organic contamination than others (Hilsenhoff 1988). Callisto et al. (2001) reiterate that the use of macroinvertebrates as indicators of environmental quality should not be restricted to its presence in a given watercourse, but mainly to their abundance within the community. The biotic attributes (diversity, density, richness and equitability) structuring the aquatic macroinvertebrate community did not show temporal variation between the sampled seasons, similarly to other studies carried out in the country (Melo and Froelich 2001; Costa et al. 2006; Buckup et al 2007; Crisci-Bispo et al. 2007; König et al. 2008; Bieger et al. 2010). In general, the values found for these attributes were high; Chagas et al. (2017) reported similar results associated with streams of good water quality.

Density varied significantly among the investigated tributaries, and the streams in the upper region of the basin had the highest average density of individuals per $m^2$. The sampling points from this region, even though containing the most considerable portion of riparian vegetation among the investigated streams, show a physiognomy of the surroundings conditioned to disturbances in agricultural and livestock practices close to the banks, with direct access by cattle. In part, such results may be associated with the level of disturbance around these water courses, which favor the predominance of tolerant or resistant taxa (Strieder et al. 2006b; Milesi et al. 2009).

For the richness attribute, the highest average was recorded in the Guaracapa stream, located in the lower region of the basin. This stream has a more closed riparian forest, which is difficult to access, when compared to other tributaries analyzed in this study. In streams in the middle region of the basin, the surrounding vegetation is present, but it is more conditioned to disturbances, and in these places the lowest average values of richness were found. Therefore, in the evaluated streams, the extent of riparian vegetation, solely, does not represent an indicator of environmental integrity. It is necessary to assess how the surrounding environment interacts with these areas, enabling sources of non-specific impacts on water courses.

Concerning the trophic-functional groups, besides the fact that predators showed a high taxonomic richness, the abundance was relatively low when compared with gathering-collectors and filtering-collectors. These two groups were predominant in the total sample, representing more than 70% of all sampled individuals. This is mainly due to the fact that the most abundant families (Hydropsychidae, Philopotamidae and Simuliidae) are mostly collector-filters. However, it is important to highlight that some families or groups may have a generalist habit, adapting to food resources availability (Silveira-Manzotti et al. 2016). De Castro et al. (2016) found that changes in land use, such as the cultivation of sugar cane and livestock, can lead aquatic macroinvertebrate assemblages to exhibit more generalist feeding habits.

According to Cummins et al. (2005), the occurrence rates of the functional groups are indicative of the streams ecosystem attributes. In this case, a higher abundance of filtering-collectors and gathering-collectors indicate availability of particulate organic matter in suspension and deposited in the bottom. Callisto et al. (2001) observed a dominance of the collecting groups in headwater streams in the Midwest of Brazil, with characteristics of narrow beds, rocky bottoms and preserved riparian vegetation, with riparian vegetation being the most influential substrate in the richness. Such environmental descriptors are similar to those found in the streams analyzed in Piratinim, which in turn are all located in rural areas. Dovciak and Perry (2002) sampled hydrographic basins inserted in agro-regions of the USA, and found that filtering-collectors were dominant in areas of good environmental integrity. With a larger availability of food resources, this group is favored due to the morphological adaptations of many of its representatives, which require stable substrates to filter fine particulate organic matter. As the restrictions on microhabitats increased, the abundance of this group was reduced, while gathering-collectors became predominant.

The analysis showed that seasonality represented the most determining factor regulating the distribution of macroinvertebrate taxa (CCA1). During the spring, the electrical conductivity parameter showed the highest values, most clearly associated with streams in the upper region of the basin. Among the families of which the spatial distribution was associated with such condition, are the dipterans Chironomidae and Simuliidae. During autumn, we recorded the highest levels of dissolved oxygen, being more associated with the mouth of the basin. For this season, several families were correlated, such as the hemiptera Veliidae and Gerridae.

Electrical conductivity can be considered one of the factors that significantly influence fauna distribution (Braun et al. 2014; Salvarrey et al. 2014), however, this condition occurs only in extreme values or when associated with organic pollution (Bispo et al. 2006), as well as in areas of agricultural crops. The pH can also influence the values of electrical conductivity (Esteves 1988), but this parameter was not significant in our study. Factors such as local geology and climate also influence these parameters (Pedrosa and Rezende 1999).

On the axis corresponding to CCA2, segregation of the upper and lower regions of the basin were once again observed. The streams located in the upper basin, of higher altitude and extension of riparian forest, were correlated with the distribution of the families Hydrobiidae and Baetidae. However, the streams located in the lower basin, of lower altitude, exhibited a reduction in the average extension of the riparian forest, in relation to the other streams.

In fact, among the environmental variables evaluated, the width of the riparian forest, given its presence and preservation, was the one that demonstrated crucial influence in determining the distribution of the macroinvertebrate community of the streams analyzed. Moraes et al. (2014) verified the impact of the removal of riparian vegetation on streams in Rio Grande do Sul. These authors verified that the riparian zone should not be less than 15 m wide, on both banks, so that the composition of the macroinvertebrate community remains similar to that found in reference preservation sites.

Degradation and removal of riparian vegetation is considered one of the factors that may lead to an increase in water temperature of streams (Caisie 2006; Fantin-Cruz et al. 2010; Ferreira et al. 2014; Hepp et al. 2016), practices that are relatively common in agricultural areas (Delong and Brusven 1998; Hepp et al. 2010). In addition to reducing the entry of sediments from soil erosion, riparian forest is an efficient controller of water temperature and dissolved oxygen rates, contributing to the balance of benthic populations (Percebon et al. 2005; Siegloch et al. 2016).

However, despite the variations and the influence of riparian forest in taxa distribution, it is important to highlight that the average stream width in the upper basin was slightly higher than in the tributaries from the low region, considering that such variables may be proportional. According to Chaves et al. (2005), the size or width of a stream is among the best predictors of aquatic macroinvertebrate richness, yielding increases in diversity as the flows become larger. However, Lenat (1988) found that small streams do not show a considerable reduction in taxa richness under adequate rainfall conditions.

## Conclusion

When high values of richness and diversity are verified in a study, it is assumed that the composition and structure of a community are similar to those found in areas of environmental integrity. The results found for the Piratinim River streams revealed a richness of aquatic macroinvertebrates similar or higher to those found in other studies conducted in southern Brazil, evidently influenced by seasonal and spatial aspects. However, these studies also demonstrate the influence of non-specific sources of impact affecting these organisms. The Piratinim River drainage basin is located in an agricultural region, where the reduction of natural vegetation coverage, especially native grasslands, contributes to landscape homogenization, also affecting aquatic biodiversity.

In this sense, fauna surveys and the investigation of spatial distribution patterns and community structure of aquatic macroinvertebrates contribute to fill the current knowledge gap concerning these taxa in the Pampa biome, and to expand the patterns already described for the south of Brazil. Therefore, awareness-raising and management activities are necessary to promote the maintenance of environmental quality along the evaluated water courses.

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## Supplementary material 1

**Table S1**

Authors: Sirlei Maria Hentges, Tieli Cláudia Menzel, Cristiane Maria Loebens, Samuel Elias Siveris, David Augusto Reynalte-Tataje, Milton Norberto Strieder

Data type: occurrence

Explanation note: Geographic coordinates and altitude of the streams at 18 sampling points in the Piratinim river watershed, southern Brazil, during spring 2017 and autumn 2018.



Link: https://doi.org/10.3897/neotropical.16.e60579.suppl1

## Supplementary material 2

**Table S2**

Authors: Sirlei Maria Hentges, Tieli Cláudia Menzel, Cristiane Maria Loebens, Samuel Elias Siveris, David Augusto Reynalte-Tataje, Milton Norberto Strieder

Data type: species data

Explanation note: Taxonomic composition (diversity, absolute frequency and trophic-functional groups *) of aquatic macroinvertebrates collected in 18 sampling points of six streams in the hydrographic basin of the Piratinim River, southern Brazil, in the Upstream (U), Intermediate (I) and Downstream (D) sections, during the spring (P) of 2017 and autumn (O) of 2018. * Gtf: Trophic-functional group (P = predator, S = scraper, Sh = shredders, FC = filtering collector, GC = gathering collector).



Link: https://doi.org/10.3897/neotropical.16.e60579.suppl2

## Supplementary material 3

**Table S3**

Authors: Sirlei Maria Hentges, Tieli Cláudia Menzel, Cristiane Maria Loebens, Samuel Elias Siveris, David Augusto Reynalte-Tataje, Milton Norberto Strieder

Data type: species data

Explanation note: Abiotic factors of the streams at 18 sampling points in the Piratinim river watershed, southern Brazil, during spring 2017 and autumn 2018.



Link: https://doi.org/10.3897/neotropical.16.e60579.suppl3