Benthic macroinvertebrate community in the Sinos river drainage basin, Rio Grande do Sul, Brazil

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Abstract
Aquatic macroinvertebrate fauna is a relevant component of limnic continental aquatic ecosystems, playing an important role in several processes with relevant biocomplexity. The present study characterized the benthic macroinvertebrate fauna found in three hydric bodies in the Sinos river drainage basin regarding community structure. Sample was collected from January to December 2013 in three locations in the basin: the city of Caraá (29°45’45.5”S/50°19’37.3”W), the city of Rolante (29°38’34.4”S/50°32’33.2”W) and the city of Igrejinha (29°36’10.84”S/50°48’49.3”W). Abiotic components (pH, dissolved oxygen and temperature) were registered and collected samples were identified up to family type. Average annual pH, dissolved oxygen and temperature were similar in all locations. A total of 26,170 samples were collected. Class Insecta (Arthropods) represented 85.5% of total sample. Platyhelmintes, Mollusca and Annelida samples were also registered. A total of 57 families were identified for the drainage basin and estimators (Chao-1, Chao-2 and jackknife 2) estimated richness varying from 60 to 72 families.

Keywords: aquatic invertebrates, community structure, diversity indices.
According to Silveira and Queiroz (2006), benthic macroinvertebrates are a group of animals visible to the naked eye, made up mainly by mollusks, crustaceans and insects that inhabit the substrate at the bottom of rivers. They are important in limnic environments, serving as food for fish and taking part in the energy flow and nutrient cycling (Ayres-Peres et al., 2006). As they reflect changes in the environment, they are recommended as bioindicators of water quality (Bueno et al., 2003), representing an important tool to understand the functioning and structure of lotic ecosystems (Galdean et al., 2001).

According to Franz et al. (2010), the Sinos river basin is among the most populated in the state of Rio Grande do Sul and represent a history marked by European colonization which took place from the 19th century until the 1940’s. Occupation of lowlands and hillsides caused changes in the characteristics of natural areas. Forests were replaced by rural areas, and later by urban intensification. The impact of human activity, mainly the pollution of water with domestic sewage without treatment, add up along the river, and high levels of fecal coliform reflect the great sanitation deficit in the drainage basin, especially along the middle and lower courses of the Sinos river (Blume et al., 2010).

There is few available data on the structure of the benthic macroinvertebrate community along the drainage basins in the state of Rio Grande do Sul, highlight is given to studies by Bueno et al. (2003), Stenert et al. (2004), Volkmert-Ribeiro et al. (2004), Ayres-Peres et al. (2006), Piedras et al. (2006), Buckup et al. (2007), Milesi et al. (2009) and Biasi et al. (2010). The following studies are highlighted for the drainage basin of the Sinos river: Mansur and Pereira (2006), Strieder et al. (2006), Bieger et al. (2010) and Maltchik et al. (2010). The objective of the present study is to characterize the benthic macroinvertebrate fauna found in three water bodies located in the Sinos river drainage basin regarding community structure.

2. Material and Methods

2.1. Study area

The Sinos river drainage basin is located in the northeastern region of the state of Rio Grande do Sul, Brazil (29°20’ - 30°10’S/50°15’ - 51°20’W), and covers two geomorphic provinces: the Southern Plateau and the Central Depression. It is part of the Guaiuba drainage basin and presents an area of approximately 800 km², including 32 cities (FEPAM, 2014). The Sinos river drainage basin provides water to about 1.3 million people, with a population density of approximately 300 people per square kilometer, some urban areas and densely populated and area located along the lower course of the river. The region presents diversified industrial production: footwear and leather, mechanics and metallurgy, tourism and hospitality, where the lower portions of the drainage basin are under strong anthropic pressure due to the growth of the largest industrial park in the state (Blume et al., 2010).

2.2. Sampling sites

In order to determine physical and chemical characteristics, benthic macroinvertebrate and water samples were collected in three different sites along the drainage basin (Figure 1), in the major water bodies: upper Sinos river, Rolante river and Paranhana river, always in superficial waters of the water body itself.

P1 – Site 1 - (29°45’45.5”S/50°19’37.3”W). City of Caraá. Established in Lageadinho, this sampling site is located in the beginning of the formation of the Sinos river, although it is not characterized as the source of the river, as it already presents the influence of some small contributors. At this location, there are strong currents and whenever compared to the other two sites the bottom is made up of a rocky substrate, pebbles with various sizes intermingled with little decomposing organic matter. The city presents an area of 29538 hectares of which 23% are still originally covered by the Atlantic forest (Fundação SOS Mata Atlântica, 2014), and an estimated population of 7742 inhabitants (IBGE, 2010). Sampling point does not suffer the impact of great urban conglomerates located on upstream, thus the anthropic impact is considered low.

P2 – Site 2 - (29°38’34.4”S/50°32’33.2”W). City of Rolante. Established in a location best known as “Reichert”, sampling point is located in the Rolante River, five kilometers upstream of city center (urban density) and receives contributions from rivers Riozinho and Mascarada, the river drains an area of 500 km². Sampling point is located 22 km from the mouth of the Sinos river, which is located in the rural area of the city of Taquara. The river currents are strong at sampling site and the bottom is made up of a sandy and rocky (pebbles) substrate, with various sizes intermingled with decomposing organic matter made up mainly of tree leaves from riparian vegetation located upstream. A greater environmental heterogeneity is found at this point with the decomposition of the sandy substrate. The city presents an area of 29675 hectares of which 17% are still originally covered by the Atlantic forest (Fundação SOS Mata Atlântica, 2014), and an estimated population of 20479 inhabitants in 2013 (IBGE, 2010). Sampling point is under the impact of large urban conglomerates located upstream, such as the cities of Riozinho and São Francisco de Paula.

P3 – Site 3 - (29°36’10.8”S/50°48’49.3”W). City of Igrejinha. Established in the “Casa da Pedra” district, sampling site is located in the Paranhana river, five kilometers downstream of city center (urban density) and 15 kilometers from the mouth of the Sinos river, which is located in the rural area of the city of Taquara, the river drains an area of 580 km². The river currents are strong at sampling site and the bottom is made up of a sandy and rocky (pebbles) substrate, with various sizes intermingled with decomposing organic matter made up mainly of tree leaves from riparian vegetation located upstream. A greater environmental heterogeneity is found at this point with the decomposition of the sandy substrate. The city presents an area of 13557 hectares of which 22% are still originally covered by the Atlantic forest (Fundação SOS Mata Atlântica, 2014).
Mata Atlântica, 2014), and an estimated population of 33711 inhabitants in 2013 (IBGE, 2010). At this point, the Salto Dam System is important for the water dynamics of the river, since the dam system enables the regularization and transposition of water from the Caí river basin to the Sinos river basin for the production of electricity since 1956 through the Paranahaha river (Macedo, 2010), thus, the water from the Caí river flows through this site in an inconstant and variable manner with maximum water flow of up to 11.6 m$^3$/s for this transposition. Sampling point is partially under the impact of large urban conglomerates located upstream, such as the cities of Três Coroas, Gramado, Canela and São Francisco de Paula.

Measurement of dissolved oxygen was conducted by the Analytic Department at FEEVALE University, a FEPAM-RS certified laboratory. Sample collection, as well as all measurements, was carried out according to the Standard Methods for Examination of Water and Wastewater, 22nd Ed (Rice et al., 2012). Water temperature and pH were recorded in the field by using pHmetro Hanna Instruments (HI 98128).

BIOESTAT 5.0 (Ayres et al., 2007) and PAST (Hammer et al., 2001) were used for statistical analysis and biotic index calculations. Student’s t-test was used to compare H value (Shannon Diversity Index) between the points. Group method was considered to calculate Morisita Similarity Index ($S_m$). Unweighted Pair Group Method with Arithmetic Mean (UPGMA) was used, the result is represented by a dendrogram. This analysis was carried out by software PAST - Version 2.16. (Hammer et al., 2001). Non-parametric richness estimators: Chao-1, Chao-2 and second order jackknife, Colwell and Coddington (1994) revised these estimator and concluded that Chao-2 and second order jackknife present better performance.

2.3. Macroinvertebrate sampling

Macroinvertebrate and water sampling to determine physical and chemical characteristics took place from January to December 2013. A 60cm × 40cm (2400 cm$^2$) small fishing net with a 2mm mesh size. Stream sampling method (kick-sampling) was used, which is a method that consists in moving pebbles at the bottom of the river with the objective of carrying dislocated animals into the net. All collected organisms were fixed on site using 70% ethanol and were stored in plastic buckets. Once in the laboratory, the material was screened and the samples were indentified up to family type by using bibliography according to each taxonomic group (Lopretto and Tell, 1995; Merrit and Cummins, 1996; Moretti, 2004; Salles et al., 2004; Benetti et al., 2006; Mansur and Pereira, 2006; Costa et al., 2006; Froehlich, 2007; Mugnai et al., 2010; Carter et al., 2011).
3. Results and Discussion

3.1. Physical and chemical characteristics

The three sampling sites are similar regarding limnologic characteristics of zonation, such as high current speed and substrate made up of fixed rocks, stones, gravel and thin sand, with deposition of mud and allochtonous leaves in small puddles or protected areas. Sampling sites can be traditionally classified as rithron, although they do not present great slopes. Another important characteristic of the sampling points is the transparency of the water, with little suspended material that could be visually identified during sampling. Sites are located in erosion areas, which is caused by the pluviometric regime and not by sediment deposition.

In regards to temperature variation, Hawkes (1975) characterizes a rital zone with an annual temperature variation that does not go over 20 °C, temperature varied less in the three sampling sites: Site 1 (8.1 up to 22.7 °C; \( \mu = 17.7 \) °C), Ponto 2 (9.0 up to 24.6 °C; \( \mu = 19.0 \) °C) e Ponto 3 (9.0 up to 25.6 °C; \( \mu = 21.2 \) °C). Site 1 presents the smallest observed amplitude, followed by Sites 2 and 3 (Figure 2), in regards to average annual temperature the same behavior occurred, with the average increasing towards the mouth of the basin. This classification based in thermal balance could cover stretches such as mountain rivers, but the sites are already located in areas that present a decrease in laminar flow.

Regarding pH, annual average, calculated over 12 months, presented neutral values (Site 1 – 7.04, Site 2 – 7.08 and Site 3 – 6.85). These values are expected in continental natural waters and are among the variation predicted by CONAMA resolution No. 357/2005 (Brasil, 2005) for class 1 waters. Extreme recorded pH values were 6.17 at Site 3 (the lowest) and 7.69 (the highest) at Site 1 (Figure 3). Most species of aquatic organisms are very sensitive to pH variations and very acidic or alkaline waters may be harmful to aquatic communities, therefore, the recorded pH variation is not a compromising factor for the maintenance of aquatic life in the sites that were studied. According to Esteves (1998), most continental water bodies have a pH that varies between 6 and 8.

In regards to dissolved oxygen (DO), the annual average presented high values in all of the monitored sites: Site 1 – 8.71 mgO2L\(^{-1}\), Site 2 – 8.94 mgO2L\(^{-1}\) and Site 3 – 8.42 mgO2L\(^{-1}\). The smallest recorded value was 7.3 mgO2L\(^{-1}\), in the month of December at Site 3, and the highest was 10.85 mgO2L\(^{-1}\), in the month of July at Site 2. These are expected values for natural waters, being above values predicted by CONAMA resolution No. 357/2005 (Brasil, 2005) for class 1 waters, not constituting a compromising factor for the maintenance of aquatic biota at the studied sites. It is important to observe the inverse relationship between high values of dissolved oxygen at all three sites (Figure 4) in the month of July 2013, with the lower temperatures (Figure 2) recorded during the same month. Schäfer (1985) notes that oxygen balance must be understood as the most important factor in assessing an aquatic ecosystem, still, he considers the phenomena that with temperature rise there is a decrease in solubility of the oxygen found in the water and an increase of intensity for most biological processes, which means a higher consumption of oxygen.

Statistically significant differences were not found among the annual averages for all three sites in regards to the following characteristics: temperature (ANOVA: \( F_{\text{calc}} : 1.28 \leq F_{\text{crit}} 3.44\));
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Ph (ANOVA: $F_{\text{calc}}: 2.437 \leq F_{\text{crit}}: 3.44$) and dissolved oxygen (ANOVA: $F_{\text{calc}}: 0.7958 \leq F_{\text{crit}}: 3.44; \alpha: 0.05$).

3.2. Biodiversity, community structure and composition

A total of 26,170 samples, including immature individuals, were collected during sampling period. From the total, 5647 specimens were sampled at Site 1 (Lageadinho, Caraá), 10444 were sampled at Site 2 (Reichert, Rolante) and 10079 were sampled at Site 3 (Casa de Pedra, Igrejinha). This number is closed to the value found by Buckup et al. (2007), who collected 28694 specimens during samplings in three rivers from the Pelotas river basin, state of Rio Grande do Sul, which can be characterized as Southern Brazilian mountain rivers.

High abundance of specimens at Sites 2 and 3 may be explained by the great quantity of allochthonous leaf material deposited among the pebbles in the river bottom, from the riparian vegetation located upstream. According to Bueno et al. (2003) the leaf material serves as food and shelter for maggots of many types of insects, as well as support for adult individuals during periods of drought. Greater substrate heterogeneity with the occurrence of sand deposits in both sites may also be positively influencing the abundance of benthic macroinvertebrate species.

A total of 57 benthic macroinvertebrate families were recorded for this water basin, 51 families for Site 1, 42 for Site 2 and 35 families for Site 3 (Table 1). Classic diversity indices (Table 2) were established for all three sites, with the Shannon diversity index ($H$) being the highest (2,494).

<table>
<thead>
<tr>
<th>Filo/Class</th>
<th>Order</th>
<th>Family</th>
<th>P1</th>
<th>P2</th>
<th>P3</th>
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<td>167</td>
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</table>
Shannon Diversity Index (H’) varied from 1,939 (Site 3) to 2,494 (Site 1), which are values close to the ones found by Bueno et al. (2003) in small streams in the cities of Taquara and São Francisco de Paula, where H’ varied from 1,000 to 3,580.

Richness estimator Chao-1 calculated the possible number of families for each site (Site 1 – 54, Site 2 – 45 and Site 3 – 37), where estimated basin value was 60 families, close to the 57 families recorded by this study. Stenert et al., (2004) recorded 84 macroinvertebrate families in an extensive study conducted in 146 humid areas distributed along the state, therefore so far, families found at the Sinos

Table 2. Diversity index of benthic invertebrate communities, calculated over samples collected in 2013. For all three sites, N: represents the total number and sampled specimens; S: represents the richness of the families; H’: represents Shannon Index; D_Mg: represents Margalef Index; Chao-1: represents a richness predictor and E’: represents an evenness index.

<table>
<thead>
<tr>
<th>Locais</th>
<th>N</th>
<th>S</th>
<th>H’</th>
<th>D_Mg</th>
<th>Chao-1</th>
<th>E’</th>
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</thead>
<tbody>
<tr>
<td>Site 1</td>
<td>5,647</td>
<td>51</td>
<td>2,494</td>
<td>5,788</td>
<td>54</td>
<td>0.6344</td>
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<td>Site 2</td>
<td>10,444</td>
<td>42</td>
<td>2,416</td>
<td>4,431</td>
<td>45</td>
<td>0.6465</td>
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<tr>
<td>Site 3</td>
<td>10,079</td>
<td>35</td>
<td>1,939</td>
<td>3,688</td>
<td>37</td>
<td>0.5454</td>
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</table>

and Margalef Index also for Site 1 (5,7880). The index difference found may be explained by the conditions of their calculations, as Shannon places value on species proportional abundance placing emphasis on richness and homogeneity, besides rare species, and the Margalef Index expresses richness weighed by sample size; however, both indices indicate Site 1 as the site with the greatest diversity. Although this site also presented less abundance in specimens (5647), the highest family absolute richness (51) was found here. The values may indicate an increase in degradation of the environmental quality of the basin from upstream to downstream sites, where there is a synergic effect from the increase of anthropic impact on the waters of the ecosystem. Student’s t test revealed that there was no significant different between sampling sites when comparing H’ between Sites 1 and 2; 1 and 3; and 2 and 3 (tcals: 3.86; gl: 11,400; tcalc: 26.39; gl: 12,515; tcalc: 26.89; gl: 20,154; α: 0.05).

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River basin represent 68% of the total amount registered for the state of Rio Grande do Sul.

Bieger et al. (2010), registered 54 macroinvertebrate families in small streams in the Sinos River basin. For these 54 families, the following were not registered in this study: Mycetopodidae and Sphaeridae (Bivalvia/Mollusca) and Lymnaeidae and Physidae (Gastropoda/Mollusca); Dodieliinotidae (Arthropoda/Crustacea/Amphipoda) and Aegillidae (Arthropoda/Crustacea/Decapoda); Aeshnidae (Arthropoda/Insecta/Odonata); Noteridae (Arthropoda/Insecta/Coleoptera); Euthyplocidae (Arthropoda/Insecta/Ephemeroptera); Nepidae, Hydrometridae, Gelastocoridae and Corixidae (Arthropoda/Insecta/Hemiptera); Dixidae, Ceratopogonidae and Blephaceridae (Arthropoda/Insecta/Diptera).

Most registered families (n = 30) were found at all three sampling sites along the Sinos River basin, with some singularities: Planorbiidae and Hyriidae (Mollusca) and Gerridae, Pleidae, Mesoveliidae and Belostomatidae (Arthropoda/Insecta) were found with only one specimen each, thus being considered rare in the samples collected. Sample collection method was probably not efficient for species of these families, as they are commonly found in continental freshwaters. The similarity dendrogram (Figure 5), found according to the Morisita Similarity Index (S_m), separated sites in two distinctive groups, revealing greater similarity between Sites 1 and 2.

Equability (E’), also known as Pielou Evenness Index (J), was calculated for all three sites (Table 2), with maximum value found at Site 2 (0.06465) in an interval from 0 > E ≥ 1; for this index, values close to one (1) show little monospecific dominance, which means that theoretically this environment is more diverse.

Some families were abundant in the samples, such as Hydropsychidae (n = 5,571), Leptophlebiidae (n = 4,309), Chironomidae (n = 3,703) and Lithoglyphidae (n = 3,002). When added, these four families (n = 16,585) represent 63.4% of total sample size, with Arthropoda/Insecta at the top 3. Arthropodes totaled 22,429 specimens (85.7%) among the four phylum registered in the samples (Platyhelminthes, Mollusca, Annelida and Arthropoda) constituting the dominant macroinvertebrates in the basin.

From the total collected specimens, the Insecta Class represents 85.5% of the total amount. According to Rosenberg and Resh (1993), insects are dominant in continental water communities, being their great capacity of inhabiting and keeping high diversity in most water ecosystems one of the most surprising aspects of their biology. Among their abilities, special mention is made to their capacity to burry themselves in the substrate (sand, pebbles and leaves deposited at the bottom of the river) or to crawl in interstitial spaces, besides their respiratory adaptations which facilitate recolonization of different micro-habitats after catastrophic events such as floods (Kikuchi and Uieda, 1998; Buss et al., 2002).

According to Spilki and Tundisi (2010), the Sinos River basin is frequently refered to as largely degraded; a series of impacts on the quality of the water, soil and air have been reported for this area over the last years. In the present study, this community was characterized by monitoring water macroinvertebrates, and it theoretically reflects the environmental conditions. For the basin, 57 families were found and predictor Chao-1 estimated 60 as an expected amount, Chao-2 estimated 64 families and jackknife 2 predicted 72 families, however, when adding the families found by Bieger at al. (2010) which were not found in this study (16), we come to a total of 73 taxa (57 + 16). This value can be considered high for the area, considering sampling sites are quite distinct from one another. In this context, it is possible to predict that the richness of invertebrates families found in the Sinos River basin can be elevated by using different sampling methods in areas which have yet to be explored.

4. Conclusion

Benthic macroinvertebrate species are differentially sensitive to many biotic and abiotic factors in their environment. Consequently, macroinvertebrate community structure has commonly been used as an indicator of the condition of an aquatic system. A total of 26,170 specimens were collected. A total of 57 families were identified for the drainage basin and estimators (Chao-1, Chao-2 and jackknife 2) estimated richness varying from 60 to 72 families. In the sampling sites, the community structure is typical of temperate rivers, despite having serious environmental impacts, the Basin of the Sinos River still has a high biodiversity and abundance of individuals.
References


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Aquatic macroinvertebrate at the Sinos River basin, RS, Brazil


