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The influence of taxonomic resolution of Oligochaeta on the evaluation of water quality in an urban stream in Minas Gerais, Brazil

A influência da resolução taxonômica de Oligochaeta na avaliação da qualidade da água em um córrego urbano em Minas Gerais, Brasil

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Abstract: Objective: The objective of this study was to verify the identification of specimens of the Oligochaeta in different taxonomic levels (family and species) has the same potential for assessing the water quality of an urban stream in Minas Gerais, Brazil. **Methods:** Oligochaeta specimens were collected from eight sampling stations in July 2007. Four stations were located in rural areas and the other four in urban areas. Were measured concentrations of dissolved oxygen, phosphorus and total nitrogen, pH, electrical conductivity and BOD. To evaluate the influence of taxonomic level, Oligochaeta specimens were identified at the family and species. We performed a principal component analysis (PCA) to determine which abiotic variables best explained the distribution of Oligochaeta along the sampling stations. Cluster analysis was performed with the abundance of Oligochaeta in the family and species levels, separately, to assess the degree of similarity between the stations and check the level of identification of organisms could interfere with the associations formed. **Results:** In general, the sampling stations located in urban areas had high pH, BOD and total nitrogen and phosphorus, while rural stations had a higher concentration of oxygen. Three families of Oligochaeta were found: Tubificidae, Naididae and Enchytraeidae. Tubificidae and *Limnodrilus hoffmeisteri* were the family and the species with the highest density, respectively, especially at those stations located in urban areas. Both the PCA analysis and cluster analysis showed that the sampling stations in urban areas and rural areas have different characteristics that separate **Conclusions:** The studied environment presents two distinct regions: the urban region with a high degree of organic pollution and high density Tubificidae and *L. hoffmeisteri*, and rural, with less human influence and low density of organisms Oligochaeta. These features made the use of the taxonomic level of family allow a good assessment of water quality in the San Pedro creek without any significant loss of community data Oligochaeta.

Keywords: organic pollution, taxonomic sufficiency, Tubificidae, bioindicators of water quality.

Resumo: Objetivo: O objetivo deste estudo foi verificar se a identificação de espécimes de Oligochaeta em diferentes níveis taxonômicos (família e espécie) tem o mesmo potencial para a avaliação da qualidade da água de um córrego urbano em Minas Gerais, Brasil. **Métodos:** Espécimes de Oligochaeta foram coletados em oito estações amostrais em julho de 2007. Quatro estações estavam localizadas em zona rural e as demais em zona urbana. Foram medidas as concentrações de oxigênio dissolvido, fósforo e nitrogênio total, pH, condutividade elétrica e DBO. Para avaliar a influência do nível taxonômico, os espécimes de Oligochaeta foram identificados ao nível de família e espécie. Foi realizada uma análise de componentes principais (PCA) para verificar quais variáveis abióticas melhor explicaram a distribuição dos Oligochaeta ao longo das estações amostrais. Análise de agrupamento foi realizada com a abundância Oligochaeta nos níveis de família e espécie, separadamente, para avaliar o grau de similaridade entre as estações e verificar se o nível de identificação dos organismos poderia interferir nas associações formadas. **Resultados:** Em geral, as estações amostrais situadas na zona urbana apresentaram altos valores de pH, DBO e fósforo e nitrogênio total, enquanto as estações da zona rural apresentaram maior concentração de oxigênio. Três famílias de Oligochaeta foram encontradas: Tubificidae, Naididae e Enchytraeidae. Tubificidae e

Limnodrilus hoffmeisteri foram a família e a espécie com maior densidade, respectivamente, particularmente naquelas estações localizadas na zona urbana. Tanto a análise de PCA quanto a análise de agrupamento mostraram que as estações amostrais da zona urbana e zona rural possuem características diferentes que as separam **Conclusões:** O ambiente estudado apresenta duas regiões distintas: a região urbana com alto grau de poluição orgânica e alta densidade de Tubificidae e *L. hoffmeisteri*, e a região rural, com menor influência antrópica e baixa densidade de organismos Oligochaeta. Estas características proporcionaram que o uso do nível taxonômico de família permitisse uma boa avaliação da qualidade da água do córrego São Pedro sem que houvesse perda significante dos dados da comunidade de Oligochaeta.

Palavras-chave: poluição orgânica, suficiência taxonômica, Tubificidae, bioindicadores de qualidade da água.

1. Introduction

Streams located in urban areas are vulnerable to various impacts, such as discharge of domestic and industrial effluents, erosion, removal of riparian vegetation and modification of the substrate. All of these factors change the structure of the benthic community (Collier, 1995; Guimarães et al., 2009).

Studies have shown the effects of anthropic activities on richness and abundance of Oligochaeta (Alves and Lucca 2000; Martins et al., 2008) and Chironomidae (Callisto et al., 2002; Kleine and Trivinho-Strixino, 2005; Corbi and Trivinho-Strixino, 2006) in Brazilian ecosystems, confirming the potential of these invertebrates as pollution indicators (Guimarães et al., 2009). However, there are few studies of which taxonomic resolution level is best for biological evaluation of the anthropogenic impacts on aquatic communities (Kuhlmann et al., 2005; Melo, 2005; Corbi and Trivinho-Strixino, 2006; Carneiro et al., 2010).

According to Schmidt-Kloiber and Nijboer (2004), the taxonomic level used depends on the objectives of the study. In conservation studies, for example, it is generally necessary that the taxonomic resolution of the organisms of interest reach the species level (Bailey et al., 2001), especially when the work involves groups that are highly taxonomically diversified (Trigal-Domínguez et al., 2009).

The identification level of aquatic organisms varies according to the group studied. Groups such as fishes and diatoms are generally identified to the species level, while the level for macroinvertebrates can range from species to order (Lenat and Resh, 2001). Hill et al. (2001) recommended using identification of macroinvertebrates only to the genus level because it is quicker, requires less training of lab assistants and is less subject to problems that can be found with existing identification keys.

According to Lenat and Resh (2001), there is a shortage of people specialized in identifying aquatic invertebrates to the species level. Identification to this taxonomic resolution is more costly and the results obtained do not always differ from those found using less refined taxonomic levels (Sajan et al., 2010). Chessman et al. (2007) justified the use of more detailed identification levels when the objectives require a higher level of discrimination of data and when this cannot be obtained through other alternatives, such as the use of metrics with better responses.

Among the benthic macroinvertebrates, the Oligochaeta have been indicated as an important group to evaluate water pollution (Lang, 1998; Alves et al., 2006). Organic enrichment in ecosystems with few species of this group can achieve great abundance, particularly species belonging to the family Tubificidae.

Tubificidae organisms can compose all the local fauna of Oligochaeta in many polluted environments. Thus, this family is commonly used to determine the degree of pollution of an ecosystem due to its importance as bioindicators (Lin and Yo, 2008). Among tubificídeos, *Limnodrilus. hoffmeisteri* is a more tolerant species (Alves and Lucca, 2000; Milbrink et al., 2002; Pagliosa and Barbosa, 2006), so its abundance is used to assess the level of pollution of aquatic systems (Brinkhurst, 1967; Martins et al. 2008).

However, because of the difficulty of identifying them, these invertebrates are commonly excluded from biomonitoring studies of Brazilian aquatic ecosystems. Therefore, the aim of this study was to verify whether the identification of Oligochaeta specimens at different taxonomic levels (family and species) has the same potential for the evaluation of the water quality in an urban stream in the state of Minas Gerais, Brazil

2. Material and Methods

São Pedro Stream is part of the Paraibuna River basin and is located in the southwestern part of

the city of Juiz de Fora, Minas Gerais. The main stream channel is 13,250 meters long (water course) and crosses various districts of the city. In the sub-basin, 41.85% of the area is classified as having urban occupation. The area includes São Pedro Dam, which is responsible for supplying 9% of the municipality's water (Latuf, 2004).

The Oligochaeta specimens were gathered from eight sampling stations in July 2007. Four of them (I, II, III and IV) were located in the rural zone, near the headwaters, in a pasture area and with less human influence, and the others (V, VI, VII and VIII) were located in a region with large urban settlements, where it can be directly observed release of domestic sewage *in natura*. The station V was located at the beginning of the urban and the other three (VI, VII and VIII) in the area with dense urban concentration, with the train VII in an area near a waterfall (Figure 1).

At each collection station we obtained sediment samples in triplicate, using a Petersen grab (area of 0.189 m^2), fixed in 8% formaldehyde and washed in a 210-µm mesh sieve. The Oligochaeta retained in the sieve were sorted in a light transluced-tray

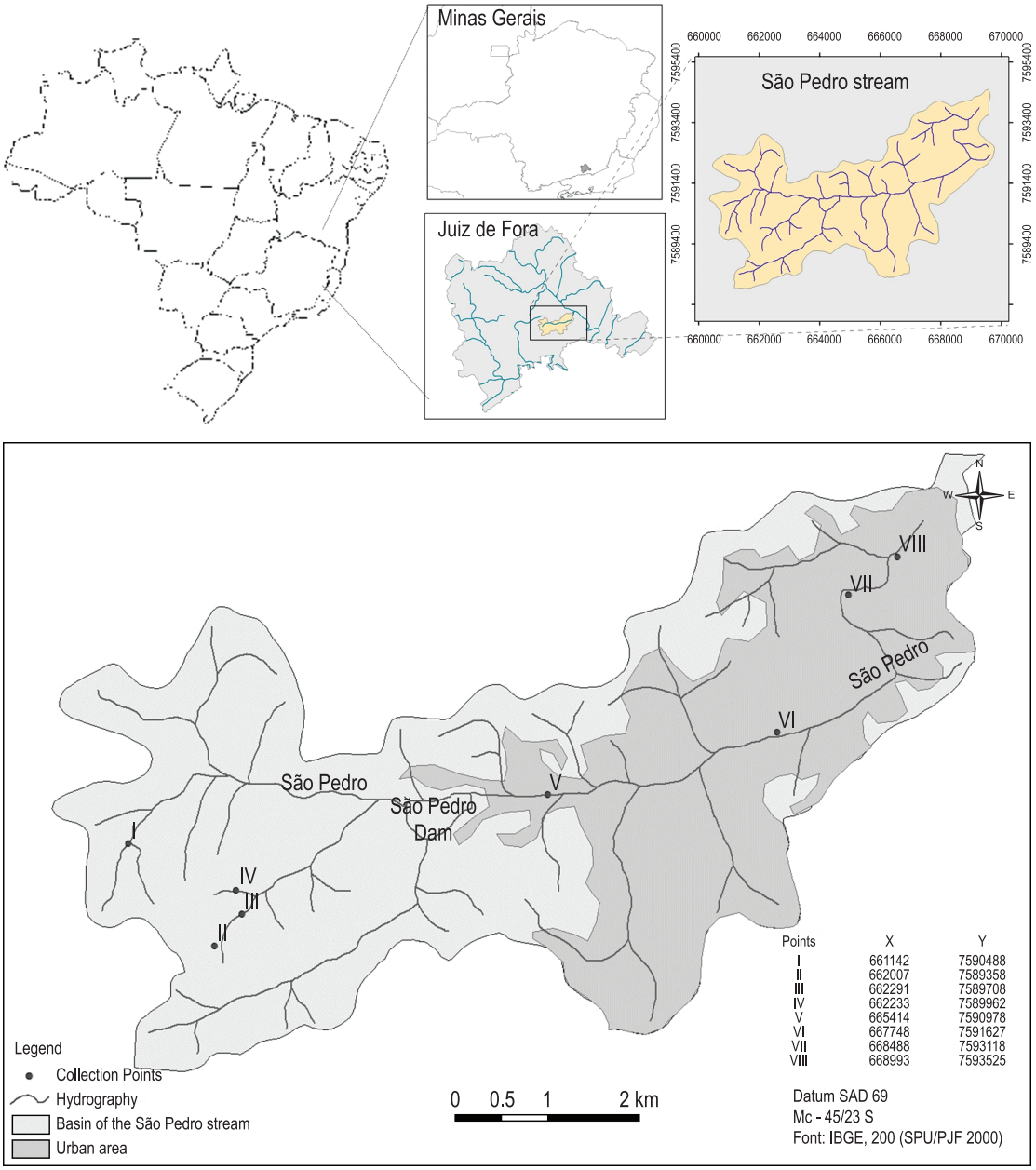

Figure 1. Map showing the sampling stations located in the rural (I, II, III, IV) and urban zones (V, VI, VII, VIII) through which São Pedro Stream flows, in the municipality of Juiz de Fora, MG.

and then placed in receptacles with 70% alcohol (Alves et al., 2006).

The specimens were then mounted on semi-permanent slides with lactophenol and identified according to the taxonomic criteria used by Righi (1984) and Brinkhurst and Marchese (1989). To assess the influence of the taxonomic level, the Oligochaeta specimens were identified to the family and species levels.

During field sampling, a Horiba (U-10) digital multimeter was used to measure the following parameters: dissolved oxygen concentrations, pH and electrical conductivity. A water sample from each collection site was taken to analyze the nutrients (total nitrogen and phosphorus) and biochemical oxygen demand(BOD) in the Laboratório de Ecologia Aquática in Universidade Federal de Juiz de Fora.

The fauna specimens were analyzed through the density of Tubificidae (Howmiller and Beeton, 1971) and the percentage of *Limnodrilus hoffmeisteri* Claperede,1862 (Brinkhurst, 1967). To verify whether there was a significant difference between the abiotic variables at the sampling sites in the urban versus rural areas, we applied the Mann-Whitney test. To assess the degree of similarity of the sampling sites and whether the identification level affects the associations formed, we performed cluster analysis for the Oligochaeta identified at the family and species level separately, using the Bray-Curtis coefficient.

Finally, we performed principal component analysis (PCA) to verify which abiotic variables can better explain the spatial distribution of the Oligochaeta along the stream. The data were analyzed using the programs "PAST (version 2.02) and MVSP (version 3.12)".

3. Results

The values found in the stream for abiotic variables studied showed significant differences ($p < 0.05$) between urban and rural (Table 1). The sampling stations located in urban areas had higher pH, BOD and phosphorus (P) and nitrogen (N) total, while stations in rural oxygen concentrations were higher. However, the station VII (urban) also found high value of this variable, which can be attributed to the fact that this station is located after a waterfall. A similar result was observed by Martins et al. (2008) for the same stream when they found high concentrations of oxygen to the sampling station near the waterfall.

This difference associated with the use and occupation of land can also be verified by the composition and distribution of the group Oligochaeta. Among the 7747 specimens, represented by the families Enchytraeidae, Tubificidae and Naididae, only 6% were found in the sampling stations in rural areas, and the station I was not registered any Oligochaeta (Table 2). Only the station III presented specimens of all families.

Tubificidae was the only family present in all sampling stations (except I) and, with the exception of station II had a high density of organisms, especially those located in the urban stations. We found two species of Tubificidae, *Tubifex tubifex* and *L. hoffmeisteri,* the last being the predominant species in the sampling stations. In urban areas 98% of organisms were *L. hoffmeisteri*.

Naididae was represented by four species, although the richest, the density of these organisms corresponded to less than 5% of the presented in this study. Among the species of Naididae, *Nais communis* was the most frequent, found in three sampling stations (III, IV and VIII).

The specimens of the family Enchytraeidae, present only at stations III and VII, were not identified to higher levels due to difficulties of identification.

The data obtained showed that the abiotic variables influence the spatial distribution of Oligochaeta, reflecting differences in water quality

Table 1. Abiotic variables at sampling stations I, II, III, IV (rural zone) and V, VI, VII, VIII (urban zone) of São Pedro Stream, municipality of Juiz de Fora, MG.

Points	DO ($mg.L^{-1}$)	Electrical conductivity ($\mu S.cm^{-1}$)	pH	BOD ($mg.L^{-1}$)	Total P ($mg.L^{-1}$)	Total N ($mg.L^{-1}$)
I	8.35	18.6	5.81	4.5	0.39	0.1
II	7.12	20.2	6.54	3.2	0.46	3.9
III	7.46	20.2	6.16	14.2	0.4	2.1
IV	2.01	66.6	6.84	25.6	1.41	5.2
V	0.66	191.6	7.27	78	3.5	12
VI	3.81	231.3	7.34	55.9	3.5	18.6
VII	7.67	197.8	8.10	35.5	3.5	15.8
VIII	2.65	222.9	7.83	40.8	3.5	13.7

Table 2. Densities (ind.m^{-2}) of Oligochaeta specimens found at sampling stations II, III and IV (rural zone) and V, VI, VII and VIII (urban zone) of São Pedro Stream in the municipality of Juiz de Fora, MG.

Oligochaeta	II	III	IV	V	VI	VII	VIII
Enchytraeidae	0	846.5	0	0	0	158.7	0
Tubificidae							
Limnodrilus hoffmeisteri Claperede,1862	52.9	2328	19947	51164	8941.8	101058.2	219312.1
Tubifex tubifex Müller, 1774	0	0	211.6	0	158.7	52.9	13
Naididae							
Nais communis Piguet, 1906	0	105.8	158.7	0	0	0	52.9
Slavina evelinae (Marcus, 1942)	0	529.1	0	0	0	0	0
Dero sp.	0	0	158.7	0	0	0	52.9
Dero furcatus (Müller, 1773)	0	0	264.5	0	0	0	0
Density of Tubificidae	52.9	2328	20158.7	51164	9100.5	101111.1	219325.2
L. hoffmeisteri (%)	100	61.1	96.1	100	98.2	99.7	99.9

of the stream studied, as a result of the use and occupation of the region. These conditions could be found by principal component analysis (PCA) and analysis of Bray-Curtis.

In PCA axes 1 and 2 explained 92.86% of data variability. The variables phosphorus, nitrogen, pH, electrical conductivity and BOD and all sampling stations, with the exception of IV were associated with the axis 1. The variable oxygen was associated with axis 2. The abiotic variables associated with axis 1 were associated with the sampling stations located in urban areas (V, VI, VII and VIII) and the rural stations (I, II and III) had the greatest association with variable oxygen (Figure 2).

The results of cluster analysis were similar (Figures 3 and 4) for the two analyzed taxonomic levels (family and species), where you can observe the formation of two clusters, one formed by the stations V, VII and VIII, formed by the other stations IV, VI and III. Station II was not included in this analysis by presenting only one specimen of Oligochaeta belonging to the family Tubificidae.

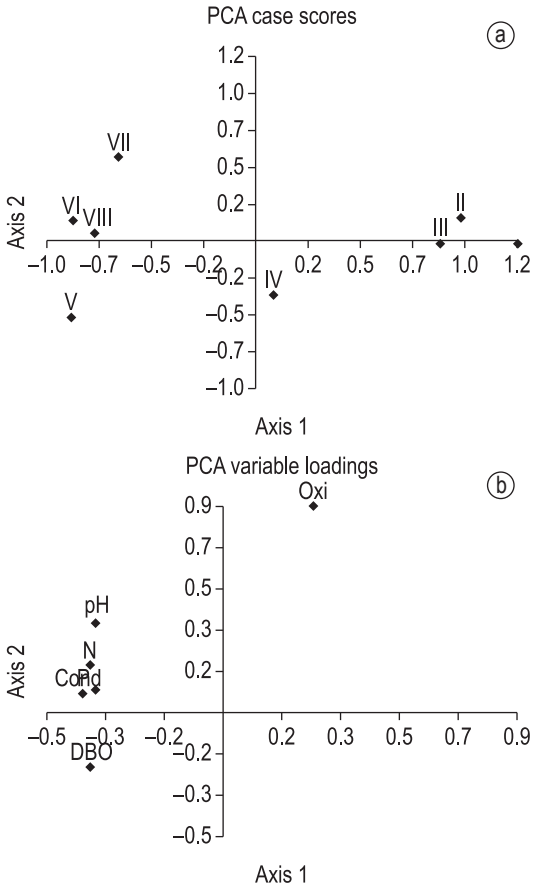

Figure 2. Result of the principal component analysis (PCA) of the abiotic variables (a) associated with sampling stations I, II, III and IV (rural zone) and (b) V, VI, VII and VIII (urban zone) of São Pedro Stream in the municipality of Juiz de Fora, MG.

4. Discussion

The discharge of domestic and industrial untreated effluents in aquatic systems increases the electrical conductivity and level of nutrients and reduces the concentration of oxygen in the water (Nedeau et al., 2003), causing changes in the species composition and density of organisms (Ogbeibu and Oribhador, 2002; Tavzes et al., 2006).

The levels of nitrogen, phosphorus, BOD, electrical conductivity and dissolved oxygen found in the urban zone of São Pedro Stream indicate that there is a larger aport of organic material of domestic sewage in the urban areas than in the rural zone.

These conditions have an influence on the distribution and abundance of the Oligochaeta organisms, contributing to the high numerical densities of specimens of Tubificidae (Alves et al., 2006) found in the urban zone. Martins et al. (2008) also found this same stream with high abundance of Tubificidae and numerical superiority of the species *L. hoffmeisteri*.

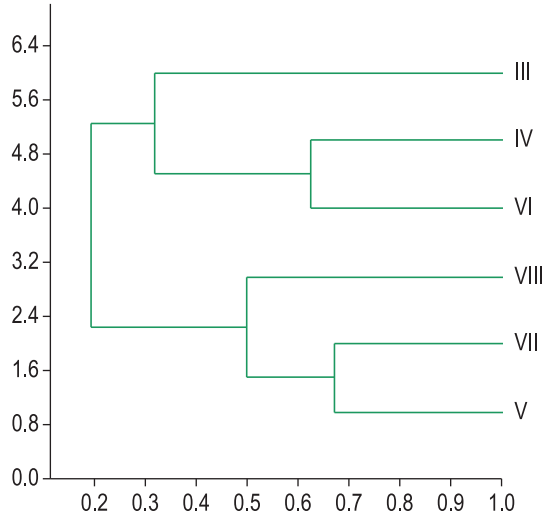

Figure 3. Cluster analysis of stations III, IV, V, VI, VII and VIII based on the abundance of the Oligochaeta fauna identified at the family level. Coefficient = 0.7711.

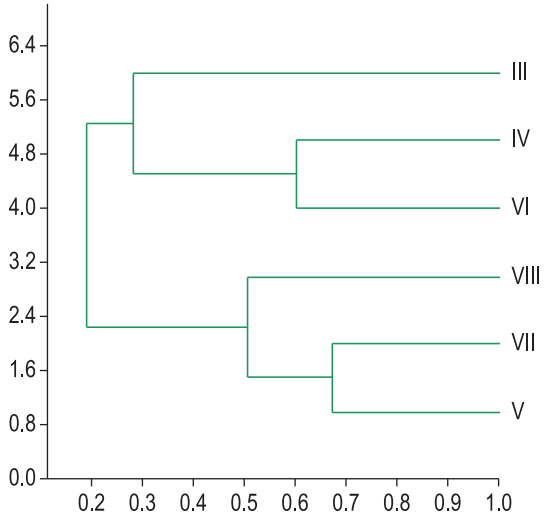

Figure 4. Cluster analysis of stations III, IV, V, VI, VII and VIII based on the abundance of the Oligochaeta fauna identified at the species level. Coefficient = 0.7729.

Although the presence of large numbers of specimens of the Oligochaeta in most sampling stations, we noticed the absence of organisms in the first season. Similar fact was also observed by Martins et al. (2008). These authors conducted monthly collections for one year in the same stream and found only one specimen of oligochaete in his first season, also located in the countryside.

The principal components analysis showed a separation between the sampling stations in the rural and urban zones, reflecting the difference in the water quality between the two regions. This result was also observed by Chessman et al. (2007) in a study carried out in streams in various rural and urban areas in Australia. In the present study, stations I, II and III were associated with the oxygen variable because they are located in the rural zone, where the values of this variable were higher. Stations V, VI, VII and VIII were associated with higher electrical conductivity, total phosphorus and nitrogen levels because of their location in the urban zone, where larger amounts of organic material are released into the stream. Although there was a high oxygen level in the water sample from station VII, the value of the other variables indicated the urban influence on the water quality.

The results of the cluster analysis for both family and species were equal, showing separation between the sampling stations in the rural and urban zones, except for station VI, which presented lower numerical density of Tubificidae specimens in relation to the other stations located in the urban zone. The results also indicate that stations V, VII and VIII presented greater similarity both at the family level (predominance of Tubificidae) and species level (predominance of *L. hoffmeisteri)*. On the other hand, stations III, IV and VI were grouped for having lower densities of Tubificidae and *L. hoffmeisteri*. Station III stood apart from the others for having representatives of all three families found in this study. The greater numerical density of Enchytraeidae also contributed to this dissimilarity. Station IV (rural zone) had a higher association with station VI (urban zone) because of the high density of Oligochaeta Tubificidae and *L. hoffmeisteri.* Therefore, the faunal and abiotic data together demonstrate that this station could be considered as being in a transition zone between the rural and urban environments.

The aquatic system studied is highly impacted by organic pollution and contain high densities of Oligochaeta of the Tubificidae family, organisms that can tolerate these conditions (Pagliosa and Barbosa, 2006). The separation of the rural and urban zones utilizing the family and species taxonomic levels showed that for the group of study (Oligochaeta) the use of a higher taxonomic level is sufficient to assess the water quality in São Pedro Stream. According to Roach et al. (2001), using the family level provides less detail about the community. However, analyses performed relying on this taxonomic level can produce satisfactory results in places with high degree of pollution without forgoing important information about the environment (Lenat and Resh, 2001).

Hill et al. (2001) did not notice significant lack of data on the community studied when using a taxonomic level higher than species. According to them, when there are few taxonomic indicators, the identification at other levels appears to reflect the properties of the aquatic biota adequately. With the predominance of one family and one species, Tubificidae and *L. hoffmeisteri,* respectively, the identification of the organisms found to the family taxonomic level was satisfactory. Martins et al. (2008) achieved a higher number of species of Oligochaeta in their study due to increased sampling effort, however, the highest density of organisms belonging to the family Tubificidae and especially the specie *L. hoffmeisteri*, similar to what was found in the present study indicate that the identification at the family level is sufficient to detect the difference in the degree of organic pollution between rural and urban areas.

The use of a taxonomic level higher than species may not be able to discriminate small differences that may exist in water quality. Therefore, the classification of streams as to water quality depends on the taxonomic resolution utilized (Lenat and Resh, 2001; Verdonschot, 2006). In the present study the physical and chemical variables, confirmed by the Oligochaeta fauna identified both at the species and family levels, showed that the pollution levels differed markedly between the two regions.

The use of the family level in this study was satisfactory, by permitting a good assessment of the water quality in the stream studied. Other studies performed in Brazil have also obtained a satisfactory evaluation of aquatic systems using identification at the family or sub-family level of macroinvertebrates (Moretti and Callisto, 2005) and Chironomidae (Corbi and Trivinho-Strixino, 2006). According to Barbosa and Galdean (1997), the use of other taxonomic levels is necessary because of the difficulty of reaching the species level in some cases, such as when there is a lack of trained personnel and funding (Schmidt-Kloiber and Nijboer, 2004). The findings here show that the identification of organisms at other levels can be used, especially in quick environmental assessments.

Although the use of higher taxonomic levels has not compromised the results of various studies, the identification to the species level is still more advisable since this level of detail can provide additional information about the aquatic system (Bailey et al., 2001; Kuhlmann et al., 2005), mainly with respect to preserved locations, and thus contribute to efforts to conserve these ecosystems (Barbosa and Galdean 1997; Galdean et al., 1999).

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