Tubificidae (Annelida: Oligochaeta) as an indicator of water quality in an urban stream in southeast Brazil

Tubificidae (Annelida: Oligochaeta) como indicador da qualidade da água de um córrego urbano do sudeste Brasileiro

Martins, RT., Stephan, NNC. and Alves, RG.

Departamento de Zoologia, Laboratório de Invertebrados Bentônicos – LIB, Instituto de Ciências Biológicas, Universidade Federal de Juiz de Fora – UFJF, Campos Universitário, s/n, Martelos, CEP 36036 900, Juiz de Fora, Minas Gerais, Brazil
e-mail: martinsrt@gmail.com, nilostephan@yahoo.com.br, gama.alves@ufjf.edu.br

Abstract: The water quality of an urban stream in southeast Brazil was evaluated using species of Tubificidae (Annelida: Oligochaeta) as biological indicators. From May 2005 to April 2006, a total of 75,746 specimens were collected, from which six species (*Aulodrilus limnobius*, *Bothrioneurum* sp., *B. vejdovskyanum*, *L. hoffmeisteri*, *L. udekemianus*, *Tubifex tubifex*) were found. In the majority of the sampling sites, the Tubificidae species were found at high densities (>5,000 ind.m^{-2}). *Limnodrilus hoffmeisteri*, which is widely used as an indicator of organic pollution, composed more than 75% of collected fauna. Using some biotic indices such as density of Tubificidae, percentage of *L. hoffmneisteri* and Modified Howmiller and Scott Environmental Index, it was possible to verify that São Pedro stream receives large amounts of organic pollutants. These findings confirm Tubificidae as an effective biological indicator of stream conditions.

Keywords: Tubificidae, organic pollution, bioindicator, urban stream.

Resumo : Utilizando espécies da família Tubificidae (Annelida:Oligochaeta) avaliou-se a qualidade da água de um córrego urbano, no sudeste do Brasil. De maio de 2005 a abril de 2006, foram coletadas seis espécies (*Aulodrilus limnobius*, *Bothrioneurum* sp., *B. vejdovskyanum*, *L. hoffmeisteri*, *L. udekemianus*, *Tubifex tubifex*) num total de 75.746 espécimes. Em todos os pontos de coleta, com exceção do ponto I, os tubificideos ocorreram em elevada densidade (>5.000 ind.m^{-2}), sendo *Limnodrilus hoffmeisteri*, espécie amplamente reconhecida como indicadora de poluição orgânica, compôs mais de 75% da fauna coletada. Através da utilização dos seguintes índices bióticos, como a densidade de Tubificidae, porcentagem de *L. hoffmneisteri* e Índice Ambiental Modificado de Howmiller and Scott foi possível constatar que o córrego estudado recebe elevada carga de material orgânico oriundo de atividades humanas, confirmando o potencial dos oligoquetos tubificideos na avaliação da qualidade de ambientes aquáticos.

Palavras-chave: Tubificidae, poluição orgânica, bioindicador, córrego urbano.

1. Introduction

Macroinvertebrates are by far the most commonly group used in the assessment of water quality (Rosenberg and Resh, 1993). Oligochaeta, especially the Tubificidae family, because its capacity of increase in number with increasing organic matter, replacing other benthic macroinvertebrates less tolerant for this condition (Schenková and Helešic, 2006), have been universally applied on bioassessment assays, as bioindicators to reflect the organic pollution in rivers and streams (Lin and Yo, 2008).

Biotic indices that use Oligochaeta as a biological indicator of stream conditions have long been used to evaluate the level of aquatic pollution. Howmiller and Beeton (1971), for instance, consider the high abundance of Oligochaeta as an indication of organic enrichment, while Lafont (1984) on the other hand uses the relative abundance of Tubificidae in a community of Oligochaeta to identify organic enrichment. Moreover, the Howmiller and Scott's index (1977) provides detailed information on the quality of an aquatic habitat because it relies not only on the full identification of all constituent species but also on the knowledge of the ecological demands of a fair number of the most abundant species in the environment.

Studies have shown that species of Oligochaeta Tubificidae are generally tolerant to organic pollutants (Verdonschot, 1989; Kazanci and Girgin, 1996; Finogenova, 1996; Schenková et al., 2001; Othman et al., 2002; Nijboer et al., 2004; Alves et al., 2008). It is possible that what can account for the frequently massive presence of Tubificidae in polluted streams are not only their tolerance to considerable low levels of dissolved oxygen (Aston, 1973) but also a relative decrease in both the rates of competition and predation in such environment (Brinkhurst and Jamieson, 1971).

In Brazil, only a few studies rely on Oligochaeta to evaluate polluted aquatic environments (Alves and Lucca, 2000; Dornfeld et al., 2006; Alves et al., 2006). In most of these studies, however, when samples were not omitted from the benthic community composition, they have been

identified either to Class or Family levels only. So, it was the aim of this study to use some species of Tubificidae as indicator of pollutants to analyze the water quality of an urban stream in southeast Brazil. The term water quality in the present study refers to the level of organic pollution in the environment.

2. Material and Methods

São Pedro stream, where this study was conducted, is 13.25 km long and flows into the Paraibuna river, in the Southwest area of the city of Juiz de Fora, Minas Gerais (Figure 1). Its drainage basin cuts several neighborhoods of the city and provisions a dam that is responsible for nearly 9% of the city water supply (Latuf, 2004).

Four stations along the stream were selected for water, sediment, and benthic macroinvertebrate sampling: station I (21° 46' 51.9" S and 43° 26' 29.6" W) was located in the rural zone, station II (21° 46' 36.8" S and 43° 26' 07.6" W) was located in the beginning of the urban mesh, and both stations III (21° 46' 11.07" S and 43° 22' 20.00" W) and IV (21° 45' 14.84" S and 43° 21' 58.11" W) in the area of dense urban concentration (Figure 1).

Between May 2005 and April 2006, three samples of sediment were obtained monthly, with the aid of both Petersen (0.0189 m^2) and van Veen (0.0518 m^2) dredges. The sediment samples were fixed in 4% formaldehyde until the moment of washing in a 210 μm mesh sieve. After selection, the Tubificidae specimens were preserved in 70% alcohol. The species were identified according to the taxonomic criteria adopted by Brinkhust and Marchese (1989) and Righi (1984). Fauna data of each sampling station in each month were analyzed as means of density (ind.m^{-2}).

The climatological data for the period of collection were obtained in Laboratório de Climatologia e Análise Ambiental/Universidade Federal de Juiz de Fora. Percentages of gravel and silt-clay as well as different sand grain sizes for each sediment sample were verified in April 2006.

Monthly in the sampling stations pH data were measured in situ with portable pH meter, the level of dissolved oxygen was measured using spectrophotometry and chlorophyll-*a* with a fluorimeter (Turner). Water sub-samples were filtered (black porous 0.2 μm polycarbonate filters) and stained with acridine orange to determine heterotrophic bacteria density.

Oligochaeta fauna was analyzed according to density of Tubificidae (Howmiller and Beeton, 1971), percentage of *Limnodrilus hoffmeisteri* (Brinkhurst, 1967) and Modified Howmiller and Scott Environmental Index (TC) (Milbrink, 1983). TC is a modification of the original Howmiller and Scott's index (1977) that has been proposed by Milbrink (1983). Such index groups different Oligochaeta species (excluding Naididae and Enchytraidae) into four categories, according to their tolerance to organic enrichment, which in turn, ranges from 0 (indicating that species are intolerant

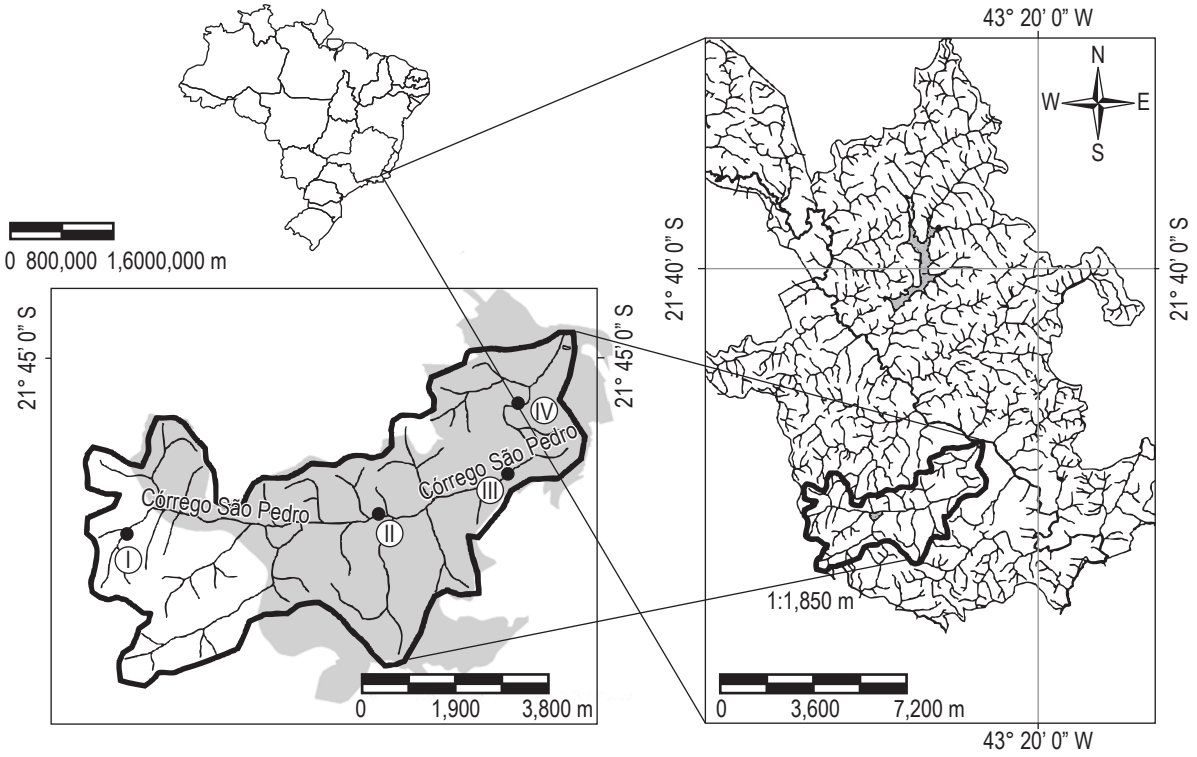

Figure 1. São Pedro drainage and the indications of the four sampling sites (I, II, III and IV).

to organic enrichment and frequently found in oligotrophic environment) to 3 (indicating that species are tolerant to the enrichment and frequently found in highly eutrophic conditions). TC index is given by: $TC = c.\ [(1/2\sum n_o + \sum n_1 + 2\sum n_2 + 3\sum n_3)/ (\sum n_o + \sum n_1 + \sum n_2 + \sum n_3)$, where c ranges from 0 (<30 ind.m^{-2}) to 1 (>3,600 ind.m^{-2}) according to the abundance of organisms. In order to calculate TC, juvenile and adult individuals were considered a single taxon.

To assess the changes in Tubificidae density between the rainy and dry period was applied the Kruskal-Wallis test. The same not parametric test was used to verify the existence of significant differences in tubificidae density, percentage of *L. hoffmeisteri* and Modified Howmiller Scott & Environmental Index between the sampling stations. The ANOVA one-way was used to assess the existence of significant difference of the chlorophyll-*a* concentration, pH, dissolved oxygen and bacterial density between the sampling stations. These tests were performed in the BioEstat 5.0.

Faunistic similarity among sampling stations was calculated by the Unweighted Pair Group Method of Arithmetic means (UPGMA) and Bray Curtis coefficient. Data were analyzed using Fitopac software.

3. Results

The sediment of São Pedro stream was found to be predominantly sandy, with important contribution of medium and fine sand granulometry. In station II, granulometry of both fine sand and silt-clay corresponded to 75.03% of the sediment, while in stations I, III and IV the larger size classes (medium sand, thick sand and gravel) predominated (Table 1).

Chlorophyll, pH, and bacteria data were found to increase towards the downstream direction. Oxygen concentration decreased in station II but increased in both stations III and IV (Table 2). On average, not only had station I the highest oxygen concentration but also the lowest values for pH, chlorophyll and bacteria. The highest average chlorophyll and pH concentration were found in both stations III and IV. On the other hand, both stations II and III were the ones that had the lowest average oxygen concentration. The largest bacterial densities were registered in stations II, III and IV. The ANOVA one-way was detected significant difference between the sampling stations to the variables chlorophyll-*a* concentration ($p = 0.02$; $F = 3.62$), pH ($p < 0.00$; $F = 22.30$) and dissolved oxygen ($p < 0.00$; $F = 18.84$).

Considering the climatological data, two seasonal periods were defined. A hot wet season was defined from November 2005 to March 2006 (mean atmospheric temperature 21 °C and precipitations between 177 mm and 353.33 mm), and another cold dry season was defined from May 2005 to October 2005 and April 2006 (mean atmospheric temperature 18 °C and 20.5 to 64 mm precipitations).

On average, the lowest densities of Tubificidae were registered in the wet season (Figure 2). However, considering both the wet and dry seasons together, there was a significant difference ($p = 0.03$; $H = 8.49$) in the density of organisms between the two seasons.

From 134 sediment samples, a total of 75,746 individuals of the Family Tubificidae, distributed in six species, were identified (Table 3). Adult and juvenile individuals of *Limnodrilus hoffmeisteri* Claparede, 1862 were the most abundant in the urban sampling stations.

Biotic indices were not calculated for station I due to the presence of a single specimen of *Limnodrilus udekemianus* Claparede, 1862 in this station. For the calculation of Modified Howmiller and Scott Environmental Index (TC) the following species in our study were join into three groups: 1 - *Aulodrilus limnobius* Bretscher, 1899 and *Bothrioneurum vejdovskyanum* Stolc, 1988; 2 - *L. udekemianus*; 3 - *L. hoffmeisteri* and *Tubifex tubifex* Müller, 1774. In urban stations the values of TC, percentage of *L. hoffmeisteri* and density means were superior to 2.50, 75%, and 5,000 ind.m^{-2}, respectively. The

Table 1. Sediment grain size distribution (percentage) on the São Pedro stream (southeast Brazil).

	I	II	III	IV
Gravel (>4,8 mm)	3.70	0.45	12.99	18.61
Thick sand (4,8-2,4 mm)	4.89	0.82	7.17	6.18
Medium sand (2,4-0,6 mm)	48.18	23.70	55.70	60.96
Fine sand (0,6-0,075 mm)	35.73	42.27	17.06	10.24
Silt-Clay (<0,075 mm)	7.50	32.76	7.08	4.01

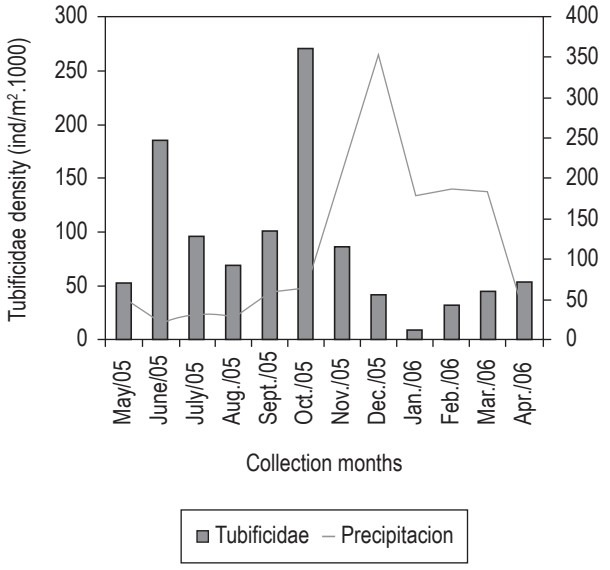

Figure 2. Tubificidae Density (ind.m^{-2}.1000) and precipitation (mm) from May 2005 to April 2006 in São Pedro stream (southeast Brazil).

Table 2. Means and Standard Deviation values found for chlorophyll-*a* concentration (μg.L^{-1}), pH, dissolved oxygen (D.O.) and bacterial density (10^9 cells.L^{-1}) in São Pedro stream (southeast Brazil).

	I	II	III	IV
Chlorophyll-*a*	33.67 ± 15.02	48.28 ± 26.70	62.69 ± 15.95	57.01 ± 19.83
pH	5.92 ± 0.83	6.52 ± 0.29	7.16 ± 0.26	7.58 ± 0.33
D.O.	6.23 ± 3.28	2.30 ± 1.38	4.33 ± 2.45	5.94 ± 2.90
Bacteria	0.30 ± 0.32	0.86 ± 0.37	1.07 ± 0.43	0.71 ± 0.40

Table 3. Tubificidae density means (ind.m^{-2}), Modified Howmiller and Scott Environmental Index (TC) and percentage of *Limnodrilus hoffmeisteri* in São Pedro stream (southeast Brazil).

Taxons	I	II	III	IV
	ind.m^{-2}	ind.m^{-2}	ind.m^{-2}	ind.m^{-2}
Aulodrilus limnobius Bretscher, 1899	0	4.41	0	0
Bothrioneurum sp.	0	435.04	285.77	11146.05
B. vejdovskyanum Stolc, 1988	0	0	0	5.88
Limnodrilus hoffmeisteri Claparede, 1862	0	1359.44	4584.12	15556.00
L. hoffmeisteri juveniles	0	3912.82	2862.78	41534.47
L. udekemianus Claparede, 1862	0.54	1.47	6.09	198.11
L. udekemianus juveniles	0	4.23	3.81	528.95
Tubifex tubifex Müller, 1774	0	7.35	26.72	1141.43
Density mean	0.54	5724.76	7769.29	70110.89
TC	-	2.77	2.89	2.51
L. hoffmeisteri (%)	-	75.59	95.85	81.43

Kruskal-wallis test were detected significant differences on both Tubificidae density (p = 0.00; H = 13.20) and percentage of *L. hoffmeisteri* (p = 0.01; H = 8.57) among the sampling stations. However, significant difference in the TC (p = 0.54; H = 1.25) was not found.

The cluster analyses (cofenetic correlation= 0.99) indicating separated the stations located in urban area of the rural area station (Figure 3). This separation occurred because of very low density recorded in the last area.

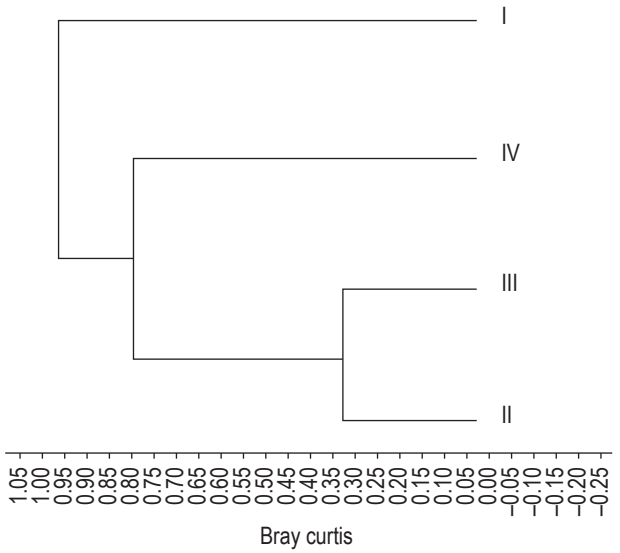

Figure 3. Cluster analysis (UPGMA, Bray-Curtis coefficient) based on the numeric density means of the Tubificidae fauna found in four sampling stations in São Pedro stream (Juiz de Fora, MG).

4. Discussion

The highest mean values found for chlorophyll-*a* concentration, pH and bacteria density, as well as the lowest oxygen concentration in the urban sites, indicate that the water receives domestic effluent. Water falls precede site IV (Latuf, 2004) and they may have contributed to the reestablishment of the dissolved oxygen concentration

In the rainy period organisms can be dragged away by the increased velocity of water flows (Bispo et al., 2001), which may explain why the lowest Tubificidae densities were found in the months of high pluviosity. Diniz-Filho et al. (1998) attributed the highest macroinvertebrate density in the dry season not only to low habitat availability but also to the increase of aggregation among the individuals, due to a reduction in water levels. Lin et al. (2005) found that the abundance of *L. hoffmeisteri* in the river Dali (Taiwan) tended to increase in the winter season, due to organic enrichment in the dry season.

The high densities of juveniles of *Limnodrilus* suggest that food availability (organic matter) together with rare opportunities for biotic interactions such as predation and

competition as a consequence of water pollution may play an important role in the fitness of such genus in São Pedro stream.

High densities of Tubificidae in stations of different granulometric characteristics indicates that the entrance of organic matter in the system was the main feature in the determination of not only the distribution but also the abundance of species within the Family Tubificidae, being the physical characteristics of the substrate less important than the complex effects of pollution (Slepukhina, 1984).

Features such as pollution by heavy metals (Chapman, 2001), prevalence of gravelly sediment (Lin and Yo, 2008), low availability of organic matter (Schenková and Helešic, 2006), competition and predation (Martin et al., 2008) may interfere negatively in the numeric abundance of Oligochaeta. However, none of these factors alone could explain the presence of only one Oligochaeta specimen in station I during the sampling. In a study on Lake Ontario, Brinkhurst (1970) in most of the sediment samples has also found a single individual of *L. udekemianus*, however the author does not discuss the possible factors influencing the low overall abundance.

Increased densities of Oligochaeta followed by a decrease in the diversity of benthonic species in continental waters usually indicate organic enrichment (Slepukhina, 1984). The present study revealed high numeric densities of *L. hoffmeisteri* in the urban stations, indicating pollution by organic matter in São Pedro stream. The percentage of *L. hoffmeisteri* in an aquatic system is largely used as an index to verify the level of organic pollution (Verdonschot, 1989; Marchese and Ezcurra de Drago, 1999), due to the frequent high abundance of this species in polluted areas (Brinkhurst and Jamieson, 1971; Aston, 1973).

Alves et al. (2006) have found a similar Tubificidae assemblage structure in Monjolinho River, an organically polluted river in the state of São Paulo (southeast Brazil). Those authors have found a dominance of *L. hoffmeisteri* and a low numeric density of both *L. udekeminaus* and *T. tubifex*, what differs from the higher average density found for those species in the present study. From all three species, which are usually associated with organically polluted environments, *L. hoffmeisteri* is considered the most tolerant species to pollution (Verdonschot, 1989), *T. tubifex* is particularly vulnerable to competition and *L. udekemianus*, though tolerant to poor oxygenated waters, does not usually inhabit greatly polluted waters (Milbrink, 1973).

In this study the values found for the Modified Environmental Index were close to 3.0, what is mainly due to the presence of dense populations of *L. hoffmeisteri*, once *Tubifex tubifex*, which is also tolerant to organic pollutants (Aston, 1973), was only found in low densities. From all the indices that were calculated in this study, the Modified Environmental Index was the only one that did not significantly differ among the sampling stations. This is probably due to the small number of Tubificidae species found in the studied stream, what prevented each sampling station from been distinguished according to the level of pollution.

The results indicate that Oligochaeta Tubificidae was efficient in the evaluation of the water quality in the studied stream, therefore confirming the potential of this taxonomic group as indicators of organic pollution.

Acknowledgements

We would like thanks Fundação de Apoio à Pesquisa do Estado de Minas Gerais (FAPEMIG) for the financial support (CRA 1291/05) and the scholarship to R.T. Martins.

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Received: 28 May 2008
Accepted: 06 October 2008