Oligochaeta (Annelida, Clitellata) in lotic environments in the State of São Paulo, Brazil

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ABSTRACT. Despite the importance of Oligochaeta to the dynamics of aquatic ecosystems and to studies of the biology of pollution, there is currently a dearth of information on this group's ecology in Brazil. The aim of this study was to describe the Oligochaeta fauna in four watercourses – three urban and one rural – in the State of São Paulo: the Pinheirinho stream, the Água Branca stream, the Monjolinho River and the Gouveia stream, respectively. Sediment samples were taken with a Van Veen grab in two areas from each watercourse, during the summer and winter of 2001. In all collection areas, measurements of the pH, electrical conductivity, dissolved oxygen and turbidity of the water were made with a Horiba U-10 device. Principal component analysis showed that axes 1 and 2 explained 68.18% of the results' variability, with the first axis predominantly associated with the granulometric data and the second one with the limnological data. Cluster analysis indicated that area II of the Monjolinho River differed from the other collection sites. In the present study, the Oligochaeta group was represented by Tubificidae, Naididae, Alluroididae, Narapidae and Enchytraeidae. Among the three species of Tubificidae, *Limnodrilus hoffmeisteri* Claparede, 1862, was the most abundant and most frequent species. The results provided important information on the ecology and distribution of limnic Oligochaeta.

KEYWORDS. Tubificidae, Naididae, Alluroididae, Narapidae, Enchytraeidae.

RESUMO. Oligochaeta (Annelida, Clitellata) em ambientes lóticos do Estado de São Paulo, Brasil. Apesar da importância dos Oligochaeta para a dinâmica dos ecossistemas aquáticos e para os estudos sobre a biologia da poluição, existe atualmente, no Brasil, uma carência de informação sobre a ecologia desse grupo. O objetivo do estudo foi caracterizar a fauna de Oligochaeta em três córregos urbanos e um córrego rural, localizados na região central do Estado de São Paulo, sendo estes o córrego do Pinheirinho, Água Branca, rio Monjolinho e o córrego do Gouveia, respectivamente. Amostras do sedimento foram obtidas com um pegador Van Veen em duas áreas, durante o verão e inverno de 2001, em cada um dos ambientes estudados. Em todas as áreas de coletas foram tomadas medidas de pH, condutividade elétrica, oxigênio dissolvido e turbidez da água com o aparelho U-10 Horiba. A análise de componentes principais mostrou que os eixos I e II explicaram 68,18% da variabilidade dos resultados, sendo que, o primeiro eixo foi predominantemente explicado pelas variáveis granulométricas e o segundo eixo pelas variáveis limnológicas. A análise de agrupamento indicou que a área II do rio Monjolinho diferiu dos demais pontos de coleta. No presente estudo, o grupo Oligochaeta foi representado pelas famílias Tubificidae, Naididae, Alluroididae, Narapidae e Enchytraeidae. Entre as três espécies de Tubificidae, *Limnodrilus hoffmeisteri* Claparede, 1862 foi a mais abundante e mais freqüente. Os resultados forneceram informações importantes sobre a ecologia e distribuição de Oligochaeta límnicos.

PALAVRAS-CHAVE. Tubificidae, Naididae, Alluroididae, Narapidae, Enchytraeidae.

Despite the importance of Oligochaeta to the dynamics of aquatic ecosystems (Fisher & Beeton, 1975; Loteste & Marchese, 1994) and to studies of the biology of pollution (Milbrink, 1983; Marchese & Drago, 1999, Prygiel *et al*., 2000; Nijboer *et al*., 2004), the small number of researchers focusing on this group means there is much less knowledge on their distribution and preferred habitats than for other groups which make up the benthic macroinvertebrate communities of the Brazilian continental environments.

Even though they are present in samples of benthic macroinvertebrates, Oligochaeta worms are generally referred to at the class or family level, or are omitted from any analysis of the faunistic structure and composition of lotic environments. In Brazil the studies carried out by Takeda (1999), Montanholi-Martins & Takeda (1999, 2001) and Takeda (2001), in the upper Paraná River and its tributaries, and Alves & De Lucca (2000) in urban streams in São Paulo provided information about structure and distribution of this group.

Technical difficulties faced in the studies of Oligochaeta, combined with their unattractiveness and secretive behavior are the main reasons for the lack of studies on this group (Righi, 1984).

The aim of this study was to describe the Oligochaeta fauna in four streams (three urban and one rural) in the central region of the state of São Paulo, Brazil, and to try to establish a relationship with abiotic variables that can explain the occurrence and abundance of the most representative species.

MATERIAL AND METHODS

Oligochaeta specimens were collected in the Pinheirinho stream (P) (21°45'S, 48°07'W), in the Água Branca stream (A) (21°48'S, 48°08'W), both belonging to the Ribeirão do Ouro watershed; in the Monjolinho River (M) (21°59'S, 47°50'W), part of the watershed of the same name; and in the Gouveia stream (G) (22°16'S, 48°05'W), belonging to the Jacaré-Pepira River watershed.

Samples were obtained in the summer and winter of 2001 from each of the environments studied. In each environment were elected two areas (called Area I and Area II) for sediment collection and measurement of the

limnological variables. Area I was located upstream from Area II in all cases except the Gouveia stream, in which the two areas were located in its middle segment. To the extent possible, the areas were chosen so that the first was subject to less anthropic influences than the second. From the four sediment samples (summer and winter for each of the two areas), obtained with a Van Veen sediment grab (area equal to 870 cm^2), three were used for analysis of the fauna and one for granulometric analysis. The sediment samples were placed in 4% formaldehyde until the moment of washing in a 210-µm mesh sieve. After selection, the organisms were preserved in 70% alcohol, and mounted on non-permanent slides with lactophenol for identification. The criterion adopted by BRINKHURST & JAMIESON (1971), RIGHI (1984) and BRINKHURST & MARCHESE (1989) was followed for the identification of the Oligochaeta species.

In all collection areas the pH, electrical conductivity, dissolved oxygen and turbidity of the water were measured with a Horiba U-10 device. The granulometric analysis followed the methodology proposed by the Brazilian Association of Technical Norms (ABNT, 1982). Principal component analysis (PCA) was performed to identify which variables best explained the variability of the faunistic results, and cluster analysis of the mean values of the physical and chemical water variables and granulometric variables was performed using UPGMA and the Manhattan distance coefficient. The analyses were run with the MVSP program, version 12. The Oligochaeta species were deposited at the Zoology Museum at the São Paulo University, (Museu de Zoologia, Universidade de São Paulo - MZUSP).

RESULTS

The principal component analysis showed that axes 1 and 2 explained 68.18% of the variability of the results. The first axis was predominantly associated with the granulometric variables and the second with the limnological ones (Tab. I). The fact that axis 1 was linked to the granulometric data indicates the importance of substrate to Oligochaeta, since this is where the worms find conditions for their survival and reproduction.

The isolation of M2 (area II of the Monjolinho River), detected in the cluster analysis (Fig. 1), indicates that this area differs from the others, because the electrical conductivity and turbidity values are considerably higher than those in the other areas studied. The second group can be divided into three subgroups. The subgroup comprised of A2 and P2, representing the lower stretches of the Água Branca and Pinheirinho streams, respectively, had midrange electrical conductivity values, low oxygen concentrations and greater average values of gross and medium sediment fractions. In contrast, the subgroup comprised of A1 and P1, respectively representing the upper stretches of these two streams, was characterized by low conductivity and turbidity values, and the substrate was composed mainly of fractions of medium and fine sand. The last subgroup is composed of G1 and G2, representing the two stretches of the Gouveia stream

Table I. Factor loading values for axes 1 and 2 in the principal components analysis of the granulometric and limnological data.

	Factor	Factor
Conductivity	-0.178652	-0.960398
Temperature	0.862427	-0.042668
Oxigen	0.367059	0.033469
PH	0.356898	-0.779624
Turbidity	-0.506852	-0.812288
Gross sand	0.883348	-0.197005
Medium sand	0.924769	-0.034447
Fine sand	-0.853387	0.136880
Silt	-0.760567	-0.208495
Argil	-0.475860	0.244633

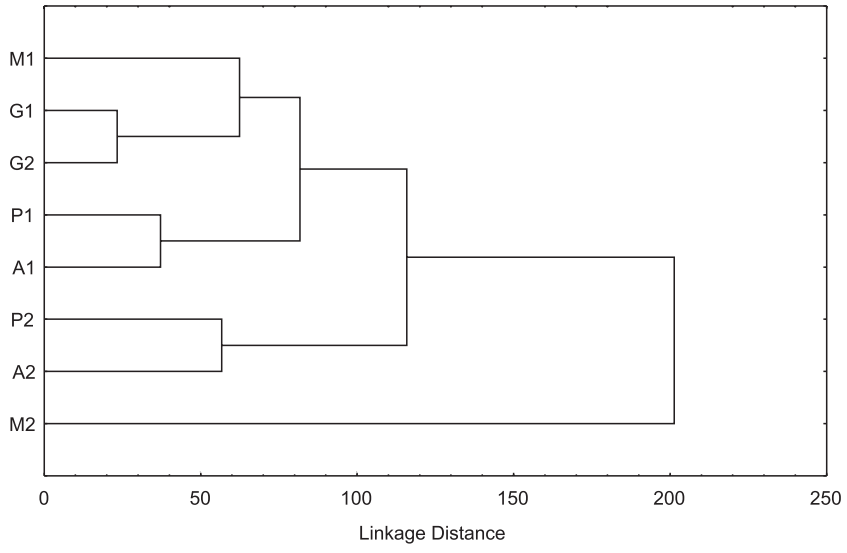

Fig. 1. Dendogram analysis of the collection locations using UPGMA and the Manhattan correlation coefficient (M1 and M2, Monjolinho River, areas I and II; P1 and P2, Pinheirinho Stream, areas I and II; A1 and A2, Água Branca Stream, areas I and II; G1 and G2, Gouveia Stream, areas I and II).

(areas I and II), both located in a rural region, where their banks are in some places protected by riparian vegetation. Area I of the Monjolinho River (M1) was also associated to G1 and G2 because that stream's upper stretch is also located in a rural area. The areas studied in this last subgroup are characterized by lower values of electrical conductivity, greater oxygen levels and lower turbidity than in area II of the Monjolinho River. Sediment is poor in gross sand (even being absent sometimes), predominating fine sand.

In relation to the limnological variables analyzed (Tab. II), the pH ranged from 3.56 to 7.10. The lowest conductivity was found in the Gouveia stream, and the highest values for this variable, as well as for turbidity, were detected in area II of the Monjolinho River, indicating a probable local external influence. The lowest turbidity values were obtained in area I of the Água Branca and Pinheirinho streams, where the water was clear due to the proximity to their respective sources. Water temperature was seasonally warmer in the summer.

Regarding the fauna, the species richness varied from 1 to 5, reaching its highest level in area II of the Monjolinho River, where density was also greater (2,361 individuals/m^2). The richness and density of Oligochaeta were lower in the other environments (Fig. 2).

The results indicated the presence of four species of Tubificidae, eleven of Naididae, one of Narapidae and one of Alluroididae. The specimens of Enchytraeidae were represented by only one morphotype (Tab. III). In the Monjolinho River, *Limnodrilus hoffmeisteri* Claparede, 1862 was the species that stood out numerically.

Among the environments studied, the Pinheirinho stream had most families (Tubificidae, Naididae, Alluroididae and Enchytraeidae), genera (*Limnodrilus* Claparede, 1862, *Haemonais* Bretscher, 1900, *Pristina* Ehrenberg, 1828, *Pristinella* Brinkhurst, 1985, *Nais* Müller, 1773, *Allonais* Sperber, 1948, and *Brinkhurstia* Brinkhurst, 1985) and species (Tab. III).

Limnodrilus neotropicus Cernosvitov, 1939 was present only in sediments of the Água Branca and Gouveia streams. Specimens of *Narapa bonetoi* Righi & Varela, 2001 were found in sediments from area II of the Gouveia stream.

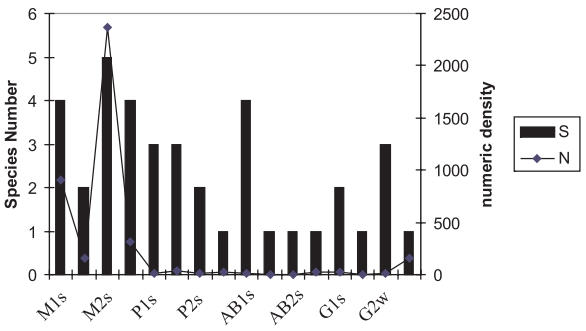

Fig. 2. Relation between the number of species (S) and numeric density (N) of Oligochaeta in the areas studied (AB1 and AB2, Água Branca Stream, areas I and II; G1 and G2, Gouveia Stream, areas I and II; M1 and M2, Monjolinho River, areas I and II; P1 and P2, Pinheirinho Stream, areas I and II; s, summer; w, winter).

In general, the granulometric analysis showed predominance of medium and fine sand, whereas a gravel fraction was only present in the Monjolinho River (Tab. IV).

DISCUSSION

The presence and distribution of Oligochaeta species in aquatic environments depends on the type of substrate, physical and chemical variations in the water, biotic interactions, along with water quality and food availability (VERDONSCHOT, 1989). In the present work, the principal component analysis indicated that the water's physical and chemical variables and the substrate characteristics had a considerable influence on the distribution of Oligochaeta, considering that axes 1 and 2 explained 68.18% of the results' variability. Cluster analysis showed that the environments differed in regard to these variables, with area II of the Monjolinho River standing apart as to limnological and granulometric characteristics.

The organic enrichment, shown by the limnological variables (high electrical conductivity and turbidity and low dissolved oxygen levels), contributed to the greater abundance of Tubificidae organisms in area II of the Monjolinho River. The species *L. hoffmeisteri*, present in the samples from this area, is generally associated with

Table II. Values of pH, electrical conductivity, temperature, oxygen content and turbidity of the water in the Monjolinho River and Pinheirinho Stream, Água Branca Stream and Gouveia Stream (areas I and II) in summer and winter 2001.

	pH	Conductivity (µS/cm)	Temperature (°C)	Oxigen (mg/l)	Turbidity (NTU)
MONJOLINHO RIVER					
AREA I					
March	4.88	37.30	23.40	2.62	10.20
July	6.27	21.50	16.90	4.21	5.70
AREA II					
March	5.65	183.3	23.40	1.32	26.70
July	7.10	129.5	18.80	3.71	42.70
PINHEIRINHO STREAM					
AREA I					
January	5.51	20.90	23.70	2.17	1.40
July	5.64	17.3	21.80	5.14	1.00
AREA II					
January	6.38	85.58	24.80	2.91	7.00
July	7.05	52.90	19.80	2.92	7.20
ÁGUA BRANCA STREAM					
AREA I					
January	5.50	33.00	23.30	1.20	0.20
July	5.40	20.50	24.00	1.80	1.50
AREA II					
January	6.86	74.30	25.70	2.86	22.10
July	6.86	49.30	22.50	2.35	5.90
GOUVEIA STREAM					
AREA I					
March	6.02	17.80	23.70	3.50	11.30
July	6.33	12.2	16.90	6.67	7.40
AREA II					
March	3.56	16.10	24.80	3.48	12.70
July	6.65	12.10	17.40	7.26	6.60

organically enriched environments (VERDONSCHOT, 1989; LANG, 1990; STACEY & COATES, 1996; MARCHESE & DRAGO, 1999).

The presence of a higher percentage of fine fraction (fine sand, silt and clay) in sediments from the Monjolinho River is also a factor that likely contributed to the presence of Tubificidae organisms. The species *L. hoffmeisteri* and *L. udekemianus* Claparede, 1862 are usually found in places where sediment is composed of fine fraction (PAOLETTI & SAMBUGAR, 1984; BINGHAM & MULLER, 1989, ALVES & STRIXINO, 2000). SAUTER & GUDE (1996), in turn, reported the considerable ability of *L. hoffmeisteri* to colonize an ample granulometric limit, which justifies the presence of this species in the variety of habitats studied.

The greater percentage of medium sand in the two areas of the Pinheirinho stream and the shallow depth may have contributed to the richness of Naididae species, since these conditions are favorable for the development of periphyton, a food source for many species of this family (BINGHAM & MULLER, 1989).

Limnodrilus neotropicus was found in area I of the Água Branca stream, which has a sandy substrate with a considerable quantity of allochtonous material (twigs, leaves, sediment). This species, unlike the two others collected (*L. hoffmeisteri* and *L. udekemianus*), did not show any association to potentially polluted areas. This species was also found by TAKEDA (1999) in a channel on the floodplain of the Paraná River. The fauna in area II of that stream was limited to a low numerical density of immature Tubificidae without capillary setae.

In the Gouveia stream, the greater number of *Narapa bonettoi* may be related to the sandy sediment and current. This species is one of the abundant oligochaetes in the upper Paraná River (TAKEDA, 2001) and it has been recorded in lotic environments with strong currents, living in sandy sediments with little organic material (MARCHESE, 1994). Many of the organisms found

Table III. Numerical density average values (individuals/m²) of species of Oligochaeta of Monjolinho River, Pinheirinho Stream, Água Branca Stream and Gouveia Stream, São Paulo in areas I and II, in the summer and winter 2001.

	Summer		Winter	
	Area I	Area II	Area I	Area II
MONJOLINHO RIVER				
Limnodrilus hoffmeisteri Claparede, 1862	452.30	1,663.70	46.00	53.70
Limnodrilus udekemianus Claparede, 1862	0.00	15.33	0.00	0.00
Tubificidae immature	429.30	632.50	112.13	203.20
Tubifex tubifex (Muller, 1774)	0.00	7.66	0.00	0.00
Nais communis Pigueti, 1906	0.00	0.00	0.00	19.20
Dero (*D.*) *raviensis* (Stephenson, 1914)	0.00	0.00	0.00	38.29
Pristina synclites Stephenson, 1925	11.50	42.16	0.00	0.00
Pristina americana Cernosvitov, 1937	11.50	0.00	0.00	0.00
PINHEIRINHO STREAM				
L. hoffmeisteri	3.83	0.00	0.00	0.00
Pristinella jenkinae (Stephenson, 1931)	0.00	3.83	0.00	0.00
Pristinella menoni (Aiyer, 1929)	0.00	0.00	23.00	0.00
P. synclites	0.00	3.83	0.00	0.00
D.(*D.*) *raviensis*	0.00	0.00	3.83	0.00
Allonais inaequalis (Stephenson, 1911)	0.00	0.00	7.67	0.00
Haemonais waldvogeli Bretscher, 1900	3.83	0.00	0.00	0.00
Enchytraeidae	3.83	0.00	0.00	0.00
Brinkhurstia americanus (Brinkhurst, 1964)	11.50	3.83	3.83	0.00
ÁGUA BRANCAS STREAM				
L. hoffmeisteri	3.83	3.83	0.00	0.00
Limnodrilus neotropicus Cernosvitov, 1939	23.00	0.00	0.00	0.00
P. jenkinae	3.83	0.00	0.00	0.00
Pristina proboscidea Beddard, 1896	3.83	0.00	0.00	0.00
Pristina aequiseta Bourne, 1891	3.83	0.00	0.00	0.00
Pristina sp.	0.00	0.00	3.83	0.00
Slavina sp.	0.00	0.00	3.83	0.00
GOUVEIA STREAM				
L. neotropicus	19.16	7.66	7.66	0.00
Pristinella jenkinae	15.33	3.83	3.83	0.00
Pristina sp.	0.00	3.83	0.00	0.00
Slavina appendiculata D'Udekem, 1855	0.00	3.83	0.00	0.00
Narapa bonettoi Righi & Varela, 2001	0.00	161.00	0.00	0.00

Table IV. Granulometric values in the Monjolinho River and Pinheirinho, Água Branca and Gouveia streams (areas I and II) in summer and winter 2001, São Paulo.

	Gross sand (%)	Medium sand (%)	Fine sand (%)	Silt (%)	Argil (%)
Monjolinho River					
Area I	2.70	31.50	41.20	11.40	12.40
Area II	4.40	40.00	40.60	8.00	6.40
Pinheirinho Stream					
Area I	10.00	63.00	18.50	1.80	6.70
Area II	22.90	69.10	2.30	2.00	3.70
Água Branca Stream					
Area I	15.00	50.00	25.00	2.30	7.70
Area II	22.90	69.10	2.30	2.00	3.70
Gouveia Stream					
Area I	0.00	40.00	54.10	2.10	3.80
Area II	0.90	49.10	46.10	0.40	3.50

in the Gouveia stream showed scarring, indicating transversal segmentation. MARCHESE (1994) emphasized that this species reproduces both asexually and sexually. In this watercourse, Tubificidae was only represented by *L. neotropicus*. In the present study this species was related to environments whose anthropic influence is less evident, as is the case of area I of the Água Branca stream and the two areas of the Gouveia stream, where the entrance of organic material in the system is basically restricted to vegetable detritus.

Among Naididae, the genus *Pristina* presented the highest number of species (*P. aequiseta* Bourne, 1891, *P. synclites* Stephenson, 1925, *P. proboscidea* Beddard, 1896 and *Pristina* sp.) and was present in all the environments studied. This genus has also been found in sediments of other Brazilian aquatic environments, such as the upper Paraná River (MONTANHOLI–MARTINS & TAKEDA, 1999, 2001), in urban streams in the city of Araraquara (ALVES & DE LUCCA (2000) and in the Bariri Reservoir (PAMPLIN *et al.*, 2005), the latter two in the State of São Paulo.

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