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Evaluation of Water Quality of an Urban Stream in Southeastern Brazil Using Chironomidae Larvae (Insecta: Diptera)

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ABSTRACT - In order to estimate the water quality of São Pedro stream, through distribution and composition of Chironomidae larvae present in the sediment four sampling sites were selected. In each sampling site, three sediment samples were collected within a period of twelve months using the Petersen (0.0189 m^2) and the van Veen (0.0518 m^2) dredges. Samples were washed through a sieve with a 0.21 mm mesh and the collected organisms were sorted in transparent trays, with a light shine being reflected into the tray. The sites located in the greatest urban mesh showed high densities of the genus *Chironomus* and lower values for diversity, uniformity and taxa richness, in relation to sites located in a less urbanized area. A significant difference in density of Chironomidae larvae ($p = 0.02$; $H = 5.89$) was observed between the sites without domestic sewage effluents (site I) and those with the input of the effluents (sites II, III and IV). The Chironomidae larvae composition and the physical and chemical parameters were effective as indicators of the environmental alterations in São Pedro stream.

KEY WORDS: *Chironomus*, organic pollution, environmental alteration

The organic pollution causes disruption of the aquatic habitat and modifies the benthic fauna distribution and composition (Callisto *et al* 2001). The community structure of benthic invertebrates has been used in the evaluation of water quality of aquatic environments in many regions (Janssens & Gerhardt 2003, Mccormick *et al* 2004, Helson *et al* 2006).

Chironomidae are frequently abundant among invertebrates in benthic substratum of rivers (Helson *et al* 2006, Aburaya & Callil 2007), streams (Roque *et al* 2003, Siqueira & Trivinho-Strixino 2005) and dams (Correia & Trivinho-Strixino 2005, Fusari & Fonseca-Gessner 2006, Moreno & Callisto 2006), being commonly found in high densities and taxa richness (Hirabayashi & Wotton 1998).

The worldwide distribution of Chironomidae, associated with the high diversity of species with different degrees of environmental tolerance, makes it an important group in the diagnosis and monitoring of aquatic environment (Armitage *et al* 1995). In Brazil, studies in the Rio Doce basin (Marques *et al* 1999), Velhas basin (Pompeu *et al* 2005) and Rio Ribeira (Trivinho-Strixino & Strixino 2005) showed that Chironomidae larvae are efficient in water quality evaluation.

The aim of this study was to assess the water quality of an urban stream in southeastern Brazil, by means of both the distribution and the composition of Chironomidae larvae in the sediment.

Material and Methods

São Pedro stream has 13.25 km of extension and it belongs to Rio Paraibuna basin, in the southwestern area of the municipality of Juiz de Fora, Minas Gerais state. Approximately 41.85% of the total drainage basin is situated in the urban area and there are several sites of input of domestic sewage effluents. The basin supplies São Pedro Dam which is responsible for nearly 9% of the city water supply (Latuf 2004).

Four sites along the stream were selected for sediment samples (sites I, II, III e IV) (Fig 1). Site I is located almost 2.5 km away from the urban area, without input of domestic sewage effluents and it has close vegetation along its edges, while site II is located at the beginning of the urban area, thus it is less influenced by these sewage effluents. Sites III and IV are located in the urban area, receiving large amounts of domestic effluents. Site IV is located just after a series of waterfalls.

From May of 2005 to April of 2006, sediment samples (three replicates per site) were obtained monthly, with Petersen (0.0189 m^2) and van Veen (0.0518 m^2) dredges and fixed using a 4% formalin solution. Samples were then washed in a sieve of 0.21 mm mesh size and the organisms were sorted in transparent trays, with a light shine being reflected into the tray, and conserved in 70ºGL ethanol solution. The identifications of Chironomidae genera were based on Epler (1992), Trivinho-Strixino & Strixino (1995)

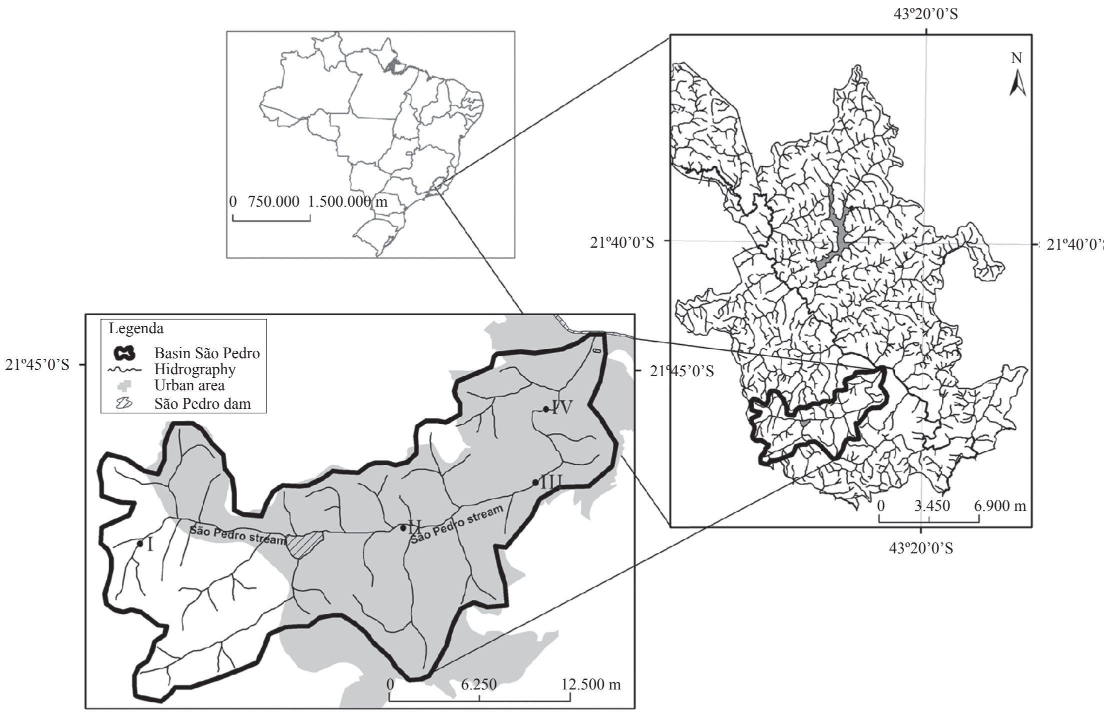

Fig 1 Drainage basin of São Pedro stream, Juiz de Fora, MG, and the localization of I, II, III and IV collecting sites.

and Wiederholm (1983). Fauna data of each sampling site in each month were analyzed as means of numeric density (individuals/m^2).

pH (measured using portable pH meter), the level of dissolved oxygen (with spectrophotometry) and chlorophyll-*a* with a Turner fluorimeter were monthly measured in all sampling stations. Water sub-samples were filtered (black porous 0.2 μm polycarbonate filters) and stained with acridine orange to determine heterotrophic bacteria density. The granulometric analysis of the sediment samples from April 2006 was conducted for each sampling site.

The Chironomidae structure and composition were analyzed by means of numeric density, taxa richness, Shannon's diversity index, Pielou's uniformity index, as well as the percentage of *Chironomus* larvae. These indices were used to evaluate the faunistic similarity among the sampling sites by means of cluster analysis (UPGMA with Euclidean distance). Analyses were performed using the PAST software (version 1.36).

In order to perform the analysis of the indicator value method (IndVal) (Dufrêne & Legendre 1997), we considered the groups formed by the similarity analysis. Taxa with an IndVal higher than 25% contribute to the habitat specificity and only these were considered as characteristic taxa. The significance of the indicator value of each species was tested using Monte Carlo statistics (1000 permutations). Analyses were performed using PCord 4.0.

One-way ANOVA was used to assess the existence of significant differences of chlorophyll-*a* concentration, pH, dissolved oxygen and bacterial density between the sampling stations. To assess the changes in taxa richness, Shannon's diversity index, Pielou's uniformity index, numeric density of Chironomidae, percentage and the numeric density of the genus *Chironomus* between the site without input of domestic sewage effluents and those located in the urban area, the Kruskal-Wallis test was applied. This non-parametric test was also used to verify the existence of significant differences in taxa richness among the three Chironomidae subfamilies found in each collection site. These tests were performed in the BioEstat 5.0.

Results

Granulometric analyses indicated that the sediment of São Pedro stream was predominantly sandy (Table 1). In sites I, III and IV predominated the medium-sized sand fraction and in site II the finer fractions (fine sand and silt-clay). Sites III and IV showed more contribution of coarse material (coarse sand and gravel) in relation to the other sites.

Values for chlorophyll-*a* concentration, pH and bacteria

Table 1 Percentage of granulometric fractions of the sediment in the four sampling sites in São Pedro stream (Juiz de Fora; MG).

Sampling sites	I	II	III	IV
Gravel (> 4.8 mm)	3.70	0.44	12.99	18.61
Coarse sand (4.8 - 2.4 mm)	4.89	0.82	7.17	6.18
Medium-sized sand (2.4 - 0.6 mm)	48.17	23.70	55.69	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

density increased in an upstream-downstream direction. The highest concentrations of dissolved oxygen were observed in sites I and IV (Table 2). One-way ANOVA detected significant differences between sampling stations to the variables chlorophyll-*a* concentration ($P = 0.02$; $F = 3.62$), pH ($P < 0.01$; $F = 22.30$) and dissolved oxygen ($P < 0.01$; $F = 18.84$).

The Chironomidae larvae that were collected in sediment samples belonged to the subfamilies Chironominae, Orthocladiinae and Tanypodinae. Larvae of Tanypodinae were restricted to site I, and they were represented by four genera. Three genera of Orthocladiinae were found, being *Cricotopus* the only genus present in all sampling sites. The subfamily Chironominae showed values significantly higher for taxa richness ($P < 0.01$; $H = 193.73$) in all sampled sites (Table 3). We observed significant difference in the numeric density of Chironomidae ($P = 0.02$; $H = 5.89$) between sites with (sites II, III e IV) and without (site I) the input of sewage effluents.

Table 2 Means and standard deviation values (x ± sd, n = 12) of chlorophyll-*a* concentration (µg.L^{-1}), pH, dissolved oxygen (mg.l^{-1}) and bacterial density (cell.10^{6}.ml^{-1}) of four sampling sites for Chironomidae in São Pedro stream from May of 2005 to April of 2006 (Juiz de Fora, MG).

Sampling sites	I	II	III	IV
Chlorophyll-*a* concentration	33.7 ± 15.02	48.3 ± 26.70	62.7 ± 15.95	57.0 ± 19.83
pH	5.9 ± 0.83	6.5 ± 0.29	7.2 ± 0.26	7.6 ± 0.33
Dissolved oxygen	6.2 ± 3.28	2.3 ± 1.38	4.3 ± 2.45	5.9 ± 2.90
Bacterial density	0.3 ± 0.32	0.9 ± 0.37	1.1 ± 0.43	0.7 ± 0.40

Table 3 Chironomidae density means (individuals/m^2) and standard deviation values (x ± sd, n = 12) in four sampling sites in São Pedro stream from May of 2005 to April of 2006 (Juiz de Fora, MG).

Sampling sites	I	II	III	IV
Chironominae				
Caladomyia	1.08 ± 6.44	1.46 ± 8.82	0	0
Chironomus	24.13 ± 122.22	2399.69 ± 4474.06	30253.96 ± 50534.32	28113.56 ± 36809.10
Cryptochironomus	6.97 ± 22.21	80.82 ± 252.80	0	0
Endotribelus	2.14 ± 8.97	1.46 ± 8.82	0	30.86 ± 90.66
Fissimentum	6.44 ± 21.15	0	0	0
Goeldichironomus	0	0	0	1.46 ± 8.82
Harnischia (?)	0	5.86 ± 21.08	0	0
Phaenopsectra	0	0	0	1.46 ± 8.82
Polypedilum	172.65 ± 506.76	121.96 ± 414.27	1.46 ± 8.82	0
Pseudochironomus (?)	0	0	0	1.46 ± 8.82
Rheotanytarsus	0	2.95 ± 17.64	0	0
Tanytarsini sp1	1.08 ± 6.44	0	0	0
Tanytarsini sp2	19.84 ± 53.91	3.07 ± 29.66	0	0
Orthocladiinae				
Cricotopus	6.42 ± 19.03	1.46 ± 8.82	1.46 ± 8.82	332.14 ± 1474.75
Onconeura	2.67 ± 10.48	1.46 ± 8.82	0	57.32 ± 326.25
Thienemanniella	2.69 ± 11.45	0	0	0
Tanypodinae				
Ablabesmyia	6.44 ± 15.31	0	0	0
Larsia	2.69 ± 11.45	0	0	0
Macropelopia (?)	1.06 ± 4.48	0	0	0
Pentaneura	2.14 ± 8.97	0	0	0

Those sites with the input of domestic sewage effluents (sites II, III and IV) showed values significantly lower of taxa richness ($P < 0.01$; $H = 8.00$), diversity ($P < 0.01$; $H = 10.74$) and uniformity indices ($P < 0.01$; $H = 10.29$) as compared to the organically unpolluted site (I) (Table 4). Sites II, III and IV showed values significantly higher of percentage ($P < 0.01$; $H = 78.57$) and the numeric density ($P < 0.01$; $H = 79.62$) of the genus *Chironomus* in relation to site I.

The cluster analysis (Cofenetic correlation = 0.99) indicated the occurrence of three groups (Fig 2): one formed by a site which is located in an area with no organic pollution from domestic sewage (site I); the second is formed by a site located in the beginning of the urban area (site II) and the third is formed by the site in the area with the largest urban concentration (sites III and IV).

In Table 5 IndVal analysis demonstrated that the genus *Polypedilum* was an indicator of the site without domestic pollution input (site I) and *Chironomus* an indicator of the sites in the area with the largest urban concentration (sites III and IV), consequently, with the highest sewage input.

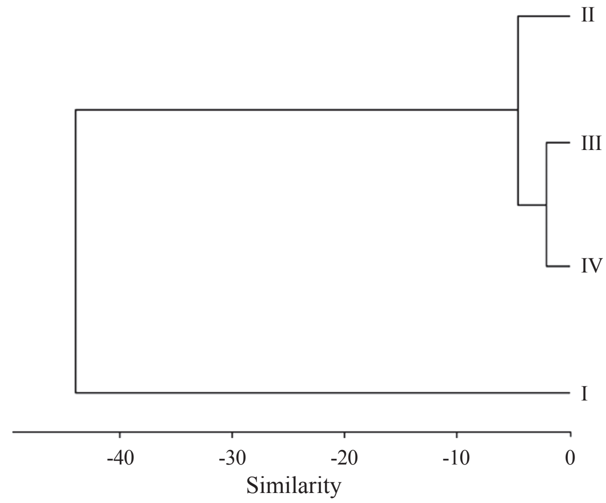

Fig 2 Cluster analysis (UPGMA and Euclidean distance) among sampling sites I, II, III and IV in São Pedro stream (Juiz de Fora, MG).

Discussion

The high mean values for chlorophyll-*a* concentration, pH, and bacterial density registered in sites II, III and IV indicate that the water was receiving domestic effluents, once an increase in nutrients availability in the water accounts for an increase in those parameters (Leandrini *et al* 2002). The highest values of dissolved oxygen in site I may be attributed to the absence of domestic sewage input (Nonato *et al* 2007), while in site IV the high value of this variable is due to the presence of waterfalls (Latuf 2004).

Tanypodinae larvae were present only in site I. This subfamily is apparently intolerant to organic pollution, once it was not found in the sites with domestic effluents, as observed elsewhere (Marques *et al* 1999, Couceiro *et al* 2007).

The low percentage of *Chironomus*, the great values of the taxa richness, diversity and uniformity indices characterized site I as the one with the best water quality in comparison to the other sampling sites.

The decrease in Chironomidae diversity in sites II, III and IV is related to the dominance of the genus *Chironomus*, which is tolerant to organic and industrial pollutants (Gower

Table 4 Taxa richness, Shannon's diversity index (H'), Pielou's uniformity index (E) and percentage of *Chironomus* (%) in four sampling sites in São Pedro stream (Juiz de Fora, MG).

Sampling sites	I	II	III	IV
Taxa richness	15	10	3	7
Shannon's diversity index (H')	1.36	0.38	0.001	0.09
Pielou's uniformity index (E)	0.50	0.17	0.01	0.05
Percentage of *Chironomus*	9.34	91.59	99.99	98.51

Table 5 Indicator value scores (IndVal) and Monte Carlo significance test (1000 permutations) for each genus of Chironomidae collected in São Pedro stream (Juiz de Fora, MG). Significant characteristic taxa of each stream have an IndVal >25 and $P < 0.05$.

	IndVal	p-value	Groups[1]
Ablabesmyia	16.7	0.01	a
Caladomyia	1.9	0.75	a
Chironomus	**90.1**	**0.01**	**c**
Cricotopus	8.9	0.41	c
Cryptochironomus	18.0	0.01	b
Endotribelus	4.7	0.44	c
Fissimentum	8.3	0.03	a
Goeldichironomus	1.4	1.00	c
Harnischia (?)	8.3	0.04	b
Larsia	5.6	0.12	a
Macropelopia (?)	5.6	0.12	a
Onconeura	2.1	0.95	c
Pentaneura	5.6	0.27	a
Phaenopsectra	1.4	1.00	c
Pseudochironomus (?)	1.4	1.00	c
Polypedilum	**37.5**	**0.01**	**a**
Rheotanytarsus	2.8	0.49	b
Tanytarsini sp1	2.8	0.48	a
Tanytarsini sp2	17.9	0.01	a
Thienemanniella	2.8	0.52	a

[1]Groups formed from cluster analysis: a = non organic pollution site (site I); b = moderate levels of organic pollution (site II); c = high levels of organic pollution (sites III e IV).

& Buckland 1978, Davies & Hawkes 1981, Barbosa & Callisto 2000, Kleine & Trivinho-Strixino 2005, Azrina *et al* 2006), and is an effective biological indicator of stream pollution.

In Jurumirim Dams, São Paulo state, Brazil, the granulometric composition of the substrate was the main determinant of *Chironomus* density (Santos & Henry 2001). However, in São Pedro stream, this genus did not show any preference for substrate particle sizes, being found in all sites. The domestic sewage input observed in the present study in the sampling sites which are in the urban area may have contributed to the increase of *Chironomus* density in these sites. According to Sibley *et al* (1997), the numerical abundance of this genus is greatly influenced by food availability independently of the size of the substrate particles.

The cluster analysis indicated differences in the structure and composition of Chironomidae fauna among the three groups involved. The formation of the groups occurred mainly due to the numeric density of *Chironomus* that influenced the values of the diversity and uniformity indices. Based on these metrics it was possible to classify the site into the following groups: sites unpolluted by organics (site I), sites with moderate levels of organic pollution (site II) and sites with high levels of organic pollution (sites III e IV).

Polypedilum was considered an indicator of site I due to its high frequency and abundance. This genus is commonly found in different kinds of substrates (Amorim *et al* 2004, Pinder & Reiss 1983) and pollution levels (Epler 1992). This ecological plasticity makes difficult to identify which of the variables analyzed determined the genus as an indicator of site I. *Chironomus* was an indicator of sites III e IV, attesting its relationship with organically polluted aquatic environments.

In conclusion, our data indicate that Chironomidae larvae were suitable indicators in the evaluation of the water quality in the studied stream, therefore confirming the potential of this taxonomic group as indicators of organic pollution.

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References

Aburaya F H, Callil C T (2007) Variação temporal de larvas de Chironomidae (Diptera) no Alto Rio Paraguai (Cáceres, Mato Grosso, Brasil). Rev Bras Zool 24: 565-572.

Amorim R M, Henriques-Oliveira A L, Nessimian J L (2004) Distribuição espacial e temporal das larvas de Chironomidae (Insecta: Diptera) na seção ritral do rio Cascatinha, Nova Friburgo, Rio de Janeiro, Brasil. Lundiana 5: 119-127.

Armitage P, Cranston P S, Pinder L C V (1995) The Chironomidae: biology and ecology of non-biting midges. London, Chapman & Hall, 584p.

Azrina M Z, Yap C K, Rahim Ismail A, Ismail A, Tan S G (2006) Anthropogenic impacts on the distribution and biodiversity of benthic macroinvertebrates and water quality of the Langat River, Peninsular Malaysia. Ecotoxicol Environ Saf 64: 337-347.

Barbosa F A R, Callisto M (2000) Rapid assessment of water quality and diversity of benthic macroinvertebrates in the upper and middle Paraguai River using the Aqua-Rap approach. Verh Internat Verein Limnol 27: 2688-2692.

Callisto M, Moreno P, Barbosa F (2001) Habitat diversity and benthic functional trophic groups at Serra do Cipó, Southeast Brazil. Rev Bras Biol 61: 259-266.

Correia L C S, Trivinho-Strixino S (2005) Chironomidae (Diptera) em substratos artificiais num pequeno reservatório: Represa do Monjolinho, São Carlos, São Paulo, Brasil. Entomol Vectores 12: 265-274.

Couceiro S R M, Hamada N, Luz S L B, Forsberg B R, Pimentel T P (2007) Deforestation and sewage effects on aquatic macroinvertebrates in urban streams in Manaus, Amazonas, Brazil. Hydrobiologia 575: 271-284.

Davies L J, Hawkes H A (1981) Some effects of organic pollution on the distribution and seasonal incidence of Chironomidae in riffles in the River Cole. Freshw Biol 11: 549-559.

Dufrêne M, Legrendre P (1997) Species assemblages and indicator species: the need for a flexible asymmetrical approach. Ecol Monogr 67: 345-366.

Epler J H (1992) Identification manual for the larval Chironomidae (Diptera) of Florida. Department of Environmental Regulation, Tallahassee, 319p.

Fusari L M, Fonseca-Gessner A A (2006) Environmental assessment of two small reservoirs in southeastern Brazil, using macroinvertebrate community metrics. Acta Limnol Brasil 18: 89-99.

Gower A M, Buckland P J (1978) Water quality and the occurrence of *Chironomus riparius* Meigen (Diptera: Chironomidae) in a stream receiving sewage effluent. Freshw Biol 8: 153-164.

Helson J E, Williams D D, Turner D (2006) Larval Chironomid community organization in four tropical rivers: human impacts and longitudinal zonation. Hydrobiologia 559: 413-431.

Hirabayashi K, Wotton R S (1998) Organic matter processing by chironomid larvae (Diptera: Chironomidae). Hydrobiologia 382: 151-159.

Janssens B L, Gerhardt A (2003) Chironomidae (Diptera, Nematocera) fauna in three small streams of Skania, Sweden. Environ Monit Assess 83: 89-102.

Kleine P, Trivinho-Strixino S (2005) Chironomidae and other aquatic macroinvertebrates of a first order stream: community response after habitat fragmentation. Acta Limnol Brasil 17: 81-90.

Latuf M O (2004) Diagnóstico das águas superficiais do Córrego São Pedro, Juiz de Fora - Minas Gerais. Geografia 13: 21-55.

Leandrini J A, Fonseca I A, Silva E L V, Rodrigues L (2002) Mudanças de biomassa da comunidade perifítica na planície alagável do alto rio Paraná. Nupélia 53-58.

Marques M M G S M, Barbosa F A R, Callisto M (1999) Distribution and abundance of Chironomidae (Diptera, Insecta) in an impacted watershed in south-east Brazil. Rev Bras Biol 59: 553-561.

Mccormick P V, Shuford R B E, Rawlik P S (2004) Changes in macroinvertebrate community structure and function along a phosphorus gradient in the Florida Everglades. Hydrobiologia 529: 113-132.

Moreno P, Callisto M (2006) Benthic macroinvertebrates in the watershed of an urban reservoir in southeastern Brazil. Hydrobiologia 560: 311–321.

Nonato E A, Viola Z G G, Almeida K C B, Schor H H R (2007) Tratamento estatístico dos parâmetros da qualidade das águas da bacia do alto curso do Rio das Velhas. Quím Nova 30: 797-804.

Pinder L C V, Reiss F (1983) The larvae of Chironominae (Diptera: Chironomidae) of the Holarctic region - keys and diagnoses, p.293-435. In Wiederholm T (ed) Chironomidae of the Holarctic region - keys and diagnoses. (Part 1 – Larvae). Entomol Scand Supp 19, 457p.

Pompeu P S, Alves C B M, Callisto M (2005) The effects of urbanization on biodiversity and water quality in the Rio das Velhas basin, Brazil. Am Fish Soc Symp 47: 11-22.

Roque F O, Corbi J J, Trivinho-Strixino S (2003) Macroinvertebrates on different technosubstrates in a stream of an urban area of São Carlos - SP, Brazil. Multiciência 5: 172-177.

Santos C M, Henry R (2001) Composição, distribuição e abundância de Chironomidae (Diptera, Insecta) na Represa de Jurumirim (Rio Paranapanema – SP). Acta Limnol Brasil 13: 99-115.

Sibley P K, Benoit D A, Ankley G T (1997) Life cycle and behavioural assessments of the influence of substrate particle size on *Chironomus tentas* (Diptera: Chironomidae) in laboratory assays. Hydrobiologia 361: 1-9.

Siqueira T, Trivinho-Strixino S (2005) Diversidade de Chironomidae (Diptera) em dois córregos de baixa ordem na região central do Estado de São Paulo, através da coleta de exúvias de pupa. Rev Bras Entomol 49: 531-534.

Trivinho-Strixino S, Strixino G (1995) Larvas de Chironomidae (Diptera) do estado de São Paulo: guia de identificação e diagnoses dos gêneros. São Carlos, PPG-ERN/UFSCar, 299p.

Trivinho-Strixino S, Strixino G (2005) Chironomidae (Diptera) do Rio Ribeira (divisa dos estados de São Paulo e Paraná) numa avaliação ambiental faunística. Entomol Vectores 12: 243-253.

Wiederholm T (1983) Chironomidae of the Holartic - keys and diagnoses (Part 1 – Larvae). Entomol Scand Supp 19: 1-457.

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