DISTRIBUTION AND ABUNDANCE OF CHIRONOMIDAE (DIPTERA, INSECTA) IN AN IMPACTED WATERSHED IN SOUTH-EAST BRAZIL

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ABSTRACT

Patterns of abundance and distribution of chironomid midges (Diptera, Chironomidae) in the middle Rio Doce basin were analysed. Human activities (mining, steel processing, and *Eucalyptus* spp. forestry) contribute to environmental degradation and low water quality in this watershed. Physical and chemical water traits (dissolved oxygen, pH, total alkalinity, electric conductivity, phosphorus and nitrogen concentrations) of 20 sampling points were used in a Principal Component Analysis (PCA) to establish the best and worst water quality. Sampling points recorded as the most polluted showed low genus richness of Chironomidae, less than five genera from the total 23, and dominance of the genus *Chironomus*, a bioindicator of environmental stress. Following *Chironomus*, the second most frequent and abundant genus was *Cricotopus*, whose distribution could not be related to pollution levels. The Tanypodinae sub-family showed certain sensitivity to low dissolved oxygen concentrations and high nutrients levels, and was not found at points of high pollution levels.

Key words: *Chironomus*, bioindicators, pollution.

RESUMO

Distribuição e abundância de Chironomidae (Diptera, Insecta) em uma bacia hidrográfica impactada no Sudeste do Brasil

Foram investigados os padrões de distribuição e abundância de larvas da família Chironomidae (Diptera, Insecta) ao longo do trecho médio da bacia do Rio Doce, onde as atividades de mineração, garimpo, siderurgia e monocultura de *Eucalyptus* spp. contribuem para a degradação ambiental e baixa qualidade de água. Utilizando-se as variáveis físicas e químicas (oxigênio dissolvido, pH, alcalinidade total, condutividade elétrica e as concentrações de nitrogênio e fósforo totais) de cada uma das 20 estações de amostragem, foi possível distinguir aquelas de pior e melhor qualidade de água, através da Análise de Componentes Principais (PCA). As estações apontadas como de pior qualidade apresentaram baixa riqueza de Chironomidae, menos de cinco gêneros de um total de 23, e dominância do gênero *Chironomus*, indicador de "stress" ambiental. Depois de *Chironomus*, o segundo gênero mais freqüente e abundante encontrado nessa bacia foi *Cricotopus*, cuja distribuição, no entanto, não foi atribuída à poluição. A subfamília Tanypodinae mostrou uma certa sensibilidade aos baixos teores de oxigênio dissolvido e altas concentrações de nutrientes, não sendo encontrada naquelas estações mais poluídas.

Palavras-chave: *Chironomus*, bioindicadores, poluição.

INTRODUCTION

The family Chironomidae is an important freshwater macroinvertebrate group due to its great abundance, high diversity, and presence in a majority of continental aquatic ecosystems (Epler, 1992). As detritivores chironomid larvae are essential to the circulation of nutrients in lakes and reservoirs and may in fact change the speed of the eutrophication process in the course of their feeding (Dévai, 1990). Furthermore, their quick generation turnover and rapid growth rate guarantee an availability of biomass to aquatic ecosystem dynamics (Menzie, 1981).

According to the "river continuum concept" (Vannote *et al*., 1980), in which functional groups distributed throughout a river are classified according to feeding habits, the Chironomidae family, excepting the predator species, should be best represented in quantitative terms in rivers of larger orders of magnitude. Chironomids tend to dominate, along with Oligochaeta and Hirudinea, in areas where there are influxes from organic sewers and low levels of oxygen (Fagundes & Shimizu, 1997). Here these groups can reach excessive densities, as observed by these authors in Sorocaba river, São Paulo State, and by Barbosa *et al.* (1997) in the middle Rio Doce basin.

Chironomidae has been used as indicadors of water quality since the beginning of the century after the introduction of the Saprobic System (Kolkwitz & Marsson, 1908, 1909, apud Chutter, 1972). Several biological indices concerning evaluation and monitoring of water quality rely heavily on them (Plafkin *et al*., 1990; Barbosa *et al.*, 1995, 1997). Changes in species composition, dominance of pollution tolerant species, and frequency of occurrance of deformities on larval head capsules, are some of the commonly used features in these types of evaluations (Johnson *et al*., 1993).

Although known to be important, knowledge on Chironomidae fauna in lotic ecosystems is still scarce in Brazil, since studies related to the benthic fauna in general and to Chironomidae in particular are, for the most part, restricted to lentic systems such as lagoons, lakes, dams, and reservoirs (Nessimian, 1995).

The present study intended to examine the distribution and abundance of Chironomidae larvae along the Piracicaba River, correlating this data with human impacts and water quality.

THE STUDY AREA

The Piracicaba river is situated in the eastern region of Minas Gerais State, Brazil, enclosing a 5,896 km^2 area and 22 municipalities. Approximately 700,000 people live in this region whose economy is based on three major activities: mining, reforestation (*Eucalyptus* spp.), and steel processing (Guerra, 1992). These activities along with an accelerating urbanization process are contributing to the increasing degradation of water bodies and their associated resources.

The predominant climate has two defined seasons: dry, from April until September, and rainy, from October until March. The topography is highly mountainous, thus faciliting erosive processes, also affecting the aquatic ecosystems in the area (Guerra, 1992).

In this area 20 sampling stations along the river were chosen (Fig. 1) in order to evaluate the major human impacts. A detailed description of these sampling areas including the predominant human activities and impacts is presented in Barbosa *et al.* (1997a).

MATERIAL AND METHODS

Collections were carried out at three dry and two wet seasons during the period July/1993-August/1995. The three first periods of collection (Jul/93, Dec/93, and Jul/94) included 15 sampling stations, while for the next two periods (Feb/95 and Aug/95) five more sampling stations were added. The last five sampling stations (16, 17, 18, 19, and 20) do not follow the spatial ordination down the basin, but they correspond to the sampling stations 6A, 7A, 9A, 10A, and 11C as described in Barbosa *et al*. (1997b).

Physical and chemical characterization of each sampling station was carried out by analyzing water samples collected from the subsurface and sediment collected from one of the margins. Concentration of dissolved oxygen (Winkler method), pH, temperature, electric conductivity, total alkalinity, total nitrogen and total phosphorus (according to Mackereth *et al.* (1978)), and the percentage of organic matter in the sediment (following Jackson (1974)) were determined and used in this characterization.

Benthic organisms were sampled with metallic nets (mesh < 1 mm) and an Ekman-Birge dredge at the same points and periods and fixed in 5% formalin. At the laboratory samples were washed and sorted out and the collected organisms fixed in 70% alcohol and deposited in the collection of benthic aquatic macroinvertebrates of the Institute of Biological Sciences, Federal University of Minas Gerais. The larvae of Chironomidae were identified at the genera level through the taxonomic keys of Oliver *et al.* (1978), Simpson & Bode (1980), Wiederholm (1983), Epler (1995), Trivinho-Strixino & Strixino (1995) and Cranston (1996). The results are expressed in terms of relative abundance (%) of each genus.

The values of physical and chemical analysis were used to ordinate the sampling stations and the periods of collection through the Principal Components Analysis (PCA) under a correlation matrix. The two defined main axes of this analysis were then used in a Canonical Correlation Analysis (CCA) together with data of abundance of the main sub-families of Chironomidae.

The numerical abundance of the sub-families was log-transformed for the accomplishment of this analysis.

RESULTS

Physical and chemical variables (Table 1) indicate enrichment with nutrients, mainly nitrogen, in sampling stations 9, 10, 11 and 19, suggesting an advanced degree of eutrophication in these stretches. Station 11 showed the highest recorded phosphorus concentrations, as well as the lowest oxygen levels.

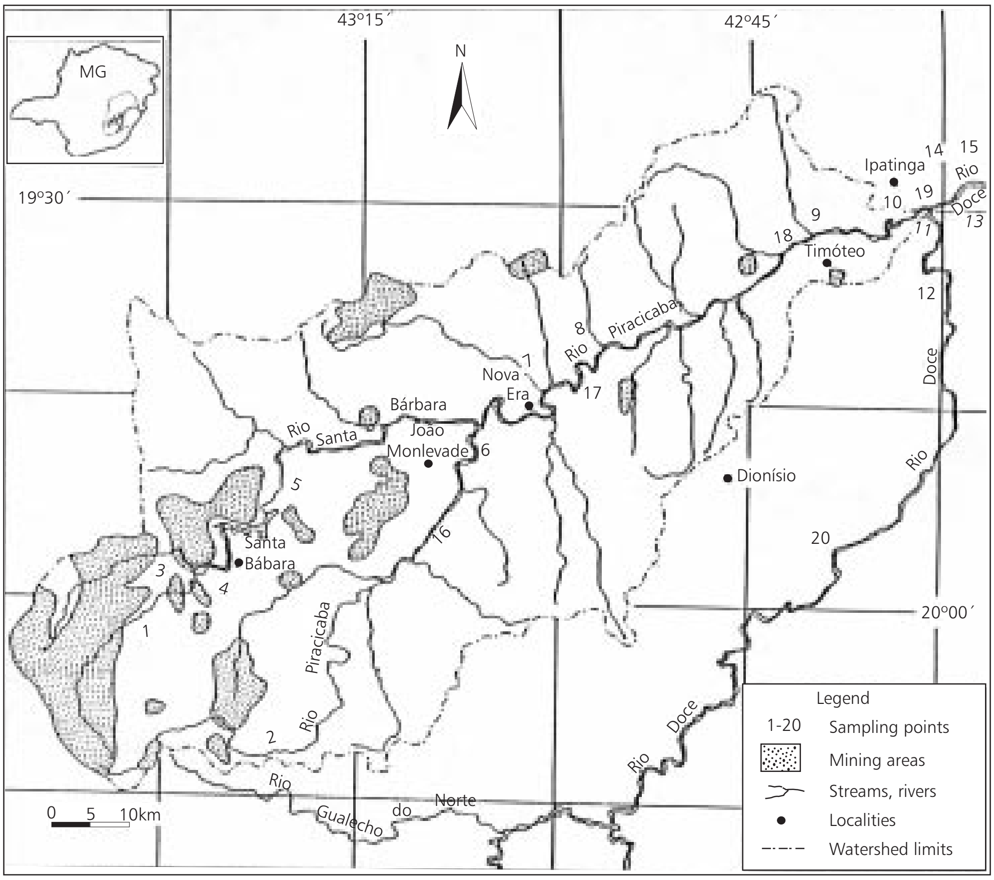

Fig. 1 — Map of the study area and sampling stations in the Rio Piracicaba basin.

TABLE 1

Physical and chemical traits in Rio Piracicaba basin sampling points. Average values for the five collecting seasons (1993/1995).

Point	Temper (ºC)	DO (mg/l)	pH	Conduct. (µS/cm)	Alkalinity ($meqCO_2/l$)	N-total µg/l	P-total µg/l	OMS %
1	17.3	9.9	3.8	17.2	0	262.4	30.3	0.2
2	20.9	8.8	7.1	59.6	0.4	420.6	72.0	3.5
3	20.1	6.6	8.6	121.6	1.0	1889	89.1	9.3
4	20.2	7.2	6.7	64.6	0.4	718.5	116.5	5.6
5	21.2	8.5	6.9	52.9	0.4	471.3	45.8	1.9
6	23.0	8.4	7.2	46.2	0.5	1219.3	146.5	5.5
7	20.0	9.2	7.0	45.5	0.3	1587	251.8	10.4
8	20.4	9.3	7.2	20.8	0.2	482.6	99.7	5.2
9	24.0	8.4	6.9	68.48	0.5	2132	103.9	6.2
10	25.9	7.7	6.9	115.6	0.4	3112	230.6	6.2
11	27.6	4.3	6.9	186.9	1.2	5257	400.5	5.8
12	25.1	9.6	7.1	43.84	0.5	454.3	101.7	6.6
13	24.3	8.3	6.9	54.0	0.2	1221	115.9	NA
14	25.0	8.2	6.9	120.3	0.5	837.8	128.7	4.9
15	25.1	9.1	7.2	70.52	0.4	538.9	166.6	7.2
16	22.1	9.5	6.4	24.1	0.2	136.2	32.8	–
17	23.3	24.4	6.7	45.5	0.3	574.5	69.4	–
18	25.3	8.8	6.5	42.1	0.3	775.6	60.2	–
19	27.0	1.3	6.8	119.6	1.6	7283	612.4	–
20	25.2	9.2	7.2	42.9	0.3	308.8	52.3	–

OMS = organic matter at sediment, DO = dissolved oxygen

On the other hand, the percentage of organic matter in the sediment was extremely low in station 1, exhibiting the highest values in stations 3 and 7.

The first two determined axes from PCA explain *ca.* 68% of the total data variation, and the first axis shows a strong positive correlation with total nitrogen, alkalinity, conductivity, and total phosphorus, and negative correlation with dissolved oxygen, thus indicating a direct pollution gradient, shown in Table 2. The second axis from the PCA only showed a strong negative correlation, with pH.

The graphical expression of this analysis (Fig. 2), suggests stations 1 and 3 as unique stations throughout the seasons, the last one, except in July of 1994, when it was in similar conditions to the remaining stations. Stations 10, 11, and 19, are also grouped in levels of higher pollution, though they do not form distinct groups. None of the remaining stations presented isolately physical or chemical features allowing their distinction, nor did they present marked differences between dry and rainy seasons.

A total of 23 genera of Chironomidae were identified from the sampling stations, a rather low figure due to the difficulties of identification of pupae and some particular groups (e.g. tribe Tanytarsini). The most frequent genera were: *Chironomus* and *Cricotopus* (88%), *Polypedilum* (82%), *Ablabesmyia* (76%), *Parachironomus* (65%), and *Cryptochironomus* (59%). Besides being most frequent, *Chironomus* and *Cricotopus* were also the most numerically abundant (Table 3).

The chironomid richness at each sampling station is shown in Fig. 3. Stations 4 and 5 exhibited the highest richness (17 and 15 genera respectively), while stations 17, 18, 19 and 20, showed the lowest values.

TABLE 2

Correlation of PCA axis and abiotic measures at Rio Piracicaba basin (1993/1995).

Abiotic measures	Axis 1	Axis 2
DO	–0.590	–0.210
Alkalinity	0.843	–0.207
Conductivity	0.815	–0.141
pH	0.365	–0.843
N-total	0.886	0.251
P-total	0.649	0.387
Explained variation	51%	17%

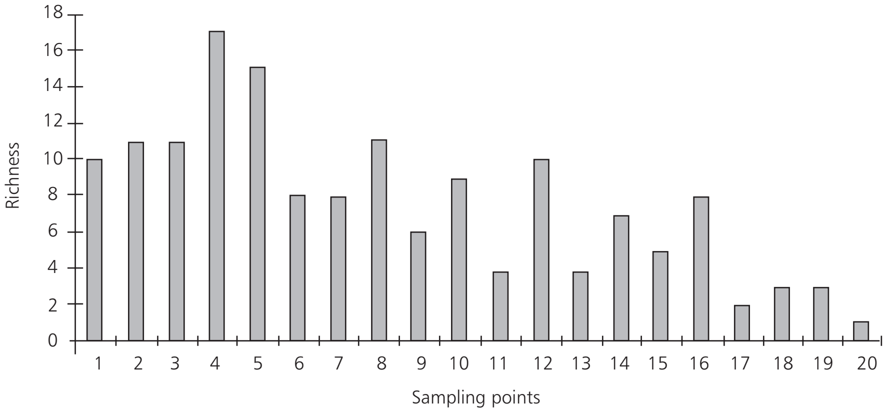

Fig. 2 — Graphical representation of the PCA showing sampling points and collecting periods.

The canonical correlation of Chironomidae sub-families and the extracted axes from PCA are significant only for the first canonic axis ($p < 0.05$, Table 4). The Chironomini tribe, represented mainly by *Chironomus* genus, and the first axis from the PCA show strong negative correlation with the first canonical axis, indicating, if not affinity for, at least some strong tolerance to eutrophic conditions. On the other hand, other sub-families, mainly Tanypodinae, are negatively associated with axis one thus demonstrating sensitivity to high pollution levels. The community structure did not show significant changes when separated according to dry and rain periods.

DISCUSSION

The canonic ordinance was successful only when explaining the distribution of the Chironomini tribe. As *Chironomus* is not only the most frequent but also the most abundant genus of the Chironomini, it had greater weight in the analysis and must be taken into account that it was responsible for such result.

The increase in density of larvae of the *Chironomus* genus in environments with eutrophic features has been registered in several types of ecosystems (Frank, 1963; Learner & Edwards, 1966; Devái, 1988; Tate & Heiny, 1995; Botts, 1997). All the stations with eutrophic features as determined by PCA (3, 10, 11 and 19) have *Chironomus* present and, with exception of station 10, this is the dominant genus.

The genus *Cricotopus* appears as dominant at stations 1, 5, 7, 10, and 15, stretches that have different trophic status and impact levels. Its distribution, therefore, cannot be primarily associated with water quality. Menzie (1981) recorded the dominance of *Cricotopus sylvestris* in *Myriophyllum*, corresponding to 80% of all associated larvae. Smiths & Young (1973), studying small ponds in England, also observed that this genus was common living in the vegetation of the margins. Dvorák (1996) found strong positive correlation between the abundance of *Cricotopus* and the biomass of diatoms on the surface of aquatic macrophytes. Thus, the distribution of this genus is more likely dependent on the presence of food supplies than the physical and chemical traits of the water column.

TABLE 3

Relative abundance of Chironomidae at sampling points in Rio Piracicaba basin, in the period 1993/1995.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Ablabesmyia	*	*	*	*	*	–	*	*	*	*	–	*	*	**	*	*	**	–	–	**
Alotanypus	–	–	*	–	–	*	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Djalmabatista	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	*	–	–	–	–
Fittkauimyia	–	*	–	*	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Labrundinia	–	–	–	*	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Monopelopia	–	*	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Pentaneura	*	–	–	–	*	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Tanypus	*	**	–	**	*	–	*	*	–	–	–	**	–	*	–	–	–	–	–	–
Tanypodinae NI	*	–	–	*	*	*	*	–	–	–	–	*	**	–	*	*	–	–	–	–
Corynoneura	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	*	–
Cricotopus	**	*	**	*	**	**	**	*	*	**	–	*	*	*	**	–	–	*	*	–
Nanocladius	–	*	*	–	*	*	*	*	–	*	–	–	–	–	–	–	–	–	–	–
Thienemanniella	–	–	*	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–		–
Orthocladiinae NI	–	–	–	*	*	*	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Asheum	–	–	*	*	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Chironomus	*	–	**	*	*	**	*	*	**	*	**	–	–	*	–	*	*	**	***	–
Cryptochironomus	–	*	*	*	*	–	*	*	*	–	–	*	–	*	–	*	–	–	–	–
Endochironomus	–	–	–	–	–	–	–	–	–	*	–	–	–	–	–	–	–	–	–	–
Goeldichironomus	*	–	–	–	*	–	–	*	–	*	*	*	–	–	–	–	–	–	–	–
Parachironomus	–	*	*	**	*	–	–	*	*	*	*	*	–	*	–	*	–	–	–	–
Paracladopelma	–	–	–	–	–	–	–	–	–	–	–	–	–	*	–	–	–	–	–	–
Polypedilum	*	*	*	*	*	*	*	*	*	*	*	*	*	–	**	**	–	–	–	–
Stenochironomus	–	–	–	*	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Tribelos	*	–	–	*	–	–	–	–	–	*	–	–	–	–	*	–	–	–	–	–
Chironomini NI	–	*	*	*	*	*	–	*	–	–	–	*	–	–	–	–	–	*	–	–
Tanytarsus	–	–	–	*	*	–	–	*	–	–	–	–	–	–	–	–	–	–	–	–
Tanytarsini g.var.	*	*	–	*	*	–	–	–	–	–	–	*	–	–	–	*	–	–	–	–
pupas NI	*	*	*	*	*	*	*	*	*	*	*	*	–	–	*	*	–	*	*	–

* relative abundance till 25%, ** relative abundance between 26 and 75%, *** relative abundance between 76%-100%, NI = not identified.

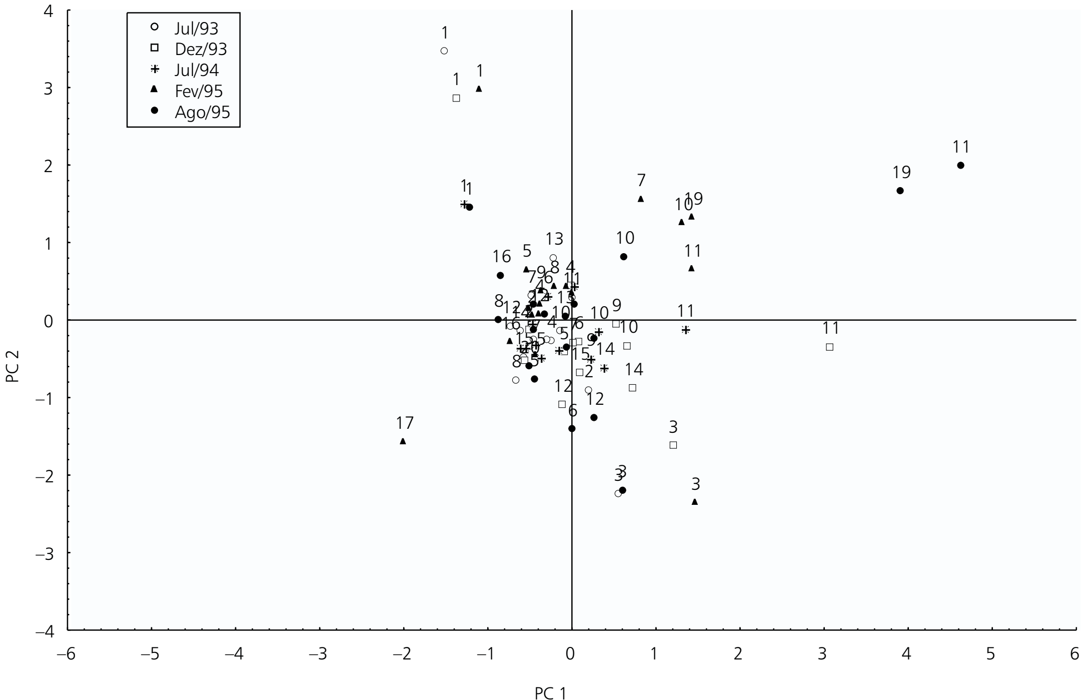

Fig. 3 — Genus richness of Chironomidae at the sampling stations of Piracicaba river during the rainy and dry seasons of 1993/1995.

TABLE 4

Canonical correlation of Chironomidae sub-families abundance and PCA axis 1 and 2.

Sub-family/tribe	**Canonic axis 1**	**Canonic axis 2**
Tanypodinae	0.460	–0.244
Orthocladiinae	0.207	–0.938
Chironomini	–0.724	–0.444
Tanytarsini	0.327	–0.002
PCA axis 1	–0.999	–0.015
PCA axis 2	0.015	–0.999
Canonical Correl. Coeficient	0.42	0.13
Chi-square	17.33	1.45
Freedom degrees	8	3
p value	0.02	0.69

Among the sub-families of Chironomidae, Tanypodinae are considered excellent predators. This is known in spite of, as recorded by Nessimian & Sanseverino (1995), the presence of fragments of vegetation and algae (Desmidiaceae, Cyanophyceae, Diatomaceae and Chlorophyceae) that can be found in its digestive system. Wolfram (1996) states that the main genus of Tanypodinae found in Neusiedler See, Austria, did not have its distribution limited by sediment type or by the concentration of nutrients in the sediment, though a slight preference for small compact sediments was shown. In this case, the horizontal distribution of the organisms inside the lake is attributed to the trophic relationships of the community. In the present work it was not possible to distinguish an evident pattern linking the distribution of Tanypodinae to water quality. However, it is interesting to note that the stations characterized as eutrophic by the PCA have a very low richness of Tanypodinae: stations 19 and 11 have no representatives of this sub-family.

All the Chironomidae genera in this study are considered common and tolerant to a wide array of environmental conditions. However, only the Chironomini sub-family, due to bulk presence of *Chironomus*, showed significant increase in abundance in response to organic enrichment by antropic action and consequent deterioration of water quality.

Such a result demonstrates the necessity of preventing generalizations of taking the whole Chironomidae family as indicator of degraded environments.

The present data allow the conclusion that only the genus *Chironomus* is a reliable indicator. Future studies on water quality must use the identification at the level of genus in order to assess the "biological status" of a water body.

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