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Bioassessment using benthic macroinvertebrates of the water quality in the Tigreiro river, Jacuí Basin

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ABSTRACT. This study aimed to evaluate the water quality in the Tigreiro river, Jacuí river Basin, using different approaches. Benthic macroinvertebrates were sampled in July 2010 (winter) and February 2011 (summer) at five sites. In this study were analyzed: microbiological, physical and chemical variables, benthic macroinvertebrates richness and diversity, rapid ecological assessment protocol and benthic biotic indices (% EPT, BMWP'-IAP, ASPT, SOMI). A total of 5,852 individuals were collected belonging to 31 taxa of three Phyla: Annelida, Mollusca and Arthropoda. Chironomidae was the most abundant taxon (63.70%). A reduction in richness, diversity H' and evenness J' was observed from the initial stretches to the end stretches of Tigreiro river. The use of different approaches showed that sites in the rural area were less altered. The Tigreiro river was strongly impacted, mainly due to discharge of domestic effluents in the urban area, and the combination of different metrics was useful to detect impacted sites and the consequence for the water quality.

Keywords: Chironomidae, diversity, benthic biotic indices, domestic effluents, % EPT.

Bioavaliação por macroinvertebrados bentônicos da qualidade da água no rio Tigreiro, Bacia do Jacuí

RESUMO. O objetivo deste estudo foi avaliar a qualidade de água do rio Tigreiro, bacia do rio Jacuí, pelo uso de diferentes abordagens. Macroinvertebrados bentônicos foram coletados em julho/2010 (inverno) e fevereiro/2011 (verão) em cinco pontos. Neste estudo foram analisados: variáveis microbiológicas, físicas e químicas, riqueza e diversidade de macroinvertebrados bentônicos, protocolo de avaliação ambiental rápida e índices bióticos de bentos (% EPT, BMWP'-IAP, ASPT, SOMI). Foram coletados 5.852 indivíduos pertencentes a 31 taxa de três Filos: Annelida, Mollusca e Arthropoda. Chironomidae foi o taxon dominante (63,70%). A redução de riqueza, diversidade H' e uniformidade J' ocorreram da porção inicial em direção à porção final do rio Tigreiro. O uso das diferentes abordagens mostrou que os pontos da área rural foram menos modificados. O rio Tigreiro apresentou-se fortemente impactado, principalmente pela descarga de esgotos domésticos na área urbana e o uso de diferentes métricas foi útil para detectar locais impactados e suas consequências para a qualidade de água.

Palavras-chave: Chironomidae, diversidade, índices bióticos de bentos, esgotos domésticos, % EPT.

Introduction

The urbanization and expansion of cities have progressively resulted in deteriorating freshwater conditions. Urban watersheds have been studied to assess multiple environmental impacts in these surrounding areas (MORENO; CALLISTO, 2006). Multiple human impacts include artificial eutrophication, siltation, homogenization of the river channel, construction of dams, removal of riparian vegetation and introduction of alien species (CAMARGO et al., 2004; HALL et al., 2006). The importance of rivers as a source of drinking water, recreation and food is well recognized, on the other hand, is growing the degradation of aquatic ecosystems.

Studies worldwide show that benthic macroinvertebrates are generally good bioindicators of water quality in streams impacted by urbanization, where the distribution, occurrence and abundance depend on the environmental characteristics, like flow, substrate, food availability, refuge and environment stability (BACEY; SPURLOCK 2007; HEPP et al., 2010; NIYOGI et al., 2007; SMITH; LAMP 2008). Benthic macroinvertebrates are the most commonly community used as a bioindicator of water quality (BONADA et al., 2006), because they have several characteristics that make them easy the study, and show clear responses when faced with adverse environmental conditions (MORENO et al., 2009). Furthermore, they have an important role in the trophic structure of aquatic ecosystems, feeding on living or decaying organic matter and serving as food for invertebrate (MOULTON et al., 2010) and fish species (COPATTI et al., 2012).

At the end of the 1980s, special attention was focused on benthic macroinvertebrates in the development of biotic indices using the score system (BAPTISTA et al., 2007) for evaluating water quality in rivers. A higher resolution tends to be used in most studies, given its more favorable cost-benefit ratio in comparison with the identification of species (BUSS; VITORINO, 2010). Final site evaluations provided by multimetric indices are very important to communicate complex ecological information based on multiple variables to decision makers and to help establishing important environmental conservation actions (DAVIES; JACKSON, 2006; FERREIRA et al., 2011; PAULSEN et al., 2008).

The use of micro- and macrobiological evaluators, as well as physical and chemical variables together with benthic biotic indices is important for assessing the water quality in rivers. Furthermore, there are no studies like this in Espumoso, Rio Grande do Sul State, specifically in the Tigreiro river, Jacuí Basin, that crosses the urban area, receiving domestic sewage and other pollutants, without any treatment. Thus, the present study aimed to evaluate the water quality in the Tigreiro river in Espumoso, Rio Grande do Sul State, using different tools and predicts that habitat degradation due to anthropic activities leads to loss of benthic diversity.

Material and methods

Study sites

The field investigations were undertaken in Tigreiro river (2nd order river, Jacuí Basin, Atlantic Forest Biome, 380 m altitude approximately) which serves as a dumping of domestic sewage for Espumoso, Rio Grande do Sul State (Southern Brazil, subtropical region). It presents an average width of 2-4 m and depth of 15-30 cm, and is mostly characterized as lotic, with the presence of some lentic stretches.

We analyzed five sites at the Tigreiro river (Figure 1). The sites 1 (near the source) (28º46'32.06" S and 52°49'29.11" W) and 2 (28º45'46.32" S and 52°49'42.19" W) are located in the rural area, the site 3 is located in the entrance to the urban area (28º44'13.11 S and 52°50'41.35" W) and sites 4 (28º43'37.83" S and 52°50'59.93" W) and 5 (near the mouth) (28º43'32.75" S and 52°51'08.77" W) are located in the urban area.

Figure 1. Sampling sites at the Tigreiro river (GOOGLE EARTH, 2012).

In the site 1, riparian vegetation does not exist and planting areas alternate with pastures surrounding the area, the bottom is sandy-muddy. At the site 2, riparian vegetation has 5-10 m, with native vegetation, and the bottom is mainly stony. Besides, there are agricultural areas nearby. In the sites 3 and 4, riparian vegetation is almost absent (below 3 m), with exotic vegetation. Dwellings are very close and there is sewage discharge. Here the river bottom is sandy-muddy- stony. The site 5 is similar to 3 and 4, but the riparian vegetation is native.

Benthic macroinvertebrates

Benthic macroinvertebrates within a 10 m stretch were considered. Individuals were sampled in July 2010 (winter) and February 2011 (summer). Specimens were randomly sampled in different substrates (six rock samples in the central region and four sand and leaf litter samples in the marginal region) with a Surber sampler (0.1 m^2 area, 250 µm mesh net). At each sampling stretch, 10 pseudoreplicates were collected. Subsequently, samples were preserved in 10% formaldehyde solution in labeled plastic vials for further analysis. Afterwards the material was taken to the Entomology laboratory of the Unicruz (University of Cruz Alta), for screening.

The specimens (family level, except Annelida - class level) were later identified using Cummins et al. (2005), Melo (2005) and Domínguez and Fernández (2009) as reference. According to Melo (2005) and Corbi and Trivinho-Strixino (2006), identification of benthic macroinvertebrates to family level for biomonitoring purposes do not compromise the results. The identified material was stored in 80% ethanol.

Environmental variables

In the field, the dissolved oxygen (mg L^{-1}) was measured with an YSI-55 Oximeter. In the laboratory were analyzed the following microbiological, physical and chemical variables of the water: thermotolerant coliform (nmp 100 mL^{-1}), total coliform (nmp mL^{-1}), heterotrophic mesophilic bacteria (ufc mL^{-1}), alkalinity (mg L^{-1} $CaCO_3$), ammonia (mg L^{-1} NH_3), and pH. Analyses were made according to Clesceri and Greenberg (2005).

Benthic biotic indices

Benthic biotic indices used to assist the evaluation of water quality were:

% EPT: % Ephemeroptera, Plecoptera and Trichoptera (MANDAVILLE, 2002), where the individual abundances of these orders reflects the water quality, because, in general, most of these organisms are more sensitive to organic pollution;

BMWP'-IAP index: Biological Monitoring Work Party System by IAP (Instituto Ambiental do Paraná) (IAP, 2007) classify families of aquatic macroinvertebrates into groups by following a gradient from lower to higher tolerance of organisms to organic pollution;

ASPT index: Average Score Per Taxon (BAPTISTA, 2008; MANDAVILLE, 2002) calculates the ratio of the value obtained by calculating the sum total of BMWP'-IAP and the number of families scored in the sample, being less influenced by the size of the river;

SOMI: Development of the Serra dos Órgãos Multimetric Index (BAPTISTA et al., 2007) is a multimetric index that considers % Diptera, % Coleoptera, Family Taxa, EPT Taxa, BMWP' and % Shredders. BMWP' was adapted to BMWP'-IAP.

The BMWP'-IAP and SOMI indices were built to Atlantic Forest Biome in other regions of the Brazil, but they worked also to the characteristics of the area of this study. Besides, was used Rapid Ecological Assessment Protocol - REAP (CALLISTO et al., 2002) that assesses the water and sediments characteristics, land use, riparian vegetation, size and frequency of riffles and pools and the conservation status.

Data analysis

The rarefaction richness, Shannon diversity index (H') and Pielou evenness index (J') were calculated utilizing Biodiversity Pro (McALEECE et al., 1997). The rarefaction richness was calculated for the lowest abundance considering the two samplings (626 individuals in the site 1). Relationships between sites and richness, rarefaction richness, diversity H' or evenness J', as well as between diversity and richness or individual abundances were determined with the Sigma Plot 11.0 software. Comparisons for differences in richness and individual abundances between months and sites were performed by one-way analysis of variance considering each pseudoreplicate and Duncan test, using the software Statistica 7.1 ($p < 0.05$).

Results

A total of 5,852 individuals were collected belonging to 31 taxa of three Phyla: Annelida (Oligochaeta and Hirudinea), Mollusca (Gastropoda) and Arthropoda (Crustacea and Insecta).

In Arthropoda, Crustacea was represented by the order Decapoda and Insecta was represented by eight orders (Diptera, Trichoptera, Plecoptera, Ephemeroptera, Coleoptera, Odonata, Hemiptera and Megaloptera). Chironomidae was the dominant taxon for the sites 1 (58.31%), 3 (67.75%), 4 (77.13%) and 5 (90.27%). In the site 2, Hydropsychidae was the dominant taxon (38.18%), followed by Chironomidae (18.78%). In total, Chironomidae presented 3,728 individuals (63.70% of total individuals) and was the only taxon present in all samples. In July 2010 and February 2011 were collected 2,898 and 2,958 individuals and 23 and 25 taxa, respectively. In the sites 1 and 5 were collected the minor and major number of individuals, 626 and 2014 individuals, respectively (Table 1). There were no significant differences between the sites as for individual abundances.

The sites 4 and 5 presented 10 and 9 taxa, respectively; on the other hand, the sites 1 and 2 presented 27 and 29 taxa, respectively. The richness was significantly higher in the sites 1 and 2. The richness in the site 3 (18 taxa) was significantly higher than of sites 4 and 5. The reduction in the total richness, rarefaction richness (626 individuals), diversity H' and evenness J' from the initial stretches towards the end stretches of Tigreiro river can be also seen in the Figure 2.

Besides, the diversity H' was significantly correlated with the richness considering rarefaction ($r^2 = 0.93$; $p < 0.001$) or no rarefaction ($r^2 = 0.98$; $p < 0.008$), although no relationship was detected between the diversity and the individual abundances ($r^2 = 0.13$; $p > 0.05$).

Table 2 lists values of REAP and benthic biotic indices (% EPT, BMWP'-IAP, ASPT and SOMI) in the Tigreiro river for the water quality and presents a final evaluation based on the average of the indices. The microbiological, physical and chemical variables in the Tigreiro river are shown in Table 3.

Table 1. Benthic macroinvertebrates in the Tigreiro river.

Major group	Family	Site										Total
		1	2	3	4	5	1	2	3	4	5	
		July 2010					February 2011					
Oligochaeta		14	12	1	-	2	2	10	1	7	22	71
Hirudina		-	-	-	2	4	8	2	1	27	43	87
Gastropoda	Hydrobiidae	-	-	-	2	14	20	-	4	148	75	263
Decapoda	Aeglidae	-	5	4	-	-	9	13	6	-	-	37
Ephemeroptera	Baetidae	26	58	6	1	3	-	8	3	-	-	105
	Leptophlebiidae	16	41	6	-	-	6	124	44	-	-	237
	Tricorythidae	-	-	-	-	-	-	5	10	-	-	15
Odonata	Aeshnidae	-	-	-	-	-	1	-	-	-	-	1
	Libellulidae	-	-	-	-	-	15	7	-	-	-	22
	Coenagrionidae	1	3	-	-	-	-	-	-	-	-	4
	Lestidae	1	3	-	-	-	-	-	-	-	-	4
	Corduliidae	1	1	-	-	-	6	4	3	-	-	15
Plecoptera	Perlidae	1	4	2	-	2	-	-	-	-	-	9
	Gripopterygidae	3	14	7	-	-	-	4	-	-	-	28
Hemiptera	Veliidae	1	1	1	-	-	3	-	-	-	-	5
	Belostomatidae	-	-	-	-	-	1	-	-	-	-	1
	Gerridae	-	-	-	-	-	1	52	-	-	-	53
Megaloptera	Corydalidae	-	-	-	-	-	-	13	-	-	-	13
Trichoptera	Hydropsychidae	34	180	30	5	10	24	379	78	-	2	742
	Philopotamidae	3	12	-	-	-	-	1	-	-	-	16
	Helicopsychidae	-	5	-	-	-	-	-	-	-	-	5
Diptera	Culicidae	4	3	2	1	1	-	-	-	-	-	11
	Chaoboridae	4	1	-	-	-	-	-	-	-	-	5
	Chironomidae	341	188	351	446	778	24	87	231	242	1040	3728
	Simuliidae	30	62	51	9	18	-	14	3	-	-	188
Coleoptera	Dryopidae	4	51	1	1	-	10	22	7	-	-	96
	Hydrophilidae	1	1	1	-	-	4	-	-	-	-	7
	Curculionidae	-	-	-	-	-	-	1	-	-	-	1
	Elmidae	-	-	-	-	-	2	51	3	-	-	56
	Scirtidae	1	1	-	-	-	-	1	-	-	-	3
	Psephenidae	-	2	-	-	-	4	16	2	-	-	24
Total individuals		486	648	463	468	832	140	816	396	424	1182	
Total taxa		18	21	13	9	9	17	21	14	4	5	

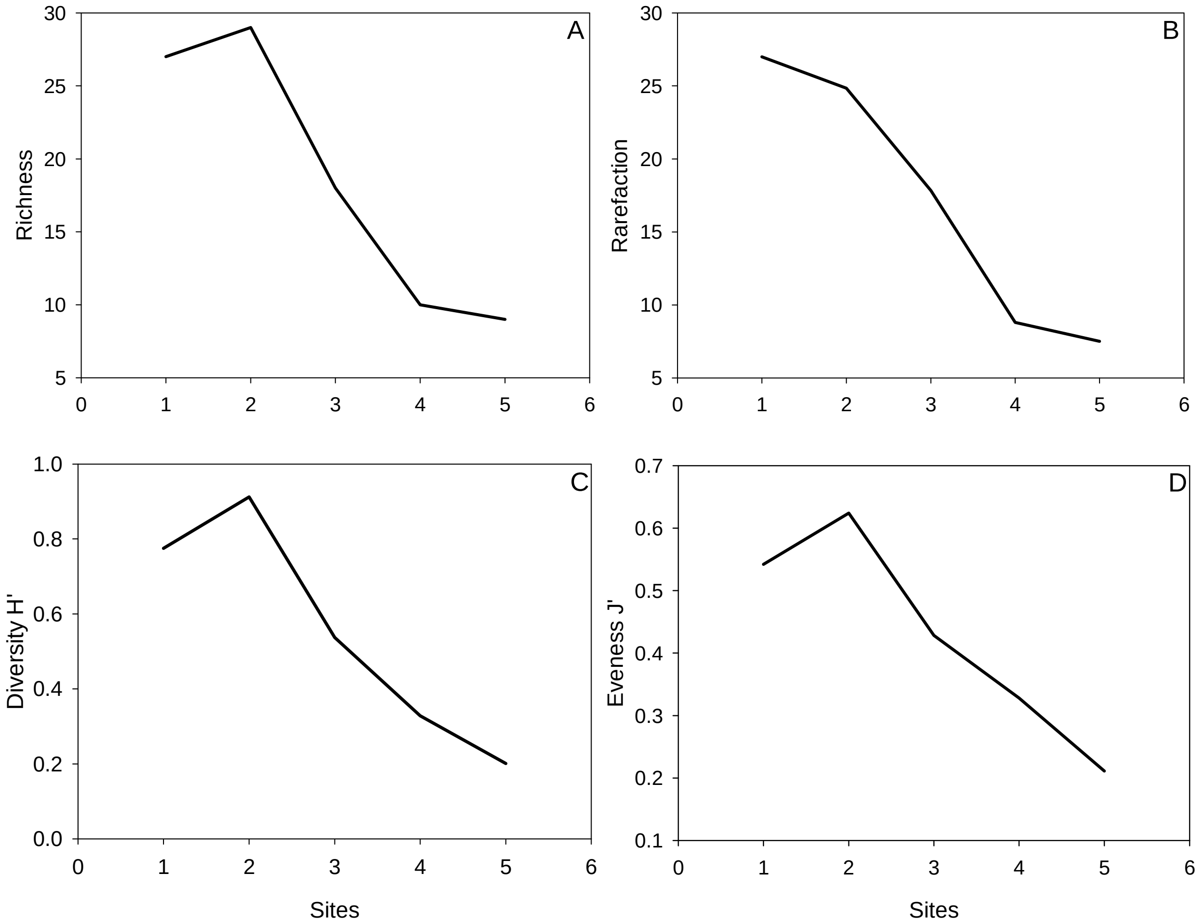

Figure 2. Relationship between site and richness (A), rarefaction richness (B), diversity H' and evenness J' (D). The following equations were fitted to the data: A: y= 33.71-5.50x, r^2= 0.93; B: y= 35.10-5.50x, r^2= 0.84; C: y= 1.07-0.17x, r^2= 0.80; D: y= 0.71-0.10x, r^2= 0.80; where: x= sites.

Table 2. Values of REAP and benthic biotic indices (% EPT, BMWP'-IAP, ASPT and SOMI) in the Tigreiro river for water quality. G = Good. R = Regular. B = Bad. VD = Very Bad. Values in parentheses refer to score.

Index	Sites				
	1	2	3	4	5
REAP	R (54)	R (59)	B (36)	B (33)	B (35)
% EPT	B (18.05)	G (57.03)	B (21.65)	VB (0.78)	VB (0.84)
BMWP'-IAP	G (137)	G (148)	R (94)	VB (29)	VB (34)
ASPT	R (4.72)	G (5.10)	R (4.94)	VB (2.90)	B (3.78)
SOMI	R (18)	G (22)	VB (8)	VB (8)	VB (6)
Final evaluation	R	G	B	VB	VB

Table 3. Microbiological, physical and chemical variables in the Tigreiro river.

Variables	Site									
	1	2	3	4	5	1	2	3	4	5
	July 2010					February 2011				
Dissolved oxygen	8.7	9.3	6.9	5.2	6.1	9.1	9.7	7.0	5.6	5.9
Alkalinity	45	45	50	60	60	45	45	50	50	50
Ammonia	0.0	0.0	0.5	1.5	1.25	0.0	0.0	0.75	1.75	1.5
pH	6.5	6.5	7.2	7.5	7.5	6.5	6.5	7.0	7.2	7.2
Total coliform	0	0	9	460	460	0	0	3	93	7
Thermotolerant coliform	0	0	9	460	240	0	0	2	4	3
Heterotrophic mesophilic	50	50	580	>1,000	>1,000	50	50	5	500	5

Discussion

Patterns of benthic macroinvertebrates for the assessment of water quality are available for various Brazilian rivers, but researches seeking to integrate these patterns are not as common as well. Although there were no significant differences between the sites for individual abundances, the taxa richness was significantly higher in the sites 1 and 2. The sites contained a larger number of individuals from a sole family (Chironomidae), which was reflected in the lowest evenness index for all the sites (Figure 2), lowest final evaluation of benthic biotic indices (Table 2) and worst microbiological, physical and chemical variables (Table 3).

Chironomidae are common organisms of most aquatic habitats, and often dominate aquatic insect communities in abundance and has individuals resistant to disturbances in the water (FERRINGTON JR., 2008; HEINO; PAASIVIRTA, 2008; RAUNIO et al., 2011) and the inclusion of Chironomidae improves the chance to detect human disturbances in these medium sized rivers (RAUNIO et al., 2011). Studies have shown Chironomidae as one of the dominant taxa in natural (COPATTI et al., 2010; HEPP et al., 2010; OLIVEIRA; CALLISTO, 2010; RIBEIRO; UIEDA, 2005) or non-natural environments (MORENO; CALLISTO, 2006; HEPP et al., 2010; SILVEIRA et al., 2011).

However, for being a group with many species and wide distribution, the discharge of domestic sewage into Tigreiro river may have favored its occurrence, but in accordance with to Ferrington Jr. (2008), factors identified as contributing to regional richness include (1) ecological heterogeneity, (2) size of stream, (3) altitude, (4) latitude and (5) “biogeographical potential” must be also taken into account. Roque et al. (2010) verified the importance of local and landscape variables, as well as the spatial relationships between sampling sites, for explaining aquatic insect community (Chironomidae) patterns in streams.

The initial stretches (not receiving the input of urban pollutants) presented a higher taxa richness, characteristic of less disturbed environments. The final stretches presented a lower richness, with high predominance of Chironomidae. High richness in preserved habitats and low richness in impacted habitats were found in other works (BUENO et al., 2003; COPATTI et al., 2010; COUCEIRO et al., 2007; HEPP et al., 2010; ILMONEN; PAASIVIRTA, 2005). Azevedo et al. (2012) concluded that richness, diversity, evenness and density values of benthic macroinvertebrates have varied according to environmental changes in the Mato Grosso river.

Besides that, the site 3 had already shown a reduction in richness, diversity H’ and evenness J’ in comparison with the sites 1 and 2 located in the rural area. This reduction intensifies when the Tigreiro river nears its mouth. From the site 3, there was an increase in the discharge of domestic sewage into Tigreiro river, which represents a strong impact for many benthic macroinvertebrates (Figure 2). The richness and evenness are key elements in the evaluation of diversity, and with the same richness, communities in which there are no dominant species have a higher diversity (SIEGLOCH et al., 2008).

In this study, the lowest diversity and richness in the final stretches were influenced by a high dominance of few taxa. A common result of urbanization and other human activities in stream ecosystems is a reduction in the number of taxa with low tolerant to changes in the water quality, together with an increase in the number of pollution-tolerant taxa (SMITH; LAMP, 2008). Changes in the diversity and richness of benthic macroinvertebrates in the Tigreiro river may be related to the frequency of disturbances or disorders in the environment, because only few groups support these disturbances. Similarity, Moreno and Callisto (2006) verified in an urban reservoir in southeastern Brazil an environmental degradation as a result of the intense discharge of domestic sewage into the streams, leading to low values of richness and diversity and high densities of tolerant organisms.

The use of biological protocols, physical and chemical variables and analysis of the environment is important to diagnose degradation of rivers (MORLEY; KARR 2002). The use of REAP is an important mechanism for the development of monitoring and environmental restoration programs. The REAP of Callisto et al. (2002) and benthic biotic indices applied in the present study indicated that no site showed a very good quality, but the site 2 has showed a good water quality for most parameters. The analysis of the indices used also revealed that sites 1, 3, 4 and 5 presented respectively regular, bad, very bad and very bad water quality (Table 2).

Data presented in Table 2 agree with the Figure 2, once sites with higher diversity were also those with better final assessment for the water quality. The use of REAP in the Tigreiro river indicated that no site has kept the natural characteristics, although the sites 1 and 2 presented less alteration in the original habitats (Table 3). The main factors that tend to accelerate environmental stress in the

Tigreiro river were: reduction and/or absence of riparian forest, erosion of margins, siltation of river bed, close agricultural areas (sites 1 and 2) and domestic sewage discharge and urbanization (sites 3, 4 and 5) (COPATTI; COPATTI, 2011; HEPP et al., 2010; MOORE; PALMER, 2005; PARK et al., 2011). Streams under urban influence receive considerable amounts of organic waste (ROY et al., 2003) that can influence the loss of water quality, as verified in the Tigreiro river.

EPT orders receive greater importance in biomonitoring studies due to their sensitivity to pollution and their frequency has been lower in impacted environments (BACEY; SPURLOCK 2007; CRISCI-BISPO et al., 2007), because these organisms tend to decrease in numbers or even disappear in regions where sources of (urban) pollution are introduced (HEPP et al., 2010). In this study, the % EPT orders showed severe situations in the Tigreiro river, except for the site 2 (Table 2). The EPT may have been affected by reduced riparian forest, because in the site 2, the riparian forest was less reduced than in other sites. This situation added to agricultural areas nearby (sites 1 and 2), domestic sewage discharge and urbanization (sites 3, 4 and 5) may have affected EPT.

The presence of environmental impacts, particularly resulting from the discharge of wastewater at the site 3, is so pronounced that the environment can no longer maintain its natural characteristics. As a result, many organisms with sensitivity to pollution cease to occur and this is also reflected by evaluating the BMWP'-IAP, ASPT and SOMI indices. Although all sites have shown some degradation, the sites 1 and 2, without influence from the discharge of domestic sewage were less affected (Table 2).

The benthic biotic index needs integrated tools, including water chemical analysis, environmental integrity assessment and biological information (BAPTISTA et al., 2007). Rare species may be affected by variables that are difficult to measure, particularly biotic factors (SIQUEIRA et al., 2012), whereas common species may respond mainly to conspicuous environmental variables (LENNON et al., 2011). For this study, since benthic macroinvertebrates respond strongly to localized variation in water (HEINO; MYKRÄ, 2006), we also evaluated microbiological, physical and chemical variables in the Tigreiro river (Table 3), which affect the occurrence and distribution of benthic macroinvertebrates (PEETERS et al., 2004).

In the rural area (sites 1 and 2) there was no contamination evidenced. In the sites 4 and 5, occurred the most worrisome values of microbiological variables (total coliform, thermotolerant coliform and heterotrophic mesophilic), ammonia and dissolved oxygen. The contamination can already be seen at the site 3 (Table 3). Physical and chemical variables analyzed corroborate with the indices and multimetric approaches data (Table 2) and diversity values (Figure 2), because the sites with better microbiological, physical and chemical variables of water quality (1 and 2) were those that had the highest diversity and the best final evaluation by benthic biotic indices. According to Hering et al. (2006), benthic macroinvertebrates are more directly affected by oxygen condition and showed significant response to eutrophication/organic pollution gradients in 185 streams in nine European countries, but responses to land use and hydromorphology were less strong. Urban streams have lower concentrations of dissolved oxygen and higher concentrations of ammonia, affecting the distribution and occurrence of the EPT orders (OMETTO et al., 2004). This was also verified in this study (Table 2).

These data reinforce the idea that Tigreiro river presents eutrophic characteristics from the stretch it enters into the urban area, affecting the structure of benthic macroinvertebrates. Higher impacts are represented by raw domestic effluents discharged into the Tigreiro river. The environmental evaluation proposed by this study is an efficient and low cost approach and can be applied in other studies. It integrates biological and environmental parameters and diversity and benthic biotic indices and encourages the use of ecological assessment protocols as an effective measure to determine the environmental quality in small rivers, mainly those under anthropogenic impacts.

Conclusion

The Tigreiro river was impacted by human activities mainly in the urban area. It was demonstrated by a combination of different metrics to detect impacted sites and the consequence for the water quality.

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