

Water quality characterization of urban streams using benthic macroinvertebrate community metrics

Caracterização da qualidade da água de córregos de uma área urbana utilizando métricas da comunidade de macroinvertebrados bentônicos

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Abstract: Aim: The aim of this study was to evaluate the water quality of streams in the urban area of Uberlândia - MG, using metrics of benthic macroinvertebrate communities, and to identify the metrics that better respond to the differences in environmental quality of the studied streams; **Methods:** Four streams were studied and three sampling sites were set in each one. The Cabeceira do Lageado stream (Stream 1) is located in a Natural Reserve and the Buritizinho (Stream 2), Lobo (Stream 3) and Bons Olhos (Stream 4) streams are located in the urban area. We evaluated the ecological conditions of the sites through a rapid assessment protocol and calculated the indices BMWP, Shannon-Wiener diversity, Pielou evenness, taxa richness, percentage of EPT, Chironomidae and Oligochaeta. These metrics were compared among streams, sites and sampling times using a three-way ANOVA without replication and the relationship between the metrics was held by a Principal Components Analysis (PCA); **Results:** Stream 1 was the only one classified as a natural area in all sampling sites, while the other streams were classified as impacted and altered. There was a significant difference in richness among sites. Stream 1 had higher values of BMWP index and percentage of EPT than Streams 2, 3 and 4. No difference was detected in diversity, evenness and in the percentage of Chironomidae among streams, sites or seasons. The percentage of Oligochaeta was higher in Stream 3 than in Streams 1 and 4. In the PCA, Stream 1 was separated from the others in axis 1, mainly by the % of EPT, richness and BMWP; **Conclusions:** The metrics % EPT, richness and BMWP better reflected the environmental quality of streams, referring to the good quality of Stream 1, followed by Stream 4, and to worst condition the Streams 2 and 3.

Keywords: benthic macroinvertebrates, environmental evaluation, biotic indices, lotic systems, BMWP.

Resumo: Objetivo: O objetivo deste estudo foi avaliar a qualidade da água de córregos da área urbana de Uberlândia - MG, utilizando métricas das comunidades de macroinvertebrados bentônicos, além de verificar quais métricas respondem melhor em relação às diferenças na qualidade ambiental dos córregos estudados; **Métodos:** Estudou-se quatro córregos, nos quais foram estabelecidos três setores de amostragem. O córrego Cabeceira do Lageado (Córrego 1) situa-se em uma Reserva Ecológica e os córregos Buritizinho (Córrego 2), Lobo (Córrego 3) e Bons Olhos (Córrego 4) estão localizados na malha urbana. Foram avaliadas as condições ecológicas dos locais através de um protocolo de avaliação rápida e calculados os índices BMWP, diversidade de Shannon-Wiener, equidade de Pielou, riqueza de taxa, percentagem de EPT, Chironomidae e Oligochaeta. Comparou-se essas métricas entre córregos, setores e períodos de amostragem utilizando-se ANOVA de três fatores sem replicação e a relação entre as métricas foi realizada por meio de uma Análise de Componentes Principais (PCA); **Resultados:** O córrego 1 foi o único que obteve em todos os setores a classificação de área natural, enquanto os demais córregos foram classificados como impactados e alterados. Houve diferença significativa na riqueza entre setores de amostragem. O córrego 1 teve maiores valores do índice BMWP e de percentagem de EPT que os córregos 2, 3 e 4. Não foi detectada diferença na diversidade, equidade e na percentagem de Chironomidae entre os córregos, setores e estações. A percentagem de Oligochaeta foi maior no córrego 3 que nos córregos 1 e 4. Na PCA o córrego 1 separou-se dos demais no eixo 1, principalmente pela % de EPT, riqueza e BMWP; **Conclusões:** As métricas % EPT, riqueza e BMWP refletiram melhor a qualidade ambiental dos córregos, remetendo à boa qualidade do córrego 1, seguida do córrego 4, e em piores condições os córregos 2 e 3.

Palavras-chave: macroinvertebrados bentônicos, avaliação ambiental, índices bióticos, sistemas lóticos, BMWP.

1. Introduction

The biological assessment has been widely used in programs for monitoring and management of quality and integrity of aquatic ecosystems, complementing traditional physical and chemical methods (Karr, 1999; Linke et al., 2005). In Europe and North America the use of bioindicators to monitor watersheds is already an usual practice, governed by technical standards (Junqueira et al., 2000). The biomonitoring of water bodies using benthic macroinvertebrates has been increasingly used and accepted as an important tool in assessing water quality (Callisto, 2000; Goulart and Callisto, 2003).

The organisms living in a given ecosystem are adapted to their environmental conditions, and therefore should reflect the level of preservation of natural conditions or changes caused by the emission of environmental pollutants (Hynes, 1974). In general, the greater the intensity of environmental impacts, more intense are the ecological responses of the communities, with changes in the relative abundance of some groups, population increases of opportunistic organisms or even the exclusion of species (Margalef, 1983; Callisto et al., 2001).

The assessment of environmental quality through the community of benthic macroinvertebrates is based on the use of biotic indices and metrics that can provide important information about the environmental status of the aquatic ecosystems. The biotic indices are based on the premise that tolerance to pollution differs among benthic organisms (Resh et al., 1996) and they represent one of several types of measures that are often used in biological monitoring. However, most recent approaches use multiple measures, also referred as metrics of community structure and function, which can be grouped into five categories: taxa richness; enumeration (number of all collected organisms, proportion of groups), diversity, similarity and trophic functional groups (Resh and Jackson, 1993; Barbour et al., 1996). The use of multimetric indices, that consider a set of metrics grouped in one index, and biotic indices have been widely explored in studies focusing rivers and streams (Karr, 1999; Linke et al., 2005; Silveira et al., 2005), allowing a more complete approach to the environmental situation of these lotic aquatic systems.

Considering the feasibility of conducting research on benthic macroinvertebrates and the processing time of samples (collection, sorting and identification), an approach at the level of family or broader taxonomic groups has been the choice of several studies assessing the environmental quality of aquatic ecosystems (Pereira and De Luca, 2003; Semenchenko and Moroz, 2005; Silva et al., 2007). The indices and metrics of the benthic macroinvertebrate fauna reflect the structure and composition of the community, which is directly or indirectly influenced by physical and chemical variables of water, type of substrate, by the sur-

rounding environmental conditions (Palmer et al. 1994; Allan, 1995), and also by seasonal factors related to hydrological changes (Statzner and Higler, 1985). Therefore, since the metrics of the benthic macroinvertebrate community indicate the environmental quality, it is expected that in better quality environments are found higher values of good environmental quality metrics, and in the more degraded, that these values are lower.

The aim of this study was to evaluate the water quality of streams in the urban area of Uberlândia - MG, using metrics of benthic macroinvertebrate communities. Additionally, we tried to assess which metrics had better responses to differences in environmental quality of the streams studied.

2. Material and Methods

2.1. Study area

The basin of the Uberabinha river is located in the geographical area of Triângulo Mineiro, comprising part of Uberaba, Uberlândia and Tupaciguara municipalities, in an approximate area of 2,000 km² (Schneider, 1996). It integrates the Paraná river basin, represented by the Mesozoic age lithologies: sandstones of Botucatu Formation, basalts of Serra Geral Formation and rocks of the Bauru Group (Nishiyama, 1989). The local climate is tropical and, according to the climate classification of Köppen is Aw type, megatermic, with summer rains and winter drought (Rosa et al., 1991).

We studied four streams (Figure 1) located in the urban area of Uberlândia (18° 55' 08" S and 48° 16' 37" W). In this city, which has more than 608 thousand inhabitants (IBGE, 2008) and an area of over 135 km², the aquatic ecosystems are being affected by the increasing urbanization (Borges et al., 2006).

The criteria for selecting the streams were the standardization of their magnitude order (all first-order streams) and location, in order to sample different regions of the basin. In each stream we established three sampling sites, one near the source (S1), another near the mouth (S3) and the other (S2), intermediate to these sites. The headwaters of the Lageado stream (Stream 1) is located in a swampy area (Vereda) of the Ecological Reserve of Caça e Pesca Club. The Buritizinho (Stream 2), Lobo (Stream 3) and Bons Olhos (Stream 4) streams are directly inserted into the urban area of Uberlândia and they are subject to various anthropogenic impacts.

2.2. Benthic macroinvertebrate sampling

Sampling of benthic macroinvertebrates was performed in rainy (March/07) and dry (July/07) seasons. At each sampling site of the streams, three substrate sub-samples were randomly collected, using a Surber collector of 90 cm² and of 0.250 mm mesh size. The three sub-samples at each sam-

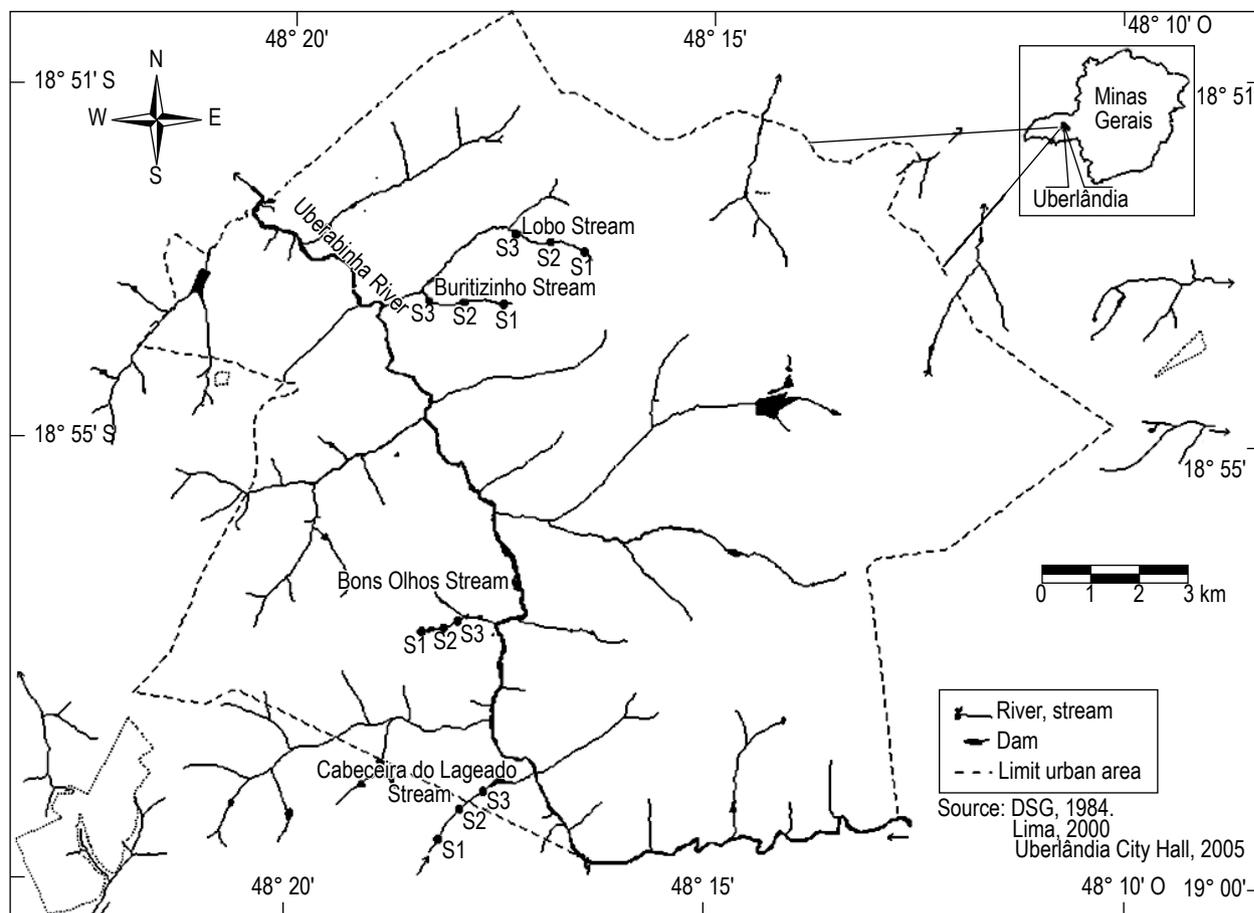


Figure 1. Uberabinha River Basin in the urban area of Uberlândia - MG and location of the studied streams and sampling sites (S1; S2; S3).

pling site were evaluated together, representing one sample, thus we obtained 12 samples per sampling period.

The samples were packed into plastic bags, labeled, fixed in a 10% formalin solution and transported to the laboratory for processing. The collected material was washed on a mesh of 0.250 mm, and sorted in Petri dishes, using a stereomicroscope. The benthic macroinvertebrates were identified to the family level - except the mollusks (Class), annelids (Subclass), nematodes (Phylum) and isopods (Order) - using specific identification keys (Morretes, 1949; Wiggins, 1977; Merritt and Cummins, 1984; Castro and Silva, 1985; Righi, 2002; Costa et al., 2004) and subsequently confirmed by a specialist.

2.3. Evaluation of stream ecological conditions

At each sampling site we applied a rapid assessment protocol of ecological conditions (Callisto et al., 2002). In this protocol 22 parameters were evaluated, receiving higher scores for natural and lower for altered conditions. Thus, we evaluated the conservation degree of the areas, based on information from its use and occupancy, including observations on vegetation cover, soil types, occupation, presence of pollutants in stream bed, type of substrate, among others.

The sum of scores can vary from zero to 100, and the state of preservation can be defined as impacted (ranging between zero and 40 points), altered (between 41 and 60 points) and natural, with scores above 60 points.

2.4. Calculation and comparison of macroinvertebrate community metrics

For each sampling site it was calculated the index BMWP (Biological Monitoring Working Party), applied according to Alba-Tercedor (1996) and Junqueira and Campos (1998). We also calculated the indices of Shannon-Wiener diversity (H'), Pielou evenness (J') (Krebs, 1989), taxa richness and the percentage of Ephemeroptera, Plecoptera and Trichoptera (EPT), Chironomidae and Oligochaeta.

A three-way analysis of variance (ANOVA) without replication (Sokal and Rohlf, 1981) was performed to compare the metrics of the benthic macroinvertebrate communities (richness, BMWP, evenness (J'), diversity (H') and percentages of Chironomidae, Oligochaeta and EPT) among streams, sites and sampling periods. Data expressed in percentage were previously changed to proportions and then arcsine square root transformed and the biological

indices richness and BMWP were square root transformed, to better fit the normal distribution (Clarke et al., 2002). Residual analyses were performed to check the assumptions of ANOVA.

To assess the relationship among the biotic metrics used, a Principal Component Analysis (PCA) was performed on the correlation matrix of the metrics. For this analysis the values of the metrics were first transformed to reduce the discrepancies among sampling sites. The data expressed in percentages were transformed into arcsine of the square root of the ratio, the richness index and BMWP in base 10 logarithms and diversity and evenness in the square root.

3. Results

The application of the Rapid Assessment Protocol of ecological conditions generated the scores and categories described in Table 1. Stream 1 was the only with all sampling sites classified as natural areas, while the other streams were classified as impacted and changed. In all streams the highest scores were obtained at sites located near the source (S1).

Regarding the fauna, we obtained a total of 53,664 individuals, 5,544 (10.33%) found in Stream 1, 18,614 (34.69%) in Stream 2, 22,818 (42.52%) in Stream 3 and 6,688 (12.46%) in Stream 4. We found 35 insect families, as well as isopods, mollusks, annelids and nematodes. The highest values of richness were found at sites S1 and S2 of the Stream 1, regardless of season. Stream 1 had a higher percentage of EPTs, followed by Streams 4 and 2. In Stream 3, representatives of these groups were not recorded. The percentage of Chironomidae was high in all streams, while the percentage of Oligochaeta was low in Streams 1 and 4 and high in Streams 2 and 3 (Figure 2).

Table 1. Characterization of ecological conditions of streams in the urban area of Uberlândia - MG, 2007, using the Rapid Assessment Protocol proposed by Callisto et al. (2002).

	Stream 1			Stream 2			Stream 3			Stream 4		
	S1	S2	S3									
Score	81	89	69	50	38	35	51	39	34	56	30	49
Classification	N	N	N	A	I	I	A	I	I	A	I	A

N - natural; A - altered; I - impacted.

For the index BMWP, only Stream 1 showed great water-quality, in sites 1 and 2. Stream 4 was classified as satisfactory during dry season and the other streams were classified as poor and very poor (Figure 3).

There was a significant difference in richness among sites ($F_{2,6} = 5.844$; $p = 0.039$), but not among streams ($F_{3,6} = 4.330$; $p = 0.060$), neither among seasons ($F_{1,6} = 2.877$; $p = 0.141$). On average, richness had a marginally significant trend to be lower in site 3 than in sites 1 and 2 (Tukey, $p = 0.052$ and $p = 0.064$, respectively). The interactions between sites and stream ($F_{6,6} = 2,368$; $p = 0,159$), between season and stream ($F_{3,6} = 2,019$; $p = 0,213$) and between season and site ($F_{2,6} = 0,425$; $p = 0,672$) were not significant.

For the BMWP index, the interaction between stream and site was significant ($F_{6,6} = 7.164$; $p = 0.015$) and data were analyzed separately by site. For sampling sites 1 and 2 there was a significant difference between streams ($F_{3,3} = 20.884$; $p = 0.016$ and $F_{3,3} = 24.519$; $p = 0.013$, respectively) but not between seasons ($F_{1,3} = 0.945$; $p = 0.403$ and $F_{1,3} = 2.646$; $p = 0.202$, respectively). For sampling site 3 there was no difference between streams ($F_{3,3} = 0.617$; $p = 0.649$) or seasons ($F_{1,3} = 0.443$; $p = 0.553$). Considering only the sampling site 1, Stream 1 had higher values than Streams 2 and 3 (Tukey, $p = 0.018$ and $p = 0.021$, respectively) and only the site 2, the Stream 1 had higher values than streams 2, 3 and 4 (Tukey, $p = 0.013$, $p = 0.023$ and $p = 0.023$, respectively).

No difference was detected among streams, sites or seasons on the values of diversity (H'), evenness (J') and percentage of Chironomidae, although there was a tendency of higher percentage of Chironomidae in the wet season ($F_{1,6} = 5.561$; $p = 0.056$). The interactions between site and stream, season and stream, and between season and site were not significant for these metrics (Table 2).

For the percentage of EPT, the interaction between stream and sampling site was significant ($F_{6,6} = 10.449$; $p = 0.006$) and data were analyzed separately by site. For sites 1 and 2 there was a significant difference among streams ($F_{3,3} = 407,668$; $p < 0.001$ and $F_{3,3} = 153.744$; $p = 0.001$, respectively) but not between seasons ($F_{1,3} = 0.706$; $p = 0.462$ and $F_{1,3} = 0.373$; $p = 0.584$, respectively). For site 3 there

Table 2. Results of the three-way ANOVA without replication for the variables diversity (H'), evenness (J') and percentage of Chironomidae.

Factor	df	Diversity H'		Evenness J'		Chironomidae (%)	
		F	p	F	p	F	p
Stream	3; 6	0.247	0.861	0.341	0.815	2.511	0.155
Sampling site	2; 6	1.765	0.250	0.019	0.981	0.753	0.511
Season	1; 6	2.538	0.162	0.648	0.451	5.561	0.056
Stream * sampling site	6; 6	3.322	0.085	1.358	0.360	0.338	0.894
Stream * season	3; 6	1.246	0.373	1.070	0.430	1.745	0.257
Sampling site * season	2; 6	1.418	0.313	0.435	0.666	0.954	0.437

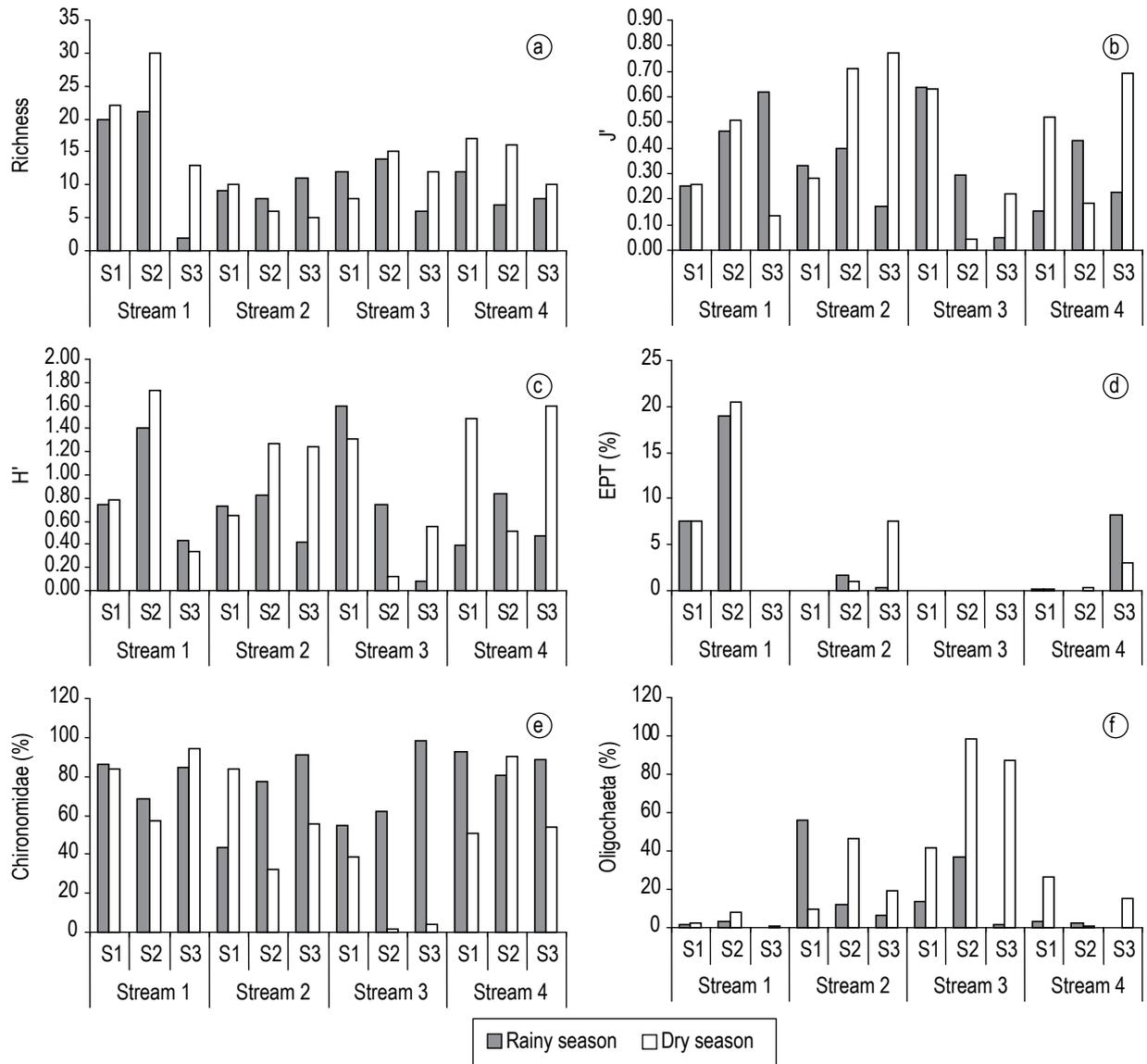


Figure 2. Values of richness (a) evenness (b), Shannon-Wiener diversity (H') (c) and percentage of EPT (d), Chironomidae (e) and Oligochaeta (f) in streams in the urban area of Uberlândia - MG, in different climatic seasons of the year 2007.

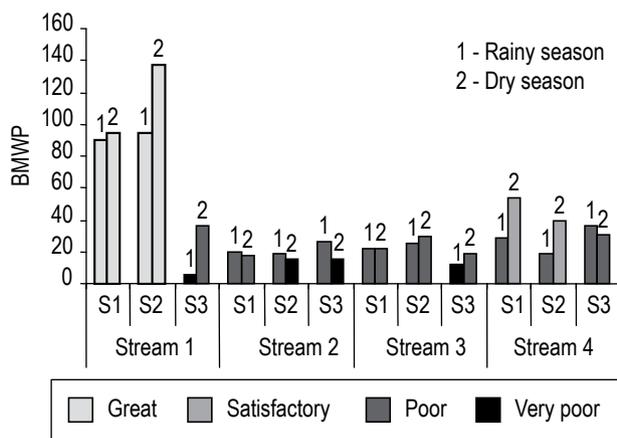


Figure 3. Values of BMWP in streams in the urban area of Uberlândia - MG, in different seasons of 2007. Water quality based on Junqueira and Campos (1998).

was no difference among streams ($F_{3;3} = 2975$; $p = 0.197$) nor between seasons ($F_{1;3} = 0.127$; $p = 0.745$). Stream 1 had higher values than Streams 2, 3 and 4 both for site 1 (Tukey, $p < 0.001$, $p = 0.042$ and $p = 0.093$, respectively) and site 2 (Tukey, $p = 0.002$, $p = 0.001$ and $p = 0.001$, respectively).

There was a difference in the percentage of Oligochaeta among streams ($F_{3;6} = 9.335$; $p = 0.011$). On average, the percentage of Oligochaeta was higher in Stream 3 than in Streams 1 and 4 (Tukey, $p = 0.012$ and $p = 0.026$, respectively) and higher in dry season than in rainy season ($F_{1;6} = 8.454$; $p = 0.027$) but did not differ among sampling sites ($F_{2;6} = 1.236$; $p = 0.355$). The interactions between site and stream ($F_{6;6} = 1.040$; $p = 0.482$), season and stream ($F_{3;6} = 3.221$; $p = 0.104$) and between season and site ($F_{2;6} = 1.650$; $p = 0.269$) were not significant.

The first two axes of Principal Component Analysis (PCA) explained, respectively, 39.86 and 30.31% of the total variation (Figure 4). The most important metrics in the first axis were the BMWP index, richness and percentage of EPT, all of them with positive loadings, and in the second axis the most important were the diversity H' , evenness (J') and percentage of Oligochaeta, with negative loadings and percentage of Chironomidae, with a positive loading (Table 3).

On PCA, the sites of Stream 1 near the source were separated from the others, due to their higher values of % EPT, richness and BMWP. Only the sampling site 3 of the Stream 1, for both dry and rainy season, did not show the same ordination of other sites of this stream.

Table 3. Component loadings for the first two principal components based on the seven metrics of benthic macroinvertebrates from streams in the urban area of Uberlândia - MG, 2007.

Metrics	Axis 1	Axis 2
BMWP	0.565890	0.149217
Richness	0.469672	0.079117
EPT (%)	0.463090	0.099502
Chironomidae (%)	-0.005194	0.621504
Oligochaeta (%)	0.122187	0.548579
H'	0.433889	0.350890
J'	0.203733	0.388901

4. Discussion

The highest values of the environmental quality index of Stream 1 are due to its location within a conservation unit, a rather preserved place, with the presence of natural vegetation, diversity of habitats, stability of margins and lack of direct anthropogenic impacts around this aquatic system. However, the other streams, located directly in the urban area, are vulnerable to various urban impacts, such as erosion, release of domestic and industrial effluents, deforestation, and substrate modification, among others.

The higher scores of the headwaters sampling sites compared with the other sites indicate that these environments are still a little better preserved, but much less than expected, since headwaters are places of great importance for the aquatic ecosystems, interfering in flow and quality of water downstream (waste disposal) and contribute to drift, a common process of dispersal in the benthic community, which favors downstream colonization (Smock, 1996).

The sites classified as impacted were characterized by the presence of strong erosive processes, silted banks with little or no vegetation in the margins, presence of household waste and constructions, among others. All these factors contribute to reduce the lotic system function to exercise their “ecological services,” notably the maintenance of biological diversity (Brown, 2007) since habitat heterogeneity is a very important factor in the population dynamics

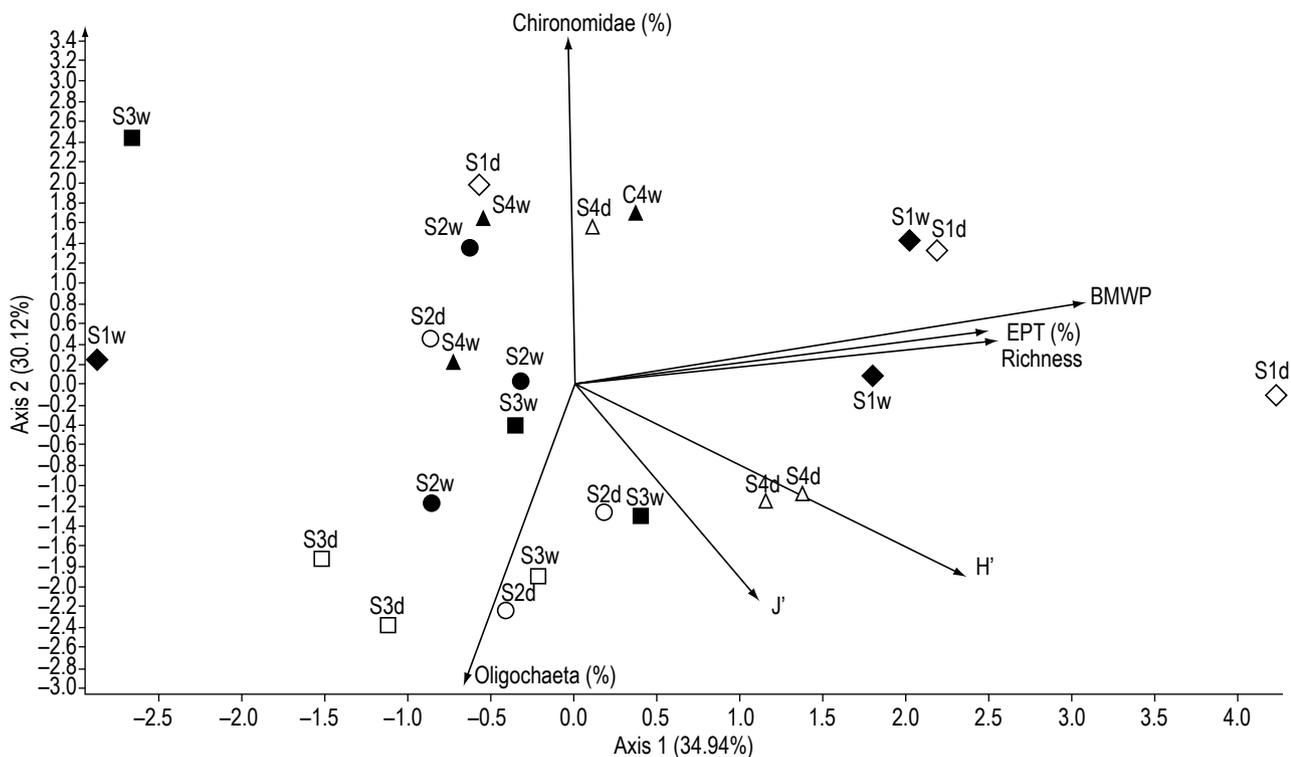


Figure 4. Ordination diagram of sampling sites by Principal Component Analysis (PCA), based on the metrics of benthic macroinvertebrate communities from streams in the urban area of Uberlândia - MG, 2007. S: stream (1, 2, 3 and 4); w: wet season; d: dry season.

(Silver et al., 2000) and community structure (Hansen, 2000; Tews et al., 2004).

As a result of the better environmental quality of Stream 1, higher levels of richness, BMWP and percentage of EPT were found for this stream. The relatively low values of richness, diversity, BMWP and percentage of EPT in site 3 of this stream may be related to its environmental characteristics. This place presents shallow waters and lentic features. There is a dense vegetation cover on the watercourse, causing an almost complete shade. These local characteristics favor the formation of a sort of swamp, which could influence the composition and the establishment of the benthic macroinvertebrates. Probably as a result of these factors other statistically significant differences were not found among the metrics of the Stream 1 and the other streams. This situation may explain, for example, the absence of differences in the percentage of EPT and BMWP in site 3 of this stream in relation to the others.

The lower values of richness in site 3 of all streams refer to a sum of anthropogenic impacts whose effects on aquatic communities are much more pronounced downstream. The low values of the BMWP index and richness of Stream 2 in the dry season refer to dominance of a few pollution tolerant groups and show the poor environmental quality of this stream. In impacted streams, almost all EPT individuals recorded belong to the family Hydropsychidae, which agrees with the fact that this family is not very sensitive to pollution (Buss et al., 2002).

The absence of differences in evenness among streams and the low values found in all of them refer to the occurrence of dominant groups, more specifically, the dominance of Chironomidae, which occurred at high percentages in all streams. Other studies also recorded the dominance of Chironomidae (Baptista et al., 1998; Kikuchi and Uieda, 1998; Brittain et al., 2001) in macroinvertebrate communities. This situation can be explained by the remarkable competitive ability of the members of this family, its capacity to tolerate extreme hypoxia (Nessimian, 1995; Callisto et al., 2001) and its rapid growth rate (Jacobsen and Encalada, 1998).

Despite the dominance of Chironomidae in all streams, it is possible that there is greater variability of genera of this family in Stream 1, as it is more preserved and consequently it has greater niche availability. In other streams, the composition of Chironomidae are probably restricted to a few genera, as it is recognized that in case of water quality deterioration changes in species composition, dominance of pollution tolerant species and deformities in head capsule of the individuals may occur (Johnson et al., 1993).

The high values in percentage of Oligochaeta in Streams 2 and 3, significantly higher in Stream 3 in the dry season, are indicative of organic enrichment of these environments and, consequently, poor water quality. The Oligochaeta are well adapted to these environments, since they can tolerate

hypoxia conditions living in water-sediment interface and are detritivores, feeding on organic matter deposited in the sediment (Giere et al., 1999).

Higher values of macroinvertebrate abundance would be expected in the dry season, due to the greater physical stability at this period. On the other hand, the hydrological changes that occur in the rainy season, such as the water flow increase, promote population shifts, causing a homogenizing effect, thereby reducing the environmental gradients (Oliveira et al., 1997; Kikuchi and Uieda, 1998; Huamantínco and Nessimian, 1999; Ribeiro and Uieda, 2005; Shuvartz et al., 2005). However, no seasonal differences were recorded in the metrics of benthic macroinvertebrates in impacted streams (2, 3, 4). This may be related to the fact that these environmental impacts are so pronounced that even in drought, a period that would be expected to show higher values of richness and abundance, no changes occur.

The absence of seasonal differences in Stream 1 may be related to its greater habitat stability due to the abundant herbaceous vegetation surrounding the margins in both dry and rainy season. Furthermore, as the water course has low inclination, possibly no relevant flow changes occur in the rainy season which can significantly influence the local macroinvertebrate community.

The dominance of Chironomidae in almost all sampling sites in both periods may also have favored the absence of differences among streams and between periods for 'J' and 'H' metrics, as the very high values of abundance may have masked possible differences in the community. Uieda and Ribeiro (2005) suggested that the removal of this group from the analysis could probably show other patterns, thus highlighting the importance of Chironomidae in structuring aquatic communities.

The Principal Component Analysis showed that the vectors that determine the separation of the Stream 1, a preserved stream, from the other streams were the percentage of EPT, richness and BMWP. Thus, it seems reasonable to consider that these metrics are good indicators of the environmental quality of the streams studied, corroborating the study of Semenchenko and Moroz (2005). These authors compared the sensitivity of different biotic indices and concluded that BMWP and EPT were the most sensitive to water quality variation.

The other metrics presented limitations. As Chironomidae is often the dominant group in aquatic environments (Nessimian, 1995), an assessment of environmental quality based solely on this parameter would require identifying the organisms at the level of genus. Oligochaeta already, despite being fairly abundant in two of the three impacted streams (mainly in Stream 3), were not so abundant in Stream 4. The Shannon-Wiener diversity index was not a metric that reflected the true conditions of the streams. To calculate this index, the abundance and the taxa richness are considered,

thus, as in Stream 1 the abundance of Chironomidae was very high relative to other groups, the diversity values were shifted down. The low values of evenness in all streams, probably due to the presence of dominant groups, also did not distinguish stream quality.

The lack of interaction between stream and sampling period indicates that the community patterns largely remain, so considering a proposal for long-term biomonitoring, it would not be necessary to sample in both seasons, thus reducing costs and time spent to obtain the data. However, the interaction between site and stream indicates that the selection of sampling sites may influence the characterization of the communities and, consequently, the determination of environmental conditions. Thus, the selection of representative sampling sites in a given stream is of main importance.

We can conclude that the percentage of EPT, BMWP index and richness were the metrics that best reflected the environmental quality of the streams studied, referring to the good environmental quality of Stream 1, followed by Stream 4, and in worst conditions Stream 3 with absence of EPT and Stream 2, which showed very low values of BMWP.

Acknowledgements

We thank Dr. Leandro Gonçalves Oliveira for EPT identification and all colleagues which help in field work and macroinvertebrate sorting. R. M. Guimarães was supported by Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES) and Programa de Pós-Graduação em Ecologia e Conservação de Recursos Naturais.

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Received: 25 March 2009

Accepted: 19 June 2009