doi: 10.5123/S2176-62232016000300002

Application of the biological indices Biological Monitoring Working Party and Average Score per Taxon to assess the water quality of Ouricuri river in the Municipality of Capanema, Pará State, Brazil*

Aplicação dos índices biológicos *Biological Monitoring Working Party* e *Average Score per Taxon* para avaliar a qualidade de água do rio Ouricuri no Município de Capanema, Estado do Pará, Brasil

Aplicación de los índices biológicos *Biological Monitoring Working Party* y *Average Score per Taxon* para evaluar la calidad del agua del río Ouricuri en el Municipio de Capanema, Estado de Pará, Brasil

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ABSTRACT

Environmental problems related to water quality in continental ecosystems have conducted studies aimed at the protection and conservation of these environments. The current study aimed to evaluate the water quality in five points of Ouricuri river, located inside and outside of the urban area of the Municipality of Capanema, Pará State, Brazil, using the biological indices of Biological Monitoring Working Party and Average Score per Taxon. The result of the biological indices identified a pattern of water quality that was presented as doubtful (P1), critical (P2, P3 and P4) and very critical (P5), polluted water in moderate and severe form. The values of taxonomic richness tend to decrease downstream from point P2, with increased levels of turbidity, organic matter and total phosphorus and these last two are measured at substrate level. In the five sampled points, 1,039 individuals were identified which belong to 14 families with the main groups identified as Chironomidae, Oligochaeta and Thiaridae. The change in macroinvertebrate community composition along the Ouricuri river appears as a result of the combination of human factors associated with it, such as: loss of riparian forest, margin erosion, substrate change, domestic wastewater flows and proliferation of macrophytes.

Keywords: Macroinvertebrates; Bioindicators; Potability; Conservation.

INTRODUCTION

Many of the changes observed in aquatic environments have resulted in large part from the expansion of agriculture and, therefore, of anthropic actions and are currently causing great concern regarding the availability and quality of water bodies[1]. Rivers and streams are ecosystems that have been highly impacted by population growth, the discharge of high quantities of industrial and domestic effluents, construction of dams, destruction of habitats, and introduction of exotic species[2,3]. These anthropic events result in imbalances in continental freshwater ecosystems and affect trophic interactions and biodiversity[4]. These effects result from

* Article presented at the I Seminar of Environmental and Conservation Research (I Seminário de Pesquisa em Meio Ambiente e Conservação - I SPMAC) organized by the Sciences and Environment Graduate Program (Programa de Pós- Graduação em Ciência e Meio Ambiente - PPGCMA) and the Environmental Computer Simulation Laboratory (Laboratório de Simulação Computacional em Meio Ambiente - LSCMAM) of the Universidade Federal do Pará (UFPA), which took place from 4 to 8 May 2015 in the city of Belém, state of Pará, Brazil. The editors wish to thank the PPGCMA/UFPA and LSCMAM/UFPA partnership and the selection of the Pan-Amazonian Journal of Health for the publication of the excellent studies presented at this event.

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increased nutrient and pollutant input originating from agricultural, industrial, and domestic sources[5], which are the primary causes determining river quality and biodiversity decline. For this reason, much effort has been dedicated to detecting, quantifying, and mitigating these effects over the last few decades.

Natural lotic environments can be characterized by the presence, quantity, and composition of organic and inorganic agents and the diversity of their aquatic communities, and these habitats are subject to structural and seasonal variation due to internal and external factors[6]. The primary function of water resource monitoring is to evaluate whether certain organisms are present or absent in some regions of the lotic system. The quantity and diversity of species sensitive to frequent disturbances in these environments[7], i.e., the balance between different communities in the ecosystem, are evaluated. The composition of aquatic organisms, especially invertebrates, reflects the changes in aquatic systems[8] and is affected not only by factors specifically related to the water conditions but also by the dynamics between biotic and abiotic factors (biotope) of the ecosystem[9].

Benthic macroinvertebrates are aquatic animals at least 0.25 mm in length that inhabit the sediment and can colonize different types of substrate, such as branches, leaves, stones, and aquatic macrophytes, during all or part of their life cycles[10,11]. Their distribution and the specific communities that they form in aquatic environments are affected by the substrate composition, food availability[12], and the physicochemical characteristics of water[13]. Because the integrity of benthic macroinvertebrate communities is closely related to the presence of pollutants in the habitat, benthic macroinvertebrates can be effectively used in environmental impact studies to evaluate continental ecosystems[14,15]. Therefore, these animals can be used as bioindicators of water quality, allowing for evaluating the ecological effects of different water pollution sources[16]. They can be used in environmental quality studies due to characteristics such as their varying abundances in different aquatic ecosystems (lentic and lotic), the extent of their locomotive ability, and their presence or absence in samples before and after environmental impact events[17,18,19,20].

Changes in the natural composition of benthic macroinvertebrate populations, regarding spatial dynamics, have been used as efficient biological tools in water pollution monitoring studies[21]. These studies gained full relevance when they described the impacts on aquatic trophic chains[22]. One study analyzed macroinvertebrate diversity at different points in the River Thames in the United Kingdom for one year using the Biological Monitoring Working Party (BMWP), average score per taxon (ASPT), and Shannon-Wiener diversity index to evaluate the impacts of water quality factors and physical changes to the habitats of these organisms[23]. The results indicated that less altered sampling sites harbored greater diversity of organisms and that water quality was the primary limiting factor of biodiversity. In Brazil, the BMWP index has been used in studies performed in the Doce River basin in the state of Minas Gerais[24], in an Atlantic forest fragment also in Minas Gerais[25] and in the Sinos River in the state of Rio Grande do Sul[26], indicating that water quality biomonitoring studies in Brazil are still scarce and geographically restricted.

Many studies of continental aquatic environments have been performed in temperate and tropical climates using benthic macroinvertebrates as water quality indicators[27,28,29,30], but few studies have been conducted in the Amazon region. This lack is the cause of great concern since many of the cities in this region are closely associated with water bodies (e.g., for transport, recreation, and food). A ten-year study of bauxite waste discharge into Lake Batata in the municipality of Oriximiná, state of Pará, reported a decrease in the density of benthic macroinvertebrates in specific locations in the lake when compared to Lake Mussurá located in the same municipality, but that was not anthropized, which raised questions related to substrate particle size and its correlation to higher or lower biodiversity[29]. A three-year study on physicochemical and biological conditions at five locations in the Mindu Stream in the city of Manaus in the state of Amazonas identified an apparent decrease in macroinvertebrate diversity in areas under anthropic pressure that was driven by the deforestation of riparian forests, illegal land occupation, and consequently high domestic waste disposal[31]. The same study also observed greater macroinvertebrate diversity in areas with less urbanization despite decreased riparian forests in those areas. A study of the water conditions at 12 points along the Maroaga River, located in Presidente Figueiredo, in the state of Amazonas classified the river as class I of the BMWP index, which means it is "clean or not significantly altered"[32].

The present study aimed to evaluate the water quality conditions in a stretch of the Ouricuri River located in the municipality of Capanema in the northeastern state of Pará, using the BMWP and ASPT indices.

MATERIALS AND METHODS

Samples were taken from a stretch of the Ouricuri River where it runs along the urban perimeter of the municipality of Capanema, located approximately 165 km from Belém, the state capital of Pará (Figure 1). Five sampling sites were selected along the river: P1 (01°11'30.2"S, 47°09'36.1"W), located upriver from the city of Capanema, P2 (01°11'16.7"S, 47°10'16.0"W), P3 (01°11'22.1"S, 47°10'47.4"W), and P4 (01°11'23.8"S, 47°11'18.4"W) within the city grid, and P5 (01°11'22.8"S, 47°11'32.7"W) downriver from the city (Figure 2).

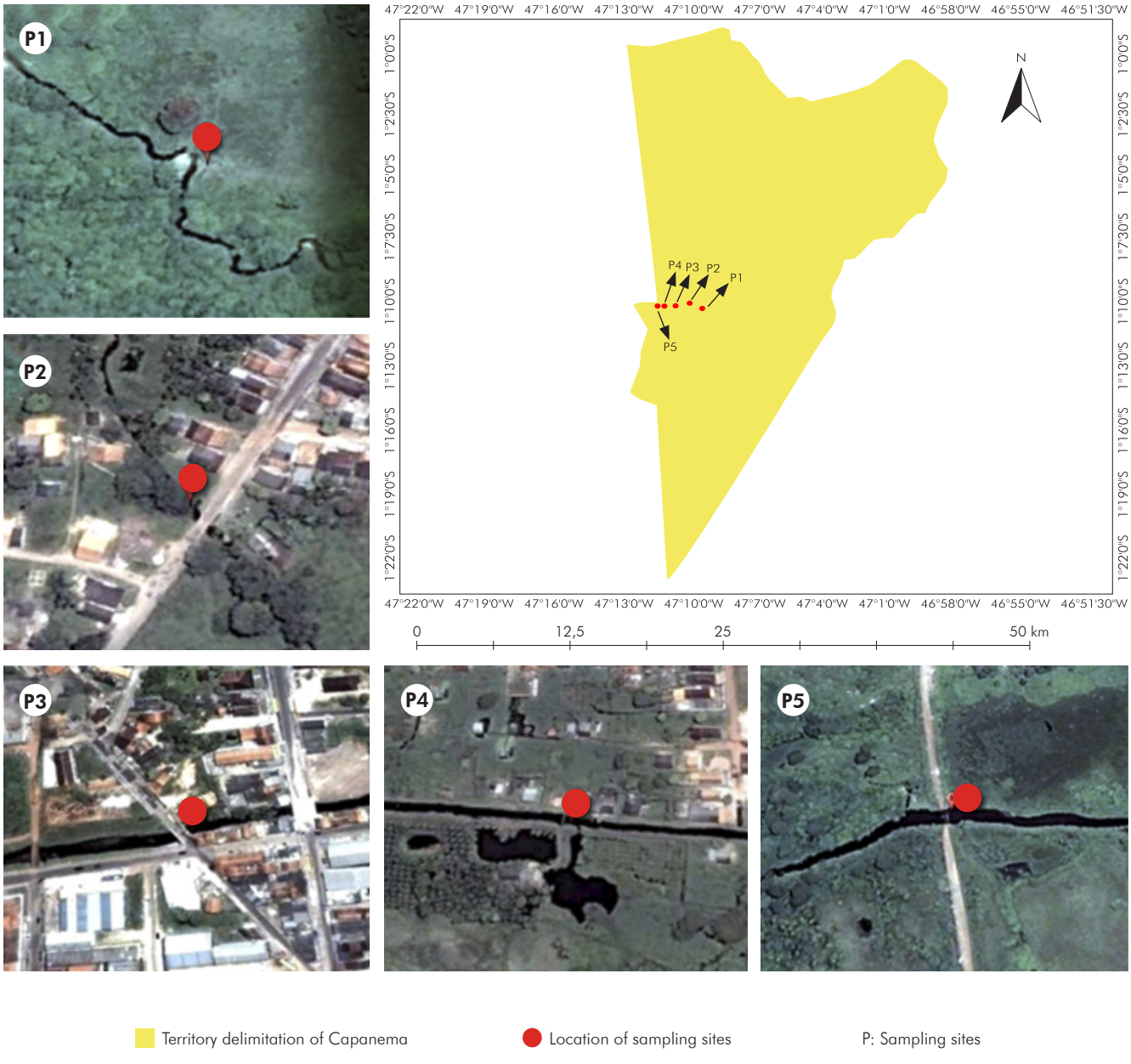
Two substrate samples were taken at each sampling site during the drought season (October 2013). The samples were placed in 2-liter containers, labeled and transported to the laboratory, washed in running water, and filtered through a 300-µm mesh sieve, and the benthic macrofauna was preserved in 70% alcohol for subsequent analysis. According to the State of Rio

de Janeiro Aquatic Macroinvertebrate Identification Manual (Manual de Identificação de Macroinvertebrados Aquáticos do Estado do Rio de Janeiro), sediment macrozoobenthos were isolated using a stereoscopic microscope, quantified, and identified to the family level[33]. Intact and deep profile sediment samples were obtained using a polyvinyl polychloride tubular core sampler 7.5 cm in diameter and 80 cm long.

Physicochemical parameters of the water, such as temperature (°C), dissolved oxygen (mg/L), turbidity (NTU), total phosphorus (P), and organic matter (g/Kg), were evaluated at all sampling sites. Temperature, dissolved oxygen, and turbidity were evaluated using 1-liter water samples. Total phosphorus and organic matter samples (500 g) were sent to the Brazilian Agricultural Research Corporation (Empresa Brasileira de Pesquisa Agropecuária - Embrapa), Western Amazon.

Benthic macrofauna data were analyzed using the BMWP, ASPT, and Shannon-Wiener diversity index. The BMWP index classifies the degree of resilience of benthic macroinvertebrate families using a scale from 1 to 10. High BMWP scores were attributed to highly sensitive benthic taxa and low scores to benthic taxa with a high tolerance to organic pollution, enabling their use as a tool to diagnose water body contamination by organic material[34]. The score for a given sampling site was obtained by adding the individual scores for all families present and the total score corresponded to a water quality class varying from good to very critical (Table 1).

The ASPT index was calculated by dividing the BMWP score by the number of families identified at a given sampling site. High ASPT scores indicate good water quality and represent a relatively high number of taxa present[35] (Table 2).



Datum: WGS84; Geographic Coordinate System Latitude/Longitude; Images: Landsat/DigitalGlobe/Google Earth Software; Map production date: February/2014.

Figure 1 – Location of benthic substrate sampling sites along the Ouricuri River in the municipality of Capanema, Pará, Brazil

P: Sampling sites.

Figure 2 – Substrate sampling sites along the Ouricuri River in Capanema, Pará, Brazil

Table 1 – Biological Monitoring Working Party (BMWP) classes, scores, categories, and interpretations from a water quality analysis of the Ouricuri River, Capanema, Pará, Brazil

Class	BMWP score	Category	Interpretation
I	>150	Good	Clean water
	101–150		Clean or not significantly altered
II	61–100	Acceptable	Clean but slightly impaired
III	36–60	Questionable	Moderately impaired
IV	15–35	Critical	Polluted or impaired
V	<15	Very critical	Heavily pollut

Table 2 – Reference average score per taxon (ASPT) scores and interpretations used in water quality analysis for the Ouricuri River, Capanema, Pará, Brazil

$ASPT_{score}$	Interpretation
>6	Clean water
5–6	Questionable water quality
4–5	Probable moderate pollution
<4	Probable severe pollution

Biodiversity was evaluated by calculating the Shannon-Wiener index (H') [$H' = -\sum(pi)(\log_2 pi)$], which supplies information on the stability of the benthic community[36], using BioEstat v5.0 software. The Shannon-Wiener index evaluates species abundance in a sample considering both evenness and richness of the species present. As pollution increases, the whole benthic community is exposed to intense stress, which consequently destabilizes it. The most sensitive organisms disappear, whereas the most tolerant, due to the absence of competition for food and space, spread rapidly throughout the aquatic system resulting in decreased biodiversity and thus a decreased H'.

RESULTS

The temperature did not vary significantly between sampling sites varying within approximately 1 °C. However, there was significant variation in dissolved oxygen, turbidity, total phosphorus, and organic matter among the five sampling sites. As the water body approximated the urban area, dissolved oxygen decreased and other parameters increased (Figure 3).

A total of 1039 individuals belonging to 14 families were collected and identified and constituted the benthic macrofauna at the five sampling sites visited in the Ouricuri River (Table 3). Following identification, the BMWP score was determined for each taxon. Of the 14 invertebrate families identified, 13 (92.8%) were found at P1 and P2, and only five (35.7%) were found at P3, P4, and P5. These results indicate an apparent decrease in biodiversity with increasing proximity to the city center. Similarly, the BMWP scores also decreased along the river (P1: 36; P2: 32; P3: 16; P4: 19; P5: 13).

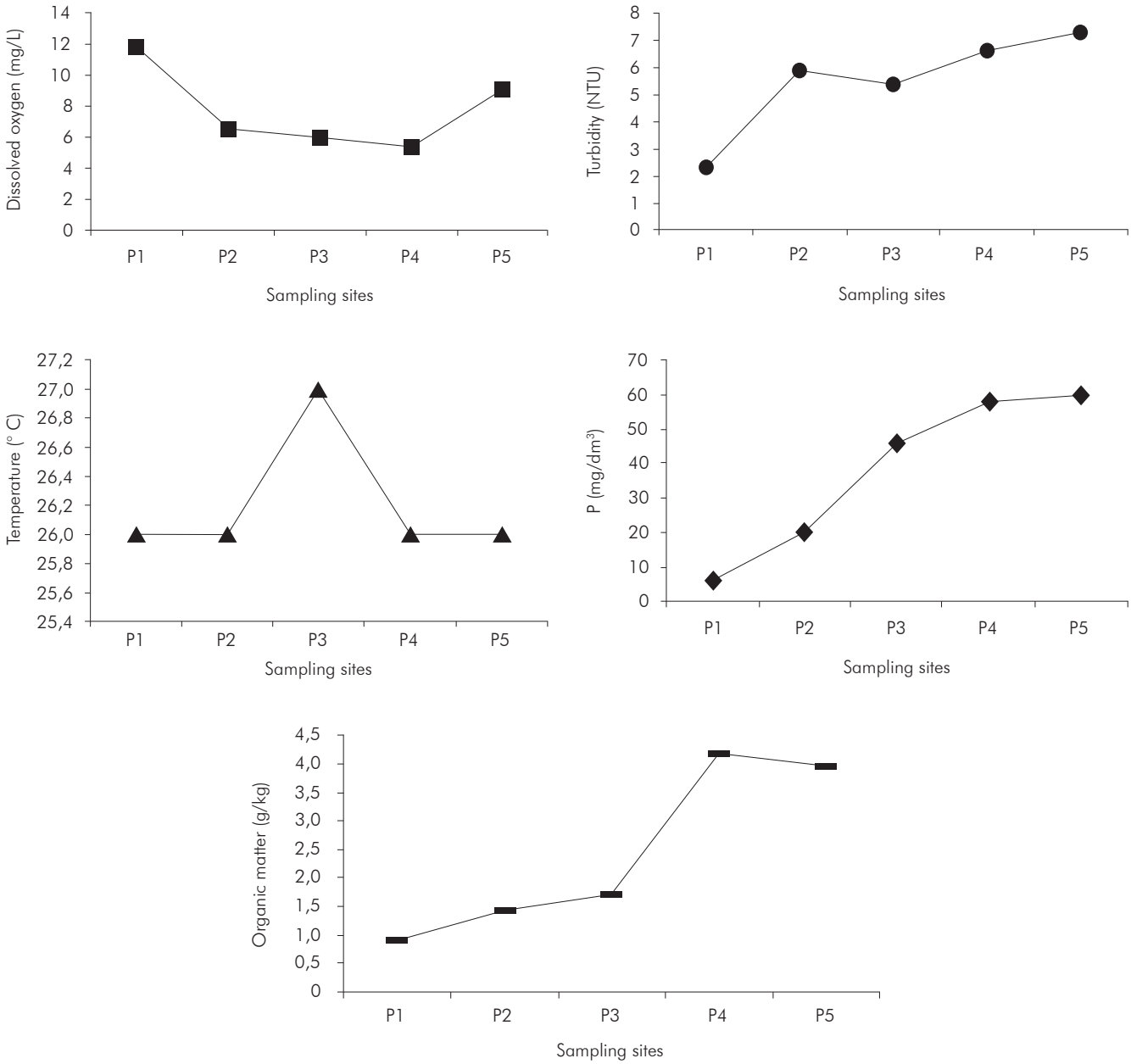


Figure 3 – Variation of physicochemical parameters in the Ouricuri River, in Capanema, Pará, Brazil, across five sampling sites

Tolerant species were more abundant at P2, P3, and P4, and the presence of pollution-sensitive organisms and indicators of low pollution levels was only observed at P1 (Table 3). The BMWP scores classified the water quality in P1 as questionable, in P2, P3, and P4 as critical, and in P5 as very critical (Table 4). The ASPT scores varied from 3.1 to 4.3 and characterized the five sampling sites as impacted environments varying from moderate (P1 and P5) to severe (P2, P3, and P4) (Table 5). Similar to the determination by the BMWP score, the environmental quality of P1 was identified as being the least anthropized.

Shannon-Wiener index values varied from 0.27 to 0.49, with the highest for P1, P2, and P3 (Table 5). This index is based on the proportional abundance of a species in a sample and accounts for species evenness (equitability) and richness. Homogeneity (E; *Pielou*'s equitability index) was calculated as the ratio between diversity observed and maximum diversity ranging from 0 to 1, where 1 indicates a situation in which all species in a given sample were equally abundant. The site with the highest equitability value was P3.

DISCUSSION

Although P1 was distant from the urban area, it exhibited similar taxonomic richness to P3 and P4, which were located within the urban area and strongly impacted. This result may be due to a combination of external and internal factors, namely the decrease in the riparian forest followed by shoreline erosion and low substrate organic matter content limiting the number of taxa present. A study conducted in Lake Batata in the municipality of Oriximiná reported a decrease in macroinvertebrate diversity in a water body exhibiting a high quantity of clay-dominated sediment originating from bauxite extraction, which altered the local sediment that was originally sandy[37]. The increased turbidity downriver from P2 may be related to the decreased diversity observed in P3, P4, and P5.

Table 3 – Benthic macroinvertebrate community data from the Ouricuri River in the municipality of Capanema, Pará, Brazil

Taxa	Tolerance index	Number of individuals per sampling site				
	BMWP	P1	P2	P3	P4	P5
Diptera						
Chironomidae	2	30	166	7	24	–
Ceratopogonidae	4	1	–	7	–	2
Dixidae	4	1	–	–	2	–
Culicidae	2	–	1	–	–	–
Physidae	3	–	1	–	–	–
Psychodidae	4	–	2	–	–	–
Trichoptera						
Philopotamidae	8	2	–	–	–	–
Annelida						
Oligochaeta	1	4	2	103	6	–
Hirudinea	3	–	–	27	4	–
Turbelaria						
Planariidae	5	4	4	–	–	–
Gastropoda						
Thiaridae	6	83	319	24	158	12
Ancylidae	6	1	1	–	–	–
Ampullariidae	3	–	28	–	–	1
Planorbidae	3	–	2	–	–	–
Taxa richness		8	10	5	5	3
Total density		126	536	168	194	15

BMWP: Biological Monitoring Working Party score; P1-P5: the five sampling sites; –: Numeric data equal to zero, not resulting from rounding.

Table 4 – Biological Monitoring Working Party (BMWP) and average score per taxon (ASPT) scores for five sampling sites in the Ouricuri River in the municipality of Capanema, Pará, Brazil

Sampling site	Class	Color	BMWP	Quality	ASPT	Quality
P1	IV		36	Questionable	4,3	Probable moderate pollution
P2	V		32	Critical	3,5	Probable severe pollution
P3	V		16	Critical	3,2	Probable severe pollution
P4	V		19	Critical	3,1	Probable severe pollution
P5	VI		13	Very critical	4,3	Probable moderate pollution

Table 5 – Shannon-Wiener diversity index values for five sampling sites (P1-P5) in the Ouricuri River in the municipality of Capanema, Pará, Brazil

	P1	P2	P3	P4	P5
Sample size	126	526	168	194	15
Number of categories	8	10	5	5	3
Shannon-Wiener (H')	0,4415	0,4168	0,4936	0,2868	0,2726
Maximum diversity (H'max)	0,9031	1,0000	0,6990	0,6990	0,4771
Homogeneity (E; H'/H'max)	0,4889	0,4168	0,7062	0,4103	0,5714
Heterogeneity	0,5111	0,5832	0,2938	0,5897	0,4286

A previous study evaluated the water and bottom sediment quality of a lake located in the municipality of Castelo in the state of Espírito Santo and showed that the instance of substrate phosphorus content greater than 40 mg/dm^3 was high and could be related to eutrophication[38]. The presence of a considerable quantity of macrophytes observed at P5 may be related to high substrate phosphorus contents, which would directly or indirectly aid their proliferation. Phosphorus is the main eutrophication agent in continental aquatic environments, and the decrease or disappearance of some specialist species and their replacement with more

tolerant generalist groups is commonly observed in impacted aquatic environments[39].

The higher biodiversity observed at P2 was likely related to its less anthropized conditions, driven by higher organic matter and phosphorus levels at P3 and the remaining downriver sites. These increased values promoted increased metabolic activity in decomposers with a consequent decrease in dissolved oxygen and a reduction of the least tolerant taxa. This was confirmed by the presence of the Oligochaeta species, a bioindicator of anthropized environments, observed in higher quantities in P3.

The biological indices estimated for the sampling sites classified the Ouricuri River as questionable, critical, or very critical and moderately polluted to severely polluted. These biological index scores were lower than those observed in previous studies of continental Brazilian water bodies[24,30] in which a reserved area was compared to an urbanized area in the state of Minas Gerais and benthic invertebrate diversity BMWP scores ranged from 103 to 186. The change in the composition of the aquatic macroinvertebrate fauna in the Ouricuri River directly resulted from factors such as hydrological and substrate composition changes and organic material and sediment input. Specifically, a clear increase in organic material and sediment input, accompanied by a decrease in dissolved oxygen, was observed at P2.

The Shannon-Wiener index values for the five sampling sites were equal to or lower than those observed in a study of a stream in the micro basin of the Cambará River in the municipality of Cruz Alta in the state of Rio Grande do Sul[40]. Based on the BMWP scores, the stream was characterized as having questionable water quality (H' = 0.46). Therefore, it was suggested that the five sampling sites analyzed had low diversity, and P4 and P5 were the most worrisome due to their low scores.

In the present study, indicator taxa of low water quality, such as Chironomidae, Oligochaeta, Planorbidae, and Planariidae, were present at sites considered altered and impacted. These benthic taxa are known to be highly resistant to anthropogenic changes, such as domestic or industrial waste discharges or the absence of riparian forests[41]. Dipterans belonging to the family Chironomidae were the most frequent taxa overall and were potentially responsible for a large part of the quantitative changes observed in the macrofaunal community. This is in accordance with the results of previous impact studies in which organic material discharge has been associated with urban expansion[42,43,44,45]. The family Chironomidae is described as the most abundant organism in aquatic environments subjected to anthropic disturbances, more frequent in areas directly affected by water quality changes due to the presence of organic pollutants originating from domestic waste discharge[46,47].

CONCLUSION

The present study results showed evidence of environmental impact caused by anthropic actions for five sampling sites along the Ouricuri River. The presence of houses in several locations adjacent to the river was the main contamination source.

ACKNOWLEDGMENTS

The authors wish to thank the Instituto Federal de Educação, Ciência e Tecnologia do Pará, campus Bragança, for the use of the Laboratory of Molecular and Environmental Biology as well as the Embrapa.

Aplicação dos índices biológicos *Biological Monitoring Working Party* e *Average Score per Taxon* para avaliar a qualidade de água do rio Ouricuri no Município de Capanema, Estado do Pará, Brasil

RESUMO

Problemas ambientais relacionados à qualidade da água em ecossistemas continentais têm motivado a realização de estudos que visam à proteção e conservação destes ambientes. O presente estudo teve como objetivo avaliar a qualidade da água em cinco pontos do rio Ouricuri, localizados dentro e fora da zona urbana do Município de Capanema, Estado do Pará, Brasil, utilizando os índices biológicos *Biological Monitoring Working Party* (BMWP) e *Average Score per Taxon* (ASPT). O resultado da avaliação dos índices biológicos identificou um padrão de qualidade de água que se apresentou como duvidosa (P1), crítica (P2, P3 e P4) e muito crítica (P5), poluídas de forma moderada e severa. Os valores de riqueza taxonômica tendem a diminuir à jusante do ponto P2, acompanhados pelo aumento dos níveis de turbidez, matéria orgânica e fósforo total, sendo os dois últimos medidos em nível de substrato. Foram identificados 1.039 indivíduos pertencentes a 14 famílias nos cinco pontos amostrados, sendo os principais grupos identificados como Chironomidae, Oligochaeta e Thiaridae. A mudança na composição da fauna de macroinvertebrados ao longo do rio Ouricuri apresenta-se como resultado da combinação de fatores antrópicos associados ao mesmo, tais como: perda de mata ciliar, erosão de margem, mudança de substrato, fluxo de efluentes domésticos e proliferação de macrófitas.

Palavras-chave: Macroinvertebrados; Bioindicadores; Potabilidade; Conservação.

Aplicación de los índices biológicos *Biological Monitoring Working Party* y *Average Score per Taxon* para evaluar la calidad del agua del río Ouricuri en el Municipio de Capanema, Estado de Pará, Brasil

RESUMEN

Problemas ambientales relacionados a la calidad del agua en ecosistemas continentales ha motivado la realización de estudios para proteger y conservar estos ambientes. El presente estudio tuvo como objetivo evaluar la calidad del agua en cinco puntos del río Ouricuri, localizados dentro y fuera de la zona urbana del Municipio de Capanema, Estado de Pará, Brasil, utilizando los índices biológicos *Biological Monitoring Working Party* (BMWP) y *Average Score per Taxon* (ASPT). El resultado de la evaluación de los índices biológicos identificó un estándar de calidad de agua que se presentó como dudosa (P1), crítica (P2, P3 y P4) y muy crítica (P5), contaminadas de forma moderada y severa. Los valores de riqueza taxonómica tienden a disminuir de modo descendiente del punto P2, acompañados por el aumento de los niveles de turbidez, materia orgánica y fósforo total, estos dos últimos medidos a nivel de sustrato. Se identificaron 1.039 individuos pertenecientes a 14 familias en los cinco puntos muestreados, y los principales grupos fueron identificados como Chironomidae, Oligochaeta y Thiaridae. El cambio en la composición de la fauna de macroinvertebrados a lo largo del río Ouricuri se muestra como resultado de la combinación de factores antrópicos asociados al mismo, tales como: pérdida de bosques de galería, erosión de márgenes, cambio de sustrato, flujo de efluentes domésticos y proliferación de macrófitas.

Palabras clave: Macroinvertebrados; Bioindicadores; Potabilidad; Conservación.

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Received / Recebido em / Recibido en: 6/7/2015
Accepted / Aceito em / Aceptado en: 16/6/2016

Article originally published in Portuguese (http://dx.doi.org/10.5123/S2176-62232016000300002)
Translated by: Editage.
Edited by: Luana Lemos.