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BENTHIC MACROINVERTEBRATES AS BIOINDICATORS OF CAMPINARANA'S STREAMS OF THE VALE DO JURUÁ MICROREGION

MACROINVERTEBRADOS BENTÔNICOS COMO INDICADORES DE RIACHOS DE CAMPINARANA DA MICRORREGIÃO DO VALE DO JURUÁ

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ABSTRACT

This study aims to evaluate the effects of sand extraction on water quality and the composition of the benthic macroinvertebrate community. Aquatic invertebrates are diverse and their abundance and distribution are influenced by biotic and abiotic factors, making them a great tool in studies of biomonitoring and bioindication in aquatic environments. The samples was carried out in four streams of a campinarana vegetation complex in the State of Acre, Brazil, at impacted and less impacted points affected by sand extraction. A total of 198 macroinvertebrates were collected, belonging to 11 orders and 24 families. There was a significant difference between streams with respect to their community compositions (Pseudo-F = 4.79; P = 0.001). This study identified that the predominance and greater density of families in impacted and non-impacted areas belong to the order Diptera (52.6 ± 30.3), probably due to their opportunistic habits. In addition, impacted streams had less abundance and richness of ETP and were characterized by the BMWP index with "dubious" quality.

Keywords: Aquatic Insects; Amazon; BMWP (Biological Monitoring Working Party); Water Quality.

RESUMO

Este estudo objetiva avaliar os efeitos da extração de areia sobre a qualidade da água e a composição da comunidade de macroinvertebrados bentônicos. Os invertebrados aquáticos são diversos e sua abundância e distribuição estão relacionados diretamente a fatores bióticos e abióticos, tornando-os uma ótima ferramenta em estudos de biomonitoramento e bioindicação em ambientes aquáticos. Este trabalho foi realizado em quatro riachos de um complexo vegetacional de campinarana no Estado do Acre, Brasil, amostrados em pontos impactados e menos impactados pela extração de areia. Foram coletados um total de 198 macroinvertebrados, pertencentes a 11 ordens e 24 famílias. Houve diferença significativa entre os riachos em relação às suas composições da comunidade (Pseudo-F = 4.79; P = 0.001). Esse estudo identificou que a predominância e a maior densidade das famílias em áreas impactadas e não impactadas pertencem a ordem Diptera (52.6±30.3), provavelmente devido aos seus hábitos oportunistas. Além disso, riachos impactados tiveram menor abundancia e riqueza de ETP e foram caracterizados pelo índice BMWP com qualidade "duvidosa".

Palavras-chave: Amazônia; BMWP (Biological Monitoring Working Party); Insetos Aquáticos; Qualidade da Água.

1. INTRODUCTION

The Amazon rainforest has one of the largest river basin systems in the world. It is composed of several water bodies, forming an extensive stream network that drain forest water and form the great Amazonian rivers [1]. It contains different types of vegetation, including the campinarana forests, which are environments of savanna formation, associated with the Amazon Forest, distinguished mainly by the predominance of white sandy soil [2]. The characteristics presented by the campinarana forest soils act as a powerful evaluator for

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environmental selection, generating a limited environment and forcing the diversity to develop adaptive characteristics endemic to the region [3, 4].

Wood removal of riparian vegetation and the illegal extraction of white sand for civil construction purposes are causing loss of the integrity of campinaranas's streams, causing the degradation of vegetation cover and diversity of forest and aquatic species. Impacts on small streams watercourses may result in a cascade effect on large river networks [5], reducing these basins water flow. These activities are practiced in an unsustainable and unproductive manner in these extremely slow-recovery habitats [6], which indicates a great environmental impact.

The aquatic systems have a strong relationship to their surroundings [7], reflecting directly on biotic and abiotic components, which allow the integration of an information network regarding changes of anthropic origin [8]. Among the ways of obtaining information through biotic components, the biomonitoring is highlighted, i.e., the use of communities of living organisms to evaluate the changes occurred in the environment.

The benthic invertebrate community is diverse and abundant, composed of several phyla (Arthropoda, Mollusca, Annelida and Platyhelminthes) [9, 10]. Its abundance and distribution are directly related to and dependent on biotic factors (food availability and presence of predators) and abiotic (water flow velocity, substrate type, pH, temperature, oxygen dissolved in water, presence of riparian forest among many other variables) [11, 12] becoming a great study tool.

Macroinvertebrates are commonly used in bioindicator studies because they are sensitive to pollution, habitat variations and have long aquatic life cycle, making it possible to verify such changes in the environment [13]. Still, studies with macroinvertebrate communities remain scarce in the Amazon region [14], and there are fewer studies that address the fauna of these organisms in the State of Acre and none of them has so far evaluated the communities in the northwestern campinarana forests. The characterization of diversity and abundance of benthic macroinvertebrate communities is one of the first steps to solve environmental problems and provides subsidies for future research aiming to assess the environmental quality of these streams and to implement environmental control actions to encourage better interactions between human being and these ecosystems.

In this context, we aim to evaluate the influence of anthropic actions due to sand extraction in low-order streams, using as a tool the aquatic macroinvertebrate community. More specifically, we aim: (i) To evaluate how changes in the impacted stretches influence the density, richness, abundance, equitability and diversity of macroinvertebrates; (ii) To verify the

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degree of conservation of streams environments through the use of BMWP and EPT indices; (iii) To analyze the difference in macroinvertebrate fauna composition between impacted and non-impacted stretches in different periods of the hydrological cycle.

2. METHODS

2.1 Study area

The study was carried out in the city of Cruzeiro do Sul, State of Acre through samplings in low order streams, part of the Moa River. The samples were collected in surroundings of the highway AC-307, place known as Morapiranga (7º 34'44,93" - S; 72º 45'19,27" - W). The region has an equatorial climate and a complex hydrological river system, lakes and streams form the Juruá basin. In this location, white sand, mud and pebble are exploited due to soil characteristics of this ecosystem. Stream waters are black, characteristic of this environment, with the presence of organic materials that commonly fall in the streambed when the marginal vegetation is present.

2.2 Sampling

Three samplings were carried out in each stream at the end of flood, beginning of ebb and drought, between April 2015 to October 2016. Samplings were performed in four streams, each one divided into two stretches of 50m: impacted and less impacted. The level of riparian forest preservation was used to define the impact of the stretches, according to Law No. 12,651, May 25, 2012 - New Brazilian Forest Code, so that the less preserved, the more impacted by sand extraction.

2.3 Data collection

Samples were collected using a D-web sampler (500 μm mesh and 0.155 m² area). The sampler was dragged on stream banks and bottoms. The contents, including sediment, foliage and water were fixed in 5% formalin solution. The samples were sent to the Didactic Zoology Laboratory of the Federal University of Acre, Campus Floresta, for analysis using Leica EZ4 stereomicroscope. The organisms found were photographed, identified at the family level using identification keys [10, 15, 16] and stored in 70% hydro alcoholic solution.

2.4 Data analysis

In order to determine the ecological quality between impacted and less impacted stream areas, were used biotic metrics such as taxonomic richness, Shannon-Wiener diversity (H'), Pielou equitability (J), richness and abundance of EPT (Ephemeroptera, Plecoptera and

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Trichoptera), total abundance, macroinvertebrate density and Biological Monitoring Working Party (BMWP) index adapted by [17].

To compare biotic metrics based in macroinvertebrate fauna between impacted and non-impacted sampling points was performed the Student's t-test.

The Permutational Multivariate Analysis of Variance (PERMANOVA) tested the multivariate differences in the Bray-Curtis matrix of macroinvertebrate species composition between the stream sampling points and the hydrological cycle periods. PERMANOVA considers the samples from each stream as replicates. We used the Monte Carlo permutations test (N = 999) of the similarity matrix to test the statistical significance of $P \leq 0.05$. PERMANOVA was performed using the PRIMER software version 6.0 [18].

In order to verify which species were indicators among streams, the Indicator Value (IndVal) method [19] was applied, where the value of the indicator species varies from 0 to 100, reaching its maximum value when all individuals of a species occur at all sites within a single group. The significance of the indicator value was tested for each species using a Monte Carlo permutation test with 4999 permutations. For this analysis the PC-ORD software version 5.0 was used [20].

3. RESULTS

A total of 198 macroinvertebrates distributed into 11 orders and 24 families were collected. The highest species density was found in non-impacted areas (Table 1), and the order Diptera showed the highest density, with the most representative species of the families Empididae and Simuliidae, followed by the order Trichoptera with the Hydroptilidae family. The Chironomidae and Culicidae family of order Diptera were presented the greatest density in impacted areas.

Table 1. Average density (ind/m2) of aquatic macroinvertebrates collected in four streams (P1, P2, P3 and P4) in three samplings divided in impacted and non-impacted points in a campinarana vegetation complex in northwestern Acre, Brazil.

		Non-impacted				Impacted			
Order	Family	P1	P2	P3	P4	P1	P2	P3	P4
Cladocera	Chydoridae	6.45	0.0	6.45	0.0	0.0	0.0	12.9	0.0
Coleoptera	Dystiscidae	6.45	0.0	0.0	0.0	0.0	0.0	0.0	6.45
	Sphaerisuidae	0.0	0.0	0.0	0.0	6.45	0.0	0.0	0.0

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Copepoda	Cyclopidae	6.45	0.0	19.35	0.0	0.0	0.0	12.9	6.45
	Lyocryptidae	0.0	0.0	6.45	0.0	0.0	0.0	6.45	0.0
Diptera	Ceratopogonidae	12.9	25.8	6.45	0.0	32.25	0.0	6.45	0.0
	Chironomidae	109.67	70.96	12.9	0.0	6.45	25.8	180.65	0.0
	Culicidae	0.0	0.0	45.16	0.0	0.0	0.0	70.96	0.0
	Empididae	161.29	6.45	0.0	0.0	0.0	6.45	0.0	0.0
	Pupa	12.9	19.35	32.25	0.0	6.45	0.0	77.41	12.9
	Simuliidae	148.38	0.0	19.35	0.0	0.0	0.0	0.0	0.0
	Syrphidae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.45
Hemiptera	Hebridae	0.0	0.0	0.0	0.0	0.0	0.0	6.45	0.0
	Naucoroidea	0.0	19.35	0.0	0.0	0.0	0.0	0.0	0.0
Ephemeroptera	Baetidae	0.0	0.0	6.45	0.0	0.0	0.0	0.0	0.0
	Leptophlebiidae	0.0	6.45	6.45	0.0	6.45	0.0	0.0	6.45
Megaloptera	Sialidae	0.0	0.0	0.0	0.0	0.0	6.45	0.0	0.0
Odonata	Coenagrionidae	0.0	0.0	6.45	0.0	0.0	0.0	0.0	0.0
	Libellulidae	0.0	6.45	12.9	0.0	0.0	0.0	0.0	6.45
Plecoptera	Perlidae	0.0	6.45	6.45	0.0	0.0	12.9	0.0	0.0
Trichoptera	Hydroptilidae	0.0	38.7	12.9	0.0	0.0	6.45	6.45	0.0
	Xiphocentronidae	6.45	0.0	6.45	0.0	0.0	0.0	0.0	0.0
Trombidiformes	Arrenuridae	0.0	0.0	6.45	0.0	0.0	0.0	12.9	0.0
	Dermanyssidae	12.9	0.0	12.9	0.0	0.0	0.0	6.45	6.45

The richness and diversity of macroinvertebrate families were significantly greater in forested areas and lower in impacted areas (t=2.57; p=0.02) (Table 2).

According to the Biological Monitoring Working Party (BMWP) index, only less impacted streams showed a great environmental quality, different of impacted streams that showed doubtful environmental quality. Both EPT richness (t = 2.88, p = 0.01) and relative abundance (%) of EPT (t = 3.12, p = 0.01) were also higher at non-impacted areas and presented significant difference between areas (Table 2).

Table 2. Comparison between biotic averages of macroinvertebrate fauna for impacted and non-impacted streams of a campinarana vegetation complex in the municipality of Cruzeiro do Sul, State of Acre, Brazil.

Parameters	Non-impacted	Impacted	t	P
Richness (S)	4.25±5.0	6.6±2.0	-2.57	0.02

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Abundance	29.5±8.0	20.2±26.5	-1.50	0.21
Density (ind/m²)	84.4±51.0	65.2±61.1	-1.67	0.15
Diversity (H)	1.9±0.1	1.08±0.3	-2.82	0.01
Equitability (J)	0.5±0.1	0.7±0.1	-1.30	0.21
Richness EPT	2.5±1.9	1±0.57	2.88	0.01
Relative abundance EPT (%)	19.3±3.2	5.68±0.11	3.12	0.01
BMWP	202	88	2.12	0.01
Classification BMWP	Great	Doubtful	*	*

There was a significant difference between streams regarding their macroinvertebrate composition (Pseudo-F = 4.79, P = 0.001). The post-hoc comparison of interactions revealed that the difference between impacted and non-impacted streams occurred during the flood (t = 2.11, p = 0.001), ebb (t = 2.23, p = 0.003) and dry periods (t = 2.33; p = 0.002).

The indicator families that most influenced the impacted and non-impacted streams ordination were Libellulidae (P = 0.005) and Perlidae (p = 0.03) with an average abundance greater in non-impacted streams. Chironomidae (P = 0.01) presented higher average abundance in impacted streams (Table 3).

Table 3. Indicator value (IndVal) of sample species for impacted and non-impacted streams in a campinarana vegetation complex in northwestern Acre, Brazil.

Family	Area	INDVAL	Mean	Standard dev.	p
Chironomidae	Impacted	56.9	40.5	9.2	0.01
Empididae	Non-impacted	41.7	19.3	7.51	0.04
Coenagrionidae	Non-impacted	41.7	19.1	6.96	0.03
Libellulidae	Non-impacted	58.3	24.2	8.25	0.005
Perlidae	Non-impacted	41.7	19.5	7.36	0.03

4. DISCUSSION

The use of natural areas for sand extraction promotes the change of land use through the removal of riparian vegetation and soil layers, as well as silting and death of streams [21]. Consequently, several species found in campinarana areas may disappear, thus the present study points out the need to recover and preserve these spring water areas.

As expected, the present study showed that anthropic activities related to sand extraction and removal of riparian vegetation from aquatic systems influenced the macroinvertebrates

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density, diversity and richness. According to [10], aquatic insects show great habitat plasticity and can be classified from grabbers and climbers to skaters and divers. Thus, sediment and surrounding vegetation play a major role in their survival. [22] shows that it has long been known that substrate complexity favors the development of aquatic species and the increase of macroinvertebrate richness, since this, together with other variables such as presence of aquatic vegetation and riparian forest, which are more likely to be associated with higher habitat quality [11, 23].

This study identified the predominance of families of order Diptera in impacted systems, mainly Chironomidae, Culicidae and Ceratopogonidae, as expected in literature [24, 25]. Diptera also showed higher density in preserved regions, which may suggest that it, is an opportunistic and adaptive order. This fact may be due to developed morphological adaptations of these families that support alterations such as removal of riparian vegetation, streams sedimentation and, consequently, decrease of dissolved oxygen [10, 24].

Moreover, impacted streams had low abundance and richness rate in the ETP group. In other studies [13, 26] the predominance of families Trichoptera, Plecoptera and Ephemeroptera is associated with great microhabitat heterogeneity, since these organisms prefer to live adhered to substrate, trunks, leaves, stones and plant materials [10, 13]. Thus, ETP species richness is generally affected by negative impacts on stream environments and is considered one of the best indicators of aquatic environments degradation [27].

The BMWP index identified that the impacted streams presented "dubious" conservation quality, which can be verified due to the condition of these streams, which are usually on the edge of dirt roads subject to silting and constant degradation of their margin. These results means that these areas have not yet reached a critical level, and there is a possibility of recovery of these degraded areas.

5. CONCLUSIONS

In this context, the change in water quality in impacted areas, evidenced by the metrics variation of benthic invertebrate community, demonstrated the need for the intervention of government agencies, conservation units and the population itself in order to improve the preservation of natural resources. Thus, we seek to encourage the implementation of actions that reverse the degradation process before the total loss of campinarana streams.

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