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EFFECTS OF LAND USE ON THE COMMUNITY OF BENTHIC MACROINVERTEBRATES IN STREAMS OF THE IQUIRI RIVER BASIN (ACRE, BRAZIL)

EFEITOS DO USO DO SOLO SOBRE A COMUNIDADE DE MACROINVERTEBRADOS BENTÔNICOS EM RIACHOS DE PEQUENA ORDEM NA BACIA DO RIO IQUIRI (ACRE, BRASIL)

Diego Viana Melo Lima*[1]; Luís Pedro de Melo Plese[2]; Igor Honorato Leduino da Silva[3]
[1]Campus Rio Branco, Instituto Federal do Acre (IFAC), Rio Branco/Acre; [2] Campus Rio Branco, Instituto Federal do Acre (IFAC), Rio Branco/Acre; [3] Secretaria de Estado de Produção e Agronegócio (Sepa).

*Autor correspondente: Diego Viana Melo Lima. e-mail: diego.lima@ifac.edu.br

ABSTRACT

The present work aimed to verify whether the change in land use affects the composition and community attributes of benthic macroinvertebrates in small streams in eastern Acre State. The research was developed in streams of the Iquiri River, which belongs to the Acre river watershed, region of Baixo Acre in the municipality of Capixaba (AC). Fourteen streams, all tributaries of the Iquiri River, were selected and grouped in three types of land use: forest (continuous forest), pasture and sugarcane planting. Hydrogen ionic potential (pH), electrical conductivity ($\mu S.cm^{-1}$), water temperature (ºC), dissolved oxygen ($ml.L^{-1}$) and water resistance (Ωm) were determined. In order to analyze possible differences in physicochemical values among the three environments, it was used the Variance Analysis (ANOVA) measure with value significance of 5%. In our study, a strong reduction was observed in the % collectors in streams with presence of pasture, possibly as a consequence of the reduction of fine organic matter, lower in areas where riparian vegetation is reduced or absent.
Key words: grassland, impact, aquatic system, EPT, composition.

RESUMO

O presente trabalho teve como objetivo verificar se a mudança no uso da terra afeta a composição e os atributos da comunidade de macroinvertebrados bentônicos em pequenos riachos no leste do Estado do Acre. A pesquisa foi desenvolvida em riachos do rio Iquiri, pertencente à bacia hidrográfica do rio Acre, região do Baixo Acre, no município de Capixaba (AC). Quatorze córregos, todos afluentes do rio Iquiri, foram selecionados e agrupados em três tipos de uso da terra: floresta (floresta contínua), pastagem e plantio de cana-de-açúcar. Foram determinados o potencial iônico hidrogênio (pH), a condutividade elétrica ($\mu S.cm^{-1}$), a temperatura da água (ºC), o oxigênio dissolvido ($ml.L^{-1}$) e a resistência à água (Ωm). Para analisar possíveis diferenças nos valores físico-químicos entre os três ambientes, foi utilizada a medida de Análise de Variância (ANOVA), com significância de valor de 5%. Em nosso estudo, foi observada uma forte redução na % coletores em córregos com presença de pastagem, possivelmente como consequência da redução de matéria orgânica fina, menor em áreas onde a vegetação ripária é reduzida ou ausente.
Palavras-chave: pastagem, impacto, sistema aquático, EPT, composição.

1. INTRODUCTION

Deforestation is one of the main problems affecting ecosystems. Among the consequences of this anthropic action we highlight the difficulty to practice sustainable activities such as the extraction of native species (eg acai and Brazil nuts) [1], change in soil quality [2], loss terrestrial and aquatic biodiversity [3], changes in forest evapotranspiration.

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In the Amazon, deforestation has attracted attention, especially in the last 30 years [1]. In part, this growth is a result of the pressure caused by the historical economic policy (such as the launch of the Real plan), as well as the difficulties in the scope of the activities of supervisors and regulators of activities with high impact on the environment (large extension of the Amazon and low quantity human resources).

The aquatic environment is directly related to the terrestrial environment. Small-order streams require energy input to maintain their activities and maintain the aquatic biota, including determining the composition and abundance of the aquatic biota [4–6]. When riparian vegetation is altered, the consequences go beyond the change in plant physiognomy, modifying the physicochemical parameters of water [2, 7] and the aquatic community [8–10].

Benthic macroinvertebrates (MIB) are organisms that use some type of substrate for food, habitat, protection or other activity throughout their development, and part of their life cycle is in water [4]. They can present different functions in the community from herbivores to predators, directly participating in energy flows in water [5]. Odonate larvae, some Diptera of the Chironomidae family (genera *Ablabesmyia*, *Clinotanypus* and *Tanypus*) and Hemiptera are examples of predators [11, 12].

The relationship between terrestrial and aquatic environment directly affects the MIB community. Some orders are more sensitive to changes in vegetation such as mayflies, stonefly and caddisflies [13–16], which suffer a reduction in abundance and composition when exposed to environmental changes. Other species are more resistant to impacts and increase abundance because they have the characteristics of tolerant and generalists, as occurs with chironomids (Diptera), Oligochaeta and Hirudinea [3, 17–19].

Based on the knowledge that MIBs respond to environmental changes, some researchers have been looking for ways to measure the magnitude of these impacts. Some of these metrics have shown satisfactory results such as trophic functional group analysis [9,20], percentage of taxa (por exemplo, % Chironomidae, % EPT – Ephemeroptera, Plecoptera e Trichoptera) [21], fauna diversity and composition [3, 14].

Thus, it is noted that this group has great importance for the trophic structure of aquatic systems, however, the low we have little information about the use of these organisms in the evaluation of different land uses. The east of Acre is the place with the most advanced deforestation practices in this state and lacks tools for assessment and monitoring of water resources.

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Thus, the present work aimed to verify how the change in land use affects the composition and community attributes of benthic macroinvertebrates in small streams in eastern Acre State.

2. MATERIAL AND METHODS

2.1 Area of study

The research was developed in streams of the Iquiri River, which belongs to the Acre river watershed, region of Baixo Acre in the municipality of Capixaba (AC) (Figure 1, Table 1). The Iquiri River borders the Zaquel Machado rural settlement project and Green Alcohol Sugarcane mill.

The study area is characterized by the great diversity of occupation and land use, ranging from forest fragments kept in the permanent preservation area of streams, areas used for natural and planted pastures, and sugarcane monoculture areas.

Sampling plan

Fourteen streams, all tributaries of the Iquiri River, were selected and distributed in three types of land use: forest (continuous forest), pasture and sugarcane planting (Figure 1). All streams selected for sampling had a permanent protection area [22], therefore distinct in terms of land use around them. For pasture and weed land use we assigned the titles of pasture 1, 2, 3 and 4 and forest 1, 2, 3 and 4. The points defined as sugarcane were characterized by the planting of sugarcane, denominating sugarcane 1, 2, 3, 4, 5 and 6.

The region where this study was developed has intense anthropic activity as the region has rural settlements, as is the case of the rural settlement project (Zaquel Machado), as well as an industrial enterprise for ethanol production, called the Álcool Verde industry. The streams presented an average width of 1.40 m ± 0.40 m, with an average depth of 0.80 m ± 0.20 m, and predominant substrate of leaf bank and clay. All streams were identified in 1st to 3rd order, according to [5]. The points were marked with Garmin brand GPS and GPSmap 60CSx model.

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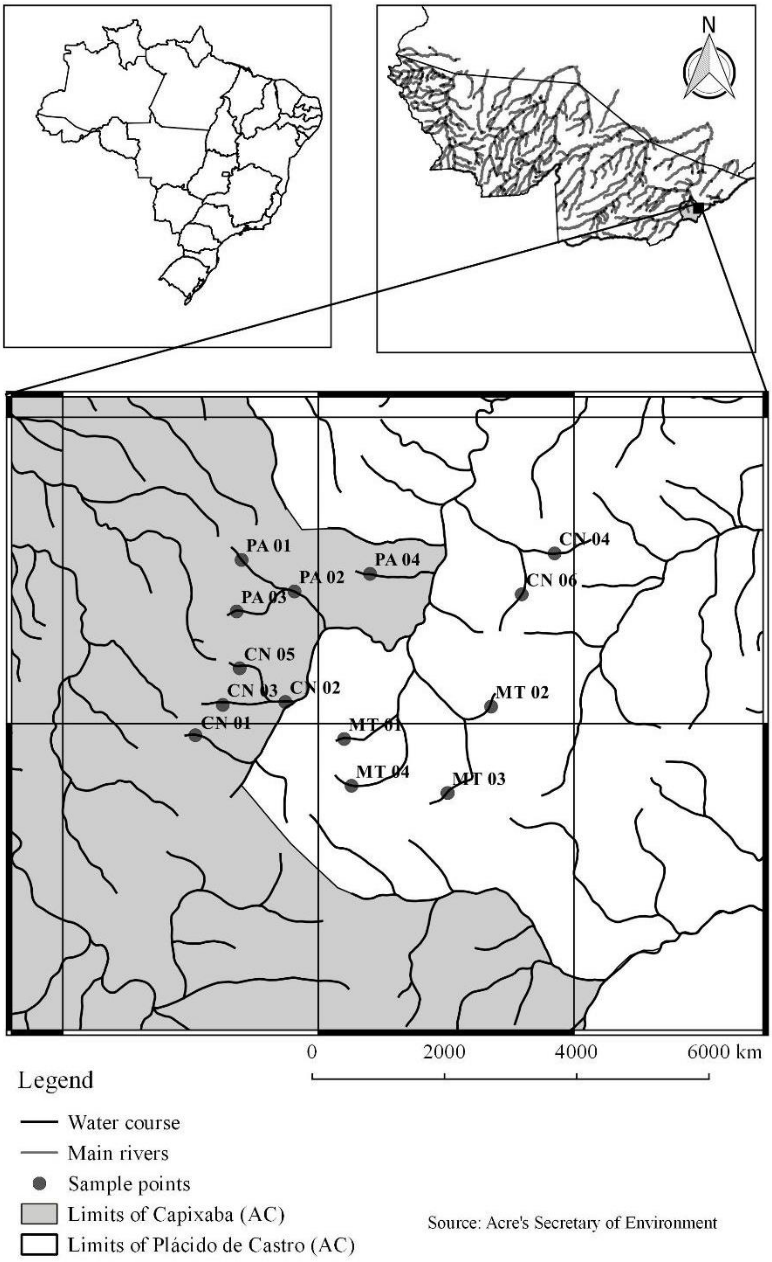

Figure 1. Map with the location of the streams collection areas that make up the basin headwater of the Iquiri River, Capixaba, Acre, Brazil.

Table 1. Geographical location of the sampling points of the study area, in streams of basin headwater of the Iquiri River, Capixaba, Acre, 2010. (MT = forest; PA = pasture; CN = sugarcane).

Location	Identification	Longitude	Latitude
MT 01	Forest	-67.675340	-10.426990
MT 02	Forest	-67.734300	-10.415606
MT 03	Forest	-67.728400	-10.423240
MT 04	Forest	-67.673490	-10.442715
PA 01	Pasture	-67.708054	-10.365932
PA 02	Pasture	-67.690200	-10.377196

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PA 03	Pasture	-67.710513	-10.383025
PA 04	Pasture	-67.663949	-10.372415
CN 01	Sugarcane	-67.720456	-10.398563
CN 02	Sugarcane	-67.729827	-10.364152
CN 03	Sugarcane	-67.716688	-10.413869
CN 04	Sugarcane	-67.719406	-10.350912
CN 05	Sugarcane	-67.710320	-10.402040
CN 06	Sugarcane	-67.741134	-10.371355

Source: authors.

2.2 Physicochemical Parameters

The physicochemical parameters were determined using a YSI model 600R limnological probe. Hydrogen ionic potential (pH), electrical conductivity ($\mu S.cm^{-1}$), water temperature (ºC), dissolved oxygen ($ml.L^{-1}$) and water resistance (Ωm) were determined (Table 2). Total nitrogen and total phosphorus analyzes were performed according to the Standard Methods for the Examination of Water and Wastewater [23]. All these parameters, including water temperature (ºC) were measured at four points to characterize the extension of the studied stream.

2.3 Collection of macroinvertebrates

The macroinvertebrate specimens were sampled using the Suber sampler [24]. In each stream a 100 m length was determined as the sampling unit for each stream. Semi-quantitative sampling was adopted using the Surber sampler (mesh: 250 µm; area: 0.09 m^2). In order to maximize the number of sampled habitats, riffles and pools microhabitats were selected. In the riffles samples three sub-samples were obtained per point: left margin, center and right margin. This procedure was repeated in the three riflles samples. In the pools three samples were obtained, totaling 12 sample units in each sample unit.

The collected individuals were stored in plastic bags with capacity of 5L and fixed in 70% alcohol, and transported in 50L bottles to avoid damage to the material during transportation. The identification of biological material was performed in the Entomology laboratory of the Federal University of Acre (UFAC).

All organisms were identified up to the family level, which were identified by dichotomous identification keys for the collected groups [25–28].

2.4 Statistical analysis

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In order to analyze possible differences in physicochemical values among the three environments, it was used the Variance Analysis (ANOVA) measure with value significance of 5%. A principal component analysis (PCA) was applied to the physicochemical variables with the purpose of determining which were more significant for characterization of the streams in the different uses of the land (similarity adopted from 80%) [29].

The biotic analysis was based on 17 metrics communities: % Chironomidae, % Coleoptera, % Diptera, % Ephemeroptera, % EPT, % Shredder, % Predator, % Scraper, % Collector, % Filtrate, richness families, richness families Plecoptera, richness family Trichoptera, total abundance, dominance, Shannon diversity and evenness [30]. These metrics were submitted to the Cluster analysis (Bray-Curtis) to verify if there is similarity in the composition of the fauna among the types of environments. A principal component analysis was applied to community metrics to determine which metric is most determinant in impact detection. The analyzes were performed by the PAST statistical program.

3. RESULTS

3.1 Environmental variables characterization

The general pattern of streams of forest environments in this study was of more oxygenated waters, with a tendency to alkalinity and higher concentration of nitrogen and total phosphorus. Streams that pass through pasture areas presented cooler waters, although more acidic and anoxic conditions. Streams from sugarcane plantation area were hotter and with more electrical conductivity, with lower concentrations for nitrogen and total phosphorus (Table 2).

Table 2. Mean and standard deviation of the physicochemical variables measured for the streams that cross the forest, pasture and sugarcane environments, in the municipality of Capixaba, AC, 2009.

Variables	Forest	Pasture	Sugarcane
Temperature (ºC)	28.68±0,91	28.22±1,87	28.82±2,49
Dissolved oxygen ($mg.L^{-1}$)	1.05±1.70	0.26±0.10	0.59±0.79
pH	6.27±0.23	6.20±0.09	6.23±0.37
Electric conductivity ($Ms.cm^{-1}$)	8.63±1.11	7.63±2.02	15.17±16.27
Resistance	126.97±17.66	127.47±27.67	121.71±63.86
Total nitrogen ($mg.L^{-1}$)	0.079±0.04	0.070±0.04	0.058±0.030
Total phosphorus ($mg.L^{-1}$)	0.77±0.32	0.69±0.28	0.550±0.197

Source: authors.

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According to ANOVA, only the total nitrogen variables (F = 4.54, value p = 0.01) and total phosphorus (F = 9.29, value p= 0.00) showed significant differences, while the temperature variables (F=2.13; value p=0.16), dissolved oxygen (F=0.59; value p=0.57), pH (F=2.36; value p=0.14), electrical conductivity (F=1.20; value p=0.34), and resistance (F=1.91; value p=0.19), they were not different.

The first two components of the PCA explain 60.2% of the total variability in the analyzed data (Table 3). The electrical conductivity, the resistance and the pH were more decisive to explain the variation in the first component, so that, streams near areas with sugarcane plantation showed more electrical conductivity, in areas with presence of ciliary vegetation had more alkaline waters and pasture areas, greater resistance in water. In the second component, total phosphorus was the main variable in the explanation of the streams variation, being characteristic of pasture streams (Figure 2).

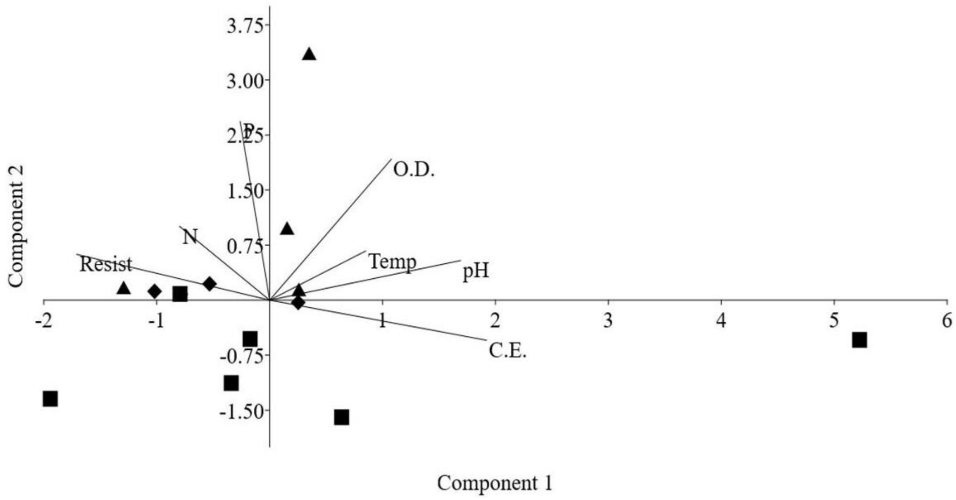

Figure 2. Principal component analysis (PCA) using physicochemical variables, collected from samples of streams in forest areas (triangle), pasture (lozenge) and sugarcane plantation (square). Temp. = temperature; D. O. = dissolved oxygen; pH = Hydrogen potential; P = total phosphorus; N = total Nitrogen; E. C. = electrical conductivity; Resist. = resistance.

Table 3. Correlation of abiotic variables with the axes (components) of principal component analysis (PCA) for analyzed variables of samples from the headwater of the Iquiri River, Capixaba (Acre, Brazil).

Variables	Axis 1	Axis 2	Axis 3	Axis 4
Temperature	0.18964	0.16088	0.87227	-0.02545
Oxygen dissolved	0.49703	0.086445	-0.06388	0.090847
pH	0.42435	0.37373	0.16463	-0.08164
Electrical conductivity	0.52354	-0.077772	-0.16269	0.14496
Resistance	-0.45773	0.013743	0.33995	-0.07092
Total nitrogen	-0.19905	0.47709	-0.0379	0.85409
Total phosphorus	-0.11699	0.77014	-0.25395	-0.47845

Source: authors.

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3.2 Community Pattern

A number of 3.968 macroinvertebrates were collected, being Diptera the most abundant order with 2,661 organisms, representing about 67% of the total of invertebrates collected in this study. The Trichoptera order obtained 426 organisms and it was the second most represented group. Plecoptera and Megaloptera were less abundant with only 4 organisms each.

The analysis of the community pattern revealed a greater similarity between the community of macroinvertebrates of streams present in sugarcane and pasture, than the biotic identified in places with presence of ciliary forest (Figure 3).

The analysis of the principal components explained 95.36% of the total variation, being the first component responsible for explaining 80.15 % of the variation data, and the second component explained 15.21 %. The main metric responsible for the variation in the first component was % collector, and in the second component, % EPT (Table 4, Figure 4). Low values for % collectors was a common characteristic related to streams from pasture areas, same result obtained in % EPT.

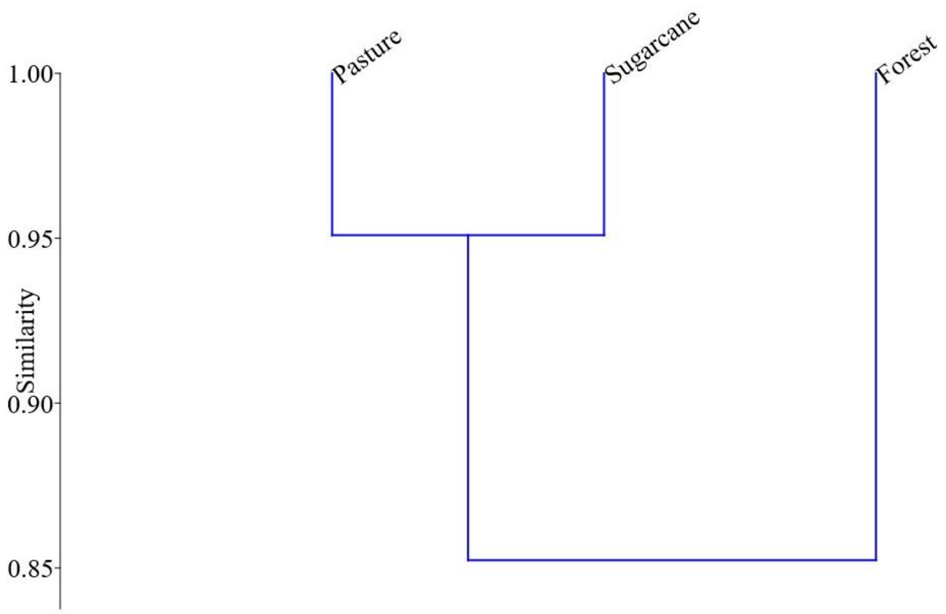

Figure 3. Cluster analysis based on the Bray-Curtis similarity matrix, based on the 17 metrics of communities obtained from the streams samples in areas of forest, pasture and sugarcane plantation.

Table 4. Community descriptors of macroinvertebrates obtained from streams samples in forest, pasture and sugarcane fields, in Capixaba, AC, 2009

Community metrics	PC 1	PC 2
% Chironomidae	-0.004	-0.011
% Coleoptera	0.047	-0.132
% Diptera	-0.197	-0.296
% Ephemeroptera	0.091	0.367
% EPT	-0.117	0.709
% Shredder	0.217	0.030

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% Predator	0.033	-0.422
% Scraper	0.225	0.031
% Collector	-0.768	0.079
% Filtrate	0.111	0.255
Richness families	0.005	0.014
Richness families Plecoptera	0.228	0.028
Richness families Trichopetra	0.205	0.048
Abundance	-0.087	0.032
Dominance	0.226	0.028
Diversity	0.193	0.023
Evenness	0.217	0.026

Source: authors.

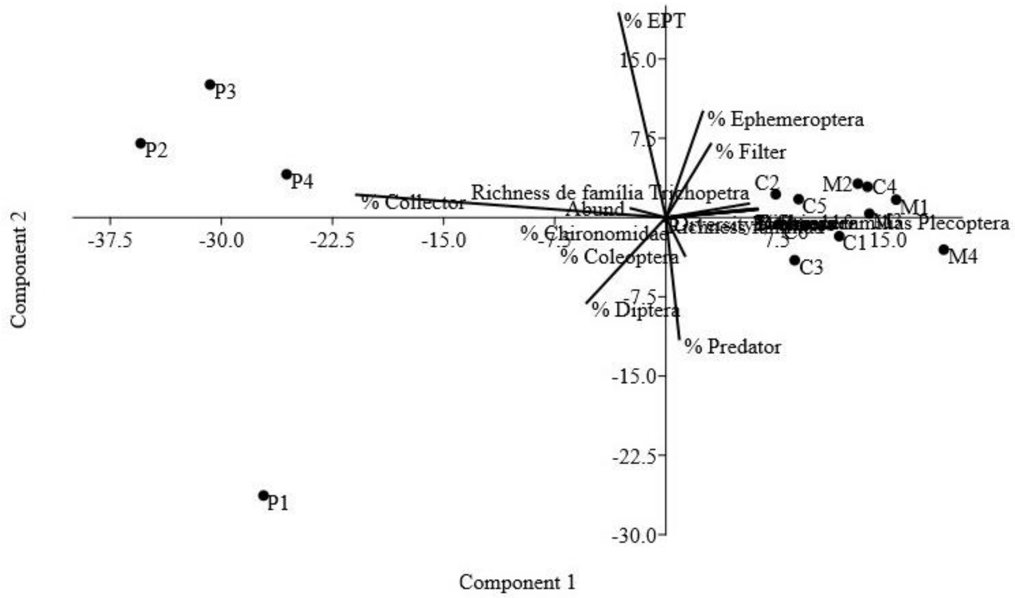

Figure 4. Principal component analysis using the 17 metric benthic macroinvertebrates obtained from streams samples in areas of forest, pasture and sugarcane plantation. P = pasture samples; M = forest samples; C = sugarcane samples.

4. DISCUSSION

The physicochemical pattern identified in this study followed the general behavior of preserved areas in streams of tropical environments, with greater evidence for the total nitrogen and total phosphorus variables. Waters with a high concentration of dissolved oxygen and less hot temperatures are a consequence of the vegetal cover provided by the maintenance of ciliary vegetation with extensive canopy and, in this way, with a greater proportion of shaded areas, helping to regulate the temperature of the understory and consequently in aquatic systems [8, 31].

It is common to identify physical-chemical changes in water in places where there is a change in land use. The working model of aquatic ecosystems describes the strong relationship of the changes of the terrestrial environment, especially when the streams are closer to

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headwater where the relationship with land nutrients can alter the chemistry of water, as assumptions of the River Continuum Concept [5].

On the other hand, some physicochemical variables change over natural gradients, and may aggravate natural conditions when there is interference from anthropic impacts. For example, pH and electrical conductivity are modified by changes in longitudinal gradients. However, when these water systems are subject to changing conditions in land use, these variables are modified more intensely because of imbalance in nutrient cycling [1, 4, 16]. [14] identified changes in physicochemical characteristics associated with land use, especially in activities of great impact on areas of permanent preservation, such as livestock and agriculture, where it is common to reduce and even completely remove the protection of streams, resulting, among other things, in an increase in water temperature.

Low magnitude changes sometimes retain the functionality of forest fragments, and can guarantee oscillations in the physicochemical variables within acceptable ranges for ecological integrity. Some studies show that samples from streams with forest remnants can improve and even stabilize the quality of their environments [14, 31, 32]. The reduction of dissolved oxygen, for example, may be due to the increase in temperature, reduction of atmospheric pressure or the increase of organic matter inside the stream [15, 33]. The streams with passages inside sugarcane areas plantation showed greater decline in average values of dissolved oxygen, certainly as a result of the increase of the byproducts from planting cycles and the use of agricultural pesticides common to this crop, which, after the leaching process, adduce organic matter with implications on the chemistry of aquatic systems.

In this study, although the differences were not so extreme, possibly due to the temporary suspension of the sugarcane plantation cycle, we identified a tendency to change both in water properties and in aquatic biotic, the latter being more sensitive than the former.

The community of aquatic macroinvertebrates is an important tool to control environmental quality, monitoring and evaluation of impacts on aquatic systems. Our results confirmed the hypothesis of alteration in fauna composition due to changes in land use, with greater similarity between the taxonomic composition of pasture and sugarcane, different from the biotic with presence of ciliary vegetation. The fauna of macroinvertebrates revealed greater power of response in the detection of impacts, demonstrating greater efficiency when compared to the conclusions obtained by the physicochemical variables. These implications are associated with changes occurring in land use, with removal and / or alteration of ciliary vegetation, implying changes in the functioning of aquatic systems, as the reduction of fine particulate organic matter, one of the main resources available for the maintenance of the aquatic biotic.

Another important factor to be highlighted is the preservation of the headwater. In general these environments are vulnerable to changes in land use affecting, for example, the environmental heterogeneity of aquatic systems and the availability of organic matter and, consequently, in releasing organic fine particulate matter, main food source of some macroinvertebrate groups, such as Diptera and Ephemeroptera (Baetidae) [4, 5, 19].

Within the macroinvertebrate community, the order Diptera is dominant in practically all types of aquatic systems [2, 14, 31]. The species of this order have high alimentary plasticity and wide range of tolerance for the environmental variables, so that conditions considered uninhabitable by some taxa (nymphs of Plecoptera, for example) are easily adapted for some families (for example, Chironomidae) [14, 31, 34]. The Chironomidae family can colonize different environments and presents diversified responses to environmental conditions, besides presenting the ability to characterize impacted rivers, with very low concentrations of dissolved oxygen and high concentrations of turbidity [14]. For example, [24], reported that Chironomidade family together with Odonata and Ephemeroptera, were the most representative in preserved environments with different types of water (clear and white) in the western Amazon, revealing that this group is naturally abundant, even in places with high environmental preservation conditions, same identifier pattern by [19].

As a result, it is becoming increasingly difficult to establish reference areas because of the intense deforestation carry on in this region. In this study we verified the high number of conversion of forest to pasture, the main activity along BR 317, commonly called the Pacific Highway. As a result, the forest continues are becoming smaller and smaller, and the areas near the streams become subject to being kept with smaller and smaller forest fragments. As a consequence of this, in our study the Plecoptera order was identified in only one collection point (Forest 1). This order is represented by organisms sensitive to environmental changes, whose tolerance range is narrow related to dissolved oxygen and turbidity, and it is, therefore, always associated with an environment with high environmental quality acting as one of the main bioindicators of good ecological quality [15, 16, 35].

The presence of collectors is related to the activity of fragments on organic matter, available by ciliary vegetation. When this organic matter enters the aquatic system, the shredders soon come into action, converting into fine organic matter available to the collectors. In our study, a strong reduction was observed in the % collectors in streams with presence of

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pasture, possibly as a consequence of the reduction of fine organic matter, lower in areas where riparian vegetation is reduced or absent [12, 36].

CONCLUSION

This research confirmed that the composition and diversity of macroinvertebrates changed along different soil uses. With this, we suggest the expansion of this research to know how these organisms respond in other localities of the State of Acre, considering the different forest types existing in this part of the Amazon. With this, we suggest the expansion of this research to know how these organisms respond in other localities of the State of Acre, considering the different forest types existing in this part of the Amazon.

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