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Colonization of artificial substrates by macroinvertebrates: an approach for assessing the water quality of the La Vega river in Tunja, Boyacá

Colonización de sustratos artificiales por Macroinvertebrados: Un enfoque para la evaluación de la calidad del agua del río la Vega en Tunja, Boyacá

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ABSTRACT

Macroinvertebrates are organisms used in water quality monitoring. The ecological quality of the La Vega river as it passes through Pedagogical and Technological University of Colombia (UPTC) was evaluated through the analysis of artificial substrate colonization by aquatic macroinvertebrates. Five sampling points were selected, where two bricks, one clay and one wooden, were placed to allow colonization by these organisms. Macroinvertebrates were collected at each point, along with the measurement of physicochemical and environmental variables. Families such as Physidae, Polycentropodidae, and Chironomidae were notable, with significant colonization on the wooden brick due to its higher adhesive capacity. Additionally, a strong correlation was found between macroinvertebrates and variables such as light intensity, dissolved oxygen, conductivity, and river depth. Finally, there was evidence of poor water quality in the river according to the Andean Biotic Index (ABI), possibly due to the influence of anthropic activities.

Keywords: Macroinvertebrates, Glossiphoniidae, Tunja

RESUMEN

Los macroinvertebrados son organismos utilizados en el monitoreo de la calidad del agua. Se evaluó la calidad ecológica del río La Vega a su paso por la Universidad Pedagógica y Tecnológica de Colombia (UPTC) a través del análisis de la colonización de sustratos artificiales por macroinvertebrados acuáticos. Se seleccionaron cinco puntos de muestreo, en donde se ubicaron dos ladrillos, uno de arcilla y uno madera, para permitir la colonización por estos organismos. En cada punto se realizó la recolección de macroinvertebrados, junto con la medición de variables físicoquímicas y ambientales. Se destacan familias como Physidae, Polycentropodidae y Chironomidae, con una colonización notable en el ladrillo de madera debido a la mayor capacidad de adherencia proporcionada. Además, se encontró una fuerte correlación entre los macroinvertebrados y variables como intensidad lumínica, oxígeno disuelto, conductividad y profundidad del río. Finalmente se evidenció una mala calidad del agua en el río según el Índice Biótico Andino (ABI), posiblemente por la influencia de actividades antrópicas.

Palabras Clave: Macroinvertebrados, Glossiphoniidae, Tunja.

1 INTRODUCTION

Aquatic macroinvertebrates are organisms larger than 500 µm, which play a fundamental role in the food chain of lotic ecosystems [1]. The presence and establishment of aquatic macroinvertebrates is determined by the nature of the available substrate, where tolerant taxa occur throughout the area due to increased activities such as agriculture, and pollution-sensitive groups are associated with the remaining patches of forest [2]. For this reason, aquatic macroinvertebrates have been used worldwide in bioindication and monitoring studies to determine the water

quality of rivers, streams, lakes and other water bodies they inhabit. The use of this group for such studies is based on their high abundance, specific ranges of requirements and tolerance of both biotic and abiotic characteristics; their collection methodology is simple and inexpensive and their use is based on biotic indices that allow estimating tolerance and sensitivity to pollutants [3]. The objective of this work was to evaluate the ecological quality of the La Vega river as it passes through the UPTC through the analysis of the colonization of artificial substrates by aquatic macroinvertebrates.

2 METHODOLOGY

2.1 Sampling Stations

Five sampling points, each five meters apart, were established along the La Vega River as it passes through UPTC. These points were chosen to encompass the maximum number of possible meso-habitats (P1:Rapids, P2:Runs, P3:Rapids & Runs, P4:Rapids & Runs, P5: Pools). In the middle section of each point, two bricks were placed, one made of clay and one of wood both measuring: Length (24.5 cm), width (12 cm), and height (6 cm). Each structure in the middle contained two square holes measuring 7 cm and a rectangle in the center between the two 7 cm squares, measuring 1.5 cm in width. The placement of these structures at each site was facilitated using a wooden stabilizer. At each sampling point, five physicochemical variables of water were measured: water temperature (WT)°C, potential hydrogen (pH), dissolved solids (DS) ppm, conductivity (C) μS and dissolved oxygen (DO) mg/L. Three hydraulic variables were recorded: river depth (RD) cm, water velocity (WV) m/s, and river width (RW) m. Additionally, four environmental variables were assessed: light intensity (LI) Lux, air velocity (AV) m/s, ambient temperature (AT) °C, and humidity (H) %.

2.2 Collecting macroinvertebrates

The collection was carried out in specific weeks: in the first week, at point one; in the third week, at point two; in the fifth week, at point three; in the sixth week, at point four; and in the seventh week, at point five. Macroinvertebrates were stored in glass containers with 70% alcohol. Identification was done up to the taxonomic family level using dichotomous keys and equipment provided by the Laboratory of the Unit of Ecology in Aquatic Ecosystems (UDESA) at the Pedagogical and Technological University of Colombia.

2.3 Data processing

The analyses were conducted using RStudio version 2023.03.1 +446. Dominance of macroinvertebrate families on each substrate was assessed using an abundance rank curve with the BiodiversityR package. Family richness and diversity on the substrates were evaluated using Hill numbers and presented in boxplots through the Vegan package (Community Ecology Package). An analysis of variance (ANOVA) was performed to identify significant differences between substrate families, and a heat map illustrated their distribution. Physical, chemical, environmental, and hydraulic variables were normalized for Principal Component Analysis (PCA) to identify uncorrelated explanatory variables. Canonical Correspondence Analysis (CCA) explored correlations between variables and identified families. Finally, the ecological quality of La Vega River at UPTC was determined using the Andean Biotic Index (ABI) [4].

3 RESULTS

The identification was carried out up to the taxonomic level of family, as it is the one used by the Andean Biotic Index (ABI) and also represents the highest level achievable considering time constraints, available identification materials, and budget limitations. These factors prevented a more detailed examination of certain organism structures, the use of more updated keys, or the application of molecular techniques for a more precise identification.

In this study, a total of eleven families of macroinvertebrates were identified, which are: Chironomidae, Polycentropodidae, Philopotamidae, Physidae, Psychodidae, Elmidae, Lumbriculidae, Planorbidae, Glossiphoniidae and Ptilodactylidae. The families with the highest relative abundances on both substrates were Physidae, Polycentropodidae and Lumbriculidae (Fig. 1).

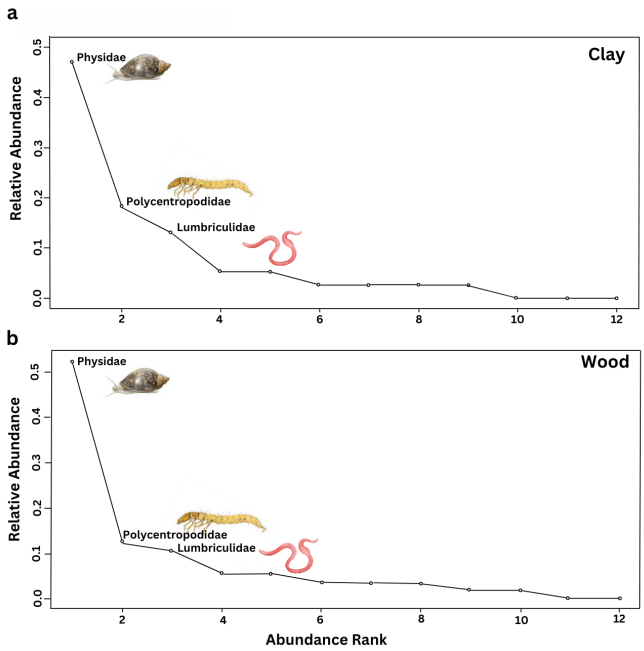

Fig. 1. Abundance Rank Curve. (a) Abundance rank curve for families in the wood substrate. (b) Abundance rank curve for families in the clay substrate.

No significant differences were found in richness and diversity analyzed using Hill numbers when comparing the two substrates ($p - value > 0.05$), indicating similar distribution of recorded families on both substrates. Notably, families Physidae, Planor-

bidae, Philopotamidae, Ptilodactylidae, Elmidae, Polycentropodidae, and Chironomidae showed higher abundance on the wooden brick. Conversely, families Psychodidae, Glossiphoniidae, and Lumbriculidae were predominantly distributed on the clay brick (Fig. 2), suggesting most families had higher abundances on the wooden brick possibly due to its rough, porous surface, providing benefits for macroinvertebrates to avoid being washed away [5]. Regarding substrate-specific families, Glossiphoniidae and Psychodidae naturally inhabit smooth surfaces similar to the clay brick [6], [7], while Ptilodactylidae is found on wooden bricks as it forms their primary food source [8].

Table 1. ABI score for different sample points. PQ: poor water quality, vPQ: very poor water quality.

P1	P2	P3	P4	P5
24	22	17	6	15
PQ	PQ	PQ	vPQ	PQ

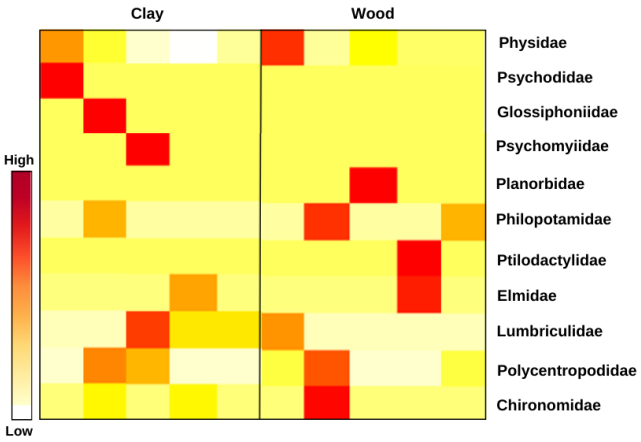

Fig. 2. Heat map depicting the relationship between family abundance on two substrates, considering the five sampling points.

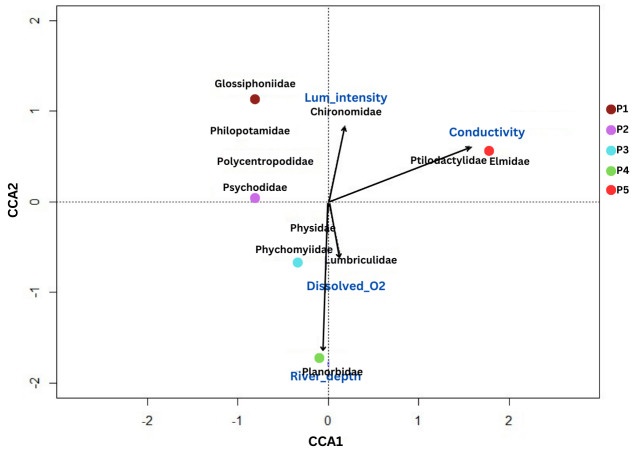

Fig. 3. Canonical correspondence analysis among environmental variables, macroinvertebrate families, and sampling points.

The environmental variables that showed the highest correlation with the observed families according to the CCA were light intensity, dissolved oxygen, conductivity, and river depth (Fig. 3) [9], [10]. The families Elmidae and Ptilodactilidae were found exclusively at P5, which is a well and were related to water conductivity. This correlation with conductivity could be explained by the proximity to agricultural activities due to the crops in the surrounding areas or also by the presence of cattle and horse manure, which could increase the salt concentration [11]. Likewise, P4 presumably presents the effects of the aforementioned anthropogenic activities. This point mainly presented a shallow mesohabitat such as runs and riffles, which led to a negative correlation with river depth. The family Planorbidae is correlated with this point because there is a run, meaning there is a slow flow of water and the possible availability of food such as fine organic deposits [12], furthermore, this family shows tolerance to pollution according to the Biological Monitoring Working Party (BMWP) [13]. A bioindicator taxon, the family Polycentropodidae, and two tolerant taxa, the families Chironomidae and Glossiphoniidae, were recorded. These tolerant families can develop in environments with a high level of disturbance due to anthropogenic activities such as livestock, agriculture, and wastewater discharge, because they have the ability to colonize areas with low oxygen availability and exhibit great adaptability [14], [15]. Finally, the ABI index recorded poor water quality at four of the sampling points and very poor water quality at one of the points, based on the recorded families (Table 1).

4 CONCLUSIONS.

When assessing the ecological quality of the La Vega River through the analysis of colonization of artificial substrates by aquatic macroinvertebrates using the (ABI) index, poor water quality was found. The findings underscore the importance of considering the interaction between artificial substrates, environmental variables, and biological communities in the management and conservation of aquatic ecosystems, particularly in areas affected by high levels of anthropogenic contamination.

Declaration: The authors declare no conflicts of interest.

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