Original Article

# AQUATIC MACROINVERTEBRATE COMMUNITY STRUCTURE IN SOIL USE IN THE LOWER MOCACHE RIVER MICRO-WATERSHED, ECUADOR

**Guerreo Chuez Norma María[1], González Osorio Betty Beatriz[2], Pérez Anchundia Karla Micaela[3], Arriaga Loor Gabriela Jazmín[4]**
[1,2,3,4]Universidad Técnica Estatal de Quevedo. Campus "Ingeniero Manuel Agustín Haz Álvarez", Quevedo, Ecuador
Email: nguerrero@uteq.edu.ec

## Abstract

Aquatic macroinvertebrates are considered an indicator of water quality, along with physicochemical parameters, because these variables have an essential performance in the transformation of organic matter Keywords: ecological quality index, BMWP_Cr, macroinvertebrates, environmental gradient, tropical streams. The research objective was to evaluate the structure of aquatic macroinvertebrate communities in different land uses in the lower micro-watershed of the Mocache River. The D-net method with 500µm mesh was used to collect specimens of soil uses (agricultural, forest and pasture); the Shannon-Weaver diversity, Simpson's dominance and Pielou indices were applied to evaluate the quality of the water resource. Non-parametric similarity analysis (ANOSIM) and ANOVA variance analysis were used to identify the similarity of aquatic macroinvertebrate genera. To evaluate redundancy (RDA), a physicochemical analysis was performed. The BMWP_Cr index, IHF and QBR were applied to evaluate water quality in soil uses. The abundance of aquatic macroinvertebrate communities showed superficial differences in similarity based on land use, the Brechmorhoga of the order Odonata the most abundant, whose land use is forest cover, categorizing the bioindicator of water quality as "moderately regular." The order Ephemeroptera presented a greater richness of specimens in agricultural land use, pasture and forest. The physicochemical parameters pH, temperature (°C), dissolved oxygen (DO) and turbidity (NTU) are the most representative of agricultural land use and pastures due to local anthropic pressure. The IHF and QBR indices for land use in forest quality were "Good," in contrast to agricultural land use and pasture which had quality values of "Moderate" and "Poor." This indicates that human actions directly impact aquatic ecosystems, modifying land use's ecological attributes. The BMWP_Cr index showed that the forest land use had excellent water quality.

**Keywords:** Water quality, river habitat index (IHF), riparian forest quality index (QBR), BMWP-Cr index.

## INTRODUCTION

Globally, the average water availability in the world is approximately 1386 million km3 being 2.5 % (35 million km3 ) freshwater; i.e., 30 % is available for human consumption (CONAGUA, 2011). However, most freshwater is polluted due to human activities such as agriculture, residential expansion, reservoir development, and hydrological alterations that have led to ecological changes such as increased nutrient and microbial loads. (Damanik-Ambarita et al., 2016). One of the consequences of the destruction of river ecosystems is the direct exposure of agrochemicals, which reduces species and decreases the faunal composition (Carrie et al., 2017).

**Address for correspondence: Guerreo Chuez Norma María**
Campus "Ingeniero Manuel Agustín Haz Álvarez", Quevedo, Ecuador
Email: nguerrero@uteq.edu.ec



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In addition, water quality influences land use, and these factors are affected by activities such as industrialization and rural land conversion (Hassan Rashid et al., 2018).

On the other hand, Xia et al. (2016) indicate that many researchers have provided convincing evidence that the stream hydrological process and variations in water quality are associated with land use changes such as forest, grassland and agriculture. According to Bezerra et al. (2021), in his study, 80% of agricultural land use generates water pollution, while 50% of pasture land use pollutes river ecosystems; however, forest land use does not pollute the water resource as it functions as a nutrient sink for the rivers due to its effects of fixation and adsorption of pollutants. (Shi et al., 2019).

In Latin America, the primary agricultural sector is mainly responsible for water pollution due to the intensification of nitrates, phosphorus, pesticides, soil sediments, salt and pathogens from agricultural and livestock activities (Parris, 2011). For example, in Ecuador, the availability of water resources is approximately 28110 m3 per person/year, exceeding the Latin American average of 22000 m3 (Peña et al., 2019). However, the lack of water quality control causes alterations in the sensitivity to macroinvertebrate species (Ephemeroptera, Plecoptera, Trichoptera and Coleoptera) (Damanik-Ambarita et al., 2018: Selvanayagam & Abril, 2015).

The change influences the natural conditions of freshwater bodies in the use of coverage and alteration of the physicochemical characteristics of streams due to factors such as progressive human activity, expansion of land by agricultural plantations and scarce vegetation, which leads to an ecological loss that implies a decrease in resilience levels and irreparable damage to biodiversity. (Damanik-Ambarita et al., 2016)For this reason, various technologies such as the biotic index, BMWP-CR index, Horton index and biological indices have been developed throughout several studies to study surface water quality through aquatic indicators (Calvo-Brenes, 2013). These methodologies are an important tool for evaluating and monitoring water resources (González et al., 2012).

The Mocache canton bases its economy on agriculture, surrounded by surface water bodies, which are highly influenced by applying pesticides, human settlements, and agro-industrial activities, which significantly alter the structures in families and communities of aquatic macroinvertebrates (Rosado et al., 2017). Given the importance that these aquatic insects have on water systems, as well as the strategies to protect water resources, this research aims to analyze the structure of aquatic macroinvertebrate communities in different land uses of the lower microbasin of the Mocache River and water quality based on the BMWP-Cr indexes, River Habitat Quality Index (IHF) and bank quality QBR (Macías Aldaz, 2020).

## Materials and methods

Location and sampling point

The research was carried out in the lower micro-watershed of the river in the canton of Mocache, Los Ríos province, with a longitude of 79°30'28.318 "W and latitude of 1°15'32.621 "S at a temperature ranging between 23 °C and 33 °C. (Macías Aldaz, 2020). The sampling process was carried out during the last month of 2020 and at the beginning of 2021 in January and February, for which three sampling points were considered along the estuary with different land uses: pasture cover; cover with agricultural plantations, mostly African palm; and with a forest stream (Figure 1).

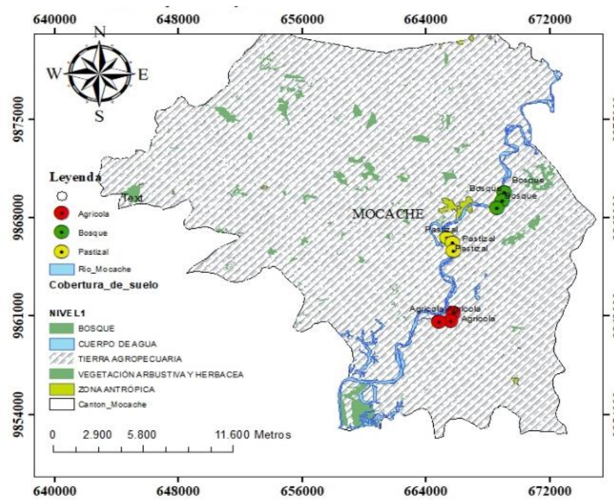


**Figure 1.** Location of sampling points

Water quality study

Physical, chemical and hydrological parameters were analyzed, sampling was performed in the rainy season, and nine sampling stations were determined in soil use (agricultural, forest and pasture). The parameters evaluated were temperature (°C), pH, electrical conductivity (µS cm-1), turbidity (NTU), hardness (mg/l), dissolved oxygen DO (mg/l) and total dissolved solids TDS (ppm). These physicochemical parameters were analyzed with multiparametric equipment Turbidity Meter (TB100), portable Ionometer YD300A measured water quality hardness, calcium and magnesium, and Water Quality Meter analyzed dissolved oxygen, electrical conductivity, pH, temperature and dissolved solids, applying the methodology of (Md Rawi et al., 2014)In addition, the physical indicators DO and pH are efficient and widely used for water quality assessment. (Yazdian et al., 2014). ; moreover, physical indicators OD and pH were also considered to measure water quality (Yazdian et al., 2014). The height and depth were determined with a meter and graduated rod in the unit of length (m). Flow rate (Q) was measured using the floating object method (Urdanigo et al., 2019).

Sampling of aquatic macroinvertebrates

Aquatic bioindicators were collected during rainy seasons.

Nine sampling points were used with a period of 45 days between each sampling in different habitats, which included vegetation zone, riparian vegetation, fast shallows, and slow shallows; the collection time was approximately 30 minutes. In addition, a D-net (405 cm2 ) with a 500 µm mesh was used to collect macroinvertebrates located downstream. The analysis and study of the species were carried out up to the family taxonomic level using a microscope and specialized taxonomic keys. (Domínguez & Fernández, 2009; Roldán, 2003).. Water samples were analyzed and stored at the Microbiology and Entomology laboratory of the Quevedo State Technical University.

Water quality index BMWP-Cr

To evaluate water quality at the sampling points, the BMWP_Cr index was estimated. It should be noted that this index is related to the richness of family taxa and is based on changes in abundance and biodiversity of macroinvertebrate communities due to the reduction of DO levels (organic pollution) and some invertebrates that may become more sensitive to pollution than others. Based on this, pollution-sensitive families receive higher scores than less tolerant families (Armitage et al., 1983).

To evaluate water quality based on the BMWP_Cr biological index, the families of aquatic macroinvertebrates and the significance of the values were considered (Tables 1 and 2).

**Table 1.** Scores and bioindicators in the aquatic macroinvertebrate families of the BMWP_Cr index.

| Families | Score |
|---|---|
| Ptilodactylidae, Calamoceratidae. Blephariceridae, Odontoceridae | 10 |
| Leptoceridae, Perlidae, Philopotomidae, Xiphocentronidae. | 8 |
| Coleoptera Sp, Isotomidae, Hebridae, Leptinidae, Limnephilidae,. Hydrobiosidae; Oligoneuriidae, Glossosomatidae, Psephenidae, Helicopsychidae, Polycentropodidae, Cossidae. | 7 |
| Hyalellidae, Coleoptera Sp3, Helolidae, Chordodidae, Hydroptilidae, Calopterygidae Leptophlebiidae, Bibionidae cf. | 6 |
| Hydropsychidae, Simuliidae, Planariidae, Hemiptera Sp1, Cicadellidae cf, Ostracoda, Gyrinidae, Belostomatidae, Dugesiidae, Pyralidae Libellulidae, Corydalidae, Dalyelliidae, Aeshnidae, Sphaeriidae, Coenagrionidae, Ancylidae, Leptohyphidae, Gomphidae. | 5 |
| Dixidae, Empididae, Dolichopodidae, Diptera Sp1, Elmidae, Staphylinidae, Hydracarina, Nematoda, Veliidae, Baetidae, Tipulidae Gerridae, Caenidae, Haliplidae. Naucoridae, Pleidae, Decapoda, Noteridae, Palaemonidae, Curculionidae. | 4 |
| Ceratopogonidae, Psychodidae, Hydrophilidae, Glossiphoniidae, Physidae, Gelastocoridae, Planorbidae, Lymnaeidae, Hirudinea, Dytiscidae. | 3 |
| Chironomidae, Culicidae, Muscidae, Ephydridae, Stratiomyidae | 2 |
| Naididae, Tubificidae, Syrphidae, Aelosomatidae | 1 |

Source: (Sánchez & Avendaño, 2004)

**Table 2.** Biological index values BMWP_Cr

| Class | Value | Meaning | Color |
|---|---|---|---|
| I | >120<br>101 - 120 | Excellent water quality<br>Water of good quality, not polluted or significantly altered | Blue |
| II | 61 - 100 | Water of fair quality moderately polluted | Green |
| III | 36 - 60 | Poor quality, contaminated water | Yellow |
| IV | 16 - 35 | Poor water quality, highly polluted | Orange |
| V | <15 | Very poor water quality, extremely polluted | Red |

Source: Sánchez Herrera (2005).

Quality of riparian forest index (QBR) and river habitat index (IHF)

The river habitat index (IHF) was used to assess the components present independently, with a score range from 0 (poor) to 100 (very good) (Table 3) (Pillasgua, 2018).

**Table 3.** Range of evaluation of the river habitat index (IHF).

| Evaluation range | Categories |
|---|---|
| 100 - 90 | Very good |
| 89 - 70 | Good |
| 69 -50 | Moderate |
| 49 - 30 | Deficient |
| 20 - 0 | Mala |

Source: (Pillasgua, 2018)

The riparian forest quality index (QBR) served to evaluate the different components in terms of grade, structure, quality of riparian cover and the degree of the fluvial channel; where a score ≤ 25 is extreme forest degradation, 75-90 slightly disturbed, 55-70 onset of major disturbance, 30-50 strong disturbance, and ≥ 95 means that the riparian is in a natural state without disturbance (Munné et al., 2003)(Table 4).

**Table 4.** Quality index of riparian forest QBR

| Quality | Score | Description of the riverbank | Color |
|---|---|---|---|
| **Very good** | ≥ 95 | Undisturbed riparian forest in natural state | **Blue** |
| **Good** | 75-90 | Slightly disturbed forest | **Green** |
| **Intermediate** | 55-70 | Onset of major alteration | **Yellow** |
| **Mala** | 30-50 | Strong alteration | **Orange** |
| **Lousy** | ≤25 | Extreme degradation | **Red** |

Source: (Munné et al., 2003)

Statistical processing

The aquatic insect community was determined for each sampling point by applying the Shannon-Weaver, Simpson and Pielou diversity and richness indices. A non-parametric similarity analysis (ANOSIM) with a significance of 1 % was performed in the PAST statistical program; in addition, an ANOVA was applied to test the differences between the indices in order to determine the similarity of the abundance of the aquatic macroinvertebrate genera in the sampling points with grassland, agricultural and forest cover. Finally, a discriminant redundancy analysis (RDA) was used to evaluate the proportion of explained variance of aquatic macroinvertebrate families influenced by physicochemical conditions of water quality.

## Results

Macroinvertebrates under different land use

In the different land uses, an average total of 1425 individuals of macroinvertebrates grouped in 10 orders, 14 families and 17 genera were identified; were, the most abundant genus was Brechmorhoga of the order Odonata with 274 specimens (19 %), followed by the genus Leptohyphes belonging to the order Ephemeroptera with 195 individuals (14 %); however, the least abundant genera were Andonectes (Coleoptera), Littorina (Mesogastropoda) and atrioplanaria (Seriata) with 6, 7 and 2 macroinvertebrate individuals respectively (Table 5).

**Table 5.** Composition and abundance of macroinvertebrates in different land use.

| Order | Family | Genre | Land uses | | |
|---|---|---|---|---|---|
| | | | Agricultural | Pasture | Forest |
| **Coleoptera** | Elmidae | Macrelmis | 0 | 0 | 24 |
| | Dytiscidae | Andonectes | 0 | 0 | 6 |
| | Ptilodactylidae | Anchytarsus | 57 | 33 | 0 |
| **Trichoptera** | Polycentropodidae | Polycentropus | 82 | 0 | 68 |
| **Gatropoda** | Thiaridae | Melanoides | 95 | 0 | 9 |
| **Ephemeroptera** | Leptohyphidae | Leptohyphes | 71 | 79 | 45 |
| | Baetidae | Camelobaetidius | 6 | 8 | 100 |
| | | Americabaetis | 0 | 35 | 82 |
| | | Mayobaetis | 0 | 0 | 64 |
| | | Baetodes | 50 | 0 | 63 |
| | Caenidae | Caenis | 4 | 1 | 46 |
| **Odonata** | Libellulidae | Brechmorhoga | 0 | 0 | 24 |
| **Diptera** | Chironomidae | Pentaneura | 0 | 0 | 6 |
| **Annelida** | Oligochaeta | Lumbricidae | 57 | 33 | 0 |
| **Hemiptera** | Naucoridae | Limnocoris | 82 | 0 | 68 |
| **Mesogastropoda** | Hydrobiidae | Littoridine | 95 | 0 | 9 |
| **Seriata** | planariidae | Atrioplanaria | 71 | 79 | 45 |

In the distribution by substrate and habitat of the aquatic macroinvertebrate communities, it was shown that the genus with the greatest predominance in agricultural land use was Melanoides of the family Thiaridae, with a substrate of rocks with leaf litter and habitat of moderate currents, while in pasture land it was the genus Leptohyphes of the family Leptohyphidae for its habitat of fast currents in a substrate of stones and sand. Finally, in the forest cover, the predominant genus was Brechmorhoga of the family Libellulidae with a habitat of slow currents and substrate of logs and leaf litter

(Table 6).

**Table 6.** Distribution of macroinvertebrate genera by substrate and habitat.

| Order | Family | Genre | Land use | Substrate | Habitat | Total |
|---|---|---|---|---|---|---|
| **Coleoptera** | Ptilodactylidae | *Anchytarsus* | Agricultural | Rocks and leaf litter | Moderate currents | 57 |
| **Trichoptera** | Polycentropodidae | *Polycentropus* | | | | 82 |
| **Caenogatropoda** | Thiaridae | *Melanoides* | | | | 95 |
| **Ephemeroptera** | Leptohyphidae | *Leptohyphes* | | | | 71 |
| | Baetidae | *Camelobaetidius* | | | | 6 |
| | | *Baetodes* | | | | 50 |
| | Caenidae | *Caenis* | | Sand and leaf litter | Fast currents | 4 |
| **Odonata** | Libellulidae | *Brechmorhoga* | | | | 83 |
| **Annelida** | Oligochaeta | *Lumbricidae* | | | | 44 |
| **Mesogastropoda** | Hydrobiidae | *Littoridine* | | Rocks and leaf litter | Moderate currents | 1 |
| **Coleoptera** | Ptilodactylidae | *Anchytarsus* | Pasture | Leaf litter and sand | Fast currents | 33 |
| **Ephemeroptera** | Leptohyphidae | *Leptohyphes* | | Stones and sand | | 79 |
| | Baetidae | *Camelobaetidius* | | | | 8 |
| | | *Americabaetis* | | | | 35 |
| | Caenidae | *Caenis* | | | | 1 |
| **Odonata** | Libellulidae | *Brechmorhoga* | | Leaf litter and sand | | 7 |
| **Diptera** | Chironomidae | *Pentaneura* | | Stones and sand | | 13 |
| **Hemiptera** | Naucoridae | *Limnocoris* | | Stones and sand | | 41 |
| **Mesogastropoda** | Hydrobiidae | *Littoridine* | | | | 3 |
| **Seriata** | planariidae | *Atrioplanaria* | | | | 2 |
| **Annelida** | Oligochaeta | *Lumbricidae* | | Mud | Slow currents | 5 |
| **Coleoptera** | Elmidae | *Macrelmis* | Forest | Hojaresca | Slow currents | 24 |
| | Dytiscidae | *Andonectes* | | | | 6 |
| **Trichoptera** | Polycentropodidae | *Polycentropus* | | | | 68 |
| **Caenogastropoda** | Thiaridae | *Melanoides* | | | | 9 |
| **Ephemeroptera** | Leptohyphidae | *Leptohyphes* | | | Moderate currents | 45 |
| | Baetidae | *Camelobaetidius* | | | | 100 |
| | | *Americabaetis* | | Logs and leaf litter | | 82 |
| | | *Mayobaetis* | | | | 64 |
| | | *Baetodes* | | | | 63 |
| | Caenidae | *Caenis* | | | | 46 |
| **Odonata** | Libellulidae | *Brechmorhoga* | | | Slow currents | 184 |
| **Diptera** | Chironomidae | *Pentaneura* | | Hojaresca | | 2 |
| **Hemiptera** | Naucoridae | *Limnocoris* | | | | 9 |
| **Mesogastropoda** | Hydrobiidae | *Littoridine* | | | | 3 |

The cluster analysis showed a similarity of 30% for agricultural, forest and pasture land uses. The groups that showed a difference above 70% were A1-2 and B2-3; with less similarity are A3, B1, and P1-2-3 because the formation of their aquatic macroinvertebrate communities is distant and not very similar (Figure. 2).

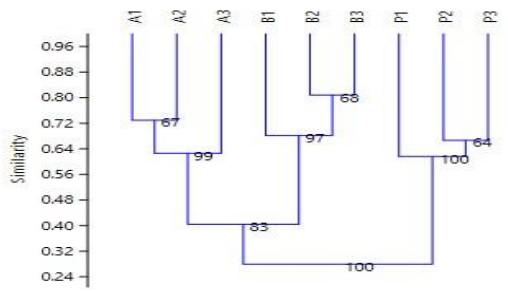


**Figure 2.** Cluster analysis of land uses in Taco Creek.

A: Agricultural; B: Forest; P: Pastureland; P: Grassland

Ecological quality assessment

Based on the results of the diversity indexes applied to the different land uses, Simpson's index (1-D) showed the greatest dominance in the forest land use with (0.88), while the lowest abundance was in the pasture land use with (0.73); the Shannon-Weaver index (H) presented a land-use with greater diversity for the forest with (2.23) and the lowest diversity was for the soil with grassland (1.62); finally, the Pielou index categorized the agricultural soil with (0.90) with the lowest richness was for the soil in grassland use with (0.77) (Table 7).

The BMWP_Cr index (Table 7) presented the quality indicator in "poor quality water very polluted" due to the pasture land use, while the highest range showing water of "excellent quality" was obtained with a weighting of 145 in the forest land use. In contrast, the agricultural land use water presented "good quality," obtaining a score of 103; however, it alters the sensitivity of the ecosystem.

The River Habitat Quality Index (IHF) showed "Moderate" water quality values in pasture soils, with a range of (50-69), the forest land use showed "Good" water quality with a range of (70-89); however, the agricultural land use indicated "Moderate" water quality with a range of (50-69). On the other hand, the riparian forest quality application (QBR) presented "Poor" water quality in the agricultural and pasture land uses with a range of (30-35), while the forest land uses indicated "Good" quality with a range of (85-90) (Table 7).

**Table 7.** Analysis of the indexes applied to three land uses.

| Land uses | Simpson_1-D | Shannon_H | Pielou | Index BMWP_Cr | IHF Index | QBR index |
|---|---|---|---|---|---|---|
| **Agricultural** | 0,8492 | **2** | 0,9032 | 5 | 55 | 30 |
| **Agricultural** | 0,8165 | **2** | 0,848 | 103 | 54 | 30 |
| **Agricultural** | 0,8313 | **2** | 0,8631 | 56 | 47 | 30 |
| **Forest** | 0,8754 | 2,226 | 0,8679 | 4 | 67 | 35 |
| **Forest** | 0,8443 | 2,109 | 0,822 | 145 | 67 | 35 |
| **Forest** | 0,8123 | 2,016 | 0,786 | 86 | 72 | 35 |
| **Pasture** | 0,7292 | 1,682 | 0,7655 | 2 | 58 | 85 |
| **Pasture** | 0,7732 | 1,619 | 0,8321 | 44 | 63 | 85 |
| **Pasture** | 0,7757 | 1,775 | 0,7711 | 30 | 60 | 85 |

Similarity analysis (ANOSIM)

The ANOSIM similarity analysis determined that the three land uses showed a good fit of (0.0035) with a correlation coefficient value in the variable (gender) of (0.8848) which showed significant differences in group 3 pasture with 88 %, while group 1 agricultural and forest showed no significant differences (Figure 3).

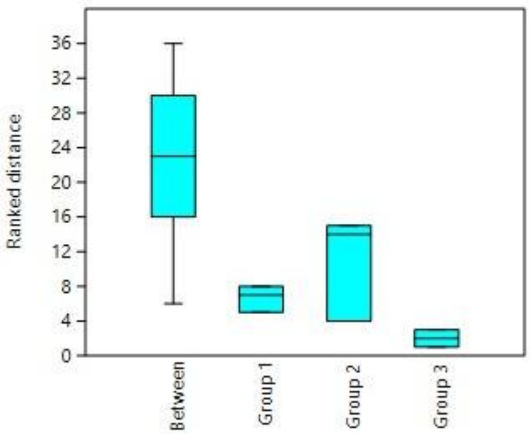


**Figure 3.** ANOSIM of land uses in the El Taco creek

Group 1: Agricultural; Group 2: forest; Group 3: pastureland

Physicochemical parameters

Within the physicochemical parameters of water, no statistically significant differences were found between land uses (temperature and hardness); however, the statistical analysis showed significant differences for (pH, electrical conductivity, SDT, OD and NTU); where pH obtained a high value for pasture land use (7.5) and a lower value for agricultural land use (6.7). As for electrical conductivity, the highest value was (126.5 µS/cm) in forest soil and the lowest value was (54.8 µS/cm) in agricultural soil.

Concerning TDS, the highest value was (63.2 mg/l) in forest soil and the lowest value was (29.3 mg/l) in agricultural soil. On the other hand, the OD had the highest value (5.8 mg/l) in pasture soil and the lowest value (0.9 mg/l) in forest soil. Likewise, turbidity indicated a higher value (108.1 NTU) in agricultural soil and a lower value (10.5 NTU) in forest soil (Table 8).

**Table 8.** ANOVA of physicochemical variables in land uses.

| Parameters | Media | P |
|---|---|---|
| **pH** | 0,101 | 0,135 |
| **Temperature** | 0,083 | 0,847 |
| **Electrical Conductivity** | 1001,23 | 0,309 |
| **Total Dissolved Solids** | 257,053 | 0,284 |
| **Dissolved Oxygen** | 5,031 | 0,142 |
| **Turbidity** | 949,301 | 0,396 |
| **Hardness** | 34,77 | 0,520 |

Redundancy analysis

Redundancy analysis with physicochemical variables and macroinvertebrate community structure based on the genera Polycentropus, Brechmorhoga, Baetodes and Melanoides had the highest correlation with turbidity in agricultural land use, while pH had the most significant influence with the genera Camelobaetidius, Americabaetis and Mayobaetis in pasture soil (Figure 4).

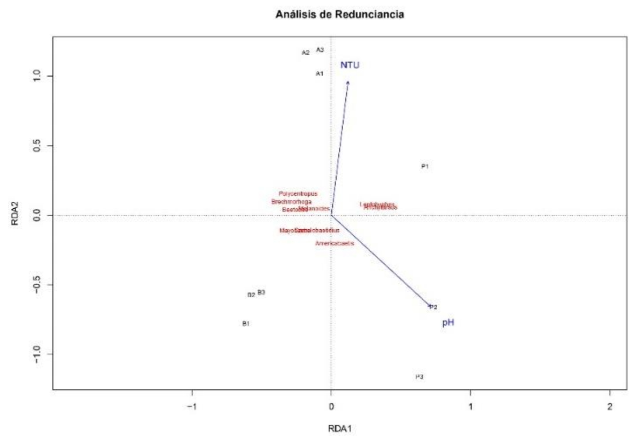


Figure 4. Redundancy analysis of land use in the Taco Creek

## Discussion

The order Ephemeroptera obtained the highest abundance of macroinvertebrates in the agricultural and forest land uses; these results coincide with the results reported by (Morelli & Verdi, 2014b)(2021), who indicated that the order Ephemeroptera had a greater influence in areas with forest cover and riparian vegetation in freshwater bodies in Uruguay. In addition, Urdanigo et al. (2019) detected that the same order presented a higher abundance in rainy season periods with native forest cover and pastures with agricultural activities in Murocomba, Ecuador. Espinoza-Toledo et al. (2021). The results indicate that this type of order is sensitive to environmental change and is primarily functional in riparian forests of tropical forests.

Thiaridae, Leptohyphidae, and Libellulidae are influenced mainly by moderate, fast and slow current habitats and rocky substrates with leaf litter, stones and logs. Espinoza-Toledo et al. (2021) indicated that the genus Leptohyphidae prefers habitats with high velocities and rocky substrates in sites with forested streams in Brazil. In addition, they stated that the family Thiaridae Damanik-Ambarita et al. (2016) stated that the family Thiaridae had the presence of 36 specimens on bed substrates, leaf litter, and macrophytes with terrestrial vegetation cover in the Guayas River, Ecuador. Cabrera et al. (2021) noted that Libellulidae was present in forested sites with preferences for sand, cobble and rock substrates and habitat characteristics in fast-flowing streams in the Ecuadorian Amazon.

The dendrogram of the different land uses showed more significant similarity between the agricultural and forest cover sampling points. However, Guerrero et al. (2022) showed differences of more than 70 % in the cluster analysis for the group of forest, agricultural, urban, mine and pasture land uses, having a significant influence by the environmental conditions of the Estero el Barro del río Quevedo (Ecuador) and riparian vegetation. Similarly, Guerrero et al. (2017) obtained a difference of 70 % of similarity in four groups of the different land covers of the El Sapanal micro-watershed, Ecuador: forest (September-December), crops (September-October), crops (November-December) and pasture (September-December).

The Simpson index was higher (0.88) in forest land use and the Shannon index was more dominant in forest cover 2.23 respectively. A similar study of Guerrero Chuez et a. (2021) reported something similar, where the Shannon index obtained (1.7) in forest land use. On the other hand, Simpson's index had a higher significance in forest land use with 0.75. Furthermore, the BMWP-Cr index showed a water quality of "bad, very polluted." These results differ from the study by Guerrero et al. (2017), who indicated that the BMWP-Cr index was of "fair" water quality due to the agricultural and pasture land use coverages, while the forest land use water had excellent water quality. On the other hand, the water quality indices were somewhat similar to the study conducted by Guerrero et al. (2022), who highlighted that the forest land use in the riparian forest index showed the "beginning of important alteration" in grassland coverages while the agricultural land use reflected "strong alteration." On the other hand, the Fluvial Habitat index showed high values in grassland and agricultural land uses with a "Moderate" quality.

The redundancy analysis obtained a relationship between the physicochemical variables and aquatic macroinvertebrates among the genera that had a higher correlation with turbidity in agricultural land use and pH in pasture land use. These results coincide with those reported by Giraldo et al. (2014). Furthermore, the results coincide with those reported by the authors of the redundancy analysis, who indicated that the parameters turbidity, nitrate and total phosphorus had the greatest influence on agricultural land use (46.5%). On the other hand, in the study by Morelli & Verdi, (2014)The ANOSIM study showed that the variables conductivity, pH and temperature directly influence the distribution of aquatic macroinvertebrates in pasture land use. The ANOSIM study showed significant differences in the use of grassland soil, while the other groups showed no differences. Similar results were obtained by Guerrero Chuez et al. (2021), who in their ANOSIM analysis presented statistical differences of similarity between agricultural, forest, mine and pasture land uses.

The physicochemical parameters of water had significant differences between soil covers for pH, electrical conductivity, STD, OD and turbidity; however, it is worth mentioning that pH had a higher incidence in pasture land use (7.5) and turbidity obtained a significant value in agricultural land use (108.1 NTU). These results are related to those described in the study carried out by Nuñez & Fragoso-Castilla, (2021), in which pH (7.90) showed relevance in pasture land use; in addition, the turbidity parameter showed very high values in agricultural land use (58.6 NTU). On the other hand, in the study by Ruiz-Picos et al. (2016). The study conducted by the University of California, USA, shows that agricultural land use sites have a higher load of organic matter and, therefore, a higher concentration of the chemical (nitrites and nitrates), microbiological (coliforms), and physical (turbidity) parameters.

## Conclusions

The abundance of aquatic macroinvertebrate communities showed very low differences in similarity with all land uses. On the other hand, the most abundant genus was Brechmorhoga of the order Odonata with a significant presence in forest cover, considered a bioindicator of moderately regular water quality; the order Ephemeroptera was detected with the greatest richness of specimens in agricultural land uses, pastures and forests.

The agricultural land use and pasture presented higher records in the physicochemical parameters pH, temperature (°C), dissolved oxygen (DO) and turbidity (NTU) due to local anthropic pressure. In addition, the BMWP_Cr index indicated that the forest land use obtained water of"excellent quality" in contrast to the IHF and QBR indexes, which showed"Goo" in forest quality, but the agricultural land use and pasture had"Moderat" and"Poo" quality values. This indicates that human actions produce direct changes that impact aquatic ecosystems by modifying ecological attributes.

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