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ORIGINAL

Comprehensive analysis of water quality in the middle and lower basin of the Marquesote River Colombian

Análisis integral de la calidad del agua en la cuenca media y baja del río Marquesote colombiano

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ABSTRACT

Different biotic indices have been used for the integral analysis of hydrographic basins in Colombia, using benthic microinverters and physicochemical parameters. A comprehensive analysis of water quality was performed in the low Marquesote river basin, using benthic macroinvertebrates and the ETP index (Ephemeroptera-Trichoptera-Plecoptera) as a biological indicator and some physicochemical parameters. Work was worked on the middle and lower basin on the Marquesote River at two times of the year (dry and rainy); standardized methods for water physicochemical variables were applied, for benthic fauna collected using a Surber network, and identifying them up to the taxonomic level of family. The study observed 22 families and 1388 individuals, where 49 % represent PTSD, indicating regular water quality; however, physicochemical variables had wide variation, noting that pH showed the greatest variability based on an analysis of major components. Environmental quality in the Marquesote river basin is compromised according to the indicators used, a more detailed study of the sources of pollution and dynamics of macroinvertebrates could provide a greater ecological knowledge of the basin.

Keywords: Environmental Quality; Biological Indicators; Biotic Indices; Biological Data; Benthic Macroinvertebrates.

RESUMEN

Se han utilizado diferentes índices bióticos para el análisis integral de cuencas hidrográficas en Colombia, utilizando microinvertebrados bentónicos y parámetros fisicoquímicos. Se realizó un análisis integral de la calidad del agua en la cuenca baja del río Marquesote, utilizando macroinvertebrados bentónicos y el índice ETP (Ephemeroptera-Trichoptera-Plecoptera) como indicador biológico y algunos parámetros fisicoquímicos. Se trabajó en la cuenca media y baja del río Marquesote en dos épocas del año (seca y lluviosa); se aplicaron métodos estandarizados para las variables fisicoquímicas del agua, para la fauna bentónica colectada utilizando una red Surber, e identificándola hasta el nivel taxonómico de familia. El estudio observó 22 familias y 1388 individuos, donde 49 % representan PTSD, indicando una calidad regular del agua; sin embargo, las variables fisicoquímicas presentaron amplia variación, destacándose que el pH mostró la mayor variabilidad con base en un análisis de componentes principales. La calidad ambiental en la cuenca del río Marquesote está comprometida de acuerdo con los indicadores utilizados, un estudio más detallado de las fuentes de contaminación y de la dinámica de los macroinvertebrados podría proporcionar un mayor conocimiento ecológico de la cuenca.

Palabras clave: Calidad Ambiental; Indicadores Biológicos; Índices Bióticos; Datos Biológicos; Macroinvertebrados Bentónicos.

INTRODUCTION

Water has two related dimensions, quality and quantity, on which human beings depend a lot as a resource, whether for direct or indirect use, the latter through environmentally healthy ecosystems. Over the last few years the concept of water quality has been rapidly changing from a purely physicochemical approach to one that integrates all the components of the ecosystem.[1,2]

Currently, many countries are supporting the use of aquatic communities and the study of their behavior over time (biomonitoring) as a key tool for assessing the quality of inland surface waters.[3] The Australian Office of Environment and Heritage (OEH) defines water quality as the physical, chemical, biological and aesthetic characteristics (appearance and smell) it presents.[4] That is, a healthy water must contain a balanced amount of nutrients and normal fluctuations in salinity and temperature, as well as a high percentage of oxygen and receive enough sunlight for proper growth of organisms. Water pollution caused by damage or alteration of its state under normal conditions and the loss of river buffer zones is a problem for the health of all living things that inhabit the planet.[3,4]

The increasing deterioration of aquatic ecosystems has been demanding the development of systems and methodologies, which allow to know their degree of alteration due to natural or anthropogenic causes, for which a set of tools have been developed, mainly water quality indexes.[3]

As a result of this deterioration, up to 80 % of the world's population affected by river degradation has been recorded,[5] which are the main freshwater environment used as a resource (water) for humans. The macroinvertebrates are an important component of biodiversity in lotic systems; as a group, these are sensitive and respond to both natural and anthropogenic changes in their environment, so the diversity of macroinvertebrates present in rivers and streams, as well as their functional composition (fragmenters, collectors, scrapers, and predators) reflect changes in river-related resources,[6] as well as human-induced factors or impacts.[7]

The concept of bioindicator or biological indicator, is applied to the water quality assessment, and is defined as a species, population or community, which has specific requirements in relation to a set of known physical or chemical variables, in such a way that absence, or changes in number of individuals, morphology, physiology or behavior indicate that the given physique-chemical variables are outside their preferred limits; in fact, in clean water it is common to find dominant populations of Efeptera, Plecopterters and Tricopters, unlike contaminated water bodies where populations of chironomides and annelids prevail.[2,8]

In Colombia, the use of macroinvertebrates as bioindicators of water quality is widespread, being an easy-to-interpret biological component, as they are important in their habitats, as their essential functions are indispensable for maintenance the functional integrity of an aquatic ecosystem; even rare species can play an important role, evident only after a disturbance.[2]

Therefore, it is necessary to continue to address the study of environmental quality, using the tools of common and functional use, to continue evaluating the lotic environments present in Colombia, especially those areas that have been less studied since this point of view. The purpose of the present work is to use the benthic macroinvertebrates and the biotic index (ETP) in conjunction with some physicochemical parameters (pH, temperature, conductivity, dissolved oxygen) to observe the environmental quality of the river Marquesote, in the colombian Caribbean.

METHODS

Study area and sampling stations

The Marquesote river basin is located south of the department of La Guajira, in the Municipality of La Jagua del Pilar in the colombian Caribbean, and has an area of 100,99 km^2. It is located at 223 m.s.n.m., and is characterized by average temperatures around 28oC, with the presence of dry tropical forest. The Marquesote River, along its route, feeds on an undetermined number of microtributaries until its mouth on the Cesar River, and has a length of 34,58 km.

The rainfall regime is presented bimodally, with two major periods (April-June and September-December) alternating with two minors (January-March and July-August). Three sampling stations were established (Station 1: 10º29'39,6"N-73º03'07,3"W; Station 2: 10º29'4"N - 073º03'0,29"W and Station 3: 10º29'44,3"N - 073º02'56,7"W) along the middle section of the river (289-274 m.s.n.m.), every 100 m away. Highlighting that the Station 1 waters higher, presents a mainly sandy substrate and moderate light inlet; Station 2 in the middle section presents abundant riparian vegetation and semifangous substrate mainly, and finally Station 3 downstream, presents equally abundant vegetation and greater leaf retention, highlighting being a recreational area for the surrounding population.

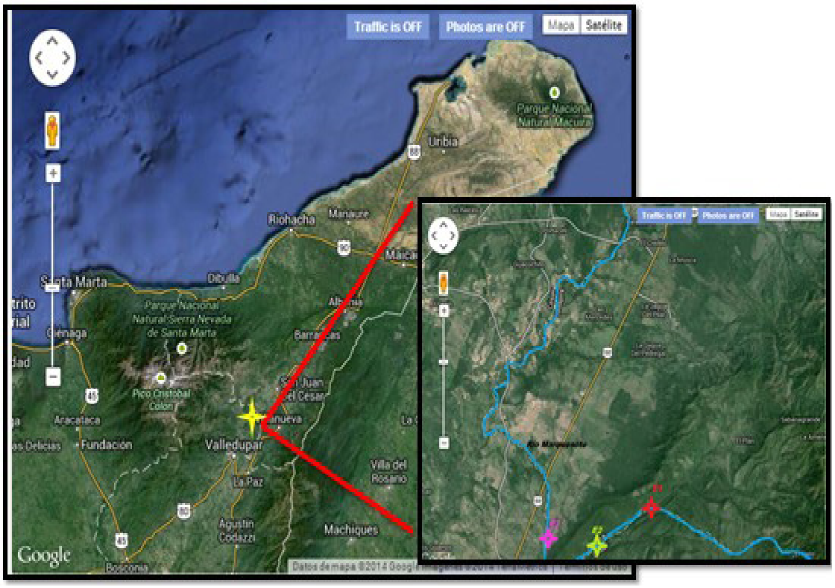

Figure 1. Location of the study area. The blue line indicates the course of the Marquesote River, colombian Caribbean

Benthic macroinvertebrates

During the July-December 2016 period, the bed was dragged to obtain macroinvertebrates and take water samples at each of the sampling stations. A Surber network was used for the collection of macroinvertebrates, which was used for 5 minutes at each station. Samples of invertebrates obtained by the network were placed in labeled hermetic seal bags, with flare rose and 70 % ethanol inside and were taken to the biology laboratory of the University of La Guajira, for separation, quantification and identification up to the family level using taxonomic keys[8] y un estereoscopio Nikon SMZ645.

Water Quality (Physicochemical Variables)

For each of the sampling stations, the water temperature variables (mercury thermometer [ºC]), pH, (pH meter brand WTWpH315-07510600), electrical conductivity (behavioral meter brand WTWCond315-08290028 [µS/cm]), saturation of the oxygen (oximeter brand WTWoxi31507291157 [%]) (Figure 1).

Data analysis and statistics

Alpha diversity was estimated through dominance index (D), Shannon-Wiener diversity (H') and Shannon's exponential ($e^{H'}$); beta diversity was also estimated through the Morisita index,[9] the latter was used to perform a cluster analysis to observe the similarity between sampling stations, this through the program Past 3.18.[10] The EPT index (Ephemeroptera, Plecoptera, Trichoptera) was used, which uses those of three groups (orders) of macroinvertebrates most sensitive to pollutants;[2] this was done through the abundance ratio of EPT, with respect to the abundance of total macroinvertebrates, the result expressed as a percentage is classified according to water quality, either very good quality (100 – 75 %), good quality (74 – 50 %), quality (49 – 25 %) poor quality (24 – 0 %).[11] A Main Composition Analysis (ACP) was performed to observe that variables explain the greatest variability observed in the study, as well as a multiple correlation analysis, to observe relationships between the abundance of macroinvertebrates and physicochemical variables. These analyses also carried out with the program Past 3.18.[10]

RESULTS

Benthic macroinvertebrates

A total of 1388 individuals were collected, where the greatest abundance was depicted in the dry season with 748 individuals collected in the corresponding months of July, September and December. The total number of collected individuals are distributed in three Phyla, the Arthropoda (9 orders of the Insect class and 1 order of Arachnida), Mollusca (Gastropodclass Class: 1 order) and Anellida (Oligochaeta Class: 1 order). Station 1 was the most abundant with 694 individuals collected for the entire study, in addition to representing 50 % of the total individuals obtained for the Marquesote River, the most representative family was Leptoceridae with 44,2 % of the relative abundance; Station 2 had 470 individuals, also with a greater relative abundance of the Family Leptoceridae (31,1 %); and finally Station 3 with 224 individuals, although the most representative family was Elmidae with 25 % relative abundance (figure 2).

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Order	Families	Station 1		Station 2		Station 3		Total	
		inds	%	inds	%	inds	%	inds	%
Ephemeróptera	Baetidae	65	9,4	41	8,7	39	17,4	**145**	**10,4**
	Leptohyphes	0	0,0	1	0,2	0	0,0	**1**	**0,1**
Coleóptera	Elmidae	91	13,1	124	26,4	56	25,0	**271**	**19,5**
	Staphylinidae	4	0,6	1	0,2	0	0,0	**5**	**0,4**
	Psephenidae	3	0,4	11	2,3	1	0,4	**15**	**1,1**
Trichóptera	Leptoceridae	307	44,2	146	31,1	48	21,4	**501**	**36,1**
	Calamoceratidae	4	0,6	2	0,4	2	0,9	**8**	**0,6**
Plecóptera	Perlidae	10	1,4	5	1,1	14	6,3	**29**	**2,1**
Díptera	Chironomidae	61	8,8	63	13,4	26	11,6	**150**	**10,8**
	Psychodidae	22	3,2	1	0,2	0	0,0	**23**	**1,7**
	Stratiomyidae	6	0,9	0	0,0	1	0,4	**7**	**0,5**
	Tabanidae	4	0,6	17	3,6	4	1,8	**25**	**1,8**
	Ceratopogonidae	3	0,4	0	0,0	2	0,9	**5**	**0,4**
Hemíptera	Vellidae	23	3,3	12	2,6	13	5,8	**48**	**3,5**
	Naucoridae	15	2,2	18	3,8	2	0,9	**35**	**2,5**
Odonata	Libellulidae	15	2,2	9	1,9	2	0,9	**26**	**1,9**
	Gomphidae	31	4,5	16	3,4	10	4,5	**57**	**4,1**
Lepidóptera	Pyralidae	25	3,6	1	0,2	0	0,0	**26**	**1,9**
Megalóptera	Corydalidae	0	0,0	0	0,0	1	0,4	**1**	**0,1**
Gasterópoda	Physidae	3	0,4	1	0,2	0	0,0	**4**	**0,3**
Haplotáxida	Tubificidae	0	0,0	1	0,2	2	0,9	**3**	**0,2**
Astigmata	Acaridae	2	0,3	0	0,0	1	0,4	**3**	**0,2**
Total		**694**	**100**	**470**	**100**	**224**	**100**	**1.388**	**100**

Figure 2. Absolute and relative abundance of the families of benthic macroinvertebrates found on the Marquesote River, colombian Caribbean

The results of the ecological indexes were relatively close in all seasons (table 1). The dominance (D) was in the ranges of 0,15 and 0,24, and was relatively low, finding the highest value in Station 1, while Shannon-Wiener's diversity index remained between 1,96 and 2,0 being higher at Station 3.

Table 1. Alpha Diversity Indexes (Dominance [D], Shannon-Wiener [H'] and Shannon Exponential [$e^{H´}$]) per sampling station on the Marquesote River, colombian Caribbean. Boldly the highest values for each index

Station	D	H´	eH´
1	0,237	1,969	7,16
2	0,231	1,966	7,14
3	0,154	2,077	7,98

By applying the EPT index with respect to all other benthic macroinvertebrates, a value of 49 % was found for the entire study area and sampling period, indicating that the water quality of the Marquesote River, at the level of the entire section studied is regular; even from the perspective of each sampling station, the water quality according to this index is regular for stations 2 and 3 with 41 and 46 % respectively, showing only good quality at Station 1 with 56 %. Cluster analyses show differentiated behavior between sampling stations according to the abundances recorded for benthic macroinvertebrate families, specifically stations 1 and 3 have a similarity of 30 %, while station 2 shows a similarity of 20% (figure 3).

Water quality

A variable water temperature behavior was observed between sampling stations, with the highest records for the month of October at Station 1 (28, 5oC); while seasons 2 and 3 for the month had temperature values below 24 oC. The trend at higher temperatures at station 1 was observed throughout the study period (figure 4 A).

Oxygen saturation showed percentages between 75 and 104 % in the July-September period for all study stations; then these percentages rose to values above 120 % saturation for the October-December period for seasons 1 and 2, while Station 3 remained constant in values around 100 % oxygen saturation (figure 4 B).

The pH values recorded for the months of July and August were very low, within the acidity field, in all the seasons studied. For the September-December period the values observed in all seasons were basic above 7,5; with a similar dynamic between them (figure 4 C).

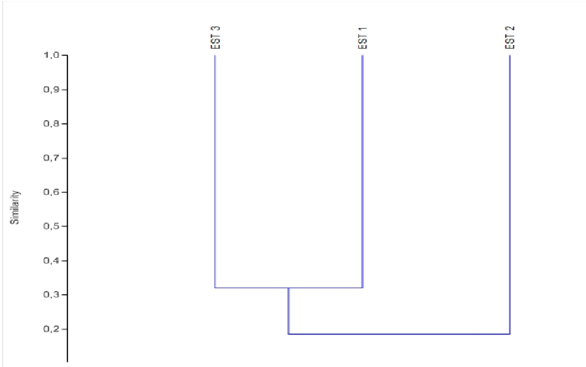

Figure 3. Cluster analysis (Morisita index), according to the abundances of macroinvertebrate families among the Marquesote River sampling stations

Conductivity presented a similar dynamic between sampling stations, for the section studied on the Marquesote River, the values of this variable were found between 240 and 290 S/cm, with a predominance of these in Station 1 from September (figure 4 D).

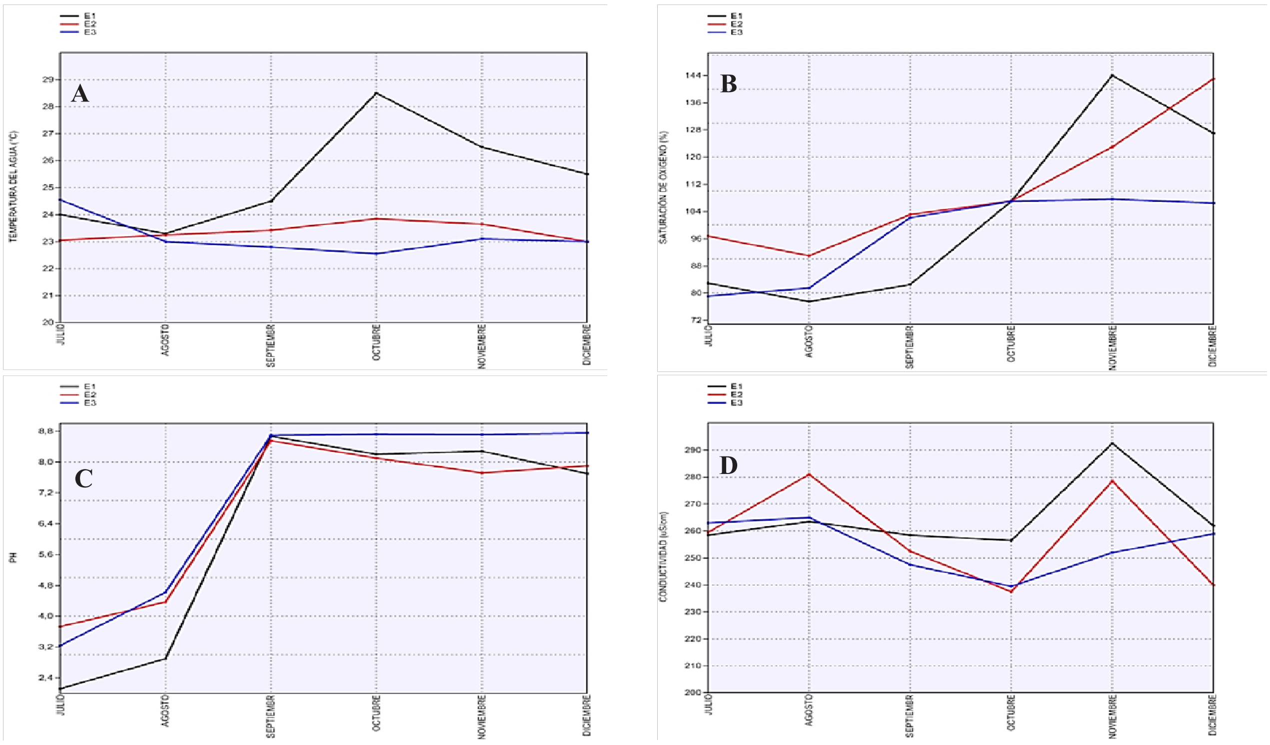

Figure 4. Values of water temperature (A), oxygen saturation (B), pH (C) and conductivity (D) per season and month of sampling of the Marquesote River, colombian Caribbean

According to the ACP based on the abundances of benthic macroinvertebrates and physicochemical variables, variability between seasons and months of sampling could be observed, mainly explained by abundance (component 1) and pH (component 2), highlighting the grouping of the months of September, November and December of seasons 1 and 2 as months with greater abundance and high pH, while September, November and December of season 3 presented low abundances and high pH values. On the other hand, the months of August at stations 1 and 2 and July for season 1 showed low pH values and greater abundances, while July of seasons 2 and 3, and August of season 3 showed low abundances and low pH (figure 5). In other words, space-time variability was observed in the Marquesote River, evidenced mainly by pH and macroinvertebrate abundance values, with these factors showing the most variation during the study.

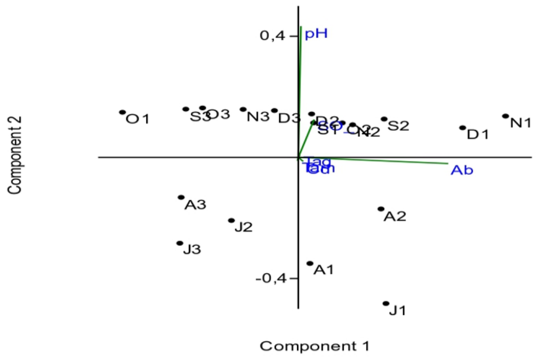

Figure 5. Analysis of Main Components with respect to the abundances of macroinvertebrates and physicochemical parameters per station (1, 2 and 3) and sampling month (July [J], August [A], September [S], October [O], November [N] and December [D])

Moreover, the correlation analysis showed no obvious relationships between the abundance of macroinvertebrates and the physicochemical variables studied, with the exception of water temperature (figure 6).

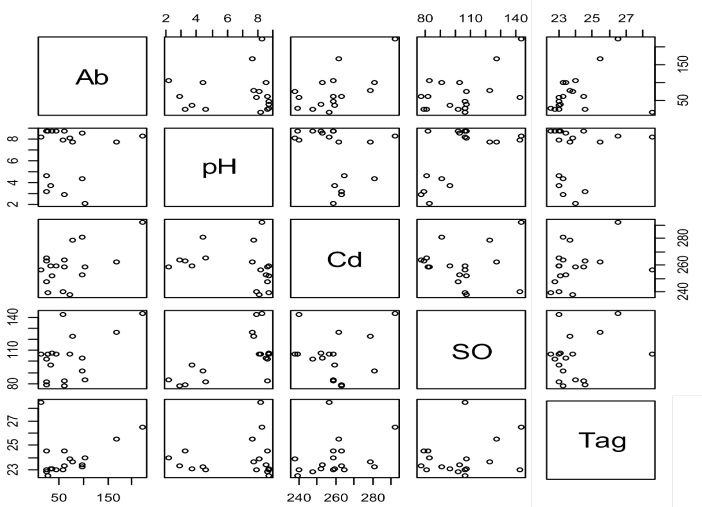

Figure 6. Analysis of multiple correlation between the abundance of macroinvertebrates and physicochemical parameters in the marquesote river, colombian Caribbean. Abundance (Ab), conductivity (Cd), oxygen saturation (OS) and water temperature (Tag)

DISCUSSION

The bioassessment of water is based on the natural capacity of the biota to respond to the effects of possible or permanent disturbances; so aquatic biota changes its structure and functioning by changing the environmental conditions of its natural habitats, which can be used to comparatively assess the ecological status of water bodies.[12]

Based on the above, the results presented in the Marquesote River indicate a low environmental quality status, reflected by a regular water quality according to the EPT index. Gamboa et al.[12] affirm the negative impact of agricultural activities on benthic macroinvertebrate communities and water quality, which is noted in the results obtained in this study by the ETP index; which could be the result of multiple factors such as the pouring of waste and substances into the channel of crops near the river system, or the domestic activities constantly developed in the body of water, which impede the processes purifying and deteriorate the organisms present in the ecosystem.

Physicochemical variables exposed environmental conditions that are relatively normal; for example, the conductivity of most freshwater bodies ranges from 10 to 1 000 µS/cm;[13] however, in contaminated water, their values may exceed these values, although this condition was not observed for this study, as they had a maximum of 292,5 S/cm in the highest part of the river, even though there is an influence of crops near the river You're a marque. Overall, water quality according to the variables studied is good, both because of the conductivity values presented, as well as the high levels of oxygen saturation (around 100 %), and the temperatures that had a range that does not exceed 30 oC; however, the pH values in the system for the start of the study period are considered low, and negative for the ecological condition of the ecosystem.(13)

As established by Huerto et al.(14) the application of biotic indexes has a great advantage over so-called diversity indexes, because they base their results on characteristics inherent to the ecological community, such as the structure of the community, and to sensitivity or tolerance that each group presents against system changes or alterations; or, by contamination processes, the ETP index (Ephemeroptera, Trichoptera and Plecoptera) which have been established by the individuals belonging to this order were applied in this study are sensitive to system variations, for which they are sensitive to system variations, for which they are truthful indicators of water quality.(15)

However, different behavior was observed for the diversity indexes employed, where the lower dominance was observed at Station 1 (D-0,154) coinciding with greater diversity according to Shannon-Wienner (H-2,077); in terms of this type of results, the Shannon exponential was used, which transforms the values of the H index to equivalent numbers of taxa, resulting in a range between 7,16 and 7,98, which is a very small variation that highlights that the stations have a similar diversity between them (number of taxa and abundanceratios ratio), so this type of transformation is most useful when comparing sampling sites using indexes.(16)

Low pH values were observed in the initial two months of study (July and August), which is consistent with the low precipitation time, and could partly explain these values, by low photosynthesis rates and a high breathing rate resulting from the decomposition of leaf litter in these areas, which is little favoured by low current speeds,(13) highlighting the lowest oxygen saturation values in these months. For the above, it was remarkable that pH was one of the most variability factors in the Marquesote River, which is a phenomenon that must be studied more carefully in the future, to understand which processes are the cause of variability, mainly temporary in the system. It is worth mentioning that the study area is not exempt from the human activities in its vicinity, which could be causing some degree of deterioration, as is common in loitic ecosystems with some degree of intervention.(7)

Environmental heterogeneity could also be playing an important role in the Marquesote River, as environmental differences were observed at the level of substrates between the seasons (on-site observations), such as mostly sandy substrate at Station 1 and increased plant toppings at stations 2 and 3.

This may explain the changes observed in the study seasons, which reflect a similarity of only 30 % and lower. This is partly confirmed by the observed relationship between temperature and the abundance of organisms, which explains how Station 1 with the highest temperatures, also showed the greatest abundances, as well as is the season of least plant cover according to the field observations, this allows for greater light input, and temperature increases,(7) although for this particular case they did not represent further degradation of the system at this particular sampling point. Recent research points to the need for a multifactorial approach, to integrate the use of chemical, biochemical and biological responses into the biomonitoring of pollutants within the procedure manuals for detecting environmental impacts on aquatic systems, suggesting the use of benthic macroinvertebrates to determine biomonitoring of freshwater ecosystems.(7,15)

CONCLUSIONS

This study represents a multi-focus on water quality determination, the values of which can be translated into similar conditions based on water quality at the spatial level that classify it as regular, which is confirmed by the physicochemical variables that exhibit normal water quality values, with pH being a factor that showed a large, mainly temporal variability. The difference found by seasons and abundance among the families found is explained by changes in abundance and presence of families exclusively in some seasons with respect to others, such as Stariomyidae and Corylidae present stations 1 and 3 respectively, even though they had low abundances. It can be concluded that the benthic macroinvertebrates present in the Marquesote River were represented by three taxonomic classes (Insecta, Acacnida and Gastropoda), 11 orders and 22 families during the period studied (July-December 2016), whose structural characteristics allow to estimate that the water quality in this ecosystem is regular; this is indicative of a midpoint between the ideal condition (good quality) and the unwanted condition (poor quality). The quality condition found can be a consequence of the proximity of the body of water to the civilian population, who carry out agricultural and domestic activities in their vicinity; so it is recommended to include in subsequent studies the monitoring of microbiological factors such as fecal coliforms, the estimation of the amount of pesticides present in water, and the body's proximity of water to crops or other activities that may represent pollution hotspots.

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Research: Stephany Romero Tobias, Geomar Molina-Bolívar, Iris Jiménez-Pitre.
Writing - proofreading and editing: Stephany Romero Tobias, Geomar Molina-Bolívar, Iris Jiménez-Pitre.