DISTRIBUIÇÃO DE MACROINVERTEBRADOS AQUÁTICOS E QUALIDADE DAS ÁGUAS SUPERFICIAIS NO PARQUE ESTADUAL DA PEDRA BRANCA

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RESUMO

A presença de organismos bioindicadores está diretamente associada à preservação dos ambientes aquáticos, pois podem ser sensíveis a poluentes orgânicos e inorgânicos e as alterações nas características limnológicas da água. Para realizar este trabalho, parâmetros de campo de dois rios do Parque Estadual da Pedra Branca, no Rio de Janeiro, Brasil, foram analisados durante a estação seca em junho de 2018, e sedimentos com macroinvertebrados aquáticos foram amostrados para a identificação de táxons. Os dados coletados foram avaliados por Escala Multidimensional Não Métrica, para analisar a similaridade entre a composição dos organismos nos locais amostrados; Análise de Redundância, para investigar as relações entre fatores bióticos e abióticos e através dos resultados quantitativos dos taxa encontrados, os índices EPT (Ephemeroptera, Plecoptera e Trichoptera), BMWP (Monitoring Working Party) e IBF (Biotic Index of Families) foram usados para obter resultados qualitativos sobre os níveis de qualidade, preservação e poluição dos rios . Os resultados obtidos são de grande importância ambiental e urbana, pois os rios do Parque Estadual da Pedra Branca são indispensáveis para o abastecimento de água dos bairros do entorno e influenciam diretamente no clima do município do Rio de Janeiro.

Palavras-chave: bioindicador, preservação, EPT, NMDS, RDA.

DISTRIBUTION OF AQUATIC MACROINVERTEBRATES AND SURFACE WATER QUALITY IN PEDRA BRANCA STATE PARK

ABSTRACT

The presence of bioindicator organisms is directly associated with the preservation of aquatic environments, as they can be sensitive to organic and inorganic pollutants and changes in the limnological characteristics of the water. To carry out this work, field parameters of two rivers of the Pedra Branca State Park, in Rio de Janeiro, Brazil were analyzed during the dry season in June 2018, and sediments with aquatic macroinvertebrates were sampled for the identification of taxa. The collected data were evaluated through Non-Metric Multidimensional Scaling, to

analyze the similarity between the composition of organisms in the sampled sites; Redundancy Analysis, to investigate the relationships between biotic and abiotic factors and through the quantitative results of the taxa found, the EPT (Ephemeroptera, Plecoptera and Trichoptera), BMWP (Monitoring Working Party) and IBF (Biotic Index of Families) indices were used to obtain qualitative results on the levels of quality, preservation and pollution of rivers . The results obtained are of great environmental and urban importance, as the rivers of the Pedra Branca State Park are indispensable for the supply of water to the surrounding neighborhoods and directly influence the climate of the municipality of Rio de Janeiro.

Key words: bioindicator, preservation, EPT, NMDS, RDA.

1. INTRODUCTION

Several parameters can be evaluated as indicators of water quality, their characterization depends on physical, chemical and biological factors; that are directly linked to the processes that occur in the water glass, in its surroundings and in its drainage basin (FUNAI, 2014). When evaluating the interaction of living organisms and the environment, it is observed that while some organisms, in their metabolic activity, alter physical and chemical properties of water; others are already suffering the effects of such changes (FUNAI, 2014).

Environmental monitoring based on biological communities is a tool of great importance, as organisms depend on the conditions of the habitat as a whole, which are not restricted only to water quality, making it possible to identify changes in the richness and density of these taxa, which may indicate, efficiently, the effect of human or natural actions on the environment, helping to identify active factors; because the decrease in these populations can change the substrate and characteristics such as decreased dissolved oxygen, increased acidity and nutrient concentration, among other effects (ZALIDIS, et al. 2002).The type of substrate also reflects on the resistance of communities, as it serves as a source of food, refuge, deposition of eggs, and most of these animals spend most of their life cycle associated with the substrate (HERSHEY, et al. 2010).

Macroinvertebrates are one of the most representative groups in aquatic fauna due to their high abundance, biodiversity, wide distribution and relatively long life cycle. In addition, most of them have known ecological characteristics, being relatively sedentary and having limited mobility. As they present different degrees of sensitivity to environmental stresses, they are excellent indicators for assessing water quality through biological indices, using macroinvertebrate families as a tool (SANTANA, et al. 2021).

Bioindication assesses surface environments by monitoring taxonomic groups, based on the behavior of ecological communities; where physicochemical and geochemical factors can subject organisms to stress conditions, as a result of pollution, plant suppression, landscape change or habitat loss (MUGNAI, et al. 2010). Biotic indices establish water quality classes based on the presence of bentofaunistic families,

using predetermined tolerance values for each taxa (SANTOS, 2021).

The Pedra Branca State Park is made up of a rocky massif, which, framed by a large area of Atlantic forest, forms a hydrographic complex, which contributes intensely to the region, where the volume and quality of water produced on its slopes are directly related with the quality of the forest; regulating hydrological, ecological, climatic and geomorphological processes (INEA 2013). It is recognized as one of the largest forests in urban areas in the world and the largest in Brazil, as there is a preservation of the largest forest fragment in the area. Atlântica, located in the municipality of Rio de Janeiro, characterized as a Submontane Dense Ombrophilous Forest, with a sub-humid climatic typology, with little or no water deficit (SOUSA, et al. 2009). The PEPB protects more than 50% of the remaining Atlantic Forest in the city of Rio de Janeiro, which is considered one of the richest and most threatened biomes in Brazil and the world (INEA 2013).

Finally, this research aimed to collect and identify the taxa of bioindicator benthic macroinvertebrates present in lotic environments in the study area, along with the results of each analyzed location, in order to associate them with the level of preservation of the streams of the Pedra Branca State Park.

2. MATERIAL AND METHODS

Seven sampling sites were analyzed, divided into two rivers in the Pedra Branca State Park; the Divisa/ Moinho River (River 1) - Vargem Grande, which was analyzed in 4 sites (Site 1, Site 2, Site 3 and Site 4) of different altitudes on 06/28/2018; and Rio Grande (River 2) - Pau da Fome/ Taquara, which was analyzed in 3 sites (Site 5, Site 6 and Site 7) of different altitudes on 06/29/2018.

To analyze the environment found at each sampling site, the following parameters were verified: location and elevation, light incidence, water pH, water temperature and river depth.

For sampling of organisms, 10 collection points (P1 to P10) were selected in each analyzed site, with the exception of site 5, which, as it is a place with little water, it was possible to analyze only 5 points (P1 to P5).

At each point, river sediments were collected with aquatic macroinvertebrates in the immature phase; they were separated into bags with alcohol and the bags identified by the site and collection point.

All data collected were applied in different statistical indices in order to obtain results that represent the qualitative characteristics of river water and its environments. In order to characterize the levels of quality, preservation and pollution of rivers, three biotic indices were used: EPT (Ephemeroptera, Plecoptera and Trichoptera), which refers to the level of water preservation, according to the number of families found in the orders : Ephemeroptera, Plecoptera and Trichoptera; BMWP (Monitoring Working Party), which indicates the level of water quality, and is calculated according to the variety of macroinvertebrate families/bioindicators found; IBF (Biotic Index of Families), which indicates the level of pollution and water quality,

according to the number of individuals found in the macroinvertebrate bioindicator families.

To analyze the similarity between the composition of organisms at the sites, Non-Metric Multidimensional Scaling (NMDS) was used, while to investigate the relationships between biotic and abiotic factors, a Redundancy Analysis (RDA) was used.

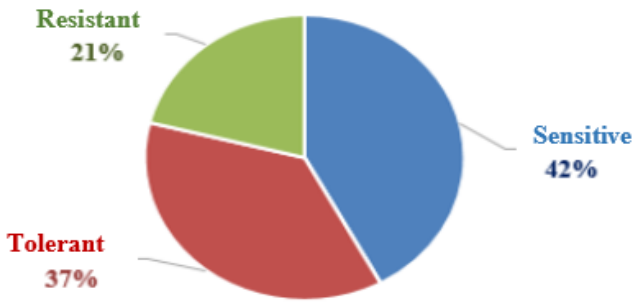
3. RESULTS AND DISCUSSION

A total of 929 immature insects were collected, which were analyzed, photographed and identified in the laboratory at the Universidade do Estado do Rio de Janeiro – Campus Zona Oeste; visualized through a stereoscopic microscope with camera and identified according to Mugnai R *et al*. (2010). Aquatic macroinvertebrates were quantified and classified in Order and Family level. The insects used in this research belong to the Phylum: Arthropods (sub-phylum: Atelocerata), Class: Insecta (Superclass: Hexapoda), Orders: Ephemeroptera, Plecoptera, Tricoptera, Odonata, Diptera, Coleoptera, Hemiptera, Lepidoptera and Collembola; and represent the Families: Baetidae(21), Leptophebiidae(11), Leptohyphidae(7), Perlidae(53), Gripopterygidae(2), Hydropsychidae(36), Calamoceratidae(26), Leptoceridae(4), Hydrobiosidae(1), Simuliidae(608), Chironomidae (70), Syrphidae(1), Tipulidae(7), Dixidae(4), Calopterigidae(7), Libellulidae(4), Dicteriadidae(1), Staphilinidae(21), Elmidae(55), Torridincolidae(2), Veliidae(5), Helotrephidae(2), Hebridae(1) and Mesoveliidae(1).

There are significant advantages in using biological indices based on macroinvertebrates, identified by order and family. Biotic analysis helps to identify possible impacts, as the predominance of orders and families that are sensitive or resistant to pollution, indicates the level of preservation of the rivers (ZAMORA-MUÑOZ, et al.1995). Despite the classification of taxa by sensitivity, to consider a healthy aquatic ecosystem it is important to have a wide variety of taxa, including sensitive, tolerant and resistant insects to impacts and changes in the water body and its surroundings (CALISTO, et al. 2001)

Among the bioindicator families used in the calculation of the BMWP biological index, which indicates water quality; 19 families were found in this research, among them: 8 sensitive to organic pollution (Leptophlebiidae, Perlidae, Leptoceridae, Calamoceratidae, Calopterygidae, Libellulidae, Hydrobiosidae and Gripopterygidae),7 families tolerant to organic pollution (Leptohyphidae, Elmidae, Hydropsychidae, Tipulidae, Simulidae, Baetidae and Dixidae) and 4 resistant to organic pollution (Mesoveliidae, Veliidae, Chironomidae and Syrphidae) The 19 families were organized in percentage by tolerance to organic pollution through figure 1.

Figure 1 – Percentage of the classification of bioindicator families by the level of tolerance to organic pollution, collected in the PEPB.



Source: Authors (2023)

The comparison of the environments found in the collection sites is a factor of great importance for this research, because according to the literature, the distribution of aquatic biota is directly or indirectly influenced by the abiotic gradients of the rivers (BRIGANTE & ESPÍNDOLA, 2003). The environmental data obtained in this research are associated with the results of field parameters: location, pH, temperature, light incidence and depth.

It was observed that the incidence of light showed great variation between the collection points. The results of the parameters tested in the field at the river collection sites: Rios da Divisa/ Moinho (R1) and Rio Grande (R2) were described by Charts 1 and 2.

Chart 1 - Results of the parameters analyzed in the field in the collection sites of Rio da Divisa/ Moinho – R1 (Vargem Grande).

R1. Divisa River/ Mill – Vargem Grande					
Place	**Location**	**ppH**	**Temperature**	**Light Incidence**	**Depth**
1	S22°50.224' W043°30.157' Elevation: 131 m	77.4	22°C	94.3 FC	21 cm
2	S22°57.067' W043°29.155' Elevation: 178 m	66.3	24°C	304 FC	44 cm
3	S22°57.164' W043°29.270' Elevation: 154 m	55.8	23°C	237 FC	27 cm

Source: Organized by the authors (2023)

Chart 2 - Results of the parameters analyzed in the field at the collection sites in Rio Grande – R2 (Pau da Fome, Taquara).

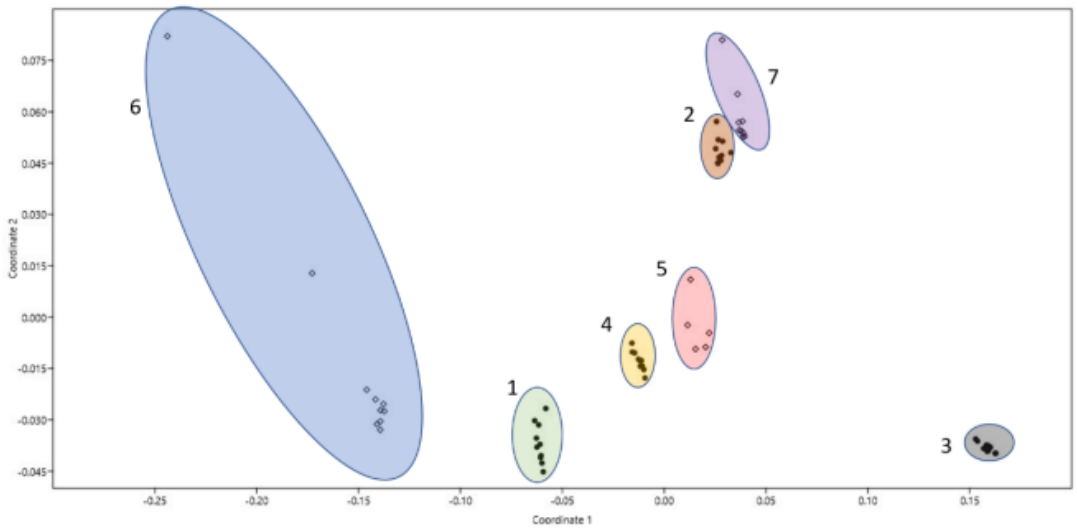
Rio 2 - Pau da Fome – Taquara					
Place	**Location**	**ppH**	**Temperature**	**Light Incidence**	**Depth**
5	S22°52.922' W043°26.651' Elevation: 115 m	55.3	19.2°C	162 FC	10 cm
6	S22°55.987' W043°26.667' Elevation: 148 m	55.8	19.8°C	46.5 FC	100 cm
7	S22°56.009' W043°26.735' Elevation: 151 m	55.7	18.2°C	320 FC	30 cm

Source: Organized by the authors (2023)

The result of the Non-Metric Multidimensional Scaling (NMDS) showed that the collection points of each site were similar to each other in most sites, forming groups, where at site 6 there was a greater difference between the collection points, generated by the waterfall environment.

There was also greater similarity between the collection points at site 2, in river 1 and at site 7, in river 2; and between site 4, in river 1 and site 5, in river 2. Such "doubles of sites" presented considerably similar results for the analyzes carried out in the field. Dispersion is observed in terms of similarity between the collection points of each analyzed site, in the Divisa/ Moinho Rivers (river 1) and Rio Grande (river 2).

Figure 2 - NMDS result showing the clusters of points according to the Bray-Curtis similarity index.

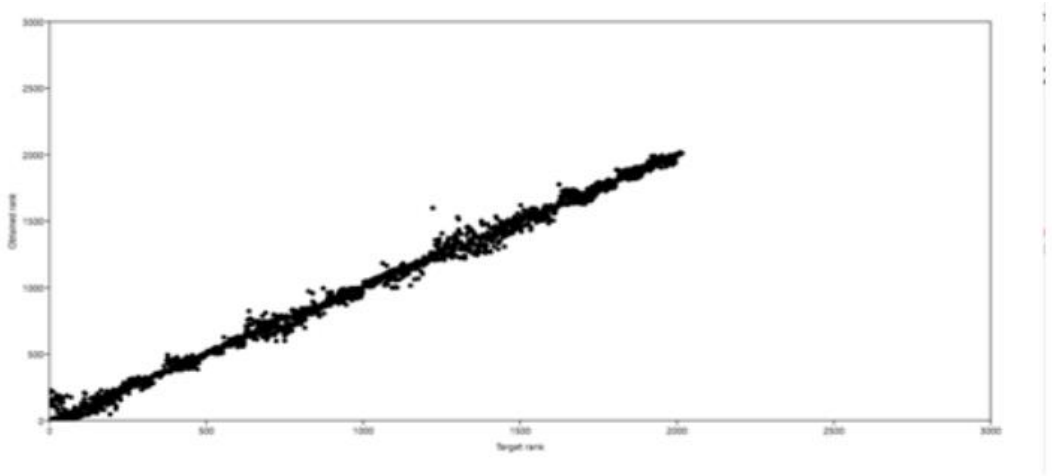


Source: Authors (2023)

The observed *stress* (*Standardzed Residual Sum of Squares*) was 0.03815 and the axes result was:

R2 axis 1=0.8252 and axis 2=0.1086. The *Stress* of the NMDS resolution indicated by ShepperdPlot, where it was considered satisfactory (Fig. 03), since the result being below 0.05 indicates that the distances in the diagram reflect the original distances well, without data loss (MELO & HEPP, 2008).

Figure 3 - *Stress* of the NMDS resolution (Stress=0.0385) R2 axis 1= 0.8252 and axis 2= 0.1086.



Source: Authors (2023)

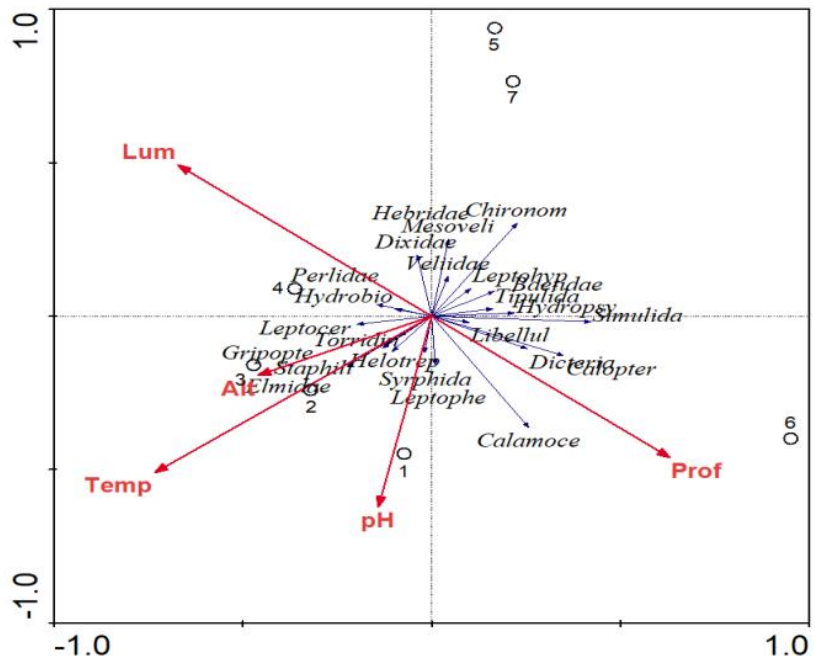
Redundancy Analysis refers to "explained variability", with RDA being one of the most complete and efficient methods of canonical sorting (BARBOZA & PAIVA 2014). The RDA also applies to biotic factors, as it was suitable for biological matrices (BARBOZA & PAIVA, 2014). The RDA showed significance only for the temperature and luminosity results.

The Helotrephidae family of the Hemiptera order, and all the families found in the Coleoptera order (Elmidae, Staphilinidae and Torridincolidae) showed positive correlations with temperature; the two orders are associated with calm waters, with low currents and with higher temperatures, since they have no affinity for very low temperatures. The Chironomidae *family* of the Diptera order, and two families of the Ephemeroptera order (Leptohyphidae and Baetidae) showed negative correlations with temperature, which corroborates data from other authors who associate the Ephemeroptera order with lower temperature waters, but also a wide temperature range (BIS & KOSMALA, 2005 ; DOMINGUEZ, et al. 2006).

The Perlidae family of the Plecoptera order, and the Hydrobiosidae family of the Trichoptera order showed positive correlations with luminosity, both families are associated with luminosity. The family Calmoceratidae of the order Trichoptera, and all the families found of the order Odonata (Libellulidae , Calopterigidae and Dicteriadidae) presented negative

correlations with the luminosity. The order Odonata is associated with places with vegetation, where it is found between rocks and leaves, preferring to stay in places with less light in the river. Furthermore, the communities of the order Odonata may differ depending on the presence or absence of riparian forest and because of this, some species have the potential to be bioindicators (BIS & KOSMALA, 2005 ; RODRIGUES, et al. 2019). The Calamoceratidae family makes cocoons with leaves from river sediments to pupate, thus remaining in contact with low light (MUGNAI, et al. 2010). We can observe the vectors of the redundancy analysis between biotic and environmental factors (Fig. 04).

Figure 4 - Redundancy Analysis (RDA) showing the correlations between the insect families sampled and the results of the parameters analyzed in the field.



Source: Authors (2023)

The EPT index evaluated the number of families of three bioindicator orders (Ephemeroptera, Plecoptera and Trichoptera), considered sensitive to organic pollution, to analyze the level of water preservation; which is a determining factor for the presence of these organisms in aquatic environments (QUEIROZ & TRIVINHO-STRIXINO, 2008).

River 1 showed the highest level of qualitative preservation; while river 2 had 1 collection point with a good level of preservation, and 2 collection points with a moderate level of preservation (Chart 3). The BMWP index, which indicated the water quality and its classification by color, analyzing families sensitive and tolerant to organic pollution (ALBA-TERCEDOR & SÁNCHEZ-ORTEGA, 1988 ; BACCA, et al. 2023), and the results obtained can be seen in the Chart 4.

Chart 3 - Quantitative and qualitative results of the EPT index, indicating the level of water preservation of the collection sites of the analyzed rivers.

analyzed river	collection site	EPT Result	Preservation level
River 1 – Rio da Divisa/ Mill (Large Vargem)	1	6	Good
	2	5	Moderate
	3	7	Good
	4	6	Good
River 2 - Rio Grande (Hunger Stick)	5	3	Moderate
	6	6	Good
	7	3	Moderate

Source: Organized by the authors (2023)

Chart 4 - Quantitative and qualitative results of the BMWP index for each collection site, indicating the water quality and its classification by color.

analyzed river	site	BMWP Result	Water quality	Color sort code
River 1 – Rio da Divisa/ Mill (Large Vargem)	1	66	Good	Green
	2	37	little polluted	Yellow
	3	61	Good	Green
	4	47	little polluted	Yellow
River 2 - Rio Grande (Hunger Stick)	5	46	little polluted	Yellow
	6	62	Good	Green
	7	39	little polluted	Yellow

Source: Organized by the authors (2023)

Like the BMWP index, the IBF index indicates water quality and the IBF calculation also presents results related to the level of organic pollution in rivers, analyzing the bioindicator families found (ZIMMERMAN, 1993).

River 1 was rated excellent water quality and no apparent organic pollution, and River 2 was rated fair water quality and reasonably significant organic pollution. In chart 5 it is possible to observe the results.

Chart 5 - Quantitative and qualitative IPF results of the water, with the degree of pollution of each analyzed river.

analyzed river	BF Result	Water quality	degree of pollution
River 1 – Rio da Divisa/ Mill (Large Vargem)	3,345	Great	No apparent organic pollution
River 2 - Rio Grande (Hunger Stick)	5,694	Reasonable	Fairly significant organic pollution

Source: Organized by the authors (2023)

Evaluating all the data presented, it was concluded that the taxonomic variety among the organisms sampled was satisfactory, as it was possible to find a good distribution of insects of the three classifications of resistance to organic pollution (sensitive, tolerant and resistant).

The sites chosen for this research are located in low points of the PEPB, with little variation in elevation between them, in order to analyze places with greater probability of urban impacts, easy access by the population and with points of water abstraction. depth in each river were the sites that present a waterfall environment, being site 2 in river 1 and site 6 in river 2 differentiated from all other collection sites, and stood out in the RDA analysis for presenting less similarity between the points.

The incidence of light and temperature, respectively, were the parameters that presented the greatest variation between the collection sites, both in river 1 and in river 2, thus being the analyzes with greater significance. River 2 had lower pH and temperature than River 1. In River 1 there was a greater pH variation between the collection points, ranging from 5.6 to 7.4; while in Rio 2 the pH varied between the sites from 5.3 to 5.8.

The MNDS analysis showed a Stress = 0.03815, which is satisfactory, indicating that the distances in the diagram well reflected the original distances found between the evaluated sites.

The similarity found by NMDS between site 2, in Rio 1 and site 7, in Rio 2; which are places with intense water volume and strong currents, was confirmed by the EPT and BMWP indexes, where both showed a moderate level of preservation, with water of little polluted quality and classification of yellow color. The similarity found by NMDS between site 4, in river 1 and site 5, in river 2; which are places of moderate to low volume of water and with weak current, was confirmed by the BMWP index, where both presented little polluted water, with yellow color classification, with almost no difference in the quantitative result (46 and 47).

According to the quantitative and qualitative results of the EPT, BMWP and IBF indices; River 1 (Rio da Divisa/ Moinho – Vargem

Grande) is classified as preserved, with good to moderate water quality and no apparent organic pollution. River 2 (Rio Grande – Pau da Fome) is classified as moderately preserved, with water quality between good, moderate and little polluted in the analyzed sections and with reasonably significant organic pollution. Therefore, Rio da Divisa/Moinho (river 1) presents better conditions of water quality, level of preservation and level of organic pollution, than Rio Grande (river 2).

River 1 is located in the Vargem Grande district, where it is protected and managed by INEA and the Quilombola CafundáAstrogilda Community; around it, the community carries out agricultural activities in the agroforestry model, without the use of pesticides; in addition to various environmental preservation and ecotourism activities. River 2 is located in Pau da fome, in the Taquara district, where it is managed by INEA and CEDAE, and supplies a water collection station for treatment and supply to the Jacarepaguá region; the site receives visitors with easier access than river 1, and also serves environmental and ecotourism activities. River 2 was analyzed around the water collection point for treatment.

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