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Environment

Integrated assessment of the environmental quality of the Palmitos microbasin

Avaliação integrada da qualidade ambiental da microbacia de Palmitos

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ABSTRACT

Aquatic ecosystems are impacted by various human activities. In view of their preservation, it is necessary to monitor their quality. In this sense, the objective of this work was to evaluate the water quality of the microbasin of the Palmitos by an integrated analysis. The Rapid Assessment Protocol (RAP) results characterized the Palmitos stream ranging from altered to impacted and the tributaries from natural to altered. Biomonitoring characterizes the water quality of the microbasin at different levels, from very bad to good. The high level of eutrophication of water bodies is highlighted due to the high concentrations of phosphorus arising from local agricultural activities, which cover about 60% of the microbasin area according to the study of land use and occupation. The analysis of the sediments showed that places with more heterogeneity present greater diversity of macroinvertebrates. The protocol of functional feeding groups reveals a destructured microbasin in its middle/lower part, due to the predominance of collecting macroinvertebrates and the absence of fragmenters. These results, together, demonstrate the high degradability of the microbasin of the Palmitos stream in the region covered by the urban area. It is expected that the results will contribute to the strengthening of proposals for monitoring and controlling water pollution, serving as a subsidy for programs to recover degraded areas.

Keywords: Biomonitoring; Water quality; Soil use and occupation

RESUMO

Os ecossistemas aquáticos são afetados por várias atividades humanas. Tendo em vista sua preservação, é necessário monitorar a sua qualidade. Nesse sentido, o objetivo deste trabalho foi avaliar a qualidade da água da microbacia do córrego Palmitos por meio de uma análise integrada. O Protocolo de Avaliação Rápida (PAR) caracterizou o córrego Palmitos variando de alterado a impactado e os tributários de naturais a alterados. O biomonitoramento caracterizou a qualidade da água da microbacia em diferentes níveis, de muito ruim a bom. O alto índice de eutrofização dos corpos d'água ganhou destaque devido às altas concentrações de fósforo decorrentes das atividades agrícolas locais, que cobrem cerca de 60% da área da microbacia segundo o estudo de uso e ocupação do solo. A análise dos sedimentos mostrou que locais com maior heterogeneidade apresentam maior diversidade de macroinvertebrados. O protocolo dos grupos funcionais de alimentação revelou uma microbacia desestruturada em sua parte média/inferior, devido à predominância de macroinvertebrados coletores e ausência de fragmentadores. Esses resultados, em conjunto, demonstram a alta degradabilidade da microbacia do córrego Palmitos na região de abrangência urbana. Espera-se que os resultados contribuam para o fortalecimento de propostas de monitoramento e controle da poluição hídrica, servindo de subsídio para programas de recuperação de áreas degradadas.

Palavras-chave: Biomonitoramento; Qualidade da água; Uso e ocupação do solo

1 INTRODUCTION

Although water is seen as a renewable resource, its availability at the necessary amount and quality can be impaired due to its inappropriate management and degradation caused by human actions such as agriculture and industrial activities. Furthermore, population growth, unorganized soil occupation, increased water consumption for several human activities and inadequate waste disposal through both surface water flow or punctual discharge, also lead to water resources' degradation (Luz et al., 2019).

Important Brazilian watersheds, such as that of Doce (Santolin et al., 2015), Piracicaba and Paraopeba rivers (Soares et al., 2020), suffer with different impacts from industrial activities, agriculture and untreated domestic waste disposal; altogether, these factors account for these rivers' environmental degradation (Garuana et al., 2020).

Some physicochemical parameters, such as conductivity, pH and dissolved oxygen, are traditionally used to evaluate water bodies (Leal et al., 2023; Lenz et al., 2024; Soares et al., 2023). Oscillations in water conductivity, even if they do not cause immediate harm to humans, may indicate contamination of the water course. Hydrogen potential (pH) is a parameter that directly influences the physiology of several aquatic species, while dissolved oxygen plays an essential role in maintaining aerobic and facultative life in the aquatic environment (Di Bernardo & Dantas, 2005). However, although fluctuations in these parameters are normally observed in contaminated water bodies, they are within the limits permitted by legislation.

So, aquatic ecosystems' control, management and conservation have been recording much accurate and safe responses (Gualdoni et al., 2011). Besides integrally assessing the impact of urbanization (Callisto et al., 2019), biomonitoring is also used to diagnose changes in rivers' limnological conditions when they cannot be detected by monitoring physical and chemical variables (Aazami et al., 2019).

Benthic macroinvertebrates have been often used to assess environmental impact on aquatic ecosystems (Blake & Rhanor, 2020; López-López et al., 2024; Ochieng et al., 2020; Pereira et al., 2020, Domingues et al., 2021). These organisms are bigger than 0.5mm, live in continental aquatic ecosystems' sediment and colonize substrates such as tree stumps, leaves accumulated on the ground, rocks, aquatic macrophytes and filamentous algae found throughout part of, or in their entire, life cycle (Morgan et al., 2006).

The integrity of biotic communities and, consequently, of natural environments, can be measured and interpreted by screening changes in species richness and diversity, in the abundance of resistant organisms and in the loss of sensitive species (Brown Jr, 1997). Thus, the presence of some benthic organisms can be indicative of good, or bad, water quality, depending on the ability of these organisms to tolerate environmental changes. Communities of these organisms do not reach their full development in disturbed environments, only few species are capable of tolerating these disturbances (Castro & Huber, 1997). Thus, benthic communities' distribution and diversity are often influenced by substrate type, ecosystem morphology and organic matter type, as well as by the presence of aquatic vegetation, the presence and extension of riparian forest, nutrient concentrations and changes in primary yield (Galdean et al., 2000).

Accordingly, changes caused by disorganized soil use and occupation in watersheds can affect rivers' integrity; consequently, they have negative effect on the aquatic biota, such as species richness and diversity reduction, as well as influence the health of these ecosystems (Ferreira et al., 2014). Thus, besides the physical-chemical and biological parameters, soil use is also a relevant indicator of disturbances caused by human action in urban microbasins (Callisto et al., 2019).

If one takes into account the importance of integrally evaluating indicators that describe and feature the ecological quality of watersheds, it is possible stating that the main aim of the present study was to relate pressure from soil use and occupation to indicators adopted to monitor water quality in Palmitos Stream microbasin.

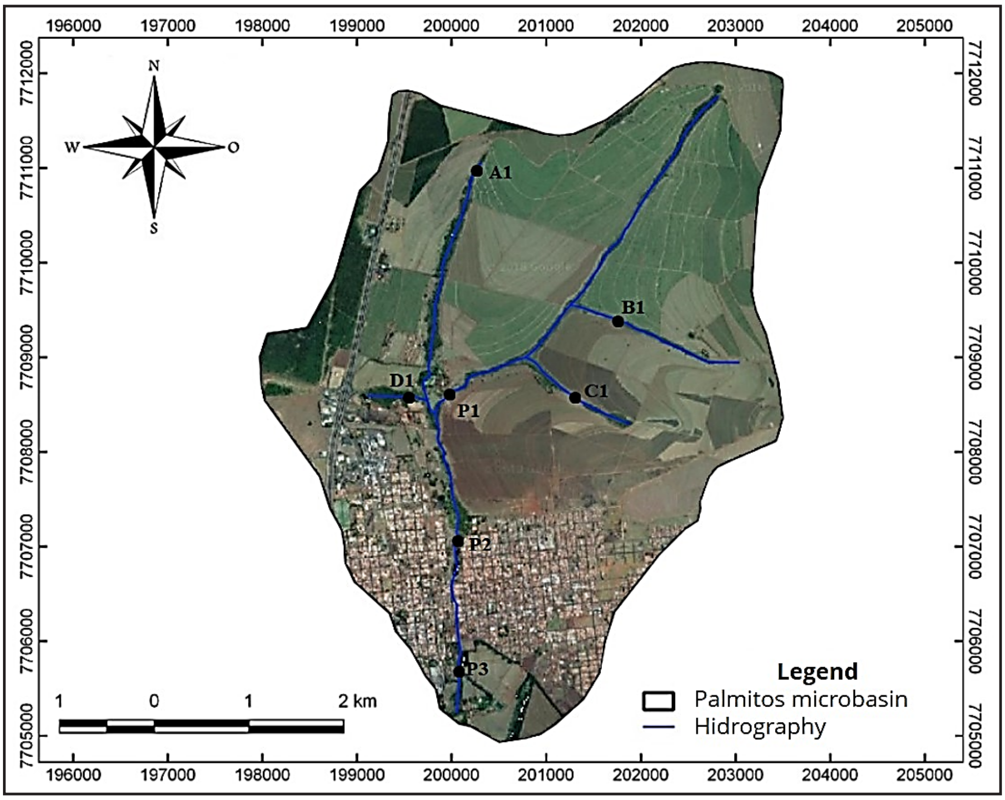
2 METHODOLOGY

2.1. Studie site

Palmitos Stream microbasin is the main watershed in Orlândia County, São Paulo State, since it is the water supply source in this county and accounts for approximately 40% of the total amount of water currently captured in it (Prefeitura Municipal de Orlândia, 2018). This microbasin is closely linked to local agricultural activities; however, nowadays, this stream has been influenced by human actions taking place in its middle/high drainage area, namely: discharge of untreated sewage and channeling of some of its parts, among others. The high part of this microbasin is occupied for rural-use purposes, such as crops and pasture (Prefeitura Municipal de Orlândia, 2018).

Collections were carried out in 7 points of Palmitos Stream microbasin, as described in the map plotted in ArcGis® software (Figure 1). Collections were performed between January and March, 2018, during the rainy season. Points P1, P2 and P3 corresponded to Palmitos Stream and points A1, B1, C1 and D1 concerned its tributaries. Points P2 and P3 are within the urban perimeter, and points P1, A1, B1, C1 and D1, in their turn, are located outside this perimeter.

Figure 1 – Points sampled in Palmitos Stream microbasin



Source: the authors (2024)

2.2 Soil use and occupation

Qgis® software was used to map and quantify soil use in Palmitos Stream microbasin based on the following classes: agriculture, pasture, natural vegetation, urban zone and reforestation.

2.3 Biomonitoring based on benthic macroinvertebrates

Substrate collection was carried out with the aid of Surber type sampler (900cm^2 and 250µm mesh) placed on the stream bed, against the stream current (Silveira et al., 2004). Three sediment collections were carried out in each point; the collected material was stored in plastic bags and fixed on 70% ethyl alcohol. The collected sediments were washed in running water, over 250 µm mesh, at the laboratory. Subsequently, previous screening was performed at naked eye in order to collect bigger-sized organisms that, then, were separated from the debris. The collected material was taken to oversaturated salt solution in order to make the macroinvertebrates float, since they are lesser dense than the oversaturated solution – this process optimized the screening process under stereoscopic magnifier (Brandimarte & Anaya, 1998). The collected macroinvertebrates were stored in flasks filled with 70% ethyl alcohol; flasks were properly sealed and identified (each point, in separate).

The animals were quantified and identified based on identification keys (Mugnai et al., 2010; Costa et al., 2006). After the sampled taxa were classified, BMWP indices (Biological Monitoring Working Party) were calculated based on Junqueira et al. (2018), as well as on Shannon-Wiener (H') diversity, Pielou equitability (J') and Berger Parker (d) dominance (Krebs, 1989; Magurran, 1988). Jaccard index was also applied to set the similarity between the assessed environments, based on sampled macroinvertebrates' richness and abundance. Results were shown in the dendrogram plotted in Bioestat 5.0® software.

Organisms' classification into trophic functional groups followed recommendations by Merrit and Cummins (1996) and Cummins et al., (2005). It was done by separating them into shredders, scrapers, strainers, collectors and predators.

2.4 Rapid Assessment Protocol

The Rapid Assessment Protocol (RAP) (Callisto et al., 2002 – with modifications) was applied through visual observation of habitat conditions. Scores were established to 22 parameters that were previously determined by the present authors. Their sum features the locations as natural (above 61 points), changed (from 41 to 60 points) or impacted (from 0 to 40 points).

2.5. Sediment analysis

Triplicate sediment collections were carried out in each analyzed point with the aid of Van Veen dredge. Samples were prepared at the laboratory (ABNT, 1986) and subjected to particle size analysis (ABNT, 1984), as well as to organic matter content determination (ABNT, 1996). Particle size composition was analyzed based on ABNT (1995) and textural classifications followed the textural triangle technique adapted by Lemos and Santos (1996).

2.6 Water physical-chemical analysis

Dissolved oxygen (DO) concentration and temperature parameters were measured in loco with the aid of Hach multiparameter probe, model HQ40D. Subsequently, dissolved oxygen was converted into oxygen saturation rate (%DOsat), since this gas is influenced by local temperature and pressure. The pH and electric conductivity (EC) analyses were performed at the laboratory in Hanna® Instruments portable multiparameter probe, model 9829. Turbidity was measured in bench equipment Ms Tecnopon Scientific Instrumentation model TB 1000.

Water samples were taken to sterile flasks filled with HNO_3 (preserver) and stored in Styrofoam boxes for further phosphorus quantification and total phosphorus analysis (Apha, 2012). Concentration values were used to calculate the Trophic State Index (TEI), which was adopted to classify waterbodies at different trophic degrees (Cunha et al., 2013).

2.7 Statistical analysis

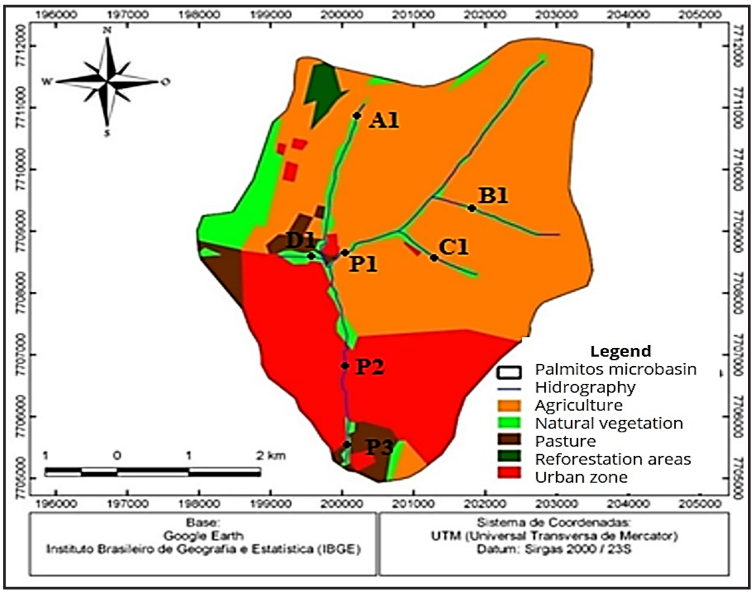
Principal Component Analysis (PCA) was carried out to assess the correlation levels between Shannon-Wiener diversity index and other variables.

3 RESULTS AND DISCUSSION

The soil use and occupation map (Figure 2) depicted the highest rate of areas occupied by agriculture (60.98%), mainly at the middle/high part of the assessed microbasin – it covered points A1, B1, C1 and P1. The urban zone was the second category accounting for the highest rate of occupied area (25.44%) – it covered point

P2; it was the only sampled point missing riparian forest. Pasture was observed in 4.08% of the microbasin area – it covered points D1 and P3, which are located inside rural properties. Reforestation areas, in their turn, totaled 1.18% of the microbasin. It is important highlighting the low rate of areas presenting natural vegetation cover (8.32%); this finding reflects the significant change observed in the microbasin's native forest.

Figure 2 – Soil use and occupation map of Palmitos Stream microbasin, and its sampling points



Source: the authors (2024)

Point A1 was the one recording the highest score in the BMWP index; it also presented good quality of water (Table 1) and great richness of the sampled taxa, such as beetles (Coleoptera), mosquitoes (Diptera), caddisflies (Tricoptera), dragonflies (Odonata), earthworms (Oligoqueta) and snails (Gastropoda). High equitability and low dominance were also observed. PAR classified this point as "natural" and, despite the fact that this fraction is closer to crops (Figure 2), it is surrounded by riparian forest - which provides diversity of habitats, food sources, and protection and reproduction sites for macroinvertebrates (Chará-Serna et al., 2015). This point also showed sediments' heterogeneity (Table 2) and the outstanding presence of smaller diameter particles.

Table 1 – Results of biological indices for assessing the environmental quality of the sampled points

	A1	B1	C1	D1	P1	P2	P3
BMWP	71	56	22	15	46	13	2
Quality	Good	Satisfactory	Bad	Very bad	Satisfactory	Very bad	Very bad
Richness	16	16	6	4	12	4	1
Abundance	35	227	126	16	34	1362	3055
H’	2.51	1.81	0.59	1.14	1.72	0.03	0
H’max	2.77	2.77	1.79	1.3	2.48	1.39	0
J’	0.91	0.65	0.33	0.82	0.69	0.02	0
D	0.2	0.34	0.83	0,5	0.56	0.99	1
RAP*	N (66)	A (60)	A (41)	A (56)	A (58)	I (30)	I (39)

*RAP: N (natural), C (changed) and I (impacted)

Source: the authors (2024)

Table 2 – Results of granulometric analysis of the sediment from the sampled points

Points	Coarse sand (%)	Medium sand (%)	Thin sand (%)	Silt (%)	Clay (%)	Textural classification
A1	0.14	55.51	29.91	2.41	12.03	Frank sand
B1	1.56	30.1	47.95	10.97	18.51	Sandy loam
C1	0.55	6.58	18.43	59.31	15.14	Silty franc
D1	0.5	46.15	38.54	4.72	10.09	Frank sand
P1	0.31	51.59	30.89	0.6	16.61	Sandy loam
P2	0.39	53.56	33.87	6.61	10.49	Frank sand
P3	3.92	74.48	15.61	3.06	5.61	Coarse

Source: the authors (2024)

A1 was the most preserved point, it was followed by B1 and P1 (Table 1). Despite reduction in riparian forests, the present analysis has shown that the quality of water in these points was satisfactory and RAP has classified them as changed environments. Based on the comparison between these two points, B1 was more preserved than P1. Besides being influenced by B1 and C1, P1 is located closer to the urban zone and presents reduced riparian forest. Along with A1, B1 evidenced greater taxa richness, among these taxa one finds organisms that are sensitive to pollution, such as those belonging to family Corduliidae, order Odonata. P1 also showed macroinvertebrates sensitive to pollution, such as Trichoptera (Calopterygidae and Leptoceridae). Both points showed high dominance of chironomids (Table 1), which are organisms extremely resistant to pollution and to habitat changes – they have already developed a whole variety of adaptive mechanisms that allow them to live in this type of environment (Callisto & Esteves, 1998). It was also possible observing intermediate variety of macroinvertebrates in these points (Table 1).

These two points, despite being located in agricultural areas (Figure 2), presented environments favorable for the presence of pollution-sensitive organisms, such as heterogeneous sediment particle sizes (Table 2); moreover, they are surrounded by riparian forest. A more diversified substrate provides greater habitat and food source availability (direct or absorbed from sediment particles), and protection against currents and predators (Carvalho & Uieda, 2004).

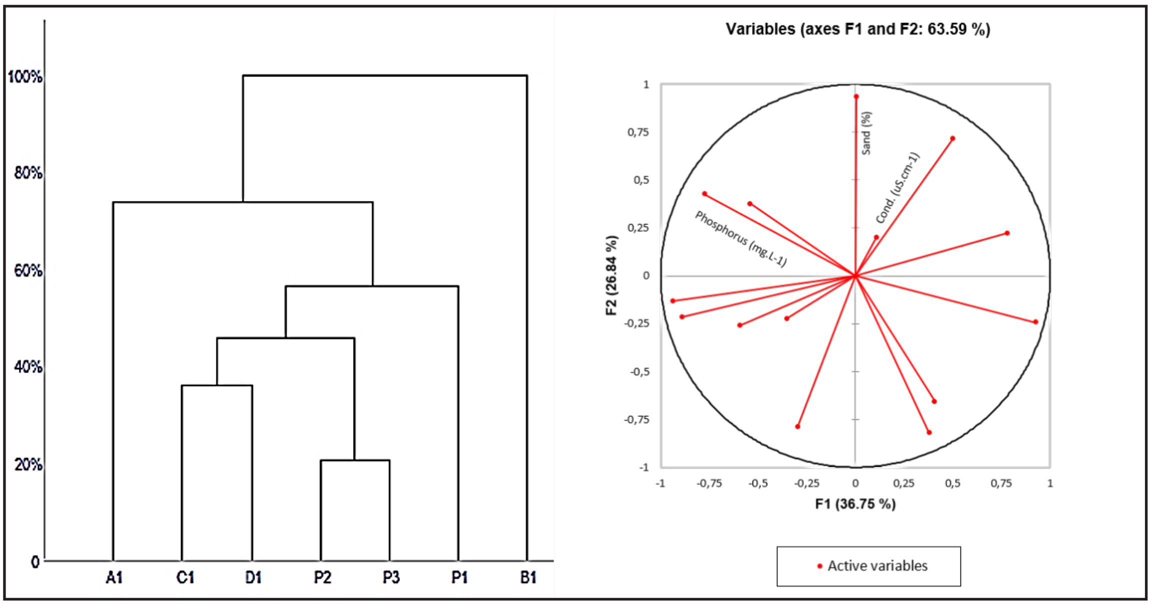
Point D1 was influenced by pasture and urban areas (Figure 2); therefore, it was classified as having very bad quality and presented the lowest amount of sampled taxa in comparison to point C1, which was classified as having bad quality based on the BMWP index (Table 1). Nevertheless, D1 presented larger riparian forest coverage than C1 (Figure 2), a fact that has contributed to the greatest diversity and equitability of sampled macroinvertebrates in it. Silva-Araújo et al. (2020) detached that riparian deforestation may strongly affect stream functioning, with consequences for biodiversity and ecosystem services. Both points were classified as changed, based on RAP.

D1 presented heterogeneous particle sizes, whereas C1 showed silt dominance; therefore, it was classified as silty (Table 2). This profile has contributed to reduce the recorded Shannon-Wiener index, since the low diversity of benthic organisms in environments with fine sediments was assumingly the result from particles' very close proximity to each other and, consequently, from the fact that they presented lower interstitial water content – a feature that reduces the capture of organic compound debris and oxygen availability (Fenoglio & Cucco, 2004).

Points P2 and P3 presented almost null and null values, respectively, for diversity, and high dominance of chironomids (Table 1). Such a fact is evidenced by the exclusive collection of benthic macroinvertebrates tolerant/resistant to pollution – these groups were represented by dipterans and mollusks. Both points were classified as impacted, based on RAP. Point P2 was located inside the urban zone (Figure 2) and it often is loaded with untreated waste. Sewage discharge without proper treatment in waterbodies can have strong impact on aquatic ecosystems, among them, one finds decreased richness of aquatic macroinvertebrates (Posseti et al., 2017). P3, in its turn, despite being located in a pasture area (Figure 2), has part of its water channeled – it lays right after the urban zone.

The aforementioned points have presented sand dominance in their sediments (Table 2). Either homogenization or silting account for reducing aquatic fauna's richness and diversity due to their straight effect on food and habitat availability (Allan, 2004). Furthermore, sandy substrates are quite unstable, they are easily dragged at stronger current times, which are common during the rainy season (Uieda et al., 2016).

Figure 3 – Dendrogram and Principal component analysis

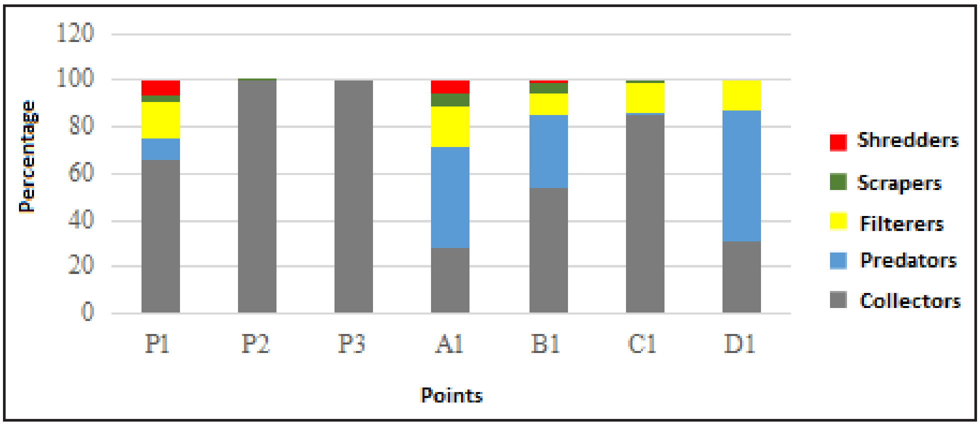


Source: the authors (2024)

Based on the dendrogram (Figure 3), there was high similarity between points P2 and P3, which are located within, and downstream, the urban zone, respectively;

consequently, they were classified as impacted. There was also high similarity between points C1 and D1, which are the most preserved locations among the ones placed outside the urban zone. This figure also shows proximity between these two groupings, since they are changed points. B1 was the point presenting the lowest similarity, because it was the most preserved point among the assessed ones; consequently, it presented a good diversity of species and the greatest abundance of macroinvertebrates, as well as the presence of species that were not sampled in the other points.

Figure 4 – Graph resulting from the functional analysis



Source: the authors (2024)

The analysis of functional groups of benthic macroinvertebrates (Figure 4) showed that the most preserved points presented greater diversity and representativeness of assessed groups than the impacted points. Collectors have dominated most samples, since they feed on organic matter (Giuliatti & Carvalho, 2009). Such a fact was expected to be observed, since all points were enriched by M.O, and presented concentrations higher than 0.50% (RASHID, 1985). The second most abundant group comprised the predators. According to Giuliatti and Carvalho (2009), predators feed on prey from all functional groups, and such a profile does not reflect the influence of external-origin food on lotic ecosystems. Shredder organisms were not identified in the most impacted points (C1, P2, P3 and D1) due to riparian vegetation removal and to the fact that these organisms feed on leaves (Cummins et al., 1973). The functional group of scrapers was observed in the preserved points, but they were not found in the changed ones; this finding is indicative of their work as environment-quality indicators (Chagas et al., 2017).

Phosphorus analysis (Table 3) showed that all points have presented trophic degrees higher than 54; therefore, they were classified as eutrophic and hypereutrophic. The weathering of phosphate rocks observed in watersheds is the phosphorus origin in natural ecosystems without anthropic pressure (Reynolds, 1978). However, activities such as agriculture around points A1, B1, C1 and P1, or urban sewage discharge, such as that in points P2 and P3, have changed the natural phosphorus concentrations in waterbodies (Cunha et al., 2011; Branco Jr et al., 2019).

Table 3 – Results of physical-chemical analyzes

	A1	**B1**	**C1**	**D1**	**P1**	**P2**	**P3**
Phosphorus (mg. L^{-1})	1.33	0.58	0,18	0.16	0.46	0.54	0.24
IET	73.15	68.84	62.77	62.15	67.64	68.47	76.22
Classification	H	H	E	E	H	H	H
OD (mg. L^{-1})	7.1	5.74	6.77	6.95	7.42	7.78	7.63
pH	7.9	7.5	7.3	7.5	7.42	7.86	7.2
T (ºC)	23.7	24.8	26.1	25.2	25	25.2	26.1
Conductivity (uS.cm^{-1})	0.8	1.2	0.8	2	2.4	1.8	1.2
Turbidity (NTU)	1.11	5.2	63	37	53	105	43
Organic matter	1.89	3.34	9.59	2.57	3.33	3.32	1.39

Source: the authors (2024)

All points presented DO values within the expected rates for class 2 rivers; in other words, higher than 5 mg. L^{-1} (Table 3) (Brasil, 2005). This finding can be related to rainfall events at sample-collection time, since rainfall increases water flow speed and, consequently, its turbulence; a factor that provides better DO mixing conditions and favors its incorporation (Silvão et al., 2020).

The recorded pH values were within the neutral pH range, namely: from 7.2 to 7.9 (Table 3). According to CONAMA Resolution 357/2005 (Brasil, 2005), pH must range from 6 to 9, regardless of the waterbody class. Water temperature in the sampled points ranged from 23.7 °C to 26.1°C (Table 3). Although the points did not present significant differences in temperature values, this parameter showed close negative correlation (-0.84) to diversity of macroinvertebrates (Figure 3). It was possible observing that the presence of both riparian vegetation and taller trees in points A1 and B1 has led to the effective protection of waterbodies, as well as kept the environmental temperature, because they provided shade to a long extension of the stream (Alves, 2010). Points accounting for bad/very bad quality showed higher temperatures, and it can be related to heat transfer, decrease or lack of riparian vegetation, or to domestic sewage discharge (Alves, 2010).

There is no electrical conductivity standard provided on the legislation. However, based on Von Sperling (2007), natural water presents conductivity contents ranging from 10 to 100 μS. cm^{-1} (Piratoba et al., 2017). Accordingly, it was possible observing that the sampled points showed very low electrical conductivity values (Table 3) because sediment in the microbasin is mainly composed of sandstone, which is a geological formation type presenting salts in its composition (Allan, 1995). Only point P2 exceeded the turbidity limit provided on CONAMA Resolution 357/2005 to Class 2 rivers, namely: up to 100 NTU – this fact is closely related to the discharge of domestic sewage close to this point (Table 3). The lowest turbidity values were recorded for point A1, i.e., the most ecologically preserved point.

4 CONCLUSIONS

Diversity, equitability, dominance and BMWP indices related to the diversity analysis applied to habitat and soil use and occupation were the main elements for the establishment of the ecosystem's biotic integrity. These studies made it possible inferring that points located closer to urban centers were the ones detected in the most changed/impacted areas; this finding suggest severe environmental impacts and their adverse effect on the ecosystem's metabolism and aquatic life. On the other hand, points located farther from these areas were the ones diagnosed as lesser impacted locations, but it does not mean that they are fully preserved.

Points showing the greatest heterogeneity of substrates, and environments presenting the largest amount of vegetal material, have presented the greatest diversity of benthic macroinvertebrates, since they made more habitat, food source and protection available. It was observed that the inappropriate management of fertilizers and pesticides in crops close to Palmitos Stream microbasin has been causing great environmental unbalance, such as eutrophication of waterbodies and damage to the aquatic biota.

The present study allowed better understanding the community of benthic macroinvertebrates living in Palmitos Stream and in its tributaries, as well as associating this technique with the analysis of physical-chemical parameters, and with soil use and occupation features in order to analyze the quality of water in this microbasin.

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