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ECOSYSTEMS

Effect of seasonality and estuarine waters on the phytoplankton of the Guamá River (Belém, Amazon, Brazil)

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Abstract: This study aimed to analyze the application of the Phytoplankton Community Index-PCI and Functional Groups-FG in determining the water quality of the Guamá River (Pará, Amazônia, Brazil). Samplings occurred monthly for analyses of phytoplankton and physical and chemical parameters, for two years, at the station where water was collected for human supply consumption. Seasonality influenced electrical conductivity, total suspended solids, dissolved oxygen, transparency, winds, true color, and N-ammoniacal. The ebb tide showed high turbidity and suspended solids. The density varied seasonally with the highest values occurring in September and December (61.1 ind mL^{-1} and 60.2 ind mL^{-1}, respectively). Chlorophyll-*a* was more elevated in December (21.0 ± 4.7 µg L^{-1}) and chlorophyll-*c* higher in relation to clorophyll- *b* indicated the dominance of diatoms. Functional Group P prevailed in the study months. Through the PCI índex the waters of Guamá River varied from reasonable to excellent and the TSI ranged from oligo to mesotrophic. The use of Functional Groups proved to be a promising tool in the determination of water quality since it covered the most abundant species in the Environment, but the PCI is not adequate to characterize Amazonian white-waters rivers, which have diatoms as the leading dominant group.

Key words: bioindicators, diatoms, functional groups, water.

INTRODUCTION

Eutrophication is one of the greatest threats to aquatic environments in the world. It comprises the increase of nutrients, mainly nitrogen and phosphorus, in environments with the consequent increase of primary producers, such as clorophytes, euglenophytes, diatoms, dinoflagellates, and cyanobacteria, the latter being important in public health studies due to the production of harmful toxins to humans (Lewis et al. 2011, Wurtsbaugh et al. 2019).

Eutrophication is a process associated with punctual and diffuses sources of nutrients, with urban sewage being the most significant contributor to its occurrence among underdeveloped countries (Suwarno et al. 2014). In the Metropolitan Region of Belém (Pará), only 15.7% of the population receives sewage collection services, and only 2.8% are treated, overall, there are 1.2 million people without sewage services (Trata Brasil 2020), and all the sewage goes to the creeks and rivers in the region, including the mouth of the Guamá River.

The mouth of the Guamá River is a fluvial-estuarine hydric system that converges, together with the Acará River and the Guajará Bay, into the Pará River estuary and the Marajó Bay, which communicates with the Atlantic Ocean (Silva et al. 2020). The hydrodynamics suffers variations linked mainly to seasonal rainfall patterns, along with astronomical tidal forcing, river discharge, and winds (Böck et al. 2010).

It has social and economic importance for the Metropolitan Region of Belém and the insular riverside population because it is essential for fishing, navigation, leisure, industry, tourism, and trade. Its waters are abstracted for the water supply system of Belém, being pumped continuously to the reservoirs Água Preta and Bolonha , which are inside the floodplain forest in a State Park (E.B. Sousa, unpublished data).

Phytoplankton is used as an indicator of water quality and changes in the aquatic environment by many countries around the world and is included in legal monitoring tools; that is, they are water quality assessment tools required by the legislation of some countries (Vadrucci et al. 2007, Kelly et al. 2007, Lobo et al. 2015, Kozak et al. 2020), although they get different approaches, such as indexes, species list, taxonomic groups, functional groups (Gharib et al. 2011, Miao et al. 2019), among others.

Among the different uses of phytoplankton, it is possible to identify, with greater or lesser effectiveness, the attributes or structures altered as a result of environmental changes, which lead to interpretations about the environment, especially the trophic state of rivers, lakes, and reservoirs (Rott et al. 2006, Rodrigues et al. 2019, Meng et al. 2020). For this purpose, there are advances in methodologies and standards on the use of phytoplankton as a bioindicator (Vadrucci et al. 2007, Varkitzi et al. 2018, Francé et al. 2021) based on local realities and international experiences to more clearly interpret the conditions of aquatic environments and assist public managers in decision making.

Brazilian health and environment agencies and councils do not use phytoplankton as a direct bioindication tool, suggesting the use of organisms and biological communities in general (Pires et al. 2015) for this purpose in paragraph § 3, article 8, of Resolution 357/2005 of the National Council for the Environment-CONAMA (CONAMA 2005). In addition, due to the increase in blooms, the monitoring of planktonic cyanobacteria receives constant updates, such as the current ordinance of the Ministry of Health n. 888/2021, aimed at monitoring water quality for human consumption.

In this context, the aim of this study was to evaluate the dynamics of phytoplankton and analyze the application of the Phytoplankton Community Index-PCI, which classifies water quality from phytoplankton groups, as an example of a local approach used in reservoirs and rivers from the state of São Paulo (CETESB 2019), and the Phytoplankton Functional Groups-FG, which describes the trophic conditions of the environment, used in many countries (Reynolds et al. 2002, Padisák et al. 2009) as tools in determining the environmental conditions of the Guamá River.

There are few studies in this region on phytoplankton, where we cite Moreira Filho et al. (1974) with the first survey on the phytoplankton composition of this river, identifying the predominance of diatoms. Paiva et al. (2006) describe the dominance, in terms of biomass, of phytoplagellates followed by diatoms.

More recent studies cite diatoms as the main components of phytoplankton, such as Monteiro et al. (2009) and Rocha Neto et al. (2017); the latter indicated a seasonal variation with higher phytoplankton biomass in the less rainy period. Thus, the studies are insipient and do not bring the relationship of phytoplankton with physical and chemical parameters and water quality, which vary seasonally and between tides (Silva et al. 2020).

The following questions guide the present study: (i) there is seasonal variation in phytoplankton? (ii) what are the main physical and chemical parameters that influence phytoplankton dynamics? and (iii) what are the trophic conditions and water quality of the Guamá River based on the PCI and FG of phytoplankton?

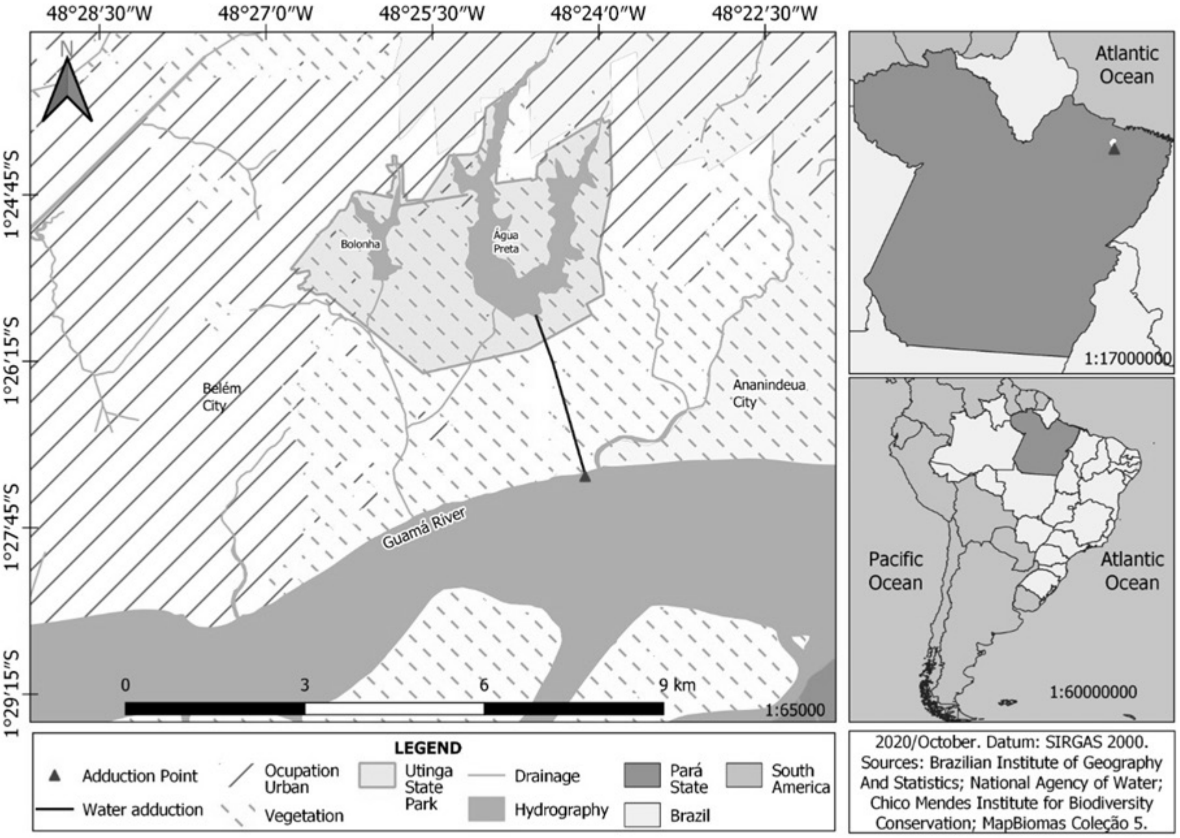
MATERIALS AND METHODS

Sample design and study area

The Guamá River is located in the state of Pará (Eastern Amazon, Brazil). It is approximately 700 km long, its mouth flows into the Pará and Acará rivers, suffering the influence of oceanic tides and receiving constant inputs of sediments from the Guajará Bay, and it may become oligohaline at the height of the less rainy season (Paiva et al. 2006, Monteiro et al. 2009).

This rivercrosses 13 cities until it flows into Belém, Ananindeua, and Marituba, the most densely urbanized municipalities in the Metropolitan Region of Belém, from which it receives the discharge from many urban drainage channels and other streams in the region, during the floods and ebbs of the river tides and by the surface runoff of continental waters through rains (Santos et al. 2012). The average annual temperature is 25 °C, air humidity above 80%, and rainfall of 2,889 mm year^{-1} (Bezerra et al. 2011, INMET 2021).

Samples were collected in the Guamá River at the point where the water is taken from the river for the Água Preta and Bolonha reservoirs (1º27’15’’S- 4º24’08’’W) (Figure 1), monthly from May/2019 to April/2021, covering two seasonal cycles of the region, during flood and ebb tides.



2020/October. Datum: SIRGAS 2000. Sources: Brazilian Institute of Geography And Statistics; National Agency of Water; Chico Mendes Institute for Biodiversity Conservation; MapBiomas Coleção 5.

Figure 1. Map of the study area (Guamá River), showing the adduction point in front of the water catchment station for the public supply reservoirs in the Metropolitan Region of Belém (Pará, Brazil).

Water samples were collected for phytoplankton analyses, and the physical and chemical parameters were measured. The rainy months are from January to May, and the less rainy (or dry) from July to November, with June being considered a rainy-dry transition and December a dry-rainy transition, according to Moraes et al. 2005.

Sampling and analyses of physical and chemical parameters

The data from precipitation and winds were collected from the Belém meteorological station (code 82191, latitude -1.43, longitude -48.42, and altitude 10 m) and provided by INMET (2021). Water transparency was estimated using a Secchi disk. The water temperature (°C), hydrogenic potential (pH), salinity, electrical conductivity (EC), total dissolved solids (TDS), and dissolved oxygen (DO) were measured in situ by the multiparametric probe HI 9828 - HANNA. For the other variables (turbidity, true color, total suspended solids (TSS), and nutrients), water samples were collected with bottles according to the 1060 B method (APHA 2017).

Turbidity and true color were determined by the nephelometric method 2130 B and 2120 D, respectively (APHA 2017), and the TSS by the photometric method (Krawczyk & Gonglewski 1969). N-ammoniacal (N-NH3), nitrate (NO3 -), and total phosphorus (TP) were determined by ion chromatography (ICS Dual 2000) method 4110 B (APHA 2017).

Sampling and analyses of biotic variables

Water samples were collected directly from the subsurface in amber bottles and refrigerated for the clorophyll analyses. For the phytoplanktonic samples water were collected directly from the subsurface.

In the laboratory, phytoplanktonic samples were fixed with neutral formaldeide (4%), methodology 10200 B (APHA 2017). Chlorophyll -*a*, *b*, and *c* samples were analyzed using spectrophotometry (D2000 HANNA®) according to the 10200 H method (APHA 2017). Methods 10200 C and 10200 F were used for sedimentation and quantification of phytoplankton (ind mL^{-1}), respectively (APHA 2017), through an optical invertoscope (AXIOVERT.A1) with camera-attached eyepieces for measuring samples (AXIOCAM ICC5) with measurement software, under a magnification of 400x. The identification, nomenclature, and taxonomic classification of phytoplankton were performed according to specialized literature: Round et al. (2007), Komárek & Anagnostidis (2005, 2008), Komárek (2013) and Bicudo & Menezes (2017).

Phytoplankton was classified into Functional Groups- FG (Reynolds et al. 2002, Padisák et al. 2009) and the Phytoplankton Community Index-PCI, which is based on phytoplankton density (ind mL^{-1}), Trophic state index (TSI) and dominance of large phytoplankton groups, weighted, which assesses water quality in the following classes: Poor (cyanobacterial dominance or total density > 10000 ind mL^{-1}; chlorophyll- *a* > 10 µg L^{-1}), Regular (dominance of chlorophytes (Chlorococcales) or total density > 5000 and < 10000 ind mL^{-1}; chlorophyll- *a* > 10 µg L^{-1}), Good (dominance of chlorophytes (Desmidaceae) or diatoms or total density > 1000 and < 5000 ind mL^{-1}; chlorophyll-*a* > 4 µg L^{-1} and < 10 µg L^{-1}) and Excellent (there is no dominance between the groups, total density < 1000 ind mL^{-1}; chlorophyll- *a* < 4 µg L^{-1}) (CETESB 2019).

The TSI classification for lotic environments was calculated according to Carlson (1977), modified by M.C. Lamparelli et al. (unpublished data), using chlorophyll and total phosphorus data, separated into classes: Ultraoligotrophic (≤ 47), Oligotrophic (47 < TSI ≤ 52), Mesotrophic (52 < ETI ≤ 59), Eutrophic (59 < ETI ≤ 63), Supereutrophic (63 < ETI ≤ 67) and Hypereutrophic (> 67).

Statistical analyses

The permutational multivariate analyses of variance (Two-way PERMANOVA) was performed using the Euclidean distance matrix to verify the temporal difference (months and seasonality) and between the tides (ebb and flood) of the physical and chemical parameters of the Guamá River. Two-way analysis of variance (Two-way ANOVA) was performed to verify the variations in density and concentrations of chlorophylls- *a*, *b*, and *c* throughout the seasonal period and tidal cycle. The data were transformed into square roots for all tests, and a significantly lower than 5% ($p< 0.05$) was considered. For these analyses, software PAST 4.06 was used (Hammer et al. 2001).

Principal Component Analyses: PCA was applied to verify the distribution pattern of the physical and chemical parameters collected during the period of study. Canonical Redundancy Analyses-RDA was performed to evaluate the relationship between phytoplankton and physical and chemical parameters, considering the abiotic data matrix and the matrix with the density of the most abundant species with the elimination of species with less than 5% abundance (Chorus & Bartram 1999), the biological matrix was transformed via Hellinger transformation (Legendre & Gallagher 2001), for ordering the Euclidean distance from the biological matrix. The abiotic matrices were standardized by ranging, and the PCA and RDA analyses were performed in the CANOCO 4.5 for Windows software (Ter Braak & Smilauer 2002).

RESULTS

Physical and chemical parameters

During the study period, the waters of the Guamá River were considered slightly acidic (6.3 ± 1.0), with an average temperature of 29.4 ± 1.5 °C, an average phosphorus concentration of 0.03 ± 0.039 $\mu g\ L^{-1}$, turbid waters (48.4 ± 41.3 NTU), with low salinity (0.02 ± 0.003 mg L^{-1}) and moderate values of EC (31.4 ± 14.7 mg L^{-1}) and TDS (17.0 ± 9.4 mg L^{-1}) (Table SI - Supplementary Material). There was a seasonal (PERMANOVA F= 4.3; df= 3; p= 0.0001) and monthly (PERMANOVA F= 2.3; df= 11; p= 0.0001) effect on the physical and chemical parameters of the Guamá River, with the distribution pattern of the factors concerning the months of study evidenced in the PCA.

In Axis 1 (PC1) (27.4%) grouped in the positive quadrant all samples from the dry months (July to November) and from the transition from dry to rainy season (December), while in the negative quadrant were grouped those from the rainy months (January to May) and transition from rainy to dry (June). The factors most influenced by seasonality were EC (0.40), TDS (0.50), DO (0.40), winds (0.34) being higher in the dry season, and the real color (-0.33) and rainfall (-0.31), in the rainy season.

In Axis 2 (PC2) (17.7%), the influence of seasonal variation was represented by rainfall (0.50), N-ammoniacal (0.53), and transparency (-0.42) (Figure 2). The effect of tides was observed on turbidity (F= 5.7; DF= 1; p= 0.02) and TSS (F= 8.8; DF= 1; p= 0.004), which were higher during the ebb tides (48 ± 40 NTU and 29.5 ± 19.0 mg L-1, respectively). Turbidity was above the limit allowed by environmental legislation (CONAMA 2005) in September (> 100 NTU).

Biotic variables

A total of 113 species distributed in 62 genera and eight divisions were recorded. The most representative divisions were Bacillariophyta (77 spp.), Cyanobacteria (10 spp.), and Chlorophyta (10 spp.). The minimum density was 2.83 ind mL^{-1} (March/2021, flood tide), and the maximum density was 110.7 ind mL^{-1} (December/2019, ebb tide). Significant variations in density occurred

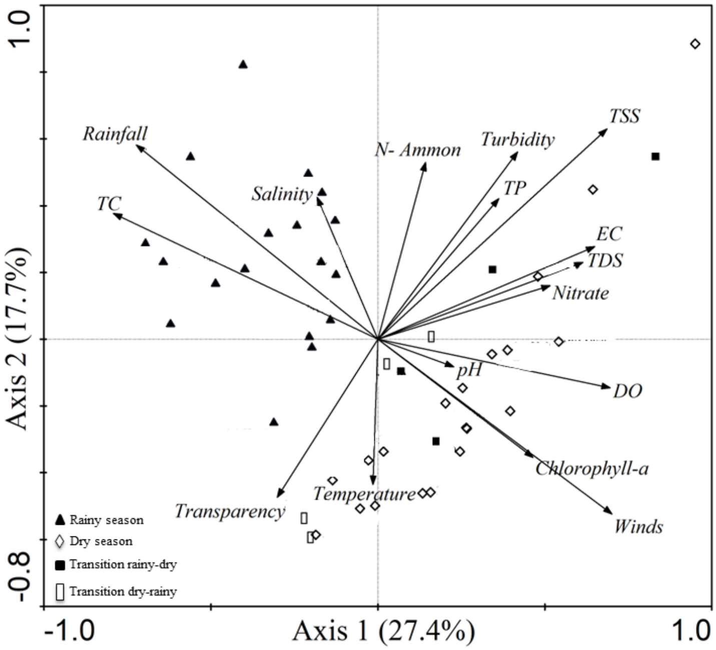


Figure 2. **Principal Component Analyses of the physical and chemical parameters of the Guamá River (Pará, Brazil). Legend: DO: Dissolved Oxygen; EC: Electrical Conductivity; N-Ammon: Ammoniacal Nitrogen; TC: True Color; TP: Total Phosphorus; TDS: Total Dissolved Solids; TSS: Total Suspended Solids.**

between months (F= 3.5; df= 11; p= 0.0006) March presented the lowest density (3.0 ± 0.8 ind mL^{-1}), September and December the highest densities with 61.1 ind mL^{-1} and 60.2 ind mL^{-1}, respectively. Chlorophyll- *a* concentration followed the variations in densities but was significantly ($p < 0.05$) higher in December (21.0 ± 4.7 µg L^{-1}), and the concentration of chlorophyll- *c* was higher than chlorophyll- *b*, indicating the dominance of diatoms with more than 80% during the entire study period (Figure 3).

Only 49 species were classified in 21 phytoplankton FG (Table SII), representing 43.4% of the identified species. There was no visualization of seasonality in the FG, as the P group dominated in all months (Figure 4); this FG groups the species of *Aulacoseira*, abundant throughout the study period.

The phytoplankton community índex: PCI allowed the classification of the water quality of the Guamá River, ranging from excellent (rainy months) to good (less rainy) in terms of environmental quality, during the two years of investigation. Evaluating the three criteria addressed, following considerations were made: low density, diatoms invariably dominate the environment, and the TSI ranges from ultraoligotrophic (March) to mesotrophic (September).

The RDA performed 19.4% of the species variation concerning physical and chemical parameters. Axis 1 (7.0%) showed N-ammoniacal (-0.57) as the main factor influencing part of the rainy and less rainy months, especially March, October, and December. It favored the non-specific group *Aulacoseira* spp., and *Actinocyclus normanii* (Gregory) Hustedt. Contrary to the species *Coscinodiscus rothii* (Ehrenberg) Grunow and *Polymyxus coronalis* L. W. Bailey that were in opposite influence to N- ammoniacal being dominant in the dry period and under the direct result of estuarine waters.

In axis 2 (8.3%), the estuarine influence was also present, where the species *Coscinodiscus* spp. were associated with high TSS (0.48), unlike the freshwater species *Thalassiosira oestrupii* (Ostenfeld) Hasle and *Scenedesmus* sp., which were associated with more transparent waters and higher true color in the months of June and May (Figure 5).

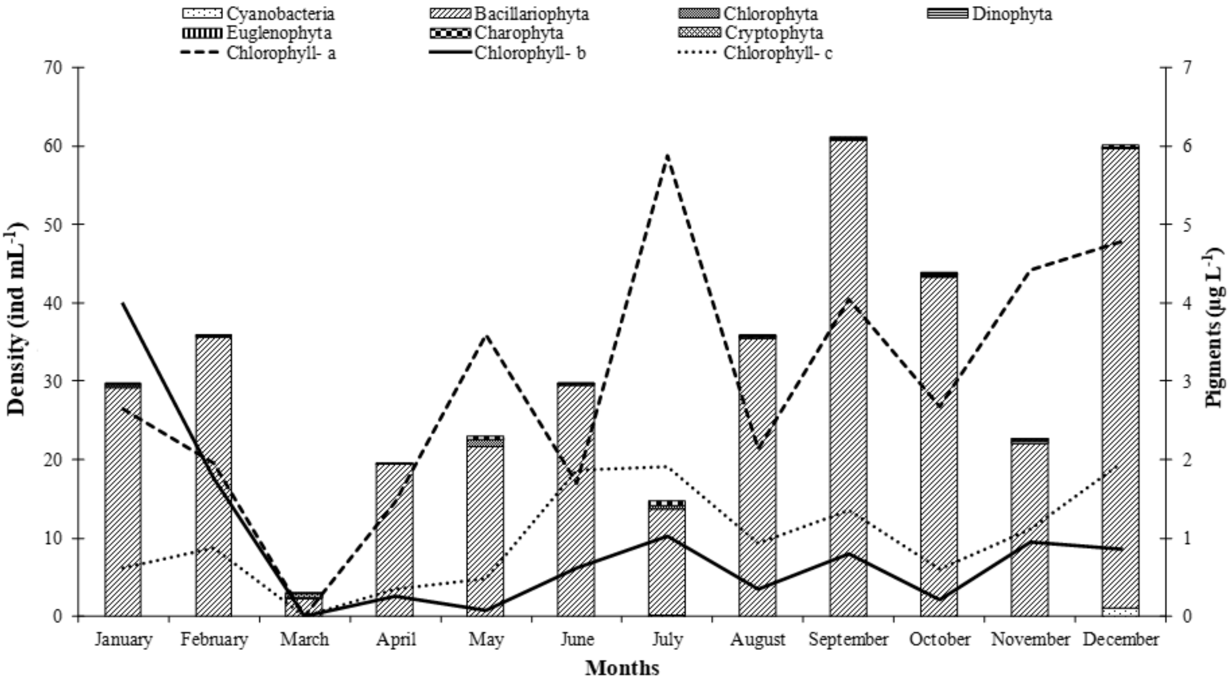


Figure 3. Temporal variation of density (ind mL^{-1}) and phytoplankton biomass (µg L^{-1}) of the Guamá River (Pará, Brazil).

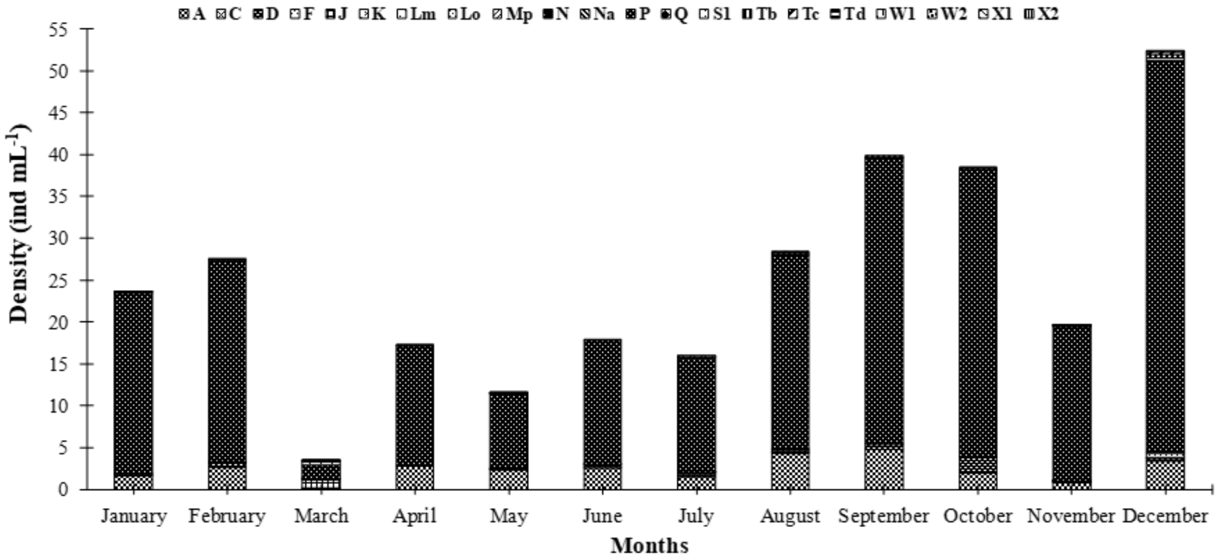


Figure 4. Temporal variation of the density of the Functional Groups-FG of the phytoplankton (ind mL^{-1}) of the Guamá River (Pará, Brazil).

DISCUSSION

The seasonal behavior of physical and chemical parameters evidenced that in the Axis 1 of PCA is characteristic of the Guamá River and was also observed by Paiva et al. (2006) and Alencar et al. (2019) in this river and by Gomes et al. (2021) in the Pará River which is connected to the study area. Rocha Neto et al. (2017), studying the

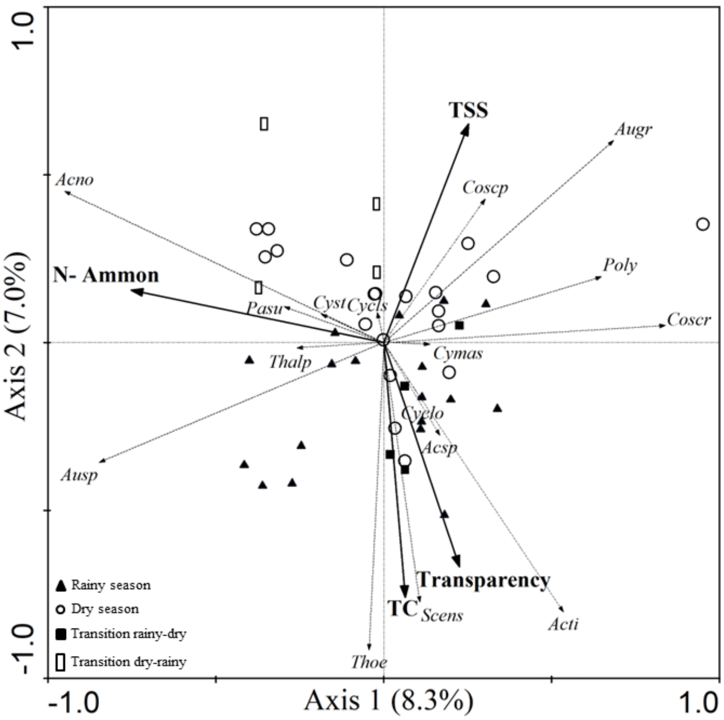


Figure 5. Redundancy Analyses (RDA) showing the temporal variation of the relationships between phytoplankton and physical and chemical parameters in the Guamá River (Pará, Brazil). Legend: Acno- *Actinocyclus normanii*, Acsp- *Actinoptychus splendens*., Acti- *Actinocyclus* sp., Ausp- *Aulacoseira* spp., Augr- *Aulacoseira granulata*, Coscr-*Coscinodiscus rothii*, Coscp- *Coscinodiscus* spp., Cyst-*Cyclotella striata*, Cyclo- *Cyclotella stylorum*, Cycls- *Cyclotella* sp., Cymas- *Cymatosira* sp., Pasu- *Paralia sulcata*, Poly- *Polymyxus coronalis*, Scens- *Scenedesmus* sp., Thalp-*Thalassiosira* spp., Thoe- *Thalassiosira oestrupii*; N-Ammon: Ammoniacal Nitrogen; TC: True Color; TSS: Total Suspended Solids.

Guamá River, did not identify a significant effect of seasonality on the physical and chemical parameters but cited the increase in salinity, EC, nitrate, and silicate during the less rainy months, coinciding with the present study.

Varela et al. (2020) also did not identify a significant effect of seasonality on the physical and chemical parameters of the Guamá River but showed higher pH, TSS, turbidity, and total phosphorus fluctuations in the less rainy months.

The presence of N- ammoniacal can be associated with natural sources of vegetal decomposition, since the river is bordered, but also, evidence the occurrence of anthropogenic influence in the river due to its association with the freshly dumped organic matter, usually containing nitrogenous excreta and industrial effluents (Souza Filho et al. 2020, Dey et al. 2021); however, its relationship with the intensity of rainfall is associated with the runoff provided by the rainy season, which contributes to the increase of this compound in water bodies. Although, the concentrations of N- ammoniacal did not exceed the limits tolerated by the legislation (CONAMA 2005).

Regarding the high turbidity and the TSS during the ebb tide, can be associated with the fact that the region does not have adequate sanitation coverage, where urban drainage channels, considered “open sewers” cross the entire city of Belém and that during the ebb tide are dumped in the Guajará Bay and Guamá River. Drainage channels have considerable concentrations of organic and inorganic pollutants (Cavalcante et al. 2007), contributing to greater turbidity and suspended solids concentrations.

The estuarine influence on the Guamá River comes from the Pará River estuary, which receives oceanic discharges that are stronger during the rainy season, leaving the waters with salinity ranging from 0.5 g kg to 1.6 g kg (Bezerra et al. 2011) such discharges are capable of entering the tributaries of this estuary, reaching up to 120 km from the mouth of this river to the city of Belém (R.P. Rosário et al. unpublished data, Rosário et al. 2009).

This oceanic influence also acts on the tidal regimes at the mouth of the Guamá River, which is reflected in the composition of phytoplankton species, since it is formed mainly by marine diatoms (Paiva et al. 2006), which predominate in estuarine environments (Moser et al. 2002, Paiva et al. 2006, Leão et al. 2008, Monteiro et al. 2009, Sousa et al. 2009, Vilhena et al. 2014, Reis et al. 2020, Cereja et al. 2021, Sá et al. 2022). Amazonian white-water rivers (Sioli & Klinge 1962) have low density, and diatoms are the leading phytoplankton group (Sousa et al. 2013).

In the aquatic environment, suspended particles of organic or inorganic material can attenuate the penetration of light. Diatoms have different pigment compositions from other phytoplankton groups because, in addition to chlorophyll- *a* they have chlorophyll- *c* and carotenoids such as *β*- carotene and fucoxanthins, which gives them more significant advantages over other algae in environments with less light incidence, since the accessory chlorophyll- *c* works mainly in the absorption of attenuated light (blue light). Furthermore, this type of light significantly impacts diatoms, producing more cells with higher photosynthetic activity than direct (white) sunlight (Kuczynska et al. 2015). Freshwater environments rich in N-ammoniacal, such as the Guamá River, confer advantages on diatoms since they act directly in the cycling of nitrogen compounds, which are essential for their growth and development (Allen et al. 2011).

The variation in phytoplankton density in the Guamá River followed a seasonal pattern, with the lowest values occurring in the rainier months. Several studies point to lower phytoplankton concentration in rivers (Paiva et al. 2006, Sousa et al. 2013, Rocha Neto et al. 2017, Wang et al. 2021) and reservoirs (Costa et al. 2010, Rodrigues et al. 2018) in the rainiest periods, since the interaction of rain and suspended solids in this period causes the attenuation of light in the aquatic environment (Sousa et al. 2020), and therefore, interferes with the development of phytoplanktonic organisms, since they are entirely dependent on the availability of light (Stumpner et al. 2020).

Despite the low inclusion in functional groups of the species found in Brazilian rivers, especially the Amazon ones, the functional groups in this study were relatively successful, as they encompassed the species with higher densities, which are classified in the P group, which grouped the genus *Aulacoseira*, establishing itself as a promising approach for the Guamá River, since all species sufficiently counted (Chorus & Bartram 1999) were included in the FG.

In addition, the number of functional groups found is consistent with other river studies (Wang et al. 2021). However, attention is drawn to a widespread species in the waters of the Guamá River, abundant from September to December, which was *Polymyxus coronalis*, but still does not have a classification into functional groups. In this case, further studies are suggested in the region to fit this species into FG.

In this criterion, the functional group P includes species that inhabit the eutrophic epilimnion that tolerates soft light and carbon-deficient water but are sensitive to stratification and silica depletion (Reynolds et al. 2002). Reflecting the main characteristics present in the Guamá River environment, such as, turbid waters and high silicate presence (Santos et al. 2014), essential for developing diatoms, which need this component to form their frustules.

Regarding the PCI, the strong presence of diatoms and the relatively low densities consider the Guamá River to be a good quality environment. In this context, when compared to other studies in Brazilian rivers, the phytoplankton density of the Guamá River is very low (Soares et al. 2007, Leão et al. 2008, Sousa et al. 2009, 2013), since the conditions present in the environment act as species selectors and influence the phytoplankton population dynamics.

The Guamá River has a very striking feature, its high turbidity, which directly interferes with the phytoplankton community, preventing species sensitive to low light from prevailing (Stumpner et al. 2020); in this way, diatoms can dominate this environment to tolerate the lowest light incidence (Reynolds et al. 2002, Kruk & Segura 2012). In addition, the estuarine influence also acts on the environmental composition since a large part of the composition is estuarine organisms (Paiva et al. 2006).

On the other hand, the dominance of diatoms does not always characterize the environment as good; for example, the most frequent species in the Guamá River, such as *Aulacoseira granulata* (Ehrenberg) Simonsen, wich despite being cosmopolitan occurs preferentially in eutrophicated environment (Bicudo et al. 2016, Wang et al. 2021), and in this way, the use of phytoplankton divisions in a generalized way by the PCI supposes a fragility of the index, since it does not take into account the specificities of the species or combined phytoplankton assemblages.

In this way, this approach becomes better usable in terms of detecting algal blooms that are generally known to be present in eutrophic environments, such as cyanobacteria (Oliver et al. 2020) and euglenophytes (Lopez et al. 2008), when used in the generalization of groups of diatoms and chlorophytes, analyses of the species present in the environment and their relationship with the trophic state is necessary.

Regarding the TSI, results contrary to studies performed in the region are described since Santos et al. (2014) and Varela et al. (2020) show the variation in the trophic state of the Guamá River, ranging from mesotrophic to supereutrophic. This is probably due to the sampling stations of these studies, which are closer to the city's drainage channels and dumped adjacent to Guajará Bay. In the present work, the water samples were collected close to the mouth of the Guamá River, with less influence on the sewage discharge the water body receives.

Analyzing the chemical variation of the most impacted drainage channels of the metropolitan region of Belém Cavalcante et al. (2007) concluded that, although these channels are polluted in the Guajarino estuary and Guamá River, these pollutants are dissipated due to the abundant rainfall and the semi-diurnal tidal dynamics. It is believed that this dissipation effect was felt at the collection point of the present study, hence the discrepant values when compared to other studies in the region. However, the increasing urbanization and waste production dumped in the watersheds can generate unmitigated harmful effects in the Amazon estuaries (Cavalcante et al. 2007).

The low percentage of explanation of the RDA was possibly due to the dominance of few species in the region from the estuarine waters of the Amazon River and Pará River that influence the Guamá River, mainly in the less rainy period, through the Estreito de Breves (Gregório & Mendes 2009). On the other hand, the most notable species are diatoms, which require considerable concentrations of silicate from the environment to form their frustules. However, this factor was not analyzed in the present study, leaving a suggestion for future investigations since, during the two years of study, these microalgae composed more than 80% of the entire composition in all months. Thus, possibly the association of *Coscinodiscus* spp. They occurred with the silica present in the TSS components, as verified in the RDA.

In this scenario, we understand that N-ammoniacal marks the anthropic influence on the Guamá River, as its presence suggests recent contamination by organic matter, probably domestic sewage, which drastically reduced the density in March, when N- ammoniacal occurred with the highest concentration (0.5 ± 0.1 mg L^{-1}) and low DO values (2.7 ± 1.4 mg L^{-1}), below the limit established by environmental legislation (CONAMA 2005), suggesting the presence of aerobic bacteria degrading organic matter. In this aspect, the DO was low (< 5.0 mg L^{-1}) throughout the rainy season.

Vilhena et al. (2014) found that 85% of the phytoplankton composition of the Pará and Mocajuba Rivers (Pará), near the Guamá River, constituted by diatoms and suggested that these algae are efficient in concentrating metals, mainly *A. granulata, P. coronalis* and *A. normanii*, in which high levels of Al, Fe, K, Ca and P were found, so it is suggested that future studies include these metals to verify the correlation with the abundance of these species.

CONCLUSION

The Guamá River phytoplankton presented seasonal dynamics mainly influenced by N- ammoniacal, transparency, and TSS. The Pará River influences the Guamá River's phytoplankton through the intrusion of estuarine waters and, with them, estuarine and marine diatom species. The use of Functional Groups proved to be a promising tool in the determination of water quality since it covered the most abundant species in the environment, recommending that there be more studies to insert the species *Polymyxus coronalis* among the functional groups, better to understand the role of this species in the environment of the Guamá River. The PCI classified the waters ranging from good to great, but it is inadequate to characterize Amazonian white-waters, which have diatoms as the leading dominant group.

Through the trophic índex (TSI) the waters of Guamá River can be classified as oligo to mesotrophic, corroborating the results observed in the PCI. It is suggested that future works include the analyses of silica and metals in the water to understand the dynamics of diatoms in Amazonian rivers.

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SUPPLEMENTARY MATERIAL

Tables SI-SII.

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