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Hydrologic cycle influence on desmid abundance in a shallow floodplain lagoon in the Brazilian semiarid region

Influência do ciclo hidrológico sobre a abundância de desmídias em uma lagoa rasa de planície de inundação do semiárido brasileiro

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Abstract: Aim: Knowledge of hydrological characteristics is essential for understanding ecological processes in floodplains, which can support sustainable management. We evaluated environmental variations in a shallow floodplain lagoon located in the Chapada Diamantina, Andaraí, Bahia. We aim to identify phases of the hydrologic cycle and their influence on desmid density, which is a group of algae known for its potential as bioindicator of trophic changes. **Methods:** Bimonthly samplings were performed at four points in the lagoon. Abiotic (temperature, conductivity, pH, transparency, depth, dissolved oxygen, total and dissolved nutrients) and biotic (macrophyte cover, phytoplankton chlorophyll-a, and desmid density) variables were determined. The Trophic State Index (TSI) was calculated based on phytoplankton chlorophyll-a, and total phosphorus concentration. **Results:** The lagoon was characterized by well-oxygenated, slightly acidic waters with low electrical conductivity. According to the TSI, the lagoon varied from mesotrophic to hypereutrophic during the study period. The driest months (August and October) were marked by high water transparency, low depth, nitrogen concentration, and macrophyte coverage. The highest value of accumulated precipitation was registered in December, when there was an increase in depth and a decrease in electrical conductivity and PT concentration. Two phases of the hydrologic cycle were evidenced and determined by the depth and nutrient concentrations. The highest abundance of desmids occurred at the end of the rainy season when the nutrient availability and pH were higher, and the depth was reduced. **Conclusions:** Our results suggest that the flood pulse was the determining factor of the local environmental conditions and that, together with the macrophyte morphological traits, it influenced desmid abundance and distribution in a floodplain lagoon in the semiarid region.

Keywords: caatinga; phases of hydrologic cycle; flood pulse; periphytic desmids.

Resumo: Objetivo: O conhecimento das características hidrológicas é essencial para a compreensão dos processos ecológicos nas planícies de inundação, o que pode subsidiar um gerenciamento sustentável. Nós avaliamos as variações ambientais em uma lagoa rasa de planície de inundação, localizada na Chapada Diamantina, Andaraí, Bahia. Nosso objetivo foi identificar as fases do ciclo hidrológico e sua influência na densidade de desmídias, um grupo de algas conhecido por seu potencial como bioindicador de mudanças tróficas. **Métodos:** Amostragens bimestrais foram realizadas em quatro pontos da lagoa. Foram determinadas as variáveis abióticas (temperatura, condutividade, pH, transparência, profundidade, oxigênio dissolvido, concentração de nutrientes totais e dissolvidos) e bióticas (cobertura de macrófitas, clorofila-a do fitoplâncton e densidade de desmídias). O Índice de Estado Trófico (IET) foi calculado com base na clorofila-a do fitoplâncton e concentração de fósforo total. **Resultados:** A lagoa foi caracterizada por águas bem oxigenadas, levemente ácidas e com baixa condutividade elétrica. De acordo com o IET, a lagoa variou de mesotrófica a hipereutrófica durante o período de estudo. Os meses mais secos (agosto e outubro) foram marcados pela elevada transparência, baixa profundidade, concentração de nitrogênio e cobertura de macrófitas. O maior valor de precipitação acumulada foi registrado em dezembro, quando houve um aumento da profundidade e a diminuição da condutividade elétrica e concentração de PT. Evidenciou-se ocorrência de duas fases limnológicas, as quais foram determinadas pela profundidade e concentração de nutrientes. A maior abundância de desmídias ocorreu no final da época chuvosa, quando a disponibilidade de nutrientes e pH eram elevados e a profundidade reduzida. **Conclusões:** Nossos resultados sugerem que o pulso hidrológico foi o fator determinante da condição limnológica e que, juntamente com as características morfológicas das macrófitas, tenha influenciado na abundância e distribuição das desmídias em uma lagoa de planície de inundação no semiárido.

Palavras-chave: caatinga; fases do ciclo hidrológico; pulso de inundação; desmídias perifíticas.

1 Introduction

Tropical floodplains are highly productive and dynamic ecosystems, where the flood pulse is considered the main regulatory force of ecological processes (Junk, 2002; Thomaz et al., 2007). The complex land-water interaction promotes high environmental heterogeneity, thereby creating different types of habitats (lakes, rivers, swamps, transition zones) that vary in their physical and limnological characteristics (Roberto et al., 2013; Junk et al., 2013). Such variations influence the structure and dynamics of aquatic communities, thereby affecting the composition, richness, density, and diversity of organisms (Dunk et al., 2016; Algarte et al., 2017; Adame et al., 2018).

Regarding primary producers, studies show that each algal community is associated with an equilibrium state in the ponds (Goldsborough & Robinson, 1996). For example, phytoplankton was dominant in the open state, and epiphyton in the open state in a subtropical lake of a floodplain (Cano et al., 2008). Thus, periphyton can play a role in floodplain ecosystem functioning, as demonstrated in the Florida Everglades (Gaiser et al., 2006; Gaiser, 2009) and Paraná River Basin (Algarte et al., 2016; Dunk et al., 2016). Periphyton participates in primary production, nutrient cycling, and the food web (Vadeboncoeur & Steinman, 2002). In periphyton, desmids form one of the most representative algal groups especially in tropical regions where the community has high species richness and abundance (Coesel, 1996; Rodrigues & Bicudo, 2001; Felisberto et al., 2014).

Most desmids have preference for slightly acidic and nutrient-poor environments (Coesel, 1996). The simple occurrence of these organisms in water can provide valuable information about the trophic state of the ecosystem, which is why they are often used in biomonitoring studies (Shetty & Gulimane, 2022; Garraza & Mataloni, 2019). From measurements of diversity and rarity of desmids species present in the community, it is also possible to determine the degree of conservation of the aquatic body (Krasznai et al., 2008; Hansen, et al. 2018) or the occurrence of disturbances (Neustupa et al., 2023). Experimental studies indicate that the group also has potential for bioremediation and is able to act in the extraction of trace elements present in aquatic environment (Krejci et al., 2011). In Brazil, studies on desmid diversity are still fragmented, which complicates the identification of temporal and spatial distribution patterns (Flora do Brasil, 2022). In the Caatinga domain, knowledge of desmids was restricted to data from Förster (1964), who carried out a taxonomic inventory of periphytic material with 116 taxa for Bahia, Piauí. However, an advance in the knowledge of the taxonomy and ecology of desmids in the lakes and rivers in Chapada Diamantina was observed (Ribeiro et al., 2015; Costa et al., 2018, 2020; Ramos et al., 2019, 2020, 2021 a, b, c). Currently, studies have revealed the high biodiversity of desmids in the region.

Thus, we investigated the occurrence of the hydrological period in a floodplain lagoon, aiming to answer the following question: Does the hydrological period influence the abundance of desmids? Considering the potential of desmids to indicate environmental changes (Coesel, 1983; Santos et al., 2022), this study contributes to a better understanding of changes in local environmental conditions, which can support the management and monitoring of the ecological quality of tropical floodplain lakes, particularly in the study area.

2 Material and Methods

2.1 Study area

The Baiano Lagoon is in the Pantanal dos Marimbus floodplain, situated in the Andaraí municipality, Chapada Diamantina, northeast Brazil (12°45'52.4" S, 41°18'34.5" W). Chapada Diamantina comprises the highest mountain complex in the Caatinga, which is a uniquely Brazilian biome. The climate of the Caatinga is marked by high temperatures and irregular rainfall, which is characteristic of the semi-arid environment (Giulietti et al., 1997; INEMA, 2020). Chapada Diamantina is composed of a landscape and altitudinal mosaic, including a variety of habitats, in which many new species of plants and algae have been discovered (Pataro et al., 2013; Ramos et al., 2019, 2021a).

The Pantanal dos Marimbus floodplain has an extension of approximately 48 km^2 and remains permanently flooded due to the inflow of water from the Santo Antônio River and its tributaries, the Utinga and São José Rivers (Funch, 2002; Gonçalves, 2021). The Marimbus floodplain is part of the Marimbus/Iraquara Environmental Protection Area (EPA) and is subdivided into the following four regions: Marimbus da Fazenda Velha, Marimbus do Ferreira, Marimbus do Remanso, and Marimbus do Baiano. The Marimbus region located to the south is formed by several interconnected lagoons, including the Baiano Lagoon. The lagoon has dark waters and large banks of aquatic macrophytes composed mainly of emergent, floating (fixed and free), and submerged plants (França et al., 2010). The Baiano lagoon has an area of approximately 0.41 km^2, a length of 974 m, and a width of 532 m. The average depth is approximately 2.5 m, and the maximum depth is 4.5 m. The region's climate varies from sub-humid to dry, with an average annual temperature and precipitation of 24.2°C and 1.049 mm, respectively (Proclima, 2021). The rainy season is from November to April, and the dry season is from May to October (Proclima, 2021).

The Pantanal dos Marimbus (Figure 1) floodplain has great ecological value but is under increasing human pressure due to various anthropological activities, including tourism, agriculture, and deforestation. Despite the intense human activities, knowledge about the functioning of the floodplain lagoons is still poorly understood (Lima et al., 2018; Gonçalves, 2021).

2.2 Sampling and analyzed variables

Bimonthly samplings were carried out at the four points randomly selected in the Baiano Lagoon totaling 24 samplings throughout 2018. The distance between each sampling station was approximately 200 m. Sampling sites include the most abundant macrophytes in the lagoon: *Cabomba caroliniana* Gray, submerged, rooted, with cut leaves; *Nymphaea amazonum* Mart. et Zucc., rooted with whole and floating leaves; and *Utricularia foliosa* L., free-floating with cut leaves. Periphyton was sampled in the three macrophyte species above mentioned.

For periphyton sampling, 30 cm long fragments of each macrophyte species were removed (including stems, petioles, and leaves) and randomly selected. Only macrophytes at an intermediate stage of maturation were sampled, thus, minimizing problems related to colonization time (Santos et al., 2013). Macrophyte fragments were transported to the laboratory at low temperatures and in the absence of light. In the laboratory, the periphyton was removed from the fragments of macrophyte by scraping using a brush and jets of distilled water. The total area of each fragment was determined using the ImageJ software to identify the total size area colonized by periphyton.

After scraping, the samples were adjusted to a constant volume with distilled water. Aliquots were taken for taxonomic and quantitative analysis. Samples for taxonomic analysis were fixed in Transeau's solution (Bicudo & Menezes, 2017) and observed under a binocular optical microscope (Olympus BX45). Quantitative samples were fixed in 0.5% Lugol solution, and counting was performed under an inverted microscope (Leica MIC5256) according to Utermöhl (1958), while respecting the settling time determined by Lund et al. (1958). The count limit was established by the species rarefaction curve and counting of 10 random fields without taxonomic novelties. At each sampling site, macrophyte coverage was

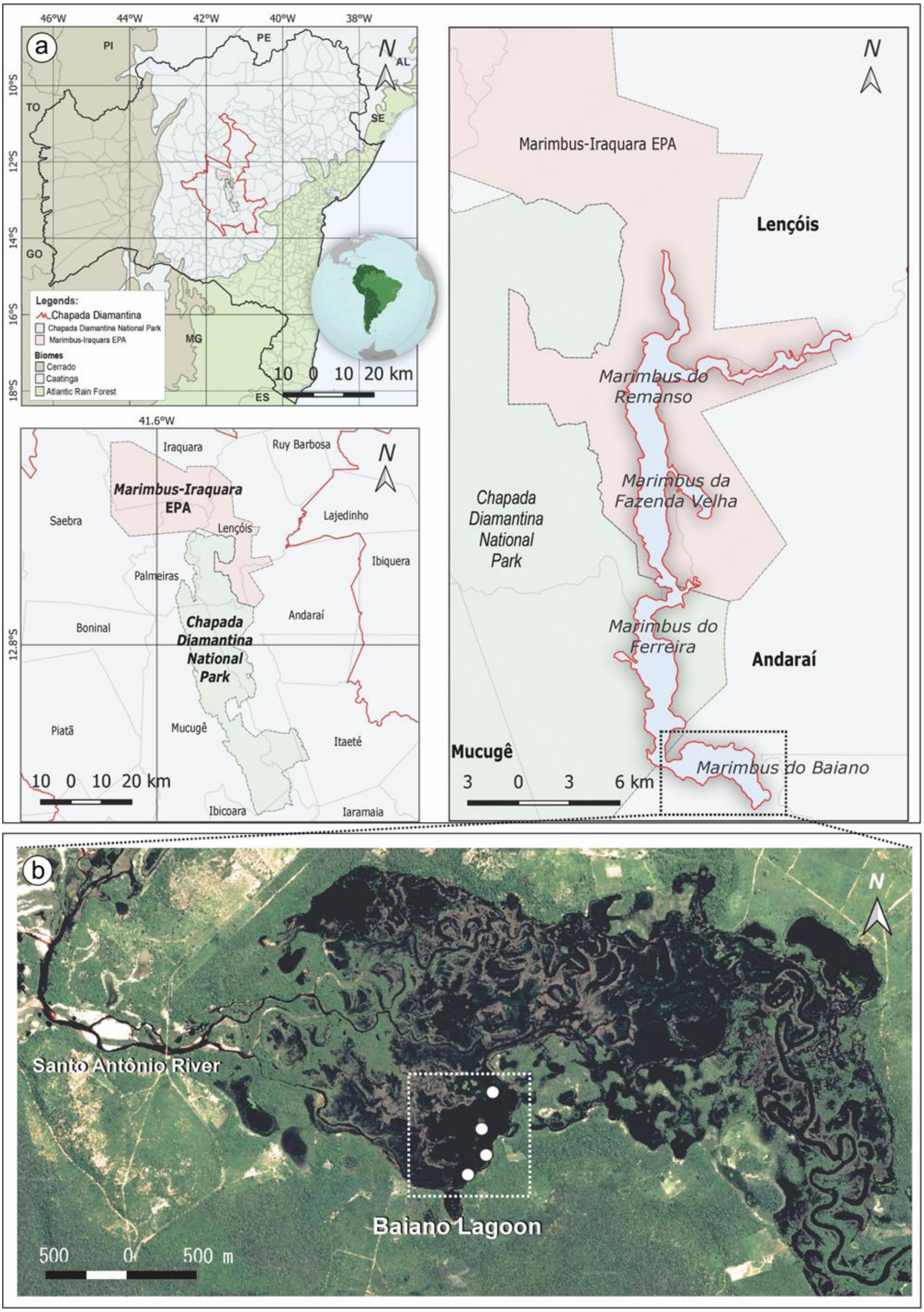

Figure 1. Map showing Andaraí municipality and Pantanal dos Marimbus (a), Bahia State, and sampling sites (white circles) in the Baiano Lagoon (dotted line), Marimbus do Baiano.

determined using a PVC square (1 m^2) divided into 100 smaller squares (Thomaz et al., 2004).

Accumulated precipitation and air temperature data were obtained from the Center for Weather Forecasting and Climate Studies of the National Institute for Space Research (CPTEC/INPE, 2021). Portable multiparameter probes were used to measure water temperature, pH, electrical conductivity, total suspended solids (Hanna - HI 98129), and dissolved oxygen (Instrutherm - MO-910). Water transparency was measured using a Secchi disk. The concentrations of ammonium (NH_4-N, phenolic method), nitrite (NO_2-N, diazotization method), nitrate (NO_3-N, cadmium reduction method), orthophosphate (PO_4-P, ascorbic acid method), orthosilicate (colorimetric method), total nitrogen (TN), dissolved inorganic nitrogen (DIN), and total phosphorus (TP) were determined according to APHA (2005). At each sampling point, we collected 500 ml of surface water for determination of phytoplankton chlorophyll-a. The algal community sampled in surface water was designated phytoplankton due to the absence of metaphyton among macrophytes. The analysis was carried out from samples filtered under low pressure (≤ 0.3 atm), using GF/F Whatman glass fiber filters and 90% ethanol as extractor (Marker et al., 1980; Sartory & Grobbelaar, 1984).

The Trophic State Index (TSI) of the lagoon was calculated based on phytoplankton chlorophyll-a and TP concentration as proposed by Lamparelli (2004) for tropical reservoirs.

Descriptors species were those with a contribution ≥ 10% to the total density in the periphyton of each macrophyte species.

2.3 Statistical analysis

We used the Moran Index to verify the existence of spatial autocorrelation between the sample units (Legendre & Legendre, 2012).

For joint evaluation of the abiotic data, we applied Principal Component Analysis (PCA), which reduces the dimensionality of the data. Abiotic data were logarithmized [log (x + 1)], except for pH. The axes that make up the graph were selected based on the Broken Stick criteria (Legendre & Legendre, 2012).

The permutational multivariate analysis of variance (Two-way PERMANOVA; α= 0.05) was used to evaluate the influence of time (months) and macrophyte species (*Cabomba caroliniana, Nymphaea amazonum,* and *Utricularia foliosa*) on the desmid community structure in the periphyton. This analysis was performed using Bray–Curtis similarity and 9999 permutations. All statistical analyzes were performed using the R software (R Development Core Team, 2021).

3. Results

The highest values of accumulated precipitation were registered in February, June and December (Figure 2). Low precipitation values were detected in August, and October (< 2.0 mm).

Local environmental conditions in Baiano Lagoon varied during the study period (Figure 3 a-l). However, the lagoon presented well-oxygenated waters (> 5.4 mg L), slightly acidic (5.1–8.5) and with low conductivity (< 0.007 µS.cm^{-1}). In June and December, the local environmental conditions were characterized by the greatest depths (2.4–4.5 m), lowest transparency (< 0.7 m), and concentrations of PO_4-P (< 14 µg L^{-1}) and orthosilicate (< 0.20 mg L^{-1}). In contrast, high transparency (> 0.7 m) and low depth (< 2.5 m) were found in August and October, when the highest orthosilicate concentrations also occurred. The highest phytoplankton chlorophyll-a occurred in February, August, and October (> 11 µg L^{-1}).

Based on the average TSI, we found a variation in the trophic state of the lagoon during the study period (Figure 4). The lowest TSI was observed in December when the lagoon was mesotrophic. In other months, the lagoon was considered eutrophic, except in February when it was hypereutrophic.

The PCA of environmental variables summarized 63.5% of the data variability in the first two axes (Figure 5). On the positive side of axis 1, sampling units from the wettest months (except April) were associated with greater depths (Pearson: r > 0.95). On the negative side of the same axis, the sampling units of the driest months (except Oc2 and Oc4) were associated with the highest values of

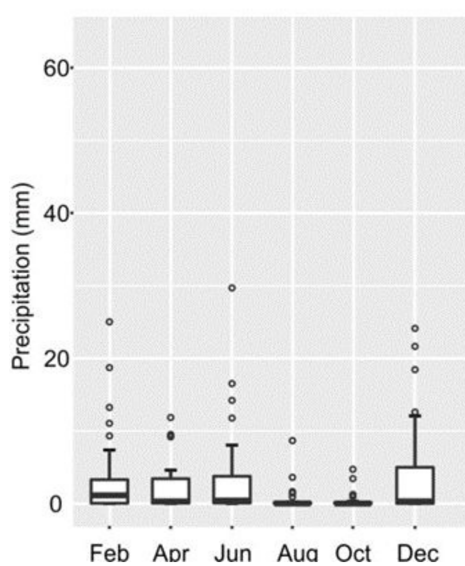

Figure 2. Mean and standard deviation of accumulated precipitation in the sampled monthly during the study period.

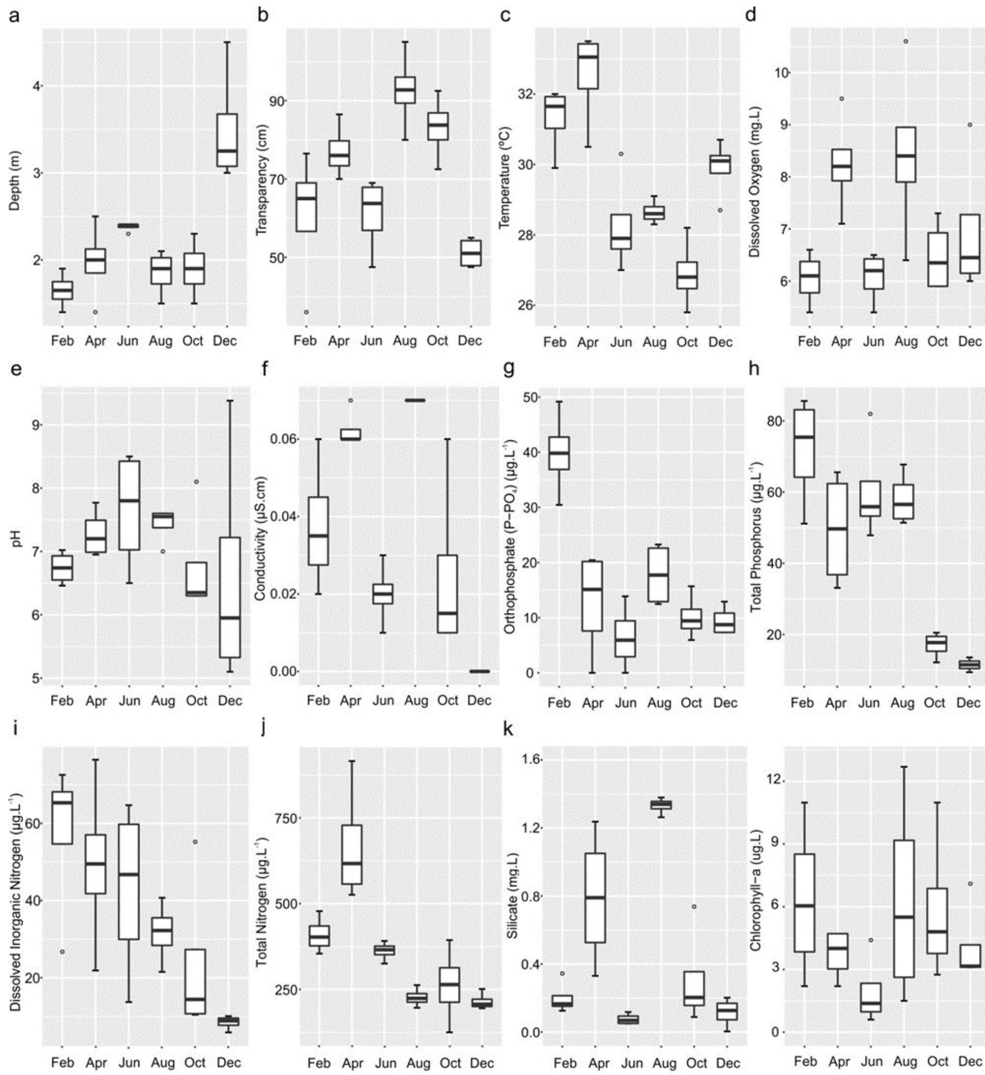

Figure 3. Median and standard error (n = 4) of environmental variables in a floodplain lagoon during the study period. a- Depth (m), b- Transparency (cm), c- Temperature (ºC), d- Dissolved Oxygen (mg.L), e- pH, f- Conductivity (µS.cm), g- Orthophosphate (P-PO_4) (µg.L^{-1}), h- Total Phosphorus (µg.L^{-1}), i- Dissolved Inorganic Nitrogen (µg.L^{-1}), j- Total Nitrogen (µg.L^{-1}), k- Silicate (mg.L), l- Chlorophyll-a (µg.L).

electrical conductivity, orthosilicate, and water transparency (Pearson: r > 0.9). Axis 2 showed a negative correlation with orthophosphate (Pearson: r > 0.9) and a positive correlation with dissolved oxygen (Pearson: r > 0.8). Based on the PCA, two phases of the hydrologic cycle were evidenced and were associated with depth variation and nutrient availability.

The highest macrophyte coverage was found in April and the lowest was in December (Figure 6).

Despite differences in temporal variation, the highest desmid density in periphyton on *Nymphaea amazonum* and *Utricularia foliosa* was found in April, and the lowest in December (Figure 7a, c). However, desmid density on *Cabomba caroliniana* was high in April and October and the lowest in August and December (Figure 7b).

The Desmid community structure was significantly influenced by time and macrophyte species, with significant interaction between the factors (Two-way PERMANOVA: time: F = 2.19, p = 0.0001; macrophyte species: F = 5.34, p = 0.001; interaction: F = 1.48, p = 0.0003).

Only six species had, on average, a relative density ≥10% on *Nymphaea amazonum*, with emphasis on *Cosmarium margaritatum* var. *margaritatum*, which was present in all months sampled. The descriptor species contributed more than 50% of the total density in August and October on periphyton of *Utricularia foliosa* and *Cabomba*

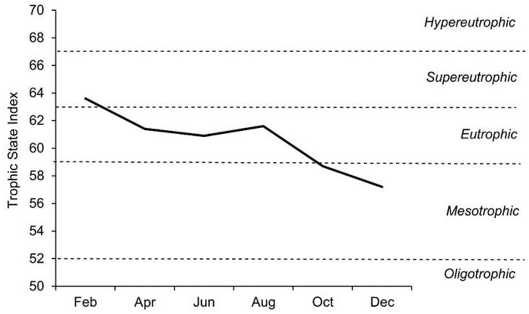

Figure 4. Trophic state index (TSI) in a floodplain lagoon during the study period.

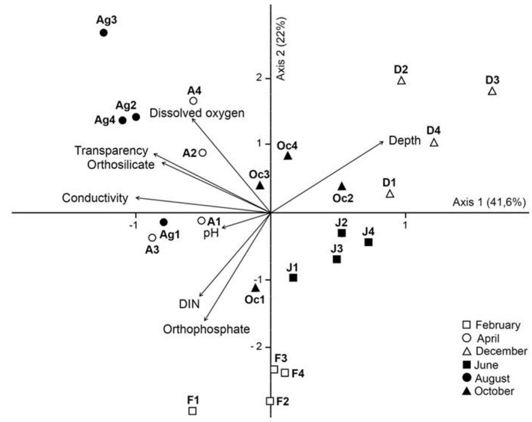

Figure 5. PCA of the limnological variables analyzed in a floodplain lagoon during the study period. Sampling unit abbreviations: the first letter indicates the sampling month, and the number indicates the sampling site (1, 2, 3, 4).

caroliniana, with emphasis on *Cosmarium blyttii* var. *blyttii*, which had a high frequency of occurrence. In *U. foliosa*, *Cosmarium subreinschii* var. *tholiforme* and *Staurastrum tetracerum* var. *tetracerum* also had a high frequency of occurrence, the latter standing out for its high density, especially in the months of October and August (Figure 8).

4. Discussion

Our findings showed the occurrence of two phases of the hydrologic cycle in a shallow floodplain lagoon in the semiarid region. The variation in depth and nutrient availability were determinants of the limnonological phases. The high-water period, characterized by high rainfall, was marked by an increase in depth and nutrient concentrations (except in December), and a decrease in water transparency and phytoplankton biomass. The flood pulse is one of the main determinants of local environmental conditions and dynamics of aquatic communities in floodplain lakes (Junk, 2002, 2005). Floods caused by increased precipitation or flooding of rivers increase lake depths and promote sediment resuspension, thereby increasing turbidity, conductivity, and nutrient concentration (Junk, 2005, 2002; Mayora et al., 2013), as noted in the Baiano Lagoon. However, when the main river is poor in nutrients, the increase in the water volume caused by flooding can have a reverse effect and consequently dilute dissolved nutrients (Junk, 2005; Depetris, 2007; Bozelli et al., 2015). This may explain the decrease in the PO_4-P and DIN concentrations in June and December, respectively. Together, the increase in water turbidity and the change in the nutrient concentrations may have negatively influenced the phytoplankton community, which, in the period, presented the lowest averages of chlorophyll-a during the study period. Changes in environmental conditions influenced the structure of the desmid community on different macrophyte species in the studied lake.

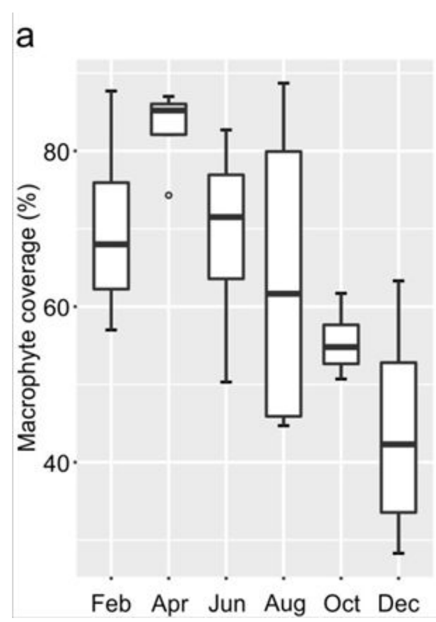

Figure 6. Mean values and standard deviation of macrophyte coverage (n = 4) in a floodplain lagoon during the study period.

Communities of aquatic macrophytes generally form large stands in shallow lakes of floodplains, thereby promoting increased habitat heterogeneity that is recognized as one of the main drivers of biodiversity (McAbendroth et al., 2005; Algarte et al., 2009). Studies show that the increase in macrophyte cover can favor (Zhang et al.,

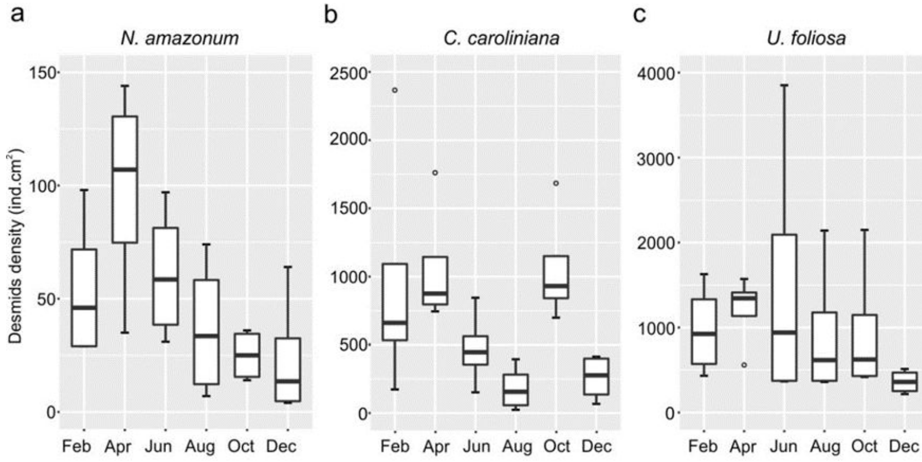

Figure 7. Mean values and standard deviation of desmid density in the periphyton on: a- *Nymphaea amazonum*, b- *Cabomba caroliniana*, and c- *Utricularia foliosa*, in a floodplain lagoon during the study period.

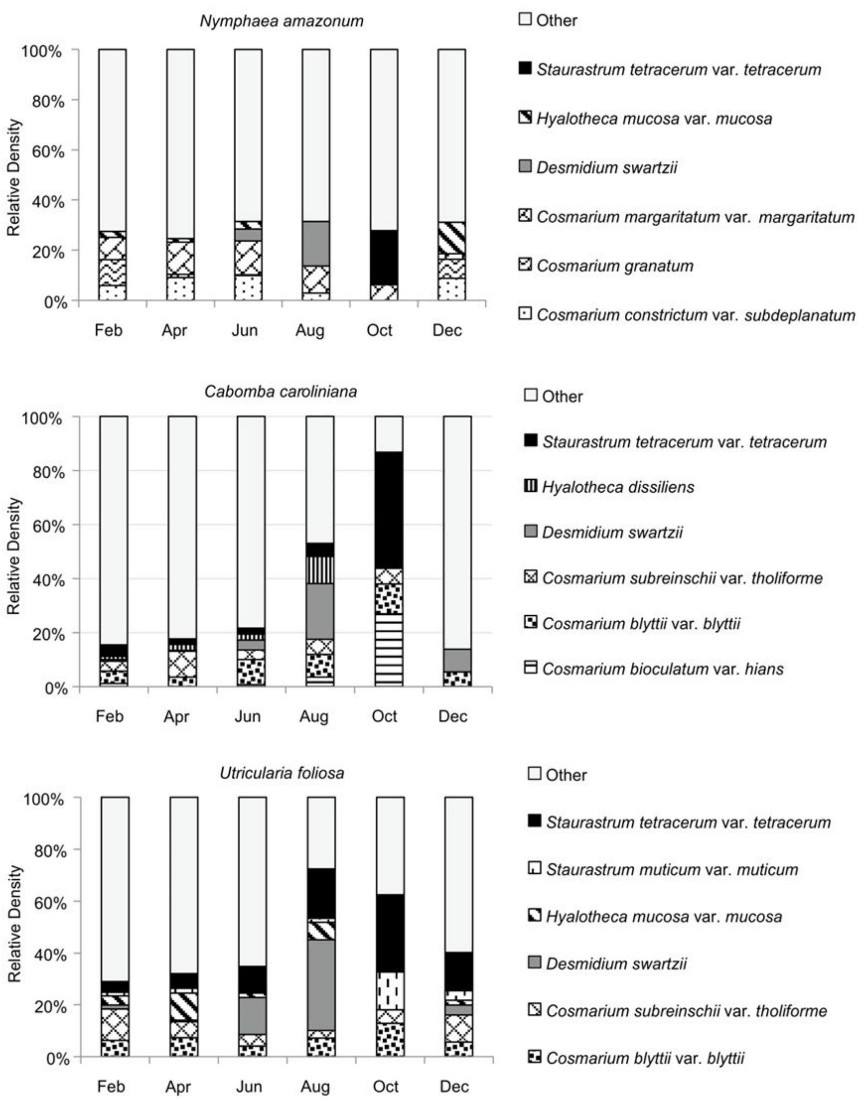

Figure 8. Desmid species with a contribution of more than 10% to total density in the periphyton on: a- *Nymphaea amazonum*, b- *Cabomba caroliniana*, and c- *Utricularia foliosa*, in a floodplain lagoon during the study period.

2020) or harm (Souza et al., 2015) the density of periphytic algae. This is because these plants can either provide an area for colonization and nutrients for the associated periphyton or compete with it for resources, such as nutrients and light (van Gerven et al., 2015). The higher macrophyte coverage in the rainy months favored the growth of desmids (except in December) probably by increasing the area available for colonization. In the same period, the increase in N concentration (except in December) may have been a crucial factor for the increase in algal biomass. N and P are generally the limiting macronutrients for algal growth (Esteves & Amado, 2011). In December, the dilution of nutrients, decrease in macrophyte cover, increase in depth, and decrease in water transparency was associated with a drastic reduction in the desmid density.

Considering the entire study period, we observed that the desmid density in Baiano Lagoon was high, especially when compared to other studies carried out in floodplain lakes in Brazil (Lopes & Bicudo, 2003; Camargo et al., 2009). Climatic and limnological characteristics may have favored the desmid growth, such as high temperatures and slightly acidic pH, which can promote the diversity group (Coesel, 1996). In floodplain lakes, studies report lower pH values, mainly due to the entry of humic compounds that tend to increase the acidity of the water (Carvalho et al., 2001).

The time (collection month), the macrophyte species, and the interaction between the two factors influenced the structure of the periphytic desmids. The variation in the physical and chemical characteristics of water over a given period directly affects on periphytic algae community (Neif et al., 2013; Carapunarla et al., 2014), especially in floodplains, where the flood pulse is considered a key factor in the structure and dynamics of aquatic communities (Loverde-Oliveira & Huszar, 2007; Junk & Wantzen, 2004).

The density of desmids and distribution of descriptor species were similar in *Cabomba caroliniana* and *Utricularia foliosa*, both highly indented macrophytes, unlike *Nymphaea amazonum*, a macrophyte with simple morphology. Studies show that morphologically complex or cut substrates tend to have a greater biomass and diversity of periphytic algae (Ferreiro et al., 2013; Casartelli & Ferragut, 2017; NemesKókai et al., 2024), because they increase the availability of microhabitats for the associated community (Pacini et al., 2009). The complexity of the substrate also influences the distribution of species in the periphyton, as complex substrates tend to accommodate species of reduced size, such as *Cosmarium blyttii* var. *blyttii*, *C. subreinschii* var. *tholiforme*, and *Staurastrum tetracerum* var. *tetracerum*.

Our findings suggest that the flood pulse was the determining factor of local environmental conditions and that, together with the macrophyte morphological traits, it influenced desmid abundance and distribution during the study period. The flood pulse is a known determining factor for floodplain lagoons (e.g., Algarte et al., 2006; Leandrini et al., 2008). Knowledge of hydrological characteristics is essential for a better understanding of ecological processes in floodplains and for supporting sustainable management (Junk, 2002; Junk & Wantzen, 2004). Thus, more studies are needed to investigate and explore different hydrological aspects and support the development of management plans for biodiversity conservation in Chapada Diamantina.

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References

Adame, K.L., Dunck, B., & Rodrigues, L., 2018. Community in lentic environments of the Upper Paraná River floodplain: seasonal and spatial variation. Acta Limnol. Bras. 30, e205. http://doi.org/10.1590/s2179-975x5017.

Algarte, V.M., Dunck, B., Leandrini, J.A., & Rodrigues, L., 2016. Periphytic diatom ecological guilds in floodplain: ten years after dam. Ecol. Indic. 69, 407-414. http://doi.org/10.1016/j.ecolind.2016.04.049.

Algarte, V.M., Moresco, C., & Rodrigues, L., 2006. Algas do perifíton de distintos ambientes na planície de inundação do alto rio Paraná. Acta Sci. Biol. Sci. 28(3), 243-251.

Algarte, V.M., Siqueira, N.S., Murakami, E.A., & Rodrigues, L., 2009. Effects of hydrological regime and connectivity on the interanual variation in taxonomic similarity of periphytic algae. Braz. J. Biol.

69(2, Suppl.), 609-616. PMid:19738967. http://doi.org/10.1590/S1519-69842009000300015.

Algarte, V.M., Siqueira, N.S., Ruwer, D.T., Osório, N.C., & Rodrigues, L., 2017. Riqueza de algas perifíticas e sua relação com atributos hidrológicos. Braz. J. Bot. 40, 735-740. http://doi.org/10.1007/s40415-017-0383-2.

American Public Health Association – APHA, 2005. Standard Methods for the Examination of Water and Wastewater. Washington: American Public Health Association, American Water Works Association, Water Environment Federation.

Bicudo, C.E.M., & Menezes, M., 2017. Gêneros de algas de águas continentais do Brasil: chave para identificação e descrições. São Carlos: Rima.

Bozelli, R.L., Thomaz, S.M., Padial, A.A., Lopes, P.M., & Bini, L.M., 2015. Floods decrease zooplankton beta diversity and environmental heterogeneity in an Amazonian floodplain system. Hydrobiologia 753(1), 233-241. http://doi.org/10.1007/s10750-015-2209-1.

Camargo, J.C., Loverde-Oliveira, S.M., Sophia, M.G., & Nogueira, F.M.B., 2009. Desmídias perifíticas da baía do Coqueiro, Pantanal Matogrossense – Brasil. Iheringia 64(2), 25-41.

Cano, M.G., Casco, M.A., Solari, L.C., MacDonagh, M.E., Gabellone, N.A., & Claps, M.C., 2008. Implications of rapid changes in chlorophyll-a of plankton, epipelon, and epiphyton in a Pampean shallow lake: an interpretation in terms of a conceptual model. Hydrobiologia 614(1), 33-45. http://doi.org/10.1007/s10750-008-9534-6.

Carapunarla, L., Baumgartner, D., & Rodrigues, L., 2014. Community structure of periphytic algae in a floodplain lake: a longterm study. Acta Sci. Biol. Sci. 36(2), 147-154. http://doi.org/10.4025/actascibiolsci.v36i2.19560.

Carvalho, P., Bini, L.M., Thomaz, S.M., Oliveira, L.G., Robertson, B., Tavechio, W.L.G., & Darwisch, A.J., 2001. Comparative limnology of South American floodplain lakes and lagoons. Acta Scientiarum 23(2), 265-273.

Casartelli, M., & Ferragut, C., 2017. The effects of habitat complexity on periphyton biomass accumulation and taxonomic structure during colonization. Hydrobiologia 807(1), 233-246. http://doi.org/10.1007/s10750-017-3396-8.

Coesel, P.F., 1983. The significance of desmids as indicators of the trophic status of freshwaters. Schweiz. Zeitsch. Hydrobiol. 45, 388-393.

Coesel, P.F.M., 1996. Biogeography of desmids. Hydrobiologia 336(1-3), 41-53. http://doi.org/10.1007/BF00010818.

Costa, F.M., Ramos, G.J.P., Oliveira, I.B., Bicudo, C.E.M., & Moura, C.W.N., 2018. Five new taxa and a new record of *Euastrum* (Desmidiaceae) from the Chapada Diamantina region, Bahia State, Brazil. Phytotaxa 372(3), 193-202. http://doi.org/10.11646/phytotaxa.372.3.2.

Costa, F.M., Ramos, G.J.P., Oliveira, I.B., Bicudo, C.E.M., & Moura, C.W.N., 2020. Notes on the genus *Euastrum* (Desmidiaceae) in Brazil, with description of a new species. Phytotaxa 451(1), 34-44. http://doi.org/10.11646/phytotaxa.451.1.3.

Centro de Previsão de Tempo e Estudos Climáticos/Instituto Nacional de Pesquisas Espaciais – CPTEC/INPE, 2021. Retrieved in 2021, January 20, from http://tempo.cptec.inpe.br/cidades/estendida/470.

Depetris, P.J., 2007. The Parana river under extreme flooding: a hydrological and hydro-geochemical insight. Interciencia 32(10), 656-662.

Dunk, B., Algarte, V.M., Cianciaruso, M.V., & Rodrigues, L., 2016. Functional diversity and trait–environment relationships of periphytic algae in subtropical floodplain lakes. Ecol. Indic. 67, 257-266. http://doi.org/10.1016/j.ecolind.2016.02.060.

Esteves, F.A., & Amado, A.M., 2011. Ciclo do Nitrogênio. In: Esteves, F.A., ed. Fundamentos de limnologia. Rio de Janeiro: Interciência, 239-258, 3 ed.

Felisberto, S.A., Rodrigues, L., & Santos, H.S., 2014. Taxonomical and ecological characteristics of the desmids placoderms in reservoir: analyzing the spatial and temporal distribution. Acta Limnol. Bras. 26(4), 392-403. http://doi.org/10.1590/S2179-975X2014000400007.

Ferreiro, N., Giorgi, A., & Feijoó, C., 2013. Effects of macrophyte architecture and leaf shape complexity on structural parameters of the epiphytic algal community in a Pampean stream. Aquat. Ecol. 47(4), 389-401. http://doi.org/10.1007/s10452-013-9452-1.

Flora do Brasil, 2022. Zygnematophyceae in Flora do Brasil. Rio de Janeiro: Jardim Botânico do Rio de Janeiro. Retrieved in 2022, January 27, from http://floradobrasil.jbrj.gov.br/reflora/floradobrasil/FB119508.

Förster, K., 1964. Desmidiaceen aus Brasilien, 2: Bahia, Goyaz, Piauhy und Nord Brasilien. Hydrobiologia 23, 321-505. http://doi.org/10.1007/BF00179497.

França, F., Melo, E., Oliveira, I.B., Reis, A.T.C.C., Alves, G.L., & Costa, M.F., 2010. Plantas vasculares das áreas alagadas dos Marimbus, Chapada Diamantina, BA, Brasil. Hoehnea 37(4), 719-730. http://doi.org/10.1590/S2236-89062010000400003.

Funch, R., 2002. Um guia para a chapada Diamantina. Cruz da Almas: Nova Civilização.

Gaiser, E.E., 2009. Periphyton as an indicator of restoration in the Florida Everglades. Ecol. Indic. 9(6), S37-S45. http://doi.org/10.1016/j.ecolind.2008.08.004.

Gaiser, E.E., Childers, D.L., Jones, R.D., Richards, J.F., Scinto, L.J., & Trexler, J.C., 2006. Periphyton responses to eutrophication in the florida everglades: cross-system patterns of structural and compositional change. Limnol. Oceanogr. 51(1), 617-630. http://doi.org/10.4319/lo.2006.51.1_part_2.0617.

Garraza, G.G., Mataloni, G., & Burdam, L., 2019. Desmids (Zygnematophyceae, Streptophyta) community drivers and potential as a monitoring tool in South American peat bogs. Hydrobiologia 833(1), 125-141. http://doi.org/10.1007/s10750-019-3895-x.

Giulietti, A.M., Pirani, J.R., & Harley, R.M., 1997. Espinhaço Range region, eastern Brazil. In: Davis, S.D., Heywood, V.H., Herrera-MacBryde, O., Villa-Lobos, J. & Hamilton, A.C., eds. Centres of plant diversity: a guide and strategy for their conservation. Oxford: Information Press, 397-404, 3 ed.

Goldsborough, L.G., & Robinson, G.G.C., 1996. Pattern in wetlands. In: Stevenson, R.J., Bothwell, M.L. & Lowe, R.L., eds. Algal ecology: freshwater benthic ecosystems. San Diego: Academic, 77–117. http://doi.org/10.1016/B978-012668450-6/50033-3.

Gonçalves, C.N., 2021. Variações na Vazão do Rio Santo Antônio, Relação com o Pantanal Marimbus e a Importância para a Biodiversidade na Região do Parque Nacional da Chapada Diamantina/BA. Biodiv. Bras. 11(4), 21-45. http://doi.org/10.37002/biobrasil.v11i4.1782.

Hansen, G., Stasny, J., Moestrup, O., & Lundholm, N., 2018. Diversity and conservation of desmids in Bornholm, Denmark – revisiting after 130 years. Nord. J. Bot. 36(10), e01994. http://doi.org/10.1111/njb.01994.

Instituto do Meio Ambiente e Recursos Hídricos – INEMA, 2020. APA Marimbus/Iraquara. Retrieved in 2020, May 20, from http://www.inema.ba.gov.br/gestao-2/unidades-de-conservacao/apa/apa-marimbus-iraquara/.

Junk, W.J., & Wantzen, K.M., 2004. The flood pulse concept: new aspects, approaches and applications - an update. In: Welcomme, R.L. & Petr, T., eds. Proceedings of the II International Symposium on the Management of Large Rivers for Fisheries. Bangkok: Food and Agriculture Organization and Mekong River Commission, FAO Regional Office for Asia and the Pacific, 117-149.

Junk, W.J., 2002. Long-term environmental trends and the future of tropical wetlands. Environ. Conserv. 29(4), 414-435. http://doi.org/10.1017/S0376892902000310.

Junk, W.J., 2005. Flood pulsing and the linkages between terrestrial, aquatic, and wetland systems. SIL Proc. 29(1), 11-38. https://doi.org/10.1080/03680770.2005.1190197.

Junk, W.J., Piedade, M.T.F., Lourival, R., Wittmann, F., Kandus, P., Lacerda, L.D., Bozelli, R.L., Esteves, F.A., Nunes da Cunha, C., Maltchik, L., Schöngart, J., Schaeffer-Novelli, Y., & Agostinho, A.A., 2013. Brazilian wetlands: their definition, delineation, and classification for research, sustainable management, and protection. Aquat. Conserv. 24(1), 5-22. http://doi.org/10.1002/aqc.2386.

Krasznai, E., Fehér, G., Borics, G., Varbiro, G., Grigorszky, I., & Tóthmérész, B., 2008. Use of desmids to assess the natural conservation value of a Hungarian oxbow (Malom-Tisza, NE-Hungary). Biologia (Bratisl.) 63(6), 928-935. http://doi.org/10.2478/s11756-008-0144-6.

Krejci, M.R., Finney, L., Vogt, S., & Joester, D., 2011. Selective sequestration of strontium in desmid green algae by biogenic Co-precipitation with barite. ChemSusChem 4(4), 470-473. PMid:21488170. http://doi.org/10.1002/cssc.201000448.

Lamparelli, M.C., 2004. Graus de trofia em corpos d'água do Estado de São Paulo: avaliação dos métodos de monitoramento. [Tese de doutorado em Ciências na Área de Ecossistemas Terrestres e Aquáticos]. São Paulo: Universidade de São Paulo.

Leandrini, J.A., Fonseca, I.A., & Rodrigues, L., 2008. Characterization of habitats based on algal periphyton biomass in the Upper Paraná River floodplain. Braz. J. Biol. 68(3), 503-509. PMid:18833470. http://doi.org/10.1590/S1519-69842008000300006.

Legendre, P., & Legendre, L., 2012. Numerical ecology. London: Elsevier Science Publication.

Lima, A.C.P., França, F., & Jesus, T.B., 2018. Evaluation of heavy metals in levels of wetland Marimbus, Bahia, Brazil. Eng. Sanit. Ambient. 23(3), 591-598. http://doi.org/10.1590/s1413-41522018164218.

Lopes, M.R.M., & Bicudo, C.E.M., 2003. Desmidioflórula de um lago da planície de inundação do Rio Acre, estado do Amazonas, Brasil. Acta Amazon. 33(2), 167-212. http://doi.org/10.1590/1809-4392200332212.

Loverde-Oliveira, S.M., & Huszar, V.L.M., 2007. Phytoplankton ecological responses to the flood pulse in a Pantanal lake. Cent. Brazil. Acta Limnol. Bras. 19(2), 117-130.

Lund, J.W.G., Kipling, C., & Le-Cren, E.D., 1958. The inverted microscope method of estimating algal number and the statistical basis of estimating by counting. Hydrobiologia 11(2), 143-170. http://doi.org/10.1007/BF00007865.

Marker, A.F.H., Nusch, E.A., Rai, H., & Riemann, B., 1980. The measurement of photosynthetic pigments in freshwaters and standardization of methods: conclusions and recommendations. Arch. Hydrobiol. 14, 91-106.

Mayora, G., Devercelli, M., & Giri, F., 2013. Spatial variability of chlorophyll-a and abiotic variables in a river–floodplain system during different hydrological phases. Hydrobiologia 717(1), 51-63. http://doi.org/10.1007/s10750-013-1566-x.

McAbendroth, L., Ramsay, P.M., Foggo, A., Rundle, S.D., & Bilton, D.T., 2005. Does macrophyte fractal complexity drive invertebrate diversity, biomass and body size distributions? Oikos 111(2), 279-290. http://doi.org/10.1111/j.0030-1299.2005.13804.x.

Neif, E.M., Behrend, R.D.L., & Rodrigues, L., 2013. Seasonal dynamics of the structure of epiphytic algal community on different substrates from a Neotropical floodplain. Rev. Bras. Bot. Braz. J. Bot. 36(3), 169-177. http://doi.org/10.1007/s40415-013-0021-6.

NemesKókai, Z., Borics, G., Csépes, E., Lukács, Á., Török, P., T-Krasznai, E., Bácsi, I., & B-Béres, V., 2024. Role of microhabitats in shaping diversity of periphytic diatom assemblages. Hydrobiologia 851, 959-972. http://doi.org/10.1007/s10750-023-05336-x.

Neustupa, J., Stastny, J., & Woodard, K., 2023. Ecological monitoring of disturbed mountain peatlands: an analysis based on desmids. Biodivers. Conserv. 32(8-9), 2671-2691. http://doi.org/10.1007/s10531-023-02624-9.

Pacini, A., Mazzoleni, S., Battisti, C., & Ricotta, C., 2009. More rich means more diverse: extending the 'environmental heterogeneity hypothesis' to taxonomic diversity. Ecol. Indic. 9(6), 1271-1274. http://doi.org/10.1016/j.ecolind.2009.01.003.

Pataro, L., Romero, R., & Roque, N., 2013. Four new species of *Microlicia* (Melastomataceae) from Chapada Diamantina, Bahia, Brazil. Kew Bull. 68(2), 1-9. http://doi.org/10.1007/s12225-013-9448-y.

Programa de Monitoramento Climático em Tempo Real da Região Nordeste – Proclima, 2021. Balanço Hídrico no município de Andaraí. Cachoeira Paulista: CPTEC/INPE. Retrieved in 2021, January 24, from http://proclima.cptec.inpe.br/balanco_hidrico/balancohidrico.shtml

Development Core Team, 2021. R: A Language and Environment for Statistical Computing. Vienna: R Foundation for Statistical Computing. Retrieved in 2022, October 20, from https://www.r-project.org/

Ramos, G.J.P., Costa, F.M., Santos, M.A., & Moura, C.W.N., 2019. Taxonomic novelties, new records, and rare species of desmids from the Chapada Diamantina region, Brazil. Phytotaxa 391(3), 185-196. http://doi.org/10.11646/phytotaxa.391.3.2.

Ramos, G.J.P., Oliveira, I.B., & Moura, C.W.N., 2021c. Taxonomic updates and a new variety of *Cosmarium redimitum* from South America. Phytotaxa 514(1), 77-84. http://doi.org/10.11646/phytotaxa.514.1.5.

Ramos, G.J.P., Santos, M.A., & Moura, C.W.N., 2021a. Taxonomic notes on some *Cosmarium* species (Desmidiaceae, Zygnematophyceae) from Brazil. Phytotaxa 483(3), 291-299. http://doi.org/10.11646/phytotaxa.483.3.9.

Ramos, G.J.P., Santos, M.A., & Moura, C.W.N., 2021b. How hidden is the diversity of the genus *Cosmarium* (Desmidiaceae) in the Brazilian Caatinga? Acta Bot. Bras. 35(2), 188-214. http://doi.org/10.1590/0102-33062020abb0370.

Ramos, G.J.P., Santos, M.A., Oliveira, I.B., & Moura, C.W.N., 2020. Taxonomic and nomenclatural notes on five taxa of *Cosmarium* (Desmidiaceae, Zygnematophyceae) from Brazil. Not. Algarum 146, 1-5.

Ribeiro, C.A., Ramos, G.J.P., Oliveira, I.B., & Moura, C.W.N., 2015. *Micrasterias* (Zygnematophyceae) de duas áreas do Pantanal dos Marimbus (Baiano e Remanso), Chapada Diamantina, Bahia, Brasil. Sitientibus Sér. Ciênc. Biol. 15, 1-12. http://doi.org/10.13102/scb578.

Roberto, M.C., Santana, F.N., & Thomaz, S.M., 2013. Limnology in the Upper Paraná River floodplain: large-scale spatial and temporal patterns, and the influence of reservoirs. Braz. J. Biol. 69(2, Suppl.), 717-725. PMid:19738977.

Rodrigues, L., & Bicudo, D.C., 2001. Similarity among periphyton algal communities in a lentic-lotic gradient of the upper Paraná river floodplain, Brazil. Rev. Bras. Bot. Braz. J. Bot. 24(3), 235-248. http://doi.org/10.1590/S0100-84042001000300001.

Santos, M.A., Ferragut, C., Simões, N.R., Silva, D.M.L., & Moura, C.W.N., 2022. What are the main environmental predictors of differences in the community structure of periphytic desmids in a semi-arid floodplain lake? Aquat. Ecol. 56(4), 1-17. http://doi.org/10.1007/s10452-022-09957-7.

Santos, T.R., Ferragut, C., & Bicudo, C.E.M., 2013. Does macrophyte architecture influence periphyton? Relationships among *Utricularia foliosa*, periphyton assemblage structure and its nutrient (C, N, P) status. Hydrobiologia 714(1), 71-83. http://doi.org/10.1007/s10750-013-1531-8.

Sartory, D.P., & Grobbelaar, J.U., 1984. Extraction of chlorophyll a from freshwater phytoplankton for spectrophotometric analysis. Hydrobiologia 114(3), 177-187. http://doi.org/10.1007/BF00031869.

Shetty, K., & Gulimane, K., 2022. Biomonitoring of freshwater lentic habitats using desmids. Limnology 23(1), 245-251. http://doi.org/10.1007/s10201-021-00664-0.

Souza, M.L., Pellegrini, B.G., & Ferragut, C., 2015. Periphytic algal community structure in relation to seasonal variation and macrophyte richness in a shallow tropical reservoir. Hydrobiologia 755(1), 183-196. http://doi.org/10.1007/s10750-015-2232-2.

Thomaz, S.M., Bini, L.M., & Bozelli, R.L., 2007. Floods increase similarity among aquatic habitats in river-floodplain systems. Hydrobiologia 579(1), 1-13. http://doi.org/10.1007/s10750-006-0285-y.

Thomaz, S.M., Bini, L.M., & Pagioro, T.A., 2004. Métodos em Limnologia: macrófitas aquáticas. In: Bicudo, C.E. & Bicudo, D.C., eds. Amostragem em Limnologia. São Carlos: Rima, 193–212.

Utermöhl, H., 1958. Zur Vervollkommnung der quantitativen Phytoplankton-Methodik. Mitt. Int Ver Theor. Angew. Limnol. 9(1), 1-38. http://doi.org/10.1080/05384680.1958.11904091.

Vadeboncoeur, Y., & Steinman, A.D., 2002. Periphyton Function in Lake Ecosystems. ScientificWorldJournal 2, 1449-1468. PMid:12805932. http://doi.org/10.1100/tsw.2002.294.

van Gerven, L.P.A., de Klein, J.J.M., Gerla, D.J., Kooi, B.W., Kuiper, J.J., & Mooij, W.M., 2015. Competition for light and nutrients in layered communities of aquatic plants. Am. Nat. 186(1), 72-83. PMid:26098340. http://doi.org/10.1086/681620.

Zhang, W., Shen, H., Zhang, J., Yu, J., Xie, P., & Chen, J., 2020. Physiological differences between free-floating and periphytic filamentous algae, and specific submerged macrophytes induce proliferation of filamentous algae: a novel implication for lake restoration. Chemosphere 239, 124702. PMid:31520979. http://doi.org/10.1016/j.chemosphere.2019.124702.

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