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Composition, frequency and seasonal distribution of periphytic microalgae in stretches of the Curiaú River, Amapá, Eastern Amazon

Composição, frequência e distribuição sazonal de microalgas perifíticas em trechos do rio Curiaú, Amapá, Amazônia Oriental

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Periphyton communities are composed of microorganisms loosely attached to the substrate, including fungi, bacteria, microinvertebrates, and mostly microalgae. Due to their photosynthesizing component, they are important primary producers that subsidize the aquatic trophic chain. This study aimed to verify the composition, frequency, and seasonal distribution of periphytic microalgae in stretches of the Curiaú River, located in the Environmental Protection Area (APA) of the Curiaú River, in the State of Amapá. For this, quarterly collections were carried out comprising the months of June 2016 to October 2017, during the dry and rainy seasons. The periphyton algal communities were obtained by squeezing parts of two macrophytes species, *Eichhornia crassipes* Mart. (Solms) and *Pistia stratiotes* L. The data were statistically treated using absolute values and the Kruskal-Wallis test, the latter considering the distribution of richness between sites and sampling periods (significance level of α=0.05). A total of 64 taxa were inventoried, aggregated into three taxonomic divisions: Chlorophyta (n=48; 75%), Cyanophyta (n=12; 18.75%) and Heterokontophyta (n=4; 6.25%). In class terms, Zygnematophyceae had the highest number of taxa (n=42; 65.63%), followed by Cyanophyceae (n=12; 18.75%), Chlorophyceae (n=5; 7.81%), Bacillariophyceae (n=4; 6.25%) and, finally, Ulvophyceae (n=1; 1.56%). Of the total number of inventoried taxa, 64.06% (n=41) presented sporadic frequency. Species richness was influenced by seasonality, as higher values were associated with the rainy season ($p<0.05$). This research is a contribution to the phycology of the Amazon region, especially in its pioneering for the state of Amapá.
Keywords: algae, periphyton, Zygnematophyceae.

A comunidade perifítica é composta por microrganismos frouxamente aderidos à substratos, incluindo, fungos, bactérias, microinvertebrados e, em sua maioria, microalgas. Devido ao seu componente fotossintetizante, são importantes produtores primários que subsidiam a cadeia trófica aquática. Este estudo teve como objetivo verificar a composição, frequência e distribuição sazonal de microalgas perifíticas em trechos do rio Curiaú, localizados na Área de Proteção Ambiental (APA) do Rio Curiaú, no Estado do Amapá. Para isso, foram realizadas coletas trimestrais compreendendo os meses de junho de 2016 a outubro de 2017, nas estações seca e chuvosa. O material perifítico foi coletado de partes espremidas de duas espécies de macrófitas aquáticas, *Eichhornia crassipes* Mart. (Solms) e *Pistia stratiotes* L. Os dados foram tratados, estatisticamente, por meio de valores absolutos e teste de Kruskal-Wallis, este último considerando a distribuição da riqueza entre os sítios e períodos de amostragem (nível de significância de α=0,05). Foram inventariados 64 táxons, agregados em três divisões taxonômicas: Chlorophyta (n=48; 75%), Cyanophyta (n=12; 18,75%) e Heterokontophyta (n=4; 6,25%). Em termos de classe, Zygnematophyceae teve o maior número de táxons (n=42; 65,63%), seguido por Cyanophyceae (n=12; 18,75%), Chlorophyceae (n=5; 7,81%), Bacillariophyceae (n=4; 6,25%) e, por fim, Ulvophyceae (n=1; 1,56%). Do total de táxons inventariados, 64,06% (n=41) apresentaram frequência esporádica. A riqueza de espécies foi influenciada pela sazonalidade, pois os maiores valores estiveram associados à estação chuvosa ($p<0,05$). Esta pesquisa é uma contribuição para a ficologia da região amazônica, especialmente em seu pioneirismo para o Estado do Amapá.
Palavras-chave: algas, perifíton, Zygnematophyceae.

1. INTRODUCTION

Microalgae are unicellular or multicellular microorganisms, constituents of the communities of primary production of the aquatic ecosystem, that convert sunlight into chemical energy through photosynthesis [1, 2]. Among the microalgae groups commonly found in freshwater environments, we report Bacillariophyta, Chlorophyta, Chryptophyta, Chrysophyta, Cyanophyta, Dinophyta, and Euglenopyta. These organisms can be found dispersed in the water column and in the form of periphyton [3, 4].

Periphyton term was first defined in 1983 at the 1st International Workshop on community adhered which living in aquatic ecosystems. Its definition includes microorganisms, such as microalgae, fungi, bacteria, and animals that adhered to organic or inorganic debris [5, 6].

Microalgae are the main organisms that compose the periphyton and have a great influence on the nutritional level of associated ecosystems [5, 7, 8]. Periphyton studies are less developed compared to phytoplankton and only from the 1980s began to be performed more comprehensively [9].

In the periphytic community, we can find a great diversity of life forms and groups of algae. For example, talophytes can range from single-celled, colonial, pseudofilamentous, unbranched simple filamentous organisms, branched filamentous, filamentous with false branching, syphonaceous or cenocytic, to pseudoparenchytic forms [10]. Among the groups of algae found in the periphytic community, we have Cyanophyceae, Chlorophyceae, Oedogoniophyceae, Zygnematophyceae, and, for the most part, Bacillariophyceae [11–13].

The periphyton is an important group of organisms that compose the base of the food chain in the aquatic ecosystem. They are a source of proteins, vitamins, and minerals [14] for zooplankton, insects, and fishes that feed on them [15]. Besides that, they are recognized as a bioindicator of water quality and trophic state, since they have a high capacity to accumulate nutrients from pollutants (i.e., insecticides) in water bodies [7, 12].

The aquatic ecosystem studied (Curiaú river) is at the Environmental Protection Area (APA) of the Curiaú River. This APA is composed of several environments rich in fauna, flora, and microbiota. Studies related to the inventory of this biodiversity are necessary to support the knowledge of existing species in the area and enable the development of environmental management policies for the monitoring of natural resources in legally protected areas.

In addition, the APA of the Curiaú River is located near the urban expansion area of the municipality of Macapá, the capital of the Amapá state, suffering pressure on its population and ecosystems. This pressure often is due to the disordered use of natural resources, resulting in short, medium, and long-term impacts [16].

Thus, this research aims to perform a taxonomic survey of the periphytic community in stretches of the Curiaú River (Macapá-AP), evaluating its frequency and seasonal distribution in an annual cycle.

2. MATERIAL AND METHODS

2.1 Study area

The Curiaú River APA is situated 8 km^2 north of the city of Macapá, in the State of Amapá, Brazil, with a total of 216.76 km^2, with demarcated boundaries between the Campina Grande community (north), BR-156 Highway (west), Macapá city (south) and the Amazon River (east) [16, 17]. The local scenery presents numerous landscapes, with a variety of fauna, flora, and associated microbiota [18]

The Curiaú river basin (Figure 1) is interconnected to permanent and temporary lakes influenced by tidal regimes, characteristic of the Amazon region. It presents two distinct seasonal periods: a) dry, comprising the months of July to December; b) rainy, comprising the months of January to June [19]. It is mainly used for recreation, plantation irrigation, artisanal fishing, and river routes [18]. Studies indicate that water from the Curiaú River presents acid pH, low electrical conductivity, and dissolved oxygen concentration between 4 and 7 mg/L, with transparency of ± 100 cm [20, 21]

2.2 Collection and sampling of periphyton

The collection of microalgae from the periphyton was carried out in quarterly campaigns, between the months of June 2016 to October 2017, totaling six collections (six replicates per sampling site) and considering the following seasonal periods: D (dry); D-R (dry-rainy); R (rainy); R-D (rainy-dry). The sampling sites (n=3), located in the Curiaú River basin between the geographic coordinates 0°08'13.69 "N; 51°02'53.35 "W and 0°08'55.86 "N; 51°02'23.55 "W (see Figure 1; Table 1), were defined due to their access logistics and presence of aquatic macrophyte banks.

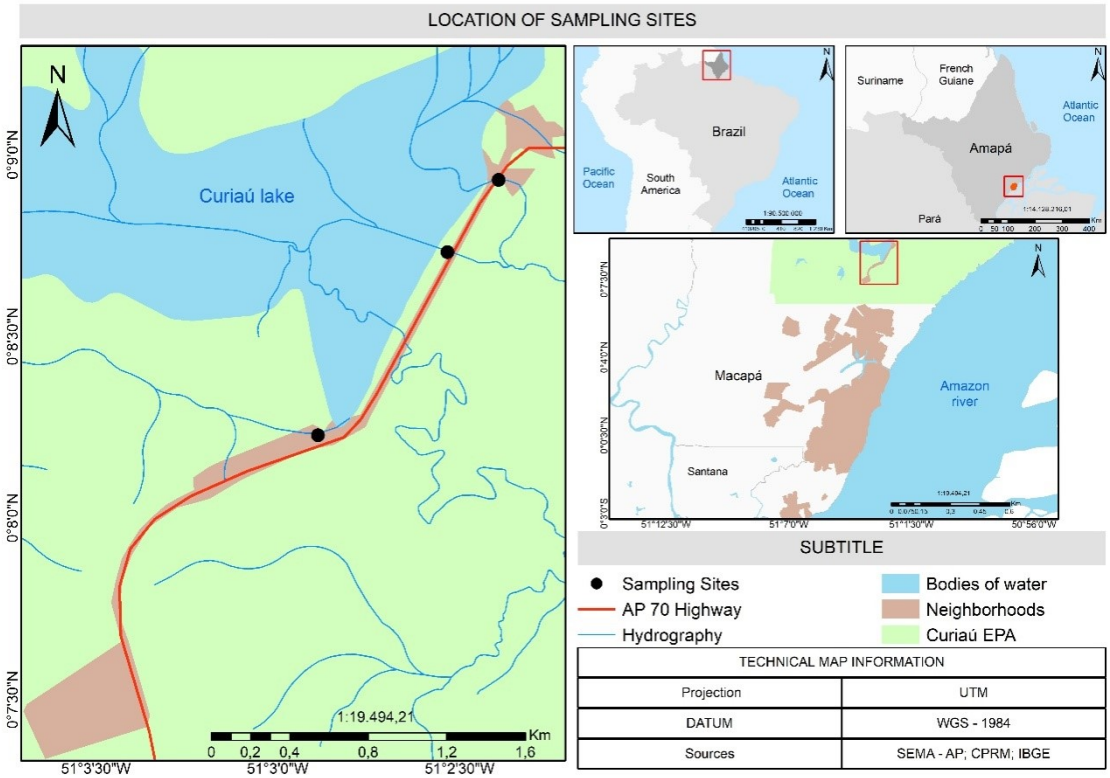

Figure 1: Map of the study site. Sampling sites on the Curiaú river.

Table 1: Geographic coordinates and general characteristics of sampling sites in the study area.

Sampling site	***Latitude***	***Longitude***	***General characteristics***
Site 1	0°08'13.69"N	51°02'53.35"W	Site close to urban occupation presents a large concentration of aquatic macrophytes dispersed on the surface, forming a dense layer. Due to the geomorphological formations and slope, in the dry period, it is the site that presents the smallest volume of water, allowing the mixture of soil sediments with water.
Site 2	0°08'43.91"N	51°02'31.98"W	Place used for recreation activities (leisure, spa), where anthropic actions are more noticeable because they are located under the bridge of the Curiaú Highway (AP 70) and because of the presence of developments such as bars and restaurants. At this site, there are also aquatic macrophytes, but they are restricted to the margins.
Site 3	0°08'55.86"N	51°02'23.55"W	It is the site closest to the banks of the Curiaú Highway (AP 70). In this place, it is common to find people fishing. There are macrophytes scattered throughout this site, but not dense. Due to the proximity to the highway, it is possible to notice in this place the accumulation of organic and inorganic waste on its banks. In the rainy season, they mix with water or add to aquatic plants.

The periphyton algal communities were obtained by squeezing parts of two macrophytes species, *Eichhornia crassipes* Mart. (Solms) and *Pistia stratiotes* L. The collected material was fixed and preserved with Transeau's solution, according to the usual methodology [22].

2.3 Taxonomic identification and frequency

The taxonomic identification of periphyton was carried out by optical microscopy at the Environmental Sanitation laboratory of the Federal University of Amapá, with the aid of specialized bibliography and identification keys [22–26].

The frequency (%) was determined according to Matteucci and Colma (1981) [27]. In this study, the result was obtained using the following formula: (n*100)/N, where n= number of samples in which the taxa occurred and N= the total number of samples (space-time) analyzed in the study period. In the end, the taxa were classified as quite common (≥70%), relatively common (<70% and ≥40%), relatively uncommon (<40% and ≥10%), and sporadic (<10%).

2.4 Statistical analysis

Data were tabulated in an Excel spreadsheet for the generation of statistical analyses through the R-statistics Software [28]. Data (raw and transformed) was submitted to Shapiro-Wilk and Levene-Bartlett normality tests to assess homogeneity and homoscedasticity, respectively. As the data were not normal, we used the non-parametric Kruskal-Wallis test (α=0.05) to assess the spatial and seasonal variation in the species richness.

3. RESULTS

A total of 64 taxa were identified, being distributed in three divisions and five taxonomic classes (Table 2).

Table 2: List of taxa with their respective frequency classes and site of occurrence. S1 (site 1); S2 (site 2); S3 (site 3); D (dry); D-R (dry-rainy); R (rainy); R-D (rainy-dry).

Class *Genus and species*	Frequency classes	Sampling sites and period																	
		R-D			D			D-R			R			R-D			D		
		S1	S2	S3	S1	S2	S3	S1	S2	S3	S1	S2	S3	S1	S2	S3	S1	S2	S3
Bacillariophyceae																			
Actinella sp.	Sporadic													x					
Aulacoseira granulate (Ehrenberg) Simonsen	Relatively uncommon													x		x			
Surirella sp.	Sporadic							x											
Terpsinoe musica Ehrenberg	Sporadic												x						
Cyanophyceae	Sporadic																		
Aphanocapsa incerta (Lemmerm.) Cronberg & Komárek	Sporadic							x											
Coelomoron sp.	Sporadic																x		
Dolichospermum solitaria (Klebahn) Wacklin, L. Hoffmann & Komárek	Sporadic													x					
Microcystis aeruginosa (Kützing) Kützing	Sporadic														x				
Microcystis wesenberguii (Komárek) Komárek ex Komárek	Relatively uncommon										x		x						
Oscillatoria princeps Vaucher ex Gomont	Relatively uncommon												x			x			
Planktolymbya limnetica (Lemmermann) Komárková-Legnerová & Cronberg	Sporadic																x		
Planktothrix planctonica (Elenkin) Anagnostidis & Komárek	Sporadic														x				
Pseudanabaena sp.	Relatively uncommon				x	x													x
Stigonema sp.	Sporadic																	x	
Synechocystis sp.	Sporadic							x											

Class *Genus and species*	Frequency classes	Sampling sites and period																	
		R-D			D			D-R			R			R-D			D		
		S1	S2	S3	S1	S2	S3	S1	S2	S3	S1	S2	S3	S1	S2	S3	S1	S2	S3
Chlorophyceae																			
Coenochloris sp.	Sporadic							x											
Eudorina elegans Chodat	Relatively uncommon							x							x				
Eudorina sp.	Sporadic				x														
Monoraphidium sp.	Sporadic														x				
Pandorina sp.	Sporadic																		x
Ulvophyceae																			
Binuclearia sp.	Relatively uncommon	x											x		x				x
Zygnematophyceae																			
Bambusinabre brissonii Kützing	Relatively uncommon	x						x								x		x	
Bambusina sp.	Sporadic							x											
Closterium kuetzingii Brébisson	Relatively uncommon					x					x	x				x			
Closterium moniliferum (Bory) Ehrenberg ex Ralfs	Relatively uncommon				x				x			x							
Closterium setaceum Ehrenberg ex Ralfs	Sporadic					x													
Closterium sp.	Relatively uncommon				x	x					x								
Cosmarium connatum O. Kirchner	Sporadic	x																	
Cosmarium contractum Kirchner	Sporadic														x				
Cosmarium mamilliferum Reinsch	Sporadic															x			
Cosmarium sp.	Sporadic	x																	
Desmidium aptogonum Brébisson ex Kützing	Relatively uncommon										x		x						
Desmidium baileyi (Ralfs) Nordstedt	Sporadic										x								

Class *Genus and species*	Frequency classes	Sampling sites and period																	
		R-D			D			D-R			R			R-D			D		
		S1	S2	S3	S1	S2	S3	S1	S2	S3	S1	S2	S3	S1	S2	S3	S1	S2	S3
Desmidium bicristatosporum R.L.Grönblad	Sporadic		x																
Desmidium graciliceps (Nordstedt) Lagerheim	Relatively uncommon	x								x									
Desmidium grevillea (Kütz. ex Ralfs) de Bary	Relatively uncommon									x		x			x				
Genicularia sp.	Relatively uncommon						x										x	x	
Genicularia spirotaenia (De Bary) De Bary	Sporadic				x														
Gonatozygon sp.	Sporadic				x														
Gonatozygon monotanieum De Bary	Relatively uncommon												x	x	x	x			
Haplotaenium minutum (Ralfs) Bando	Sporadic		x																
Haplozyga armata (Löfgren & Nordstedt) Raciborski	Relatively uncommon		x														x		
Homoeothrix juliana (Bornet et Flahault) Kirchner	Sporadic				x														
Hyalotheca dissiliens Brébisson ex Ralfs	Relatively uncommon		x					x		x	x	x	x	x					
Hyalotheca sp.	Sporadic		x																
Hyalotheca mucosa (Mertens) Ehrenberg ex Ralfs	Relatively uncommon											x							x
Mesotaenium sp.	Sporadic															x			
Micrasterias radiosa Ralfs	Sporadic												x						
Micrasterias sp.	Relatively uncommon		x	x															
Mougeotia sp.	Relatively uncommon	x						x	x		x		x	x		x			
Netrium sp.	Sporadic							x											
Onychonema filiformis Ehrenberg	Sporadic								x										
Penium margaritaceum Brébisson	Sporadic					x													
Pleurotaenium ehrenbergii (Brébisson ex Ralfs) Delponte	Relatively uncommon					x					x	x					x		

Class *Genus and species*	Frequency classes	Sampling sites and period																	
		R-D			D			D-R			R			R-D			D		
		S1	S2	S3	S1	S2	S3	S1	S2	S3	S1	S2	S3	S1	S2	S3	S1	S2	S3
Pleurotaenium sp.	Relatively uncommon			x							x				x				
Spondylosium pulchrum (Bailey) Archer	Sporadic	x																	
Spirogyra sp.	Relatively common	x					x	x	x		x	x		x		x	x		
Staurastrum sp.	Sporadic			x															
Staurastrum boergesenii Raciborski	Sporadic			x															
Staurastrum ornatum (Boldt) W.B.Turne	Sporadic	x																	
Staurodesmus conatus (P.Lundell) Thomasson	Sporadic							x											
Staurodesmus dickiei (Ralfs) S.Lill.	Sporadic											x							
Staurodesmus validus (West & G.S.West) Thomasson	Sporadic																	x	
Xantidium antilopaeum (Brébisson) Kützing	Sporadic			x															

Of the total number of inventoried taxa, 19 were identified at the genus level and 45 at the species level. The Chlorophyta division presented the highest number of taxa (n=48; 75%), followed by Cyanophyta (n=12; 18.75%) and Heterokontophyta (n=4; 6.25%). The Zygnematophyceae class had the highest number of taxa (n=42; 65.63%), followed by Cyanophyceae (n=12; 18.75%), Chlorophyceae (n=5; 7.81%), Bacillariophyceae (n=4; 6.25%) and, finally, Ulvophyceae (n=1; 1.56%) (Figure 2).

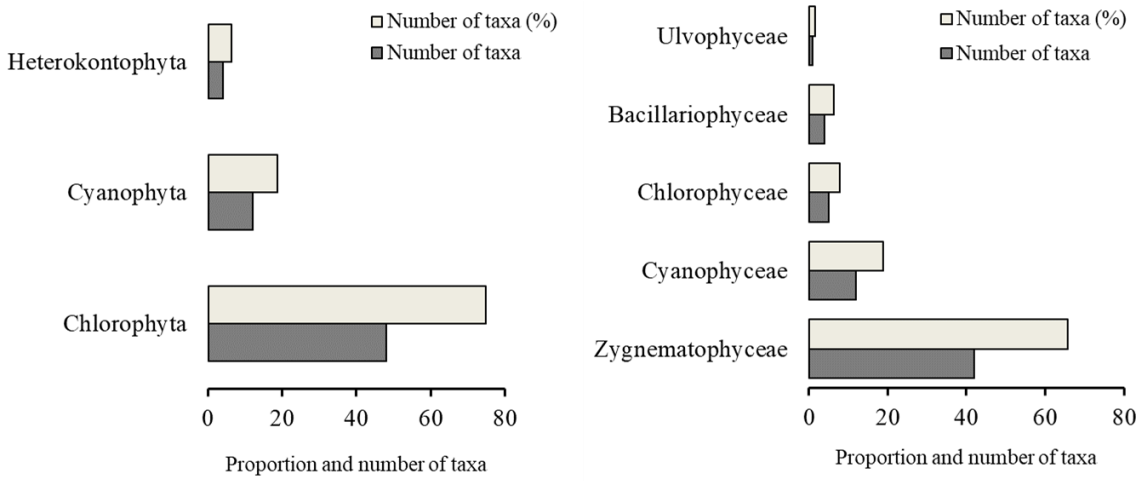

Figure 2: Distribution of taxa by division and taxonomic class, showing frequencies (light bars) and absolute values (grey bars).

Most of the taxa presented a sporadic frequency of occurrence (S) (n=41; 64.06%), characterizing an environment with a local variety of rare species. In turn, 34.48% (n=22) were relatively uncommon (RU) and only one taxon (*Spyrogira* sp.) was considered relatively common (RC) in the sampling period (n=1; 1.56%) (Figure 3).

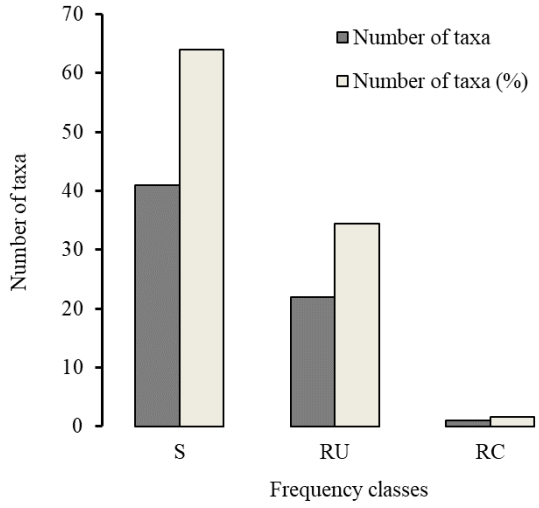

Figure 3: Distribution of the taxa by frequency classes, showing frequencies (light bars) and absolute values (grey bars). S (sporadic); RU (relatively uncommon);RC (relatively common).

Regarding the space-seasonal fluctuation, there was no significant variation between the sites of sampling for the richness of periphyton (Figure 4). However, a significant variation was observed between sampling periods ($p<0.05$), with the highest richness values associated with the rainy season (Figure 4).

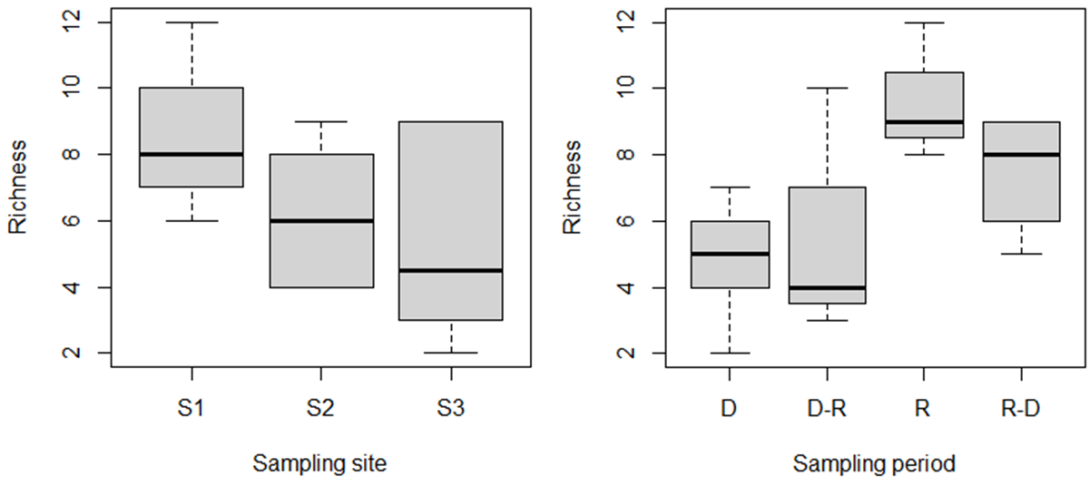

Figure 4: Boxplot of the distribution of taxa by sampling sites and period. S1 (site 1), S2 (site 2), S3 (site 3), D (dry); D-R (dry-rainy); R (rainy); R-D (rainy-dry).

4. DISCUSSION

The composition of the periphyton was distributed in three taxonomic divisions, mostly Chlorophyta. This division, despite occurring in marine environments, prevails in continental aquatic ecosystems. They can still inhabit tree trunks, soils and live-in symbiosis with fungi, protozoa, and other animals [29]. This division presents a cosmopolitan distribution but shows a greater dispersion in species richness moving towards the equator, which results in a remarkably diverse tropical environment. In addition, the thermal amplitude (25-30ºC) found in the tropics is a promising condition for the development of this group [30].

There are many species belonging to Chlorophyta that form the periphyton, being associated with aquatic macrophytes, in which they spend much of their life cycle [8]. Emphasis is given to Zygnematophyceae group, which presents morphological adaptations such as thorns, processes, warts, mucilage, among others, which help in their permanence at the substrate, such as desmids species [7].

The Zygnematophyceae class, which presented the greatest richness for the sampled stretches of the Curiaú River, represents a remarkably diverse group, with many species and genera, especially in the periphytic community [8, 31, 32]. This is due to the relatively large size that this group presents, which hinders herbivory, in addition to the high capacity of nutrient cycling [31, 33]. For this reason, it is widely used as an environmental bioindicator for the management and conservation processes of aquatic ecosystems.

The Zygnematophyceae class also represents a group overly sensitive to environmental changes, being a common class in oligotrophic environments and mesotrophic, with acidic water and low electrical conductivity [32]. This explains the expressive richness of this group in the Curiaú River, which presents such limnological characteristics, as well as other Amazonian rivers [34, 35].

The second most representative taxonomic class was Cyanophyceae. This class is formed by microorganisms, also called Cyanobacteria, and usually configures one of the most found groups in phytoplankton and periphyton [36, 37]. Cyanobacteria species, especially filamentous, are common in tropical aquatic ecosystems, growing in masses on the sediment or aquatic macrophytes, mainly in unpolluted environments [7], which may be the case in the sections studied in the Curiaú River.

However, it is known that cyanobacterial blooms occur more often in freshwater environments, due to eutrophication and global warming. This can reduce water quality with the release of toxins (e.g., microcystin), causing adverse impacts on aquatic ecosystems and human health with economic and ecological consequences [37]. Therefore, greater attention should be paid to the constant monitoring of water from the Curiaú River, which is used for balneability and irrigation in agriculture [18].

Most of the taxa presented a sporadic frequency. A similar result was observed by Bastos and Zorro (2011) [38] in the middle sector of the Xingu River, where 73 species were classified as sporadic (67.59%), 32 species as relatively uncommon (29.63%), and only 3 taxa were classified as relatively common (2.78%). The presence of rare species of microalgae in natural ecosystems often occurs. Studies show that the occurrence of sporadic species is more related to their dispersal capacity in the environment than to their affinity to the conditions found in aquatic ecosystems [39].

Regarding seasonal variation, in Amazônia the pattern of variation in rainfall indexes is remarkable, denoting two distinct periods: rainy and dry. In addition, rainfall is one of the most important variables in climate studies in the region, due to its wide variability in the temporal and spatial scales, which has been defining climatological patterns of precipitation in the rainy (January to May) and dry (July to November) regimes. This promotes pronounced variability in climatic characteristics (intensity and geographical arrangement of the maximum and minimum rainfall) in the Amazônia [40].

Due to this, species richness showed a significant variation between rainy and dry periods, with higher values associated with the rainy season. The periphytic community, in general, presents a clear spatial and temporal heterogeneity, which influences the variation of the composition, density, productivity, and biomass [41].

Factors such as water flows, seasonality, temperature, nutrient concentration, and herbivory also promote this variation [38]. Pieroni et al. (2015) [42] state that periods with higher rainfall rates tend to promote a higher occurrence of species, due to the increase in leached nutritional burden for these ecosystems, denoting a more expressive taxonomic richness, as observed in the present study.

5. CONCLUSION

The composition of the periphyton was represented by 64 taxa, with a higher presence of species of the Zygnematophyceae class, sporadic frequency, and the tendency to increase the richness associated with the rainy season. We also verified that local studies involving the periphytic community, mainly in natural substrates, are still quite scarce, showing the relevance of research development such as these for the region. This study is an important contribution to the ficology of the Brazilian Amazon, especially for its pioneering for the state of Amapá.

6. REFERENCES

1. Cunha EDS, Cunha AC, Silveira Junior AM, Faustino SMM. Phytoplankton of two rivers in the eastern Amazon: characterization of biodiversity and new occurrences. Acta Bot Brasilica. 2013 jun; 27(2):364-77. doi: 10.1590/S0102-33062013000200011
2. Cavalcante EDC, Faustino SMM, Silva LMA, Cunha AC, Oliveira EDC. Monitoramento do fitoplâncton na água bruta da ETA Macapá e inferências sobre a covid-19. Revista Ibero-Americana de Ciências Ambientais. 2021 mar;12(3):664-78. doi: 10.6008/CBPC2179-6858.2021.003.0053
3. Sousa EB, Pinto SLS, Gomes AL, Cunha CJS, Tavares VBC, Pinheiro SCC. Composition, richness and ecological index of phytoplankton of lake Bolonha (Belém, Pará). Braz J Anim Environ Res. 2020 out/dez;3(2):3263-75. doi: 10.34188/bjaerv3n4-041
4. Hao B, Wu H, Zhen W, Jo H, Cai Y, Jeppesen E, et al. Warming Effects on periphyton community and abundance in different seasons are influenced by nutrient state and plant type: ashallow lake mesocosm study. Front Plant Sci. 2020 abr;11:1-14. doi: 10.3389/fpls.2020.00404
5. Mendes NGS, Costa AG. Comunidades de microalgas e variáveis limnológicas abióticas no rio Santa Maria do Doce (Santa Teresa, ES). Nat On Line. 2016 jan/jul;14(1):32-7.
6. Herawati H, Fitri NHZ, Sahidin A, Apriliani IM, Dewanti LP. Perifiton community structure in Citarikriver. AJFAR. 2020;5(4):1-8. doi: 10.9734/ajfar/2019/v5i430083
7. Camargo VM, Ferragut C. Estrutura da comunidade de algas perifíticas em *Eleocharis acutangula* (Roxb.) Schult (Cyperaceae) em reservatório tropical raso, São Paulo, SP, Brasil. Hoehnea. 2014 mar;41(1):31-40. doi: 10.1590/S2236-89062014000100003

8. Biolo S, Algarte VM, Rodrigues L. Taxonomy of common taxa of Chlorophyceae (Chlorophyta) and Zygnematophyceae (Streptophyta) from periphyton of a Neotropical floodplain. Acta Sci Biol Sci. 2020;42:e50099. doi: 10.4025/actascibiolsci.v42i1.50099
9. Taniguchi GM, Bicudo DC, Senna PAC. Gradiente litorâneo-limnético do fitoplâncton e ficoperifíton em uma lagoa da planície de inundação do Rio Mogi-Guaçu. Braz J Bot. 2005 mar;28(1):137-47. doi: 10.1590/S0100-84042005000100011
10. Burliga LA, Schwarzbold A. Perifíton: Diversidade taxonômica e morfológica. In: Schwarzbold A, Burliga LA, Torgan LC, editores. Ecologia do Perifíton. São Paulo (SP): RIMA; 2013. p. 1-6.
11. Cetto JM, Leandrini JA, Felisberto SA, Rodrigues L. Comunidade de algas perifíticas no reservatório de Irai, Estado do Paraná, Brasil. Acta Sci Biol Sci. 2004;26(1):1-7. doi: 10.4025/actascibiolsci.v26i1.1645
12. Fonseca IA, Rodrigues L. Comunidade de algas perifíticas em distintos ambientes da planície de inundação do alto rio Paraná. Acta Sci Biol Sci. 2005;27(1):21-8. doi: 10.4025/actascibiolsci.v27i1.1354
13. Felisberto SA, Rodrigues L. Dinâmica sucessional de comunidade de algas perifíticas em um ecossistema lótico subtropical. Rodriguésia. 2012;63(2):463-73. doi: 10.1590/S2175-78602012000200018
14. Moschini-Carlos V, Henry R, Pompeo MLM. Seasonal variation of biomass and productivity of the periphytic community on artificial substrata in the Jurumirim Reservoir (Sao Paulo, Brazil). Hydrobiologia. 2000;434:35-40. doi: 10.1023/A:1004086623922
15. Vercellino IS, Bicudo DDC. Sucessão da comunidade de algas perifíticas em reservatório oligotrófico tropical (São Paulo, Brasil): comparação entre período seco e chuvoso. Braz J Bot. 2006 set;29(3):363-77. doi: 10.1590/S0100-84042006000300004
16. Costa NN, Silveira Júnior AM. Percepção ambiental de comunitários da Área de Proteção Ambiental (APA) do rio Curiaú, Amapá, Amazônia, Brasil: Instrumento de conservação e gestão. Geoambiente on-line. 2021 mai/ago;40:112-33. doi: 10.5216/revgeoamb.i40.67539
17. Brito DMC, Bastos AB, Bastos CMCB. Área de Proteção Ambiental do rio CURIAÚ em Macapá/AP: territórios de resistência e a legalização de áreas. Geo UERJ 2022;40:e64988. doi: 10.12957/geouerj.2022.64988
18. Barros ADS, Ferreira ACS, Bastos GLL, Faustino SMM, Cunha AC, Silveira Júnior AM. Cyanobacteria in the aquatic ecosystem of the environmental protection area (EPA) of Curiaú River, Amapá State, Amazon Region, Brazil. Nat Conserv. 2021 mar-mai;14(2):12-21. doi: 10.6008/CBPC2318-2881.2021.002.0002
19. Cunha AC, Vilhena JEDS, Santos ES, Saraiva JMB, Kuhn PAF, Brito DC, et al. Evento extremo de chuva-vazão na bacia hidrográfica do rio Araguari, Amapá, Brasil. Rev Bras Meteorol. 2014 dez;29:95-110. doi: 10.1590/0102-778620130051
20. Takiyama LR, Silva AQ, Costa WJP, Nascimento HS. Qualidade das águas das ressacas das bacias do Igarapé da Fortaleza e do rio Curiaú. In: Takiyama LR, Silva AQ, editores. Diagnóstico das ressacas do Estado do Amapá: bacias do igarapé fortaleza e rio curiaú. Macapá (AP): GEA/SETEC/IEPA; 2003. p. 81-104.
21. Takiyama LR, Silva URL, Jimenez EA, Pereira RA, Zacardi DM, Fernandes EF, et al. Projeto Zoneamento Ecológico Econômico Urbano das áreas de ressacas de Macapá e Santana, estado do Amapá: Relatório técnico final. 1. ed. Macapá (AP): IEPA; 2012.
22. Bicudo CEDM, Menezes M. Gêneros de Algas Continentais do Brasil: chave para identificação e descrições. 3. ed. São Paulo (SP): RIMA; 2006.
23. Anagnostid K, Komárek J. Modern approach to the classification system of Cyanophyta: Oscillatoriales. Algological Studies.1988;50:327-472.
24. Anagnostidis K, Komárek J. Modern approach to the classification system of Cyanophytes. 5 - Stigonematales. Arch Hydrobiol. 1990;3:1-73.
25. Komárek J, Kaštovský J, Mareš J, Johansen JR. Taxonomic classification of cyanoprokaryotes (cyanobacterial genera) 2014, using a polyphasic approach. Preslia. 2014;86:295-335.
26. Sant'Anna C, Tucci A, Azevedo MT, Melcher S, Werner V, Malone C, et al. Atlas de cianobactérias e microalgas de águas continentais brasileiras. 1. ed. São Paulo (SP): Instituto de Botânica; 2012.
27. Matteucci SD, Colma A. Metodología para el estudio de la vegetación. Falcon: Sectetaria General de la Organización de los Estados Americanos; 1981.
28. R Development Core Team. R: a language and environment for statistical computing; 2018. Available from: http://www.R-proje ct.orgS.
29. Marmitt DJ, Freitas EM, Marczinski F, Flesh A, Reis Blasi EA. Avaliação quali-quantitativa de algas marinhas macrófitas ocorrentes na Praia da Vigia, Garopaba/SC. Revista CEPSUL. 2015;4(1):5-15. doi: 10.37002/revistacepsul.vol4.4465-15

30. Souza KF, Melo S. Levantamento taxonômico de desmídias (Chlorophyta) do lago Novo (Amapá, Brasil): gêneros *Staurastrum*, *Staurodesmus* e *Xanthidium*. Acta Amazon. 2011;41(3):335-46. doi: 10.1590/S0044-59672011000300002
31. Burliga AL, Rosa ZM, Alves-da-silva SM. Desmídias pseudofilamentosas (Zygnematophyceae) da Área de Proteção Ambiental do Ibirapuitã, Bioma Pampa, Rio Grande do Sul, Brasil. Iheringia - Serie Botanica. 2016;71(2):201-8.
32. Hentschke GS, Prado JF. Chlorococcales s. l. (Chlorophyceae) e Zygnematales (Zygnematophyceae) em um açude do Balneário do Lérmen, Rio Grande do Sul, Brasil. Iheringia - Serie Botanica. 2012 jun;67(1):59-74.
33. Costa-Mendonça G, Mendonça Neto NA, Araujo CRC, Dellamano OMJ, Colombo-Corbi V. Perifíton e estado trófico em dois mananciais de abastecimento em Araraquara (SP). Braz J Aquat Sci Technol. 2018;22(1):30-40. doi: 10.14210/bjast.v22n1.12911
34. Carvalho A, Ferreira RL, Araújo P, Tavares-Dias M, Matos E, Videira MN. Condition factor and ecology of endohelminths in *Metynnislippincottianus* from the Curiaú river, in eastern amazon (Brazil). Bol Inst Pesca. 2020;46(2):1-6. doi: 10.20950/1678-2305.2020.46.2.559
35. Fonseca IA, Rodrigues L. Periphytic Cyanobacteria in different environments from the upper Paraná river floodplain, Brazil. Acta Limnol Bras. 2007;19(1):53-65.
36. Felisberto SA, Souza DBS. Characteristics and diversity of cyanobacteria in periphyton from Lentic Tropical Ecosystem, Brazil. Adv Microbiol. 2014;4(15):1076-87. doi: 10.4236/aim.2014.415118
37. Cui Y, Jin L, Ko S-R, Chun S-J, Oh H-S, Lee CS, et al. Periphyton effects on bacterial assemblages and harmful cyanobacterial blooms in a eutrophic freshwater lake: a mesocosm study. Sci Rep. 2017;7(7827):1-11. doi: 10.1038/s41598-017-08083-x
38. Bastos ASM, Zorro CM. Abundância e frequência de ocorrência de algas epilíticas das localidades Boa Esperançae Arroz Crudo setor do médio rio Xingu/ PA – Brasil. Bol Téc-Cient do CEPNOR. 2011;11(1):59-80.
39. Walker SC, Cyr H. Testing the standard neutral model of biodiversity in lake communities. Oikos. 2007;116:143-55. doi: 10.1111/j.2006.0030-1299.15300.x
40. Souza EB, Ferreira DBS, Guimarães JTF, Franco VDS, Azevedo FTM, Moraes BC, et al. Padrões climatológicos e tendências da precipitação nos regimes chuvoso e seco da Amazônia Oriental. Rev Bras Climat. 2017 jul/dez;21(13):81-93. doi: 10.5380/abclima.v21i0.41232
41. Signor A, Signor AA, Boscolo WR, Reidel A, Klein S, Feiden A. Periphyton biomass on artificial substrates during the summer and winter. Cienc Rural. 2015;45(1):72-8. doi: 10.1590/0103-8478cr20130635
42. Pieroni MM, Neto MJ, Blini RCB. Levantamento taxonômico de algas de água doce e cianobactérias identificados na Cascalheira-Três Lagoas/MS, durante os períodos chuvoso e seco. Periódico Eletrônico Fórum Ambiental da Alta Paulista. 2015;11(1):1-7. doi: 10.17271/19800827110120151067