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Community structure of periphytic Zygnematophyceae (Streptophyta) in urban eutrophic ponds from central Brazil (Goiânia, GO)

Estrutura de comunidades de Zygnematophyceae (Streptophyta) perifíticas em lagos urbanos do Brasil central (Goiânia, GO)

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Abstract: Aim: This study aimed to investigate the community structure of Zygnematophyceae algae in the periphyton of nine shallow urban eutrophic ponds from central Brazil. Additionally, we compared two different substrates, hypothesizing that community structure attributes (chlorophyll *a*; Zygnematophyceae density, composition and richness) would differ between them. **Methods:** Samples were carried out in August 2014. Periphyton was collected from two different substrates, macrophyte (epiphyton) and rocks (epilithon). **Results:** The ponds presented pH ranging from neutral to slightly acidic and electrical conductivity in general higher than 60 $\mu S.cm^{-1}$. Zygnematophyceae contributed with 0.82% of total periphyton community density in the epiphyton and 0.02% in the epilithon. Altogether 49 Zygnematophyceae taxa were recorded, distributed in 13 genera. Based on frequency of occurrence, most taxa were classified as rare, being present in less than 25% of the ponds. The taxa with higher densities were *Cosmarium regnesii* var. *regnesii*, *Cosmarium abbreviatum* var. *minus*, and *Mougeotia* sp. 3. When each pond was considered individually, other taxa were highlighted as the most abundant among Zygnematophyceae. It was the case of *Staurastrum smithii, Cosmarium exiguum, Mougeotia* sp. 1 and *Mougeotia* sp. 2. The two ponds with highest Zygnematophyceae density showed high similarity in the species composition (>70%); however, among the others, it was relatively low (<50%). **Conclusions:** The eutrophic ponds considered in this study presented high periphytic biomass, but with low Zygnematophyceae representativeness. The periphyton attributes were not significantly different between macrophytes and rocks. The substrate type was not a determinant factor for Zygnematophyceae periphytic algae in the studied ponds.

Keywords: desmids; diversity; epilithon; epiphyton; lentic systems.

Resumo: Objetivo: Analisar a estrutura da comunidade de algas Zygnematophyceae no perifíton de nove lagos rasos urbanos eutróficos do Brasil central. Adicionalmente, foram comparados dois tipos de substratos, macrófitas e rochas, com a hipótese de que atributos da estrutura de comunidade (clorofila *a*;

densidade, composição e riqueza de Zygnematophyceae) iriam diferir entre eles. **Métodos:** A amostragem foi feita em agosto de 2014. O perifíton foi coletado de dois substratos diferentes, macrófitas (epifíton) e pequenos seixos (epilíton). **Resultados:** Os lagos apresentaram pH variando de neutro e levemente ácido e condutividade elétrica em geral superior a 60 $\mu S.cm^{-1}$. Zygnematophyceae contribuiu com 0,82% da densidade total do perifíton no epifíton e 0,02% no epilíton. Ao todo 49 táxons de Zygnematophyceae foram registrados, distribuídos em 13 gêneros. Com base na frequência de ocorrência, a maioria dos táxons foi classificada como rara, presente em menos de 25% dos lagos. Os táxons com maiores densidades foram *Cosmarium regnesii* var. *regnesii, Cosmarium abbreviatum* var. *minus,* e *Mougeotia* sp. 3. Quando cada lago foi considerado individualmente, outros táxons se destacaram como os mais abundantes entre as Zygnematophyceae. Foi o caso de *Staurastrum smithii, Cosmarium exiguum, Mougeotia* sp. 1 e *Mougeotia* sp. 2. Os dois lagos com maior densidade de Zygnematophyceae apresentaram similaridade superior a 70%; entretanto, entre os demais lagos, a similaridade foi relativamente baixa (<50%). **Conclusões:** Os lagos eutróficos considerados neste estudo apresentaram elevada biomassa perifítica, mas baixa contribuição relativa de Zygnematophyceae. Os atributos do perifíton não apresentaram diferença significativa entre macrófitas e rochas. O tipo de substrato não foi um fator determinante para as algas Zygnematophyceae perifíticas nos lagos estudados.

Palavras-chaves: desmídias; diversidade; epilíton; epifíton; ambientes lênticos.

1. Introduction

Zygnematophyceae algae are exclusively freshwater organisms in general associated to oligo-mesotrophic environments, with pH ranging between 4 and 7 (Brook, 1981; Coesel, 1975, 1983, 1996; Gerrath, 2003). Pristine environments from central Brazil at the Cerrado biome (Brazilian savanna), with acidic waters, provide suitable habitats for this algal group (Estrela et al., 2011; Dunck et al., 2013; Fonseca & Estrela, 2015; Silva & Felisberto, 2015; Fonseca et al., 2018), differently from eutrophic systems, which are frequently dominated by other groups such as cyanobacteria, diatoms and coccoid green algae (Borduqui et al., 2008; Cordeiro et al., 2017).

Some Zygnematophyceae taxa can also be reported with relatively high abundance in eutrophic ecosystems (Coesel, 1982) and alkaline waters (Brook, 1981). For instance, species belonging to genera *Staurastrum*, *Cosmarium* and *Closterium* have been used as biological indicators of eutrophic ecosystems, under pH ranging between 6.7 and 8.5 (Růžička, 1977).

Information on Zygnematophyceae community structure in different environments, especially considering the trophic spectrum, can be useful as subsidies in the attempts to use these algae in biological typology. Proposals involving desmids as biological indicators date from last century (Coesel, 1975), and have considered community structure metrics such as species richness along with the occurrence of rare taxa and the presence of species that may be associated with ecosystem maturity (Coesel, 2001).

Although the literature about periphyton and its general role for ecosystem functioning is relatively abundant (e.g., Cattaneo et al., 1998; DeNicola & Kelly, 2014), studies focusing exclusively on the ecology of periphytic Zygnematophyceae in lakes and ponds are relatively scarce (Pals et al., 2006; Mutinová et al., 2016), especially in the tropical zone.

In Brazil, most ecological studies on periphyton in lentic ecosystems were performed in the Southeastern region. The influence of nutrient enrichment on periphyton structure was focused by Ferragut & Bicudo (2009, 2012), while the effect of substrate type was explored by Souza & Ferragut (2012) and Ferragut et al. (2010). Other studies have approached succession and/or seasonal variations (e.g., Vercellino & Bicudo, 2006; Camargo & Ferragut, 2014). In the North/Northeastern regions, França et al. (2009, 2011) and Cordeiro et al. (2017) discussed temporal variations of taxonomic structure of periphytic algae in Amazonian and semiarid lakes, respectively. In the State of Goiás, central Brazil, the knowledge about algal community in urban systems, including the ones considered in this study, is restricted to phytoplankton (e.g., Nogueira et al., 2008; Nogueira & Oliveira, 2009; Nogueira et al., 2011).

The literature cited above has confirmed the relative low contribution of Zygnematophyceae to total algal biomass in eutrophic systems. As a consequence, details on its specific community structure in these environments, such as the identity of the most abundant taxa, are seldom discussed. However, this information can be relevant for the development of biological indicator indexes (Coesel, 2001), once it allows the classification of different taxa as tolerant or sensitive to eutrophic conditions.

Concerning periphyton community structure on different substrate types, comparative investigations have shown that its attributes may be influenced by natural *versus* artificial substrates (Cattaneo & Amireault, 1992; Albay & Akcaalan, 2003; Vadeboncoeur et al., 2006; Ferragut et al., 2010), macrophyte architecture (Cattaneo et al., 1998) and surface roughness (Sousa & Ferragut, 2012). Specifically, the few studies on Zygnematophyceae algae available in the literature, which are focused on macrophytes and/or sandy sediments (Pals et al., 2006; Mutinová et al., 2016), have suggested that substrate influence is relatively low and varies with sites.

The present study aimed to investigate the community structure of Zygnematophyceae algae in the periphyton of nine urban eutrophic ponds from central Brazil. Additionally, we compared two different substrates, macrophytes and rocks, hypothesizing that community structure attributes (chlorophyll *a*; Zygnematophyceae density, composition and richness) would differ between them.

2. Material and Methods

2.1. Study area

This study was conducted in nine eutrophic ponds inserted in urban parks from the city of Goiânia (State of Goiás) (Figure 1). Their surface area ranges between 0.2 and 2.1 ha, with mean depth smaller than 2.3 m (Table 1). The urban parks present varied landscape composition, with native vegetation around springs and exotic and ornamental vegetation surrounding the ponds and recreational areas. The climate in the region is Aw according Köppen-Geiger classification, with a strong seasonality marked by a dry season from May to September and a wet season from October to April (Cardoso et al., 2014). Average annual temperature is 21.9 °C, with lower values between May and August and higher values in September; average annual precipitation is 1487.2 mm. This climate is typical from the Cerrado phytogeographic

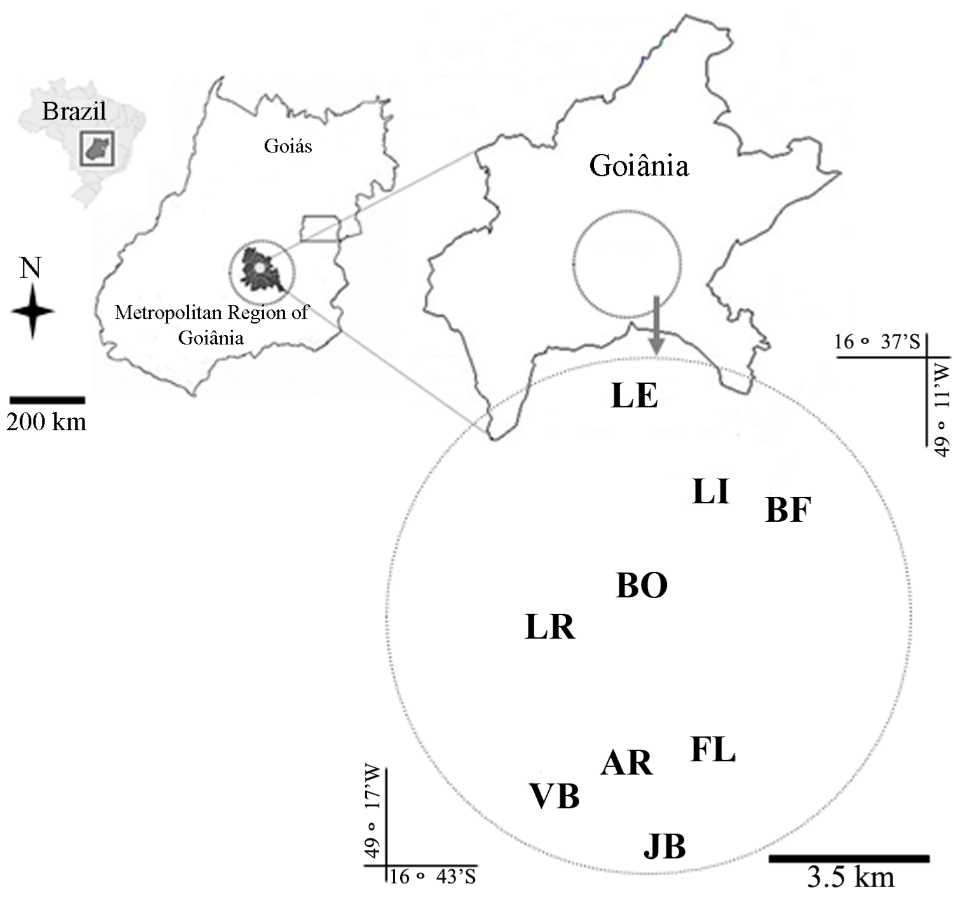

Figure 1. Study area. Codes correspond to the nine ponds (see Table 1).

Table 1. Geographic coordinates and morphometric data of nine urban eutrophic ponds from Goiânia, GO.

Ponds	Codes	Geographic coordinates	Altitude (m)	Area (ha)	Mean depth (m)
Areião	**AR**	16°42'18.05"S 49°15'14.35"W	802	1.5	2.3
Beija-flor	**BF**	16°39'9.84"S 49°13'48.16"W	702	0.4	1.4
Botafogo	**BO**	16°40'2.35"S 49°15'5.51"W	736	0.4	1.7
Flamboyant	**FL**	16°42'14.00"S 49°14'15.20"W	807	0.7	1.5
Jardim Botânico Amália T. Franco	**JB**	16°43'24.18"S 49°15'6.02"W	833	1.6	2.1
Leolídio Di Ramos Caiado	**LE**	16°37'40.87"S 49°15'29.41'W	721	2.1	1.8
Liberdade	**LI**	16°38'58.70"S 49°14'2.75"W	704	0.2	1.5
Lago das Rosas	**LR**	16°40'44.47"S 49°16'27.67"W	734	1.2	1.7
Vaca Brava	**VB**	16°42'31.79"S 49°16'15.50"W	800	1.3	1.8

domain, which predominates in the central Brazil (Bustamante et al., 2012).

2.2. Sampling

Samples were collected in August 2014, in the littoral zone. Each pond had three sampling sites. Periphyton was collected from two different substrates, macrophyte petiole (epiphyton) and rocks (epilithon). Among the nine ponds, only six presented both substrates, totalizing 45 sampling units (eight from epiphyton and seven from epilithon, each one with three replicates). The macrophytes sampled were all rooted emergent or submerged species.

The periphyton was removed from the substrate by scrapping with a razor blade (epiphyton) or by brushing (epilithon), using distilled water gentle jets. Samples were preserved with 0.5% acetic lugol solution and stored in the darkness.

Simultaneously to periphyton sampling, the following variables were measured: water temperature and pH (pH Meter MS Tecnopon mPA 210), electrical conductivity (Conductivity Meter MS Tecnopon mCA 150P), dissolved oxygen (Oxygen Meter Quimis Q758P) and turbidity (Turbidity Meter Policontrol AP2000). Chlorophyll *a* determination (corrected for phaeophytin) was performed using acetone 90% as solvent (Golterman et al., 1978).

2.3. Quantitative analysis

Periphytic algae were counted in random fields (Bicudo, 1990), using 2 mL chambers under inverted microscope (Olympus CKX41) at 400x magnification; sedimentation time followed Lund et al. (1958). For each sample, at least ten fields without new taxa were considered before stop counting. Density was calculated using the equation adapted from Ros (1979).

In order to evaluate the Zygnematophyceae contribution in relation to other taxonomic classes (Cyanobacteria, Bacillariophyceae, Chlorophyceae, Oedogoniophyceae and Others), all periphytic individuals were counted. The general algal classification followed Hoek et al. (1995) and for Zygnematophyceae, Guiry (2013). Zygnematophyceae taxa were also classified according to their frequency of occurrence (F = number of ponds where the taxon was reported / total number of ponds), following the criteria: rare ($F < 25\%$), common ($25\% \leq F < 50\%$), frequent ($50\% \leq F < 75\%$) and constant ($F \geq 75\%$).

2.4. Data analysis

Multivariate descriptive analysis was carried out by applying principal component analysis (PCA) to the abiotic data (water temperature, pH, electrical conductivity, dissolved oxygen and turbidity) along with chlorophyll *a* and Zygnematophyceae density, using a covariance matrix with data transformed by ranging $[(X - Xmin) / (Xmax - Xmin)]$. Differences between epiphyton and epilithon for the variables chlorophyll *a*, total density, Zygnematophyceae density and richness were evaluated using Mann-Whitney test. The relation between the variables total density, Zygnematophyceae density and chlorophyll *a* was separately tested by Spearman's Correlation (r_s), after data transformed by $\ln(x+1)$. Cluster analysis based on Simpson similarity index was performed with density data of Zygnematophyceae periphytic algae. It was followed by an Analysis of Similarity (ANOSIM) with data of Zygnematophyceae periphytic algae that contributed with more than 10% for at least one sample, using the same Simpson index, in order to test the hypothesis of differences between epiphyton and epilithon communities. The software PAST version 2.17c was used in these analyses

(Hammer et al., 2001). Results were considered significant when $p < 0.05$.

3. Results

The ponds presented pH ranging from neutral to slightly acidic and electrical conductivity in general higher than 60 µS cm^{-1} (Table 2).

Axis 1 and 2 of PCA explained 39 and 26% of data variability, respectively (Figure 2). The most important variables for Axis 1 ordination were Zygnematophyceae density (r = -0.64) and electrical conductivity (r = 0.63), whose vectors pointed to opposite directions. According to the graph (Figure 2), sites with lower Zygnematophyceae density (e.g., BF, LR, AR) were associated to relatively higher values of electrical conductivity, water temperature, chlorophyll *a*, turbidity and dissolved oxygen; all these variables were positively correlated to Axis 1. On the other hand, the ponds FL and LE were located at the negative side of the graph; the highest Zygnematophyceae densities were found in these sites (Table 3). Regarding the second axis, it suggested a primary production gradient, once variables directly related to photosynthesis (pH, DO and chlorophyll *a*) were the most important ones (r = 0.53, r = 0.52 and r = 0.45, respectively), positively associated to the majority of the ponds.

Chlorophyll *a* was positively and statistically correlated to total density (r_s= 0.53; $p < 0.001$), although its correlation to Zygnematophyceae density was not significant (r_s = 0.18; p = 0.22). Total and Zygnematophyceae densities were also positively and statistically correlated (r_s = 0.69; $p < 0.001$).

Zygnematophyceae mean density was 6.10^3 ind cm^{-2}. It represented 0.82% of the total periphytic community in the epiphyton and 0.02% in the epilithon. When the substrates were compared, the community structure parameters did not present statistical differences (Figure 3).

Cyanobacteria was the group that contributed most to periphyton density (6.10^6 ind cm^{-2}) especially in the epilithon, representing from 80 to almost 100% in some ponds. The class Bacillariophyceae had the second highest contribution, followed by Chlorophyceae (Figure 4).

Altogether 49 Zygnematophyceae taxa were recorded, distributed in two orders (Zygnematales and Desmidiales), five families (Mesotaeniaceae, Zygnemataceae, Closteriaceae, Desmidiaceae and Gonatozygaceae) and 13 genera. Desmidiales represented 82% of the total richness, and Desmidiaceae was the most representative family (32 taxa), followed by Closteriaceae (six taxa) and Zygnemataceae (six taxa). The genera with higher richness were *Cosmarium* (16 taxa), S*taurastrum* (nine taxa) and *Closterium* (six taxa) (Table 4).

Epiphyton showed higher Zygnematophyceae richness (45 taxa in 24 sampling units) compared

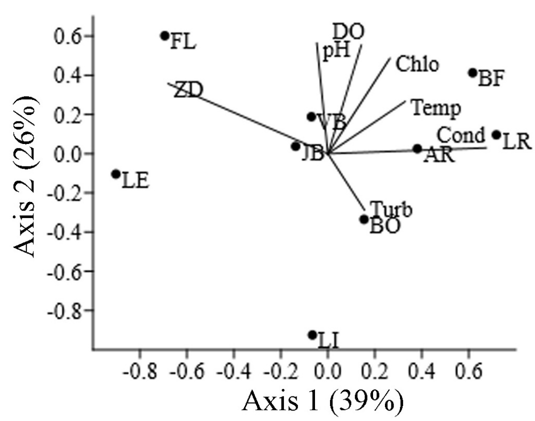

Figure 2. PCA plot of abiotic variables (Temp = water temperature, Cond = electrical conductivity, DO = dissolved oxygen, turb = turbidity), chlorophyll *a* (Chlo) and Zygnematophyceae density (ZD) in nine urban eutrophic ponds from Goiânia, GO (see codes at Table 1).

Table 2. Mean and standard deviations (n = 3) values for limnological variables in nine urban eutrophic ponds from Goiânia, GO (see codes at Table 1).

Ponds	Water temperature (°C)	pH	Electrical conductivity (µS cm^{-1})	Dissolved oxygen (mg L^{-1})	Turbidity (NTU)
AR	22.8 ± 0.7	6.7 ± 0.03	153.6 ± 0.10	7.6 ± 0.40	7.0 ± 0.05
BF	24.4 ± 0.6	6.8 ± 0.02	145.3 ± 0.10	8.5 ± 0.40	13.3 ± 2.3
BO	25.3 ± 0.5	6.7 ± 0.02	90.2 ± 0.56	5.9 ± 0.05	18.6 ± 1.2
FL	24.4 ± 0.2	7.1 ± 0.10	66.1 ± 0.25	6.9 ± 0.05	3.6 ± 0.6
JB	24.7 ± 0.6	6.8 ± 0.10	109.3 ± 0.25	7.0 ± 0.11	4.0 ± 1.0
LE	21.4 ± 0.4	6.5 ± 0.05	57.2 ± 0.47	7.1 ± 0.11	12.6 ± 2.1
LI	22.9 ± 0.1	6.0 ± 0.10	108.1 ± 0.66	4.7 ± 0.17	9.3 ± 0.6
LR	25.4 ± 0.2	6.4 ± 0.40	154.1 ± 1.01	7.2 ± 0.17	9.6 ± 2.1
VB	24.6 ± 0.8	6.5 ± 0.05	97.2 ± 0.28	7.0 ± 0.36	5.0 ± 1.0

Table 3. Mean and standard deviations (n = 6, except at AR, BO and JB, where n = 3) values for periphyton community structure in nine urban eutrophic ponds from Goiânia, GO (see codes at Table 1).

	Chlorophyll *a* (µg cm⁻²)	Total density (ind cm⁻²)	Zygnematophyceae density (ind cm⁻²)	Zygnematophyceae richness
AR*	1.9 ± 0.2	1,433,800 ± 1,469,471	1,777 ± 2,078	9
BF	2.9 ± 2.0	48,897,523 ± 116,509,514	2,982 ± 2,018	10
BO*	1.6 ± 0.4	468,506 ± 289,557	2,848 ± 2,635	8
FL	2.1 ± 1.1	1,919,243 ± 723,167	18,162 ± 18,968	26
JB*	0.8 ± 0.4	1,491,046 ± 1,867,256	7,340 ± 9,681	13
LE	1.6 ± 0.1	1,446,419 ± 1,683,964	17,588 ± 24,991	19
LI	1.1 ± 0.9	323,358 ± 412,122	2,320 ± 2,954	9
LR	2.4 ± 2.6	117,582 ± 72,945	412 ± 576	9
VB	2.3 ± 0.2	2,764,346 ± 1,430,221	8,658 ± 10,565	15

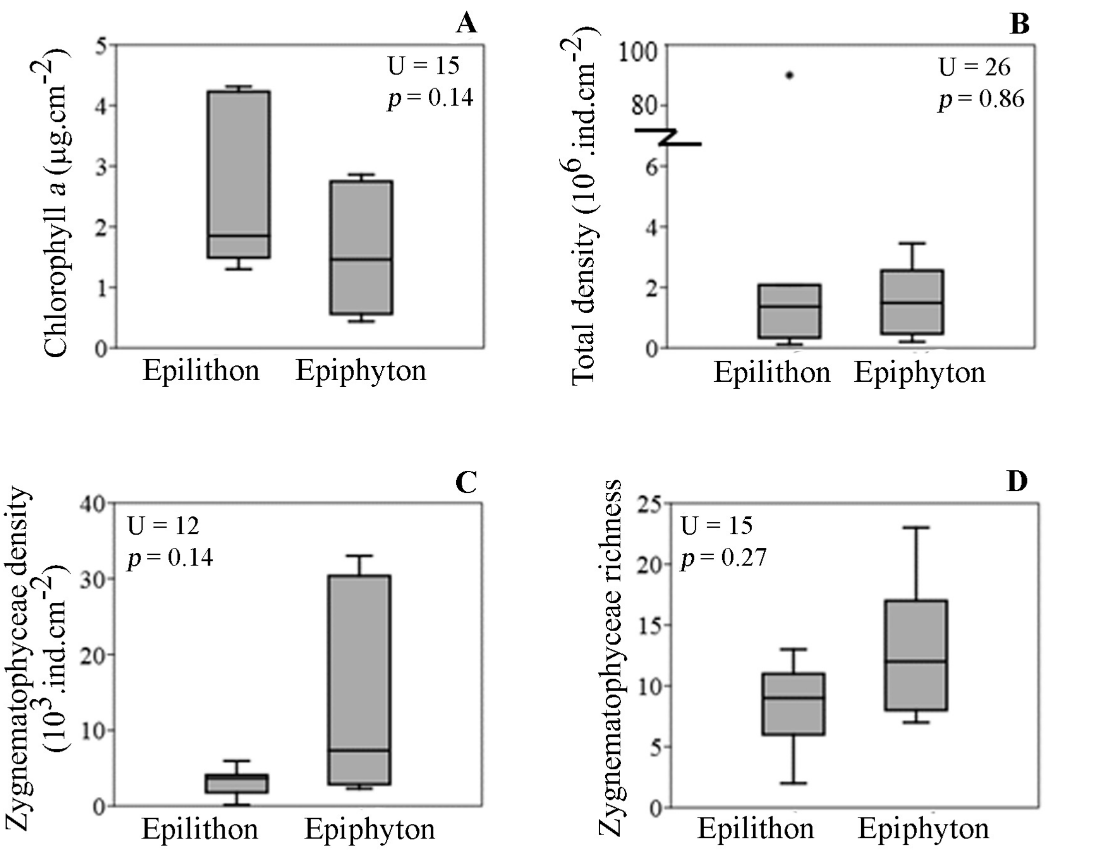

Figure 3. Box-plots of chlorophyll *a* (A), total density (B), Zygnematophyceae density (C) and Zygnematophyceae richness (D) in the epilithon and epiphyton of nine urban eutrophic ponds from Goiânia, GO.

to epilithon (29 in 21 sampling units), but the difference was not significant (Figure 3D). The number of taxa reported exclusively in the epiphyton (20) was also higher than the number of exclusive taxa from epilithon (four). The genera *Actinotaenium*, *Gonatozygon*, *Hyalotheca* e *Netrium* were restricted to epiphyton. In the epilithon, the four exclusive taxa were *Cylindrocystis brebissonii* var. *minor*, *Closterium dianae* var. *arcuatum*, *Cosmarium moniliforme* var. *moniliforme* and *Euastrum rectangulare*.

Based on frequency of occurrence, most taxa were classified as rare, being present in less than 25% of the samples (Table 4). In general, the taxa with higher densities were *Cosmarium regnesii* var. *regnesii, Cosmarium abbreviatum* var. *minus,* and *Mougeotia* sp. 3. When each pond was considered individually, other taxa were highlighted as the most

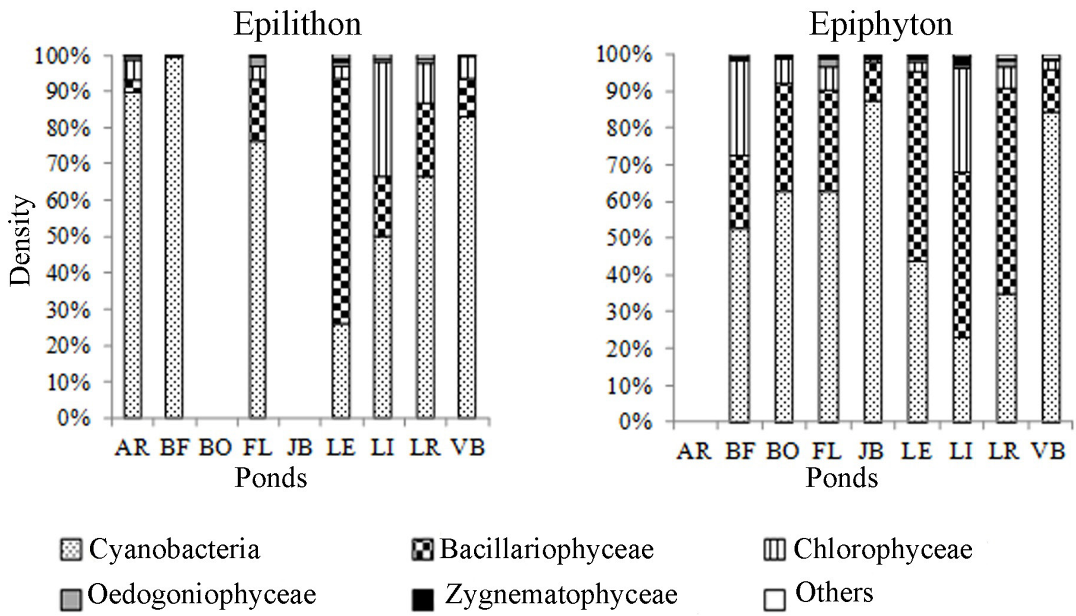

Figure 4. Relative density (%) of periphytic taxonomic classes in nine urban eutrophic ponds from Goiânia, GO (see codes at Table 1).

abundant among Zygnematophyceae. It was the case of *Staurastrum smithii*, *Cosmarium exiguum*, *Mougeotia* sp. 1 and *Mougeotia* sp. 2 (Figure 5).

The Analysis of Similarity (ANOSIM) showed no statistical differences when Zygnematophyceae composition in the epilithon was compared to the one in the epiphyton ($p = 0.18$). According to cluster analysis (Figure 6), similarity among most ponds was around 50%. The ponds FL, AR and LE presented the highest similarities (> 75%), while BF pond was the less similar one (20%).

4. Discussion

The relatively high concentrations reported in the present study for periphytic chlorophyll *a* (general mean 1.9 µg cm^{-2}) must be associated to the eutrophic condition of the nine ponds. These values are comparable to the ones reported for an eutrophic pond located at the Southeast of Brazil (Garças Pond: 0.75 – 4.00 µg cm^{-2}, according to Borduqui et al., 2008; Oliveira et al., 2010; Borduqui & Ferragut, 2012). Going further in the comparison, other ponds classified as oligo (IAG Pond) or mesotrophic (Ninfeias Pond) have been described with smaller chlorophyll *a* concentrations (~0.25 – 0.40 µg cm^{-2}) (e.g., Vercellino & Bicudo, 2006; Ferragut & Bicudo, 2009; Ferragut et al., 2010; Pellegrini & Ferragut, 2012; Souza & Ferragut, 2012; Santos & Ferragut, 2013; Camargo & Ferragut, 2014). Previous works, indeed, had already reported orthophosphate concentrations higher than 50 µg L^{-1} in the nine ponds (Nogueira et al., 2008). Also, the electrical conductivity was far higher than what would be expected in pristine ponds from Cerrado, which is in general lower than 10 µS cm^{-1} (Fonseca et al., 2018). The high phosphorus availability probably favored the photosynthetic biomass accumulation in the periphyton on macrophytes and rocks, since phosphorus is commonly the primary limiting nutrient of algal communities in shallow lakes and tropical reservoirs (Dodds, 2003; Huszar et al., 2005).

Total periphyton density in the urban ponds from Goiânia was relatively high as well. The results reported here were similar to the ones described for other Brazilian eutrophic urban lentic systems, with the predominance of Cyanobacteria, Bacillariophyceae and Chlorophyceae (Borduqui et al., 2008; Cordeiro et al., 2017), and Zygnematophyceae contribution around 1%. In oligo-mesotrophic systems, such contribution has reached around 25% (França et al., 2011; Pellegrini & Ferragut, 2012; Souza & Ferragut, 2012; Santos & Ferragut, 2013; Camargo & Ferragut, 2014). Thus, similar to the chlorophyll *a* accumulation, the periphytic algae density was certainly associated with the high phosphorus availability in eutrophic ponds. In addition, the ponds' sediments release phosphorus to the water

Table 4. Frequency of occurrence (F) of periphytic Zygnematophyceae in nine urban eutrophic ponds from Goiânia, GO.

Taxa	F	Ponds								
		AR	BF	BO	FL	JB	LE	LI	LR	VB
ZYGNEMATALES										
Mesoteniaceae										
Cylindrocystis brebissonii Menegh. ex De Bary var. *minor* West & G.S. West	*		x							
Netrium digitus (Ralfs) Itzigsohn & Rothe var. *digitus*	*						x			x
Netrium oblongum (De Bary) Lütkem. var. *cylindricum* West & G.S. West	*					x				
Zygnemataceae										
Mougeotia sp. 1	****	x		x	x		x	x	x	x
Mougeotia sp. 2	***	x			x	x	x	x	x	
Mougeotia sp. 3	****	x		x	x	x	x	x		x
Spirogyra sp. 1	****	x	x		x	x	x	x		x
Spirogyra sp. 2	**						x	x		x
Spirogyra sp. 3	*						x	x		
DESMIDIALES										
Closteriaceae										
Closterium acutum var. *variabile* (Lemmermann) Willi Kreiger	*				x					
Closterium closterioides Ralfs var. *intermedium* (J. Roy & Bisset) Růžička	*					x				
Closterium dianae Ehrenberg ex Ralfs var. *arcuatum* (Brébisson) Rabenhorst	*				x					
Closterium ehrenbergii Menegh. ex Ralfs var. *ehrenbergii*	*					x				
Closterium leibleinii Kützing *ex* Ralfs var. *leibleinii*	*						x			
Closterium parvulum Nägeli var. *parvulum*	*					x				x
Desmidiaceae										
Actinotaenium cucurbita (Bréb.) Teiling ex Růžička & Pouzar var. *cucurbita*	*				x					
Actinotaenium cf. *diplosporum* (P. Lundell) Teiling var. *americanum* (West & G.S. West) Teiling	*		x							
Actinotaenium inconspicuum (G.S. West) Teiling	*					x				x
Cosmarium abbreviatum Racib. var. *minus* (West & West) Krieger & Gerloff	**	x			x		x		x	
Cosmarium candianum Delponte var. *candianum*	**						x		x	x
Cosmarium exiguum W. Archer var. *exiguum*	**				x	x			x	x
Cosmarium margaritatum (P. Lundell) Roy & Bisset var. *margaritatum*	*			x				x		
Cosmarium moniliforme (Turpin) Ralfs var. *moniliforme*	*				x		x			
Cosmarium obsoletum (Hantzsch) Reinsch var. *obsoletum*	*									x
Cosmarium pseudoconnatum Nordst. var. *pseudoconnatum*	*				x		x			
Cosmarium cf. *pseudoretusum* Ducell.	*				x					
Cosmarium punctulatum Bréb. var. *punctulatum*	*				x		x			
Cosmarium quadrum P. Lundell var. *minus* Nordst.	**	x			x	x	x			
Cosmarium regnellii Wille var. *regnellii*	**					x	x		x	
Cosmarium regnesii Reinsch var. *regnesii*	***	x	x	x	x					x
Cosmarium reniforme (Ralfs) W. Archer var. *reniforme*	*						x			
Cosmarium subgranatum (Nordst.) Lütkem. var. *subgranatum*	**	x			x		x			
Cosmarium tenue W.Archer	*				x					
Cosmarium trilobulatum Reinsch var. *abscissum* (Schmidle) Willi Krieg. & Gerloff	**			x	x	x	x			
Euastrum denticulatum (Kirchner) Gay var. *denticulatum*	*				x					
Euastrum rectangulare F.E. Fritsh & M.F. Rich	*		x							
Hyalotheca cf. *dissiliens* Bréb. ex Ralfs	*								x	
Pleurotaenium trabecula (Ehrenb.) ex Nägeli var. *trabecula*	***	x		x	x		x			x
Staurastrum chaetoceras (Schr.) G.M. Sm. var. *convexum* Gronblad	*		x							x
Staurastrum cf. *excavatum* West & G.S. West	*				x					

*rare; **common; ***frequent; ****constant.

Table 4. Continued...

Taxa	F	Ponds								
		AR	BF	BO	FL	JB	LE	LI	LR	VB
Staurastrum cf. *excavatum* West & G.S. West var. *minimum* C.Bernard	*				x					x
Staurastrum leptocladum Nordst. var. *leptocladum* Nordstedt	*				x					
Staurastrum leptocladum Nordst. var. *cornutum* Wille	*				x					
Staurastrum smithii Teiling	*		x		x					
Staurastrum tetracerum (Kütz.) Ralfs ex Ralfs var. *tetracerum*	**		x		x					x
Staurastrum volans West & G.S.West	**		x					x	x	
Staurodesmus pterosporus (P.M.Lundell) Bourrelly	*		x					x		
Gonatozygaceae										
Gonatozygon kinahanii (W. Archer) Rabenh. var. *kinahanii*	**			x		x			x	
Gonatozygon monotaenium De Bary ex Rabenh. var. *monotaenium*	*			x						

*rare; **common; ***frequent; ****constant.

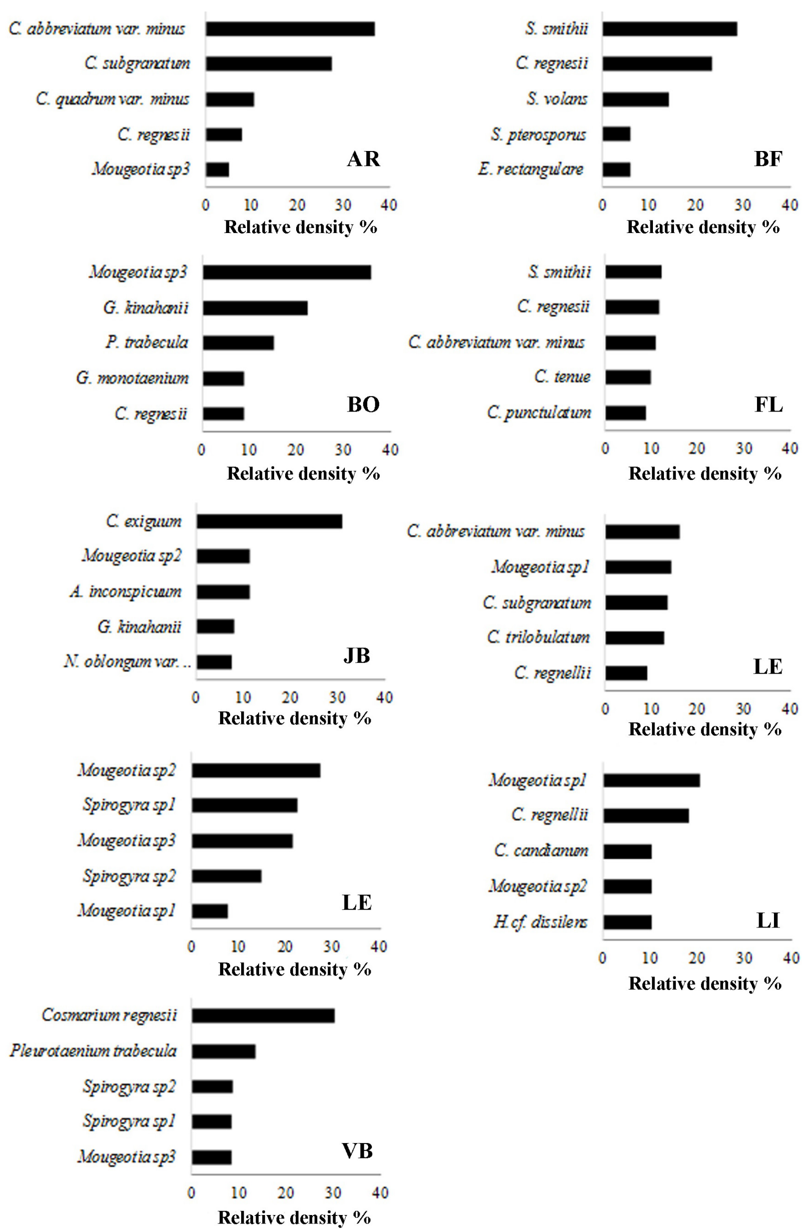

Figure 5. Relative density (%) of the five most abundant taxa among periphytic Zygnematophyceae in nine urban eutrophic ponds from Goiânia, GO (see codes at Table 1).

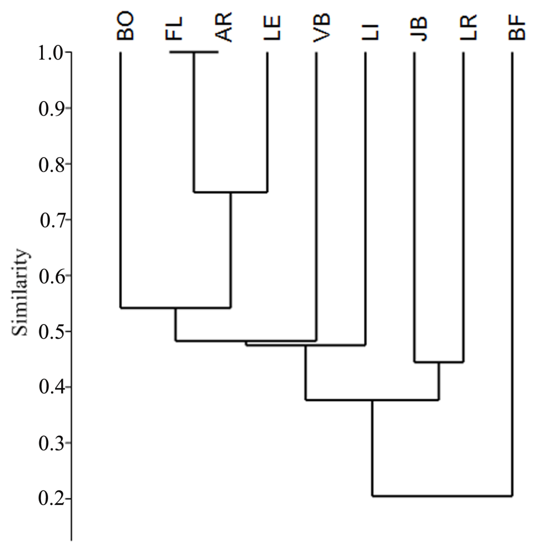

Figure 6. Similarity of the epiphytic and epilithic algae composition (Simpson Index) in nine urban eutrophic ponds from Goiânia, GO.

column (Søndergaard et al., 2003), which may have favored the development of the periphyton on macrophytes and rocks, mainly due to the small depth of the ponds.

None of the community structure parameters reported in the present study showed statistical differences between epiphyton and epilithon. Some authors have shown that other factors like spatial distance between localities and environmental variables may be more important for periphytic communities than the substrate itself (Pals et al., 2006). Concerning macrophytes, Mutinová et al. (2016) explored the role of combined effects of environmental factors and host specificity on epiphyton community structure and concluded that the influence of different macrophytes was site-specific; although some plant species such as the moss *Sphagnum* L. supported a remarkably different epiphytic community, most macrophytes showed a neutral effect. Mosses like *Sphagnum* were not among the substrates for periphyton in the studied urban eutrophic ponds. Our results suggest that the community structure of Zygnematophyceae algae was influenced by local features unrelated to substrate differences between macrophytes and rocks.

Pals et al. (2006) and Mutinová et al. (2016) found relatively negligible effects of environmental factors, such as pH and conductivity, on algal community structure in oligo-mesotrophic environments from Europe. These variables are recognized as important driver factors on desmid communities (Gerrath, 2003). However, their influence is not so evident when ecosystems with the same trophic status are compared, especially in the oligo-mesotrophic zone of the trophic spectrum (Mutinová et al., 2016). In the present study, the first axis of PCA ordinated the two ponds with the highest Zygnematophyceae density (FL and LE ponds) in the opposite direction to the electrical conductivity vector, which agrees with the ecological preference of this algal group for waters with low conductivity (Gerrath, 2003). Considering the cluster analysis, FL and LE ponds were grouped with the highest species composition similarity (75%). The AR pond, although with a relatively high electrical conductivity and lower Zygnematophyceae richness, also presented high similarity with FL pond. It probably happened because the Simpson Index used in the analysis is independent of differences in local richness (Lopes et al., 2014), and the species present in AR pond were all in FL pond as well.

Regarding the species reported in the studied urban ponds, most of them have been listed as typical from eutrophic environments, such as *Closterium acutum* var. *variabile*, *Closterium ehrenbergii* var. *ehrenbergii, Pleurotaenium trabecula* var. *trabecula, Cosmarium regnellii* var. *regnellii, Cosmarium regnesii* var. *regnesii, Cosmarium subgranatum* var. *subgranatum, Gonatozygon monotaenium* var. *monotaenium, Staurastrum tetracerum* (Coesel, 1975; Brook, 1982). The taxon *Staurastrum volans* was reported here and by Nogueira et al. (2008) for the ponds Jardim Botânico (JB), Vaca Brava (VB) and Lago das Rosas (LR). Other studies conducted in eutrophic environments have cited this species as well (Domingues & Torgan, 2011). The same happened for *Pleurotaenium trabecula* var. *trabecula* (Domingues & Torgan, 2011), *Closterium acutum* var. *variabile* (Domingues & Torgan, 2011), *Cosmarium tenue* (Šťastný, 2009, as *Cosmarium* cf. *tenue*). On the other hand, *Cosmarium regnesii* var. *regnesii, Cosmarium quadrum* var. *minus* and *C. abbreviatum* var. *minus* has been reported for both eutrophic (Coesel, 1975) and oligotrophic systems (Estrela et al., 2011), suggesting that some desmid taxa present high ecological tolerance concerning the trophic spectrum.

In summary, the nine eutrophic ponds considered in this study presented high periphytic biomass, but with low Zygnematophyceae representativeness in both epiphyton and epilithon. The periphyton attributes (chlorophyll *a*; Zygnematophyceae density, composition and richness) were not significantly different between macrophytes and rocks. We concluded that substrate type was not a determinant factor for Zygnematophyceae periphytic algae in the studied ponds.

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