Taxonomy of common taxa of Chlorophyceae (Chlorophyta) and Zygnematophyceae (Streptophyta) from periphyton of a Neotropical floodplain

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ABSTRACT. Some orders of algal groups such as Chlorophyceae and Zygnematophyceae have been reported as frequent taxa in periphytic communities of wetlands. The present study aimed at submitting these algal members which occurred in high abundance and frequency in the periphyton of 30 environments of the Upper Paraná River floodplain to a taxonomic survey and to present some ecological data concerning their richness. Periphyton were collected from petioles by scraping of Eichhornia azurea (Sw.) Kunth and preserved with Lugol acetic solution in the Upper Paraná River, Brazil, during high water period in March 2010. Taxa were counted in inverted microscope and those higher than 2,500 individuals in density with frequency of occurrence less than 50% simultaneously in the 30 environments sampled were subjected to a detailed taxonomical treatment under optical microscope coupled to a light camera and ocular micrometer under 1000x. Identifications and descriptions were made according to the algal literature. Some abiotic data were shown. Fifteen taxa belonging to the classes Chlorophyceae and Zygnematophyceae were abundant representing 64.6% of the total density. A Procruste analysis within a Detrended Correspondence Analysis showed that distribution pattern of richness of chlorophyceans and zygnematophyceans was represented by common species of these communities, highlighting the importance of knowing about these algae taxonomy.

Keywords: chlorophyceans; desmids; periphytic community; richness; Upper Paraná River

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Introduction

Periphyton community displays high algal species richness and diversity (França, Lopes, & Ferragut, 2011). The morphological structure and the taxonomical diversity of the periphytic communities are strongly related to abiotic factors e.g., physical and chemical variables (Villeneuve, Montuelle, & Bouchez, 2010). In most cases this community can be regulated by a few species with high abundance and wide frequency of occurrence, thus playing an important ecological role (Gaston, 2011). Common species, unlike rare species, present a broad environmental range (i.e., generalists) and evaluation of parameters governing distribution of these common species may help the knowledge of the general patterns influencing the spatial variation of biodiversity (Tonial et al., 2012).

Although periphyton algal community of the Upper Paraná River floodplain has been studied in various aspects (Murakami, Bicudo, & Rodrigues, 2009; Biolo & Rodrigues, 2011b; Neif, Behrend, & Rodrigues, 2013; Carapunarla, Baumgartner, & Rodrigues, 2014; Dunck, Rodrigues, & Bicudo, 2015; Bichoff, Osório, Dunck, & Rodrigues, 2016; Algarte, Siqueira, Ruwer, Osório, & Rodrigues, 2017a; Zanon, Marco, & Rodrigues, 2018, Adame, Dunck, & Rodrigues, 2018), knowledge about green microalgae mainly ecology as chlorococcaleans and desmids from this ecosystem is still incipient. Members of algal orders such as Chlorococcales and Desmidiales have been reported as frequent taxa in the periphytic communities of that floodplain (Murakami et al., 2009; Biolo & Rodrigues, 2013). These groups may contribute to characterizing the periphyton community from the Upper Paraná River floodplain exhibiting high species richness (Algarte, Rodrigues, Landeiro, Siqueira, & Bini, 2013; Bichoff et al., 2016) and abundance (Biolo & Rodrigues, 2015; Neif et al., 2015), mainly during high water periods. Furthermore, studies have been concentrated on evaluating linear relations between the taxonomic variable and environmental factors, which could not accurately represent the biological conditions (DeNicola & Kelly, 2014).
The Upper Paraná River floodplain is an important center of biological diversity in Brazil, where preservation and conservation are priorities for this wetland (Algarte, Siqueira, Murakami, & Rodrigues, 2009). In this context, taxonomic surveys of periphytic algal communities can provide valuable information and it is indispensable. Taxonomic data concerning description of periphytic taxa for the Upper Paraná River floodplain are only presented for Cyanobacteria (Fonseca & Rodrigues, 2005), for xanthophyceans and euglenoids (Biolo & Rodrigues, 2011a), for dominant algal species in an open lake (Biolo & Rodrigues, 2011b) and for a diatom genus, Gomphonema Ehrenberg (Osório, Tremarin, Ludwig, & Rodrigues, 2017).

Therefore, in the present study we aimed at carrying out a taxonomy treatment of chlorophyceans and desmids which occurred in high abundance and frequency in 30 environments of the Upper Paraná River floodplain. We also have shown some ecological data concerning how richness of those groups behaved in the periphytic community.

Material and methods

The Upper Paraná River floodplain in Brazil is located between Mato Grosso do Sul and Paraná States (22°40'-22°50'S and 53°10'-53°24'W). The study was conducted including 30 different environments of this floodplain: 12 areas belonging to the Ivinhema River subsystem; 12 areas of the Baía River subsystem; and six of the Paraná River subsystem (Figure 1).

Periphyton samples were collected at each sampling site during high water period in March 2010, the period of study which was chosen for sampling by the highest species richness of periphytic community according to earlier studies (Algarte et al., 2017b). Periphyton was removed from two petioles of the macrophyte Eichhornia azurea (Sw.) Kunth by scraping with a stainless-steel blade and jets of distilled water. Substrate is an abundant and persistent aquatic macrophyte in the studied environment and thus was chosen as the standard substrate for sampling. Periphytic material collected was placed in Wheaton flasks (150 mL) preserved with Lugol acetic solution (Bicudo & Menezes, 2017) and were deposited in the...
Common Chlorophyceae and Zygnematophyceae in periphyton

Herbarium at the Universidade Estadual de Maringá (HUM) under the numbering registers 28702-28726.

Qualitative analysis of taxa was made under optical microscope coupled to a light camera and ocular micrometer under 1000x and identifications were made as possible at the lowest taxonomic level, according to the classical and regional literature (e.g., Croasdale & Flint, 1986, 1988; Prescott, Croasdale, Vinyard, & Bicudo, 1980; Komárek & Fott, 1983; González, 1996; Domingues & Torgan, 2012; and others). Taxa higher than 2,500 individuals in density simultaneously with frequency of occurrence higher than 50% in the 30 environments were subjected to the taxonomical treatment.

Daily water-level data were obtained from Porto São José (22°43'00"S and 53°10'00"W), from February to March 2010 and are available at http://www.peld.uem.br/. Following variables were measured in the field: water temperature (° C; YSI thermistor coupled to an oximeter), electrical conductivity (µS cm⁻¹), total suspended matter (µg L⁻¹). Water samples were filtered through Whatman GF/F filters, under low pressure (<0.5 atm) and stored at −20° C for later determination of the concentrations (µg L⁻¹) of dissolved fractions of phosphorus (Mackereth, Heron, & Talling, 1978) and nitrogen (Koroleff, 1976; Giné, Bergamin, Zagatto, & Reis, 1980). Abiotic data were transferred by the Laboratory of Limnology at the NUPELIA (Núcleo de Pesquisa em Limnologia e Aquicultura).

To assess the level of whether the community of chlorophyceans and zygnematophyceans can be represented by common species, it was verified the congruence between ordinations which were carried out with common taxa and total using the Procruste (Jackson, 1993; Peres-Neto & Jackson, 2001). We used the randomization procedure of Monte Carlo (9999 with randomization) to assess their validity. Results of the Procrustes analysis (m2) were subjected to square root of their complements (r = √(1-r)). Thereby values close to 1 indicate greater similarity between the patterns of order and values close to zero greater dissimilarity between these standards. A Detrended Correspondence Analysis (DCA) was applied to show how those results behaved in our study.

**Results and discussion**

It was recorded a total of 208 taxa belonging to Chlorophyceae and Zygnematophyceae in the 30 sampled environments at the Upper Paraná River floodplain. Fifteen taxa of this total were abundant and occurred widespread. These taxa represented 64.6% of the total density and were submitted to a taxonomical treatment, classified and described in the present study as follows:

**CHLOROPHYTA**

Class Chlorophyceae

Order Chlorococcales

Family Chlorelaceae

*Ankistrodesmus falcatus* (Corda) Ralfs, Brit. Desm., 180, pl. 34, figures a-c. 1848. (Figure 2A)

Colonies composed of 1-2 fascicles with 5 cells irregularly arranged, cells 2 times longer than wide, 13.9-17.8 µm long, 0.8-1 µm wide; long, fusiform, falcate cells, slightly arched, cells joined by contact of the convex middle region; single, parietal chloroplast without pyrenoid.

Notes: Our specimens presented cellular dimensions lower than those described by González (1996), but description of cell morphology agrees with that presented by Komárek and Fott (1983). Present taxon is common in calm waters with low concentration of nutrients, in phytoplankton and periphyton (Ramos, Bicudo, Gôes Neto, & Moura, 2012).

*Ankistrodesmus fusiformis* Corda ex Korsikov, Protococcinea: 300, fig. 263. 1953. (Figure 2B)

Colonies composed of 2-4 cells, cells radially or crucially arranged, 27-30 times longer than wide, 36.4-48.6 µm long, 1.2-1.8 µm wide; elongated-fusiform cells, straight or slightly arched, gradually tapered towards the apex; single, parietal chloroplast without pyrenoid.

Notes: A. fusiformis is related to A. spiralis which the first differs by its crossed disposition of cells instead of twisted cells in the second. Our populations agree with that presented by Komárek and Fott (1985). It is considered a cosmopolitan taxon in phytoplankton and periphyton (Ramos et al., 2012).

*Monoraphidium arcuatum* (Korsikov) Hindák, Alg. Stud. 1: 25. 1970. (Figure 2C)

Cells solitary, 7 times longer than wide, 32-33 µm long, 4.5-5 µm wide; fusiform cells, arched, sometimes sigmoid, gradually tapered towards the apex; single, parietal chloroplast without pyrenoid.

Notes: M. arcuatum resembles M. indicum Hindák which the last is smaller and less rounded and curved...
than the first (Ramos et al., 2012). It is easily identified by the arcuated cells. Komárek and Fott (1983) and González (1996) stated the cosmopolitan distribution of this taxon in high nutrients concentration waters, from phytoplankton, metaphyton and periphyton (Ramos et al., 2012).

**Monoraphidium contortum** (Thuret) Komárek-Legnerová, Stud. Phycol. 104. 1969. (Figure 2D)

Cells solitary, 5 times longer than wide, 9-11 $\mu$m long, 1-2 $\mu$m wide; fusiform cells, spiraled, with 1-1.5 spirals, gradually tapered towards the apex, acuminate poles; single, parietal chloroplast without pyrenoid.

Notes: *M. contortum* is morphologically similar to *M. irregulare* (G.M. Smith) Komárková-Legnerová, but the first presented more sigmoid cells and larger cell dimensions. It is a cosmopolitan taxon, very common in waters with different trophic conditions (Ramos et al., 2012).

**Closteriopsis acicularis** (Chodat) Belcher & Swale, Brit. Phycol. Bull., 2(3): 152. 1962. (Figure 2E)

Cells solitary, 43.5-53 $\mu$m long, 4.7-7.3 $\mu$m wide; very long, spiniform cells, straight or slightly arched, tapering to sharp points at both ends; single, parietal chloroplast, with an axial row of 2-4 pyrenoids and an indentation in the middle region of cell.

Notes: Cosmopolitan. Associated with plants and in the phytoplankton (John & Tsarenko, 2002), as in the present study in the periphyton.

Family Oocystaceae

**Oocystis lacustris** R. Chodat, Bull. Herb. Boissier 5. 119, pl. 10, fig 1-7. 1897. (Figure 2F)

Colonies composed of 2-4-8 cells irregularly disposed in an hyaline, conspicuous mucilage; cells 1.4-1.6 times longer than wide, 17-25.5 $\mu$m long, 10-16 $\mu$m wide; ellipsoid cells, with rounded poles, polar thickening absent; 1-2 parietal chloroplasts, with 1 pyrenoid.

Notes: Present taxon is morphologically similar to *O. parva* West & G.S.West, which differs by the larger dimensions and the presence of the mucilaginous sheath in the first (Komárek & Fott, 1983).

**STREPTOPHYTA**

Class Zygnematophyceae

Order Desmidiales

Family Closteriaceae

**Closterium incurvum** Brébisson, Mém. Soc. Imp. Sci. Nat. Cherbourg, 4: 150, pl. 2, fig. 47. 1856. (Figure 2G)

Cells solitary, small to large, 5-7 times longer than wide, 38.8-97.2 $\mu$m long, 7.2-10.2 $\mu$m wide, strong curvature (140-160° of arc); convex dorsal margin, concave ventral margin, rounded-acuminate poles; cell wall hyaline to brown, with or without polar thickening, single, axial chloroplast, with 4-5 pyrenoids arranged in a line.

Notes: Present variety differs from the typical of species by its smaller dimensions, lateral angles less rounded and not pronounced (Felisberto & Rodrigues, 2010).

**Cosmarium abbreviatum** ex Ralfs by having more pronounced curvature of cell and acuminate poles (Oliveira, Bicudo, & Moura, 2013).

Family Desmidieae

**Cosmarium laeve** Rabenhorst, Öf. Kongl. Vet.-Akad. Förhandl., 6: 29, pl. 12, fig. 4. 1876. (Figure 2J)

Cells 1.3 times longer than wide, 15-16 $\mu$m long, 11-12 $\mu$m wide, deeply constricted at the middle, linear
median sinus, closed, dilated at the apex; semicircular to subpyramidal semicells, slightly angular, convex lateral margin, narrow apical margin, truncate; finely punctuated cell wall, hyaline, 1 chloroplast, axial, 1 pyrenoid, central.

Notes: Cells with larger sizes can be confused with *C. granatum* Brébisson ex Ralfs, although the first taxon has a less rounded cell and smaller cell width (Felisberto & Rodrigues, 2010).

*Cosmarium* regnellii Wille var. *pseudoregnellii* (Messikommer) W. Krieger & Gerloff, *Die Gattung Cosmarium* 5-4: 247, pl. 43, fig. 6. 1969. (Figure 2K)

Cells 1.03 times longer than wide, 17.39 µm long, 16.73 µm wide, deeply constricted at the middle, linear median sinus, closed, dilated at the apex; subtrapezoidal semicells, parallel lower side edge or slightly divergent, almost rectangular lower angles, sometimes slightly oblique, rounded, rounded upper corners, truncated apical margin straight to slightly concave; smooth cell wall, hyaline, 1 chloroplast, axial, 1 pyrenoid, central.

Notes: This variety differs from typical to present the lateral margins of semicell never straight in the middle and apical margin relatively wide (Felisberto & Rodrigues, 2010).
Although periphyton community displays high algal species richness and diversity (Biolo & Rodrigues, 2013; Algarte et al., 2017a), identifying the spatial (and also temporal) pattern in composition of periphytic algae is fundamental to the knowledge of its biodiversity (Svoboda, Kulichová, & St’astny, 2013). It is known that periphyton dynamics is related to climatic, hydrodynamic and abiotic variables (Larned, 2010). In our study, *Cosmarium regnesi* and C. *abbreviatum* were characteristic in environments with high conductivity and inorganic nitrogen contents related to the Paraná subsystem. *Cosmarium regnesii*, *Staurastrum micron*, *Euastrum rectangulare*, *Ankistrodesmus fusiiformis* and *Monoraphidium arcuatum* occurred in deeper environments with higher temperatures and with higher levels of orthophosphate related subsystem Ivinhema. *Closterium incurvum*, *Ankistrodemus falcatus* and *Monoraphidium contortum* preferentially occurred in more transparent waters related to Baía subsystem. Other taxa occurred under wide environmental conditions.

### Table 1. Abiotic data of 30 environments sampled during the study period.

<table>
<thead>
<tr>
<th>Abiotic data</th>
<th>Min.</th>
<th>Max.</th>
<th>Mean</th>
<th>CV(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water temperature (° C)</td>
<td>27.4</td>
<td>31.5</td>
<td>28.75</td>
<td>2.68</td>
</tr>
<tr>
<td>Conductivity (µS.cm⁻¹)</td>
<td>24</td>
<td>70.2</td>
<td>46.5</td>
<td>31.33</td>
</tr>
<tr>
<td>Total Suspended Matter (mg.L⁻¹)</td>
<td>0.22</td>
<td>7.25</td>
<td>1.14</td>
<td>125.86</td>
</tr>
<tr>
<td>Inorganic nitrogen (µg.L⁻¹)</td>
<td>0.05</td>
<td>360.4</td>
<td>68.9</td>
<td>150.38</td>
</tr>
<tr>
<td>Total phosphorus (µg.L⁻¹)</td>
<td>13.9</td>
<td>68.45</td>
<td>35.48</td>
<td>35.09</td>
</tr>
</tbody>
</table>
Figure 3. Water level in the Upper Paraná River floodplain in February and March 2010. The dashed line indicates the sampling period.

It was performed a DCA (Figure 4) with the frequent taxa of desmids and chlorococcaleans found in our study, to preview how data could behave, according to tendencies in current studies about investigations on partitioned richness. According to the result obtained by Procrustes ordination based on data from common species, a high congruence with the ranking based on all taxa was shown ($r = 0.71; p < 0.001$). This indicates that the distribution pattern of chlorophyceans and zygnematophyceans is represented by common species of these communities. Our results meet those reported by Lennon, Koleff, Greenwood, and Gaston (2004) with birds. According to them, low richness is better explained by common species than high richness by a group of rare species with the same size.
By comparing the two algal groups - zygnematophyceans and chlorophyceans - worldwide, it was observed that desmids are better known in its distribution or occurrence than other green algae, mainly because of the difficulty to identify coccoid forms of chlorococcaleans (Coesel & Krienitz, 2008). In this way, we focused on the taxonomical recording of these two frequent groups in the Paraná River floodplain in the present study.

Conclusion

We encourage taxonomic researches for the knowledge of biodiversity of the neotropical areas and tendency of more studies concerning how the richness of individual groups combine to produce the overall variation that could be observed in nature, creating diversity patterns, using data about common species.

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