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Composition and taxonomic similarity of the periphytic algal community in different natural substrates in a neotropical floodplain, Brazil

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The present study investigated the species composition and taxonomic similarity of periphytic algae on three species of macrophytes (*Eichhornia azurea* Kunth, *Nymphaea amazonum* Martius & Zuccarini and *Oxycaryum cubense* (Poeppig & Kunth) Lye) and also some limnological variables in a lake permanently connected to the Paraná River at the Upper Paraná River floodplain, Brazil, from June 2008 to March 2009. During the study period, the Paraná River showed irregular flood pulses and indistinct hydrological periods. In this same period, 406 taxa of periphytic algae were identified, distributed mainly in the classes Zygnemaphyceae, Bacillariophyceae, Chlorophyceae; and Cyanobacteria. Similarity analysis based on taxonomic composition of sampling periods and substrates showed low values and primarily represented a temporal segregation of periphytic algal community, mainly in June 2008 from others. Secondly, the microespacial segregation occurred to a lesser extent, according to the type of substrate, especially between *O. cubense* and others. It comprises first steps for understating the comparative structure of periphytic algal community in these distinct substrates at the Paraná River floodplain.

Key words: Community structure, epiphyton, macrophyte, periphyton ecology, wetlands.

INTRODUCTION

Macrophytes consist of important centres for maintenance of the aquatic biodiversity (Mormul et al., 2010), with emphasis on periphyton, since they promote the availability of large surface area for colonization of this attached community (Algarte et al., 2009). Morphoanatomical characteristics of such substrates increase spatial heterogeneity and can determine composition, abundance, biomass and productivity of the periphyton communities(Stevenson, 1997; Hinojosa-Garro et al., 2010).

Previous studies have shown that the taxonomic composition of periphyton communities can differ in distinct

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naturalsubstrates(Jonesetal.,2000).However,thestructure and dynamics of periphyton in floodplains are mainly influenced by flood pulses. Variation of the hydrometric levels, the hydrological periods and other features related to the hydrological regime of the river and its adjacent environments can alter the species composition of periphyton, as previously revealed in studies developed in the Upper Paraná River floodplain (Rodrigues et al., 2003; Rodrigues and Bicudo, 2001; 2004; Algarte et al., 2006; 2014). Nonetheless, these studies have focused on the periphytic communities from a unique natural substrate, the macrophyte *Eichhornia azurea* Kunth.

There are only few comparative studies on the composition and periphyton similarity between different substrates at the Paraná River floodplain. In the low region of this floodplain,TesolínandTell(1996)investigated the periphytic community of four species of floating aquatic macrophytes from a connected lake in Argentina. Richness of taxa in this region is very low, with only 26 taxa recorded by these authors. At the upper portion of the floodplain, Neif et al. (2013) analyzed the periphyton structure from two macrophytes, *E. azurea* and *Egeria najas* Planch - of a lake, both submerged macrophytes. Regarding macrophytes covered in the present study, *Nymphaea amazonum* Martius & Zuccarini and *Oxycaryum cubense* (Poeppig and Kunth) Lye, knowledge of the composition and similarity of periphyton is still scarce, with previous data published related to the specific richness and density of periphytic communities in these macrophytes (Biolo and Rodrigues, 2013) as part of the major project which originated this study.

Therefore, the present study aimed to investigate the composition and taxonomic similarity of periphytic algal communities attached on three aquatic macrophytes with different growth forms (*E. azurea*, emergent; *N. amazonum*, fixed floating; and *O. cubense*, epiphyte) in a permanent connected lake at the Upper Paraná River floodplain. Since diversity of macrophytes was an important factor which influences the periphytic community in this floodplain (Murakami et al., 2009), we expect that the taxonomic composition and similarity of periphytic algae in distinct substrates will be different under similar environmental conditions.

MATERIALS AND METHODS

Study area and periphyton sampling

The “Pau Véio” Lake is an open lake with a permanent connection to the Paraná River, located in the Paraná River Floodplain, between the States of Paraná and Mato Grosso do Sul, Brazil (22°44'S - 53°15'W). Sampling of the periphytic community was performed quarterly between June 2008 and March 2009, comprising two hydrological periods (high water, November to May; and low water, June to October).

Natural substrates for collecting periphyton consisted of macrophyte petioles in the adult stage of the following species (and ecological groups), according to Irgang et al. (1984): *E. azurea* Kunth (emerging) and *N. amazonum* Martius & Zuccarini (floating fixed), and the stem of *O. cubense* (Poeppig and Kunth) Lye (epiphyte). In *O. cubense*, the leaf sheath involved in the region of stem was also sampled.

Selection of substrates was done as follows: their presence in a same bank, presence of multi-species under similar environmental conditions, and in all sampling periods. In addition to presenting similar morphostructural characteristics, we attempted to standardize sampling methodologies (which could be equally applied to all substrates according to their morphology). We also aimed to supply the lack of studies of the periphytic community encompassing the last two substrates cited in the Paraná River floodplain.

Substrates collected consisted of replicates (n=2). For removal of the periphytic community of substrates, a steel blade coated on an aluminum sheet with the aid of jets of distilled water was used. Material designated to qualitative analysis was fixed in Transeau solution. Periphytic algae were identified under optical microscope based on classical and regional bibliographies.

Abiotic variables sampling

Abiotic variables were simultaneously measured during the collection of biological material and corresponded to: water temperature and dissolved oxygen (oximeter YSI model 55 laptop brand), pH (portable pH meter model Digimed DM2), electrical conductivity (Conductivity Digimed laptop model DM2), alkalinity (Carmouze, 1994), transparency of the water column (Secchi disk), turbidity (portable turbidimeter model Lamotte), total solids, organic and inorganic fractions (Wetzel and Likens, 1991), total nitrogen and nitrate (Bergamin et al., 1978; Giné et al., 1980), ammonia nitrogen (Mackereth et al., 1978), and total phosphorus (Mackereth et al., 1978) and phosphate (Mackereth et al., 1978). For analysis of the fraction of dissolved nutrients and suspended solids determination, we filtered samples using Whatman GF-C 52 filters (Golterman et al., 1978). Data of the hydrometric level of Paraná River were obtained by the measurement of the rule relating to the São José Port, Paraná. Abiotic data were ceded by the Laboratory of Limnology, at NUPELIA (“Núcleo de Pesquisas em Limnologia Ictiologia e Aquicultura”) and other details about the sampling methodology are shown in Roberto et al. (2009).

Data analysis

The species composition of the periphytic algae was evaluated based on the similarity of communities between different natural substrates (*E. azurea, N. amazonum* and *O. cubense*) and sampled months (June, September and November 2008 and March 2009). This attribute was measured by cluster analysis using criterion of presence and absence of species by Jaccard index (determination of index of similarity between communities and the index of species association) consistent with the coefficient of cophenetic correlation (e.g., the Pearson correlation coefficients between the elements of the dissimilarity matrix and the elements of cophenetic matrix). Data was analysed through ANOSIM method with 999 permutations (similarities between two or more groups of sampling units (factors) were compared), resulting in a statistic R which ranges between -1 (similar) and +1 (dissimilar) (Clarke and Gorley, 2001). All analyses were performed by the R statistical software version 3.0.0 (R Core Team, 2013).

RESULTS

Abiotic data in the Pau Véio Lake analyzed during the study period are shown in Table 1 and the hydrometric

Table 1. Abiotic data from the Pau Véio lake, at the Upper Paraná River floodplain, in the period of study June 2008 to March 2009 (Biolo and Rodrigues, 2013).

Parameter	June	September	November	March
Temperature (°C)	19.4	20.9	27.1	28.5
Dissolved oxygen (mg.L^{-1})	6.15	4.31	2.59	5.22
pH	6.83	6.55	6.62	6.91
Conductivity (µS.cm^{-1})	56.7	59.3	59.9	58.8
Alkalinity (µEq L^{-1})	468	457.5	387.2	410.4
Mean hydrometric level (m)	2.95	2.55	2.39	3.16
Transparency (Secchi) (m)	3.1	2.2	2	2.25
Turbidity (NTU)	3.33	-	2.28	3.63
Total solid material (µg.L^{-1})	2.1	0.6	0.75	1.88
Total nitrogen (µg.L^{-1})	227.5	368.1	495.2	1000.9
Nitrate (µg.L^{-1})	135.8	97.9	45.8	120.7
Ammoniacal nitrogen (NH_4^+)	4.9	2.6	19.3	7.26
Total phosphorus (µg.L^{-1})	13.2	12.1	18.6	20.6
Orthophosphate (µg.L^{-1})	4.9	3.7	13.8	5.5

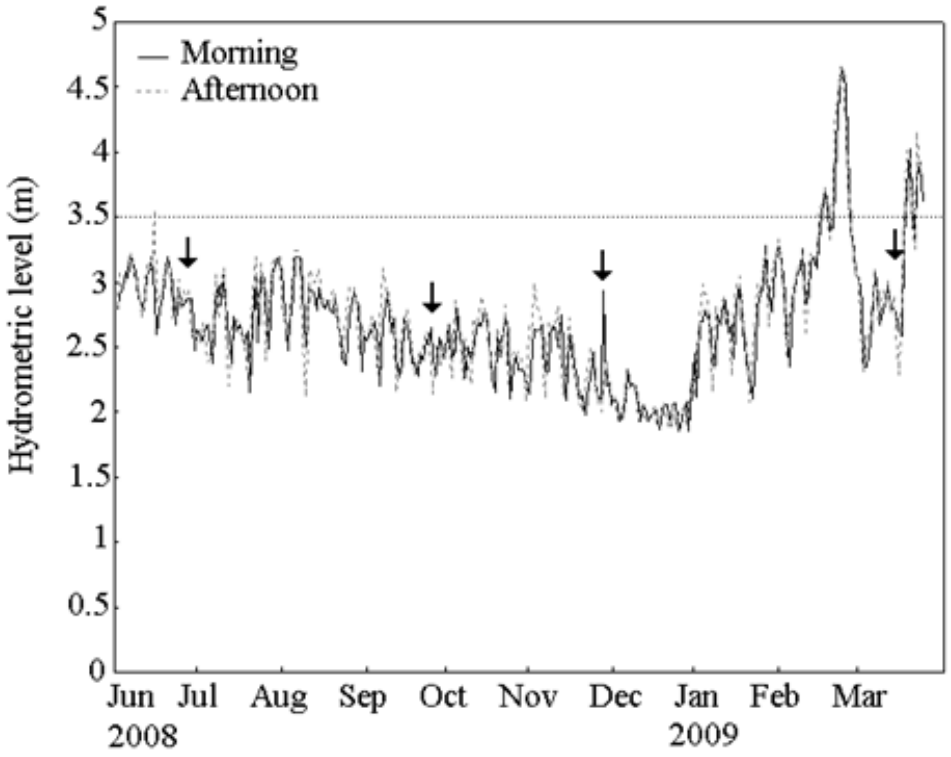

Figure 1. Hydrometric level at the Paraná River, at the Upper Paraná River floodplain in the period of study, June 2008 to March 2009 (Biolo and Rodrigues, 2013).

level of the Paraná River floodplain in Figure 1. The year 2008 was irregular in respect of the hydrological periods (high water and low water, with the prevalence of flood pulses with low intensity and low values of hydrometric levels throughout the year (Roberto et al., 2009; Biolo and Rodrigues, 2013). In 2009, floodpulses were more intense and hydrometric levels reached peaks above the level of overflow in February 2009 (between 3.53 and 4.65 m), characterizing the high water period of the floodplain.

The species composition of the periphytic algal community present in the three macrophytes and months

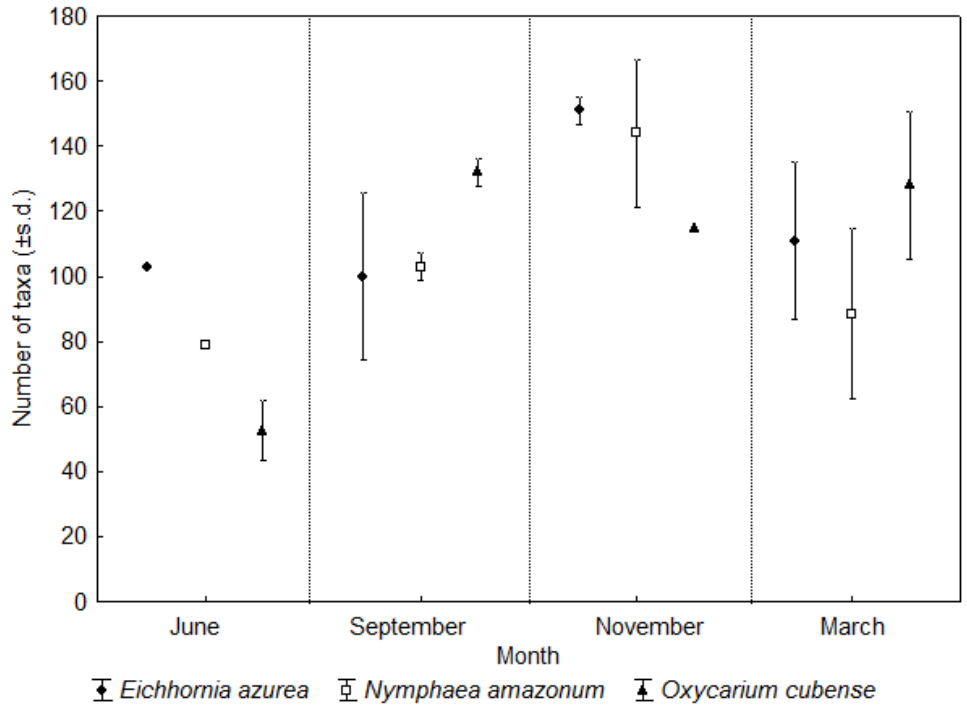

Figure 2. Number of periphytic algal taxa for each substrate and sampling period in the "Pau Véio" lake, at the Paraná River floodplain.

totaled 406 taxa belonged to 139 genera and 11 classes: Zygnemaphyceae (114), Bacillariophyceae (86), Chlorophyceae (66), Xanthophyceae (24), Euglenophyceae (23), Chrysophyceae (14), Oedogoniophyceae (9), Cryptophyceae (7), Rhodophyceae (3), Chlamydophyceae (1) and Dinophyceae (1); and Cyanobacteria (58). Figure 2 shows the distribution of main groups over the sampled periods and substrates.

Some species were present in all periods and substrates and corresponded to: *Achnanthidium minutissimum* (Kützing) Czarnecki, *Cymbella affinis* Kützing, *Encyonema mesianum* (Cholnoky) D. G. Mann, *Eunotia intermedia* (Krasske) Nörpel and Lange-Bertalot, *Fragilaria capucina* Desmazières, *Fragilaria tenera* (W.Smith) Lange-Bertalot, *Gomphoneis clevei* (Fricke) Gil, *Gomphonema brasiliense* Grunow, *Gomphonema gracile* Ehrenberg, *Nitzschia linearis* W. Smith, *Nitzschia palea* (Kützing) W. Smith and *Ulnaria ulna* (Nitzsch) P.Compère (Class Bacillariophyceae), *Desmodesmus brasiliensis* (Bohlin) E. Hegewald (Class Chlorophyceae), *Aphanocapsa parasitica* (Kützing) Komárek and Anagnostidis, *Leibleinia epiphytica* (Hieronymus) Compère and *Leptolyngbya perelegans* (Lemmermann) Anagnostidis & Komárek (Cyanobacteria), *Oedogonium* sp. (Class Oedogoniophyceae) and *Tetraedriella* cf. *jovetii* (Bourrelly) Bourrelly (Class Xanthophyceae).

Differences in composition of the periphytic algal communities from substrates and sampled periods were summarized by similarity dendrogram based on the Jaccard Similarity Index (r = 0.787, coefficient of cophenetic correlation) (Figure 3) and ANOSIM (Figure 4). The similarity coefficients ranged from 0.50 to 0.65, indicating a low similarity flora; similarity differences showed by ANOSIM suggest substantial dissimilarities in composition of the periphytic algal community between periods (R = 0.574, p = 0.002), but not between substrates (R = -0.183, p = 0.935). Firstly, a temporal division of periphytic communities in two large clusters was observed (Figure 3, Group I), related to the sampled period (June 2008 from the other). Segregation of periphytic communities mainly between September 2008 (Figure 3, Group II) and the months November 2008 and March 2009 (Figure 3, Group III) were observed. There was an apparent separation of periphytic algal communities related to the type of substrate, mainly from *O. cubense* and the other.

DISCUSSION

The "Pau Véio" lake was richly represented by periphytic algae in all sampled periods and substrates. The species composition of periphytic algae can indicate the abiotic conditions and the spatial and temporal heterogeneity in each environment (Rodrigues et al., 2003). Despite the fact that some dominant taxa were registered in all periods and substrates, the majority contributed to the

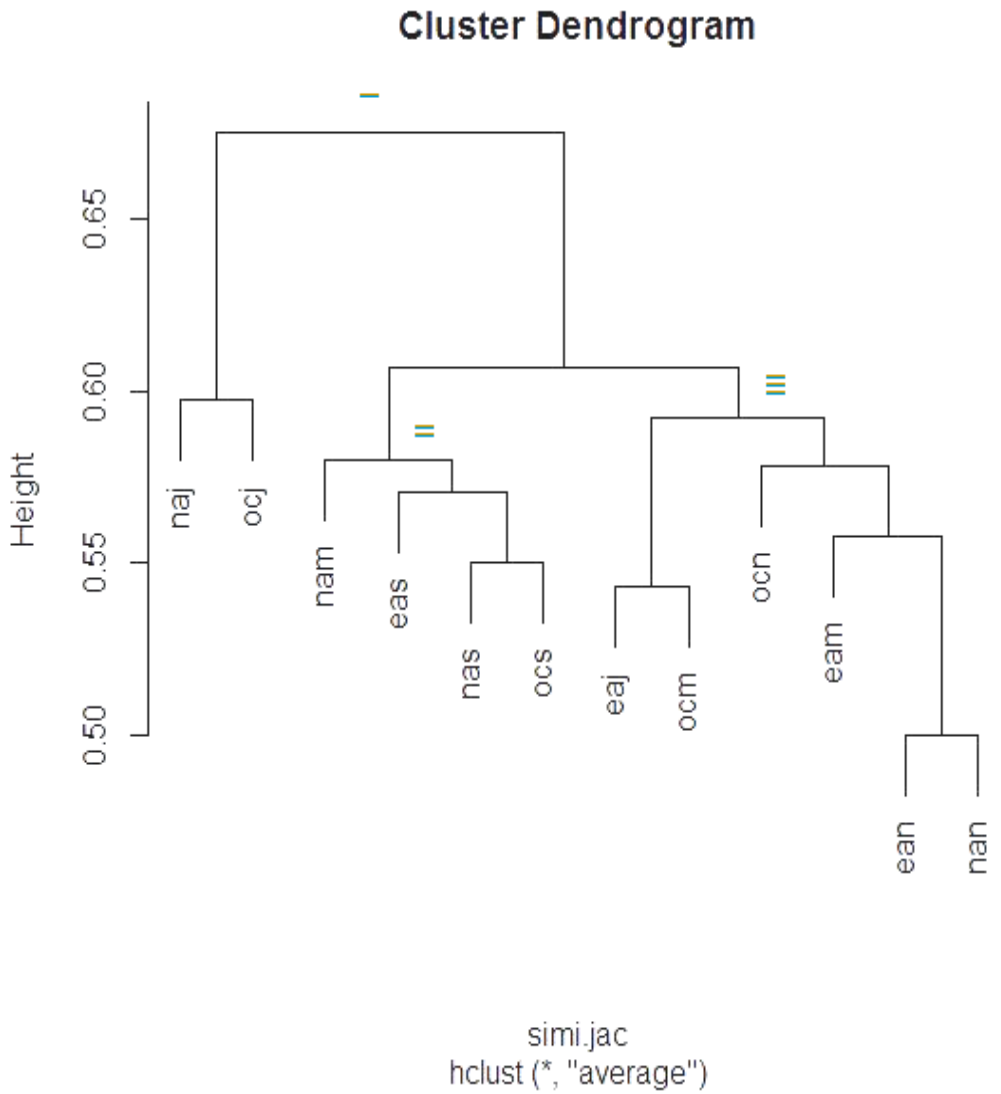

Figure 3. Similarity dendrogram (Jaccard Index; r = 0.787, coefficient of cophenetic correlation) from the periphytic algal community in distinct substrates (ea = *Eichhornia azurea;* na = *Nymphaea amazonum*; oc = *Oxycaryum cubense*) in the four months analysed (j = June 2008; s = September 2008; n = November 2008; m = March 2009), in the "Pau Véio" lake, at the Paraná River floodplain.

dissimilarity taxonomic between periphytic algal communities. Differences in taxonomic similarity were mainly temporal, related to different periods. Periphytic algal communities developed in June 2008 were more divergent between other (60% of dissimilarity). In June 2008, hydrometric level and temperature reached their lowest values (Biolo and Rodrigues, 2013), which were probably crucial for structuring the taxonomic composition of periphytic algal community (Wetzel, 1983; Murakami et al., 2009), by increasing dominance of r-strategists algae, as Bacillariophyceae and Cyanobacteria (Biggs, 1996). According to Leandrini et al. (2008), the absence of periods of flooding and the prevalence of low hydrometric levels are important factors that influence distribution, abundance, and biomass of organisms, especially for periphytic algae. In June 2008, when community were more divergent, intensity of floodpulses were very low and pulses were almost absent (Roberto et al., 2009; Biolo and Rodrigues, 2013).

High temperatures supported a rich periphytic flora in the Upper Paraná River floodplain (Murakami et al., 2009; Biolo and Rodrigues, 2013) and could also affect the species composition of this community after June 2008. Furthermore, increase in hydrometric levels and in degree of connectivity of lake with the main river, with the improvement of limnological conditions toward the year 2009 should have promoted greater entry of algal propagules in the environment and their establishment in the periphytic community (Biolo and Rodrigues, 2013). In consequence, composition of periphytic algal community

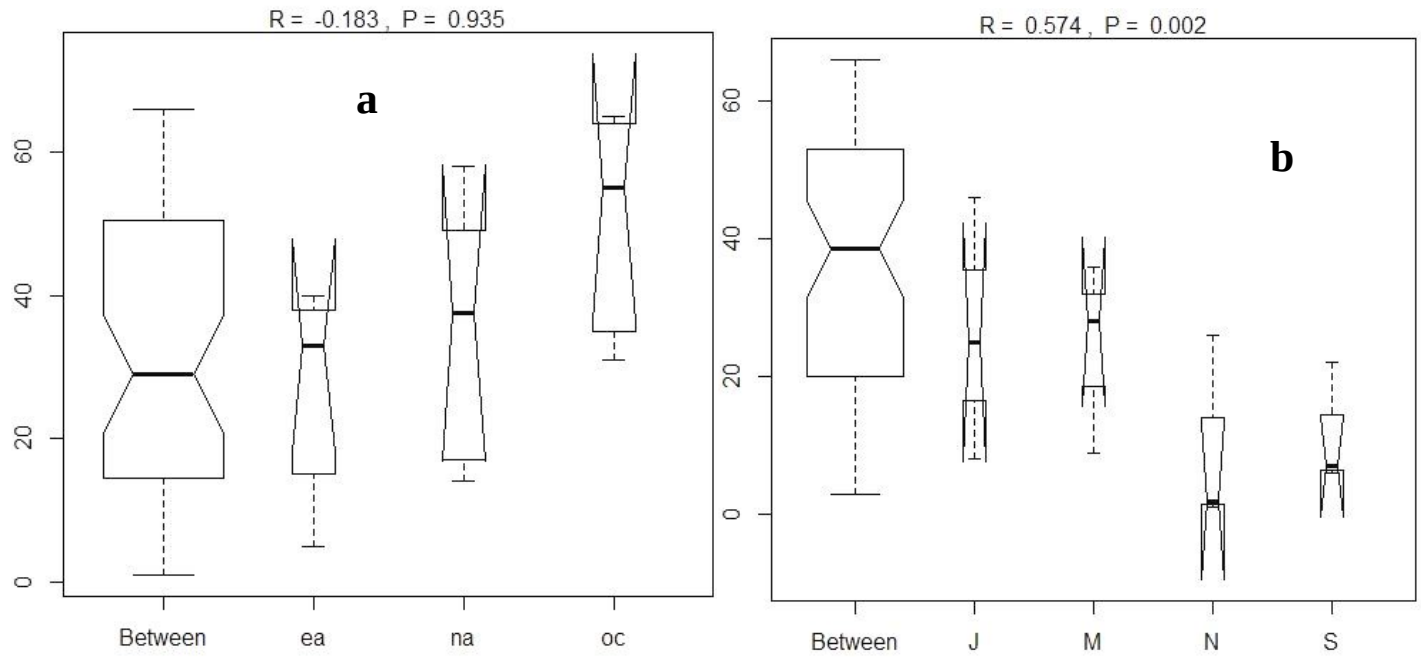

Figure 4. Analysis of similarity data (ANOSIM) from the periphytic algal community in (a) distinct substrates (ea = *Eichhornia azurea;* na = *Nymphaea amazonum*; oc = *Oxycaryum cubense*) and (b) in the four months analysed (J = June 2008; S = September 2008; N = November 2008; M = March 2009), in the "Pau Véio" lake, at the Paraná River floodplain.

may also have been affected.

Dissimilarities in the species composition of the periphytic algae in different substrates were less pronounced. Physical factors can structure epiphytic algal communities. Morphology and architecture of macrophytes, in addition to surface microstructure of the plant and the density of macrophyte hosts, are reflected particularly in their associated organisms (Pip and Robinson, 1981). Moreover, these conditions can favor selectivity between habitats and associated organisms (Messyasz and Kuczynska-Kippen, 2006). However, the present study showed that the type of substrate was not a critical factor for influencing segregation of periphytic algal communities on *E. azurea*, *N. amazonum*, and *O. cubense* under similar limnological conditions (in the same sampled period).

Indeed a large temporal influence that may have affected more strongly the *O. cubense* than the other two species of macrophytes was observed, which promoted less pronounced – but not less important - dissimilarities between communities in distinct substrates. Surface microtopography and petioles of macrophytes act similarly as substrates in emergent plants, as previously discussed by Laugaste and Reunanen (2005). This fact could be observed in the present study, which substrate provided by *O. cubense* presented more dissimilar community between other substrates (Figure 2). Its more complex morphology and life habit differs from other macrophytes (e.g., *E. azurea* and *N. amazonum*), because both apparently present more similar morphology of the petioles. Furthermore, leaves of *O. cubense* present a parallel innervation that can increase the spatial heterogeneity providing distinctive microhabitat for algal colonization (Souza and Ferragut, 2012).

These results are similar to those reported for the structural attribute density, however, contrary to the attribute species richness of periphytic algae on *E. azurea*, *N. amazonum* e *O. cubense* (Biolo and Rodrigues, 2013). In this study, Biolo and Rodrigues (2013) showed no significant differences reported in the mean values of specific richness between the same substrates, only for sampled periods and for interaction "time x substrate"; and significant differences between periphytic algae from distinct substrates were registered only for average values of density. Furthermore, Neif et al. (2013) also found no significant differences in the species composition and richness of periphytic algae of different submerged macrophytes at the same floodplain, including the attribute density, but only between periods. Our study provides first steps for understanding comparative structure of periphytic algal communities in *E. azurea*, *N. amazonum* and *O. cubense*.

According to discussions presented by Cattaneo and Kalff (1979) and Jones et al. (2000), there is a considerable controversy about factors that determine the species composition of the periphytic algal communities, especially with respect to the selective influence of the type and shape of substrate. For the present study, results suggest that composition and taxonomic similarity was probably temporally related to the influence of

environmental variables (abiotic variables, flood pulses and hydrometric levels), with influence in a lesser degree of the type of substrate.

Furthermore, we recommend natural substrate provided by the macrophyte *E. azurea* for future studies in periphyton ecology in this floodplain, since it could be easily found and collected in any period in the Paraná River floodplain. In latter case, this substrate may be replaced by *N. amazonum*, with morphology and attached algae more similar to the *E. azurea*.

Conflict of interests

The authors have not declared any conflict of interest.

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