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Periphytic diatom ecological guilds in floodplain: Ten years after dam

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ABSTRACT

Periphytic diatoms are a key primary producer in floodplain systems. In this study, we assessed the species and functional traits in the periphytic diatom community in three lentic environments directly connected to the Paraná River shortly after damming and a decade later. Samples were collected in 2001–2002 and 2010–2011 during high waters phase. Periphytic samples were obtained from *Eichhornia azurea* Kunth, found in the shore zone of these environments. We recorded a total of 90 diatom species. 47 taxa were exclusive during the period shortly after damming and 18 taxa were only found in 2010–2011. The analysis of the similarity, diversity, beta diversity and non-metric multidimensional scaling (NMDS) suggested that there were differences in the species and functional traits of the periphytic diatom community between the two study periods. Variations in water transparency and nutrient (including nitrogen and phosphorus forms) were the most important variables shaping diatom communities diatoms during the study periods. High and motile profiles were characteristic shortly after damming and taxa of high and low profiles predominated a decade later. High transparency, high water and nitrogen levels favored the development of high and low profile, such as *Gomphonema augur* var. *augur*, *Synedra goulardii* and *Amphora* sp., whereas taxa belonging to high-profile and motile algae (e.g., *Eunotia indica*, *Nitzschia amphibia*) were found in the opposite conditions. Species turnover was an important diversity component that was greatly influenced by limnologic differences over time, represented by environmental and temporal dissimilarities between the years. These changes reinforce the modifications that have occurred in the environmental component of the Upper Paraná River floodplain downstream of the dam from the start of its operation.

1. Introduction

Although dams are important for economic development (water supply, irrigation, electrical power, navigation, recreation), they also result in severe and irreversible changes to the natural hydrological regimes of rivers around the world, modify the quality of river habitats (due to factors such as thermal stress, low dissolved oxygen and nutrient cycling) and alter the dynamics of the entire biota (Bednarek and Hart, 2005; Agostinho et al., 2008; Nunes et al., 2015).

There are approximately 700 large dams in Brazil, 35 of which are located in the Paraná River basin, which also harbors the greatest human population in the country (32% of the population in only 10.5% of the Brazilian territory). The largest urban and industrial centers of South America are located within this basin, and severe impacts on the quantity and quality of water returning into the river have been observed in these areas (Agostinho et al., 2008). The water quality and ecological condition of reservoirs, as receiving water bodies, often reflect the condition and activities of their catchments (Leigh et al., 2015).

The last relevant flowing water stretch of the Paraná River is restricted to 230 km, and it consists of the floodplain area of the Upper Paraná River. This area is protected by three conservation areas: Islands and Marshes of the Paraná River Protected Area, Ilha Grande National Park, and Ivinhema State Park. Although this stretch of the Upper Paraná River has great relevance for biodiversity conservation, it is under strong anthropogenic pressure, which influences the system at different spatial and temporal scales (Agostinho et al., 2013) and causes thermal and chemical stratification patterns. These environmental dynamics directly affect the

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communities downstream from the dam. Of these communities, the periphytic community, which is an important primary producer in these ecosystems, is the focus of this study.

On go in research has investigated the periphytic algal community of the Upper Paraná River's floodplain and assessed the colonization and succession processes on artificial substrates, the spatial structure and dynamics of this community and substrate heterogeneity (Rodrigues and Bicudo, 2004; Algarte and Rodrigues, 2013; Algarte et al., 2013; Biolo and Rodrigues, 2013; Neif et al., 2014; Dunck et al., 2015b). Studies performed in this ecosystem have observed considerable modifications in hydrological conditions that have resulted in significant changes in the ecosystem's ecological conditions (Rodrigues et al., 2013).

Periphyton susceptibility to water flow and disturbances may be measured by assessing functional characteristics, such as algal growth forms. Within of periphytic matrix the algae can take an arrangement in layers, which are differentiated by size of the algae and its type of attachment. Thus, those with small size and attach by short stalks and mucilage pad remains closer to the substrate surface, forming the low profile. Those with larger sizes and attach by long stalks remain further away from the substrate surface and form the high profile. Already, those algae that can make some movement comprise the group of motile. When assessing the growth profiles of algae, low-profile species that are well attached to substrates can support physical stress better than high-profile species, which grow in a more erect manner or are only weakly capable of attaching to substrates (Round et al., 1990; Passy, 2007).

Diatoms are an important part of the periphytic algae community. These organisms have exceptional taxonomic diversity and notable morphological adaptations that favor their attachment to substrates, like the mucilage production which is secreted via structures such as apical pore field and raphe (Round et al., 1990). Despite the high taxonomic diversity, recent studies have shown that much of the richness and diversity of diatoms is yet unknown (Wehr and Sheath, 2003; Mann et al., 2008). Studies showed that periphytic algal community assembly are deterministic with respect to traits (Dunck et al., 2016), which reinforces that traits like life form, adherence and locomotion, determine algae response to dispersal patterns (Wetzel et al., 2012; Algarte et al., 2014), light (Lange et al., 2011), nutrients (Passy, 2007; Ferragut and Bicudo, 2010), sediment deposition (Piggott et al., 2012), disturbance (Passy, 2007; Schneck and Melo, 2012; Stenger-Kovács et al., 2013; Lange et al., 2016), water level (Dunck et al., 2013, 2015b), substrate roughness (Schneck et al., 2011). Throughout the world, the use of diatoms for water monitoring and aquatic environment evaluations is increasing because of their strong response to environmental changes, in both space and time, based on climatic and geomorphological conditions and water chemistry (Urrea and Sabater, 2009; Wu et al., 2010). Diatom community structure is considered one of the best descriptors of aquatic environmental conditions (Besta et al., 2015).

In Brazil, despite severe issues surrounding local water bodies, a national program for water quality management is not in place. Structural and functional knowledge of the periphytic diatom community may aid in detecting numerous natural or anthropogenic processes, including eutrophication (Gaiser et al., 2006; Besta et al., 2015). Thus, changes in the community may be predictive and promote a holistic view of ecosystems, which may broaden our understanding of structural and functional changes in Brazilian ecosystems caused by environmental modifications.

Therefore, we assessed the species and functional traits of the periphytic diatom community of lentic environments directly connected to the Paraná River shortly after it was dammed in 1998 and ten years later. A trait of species approach (Passy, 2007; Algarte et al., 2014; Dunck et al., 2016) was used to understand the determining processes that underline the assembly of diatom communities. So, we main goals were (1) evaluate similarities between different sampling periods and correlated them with limnological variables, (2) assessed the similarity and beta diversity of the periphytic diatoms within and between the two study periods, (3) evaluated the main mechanism underlying beta diversity (turnover or nestedness) and (4) evaluated the relationship between beta diversity and the dissimilarities of limnological variables, space and time.

Intense modifications occurred in regime hydrological and environmental variable along of the years in stretch of the Upper Paraná River floodplain after the dam began to function (e.g., increase in the water column transparency and nutrient levels, see Roberto et al., 2009). Assuming that hydrological regime cause variation in the biotic component, we expected differential structural and functional characteristics of the periphytic diatom community between the two sampling periods. We had three main questions: (1) Are difference in richness and density in the diatom community shortly after damming and a decade later? (2) Are shifts in functional characteristics and in similarity? (3) Beta diversity and its mechanisms (turnover and nestdness) changes between the sampling periods and within each period in particularly? Turnover refers to the replacement of species in one community by different species in the other community, while nestedness reflects the increasing dissimilarity between nested communities produced by the increasing differences in the number of species (Baselga, 2010). These patterns can be result of environmental or historical spatial restrictions or barriers (Villéger et al., 2013), or different factors that lead to species loss or gain by selective extinction or colonization, such as habitat quality, area and isolation, or species tolerance to abiotic factors (Wright et al., 1998).

We predicted: (1) greater richness and density in the diatom community shortly after damming (because are expected limnological conditions close to original), and we believe that functional characteristics will also be altered; (2) that changes in the environmental conditions provide the development of the high profile, when assimilable nitrogen and water transparency increase; (3) greater similarity within the two study periods due similar limnological (environmental) characteristics, and lower between periods; (4)greater beta diversity between the different sampling periods relative to within the sampling periods, and that beta diversity is positively related to differences in limnological variables, space and time; and finally (5) that turnover is the most important mechanism underlying beta diversity, considering that the studied lakes are permanently connected to the Paraná River.

To test these predictions, we used the composition, richness, abundance and three ecological guilds (low-profile, high-profile, and motile species; Passy, 2007) of diatoms adhered to the emergent macrophyte *Eichhornia azurea* Kunth in 2001–2002, when the Porto Primavera Dam began to function, and in 2010–2011, ten years later.

2. Material and methods

The study area was located near the Porto Rico municipality (Brazil) in the Upper Paraná River floodplain, and it encompassed three lentic environments permanently connected to the Paraná River (Fig. 1): Leopoldo lake, with 966.2 m of length, average depth of 3.1 m, 2046.9 m of perimeter and area of 2.95 ha (22°45′24″S; 53°16′7.98″W); Bilé lake, 582.6 m of length and average depth of 1.3 m (22°45′13.56″S; 53°17′9.48″W); and Pau Véio lake, 1146.4 m of length, average depth of 1.8 m and area of 3.0 ha (22°44′50.76″S; 53°15′11.16″W). *Eichhornia azurea* Kunth is a common macrophyte in the environments of these floodplain and allowed us to make comparisons (Algarte et al., 2014).