Subfossil and periphytic diatoms from the upper Paraná river, Brazil: last ~1000 years of a transition period

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ABSTRACT - (Subfossil and periphytic diatoms from the upper Paraná river, Brazil: last ~1000 years of a transition period). Considering the lack of knowledge regarding the paleolimnology and the diatom flora from the sediment in Brazilian aquatic environments, this study aimed to provide information about diatom biodiversity and autoecology in an environment located in the upper Paraná river floodplain. Sediment and periphytic samples were collected from a swamp located in an island of the upper Paraná river floodplain. Sediment samples were obtained by collecting a core of ~2 m with a calibrated date of 726 to 903 cal yr BP near the base. The core was sliced into layers of 2.5 cm, totaling 41 samples. Periphytic diatom samples were obtained by scraping macrophytes’ petioles, totaling two samples. The community was represented by 31 species belonging to 15 genera. All of the taxa were found in the sediment record, and 15 were present in the periphyton. The three new records (Eunotia longicamelus, Planothidium bagualensis and Luticola hustedtii) reinforce the importance of paleolimnological and periphytic studies to increase information about the aquatic biodiversity.

Keywords: bioindicators, floodplain, freshwater, paleolimnology

INTRODUCTION

Taxonomic diversity is one of the most important characteristics of biological communities that reflect evolutionary and ecological processes (Komulaynen 2009). Species richness is a basic and fundamental measurement of community and regional diversity (Magurran 1988). Several factors affect small-scale species richness. According to reviews, alteration, and loss of habitat, hydrological modification, pollution, and invasion have been identified as the main drivers of species reduction (Stendera et al. 2012).

Palaeolimnological studies are a tool to evaluate changes in the environments over time and access the ancient biodiversity. Past communities are very often the only available tool to provide information on natural biodiversity before human impacts (Smucker & Vis 2010). Therefore, the data from these studies become an important appliance for conservation actions in freshwater environments (Smol 1992, Saulnier-Talbot 2016).

Diatoms are widely used on paleolimnological studies (Gabito et al. 2013), these organisms precipitate and are incorporated in the sediment
due to their biogenic structures constituted of silica (Sierra-Arango et al. 2014). Diatoms respond sensibly (directly and indirectly) to a wide range of aquatic environmental stimuli, including physical and chemical changes (Douglas & Smol 1999, Stevenson & Pan 1999). The information provided by the diatoms enables us to understand the degree of changes that have been found in the habitat, for example, variation in water level and influence of erosion, or even introduction of species and extinctions (Smol 1992, Battarbee 1999).

Regardless of the importance of these studies on biodiversity changes, these applications have been scarce in tropical environments (Rühland et al. 2015). Palaeolimnological studies addressing taxonomy and richness of diatoms are even rarer, and for Brazil there are only a few studies (Fontana & Bicudo 2009, 2012, Almeida & Bicudo 2014, Silva & Bicudo 2014, Wengrat et al. 2015, Almeida et al. 2015, Faustino et al. 2016), which concentrate focus on surface sediments of reservoirs from São Paulo State. However, there is still rare taxonomic work addressing Brazilian subfossil diatoms with sediments of more than 100 years and also from the floodplain.

Therefore, considering the lack of palaeolimnological studies concerning diatom flora from the sediment of the Brazilian aquatic environments and given, the current transformations in the global and regional environments, this study aimed to provide information about the diatom biodiversity and autoecology from a tropical floodplain.

**Materials and methods**

The study area is located on a swamp on an island in the Paraná River, in the upper Paraná river floodplain, in the reach between the reservoirs of Porto Primavera and Itaipu Lake. The Mutum Island presented 15 km long, with variable width (high and low waters) between 0.5 and 1.20 km and height of 5.0 m above the average level of the River. The sampling site is located in the central region of the swamp (22°45’31.98”S and 53°17’52.60”W) (figure 1) with depth less than one meter.

A sediment core with a length of two meters was removed with a vibrocore. The sediment was analyzed according to granulometry, structure, composition, and coloration. With this analysis, it was possible to identify 5 geomorphological zones matching the geomorphological process of the fluvial islands approached in the studies of Fernandez et al. (1993) and Steauvx (1994). According to Fernandez et al. (1993) and Steauvx (1994), the fluvial islands in the upper Paraná river floodplain are formed by coalescence processes of bars to the islands. This process begins with the formation of the original island through a deposition of sediment. After its permanent establishment, there is the formation of a lateral bar of sediment on the side of the original island. The original island and the sidebar will be separated by a channel, which due to the sediment flow will become a connected lake or backwater, consequently, in a lake, transition period and, at the end of the process will be a swamp (see figure 2 in Ruwer & Rodrigues 2018).

With small amounts of sediment from the depths 0.78 m, 1.40 m and 1.90 m, data were analyzed with radiocarbon analysis. The analyses were performed by the Center for Applied Isotope Studies - CAIS (University of Georgia, USA) and the Nuclear Energy Center in Agriculture - CENA (São Paulo University). Radiocarbon ages were calibrated (cal yr BP and cal yr AD) by CALIB7.0.4 using the SHCal13 calibration curve for the Southern Hemisphere (Stuiver and Reimer 1993, Hogg et al. 2013). The absolute dating with the isotope of $^{14}$C in the samples of depths: 78 cm, 140 cm, and 190 cm, indicated modern age, 760 ± 65 yr BP (569 to 721 cal yr BP) and 920 ± 60 $^{14}$C yr BP (726 to 903 cal yr BP), respectively. In addition, the record was separated into 2.5 cm slices with 5 cm of intervals and disregarding the first 5 cm (from the top of the core). From each 2.5 cm slice, 0.01 g of sediment was removed for the preparation of permanent slides for subsequent quantitative and qualitative analysis under a microscope. The methodology for the preparation of slides was based on Battarbee et al. (2001). Diatom analysis was carried out on 32 out of 41 samples.
Nine samples were not found a sufficient number of diatoms for analysis (78307UPCB to 78310UPCB, 78318UPCB to 78322UPCB).

Given the high dominance of diatoms in periphytic samples (Biolo & Rodrigues 2013, Bichoff et al. 2016), the periphytic community was sampled in order to identify diatom communities from the current environment. The sampling of the periphytic diatom community was made in April 2016 after a period of flooding. The following abiotic parameters were measured in situ with a multi-parameter probe: dissolved oxygen (percentage saturation and g/L), pH, water temperature (°C), electric conductivity (µS/cm), turbidity (NTU), total solids (g/L) and salinity (ppt) (Mackareth et al. 1978, Wetzel & Likens 1981).

Periphytic diatom community was obtained by scraping mature petioles of an aquatic macrophyte. Two petioles were collected in the sampling site, placed in 150 ml Wheaton bottles and kept cool until further removal of the periphytic biofilm, which was performed using a stainless-steel blade wrapped in aluminum foil and jets of distilled water. After removal, periphyton was fixed and preserved in Transeau solution (Bicudo & Menezes 2017). The periphytic material was oxidized and cleaned using the Simonsen (1974) method, modified by Moreira-Filho & Valente-Moreira (1981) and prepared on permanent slides with Naphrax resin. We analyzed the non-oxidized periphyton under the optical microscope, to observe the forms of arrangement and fixation of the species.

The quantitative analysis was performed according to the method of Battarbee et al. (1986) with the count of at least 500 valves in an optical microscope. The slides were analyzed qualitatively under an optical microscope (under 1000× magnification) and scanning electron microscopy (Ferrario et al. 1995). The samples were deposited in the herbarium of Botanic Department of Universidade Federal do Paraná (78280UPCB to 78322UPCB). We recorded 329 taxa in the study, and we presented here only the taxa that occurred with a relative abundance of ≥ 20%, which contributed 74% of the relative abundance of all samples. Has been adopted the Round et al. (1990) classification system.

**Results and Discussion**

The swamp in the current period was characterized by relatively high temperature, slightly acidic pH, low conductivity, low dissolved oxygen concentration and high turbidity (table 1).

In the total 329 taxa found in the 34 samples, 31 species had a high abundance. The community was represented by 15 genera, among which the most representative were Eunotia Ehrenberg (10), Gomphonema Ehrenberg (three) and Luticola D.G. Mann (three).

**Bacillariophyta**

- Coscinodiscophyceae
- Aulacoseirales
- Aulacoseiraceae


**Figure 2**

Diameter: 8-17 µm; height: 14-30 µm; striae: 9-14/10 µm.


Ecological information: this species generally has a planktonic habitat, but can be also found in the periphytic community. Dominant in shallow lakes, it occurs in mesotrophic to eutrophic waters but is commonly found in eutrophic waters. This species occurs in alkaline waters and tolerate temperatures

Table 1. Abiotic variables of the swamp located in the Mutum island in the upper Paraná river floodplain, Brazil, in April 2016 (OD - dissolved oxygen; TDS – total dissolved solids).

<table>
<thead>
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<th>Variables</th>
<th>Values</th>
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<tr>
<td>Temperature (°C)</td>
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<tr>
<td>pH</td>
<td>6.19</td>
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<tr>
<td>Conductivity (mS/cm)</td>
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<tr>
<td>Turbidity (NTU)</td>
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<tr>
<td>DO (g/L)</td>
<td>0.0023</td>
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<td>DO (%)</td>
<td>30</td>
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<td>TDS (g/L)</td>
<td>0.073</td>
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<tr>
<td>Salinity (ppt)</td>
<td>0.1</td>
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</table>
of 15 to over 30°C (Van Dam et al. 1994, Moro & Fürstenberger 1997, Taylor et al. 2007, Zalat & Vildary 2007, Kiss et al. 2012, Estepp & Reavie 2015, Bicudo et al. 2016, Faustino et al. 2016). According to some works, this species is associated with water column mixing, high flood conditions and depth variations, and physical alterations as erosion events, turbulence, and deforestation (Zalat & Vildary 2007, Dong et al. 2008, Costa-Böddeker et al. 2012, Fontana et al. 2014). This species was found in 52% of the samples, presenting greater abundance in the transition and swamp periods, with the highest abundance between these two periods.


Figures 3-5, 64

Diameter: 9-20 µm; height: 12-24 µm; inconspicuous striae.


Ecological information: species generally of planktonic habitat, but also found in the periphytic community. Dominant in shallow lakes, occurring in oligotrophic to eutrophic waters, tolerate temperatures of 0 to 30°C (Van Dam et al. 1994, Moro & Fürstenberger 1997, Estepp & Reavie 2015). Species of *Aulacoseira* genus has heavy silicified cells with a high sinking rate (characteristic clearly observed in the *Aulacoseira italica* of this study), therefore, this species requires turbulence to maintain its presence in the water column (Bradbury 1975). This species was found in 85% of the samples. With greater abundance in the transition and swamp periods, with the highest abundance between the transition and lake periods.

*Bacillariophyceae*

Fragilariales

Fragilariaceae


Length: 36-87.8 µm; breadth: 10-10.1 µm; striae: 5-6/10 µm.


Ecological information: episamic species (Ribeiro et al. 2008), was found in 82% of the samples with higher values of abundance during the swamp and connected lake periods. In Brazil, it was recorded by Dunck et al. (2012) in a lentic, oligotrophic to mesotrophic environments and by Ribeiro et al. (2010) for sediment samples from a coastal zone.


Length: 14.1-58 µm; breadth: 4.8-9 µm; striae: 5-8/10 µm.


Ecological information: these specimens differ from *S. crassa* in this study because they have rostrate to rostrate-rounded ends than just rounded ends. This species was recorded in 91% of the samples with higher values of abundance during the swamp and connected lake.

**Eunotiales**

**Eunotia bidens** Ehrenberg, Abhandlungen der Königlichen Akademie der Wissenschaften zu Berlin, 413. 1843.

Figures 22-24
Length: 20-72 μm; breadth: 7-11 μm; striae: 9-14/10 μm.


Ecological information: periphytic species of lentic environments, occurring in acid waters, from oligotrophic to mesotrophic environments, and high temperature tolerant (Van Dam *et al.* 1994, Moro & Fürstenberger 1997, Lange-Bertalot *et al.* 2011, Faustino *et al.* 2016), associated with bryophytes in marsh environments (Furey *et al.* 2011). This species was registered in 76% of the samples, during the periods of lake and transition, but its abundance was greater during the swamp and lake.

**Eunotia cf. deformis** Metzeltin & Lange-Bertalot in Lange-Bertalot, Iconographia Diatomologica, 5: 57, pl. 16: figs. 9-11, 1998.

Figures 13-15, 70-71

Length: 19-62 μm; breadth: 7-9 μm; striae: 9-12/10 μm.


Ecological information: taxon registered for sediment of Brazilian environments (Metzeltin & Lange-Bertalot 1998). The description of *Eunotia deformis* type in Metzeltin & Lange-Bertalot (1998) presents a length variation compare to the population we were found, thus this taxon was maintained as *Eunotia cf. deformis*. This species was found in 47% of the samples, with higher abundances during the lake period.


Figures 16-17, 69

Length: 30-110 μm; breadth: 7-11 μm; striae: 10-12/10 μm.


Ecological information: species erroneously identified as *Eunotia camelus* Ehrenberg in taxonomic and ecological studies (Costa *et al*. 2017). Planktonic species of lentic and lotic acid environments,
but can be found in alkaline environments. They tolerate oligotrophic to mesotrophic conditions and temperatures of 15 to more than 30 °C (Moro & Fürstenberger 1997, Ortiz-Lerín & Cambra 2007, Faustino et al. 2016). This species was found in 91% of samples, was found in all periods, with greater abundance during the lake period.

**Eunotia major** (Smith) Rabenhorst. *Flora europaea algarum aquae dulcis et submarinae*, 1: 72, 1864 ≡ *Himantidium majus* Smith in *A synopsis of the British Diatomaceae*, 14, pl. XXXIII [33]: fig. 286, 1856.

Figures 25-26, 77-79
Length: 42-107 μm; breadth: 7.8-9 μm; striae: 8-11/10 μm.


Ecological information: periphytic species of oligotrophic and acid waters, found in lentic and lotic environments (Moreira-Filho et al. 1973). Taxon with 85% frequency, with higher values of abundance in the lake period.


Figure 27
Length: 20-85 μm; breadth: 2.7-4.2 μm; striae: 20/10 μm.

Material examined: Brazil. PARANÁ: Porto Rico, Ilha Mutum, periphyton, 12-IV-2016, Ruwer et al. (78280UPCB - 78281UPCB, 78282UPCB - 78298UPCB, 78300UPCB - 78305UPCB).

Ecological information: benthic species, adhered by mucilage foot, occurring in lentic, oligotrophic and acidic waters (Van Dam et al. 1994, Moro & Fürstenberger 1997, Montoya-Moreno & Aguirre-Ramírez 2013). This species was found in 26% of the samples, with greater abundance for the current period.


Figures 20-21
Length: 13-22 μm, breadth: 3-5 μm; striae: 16-20/10 μm.

Material examined: Brazil. PARANÁ: Porto Rico, Ilha Mutum, periphyton, 12-IV-2016, Ruwer et al. (78283UPCB - 78285UPCB, 78287UPCB - 78305UPCB).

Ecological information: epiphytic species, occurring in acidic and oligotrophic environments (Van Dam et al. 1994, Ortiz-Lerín & Cambra 2007). This species was found in 58% of the samples with greater abundance during the transition period.
Cymbellales
Gomphonemataceae

Encyonema silesiacum (Bleisch) Mann in Round, Crawford, & Mann, Diatoms, 667, 1990 = Cymbella silesiaca Bleisch in Algen Europa’s, 1802, 1864. Figures 31, 80

Length: 28-45 μm; breadth: 7.8-10 μm; striae: 9-12/10 μm.


Ecological information: E. silesiacum presented periphytic habitat, but also can be found in plankton community, is an indicator of oligotrophic water, but can be found in eutrophic waters. It occurs in lentic and lotic waters, with acidic to alkaline pH and temperature ranging from 15 to more than 30 °C (Van Dam et al. 1994, Moro & Fürstenberger 1997, Marquardt & Bicudo 2014). The taxon was reported by Faustino et al. (2016) and Almeida & Bicudo (2014), studies of paleolimnological approach in Brazil, and was related with mesotrophic to supereutrophic conditions. This species was registered in 76% of the samples, with greater abundance in the transitional period.

Gomphonema gracile Ehrenberg, Die Infusionsthierchen als vollkommene Organismen, 217, pl. 18: fig. 3, 1938. Figures 32-33, 81

Length: 24-64.3 μm; breadth: 5.7-10.4 μm; striae: 12-17/10 μm.


Ecological information: periphytic species from lentic environments, from oligotrophic to mesotrophic, neutral to alkaline waters, and tolerate temperatures from 15 to 30 °C (Valente-Moreira 1975, Contin & Oliveira 1993, Van Dam et al. 1994, Moro & Fürstenberger 1997, Marquardt & Bicudo 2014, Faustino et al. 2016). This species was related to mesotrophic and eutrophic conditions in the study of Dunck et al. (2013) and Faustino et al. (2016), and related to urban and polluted environments by Morecco & Rodrigues (2014). We have recorded the species in 61% of samples, it was absent only in the connected lake period, with higher values of abundance in the transition and current periods.

Gomphonema lagenula Kützing, Die Kieselalgen oder Diatomeen, 85, pl. 30: fig. 60, 1844. Figures 34-35, 82

Length: 19-21 μm; breadth: 5-6 μm; striae: 17-18/10 μm.

Material examined: Brazil. Paraná: Porto Rico, Ilha Mutum, periphyton, 12-IV-2016, Ruwer et al. (78280UPCB - 78281UPCB); sediment, 27-II-2012, Ruwer et al. (78282UPCB - 78306UPCB).

Ecological information: this periphytic species was related to mesotrophic and eutrophic conditions in the study of Dunck et al. (2013) and Faustino et al. (2016), and related to urban and polluted environments by Morecco & Rodrigues (2014). We have recorded the species in 79% of samples, it was absent only in the connected lake period, with higher values of abundance in the transition and current periods.

Gomphonema sp. 1 Figures 36-37, 83

Length: 22.5-44.9 μm; breadth: 5.9-7.4 μm; striae: 13-16/10 μm.


Ecological information: we observe through the periphytic samples that the specimens presenting stalks for fixation. It was found in the current environment that presented a temperature of 27.9 °C, acidic to neutral pH and low oxygen value. Occurred in 41% of the samples, more abundant in the current period.


Length: 14-24 μm; breadth: 7-10 μm; striae: 14-18/10 μm.

Ecological information: this species was in 64% of the samples, with greater abundance in the period of the backwater.

Cocconeidales
Achnanthidaceae


Figures 40-41
Length: 12.5-21 μm; breadth: 2.8-4 μm; inconspicuous striae.


Ecological information: the *Achnanthidium minutissimum* species complex is considered cosmopolitan and inhabits all freshwater habitats, mainly in lentic waters. *Achnanthidium* had a much wider tolerance range to various environmental factors. The *Achnanthidium minutissimum* is tolerant to a wide range of organic and inorganic pollution varying from oligotrophic to eutrophic conditions, although in some studies it is associated with low nutrients. It is tolerant at high temperatures (Moro & Fürstenberger 1997, Ponader & Potapova 2007, Potapova & Hamilton 2007, Faustino *et al.* 2016). This species was in 52% of the samples, with higher values of abundance in the transition and backwater period.


Figures 42-44, 84
Length: 12.9-30.8 μm; breadth: 6-9 μm; striae: 12-16/10 μm.


Ecological information: species erroneously identified as *Planothidium lanceolatum* (Brébisson ex Kützing) H. Lange-Bertalot in Brazilian studies, found in the periphytic and phytoplanktonic community, mainly in lotic environments. Species with an optimum at mesotrophic waters, tolerating a large range of temperature (Burliga *et al.* 2005, Bes *et al.* 2012, Fontana & Bicudo, 2012, Bartozek *et al.* 2013, Wetzel & Ector 2014). This species was recorded in 73% of the samples, with greater abundance in the lake phase.


Figures 45-46, 85
Length: 12-16 μm; breadth: 6-8 μm; striae: 12-16/10 μm.


Ecological information: reported in studies by the synonym *Achnanthes rostrata* Østrup or by basionym *Achnanthes lanceolata* var. *rostrata* (Østrup) Lange-Bertalot. Species mainly found in the periphytic community, prostate, in lotic environments (Moro & Fürstenberger 1997, Bartozek *et al.* 2013), also found in sedimentary samples in Brazil (Fontana & Bicudo 2012). This species was found in 64% of the samples, with higher values of abundance during the lake and backwater periods.

Naviculales
Diadesmidiaceae

*Diadesmis confervacea* Kützing, Die Kieselschaligen Bacillarien oder Diatomeen, 109, pl. 30: fig. 8, 1844.

Figures 47-48, 86-87
Length: 12-22 μm; breadth: 5-8 μm; striae: 12-14/10 μm.


Ecological information: benthic species that form long chains (observed in the periphytic samples), present in
shallow water, wet and marshy environments. Occurs in eutrophic environments with high temperatures, acidic to alkaline waters (Cholnocky 1958, Hustedt 1966, Patrick & Reimer 1966, Van Dam et al. 1994, Moro & Fürstenberger 1997, Taylor et al. 2007, Torgan & Santos 2008). This species had a broader distribution in a Brazilian study with sediment samples (Faustino et al. 2016) and was related to mesotrophic to supereutrophic conditions. This species was found in 85% of samples, showed greater abundance during the transition period.

**Humidophila contenta** (Grunow) Lowe, Kociolek, Johansen, Van de Vijver, Lange-Bertalot & Kopalová, Diatom Research, 29: 357, 2014 ≡ *Navicula contenta* Grunow in Synopsis des Diatomées de Belgique, 109, 1885.

Figures 49-50, 88-89

Length: 7-15 µm; breadth: 2.2-3 µm; inconspicuous striae.


Ecological information: recently transferred of the Diadesmis to Humidophila genus (Lowe et al. 2014). Reported in paleoecological studies in Brazilian environments (Costa-Böddeker et al. 2012, Fontana & Bicudo 2012), related to aerophilic habit and low-nutrient. Benthic species, such as *D. confervacea*, occur in shallow waters and wet environments. It tolerates low luminosity and temperatures from 15 to 30 °C, indicate mesotrophic to eutrophic environments and acid to alkaline waters (Van Dam et al. 1994, Moro & Fürstenberger 1997, Lobo et al. 2004, Taylor et al. 2007). Frequently in 91% of the samples with higher values of abundance during the transition period.

**Luticola hustedtii** Levkov, Metzeltin & Pavlov, Diatoms of Europe, 7: 131, pl. 24: fig. 49; pl. 166: figs. 24-37; pl. 168: figs. 7-26; pl. 170: figs. 1-7, 2013.

Figures 51-52, 90

Length: 10.5-25 µm; breadth: 5.8-8 µm; inconspicuous striae.


Ecological information: species of the genus *Luticola* are common in moist and swampy soils (Van de Vijver et al. 2002, Lowe et al. 2007). *Luticola hustedtii* was reported in Faustino et al. (2016) in sediment samples and was related to past oligotrophic conditions. This taxon was found in the epiphyton of slightly acidic waters in Straube et al. (2017). This species was found in 76% of samples, was abundant in the swamp and transition periods.

**Luticola muticoides** (Hustedt) Mann in Round, Crawford, & Mann, Diatoms, 671, 1990 ≡ *Navicula muticoides* Hustedt in Süsswasser-Diatomeen, 82, pl. 4: figs 33-36, 1949.

Figures 55-56, 91

Length: 10-23 µm; breadth: 6-9.5 µm; inconspicuous striae.


Ecological information: occurring lotic and lentic environments, in acidic to alkaline waters (Moro & Fürstenberger 1997). It was found in 70% of the samples with higher values of abundance during the transition.

**Luticola cf. simplex** Metzeltin, Lange-Bertalot & García-Rodríguez, Iconographia Diatomologica, 15: 116, pl. 87: figs 1-9, 2005.

Figures 53, 92

Length: 11-16 µm; breadth: 5.2-6 µm; inconspicuous striae.


Ecological information: this species was found in sediment samples of Faustino et al. (2016), where this taxon had a broad distribution range, related with oligotrophic and eutrophic conditions. Taxon occurring in 94% of samples with higher values of abundance during a transition and swamp periods.

**Brachysiraceae**


Figures 54, 93
Length: 18-20 µm; breadth: 5-6 µm; striae: 50/10 µm.


Ecological information: taxon registered for the first time in Brazil by Tremarin et al. (2015), however, we consider our specimens as Nupela cf. bicapitata due to the smaller population length. This species was found in all periods, however, presented higher values of abundance in the period of the backwater.

Sellaphoraceae

Sellaphora fusticulus (Østrup) Lange-Bertalot, Iconographia Diatomologica, 9: 216, 2000 ≡ Navicula fusticulus Østrup in Danske Diatoméer, 36; pl. 1, fig. 19, 1910.

Figures 57-58

Length: 32-46 µm; breadth: 8-9 µm; inconspicuous striae.


Ecological information: present in 70% of the samples with higher values of abundance during the transition period.

Pinnulariaceae

Pinnularia brauniana (Grunow) Studnicka in Wein, Verhandlungen der Kaiserlich-Königlichen Zoologisch-Botanischen Gesellschaft, 38: 737, 1888 ≡ Navicula brauniana Grunow in Atlas der Diatomaceen-kunde, pl. 45: figs 77-78, 1876

Figures 59-60, 94

Length: 28.1-50 µm; breadth: 5.6-8.3 µm; striae: 11-15/10 µm.


Among the 31 taxa addressed, all were found in the sediment samples and 15 were present in the periphyton community, 16 were exclusive in the sediment (table 2). It is important to highlight the great exclusive diversity of diatoms that can be found in sediments. Along the temporal variation, there are consequently physical and chemical, biological and geomorphological changes in the environment. In temporal ecology, these factors and the habitat control...
Table 2. Distribution and abundance of diatom species in the studied periods, Mutum island in the upper Paraná river floodplain, Brazil (hatched area according to range of abundance values; dark gray - 30% to 100%, gray - 20% to 30%, light gray - 5% to 20%, white - 0%) * New records for the State of Paraná according to Tremarin et al. 2009, Bertolli et al. 2010, Faria et al. 2010, Silva et al. 2010, Santos et al. 2011, Moreseco et al. 2011, Bartozek et al. 2013 - Table organized according to Round et al. 1990.

<table>
<thead>
<tr>
<th>Taxa</th>
<th>Periphyton (2016)</th>
<th>Swamp</th>
<th>Transition (&gt; 300 years)</th>
<th>Lake (&gt; 760 years)</th>
<th>Backwater (&gt; 920 years)</th>
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<td><em>Eunotia naegelli</em></td>
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<tr>
<td><em>Eunotia pseudosudetica</em></td>
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<tr>
<td><em>Eunotia rabenhorstiana</em> var. elongata*</td>
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<tr>
<td><em>Eunotia subarculatoide</em></td>
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<tr>
<td><em>Encyonema silesiacum</em></td>
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<tr>
<td><em>Gomphonema gracile</em></td>
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<td><em>Gomphonema lagenula</em></td>
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<td><em>Gomphonema sp. 1</em></td>
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<tr>
<td><em>Placoneis ovillus</em></td>
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<td><em>Achnanthidium minutissimum</em></td>
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<tr>
<td><em>Planothidium bagualensis</em> *</td>
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<tr>
<td><em>Planothidium aff. rostratum</em></td>
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<tr>
<td><em>Diadesmis confervaceae</em></td>
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<tr>
<td><em>Humidophila contenta</em></td>
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<tr>
<td><em>Luticola hustedti</em></td>
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<tr>
<td><em>Luticola muticoides</em></td>
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<td><em>Luticola cf. simplex</em></td>
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<td><em>Nupela cf. bicapitata</em></td>
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<td><em>Sellaphora fusciculus</em></td>
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<td><em>Pinnularia brauniana</em></td>
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<td><em>Pinnularia</em> sp. 1</td>
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<tr>
<td><em>Nitzschia palea</em> var. debilis*</td>
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</table>

The establishment and colonization of the species. The ability of populations to compete and persist in a habitat depends on how well species adapt to develop under specific environmental conditions (Patrick & Reimer 1966).

Each period was recognized in the record through the peculiar characteristics of each phase in the sedimentological material (Leli et al. 2017). In this research, some species presented greater abundance for each geomorphological period (backwater, lake, transition, and swamp). However, in the channel period (726-903 cal yr BP) was not found diatoms. The great dominance of periphytic species in swamp and transition periods could indicate the presence and abundance of macrophytes and vegetation located in the coastal region of the aquatic environment.
(Felisberto & Rodrigues 2010). The occurrence of some species as *Diadesmis confervacea*, *Humidophila contenta*, *Luticola muticoides*, *Luticola cf. simplex* in transition and swamp periods indicated shallow water environments, wet soils and marsh environments (Van de Vijver et al. 2002, Lowe et al. 2007, Torgan & Santos 2008). The great contribution of species of the order Naviculales in the transition period can be explained by these taxa being abundant in marshy environments as reported in the study of Vijayan & Ray (2016).

The lake period has a predominance of Eunotiaceae species (as *Eunotia longicamelus*, *Eunotia major*), which indicates a decrease of the pH, conductivity, and nutrients (Vélez et al. 2005). The occurrence of species belonging to the family Fragilariales (as *Staurosirella crassa*), in the backwater can be explained by the affinity of these taxa to unstable environments with continuous changes, characteristics that can be provided in a connected lake (Haworth 1976, Thomaz et al. 1997). Our results show a taxonomic contribution of diatoms to the region due to the three new registrations (*Luticola hustedtii*). We showed the importance of palaeolimnological studies to increase information about aquatic biodiversity and also provided the first palaeolimnological research for a Brazilian floodplain.

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**Literature cited**


Ruwer & Rodrigues: Subfossil and modern diatom communities from a tropical floodplain, Brazil


