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DIATOMS FROM SHALLOW LAKES IN THE PANTANAL OF NHECOLÂNDIA, BRAZILIAN WETLAND

Kleber Renan de Souza Santos[1], Angélica Cristina Righetti da Rocha[2] & Célia Leite Sant'Anna[1]*
[1]Instituto de Botância (IBt), Núcleo de Pesquisa em Ficologia, Av. Miguel Estéfano, 3687, São Paulo, SP, Brasil. CEP: 04301-902.
[2]Universidade Estadual Paulista (UNESP), Instituto de Biociências, Av. 24-A, 1515, Rio Claro, SP, Brasil. CEP: 13506-900.
E-mails: santoskrs@gmail.com*, celialsant@yahoo.com.br, angelica_righetti@yahoo.com.br

ABSTRACT

The diatom flora of the shallow lakes in the Pantanal of Nhecolândia is poorly known. Thus, our aim was to know the diatom biodiversity in three types of shallow lakes called "baías, salitradas and salinas", characterized by differences in pH, electrical conductivity, contact with the coalescent system and the presence of macrophytes. The samples were collected in dry and rainy seasons, from 2004 to 2007. For taxonomic identification, the material was cleaned with H_2O_2 and analyzed using light microscopy. A total of 23 diatom species were identified and each lake presented a unique species richness and composition. The greatest species richness was found in the Baía da Sede Nhumirim (21 species), followed by the Salitrada Campo Dora (8 species) and finally the lowest species richness was observed in the Salina do Meio (3 species). Only *Anomoeoneis sphaerophora* Pfitzer var. *sphaerophora* and *Craticula* cf. *buderi* (Hustedt) Lange-Bertalot occurred in the three studied systems. Except for *Eunotia binularis* (Ehrenberg) Souza and *Aulacoseira ambigua* (Grunow) Simonsen, all the others are new records to the Brazilian Pantanal.
Keywords: biodiversity; brackish water; freshwater; tropical wetland.

RESUMO

DIATOMÁCEAS DE LAGOS RASOS DO PANTANAL DA NHECOLÂNDIA, ÁREA ÚMIDA BRASILEIRA. A flora de diatomáceas dos lagos rasos do Pantanal da Nhecolândia é pouco conhecida. Portanto, nosso objetivo foi conhecer a biodiversidade de diatomáceas que ocorrem em três diferentes tipos de lagoas denominadas de "baías, salitradas e salinas", caracterizadas por diferenças de pH, condutividade elétrica, contato com o sistema coalescente e presença de macrófitas. As amostras foram coletadas nos períodos de cheia e de seca, durante os anos 2004 a 2007. O material foi submetido à limpeza com água oxigenada (H_2O_2) e analisado ao microscópio óptico para se proceder à identificação taxonômica. No total foram identificadas 23 espécies de diatomáceas e cada lagoa apresentou riqueza e composição de espécies distintas. A maior riqueza de espécies foi encontrada na Baía da Sede Nhumirim (21), seguida da Salitrada Campo Dora (8) e a Salina do Meio apresentou a menor riqueza de espécies (3). Somente *Anomoeoneis sphaerophora* Pfitzer var. *sphaerophora* e *Craticula* cf. *buderi* (Hustedt) Lange-Bertalot foram comuns aos três sistemas estudados. Com exceção de *Eunotia binularis* (Ehrenberg) Souza e *Aulacoseira ambigua* (Grunow) Simonsen, as demais espécies são citadas pela primeira vez para o Pantanal brasileiro.
Palavras-chave: biodiversidade; água doce; água salobra; áreas úmidas tropicais.

RESUMEN

DIATOMÁCEAS DE LOS LAGOS RASOS DEL PANTANAL DE NHECOLÂNDIA, ÁREA HÚMEDA BRASILERA. La flora de diatomeas de los lagos rasos del Pantal de Nhecolândia es poco conocida. Por lo tanto, nuestro objetivo fue conocer la biodiversidad de diatomáceas que ocurren en tres diferentes tipos de lagos rasos denominados de "baías, salitradas e salinas" caracterizadas por diferencias en el pH, la conductividad eléctrica, contacto con el sistema coalescente y la presencia de macrófitas. Las

muestras fueron colectadas en los periodos en que el nivel del agua sube y baja, entre los años 2004 y 2007. El material fue sometido a limpieza con agua oxigenada (H_2O_2) y analizada al microscopio óptico para proceder a la identificación taxonómica. En total fueron identificadas 23 especies de diatomáceas y cada lago presento riqueza y composición de especies diferentes. La mayor riqueza de especies fue encontrada en Baía de la Sede Nhumirim (21), seguida de la Salitrada Campo Dora (8) y la salina do Meio que presentó la menor riqueza de especies (3). Solamente *Anomoeoneis sphaerophora* Pfitzer var. *sphaerophora* y *Craticula* cf. *buderi* (Hustedt) Lange-Bertalot fueron comunes a los tres sistemas estudiados. Con exepción de *Eunotia binularis* (Ehrenberg) Souza y *Aulacoseira ambigua* (Grunow) Simonsen, las demás especies son citadas por primera vez para el Pantanal Brasilero.
Palabras claves: biodiversidad; agua dulce, agua salobre; áreas húmedas tropicales.

INTRODUCTION

The Pantanal is considered the largest wetland area in the world, covering about 200,000km² located in the center of South America and encompasses areas in three countries: Brazil (80%), Bolivia (15%) and Paraguay (5%) (Swarts 2000). The Pantanal is a globally important ecosystem and, according to UNESCO, is considered a Natural Reserve of Biosphere (Alho & Gonçalves 2005). The climate of this region is tropical, having a mean annual temperature of 25ºC and mean annual precipitation of 1,100mm with a rainy season from November to March and a dry season from April to October (Embrapa 1997, Soriano 1999). The intensity and duration of the flood periods vary from one year to another and in different regions of the Pantanal (Junk *et al.* 2006).

The Brazilian Pantanal presents eleven sub-regions characterized by the relief, soil, vegetation and flood pulse (Silva & Abdon 1998). The studied sub-region, known as the Pantanal of Nhecolândia, shows a peculiarity: thousands of shallow circular or elongated shaped lakes (maximum depth 2m), which are very ecologically distinct. These lakes are known as "baías, salitradas and salinas" (Brum & Sousa 1985, Mourão *et al.* 1988, Calheiros & Oliveira 1999). The "baías and salitradas" are freshwater lakes, with a pH ranging from 5 to 8, macrophytes are present inside and surrounding them, and during the flood period (rainy season) they are coalescent with other aquatic systems as "corixos and vazantes" (Barbiéro *et al*. 2002). The "salinas" are alkaline lakes, isolated from other lakes by a stripe of dry land covered by savanna vegetation ("cordilheiras"), contain brackish water, pH >8, and the macrophytes are totally absent (Brum & Sousa 1985, Mourão *et al.* 1988, Barbiéro *et al*. 2002, Medina-Júnior & Rietzler 2005, Almeida *et al*. 2011).

In spite of being a highly diverse ecosystem, the Pantanal has been very poorly studied with respect to microorganisms in general (Por 1995). Taxonomic studies on diatoms in the Brazilian Pantanal are extremely rare and there are only two reference: Bicudo *et al.* (1995) described 21 taxa of Centrales and Eunotiales in lakes from the Poconé region, Mato Grosso State, northern part of the Brazilian Pantanal and recently, a taxonomic study of *Aulacoseira gessneri* (Hustedt) Simonsen from Sinhá Mariana and Coqueiro lakes (also northern region of the Pantanal) was carried out by Tremarin *et al.* (2011). Ecological studies including diatoms of this region were restricted to genera or species lists (De-Lamonica-Freire & Heckman 1996, Oliveira & Calheiros 2000, Silva *et al.* 2000, Domitrovic 2002, Silva *et al*. 2011).

Concerning the diatom from Pantanal of Nhecolândia, Mato Grosso do Sul State, there are only two references: Santos *et al*. (2004) and Malone *et al.* (2007), which are based on the studies of algal composition from lakes in this region. However, such studies are restricted to a list of genera and the authors emphasized the lack of taxonomic studies on algal biodiversity in Pantanal.

With the knowledge that biodiversity is fundamental for projects dealing with management and conservation, the aim of this study was to know the diatom biodiversity in different types of shallow systems of the Pantanal of Nhecolândia.

MATERIALS AND METHODS

We selected one system of each type of shallow lake ("baía, salitrada and salina") typical in the

Pantanal of Nhecolândia. Some morphometric characteristics of the studied lakes are presented in Table 1. The instrument WTW model pH/Cond 340i was used for measuring pH, conductivity, salinity and water temperature in field. Transparency and depth were measured using a Secchi disc.

The samples were collected in the Salina do Meio (18°58'29" S, 56°38'47" W), the Salitrada Campo Dora (18º58'02" S, 56º38'59" W), and the Baía da Sede Nhumirim (18º59'37" S, 56º37'14" W). Sampling was carried out in rainy and dry seasons, from May 2004 to May 2007, using a plankton net (20µm mesh), totaling 23 samples. Samples were preserved in Transeau solution or 4% formaldehyde and are kept in the Herbarium Maria Eneyda P. Kauffmann Fidalgo (SP), Institute of Botany, São Paulo, Brazil. The material was analyzed, identified and photographed using light microscopy (LM) Axioplan 2 (Zeiss). Samples were treated with H_2O_2, according to CEN/TC 230 (2003). Permanent slides were prepared using Naphrax (IR= 1.74) as a mounting medium. Whenever possible, morphological descriptions were based on population analysis, including measures of cell length, width, length/width ratio (R l/w), and striae and areolae density in 10µm. Morphological terminology followed Hendey (1964). The system of Round *et al*. (1990) was adopted and the main diatom floras used for identification were: Metzeltin & Lange-Bertalot 1998, 2007, Krammer 2000, Rumrich *et al.* 2000, Lange-Bertalot 2001, Metzeltin *et al*. 2005 and Taylor *et al*. 2007.

The geographic distribution of diatoms in the Brazilian Pantanal was based on literature data (taxonomic papers) and on Diatom Catalog from the Central-Western region of Brazil (Silva *et al*. 2011). The Sörensen Similarity Index (Brower & Zar 1984) was used for comparing the diatom flora found in the studied lakes.

RESULTS

The abiotic variables in the studied lakes are represented in Table 2 and the distribution of the diatoms is shown in Table 3.

Table 1. Morphometric characteristics of the studied lakes in the Pantanal of Nhecolândia, Brazil.
Tabela 1*. Características morfométricas das lagoas estudadas no Pantanal da Nhecolândia, Brasil.*

	Salina do Meio (Mourão 1989)	Salitrada Campo Dora (Rezende-Filho 2006)	Baía da Sede Nhumirim (Santos & Sant'Anna 2010)
Coalescence	No or only exceptionally	In more intense flooding periods	Frequent
Maximum length (m)	436	500	ca. 390
Maximum width (m)	325	250	ca.320
Maximum depth (m)	1.1	0.44	0.80
Area (ha)	10.1	8	ca. 8

Table 2. Physical and chemical variables of the studied lakes in the Pantanal of Nhecolândia, Brazil, from 2004 to 2007. Values: average (minimum-maximum). Salina = Salina do Meio; Salitrada = Salitrada Campo Dora; Baía = Baía da Sede Nhumirim.
Tabela 2*. Variáveis físicas e químicas das lagoas estudadas no Pantanal da Nhecolândia, Brasil, de 2004 a 2007. Valores: média (mínima-máxima). Salina = Salina do Meio; Salitrada = Salitrada Campo Dora; Baía = Baía da Sede Nhumirim.*

	Rainy season			**Dry season**		
	Salina (n = 4)	Salitrada (n = 4)	Baía (n = 4)	Salina (n = 5)	Salitrada (n = 2)	Baía (n = 4)
pH	9.7 (9.0-10.2)	7.0 (5.0-8.5)	7.8 (7.5-8.1)	10.1 (9.8-10.4)	8.3 (8.2-8.4)	7.6 (6.9-8.0)
Conductivity (µS cm^{-1})	4087 (2870-5500)	465.3 (318-430)	992 (716-1453)	10270 (4380-19020)	1486 (1120-1852)	1937 (1680-2110)
Water temperature (ºC)	30.9 (25.0-34.2)	26.3 (23.0-28.4)	27.8 (25.5-29.5)	26.0 (21.7-36.1)	27.5 (23.1-32.0)	25.8 (22.1-35.1)
Depth (m)	0.45 (0.26-0.64)	0.43 (0.43-0.44)	0.47 (0.14-0.80)	0.22 (0.19-0.26)	0.17 (0.13-0.20)	0.19 (0.14-0.23)
Secchi disc (m)	0.04 (0.04-0.04)	0.40 (0.35-0.44)	0.27 (0.05-0.48)	0.03 (0.01-0.04)	0.06 (0.02-0.10)	0.08 (0.06-0.10)

Table 3. Species composition and diatom distribution in the studied lakes of the Pantanal of Nhecolândia, Brazil. Salina = Salina do Meio; Salitrada = Salitrada Campo Dora; Baía = Baía da Sede Nhumirim; - = absent; x = present.

***Table 3**. Composição de espécies e distribuição de diatomáceas nas lagoas estudadas no Pantanal da Nhecolândia. Salina = Salina do Meio; Salitrada = Salitrada Campo Dora; Baía = Baía da Sede Nhumirim; - = absent; x = present.*

	Rainy season (2004-2007)			**Dry season (2004-2007)**		
	Salina	Salitrada	Baía	Salina	Salitrada	Baía
AULACOSEIRALES						
Aulacoseira ambigua	-	-	x	-	-	x
EUNOTIALES						
Eunotia bilunaris	-	x	x	-	-	x
Eunotia sp.	-	-	x	-	-	
CYMBELLALES						
Anomoeoneis sphaerophora var. *sphaerophora*	x	x	-	x	x	x
Gomphonema augur var. *augur*	-	x	x	-	-	-
Gomphonema gracile	-	x	x	-	x	x
Gomphonema lagenula	-	-	-	-	-	x
Gomphonema sp.	-	-	x	-	-	-
NAVICULALES						
Craticula ambigua	-	-	x	-	-	-
Craticula cf. *buderi*	x	x	x	x	-	-
Diadesmis confervacea var. *confervacea*	-	-	x	-	-	x
Frustulia krammeri	-	-	x	-	-	-
Luticola mutica	-	-	x	-	-	-
Navicula brasiliana var. *guadalupensis*	-	-	x	-	-	-
Navicula microcari	x	-	-	x	-	-
Pinnularia acrosphaeria var. *acrosphaeria*	-	-	-	-	-	x
Pinnularia gibba var. *sancta*	-	-	x	-	-	x
Pinnularia huckiae	-	-	x	-	-	x
Pinnularia microstauron var. *rostrata*	-	-	x	-	-	-
Pinnularia viridis var. *viridis*	-	-	x	-	-	-
Sellaphora capitata	-	x	-	-	-	-
BACILLARIALES						
Hantzschia amphioxys	-	x	x	-	x	x
Nitzschia palea	-	x	x	-	x	x
Total	**3**	**8**	**18**	**3**	**4**	**11**

Twenty-three diatom taxa, belonging to 5 orders, 10 families and 13 genera, were identified. Naviculales was the most represented order in species number (13= 56% of the total), followed by Cymbellales (5= 22%), Eunotiales (2= 9%), Bacillariales (2= 9%) and Aulacoseirales (1= 4%). According to our results, the greatest species richness was found in the Baía da Sede Nhumirim (21 species), followed by the Salitrada Campo Dora (8 species) and the lowest species richness was detected in the Salina do Meio (3 species) (Table 2). The identified species are described as follows:

COSCINODISCOPHYCEAE
AULACOSEIRALES
AULACOSEIRACEAE

Aulacoseira ambigua (Grunow) Simonsen, Bacillaria 2: 56. 1979 (Figure 1, a, b).

Valves circular forming straight filamentous chains joined by short spines; mantle decorated with oblique striae on the longitudinal axis. Dimensions: mantle height 12-13.5µm, diameter 7.7-8.7µm; striae density 16-18 in 10µm; areolae density 16-20 in 10µm.

Studied material: Baía da Sede Nhumirim 15.X.2004 (SP390912), 4.V.2007 (SP390929).

Ecological data: pH 7.7-7.8; conductivity 716µScm^{-1}; Temp. 23.0-27.5°C.

BACILLARIOPHYCEAE
EUNOTIALES
EUNOTIACEAE

Eunotia bilunaris (Ehrenberg) Souza, Bull. Jard. Bot. Nat. Belg., 67: 265, fig.13. 1999 (Figure 1, c, d).

Valves lunate, isopolar; dorsal margin convex, ventral margin concave to lightly concave, apices attenuated to rounded; terminal nodules delicate; striae parallel in the middle, slightly radiate at the apices. Dimensions: valve length 21-93µm, width 3.5-4µm, R l/w 6.0-23.2; striae density 15-19 in 10µm.

Studied material: Salitrada Campo Dora 8.V.2005 (SP390914); Baía da Sede Nhumirim 15.X.2004 (SP390912), 4.V.2007 (SP390929).

Ecological data: pH 5.0-7.8; conductivity 648-716 µScm^{-1}; Temp. 23.0-28.5°C.

***Eunotia* sp.** (Figure 1, e).

Valves dorsiventral, isopolar; dorsal margin convex, ventral margin slightly concave; apices attenuated and rounded differentiated from the valve; terminal nodules are hardly visible in LM; striae are parallel in the middle and slightly radiate at the extremities. Dimensions: valve length 31.6-51.1µm, width 6.5-7.6µm, R l/w 4.7-6.7; striae density 8-11 in 10µm.

Studied material: *Baía da Sede Nhumirim* 4.V.2007 (SP390929).

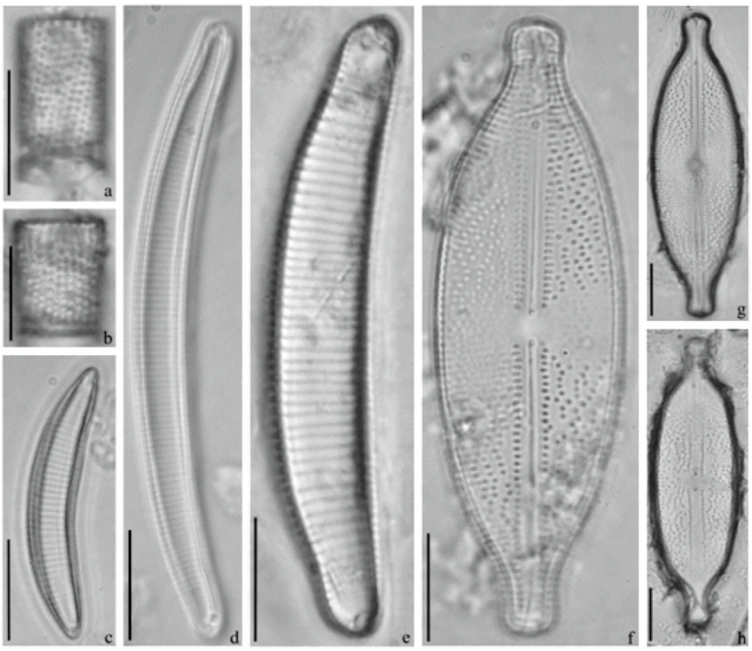

Figure 1. Diatoms of Nhecolândia: **a, b.** *Aulacoseira ambigua*; **c, d.** *Eunotia bilunaris*; **e.** *Eunotia* sp.; **f-h.** *Anomoeoneis sphaerophora* var. *sphaerophora*. Scale bars: 10 µm.

Figura 1. *Diatomáceas da Nhecolândia:* ***a, b.*** *Aulacoseira ambigua;* ***c, d.*** *Eunotia bilunaris;* ***e.*** *Eunotia sp.;* ***f-h.*** *Anomoeoneis sphaerophora var. sphaerophora. Escalas: 10 µm.*

Ecological data: pH 7.8; conductivity 716 µScm^{-1}; Temp. 28.0°C.

Eunotia sp. is morphologically similar to *Eunotia inspectabilis* Metzeltin & Lange-Bertalot, species described for Guyana, South America (Metzeltin & Lange-Bertalot 1998). However, *E. inspectabilis* presents large valves (44-60µm length, 6.6-8.5µm width), higher striae density (13-14 in 10µm) and valves less concave than the studied material.

CYMBELLALES
ANOMOEONEIDACEAE

Anomoeoneis sphaerophora Pfitzer **var. *sphaerophora***, Bot. Abhandl. Geb. Morphologie und Physiologie: 77, pl. 3, fig. 10. 1871 (Figure 1, f-h).

Valves elliptic-lanceolate, apices rostrate; striae uniseriate and irregular, formed by conspicuous areolae, slightly radiate to parallel or irregularly distributed; areolae more spaced, arranged in an orderly row on both sides of the raphe sternum; central area with irregular areolae occluded, type ghost areolae, sometimes extended to the margins of the valve; raphe filiform. Dimensions: valve length 30-51µm, width 11-15.4µm, R l/w 2.6-3.3; striae density 17-19 in 10µm.

Studied material: Salina do Meio 8.V.2005 (SP390913), 28.VIII.2006 (SP390922), 16.XI.2006 (SP390924), 4.V.2007 (SP390927); Baía da Sede Nhumirim 15.X.2004 (SP390912), 28.VIII.2006 (SP390923); Salitrada Campo Dora, 8.V.2005 (SP390914), 4.V.2007 (SP390928), 16.XI.2006 (SP390925).

Ecological data: pH 5.0-10.4; conductivity 318-12070 µScm^{-1}; Temp. 23.0-36.1°C.

GOMPHONEMATACEAE

Gomphonema augur Ehrenberg **var. *augur***, Ber. K. Akad. Wiss. Infusions, p. 211. 1840 (Figure 2, a, b).

Valves heteropolar, claviform, superior apex rostrate, inferior apex gradually attenuate, subcapitate; central area delimited by one shortened median stria; 5 stigmata located at the central nodule, two beside the shorter stria and three beside the longer stria; striae uniseriate, parallel to slightly radiate towards the ends; areolae rounded; raphe sternum linear, narrow; sinuous raphe. Dimensions: valve length 24.3-48µm, width 5-11.8µm, R l/w 2.7-4.9; striae density 10-15 in 10µm; areolae density 30-32 in 10µm.

Studied material: Baía da Sede Nhumirim 22.IV.2006 (SP390921), 4.V.2007 (SP390929); Salitrada Campo Dora 8.V.2005 (SP390914).

Ecological data: pH 7.8-8.1; conductivity 648-1453µScm^{-1}; Temp. 23.0-29.5°C.

Gomphonema gracile Ehrenberg, Infusions, p. 217, pl. 18, fig. 3. 1838 (Figure 2, c-e).

Valves slightly heteropolar, lanceolate; ends gradually attenuated, round apices; central area delimited by one shortened median stria; a stigma placed at the central nodule at the end of a long central stria; striae uniseriate, parallel to slightly radiate towards the ends; areolae rounded; raphe sternum linear, narrow; sinuous raphe, sometimes curved towards the side of the stigma. Dimensions: valve length 37.9-83.7µm, width 6.4-11.8µm, R l/w 6.3-6.9; striae density 11-13 in 10µm; areolae density 26-28 in 10µm.

Studied material: Baía da Sede Nhumirim 25.IX.2005 (SP390918), 04.V.2007 (SP390929), 22.IV.2006 (SP390921); Salitrada Campo Dora 14.VIII.2004 (SP390909), 8.V.2005 (SP390914).

Ecological data: pH 5.0-8.1; conductivity 648-1453 µScm^{-1}; Temp. 23.0-29.5°C.

Gomphonema lagenula, Kützing, Bacill., p. 85, pl. 30, Fig. 60. 1844 (Figure 2, f, g).

Valve slightly heteropolar, elliptical, lanceolate, ends subcapitate to capitate-rostrate; central area delimited by one shortened median stria; a stigma placed at the central nodule at the end of a long central stria; striae slightly radiate; inconspicuous areolae; raphe sternum linear, narrow; raphe filiform, straight, proximal and distal ends inconspicuous. Dimensions: valve length 15-21.4µm, width 5.3-5.7µm, R l/w 2.8-3.9; striae density 14-15 in 10µm.

Studied material: Baía da Sede Nhumirim 25.IX.2005 (SP390918).

Ecological data: pH 6.9; conductivity 1680µScm^{-1}; Temp. 22.8°C.

***Gomphonema* sp.** (Figure 2, h-j).

Valves slightly heteropolar, lanceolate with apices strongly protracted and elongated; central area delimited by one shortened median striae; 5 stigmata

placed at the central nodule, two beside the shorter stria and three beside the longer stria; axial area linear and narrow; raphe filiform, slightly sinuous with proximal raphe fissure dilated in a drop shape, straight or only slightly flexed toward the three stigmata. Dimensions: valve length 66.5µm, width 10.3µm, R l/w 6.4; striae density 11-12 in 10µm.

Studied material: Baía da Sede Nhumirim 4.V.2007 (SP390929).

Ecological data: pH 7.8; conductivity 716µScm^{-1}; Temp. 28.5°C.

The studied material presented heterogeneous valves, one of them slightly ornamented (Fig. 16-18). Similar forms were found by Ludwig (1996) in material from São Paulo State and they were considered as sporangial forms. It is possible that the material from the Pantanal might represent a sporangial form of *Gomphonema gracile* since both occurred in Baía da Sede Nhumirim and are similar in valve size (length 37.9-83.7µm, width 6.4-11.8µm) and striae density (11-13 in 10µm). Therefore, new studies shall be provided to confirm these data.

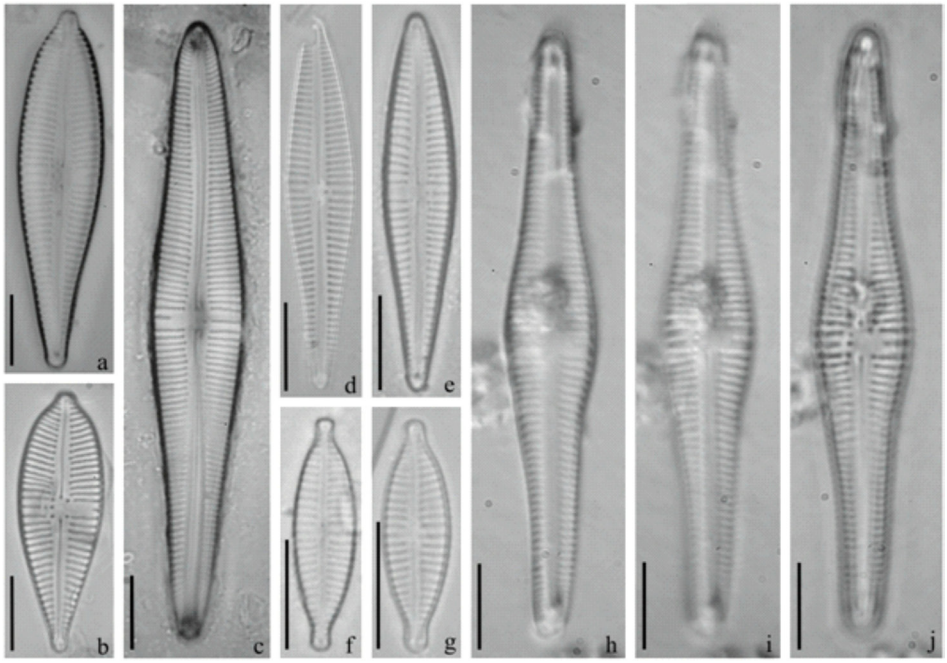

Figure 2. Diatoms of Nhecolândia: **a, b.** *Gomphonema augur* var. *augur*; **c-e.** *Gomphonema gracile*; **f,g.** *Gomphonema lagenula*; **h-j.** *Gomphonema* sp. Scale bars: 10 µm.

Figura 2. *Diatomáceas da Nhecolândia:* ***a, b.*** *Gomphonema augur var. augur;* ***c-e.*** *Gomphonema gracile;* ***f,g.*** *Gomphonema lagenula;* ***h-j.*** *Gomphonema sp. Escalas: 10 µm.*

NAVICULALES
STAURONEIDACEAE

Craticula ambigua (Ehrenberg) Mann, *In* Round, Crawford & Mann, The Diatoms, p. 666. 1990 (Figure 3, a).

Valves widely elliptic-lanceolate, ends slightly rostrate, differentiated from the valve, rounded apices; striae parallel to slightly radiate at the ends of the valve; inconspicuous areolae; raphe sternum linear, narrow; central area reduced; raphe filiform, proximal ends straight, slightly dilated pore, distal ends straight. Dimensions: valve length 65.6µm, width 20.9µm, R l/w 3.1; striae density 18 in 10µm.

Studied material: *Baía da Sede Nhumirim* 22.IV.2006 (SP390921).

Ecological data: pH 8.1; conductivity 1453µScm^{-1}; Temp. 29.5°C.

Craticula* cf. *buderi (Hustedt) Lange-Bertalot, *In* U. Rumrich, H. Lange-Bertalot & M. Rumrich, Iconogr. Diatomol., v. 9, p. 201. 2000 (Figure 3, b-d).

Valves elliptic, ends subcapitate, apices rounded; striae parallel or slightly radiate throughout the valve; raphe sternum linear, narrow; central area reduced; raphe filiform, straight, proximal and distal ends straight. Dimensions: valve length 23-40µm, width 5.5-7.2µm, R l/w 4.2-5.7; striae density 20-22 in 10µm.

Studied material: Salina do Meio 10.V.2005 (SP390907), 25.IX.2005 (SP390917), 22.IV.2006 (SP390919), 28.VIII.2006 (SP390922), 16.XI.2006

(SP390924), 4.V.2007 (SP390927); Salitrada Campo Dora 21.IV.2006 (SP390920); Baía da Sede Nhumirim 22.IV.2006 (SP390921).

Ecological data: pH 8.5-10.2; conductivity 430-19020µScm^{-1}; Temp. 23.3-36.1°C.

The Pantanal material resembles *Craticula elkab* (O. Müller) Lange-Bertalot in relation to ecology (waters rich in electrolytes, $NaCO_3$ and chloride), striae density (20-25 in 10 µm) and valve length (16-35(40) µm) (Lange-Bertalot 2001). However, the specimens from Pantanal identified as *Craticula* cf. *buderi* are larger (valve width 5.5 to 7.2µm) and the valves are less lanceolate than *Craticula elkab* (valve width 4-5.3µm). According to Lange-Bertalot (2001), the valve width was sufficient to separate *Craticula buderi* (5-8µm) of the *Craticula elkab* (4-5.3µm). Future analysis in scanning microscope can confirm this identification.

AMPHIPLEURACEAE

Frustulia krammeri Lange-Bertalot et Metzeltin, *In* Metzeltin & Lange-Bertalot, Iconogr. Diatomol., v. 5, p. 96. 1998 (Figure 3, e).

Valves rhombic-lanceolate, ends widely attenuate-rounded; striae inconspicuous; raphe sternum thickened, forming ribs; raphe filiform, arcuate, located between ribs; proximal and distal ends of the raphe straight. Dimensions: valve length 120µm, width 23µm, R l/w 5.2; striae inconspicuous.

Studied material: Baía da Sede Nhumirim 4.V.2007 (SP390929).

Ecological data: pH 7.8; conductivity 716 µScm^{-1}; Temp. 28.5°C.

DIADESMIACEAE

Diadesmis confervacea Kützing **var. *confervacea***, Bacill. 109, pl. 30, fig. 8. 1844 (Figure 3, f).

Valves lanceolate, apices atenuate-rounded; delicate striae, radiate throughout the valve; inconspicuous areolae; central area circular or rectangular; raphe sternum linear, narrow; raphe filiform. Dimensions: valve length 9.3-17.1µm, width 4.3-6.4µm, R l/w 2.6-2.7; striae density 16-17 in 10µm.

Studied material: Baía da Sede Nhumirim 25.IX.2005 (SP390918), 4.V.2007 (SP390929).

Ecological data: pH 6.9; conductivity 1680 µScm^{-1}; Temp. 22.8°C.

Luticola mutica (Kützing) Mann, *In* Round, Crawford & Mann, The Diatoms, p. 670. 1990 (Figure 3, g).

Valves elliptic, apices rounded; areolae striae, radiate throughout valve extension; areolae rounded; central area expanded laterally; stigma orbicular, conspicuous; raphe sternum linear, narrow; straight raphe, proximal ends abruptly curved to the opposite side of the stigma, distal ends curved to the same side. Dimensions: valve length 23 µm, width 6.8µm, R l/w 3.4; striae density 22-24 in 10µm; areolae density 24-28 in 10µm.

Studied material: *Baía da Sede Nhumirim* 03.II.2005 (SP390908).

Ecological data: pH 7.8; conductivity 716µScm^{-1}; Temp. 28.5°C.

NAVICULACEAE

Navicula brasiliana Cleve **var. *guadalupensis*** Manguin, *In* Bourrelly & Manguin, Alg. Guad., p. 66, pl. 4, fig. 85. 1952 (Figure 3, h, i).

Valves lanceolate, margins convex, ends subrostrate, apices rounded-truncate; striae strongly radiate, presence of more shortened striae, interspersed with others in the central region of the valve; raphe sternum linear; central area lanceolate; raphe linear, filiform, proximal ends dilated in drop shape. Dimensions: valve length 28.8-56µm, width 9-12.1µm, R l/w 3.2-4.6; striae density 18-25 in 10µm; areolae density 23-26 in 10µm.

Studied material: *Baía da Sede Nhumirim* 22.IV.2006 (SP390921).

Ecological data: pH 8.1; conductivity 1453µScm^{-1}; Temp. 29.5°C.

Navicula microcari Lange-Bertalot, Biblioth. Diatomol. 27, p. 121-122, pl. 58: figs 1-5. 1993 (Figure 3, j, k).

Valves elliptic-lanceolate, apices obtuse-rounded; striae strongly radiate in the middle, slightly convergente at the ends; inconspicuous areolae; raphe sternum linear, narrow; central area surrounded by shorter and curved irregular striae; raphe linear, filiform. Dimensions: valve length 21-23 µm, width 5.0-5.3µm, R l/w 4.2-4.3; striae density 14 in 10 µm.

Studied material: *Salina do Meio* 28.VIII.2006 (SP390922), 4.V.2007 (SP390927).

Ecological data: pH 10.1-10.2; conductivity 3890-12070µScm^{-1}; Temp. 24.7-31.0°C.

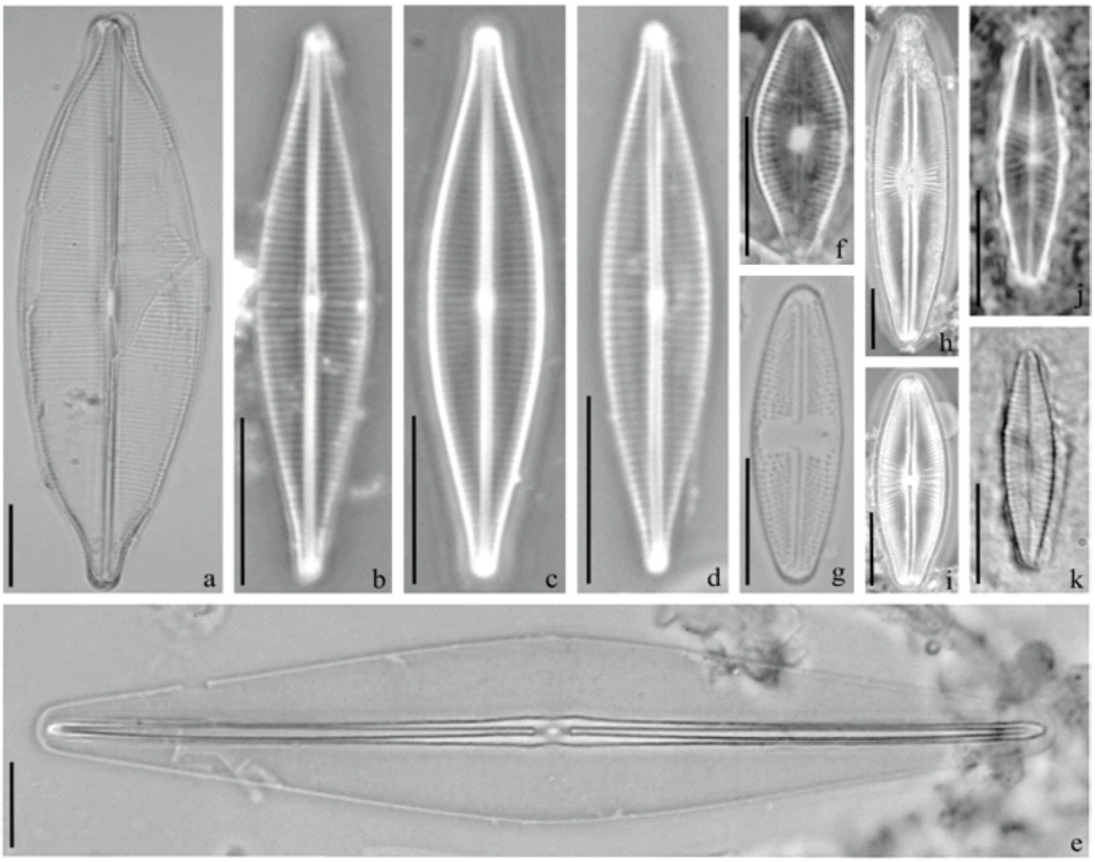

Figure 3. Diatoms of Nhecolândia: **a.** *Craticula ambigua*; **b-d.** *Craticula* cf. *buderi*; **e.** *Frustulia krammeri*; **f.** *Diadesmis confervacea* var. *confervacea*; **g.** *Luticola mutica*; **h, i.** *Navicula brasiliana* var. *guadalupensis*; **j, k.** *Navicula microcari*. Scale bars: 10 *µm*..

Figura 3. *Diatomáceas da Nhecolândia:* ***a.*** *Craticula ambigua;* ***b-d.*** *Craticula cf. buderi;* ***e.*** *Frustulia krammeri;* ***f.*** *Diadesmis confervacea var. confervacea;* ***g.*** *Luticola mutica;* ***h, i.*** *Navicula brasiliana var. guadalupensis;* ***j, k.*** *Navicula microcari. Escalas: 10 µm.*

PINNULARIACEAE

Pinnularia acrosphaeria W. Smith **var. *acrosphaeria***, Syn. British. Diat. 1: 58, pl. 19, fig. 183. 1853 (Figure 4, a, b).

Valves linear, swollen in the middle, ends slightly expanded, apices broadly rounded; striae alveolate, slightly radiate in the middle, parallel to ends; axial area linear expanded with irregular granulations; raphe filiform, slightly undulate, proximal ends, flexed in the same direction, distal ends in the form of a bayonet. Dimensions: valve length 54-103µm, width 10.6-15.2µm, R l/w 5.1-7.0; striae density 11-12 in 10µm.

Studied material: Baía da Sede Nhumirim 28.VIII.2006 (SP390923), 16.XI.2006 (SP390926).

Ecological data: pH 7.8-8.0; conductivity 2020-2110µScm^{-1}; Temp. 24.7-35.1°C.

Pinnularia gibba Ehrenberg **var. *sancta*** (Grunow ex Cleve) Meister, Kieselalgen Asien. Verlag Gebrüder Borntraeger, p. 43, fig. 140. 1932 (Figure 4, c, d).

Valves linear-lanceolate, apices rounded; striae alveolate, radiate in the middle, convergent towards the ends; axial area linear, narrow, widened in the central area of the valve where striations are interrupted; central area rhomboid, expanded laterally, forming the fascia; raphe filiform, straight to undulate, proximal ends flexed in the same direction, distal ends in shape of hook. Dimensions: valve length 49-60µm, width 8.4-9µm, R l/w 5.8-6.7; striae density 10-11 in 10µm.

Studied material: Baía da Sede Nhumirim 25.IX.2005 (SP390918), 16.XI.2006 (SP390926), 4.V.2007 (SP390929).

Ecological data: pH 6.9-7.8; conductivity 716-2020µScm^{-1}; Temp. 22.8-35.1°C.

Pinnularia huckiae Metzeltin & Lange-Bertalot, *In* Lange-Bertalot, Iconogr. Diatomol., 18: 204, pl. 230, fig. 1-5. 2007 (Figure 4, e, f).

Valves linear, margins slightly undulate to parallel, ends subrostrate, apices rounded; striae alveolate, widely radiate from the central area to parallel and convergent at the ends; axial area linear, narrow; central area elliptic; raphe filiform, undulate, proximal ends flexed in the same direction, distal ends in form of a bayonet. Dimensions: valve length 98-125µm, width 14.2-15.3µm, R l/w 6.4-8.8; striae density 6-7 in 10µm.

Studied material: Baía da Sede Nhumirim 25.IX.2005 (SP390918); 4.V.2007 (SP390929).

Ecological data: pH 6.9-7.8; conductivity 716-1680µScm^{-1}; Temp. 22.8-28.5°C.

Pinnularia microstauron (Ehrenberg) Cleve **var. *rostrata*** Krammer, Diat. Eur. 1, p.74, pl. 51, fig. 8-18. 2000 (Figure 4, g).

Valves linear-lanceolate, apices subcapitate; striae alveolate, radiate in the middle, convergent towards the ends; axial area linear-lanceolate, slightly expanded in the central area of the valve, where the striations are interrupted; central area rhomboid, expanded laterally, forming the fascia; raphe filiform, straight to, proximal ends flexed in the same direction, distal ends in shape of hook. Dimensions: valve length 32-33µm, width 6.3-6.6µm, R l/w 4.9-5.1; striae density 11-12 in 10µm.

Studied material: Baía da Sede Nhumirim 4.V.2007 (SP390929).

Ecological data: pH 7.8; conductivity 716µScm^{-1}; Temp. 28.5°C.

Pinnularia viridis (Nitzsch) Ehrenberg **var. *viridis***, Abh. K. Akad. Wiss. Berl. p. 305 (17), 385; pl. 1/1, fig. 7. 1843 (Figure 4, h).

Valves linear-elliptical, apices conical-rounded; striae alveolate, radiate in the middle, parallel and convergent at the ends; axial arearaphe sternum linear, slightly expanded in the central valve; central area rounded, not forming fascia; raphe filiform, undulate, proximal ends flexed in the same direction as the distal ends. Dimensions: valve length 99-102µm, width 19-20µm, R l/w 5.1-5.3; striae density 8-9/10µm.

Studied material: Baía da Sede Nhumirim 4.V.2007 (SP390929).

Ecological data: pH 7.8; conductivity 716µScm^{-1}; Temp. 28.5°C.

SELLAPHORACEAE

Sellaphora capitata Mann et. McDonald, Phycol. 43(4): 477, figs 4 j-l, figs 38-42. 2004 (Figure 4, i, j).

Valves linear, ends broadly subrostrate, apices rounded; striae delicate, strongly radiate in the middle, slightly radiate at the ends; central area expanded laterally; raphe sternum linear, narrow; raphe filiform, straight, proximal ends straight or slightly flexed to the same side. Dimensions: valve length 24.3 µm, width 7.4 µm, R l/w 3.3; striae density 19 in 10 µm.

Studied material: Salitrada Campo Dora 8.V.2005 (SP390914).

Ecological data: pH 5.0; conductivity 648µScm^{-1}; Temp. 23°C.

BACILLARIALES
BACILLARIACEAE

Hantzschia amphioxys (Ehrenberg) Grunow, *In* Cleve & Grunow, K. Sven. Vet. Handl., v.17, n.2, p.103. 1880 (Figure 4, k).

Valves linear to linear-lanceolate; apices subcapitate; dorsal margin straight to slightly convex; marginal fibulae slightly concave, fibulae in general regularly spaced; striae parallel to slightly radiate towards the ends. Dimensions: valve length 20-65 µm, width 5-6.4µm, R l/w 3.4-10; striae density 20-22 in 10µm; fibulae density 6-7 in 10µm.

Studied material: Baía da Sede Nhumirim 3.II.2005 (SP390908), 25.IX.2005 (SP390918), 4.V.2007 (SP390929); Salitrada Campo Dora 14.VIII.2004 (SP390909), 4.V.2007 (SP390928).

Ecological data: pH 7.6-7.8; conductivity 318-716µScm^{-1}; Temp. 27.5-28.5°C.

Nitzschia palea (Kützing) W. Smith, Syn. Brit. Diat., v. 2 , p. 89. 1856 (Figure 4, l).

Valves linear-lanceolate; apices rostrate-rounded to subcapitate; margins parallel, fibulae marginal not equidistant from each other; inconspicuous striae. Dimensions: valve length 19-53µm, width 3.8-5µm, R l/w 5-10.6; fibulae density 11-12 in 10µm.

Studied material: Baía da Sede Nhumirim 15.X.2004(SP390912),25.IX.2005(SP390918),21.

IV.2006 (SP390921), 28.VIII.2006 (SP390923), 4.V.2007 (SP390929); Salitrada Campo Dora 14.VIII.2004 (SP390909), 21.IV.2006 (SP390920).

Ecological data: pH 6.9-8.5; conductivity 430-2110µScm^{-1}; Temp. 22.8-29.5°C.

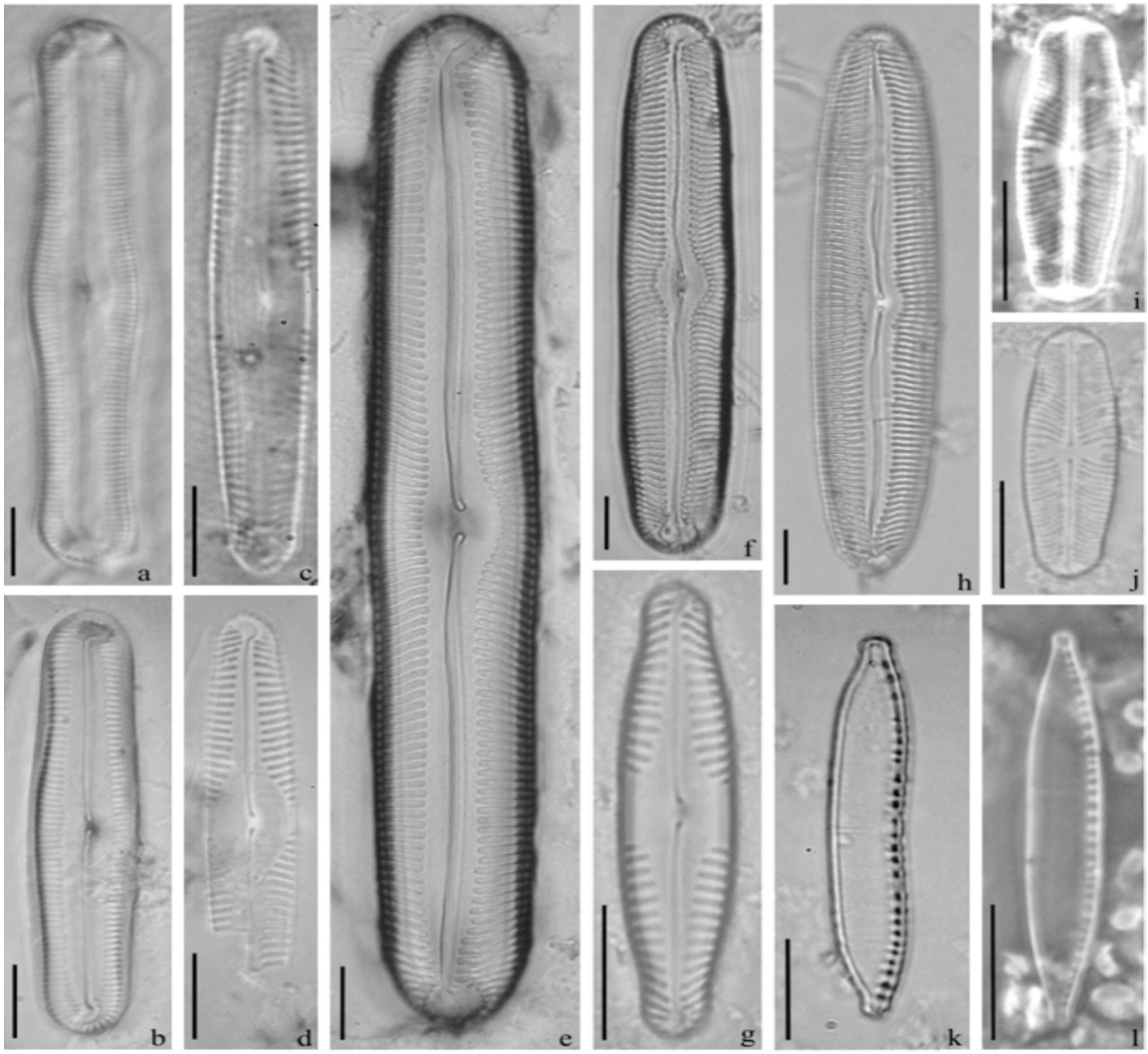

Figure 4. Diatoms of Nhecolândia: **a,b.** *Pinnularia acrosphaeria* var. *acrosphaeria*; **c,d.** *Pinnularia gibba* var. *sancta*; **e, f.** *Pinnularia huckiae*; **g.** *Pinnularia microstauron* var. *rostrata*; **h.** *Pinnularia viridis* var. *viridis*; **i, j.** *Sellaphora capitata*; **k.** *Hantzschia amphioxys*; **l.** *Nitzschia palea*. Scale bars: 10µm.

Figura 4. *Diatomáceas da Nhecolândia:* ***a,b.*** *Pinnularia acrosphaeria var. acrosphaeria;* ***c,d.*** *Pinnularia gibba var. sancta;* ***e, f.*** *Pinnularia huckiae;* ***g.*** *Pinnularia microstauron var. rostrata;* ***h.*** *Pinnularia viridis var. viridis;* ***i, j.*** *Sellaphora capitata;* ***k.*** *Hantzschia amphioxys;* ***l.*** *Nitzschia palea. Escalas: 10µm.*

DISCUSSION

The extreme environmental conditions of the Salina do Meio (pH > 9, conductivity > 2870 µScm^{-1}) are probably limiting to most diatom considering that only three species were able to survive in such conditions: *Anomoeoneis sphaerophora* var. *sphaerophora, Craticula* cf. *buderi* and *Navicula microcari*. According to Taylor *et al*. (2007), these species are common in water with moderate to high conductivity, including brackish and saline inland waters of South Africa. *C. buderi* and *N. microcari* were also found in similar environmental conditions in Chile (Rumrich *et al.* 2000) and Argentina (Vouilloud *et al.* 2005) respectively and in Europe (Lange-Bertalot 2001). Despite the fact that these species are normally referred to the benthic community (ex. Urrea & Sabater 2009, Vouilloud *et al*. 2005 - as *Navicula buderi*) it is worth highlighting that in shallow lakes, algae can occupy an imprecise limit between

planktonic and periphytic communities (Margalef 1998).

Craticula cf. *buderi* was the most common species in the Salina do Meio (found in approximately 70% of samples), forms blooms together with the cyanobacterium *Anabaenopsis elenkinii* Miller, especially during the rainy season (Santos & Sant'Anna 2010), and both species represents the most important autotrophic organisms in this alkaline lake.

Navicula microcari was only found in brackish water (Salina do Meio) in rainy and dry season (Table 2) at pH 10.1-10.2, indicating that this taxon is more closely related to these conditions. On the other hand, *Sellaphora capitata* occurred only in one freshwater sample (Salitrada Campo Dora) in the rainy season at pH 5.0. The freshwater lake Baía da Sede Nhumirim presented fourteen exclusive species, indicating that systems with less extreme environmental conditions (ex. low-neutral pH) might favor the development of a larger number of species.

The lakes that receive water from other systems during the rainy season ("salitrada and baía") presented differences in species composition between rainy and dry periods and the species richness was higher during the rainy season (Table 2). Certainly these results are related to the water input from other systems and low-pH precipitation (ex. Wolin & Duthie 1999), since the "salina", which does not receive surface water from other lakes where the pH is higher, presented the same species composition in dry and rainy seasons (Table 2).

The diatom composition showed the peculiarity of these shallow lakes, and probably the pH and conductivity are important limnological factors acting on species selection. Other parameters such as nutrients, light and turbidity certainly are also important for the species composition observed in the rainy and dry seasons (Almeida *et al.* 2011).

These results were also corroborated using the Sorensen Similarity Index: the diatom flora of the lakes presented low similarity (13%). Among the 23 identified species, only *Anomoeoneis sphaerophora* var. *sphaerophora* and *Craticula* cf. *buderi* were common to the three studied lakes. The similarity between the flora of the "salina and salitrada" was 36%; between the "salitrada" and the "baía" was 29%, and between the "baía" and the "salina" was only 17%. The diatom flora clearly showed that the studied systems are very distinct, not only in terms of limnology, geomorphology and geochemistry (Calheiros & Oliveira 1999, Barbiéro *et al*. 2002), but also in biological aspects (Almeida *et al.* 2011), especially by diatom composition.

The present study the diatom flora presented a high percentage (91%) of new records for the Brazilian Pantanal and only *Aulacoseira ambigua* and *Eunotia bilunaris* were previously cited for the Pantanal region (Bicudo *et al.* 1995). In relation to the Pantanal of Nhecolândia sub-region, all studied species are first records. These results emphasize the importance of studies on algal biodiversity in the Pantanal since thousands of other aquatic systems remain completely unknown.

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