Planktonic diatom composition and abundance in the Amazonian floodplain Cutiuaú Lake are driven by the flood pulse

A composição e a abundancia de diatomáceas planctônicas no lago Cutiuaú da planicie de inundação amazônica são controladas pelo pulso de inundação

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Biological Limnology

Abstract: Aim: The purpose of the investigation was to evaluate the composition and variation of diatom community in relation to the flood pulse in a black water lake (Jaú National Park, 01° 48.926' S and 61° 37.613' W); **Methods:** Samplings were taken during high, falling and low waters in 2003 and rising, high and low waters of 200, in 10 stations distributed in the pelagic region of Cutiuaú Lake. Water surface was collected in flasks of 200 mL, at ca. 20 cm of water surface and, fixed with Lugol solution; **Results:** A diatom community composed by 46 species (3 classes, 10 families and 16 genera) was found. Because waters are acidic (pH 3.32 to 4.52), Eunotiaceae and Pinnulariaceae were represented by the highest number of taxa. The variation of the diatom community is related to the different hydrological periods. Species richness was higher during low water (49 species) than in the other periods (23 species). Density of organisms was lower in the high waters (mean = 60 cells.mL^{-1}) and higher in the low water period (mean = 1 cells.mL^{-1}). *Aulacoseira granulata* (Ehr.) Sim var. *angustissima* (Müller) Sim was dominant in the low and rising water periods, while *A. granulata* (Ehr.) Sim var. *granulata* and *Eunotia asterionelloides* Hust. predominated during low water period; **Conclusions:** The highest richness and density of the diatom community, registered in the low water period may be related to the higher concentration of organisms in relation to the lower volume of water and the contribution of species from peryphiton and benthos.

Keywords: diatom, flood pulse, black waters, Amazon.

Resumo: Objetivo: O objetivo deste trabalho foi avaliar a composição e variação da comunidade de diatomáceas em relação ao pulso de inundação em um lago de águas pretas (Parque Nacional do Jaú, 01° 48.926' S e 61° 37.613' W); **Métodos:** Foram realizadas amostragens durante os períodos de águas altas, vazante e águas baixas de 2003, e enchente, águas altas e águas baixas de 2004, em 10 estações distribuídas na zona pelágica do lago Cutiuaú. Amostras foram coletadas com frascos de 200 mL, a cerca de 20 cm da superfície da água e fixadas com solução de Lugol; **Resultados:** Os resultados demonstraram uma comunidade de diatomáceas composta por 46 espécies, pertencentes a 3 classes, 10 famílias e 16 gêneros. As famílias Eunotiaceae e Pinnulariaceae foram representadas por maior número de táxons, em conseqüência da condição de acidez da água. A variação da comunidade de diatomáceas refletiu os diferentes períodos hidrológicos. A riqueza foi alta no período de águas baixas (49 espécies), mantendo-se baixa nos demais períodos (23 espécies). A densidade apresentou valores mínimos no período de águas altas (média = 1 célula. mL^{-1}) e valores máximos nos períodos de águas baixas (média = 60 células.mL^{-1}). *A. granulata* (Ehr.) Sim var. *angustissima* (Müller) Sim foi dominante no período de águas baixas e enchente enquanto *Aulacoseira granulata* (Ehr.) Sim var. *granulata* e *Eunotia asterionelloides* Hust. predominaram no período de águas baixas; **Conclusões:** Maior riqueza e densidade da comunidade de diatomáceas ocorrida no período de águas baixas foram, sobretudo, devidas à concentração de organismos em relação ao menor volume de água e à contribuição de espécies provenientes do perifiton e bentos.

Palavras-chave: diatomáceas, pulso de inundação, águas pretas, Amazônia.

1. Introduction

The Amazon basin covers approximately an area of 7,000 000 km^2, forming the largest river system of the Planet Earth (Tundisi, 1994). In Amazon, there are three main types of water: i) white waters, with high suspended matter, neutral pH and rich in minerals; ii) black waters with low suspended matter, high dissolved organic matter, low pH and poor in minerals; and iii) clear waters, transparent due to the low suspended matter, pH and nutrient values intermediate between white and black waters (Sioli, 1984). In the Amazon state, white and black waters predominate and are present in the Solimões/Amazonas and Negro Basins, respectively.

Along the rivers, several lakes of different sizes are found (Melack, 1984). They can or cannot be interconnected and are connected to the rivers at least part of the year. These lakes show great variation in depth during an annual cycle as a function of flood pulses (Junk et al., 1989). Four periods can be identified during an annual cycle in the floodplain lakes: rising, high, falling and low water periods. Each period shows different characteristics and exerts remarkable influence in the structure and dynamic of the aquatic communities, especially algae (Huszar and Reynolds, 1997; Huszar, 2000; Rodrigues, 1994; Ibañez, 1998).

Diatoms constitute an algal group relatively well studied in Amazonian rivers and lakes. However, the studies refer to punctual samplings and do not follow different hydrological periods. In the Negro River basin we can mention three main studies. First, the study of Uherkovich and Schmidt (1974) about phytoplankton in Castanho Lake, where *A. granulata* (Ehr.) Sim. var. *angustissima* (Müller) Sim. and *Urosolenia longiseta* Zach. were considered dominant species. Secondly, Uherkovich (1976) in the Negro River, where is cited the dominance of *Aulacoseira granulata* (Ehr.) Sim. var. *granulata* (Ehr.) Sim., *A. granulata* var. *angustissima*, *A. italica* (Ehr.) Sim., *Diatoma elongatum* (Lyngb.) C. Agardh, *Tabellaria fenestrata* (Lyngb.) Kütz., *T. fenestrata* (Lyngb.) Hütz. var. *asterionelloides* Grun., and *Urosolenia longiseta* (Zach.) Edlung and Stoermer. And thirdly, the study of Uherkovich and Raí (1979) also in Negro River and its affluents, where *Aulacoseira granulata* var. *angustissima, Eunotia asterionelloides* Hust., *Gomphonema archaevibrio* Lange-Bert. and Reich. and *Urosolenia eriensis* (H. L. Smith) Round and Crawford were registered as the main representatives. Analyzing the gut content of "Pacu" (*Myleus* sp.) in Prato Lake, a Black Lake, Souza-Mosimann et al. (1997) recognized 32 specific and interspecific taxa, mentioning that Eunotiaceae was best represented, with 50% of the total taxa registered. Recently, Melo et al. (2005) registered 49 diatoms taxa in Tupé Lake, a black water system near Manaus, being *Actinella guianensis* Grunow and *Aulacoseira granulata* (Ehrenberg) Simonsen var. *granulata* the most constant species.

In the Jaú National Park, area of the present study, 60 periphytic diatoms species were identified in the Jaú River during the high water periods from 1995 to 1997, and the Eunotiaceae family was the best represented with 43.3% of the total taxa followed by Pinnulariaceae (22%). (Díaz-Castro et al., 2003) and Surirellaceae (12%). The investigation about the phytoplankton of Cutiuaú and Tiaracá Lakes and Jaú River (Melo et al., 2005) identifyied 35 taxa representatives of Bacillariophyceae, 16% of them was found in the high water period, and 36% in the flood period. The present study aims to evaluate the composition, richness and temporal variation of diatoms in the plankton of Cutiuaú Lake during different hdrological periods.

2. Material and Methods

2.1. Study area

Jaú National Park was created in 1980 and it is one of the largest protected areas in Brazil (22720 km^2). It is located at ca. 200 km northwest Manaus, covering Jaú and Unini hydrographic basins, both affluent of the right margin of Negro River (Borges et al., 2004).

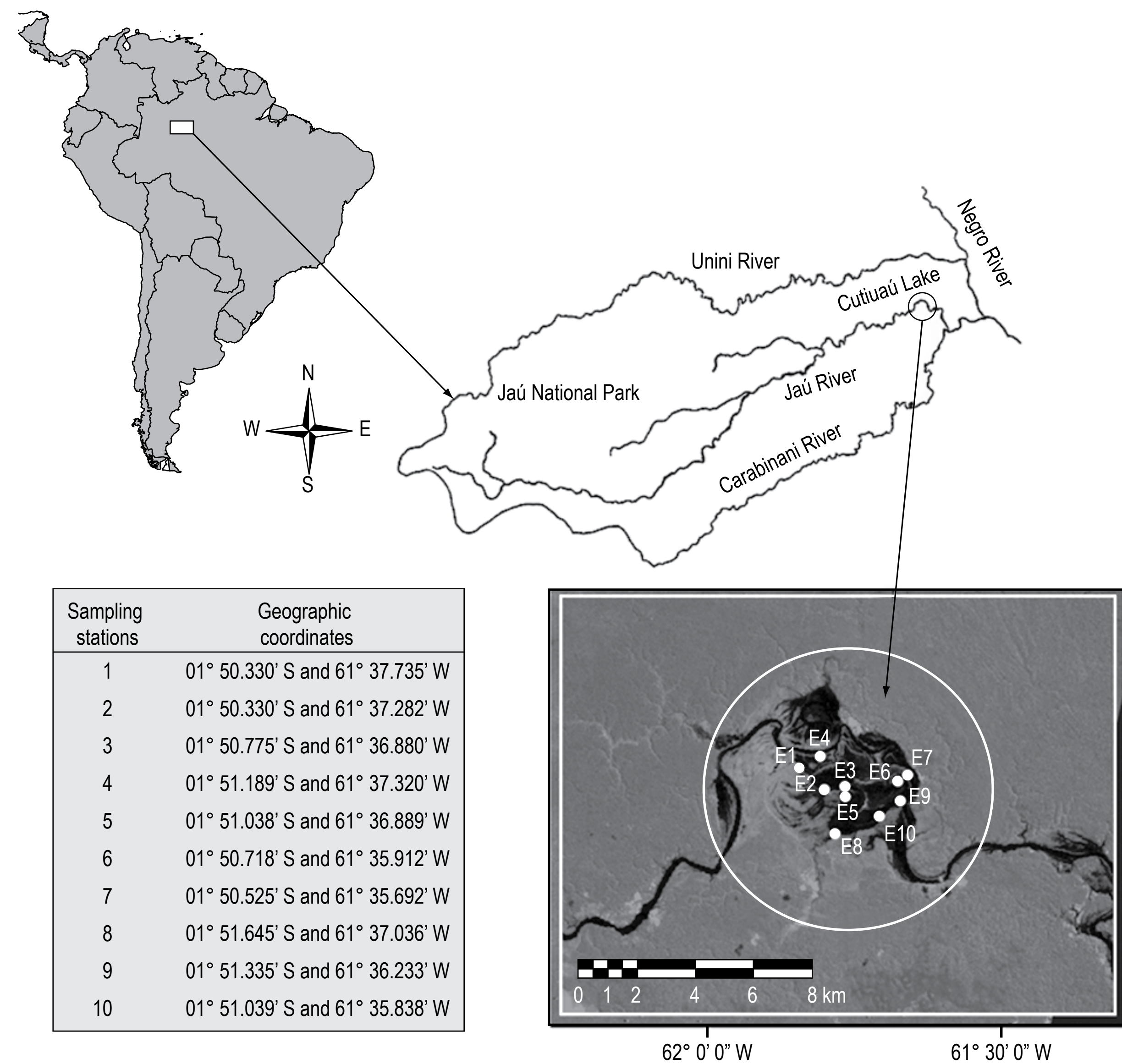
The Cutiuaú Lake is located at the right margin of Jaú River, at approximately 50 km of its mouth zone in Negro River. The annual hydrometric level fluctuation is between 6 e 10 m, and the floodplains are covered, mainly, by flooded forest, locally known as igapó forest. Precipitation is higher between January and May and the higher levels occur during June and July. High level of the river occurs in October and November (Borges et al., 2004).

2.2. Sampling procedure

The study was based on the analysis of samples collected in 10 stations distributed in the pelagic region of Cutiuaú Lake (Figure 1), covering the high waters (June), falling (September) and low waters (November) of 2003, and rising (April), high waters (June) and low waters (October) of 2004 (Table 1). Samples were taken by using flasks of 200 mL, at ca. 20 cm of water surface and fixed with Lugol solution (Sournia, 1978).

Phytoplankton populations were enumerated in random fields (Uhelinger, 1964), using the settling technique (Utermöhl, 1958). The units (cells, colonies and filaments) were enumerated, at least to 100 specimens of the most frequent species ($p < 0.05$, Lund et al., 1958). Species found at densities higher than 50% to the total species density were considered dominant; and species with numbers above the average value, obtained from the ratio between total density and number of identified species, were considered abundant (Lobo and Leighton, 1986). Population diatom density is expressed as cells. mL^{-1}.

Samples to the diatom identification were prepared following the method of Von Stoch (1970) and the material was mounting in permanent slides using Naphrax resin.



Sampling stations	Geographic coordinates
1	01° 50.330' S and 61° 37.735' W
2	01° 50.330' S and 61° 37.282' W
3	01° 50.775' S and 61° 36.880' W
4	01° 51.189' S and 61° 37.320' W
5	01° 51.038' S and 61° 36.889' W
6	01° 50.718' S and 61° 35.912' W
7	01° 50.525' S and 61° 35.692' W
8	01° 51.645' S and 61° 37.036' W
9	01° 51.335' S and 61° 36.233' W
10	01° 51.039' S and 61° 35.838' W

Figure 1. Map and the location of Cutiuaú Lake showing the sampling stations.

The taxonomic classification was performed according to Round et al. (1990). Species identification were based on Krammer and Lange-Bertalot (1986; 1988; 1991a, b) and Metzeltin and Lange-Bertalot (1998).

Simultaneously to the phytoplankton samples, some physical and chemical variables of the water were measured: temperature, oxygen saturation and dissolved oxygen (Yellow Springs Ints. model 55); pH and electrical conductivity (Yellow Springs Ints. model 63), and water transparency using Secchi disc.

3. Results

Water temperature ranged between 28.0 and 30.0 °C, and pH was low in all sampling stations (3.32, June/04, high water period to 4.52, November/03, low water period). Transparency values (Secchi disc depth) varied from 0.64 m (November/03) to 1.26m (April/04). Dissolved oxygen values showed higher variation, with values ranging from 0.34 mg.L^{-1} (June/04) to 5.46 mg.L^{-1} (June/03).

The planktonic diatom community in Cutiuaú Lake was composed by 51 species, distributed in 16 genera and 11 families (Table 1). Eunotiaceae and Pinnulariaceae showed the highest number of species (21 and 6 taxa, respectively).

Species richness was higher in the low water period and 96% of the taxa were observed. In the other periods (flood, high waters and falling) richness significantly decreased and remained low, with approximately 27.4 to 29.4% of the taxa (Table 1). The higher richness in the low water period was due to the increased contribution in density of both periphytic species (15 species, 100 cells.mL^{-1}), of the

Table 1. List of species found in the quantitative analysis at Cutiuaú Lake from June/03 to October/04. (LW = low water; R = rising; HW = high water; F = falling).

	LW	R	HW	F
COSCINODISCOPHYCEAE				
AULACOSEIRACEAE				
Aulacoseira granulata var. angustissima (O. Müller) Simonsen	x	x	x	x
Aulacoseira granulata var. granulata (Ehrenberg) Simonsen	x	x		
Aulacoseira herzogii (Lemmerman) Simonsen	x	x		
Aulacoseira sp.	x		x	
RHIZOSOLENIACEAE				
Urosolenia longiseta (Zacharias) Bukhtiyarova	x		x	x
Urosolenia eriensis var eriensis Smith	x			x
Urosolenia eriensis var. *morsa* (W. West and G. S. West) Torgan	x			x
FRAGILARIOPHYCEAE				
FRAGILARIACEAE				
Fragilaria javanica Hustedt	x			
Fragilaria capucina Desmazieres	x	x	x	
Synedra arcus Kützing	x		x	
Synedra filiformis Grunow	x			
Synedra cf. *rumpens* Kützing	x			
BACILLARIOPHYCEAE				
CYMBELLACEAE				
Encyonopsis frequentis Krammer	x	x		x
Encyonopsis sp.	x			x
EUNOTIACEAE				
Actinella brasiliensis Grunow	x			
Actinella guianensis Grunow	x			x
Actinella robusta Hustedt	x	x		
Eunotia asterionelloides Hustedt	x	x		
Eunotia cf. bilunaris (Ehrenberg) Mills	x		x	x
Eunotia cf. lunaris v. subarcuata (Naegelli) Grunow	x			
Eunotia dacostae Metzeltin and Lange-Bertalot	x	x	x	
Eunotia femoriformis (Patrick) Hustedt	x	x		
Eunotia incisa Gregory	x	x	x	x
Eunotia naegelii Migula	x	x	x	x
Eunotia paludosa Grunow	x	x	x	x
Eunotia aff. praerupta Ehrenberg	x			
Eunotia robusta Ralfs	x			
Eunotia subrobusta Hustedt	x			
Eunotia sudetica Müller	x			
Eunotia synedraeformis Hustedt			x	x
Eunotia valida Hustedt	x			
Eunotia sp.1	x		x	
Eunotia sp.4	x			
Eunotia sp.7	x			
Eunotia sp.9	x			
GOMPHONEMATHACEAE				
Gomphonema archaevibrio Metzeltin and Lange-Bertalot	x			
Gomphonema archaevibrio var. *cuneata* Metzeltin and Lange-Bertalot	x			
AMPHIPLEURACEAE				
Frustulia rhomboides (Ehrenberg) De Toni	x	x		
NAVICULACEAE				
Caloneis sp.1	x			
Navicula sp.1	x	x		
Placoneis sp.	x			

Table 1. Continued...

PINNULARIACEAE				
Pinnularia aff. braunii (Grunow) Cleve	x			
Pinnularia schroeterae Krammer	x		x	
Pinnularia schroeterae var. *eliptica* Krammer	x			
Pinnularia subgibba var. capitata Metzeltin and Lange-Bertalot	x			
Pinnularia subgibba Krammer				
Pinnularia sp.	x		x	x
SURIRELLACEAE				
Stenopterobia delicatissima (Lewis) Brébisson	x	x		x
Stenopterobia planctonica Metzeltin and Lange-Bertalot	x	x	x	x
Surirella didyma Kützing	x			
SELLAPHORACEAE				
Sellaphora pupula (Kützing) Mereschkowsky	X			

genera *Eunotia, Gomphonema*, and *Frustulia,* and benthic *Pinnularia* species (5 species, 20 cells.mL^{-1}).

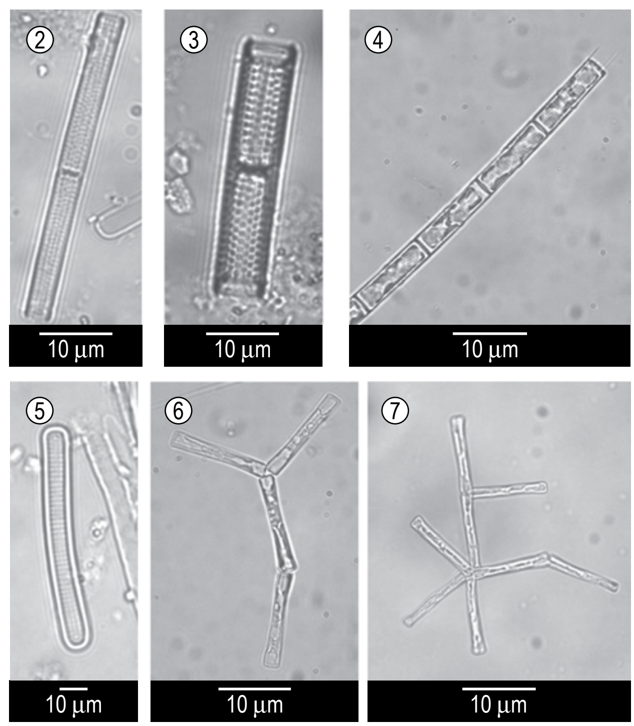
The community density showed minimum values during high water period (1 cell.mL^{-1} in June/03 and 04) and maximum values in the low water period (586 cells.mL^{-1} in November/03 and 600 cells.mL^{-1} in October/04) (Figure 8). The higher density in the low water period was due to the greater abundance of *Aulacoseira granulata* var. *angustissima* (333 cells.mL^{-1}) associated with the higher abundance of *Eunotia* (83 cells.mL^{-1}), *Frustulia* (14 cells.mL^{-1}), *Gomphonema* (3 cells.mL^{-1}) and *Pinnularia* (15 cells.mL^{-1}).

4. Discussion

Eunotiaceae and Pinnulariace were the main representative families of diatoms in terms of species numbers. Due to the acid conditions of the water, these two families are well represented in rivers and lakes of black waters in Amazon, as previously shown by earlier investigations (Uherkovich and Raí, 1979; Díaz-Castro et al., 2003; Melo et al., 2005, 2005; Ferrari et al., 2007).

The higher values of density and richness in the low water period are a consequence of the action of physical factors, like high organism concentrations in relation to the low water volume and increase in the vertical mixing of the water column. This fact makes possible the re-suspension of species from the sediments or the disruption of fixed algae in the marginal vegetation to the pelagic region of the lake. As observed in Table 1, the increase in richness and density of diatoms in Cutiuaú Lake during low waters was due to the addition of benthic and periphytic species.

The low water volume could also cause an increase in the concentration of dissolved nutrients due to re-suspension from the sediment. However, this variable was not evaluated in this study. In previous studies carried out in Amazonian Lakes, increase in density and diversity of the phytoplankton community during low waters was observed, when the water temperature and nutrient concentrations were higher (Huszar and Reynolds, 1997; Huszar, 2000; Rodrigues, 1994).



Figures 2-7. 2) *Aulacoseira granulata* var. *angustissima* (O. Müller) Simonsen; 3-4) *Aulacoseira granulata* var. *granulata* (Ehrenberg) Simonsen; 5-7) *Eunotia asterionelloides* Hustedt.

Species with higher densities in the Cutiuau Lake were *A. granulata*, *A. granulata* var. *angustissima*, and *Eunotia asterioneloides* (Figures 2-7). *Aulacoseira granulata* var. *angustissima* showed high density of 333 cells.mL^{-1}, in November 2003 (Figure 9). This species has been mentioned as abundant in Amazon in samplings performed in the Negro River by Uherkovich (1976). In Cutiuaú Lake, that species was dominant during the low water period, when the water transparency was low, corroborating the results of preference of that species by environments with

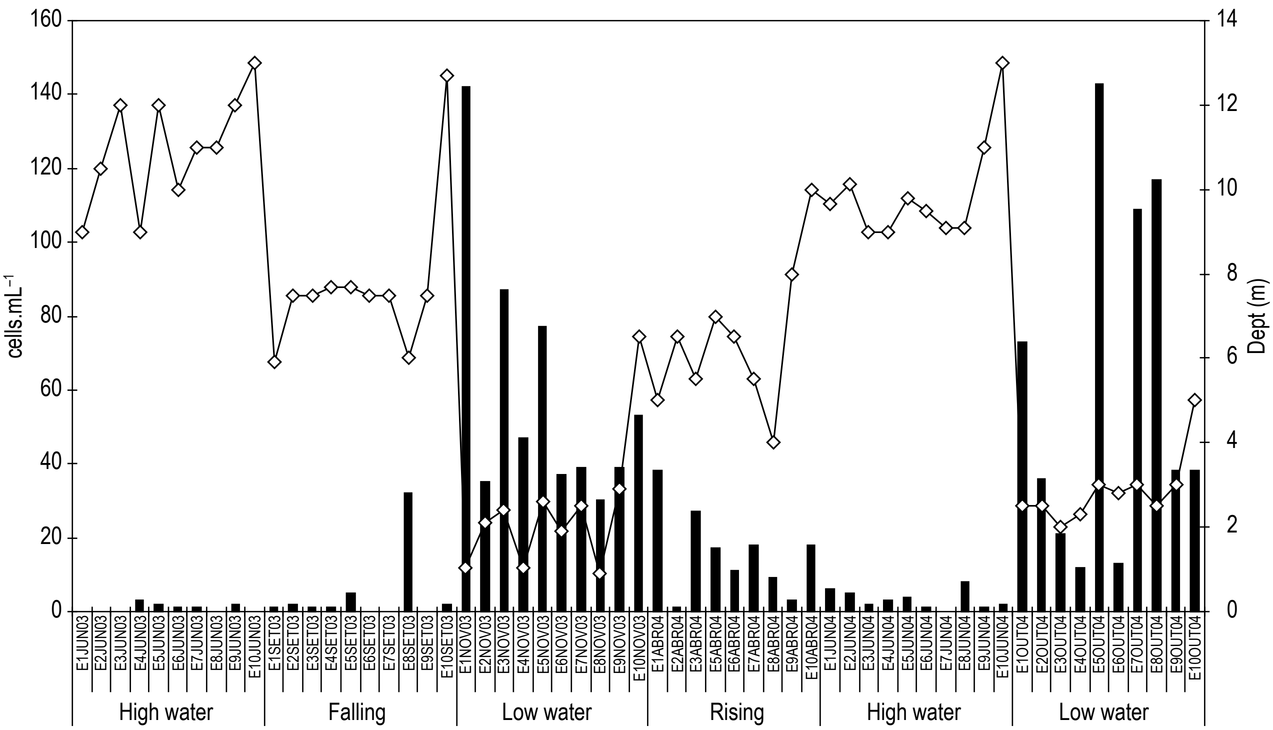


Figure 8. Density of the diatom communities in Cutiuaú Lake from June/03 to October/04, in the seven sampling stations (E).

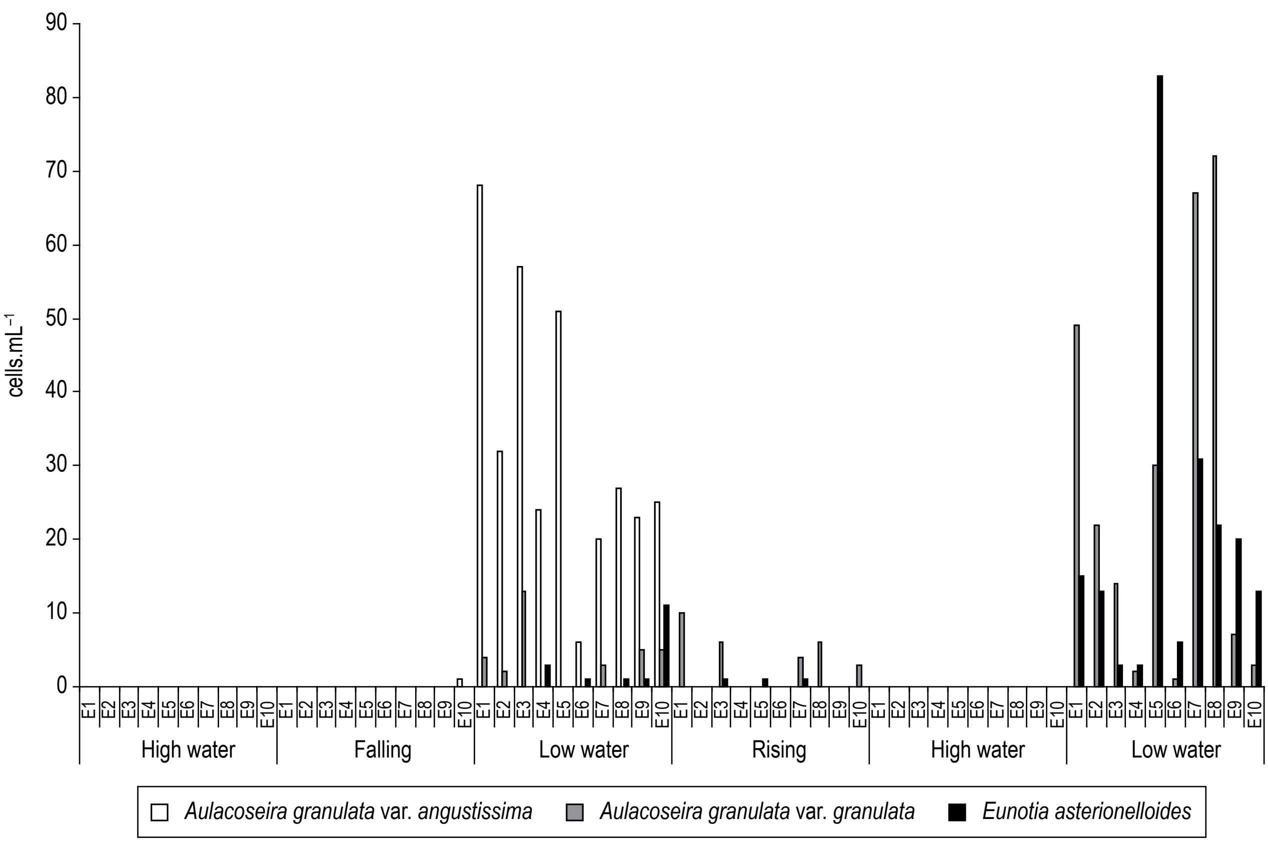


Figure 9. Density of the dominant diatoms species from Cutiuaú Lake from June/03 to October/04.

low transparency found by Moro and Fürstenberg (1997). On the other hand, *Aulacoseira herzogii* Lemmermann widely distributed in the Amazon region (Hustedt, 1952) was observed only during the low water and rising in the Cutiuaú Lake. The high density can also be related to the increase in nutrient concentrations during low water period (Ibañez, 1998; Train and Rodrigues, 1998; De Carvalho et al., 2001).

In conclusion, our data demonstrated that the higher richness and density of the diatoms community, occurred during the low water period, may be related to the high population abundance in relation to the reduced water volume, and were due to the contribution of species from the periphyton and benthos.

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References

BORGES, SH., DURIGAN, CC., PINHEIRO, MR., CAMARGO, JLC. and MURCHE, A. Planejando o estudo da biodiversidade na Amazônia brasileira: uma experiência no Parque Nacional do Jaú. In BORGES, SH., IWANAGA, S., DURIGAN, C.C. and PINHEIRO, M. R. (Eds.). *Janelas para a Biodiversidade no Parque Nacional do Jaú.* Manaus: Fundação Vitória Amazônica, 2004. p. 1-15.

De CARVALHO, P., BINI, LM., THOMAZ, SM., De OLIVEIRA, LG., ROBERTSON, B., TAVECHIO, WLG. and DARWISCH, AJ. Comparative limnology of South American floodplain lakes and lagoons. *Acta Scient.*, 2001, vol. 23, no. 2, p. 265-273.

DÍAZ-CASTRO, JG., SOUZA-MOSIMANN, RM., LAUDARES-SILVA, R. and FORSBERG, BR. Composição da comunidade de diatomáceas perifíticas do Rio Jaú, Amazonas, Brasil. *Acta Amaz.,* 2003, vol. 3, no. 4, p. 583-606.

FERRARI, F., PROCOPIAK, LK. and ALENCAR, YB. *Eunotiaceae* (Bacillariophyceae) em igarapés da Amazônia Central, Manaus e Presidente Figueiredo, Brasil. *Acta Amaz.*, 2007, vol. 37, no. 1, p. 1-16.

HUSTEDT, F. Neue and wenig bekannte Diatomeen. IV. *Bot. Not.*, 1952, parte 4, p. 365-409.

HUSZAR, VLM. Fitoplâncton. In BOZELLI, RL., ESTEVES, FA. and ROLAND, F. (Eds.). *Lago Batata*: Impacto e Recuperação de um Ecossistema Amazônico. Rio de Janeiro: Gráfica Book, 2000. 342 p.

HUSZAR, VLM. and REYNOLDS, CS. Phytoplankton periodicity and sequences of dominance in an Amazonian Floodplain Lake (Lago Batata, Pará, Brazil): Responses to gradual environmental change. *Hydrobiologia*, 1997, vol. 346, no. 1-3, p. 169-181.

IBAÑEZ, MSR. Phytoplankton composition and abundance of a Central Amazonian Floodplain Lake. *Hydrobiologia,* 1998, vol. 362, no. 1-3, p. 79-83.

JUNK, WJ., BAYLEY, PB. and SPARKS, RE. The flood pulse concept in river-floodplain systems. *Can. Spec. Publ. Fish. Aquat. Sci.*, 1989, vol. 106, p. 110-127.

KRAMMER, K. and LANGE-BERTALOT, H. Freshwater flora of Central Europe. Bacillariophyceae: Naviculaceae. In ETTL, H., GERLOFF, I., HEYNING, H. and MOLLENHAUER, D. (Eds.). *Süsswasseflora von Mitteleuropa*. Stuttgart: G. Fischer, 1986. 876 p.

KRAMMER, K. and LANGE-BERTALOT, H. Freshwater flora of Central Europe. *Bacillariophyceae: Bacillariaceae, Ephitemiaceae, Surirellaceae*. In ETTL, H., GERLOFF, I., HEYNING, H. and MOLLENHAUER, D. (Eds.). *Süsswasseflora von Mitteleuropa*. Stuttgart: G. Fischer, 1988. 596 p.

KRAMMER, K. and LANGE-BERTALOT, H. Freshwater flora of Central Europe. *Bacillariophyceae: Centrales, Fragilariaceae, Eunotiaceae*. In ETTL, H., GERLOFF, I., HEYNING, H. and MOLLENHAUER, D. (Eds.). *Süsswasseflora von Mitteleuropa*. Stuttgart: G. Fischer, 1991a. 576 p.

KRAMMER, K. and LANGE-BERTALOT, H. Freshwater flora of Central Europe. *Bacillariophyceae: Achnanthaceae, Kritische Ergänzungen* zu *Navicula (Lineolatae)* und *Gomphonema.* In ETTL, H., GERLOFF, I., HEYNING, H. and MOLLENHAUER, D. (Eds.). *Süsswasseflora von Mitteleuropa*. Stuttgart: G. Fischer, 1991b. 437 p.

LOBO, EA. and LEIGHTON, G. Estructuras Comunitárias de las Fitocenosis Límnicas en los Sistemas De Desembocaduras de Rios y Esteros de la Zona Central de Chile. *Rev. Biol. Marina*, 1986, vol. 22, no. 1, p. 1-29.

LUND, JWG., KIPLING, C. and LE-CREN, ED. The inverted microscope method of estimating algal number and the statistical basis of estimating by counting. *Hydrobiologia,* 1958, vol. 11, p. 143-170.

MELACK, JM. Amazon floodplain lakes: shape, fech and stratification. *Rev. Int. Verein. Theor. Angew. Limnol.*, 1984, vol. 22, p. 1278-1282.

MELO, S., REBELO, RM., SOUZA, KF., MENEZES, M. and TORGAN, LC. Fitoplâncton. In SANTOS-SILVA, E., APRILE, FM., SCUDELLER, VV. and MELO, S. (Orgs.). *BioTupé*: meio físico, diversidade biológica e sociocultural. Manaus: Ed. INPA, 2005. 246 p.

METZELTIN, D. and LANGE-BERTALOT, H. Tropical Diatoms of South America 1. Diversity-Taxonomy-Geobotany. In LANGE-BERTALOT, H. (Ed.). *Iconographia Diatomologica.* Königstein: Koeltz Scientific Books, 1998. 695 p.

MORO, RS. and FÜRSTENBERG, CB. *Catálogo dos principais parâmetros ecológicos de diatomáceas não –marinhas.* Ponta Grossa: Ed. UEPG, 1997. 282 p.

RODRIGUES, MS. *Biomassa e produção fitoplanctônica do Lago Camaleão (Ilha de Marchantaria, Amazonas).* Manaus: INPA; FUA, 1994. 200 p. Tese de Doutorado.

ROUND, FE., CRAWFORD, RM. and MANN, DG. *The diatoms*: Biology and Morphology of the Genera. New York: Cambridge University Press, 1990. 747 p.

SIOLI, H. The Amazon and its main affluents: hydrography, morphology of the river courses, and river types. In SIOLI, H. (Ed.). *The Amazon*: Limnology and Landscape Ecology of a Mighty Tropical River and its Basin. Dordrecht: Dr. W. Junk. Publishers, 1984. p. 127-165.

SOURNIA, A. *Phytoplankton manual.* Paris: UNESCO, 1978. 330 p. Monographs on Oceanographic Methodology.

SOUZA-MOSIMANN, RM., TAVARES, AS. and FREITAS, VP. Contribuição ao Conhecimento da Diatomoflórula do Conteúdo Estomacal de Algumas Espécies de Peixes da Amazônia. I- Myleus sp. (Pacu) do Lago do Prato, A.M., Brasil. *Acta Amaz.*, 1997, vol. 27, no. 1, p. 9-25.

TRAIN, S. and RODRIGUES, LC. Temporal fluctuations of the phytoplankton community of the Baía River, in the upper Paraná River floodplain, Mato Grosso do Sul, Brazil. *Hydrobiologia,* 1998, vol. 361, p. 125-134.

TUNDISI, JG. Tropical South América: Present and perspectives. In MARGALEF, R. (Ed.). *Limnology now*: a paradigm of planetary problems. Amsterdam: ELSEVIER, 1994. 553 p.

UHERKOVICH, G. 1976. Algen aus den Flüssen Rio Negro und Rio Tapajós. *Amazoniana*, 1976, vol. 5, no. 4, p. 465-515.

UHERKOVICH, G. Phytoplankton. In SIOLI, H. (Ed.). *The Amazon*: Limnology and landscape ecology of a mighty tropical river and its basin. Dordrecht: Dr. W. Junk Publishers, 1984. p. 265-310. Monographiae Biologicae.

UHERKOVICH, G. and RAI, H. Algen aus dem Rio Negro und seinen Nebenflüssen. *Amazoniana,* 1979, vol. 6, p. 611-638.

UHERKOVICH, G. and SCHMIDT, GW. Phytoplanktontaxa in dem zentralamazonischen Schwemmlandsee Lago do Castanho. *Amazonian*a, 1974, vol. 5, no. 2, p. 243-283.

UTHERMÖHL, H. Zur Vervollkomnung der quantitativen Phytoplankton- Methodik. *Mitt. Int. Ver. Limnol.*, 1958, vol. 9, p. 1-38.

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