KRYSNA STEPHANNY DE MORAIS FERREIRA

Distribuição estratigráfica de diatomáceas (Bacillariophyta) em sedimentos holocênicos do rio Xingu (Bacia Amazônica): reconstrução paleolimnológica

Tese apresentada ao Instituto de Botânica da Secretaria de Infraestrutura e Meio Ambiente, como parte dos requisitos exigidos para a obtenção do título de DOUTORA em BIODIVERSIDADE VEGETAL E MEIO AMBIENTE, na Área de Concentração de Plantas Vasculares em Análises Ambientais.

SÃO PAULO
2021

KRYSNA STEPHANNY DE MORAIS FERREIRA

Distribuição estratigráfica de diatomáceas (Bacillariophyta) em sedimentos holocênicos do rio Xingu (Bacia Amazônica): reconstrução paleolimnológica

Tese apresentada ao Instituto de Botânica da Secretaria de Infraestrutura e Meio Ambiente, como parte dos requisitos exigidos para a obtenção do título de DOUTORA em BIODIVERSIDADE VEGETAL E MEIO AMBIENTE, na Área de Concentração de Plantas Vasculares em Análises Ambientais.

ORIENTADOR: PROF. DR. CARLOS EDUARDO DE MATTOS BICUDO

Ficha Catalográfica elaborada pelo **NÚCLEO DE BIBLIOTECA E MEMÓRIA**

Ferreira, Krysna Stephanny de Morais

F383d Distribuição estratigráfica de diatomáceas (Bacillariophyta) em sedimentos holocênicos do rio Xingu (Bacia Amazônica): reconstruçãopaleolimnológica / Krysna Stephanny de Morais Ferreira -- São Paulo, 2021, 132p.; il.

Tese (Doutorado) -- Instituto de Botânica da Secretaria de Infraestrutura e Meio Ambiente, 2021.

Bibliografia.

1. Biodiversidade. 2. Diatomácea. 3. Paleohidrologia. I. Título.

À minha mãe Aurilene e ao meu pai Edilson, família e amigos,

dedico.

“Amar e mudar as coisas me interessa mais”

Alucinação – Belchior

AGRADECIMENTOS

Em primeiro lugar gostaria de agradecer a Deus por ser minha base e nunca ter me abandonado nos momentos mais difíceis.

Ao meu queridíssimo Prof. Dr. Carlos Eduardo de Mattos Bicudo pela confiança, incentivo e apoio. Ori, mais uma vez eu não tenho palavras para agradecer por tudo que você fez por mim ao longo desses seis anos. Obrigada de coração por tudo que me ensinou e ainda me ensina. Obrigada por ser paciente comigo e por acreditar em mim quando nem eu mesma acreditava. Obrigada por sempre ser meu apoio nas horas de “aperreio” e muito obrigada por essa amizade linda que construímos. Sem dúvidas, sentirei saudades de tudo isso.

À Profª Drª Denise de Campos Bicudo pelo conhecimento a mim passado, pelos conselhos e boas conversas na hora do café. Obrigada por ser essa pessoa paciente, alegre e iluminada. Obrigada também por sua amizade.

À Profª Drª Carla Ferragut por todo conhecimento e experiência repassado. Obrigada por ser essa pessoa querida que está sempre disposta a ajudar.

Ao Prof. Dr. Elnatan Bezerra de Souza, meu querido professor de Ficologia e Micologia da Universidade Estadual Vale do Acaraú (UEVA). Obrigada por sempre acreditar em mim e continuamente me incentivar. Se não fosse você, eu jamais iria tão longe. Obrigada de coração.

Ao Prof. Dr. Hermesson Cassiano de Oliveira, pelas inúmeras conversas sobre pós-graduação e pelo incentivo para seguir em frente mesmo quando a caminhada se tornasse difícil.

Ao Prof. Dr. Mark Brenner da Universidade da Flórida (UF) pelo incentivo e pela paciência durante os cinco meses que passei em Gainesville. Obrigada por ser essa pessoa inspiradora e querida. Sou e serei eternamente grata pela amizade que construímos.

Ao Dr. Carlos E. Wetzel e ao Dr. Luc Ector (Luxembourg Institute of Science and Technology) pelo auxilio e incentivo nos trabalhos de taxonomia. Gostaria de agradecer em especial ao Dr. Carlos E. Wetzel pela valiosa ajuda com as análises de microscopia eletrônica e por compartilhar todo seu entusiasmo e paixão pelas diatomáceas.

Gostaria de agradecer ao Dr. André Oliveira Sawakuchi e a toda a equipe de pesquisadores e pós-graduandos envolvidos no projeto principal (processo FAPESP n° 16/02656-9) no qual este estudo está inserido. Agradeço especialmente à equipe de coleta do testemunho representada por:

André Oliveira Sawakuchi, Dailson José Bertassoli, Gelvam Hartmann e Henrique Oliveira Sawakuchi.

A todos os alunos dos Laboratórios de Ecologia Aquática e Terrestre do Instituto de Botânica de São Paulo pela amizade e experiência compartilhada; sou imensamente grata a vocês por tudo que aprendi ao longo desses quatro anos. Obrigada Elaine Bartozek, Simone Oliveira, Angela Silva-Lemkhul, Elton Lemkhul, Camila Barbosa de Araújo, Lívia Costa, Samantha Faustino, Mayara Casartelli, Ruan Oliveira, Renata Costa, Luyza Amaral, Diego Tavares, Richard Lambrecht, Gisele Marquardt e Jaques Zanon. Obrigada aos meus queridos amigos que, mesmo longe, me deram forças para esta caminhada: Ana Margarita, Jennifer Moyón, Lucineide Santana, Simone Wengrat, Stéfano Zorzal e Thiago Rodrigues.

Agradeço, em especial, aos meus irmãos de coração que São Paulo me presenteou: Elaine Bartozek, Simone Oliveira, Angela Silva-Lemkhul e Elton Lemkhul. Vocês fizeram meus dias mais alegres e divertidos. Obrigada por todo apoio, conversas e incentivos diários, e por aguentarem meus “ataques” de ansiedade nestes últimos anos. Sinto e sem dúvidas sentirei falta de vocês todos os dias.

Agradeço também os meus queridos amigos do “3º turno”: Camila Barbosa de Araújo, Cássia Bazzi, Marcela Engela, Gisele Pedrosa e Yukio Hayashi Silva. Amigos, me faltam palavras para agradecer-lhes por tudo que fizeram e ainda fazem por nossa amizade. Obrigada por todos os conselhos, por serem apoio quando precisava e pelos cafezinhos na salinha dos estudantes.

Agradeço à Dorinha, Amariles e Marli pela simpatia e carinho de sempre.

Ao pessoal do Aloja, por tudo que aprendi e vivi nesses poucos meses, obrigada pelas risadas e momentos bons, em especial: Gi (Gisele Pedrosa), Iris Cavalcanti, Patrícia Gonzales, Marina Koga, Luanda Soares, Naty (Natália Martarello) e Bianca Canestraro. E a todos que no momento não recordo, mas que me deixaram histórias e experiência nesta vida.

Aos meus queridos pais, Aurilene Morais e Edilson Ferreira, obrigada pelo apoio e pelas palavras de incentivo, por acreditarem em mim e por todo amor que recebi ao longo da vida.

Aos meus queridos irmãos e família, como é bom ter pessoas como vocês ao meu lado. Obrigada também pelo incentivo e todo carinho recebido.

Aos meus queridos amigos do coração: Jacinto Farias, Wandy Policarpo, Larissa Juliana, Eloísio Ferreira, Vilmara Farias, Cátia Barroso, Patrícia Costa, Leirine Moura, Débora Aguiar e Evandernilda Ponte, muito obrigada pela amizade sincera que espero levar para a vida inteira.

Ao meu querido noivo Victor Figueira, pela paciência e pelas palavras de incentivo quando a saudade batia, obrigada meu bem, te amo imensamente!

Agradeço, à CAPES, Coordenação de Aperfeiçoamento de Pessoal de Nível Superior pela bolsa de doutorado concedida (processo nº 134042/2014-0) e pela bolsa de doutorado-sanduíche (processo nº 134042/2014-0).

Agradeço, aos membros da comissão examinadora de qualificação, Dra. Andrea Tucci, Dra. Gisele Carolina Marquardt e Dra. Luciane Fontana.

Por fim, agradeço aos membros da comissão examinadora de doutorado, Dr. André Sawakuchi, Drª Carla Ferragut, Drª Lúcia Helena Sampaio da Silva e Drª Luciane Fontana. Muito obrigada pelas valiosas sugestões, contribuições e ideias que resultaram na versão final desta tese.

E a todos que por algum motivo deixei de mencionar.

RESUMO

Apesar de ser considerado um período “recente” na escala geológica, o Holoceno (~4.000 cal anos AP) é caracterizado por períodos secos intercalados com outros mais úmidos observados em toda a Bacia Amazônica. Com o objetivo de maximizar o entendimento sobre as principais mudanças ambientais ocorridas na Amazônia Oriental, um testemunho intitulado XC-03 foi coletado em uma área de *ria* no baixo Xingu. No capítulo 1, as assembleias de diatomáceas foram relacionadas à informação física e química disponível para o testemunho, a fim de discutir as principais mudanças ocorridas durante a Idade Meghalayana. Verificou-se que as mudanças ocorridas no clima no período entre 2.600 e 1.400 cal anos AP afetaram o regime de descarga na *ria* e, consequentemente, as assembleias de diatomáceas. *Aulacoseira granulata* foi a espécie que mais respondeu às mudanças, atingindo seus valores máximos entre 2.470 e 779 cal anos AP (zona 3). O capítulo 2 apresentou as espécies mais abundantes identificadas do testemunho XC-03 com o objetivo de complementar a pesquisa florística realizada no local. Como resultado, 16 táxons entre espécies e variedades taxonômicas distribuídos em nove gêneros foram inventariados e suas preferências ecológicas discutidas. Os capíulos 3 e 4 descreveram duas espécies até então inéditas para Ciência: *Planothidium xinguense* e *Psammothidium* sp., contribuindo para o conhecimento da diversidade de diatomáceas em ecossistemas de *rias* e adicionando novos registros para os rios amazônicos de águas claras. Finalmente, a análise das diatomáceas associadas a outros multitraçadores ambientais (granulometria, geoquímica orgânica e inorgânica e dados isotópicos) permitiu expandir o conhecimento sobre as principais mudanças ambientais ocorridas na Amazônia Oriental.

Palavras-chave: biodiversidade, diatomácea, Idade Meghalayana, paleohidrologia, *ria* amazônica

ABSTRACT

Despite of considering “recent” on the geological time scale, the Holocene is characteristic by drier periods alternating with wetter ones observed across the Amazon basin. In order to understand the main environmental changes occurring in the eastern Amazon basin, a sediment core named XC-03 was retrieved in a region of *ria* in the lower Xingu River. Chapter 1 focused on the relationships between the diatom assemblage and the physical and chemical features available for the sediment core, in order to discuss the main changes that occurred during the Meghalayan Age (~4.000 cal yr BP). Climate changes were observed between 2,600 and 1,400 cal yr BP, which affected the discharge regime of the *ria* and, consequently, the diatom assemblage composition. *Aulacoseira granulata* responded for the main changes, reaching its maximum abundance between 2,470 and 779 cal yr BP (zone 3). Chapter 2 is the identification of the most abundant species in the sediment core, in order to complement the floristic survey already carried out for the study area. As a result, 16 taxa (species and taxonomic varieties) distributed in nine genera were identified and their ecological preference discussed. Chapters 3 and 4 are the description of two new species: *Planothidium xinguensis* and *Psammothidium* sp., thus contributing to the knowledge of the diatoms diversity in *ria* ecosystems, as well as adding new records to the Amazonian clear water rivers. Finally, analysis of the diatoms associated with other sedimentary biomarkers (lithological, organic and inorganic geochemistry, and isotopic data) allowed expansion of the knowledge on the environmental changes occurred in the eastern Amazon.

Keywords: biodiversity, diatom, Meghalayan Age, paleohidrology, Amazonian *rias*

Apresentação da tese

Intitulada "*Distribuição estratigráfica de diatomáceas (Bacillariophyta) em sedimentos holocênicos do rio Xingu (Bacia Amazônica): reconstrução paleolimnológica*" a presente tese está organizada em quatro capítulos que representam, de maneiras distintas, os objetivos da pesquisa realizada, a revisão da literatura pertinente, os materiais e métodos utilizados, os resultados alcançados, a discussão desses mesmos resultados e, por fim, as conclusões a que chegamos ao final da pesquisa. Menciono, finalmente, que todos os trabalhos foram organizados e formatados segundo as normas das revistas às quais foram ou serão submetidos.

A tese está constituída da seguinte maneira:

Primeiro, uma parte intitulada "Introdução e materiais e métodos geral" que aborda os referenciais teóricos utilizados para a elaboração da pesquisa, objetivos que motivaram seu desenvolvimento e os métodos aplicados.

O **capítulo 1** intitulado "A resposta das diatomáceas às mudanças paleohidrológicas ocorridas no Xingu *ria* (Bacia Amazônica) durante a Idade Meghalayana" é o esteio da tese e aborda as principais mudanças hidrológicas ocorridas no Xingu *ria* durante os últimos 4.000 cal anos AP interpretadas utilizando a relação entre a diatomoflórula e os dados paleoambientais coletados durante a pesquisa.

O **capítulo 2** intitulado "Subfossil diatoms from Xingu River, Amazon Basin, Brazil" é um complemento decorrente da pesquisa florística já realizada para o Rio Xingu submetido à publicação em "Hoehnea" (artigo colocado em "Anexo").

O **capítulo 3** intitulado "*A new species of Planothidium (Achnanthidiaceae, Bacillariophyceae) from Xingu Ria, Amazon hydrological basin, Brazil*" (publicado na revista "Phytotaxa") e o **capítulo 4** intitulado "*Psammothidium sp. nov., a subfossil diatom from Xingu river in the Brazilian Amazon basin*" são as descrições pioneiras de duas espécies detectadas durante o levantamento florístico que antecedeu à presente pesquisa e apresentadas como novidades taxonômicas para a Ciência.

Após os quatro capítulos consta uma seção intitulada "Considerações finais" que abrangeu as principais conclusões do presente estudo, assim como a formulação de certas considerações que sugerimos para futuras pesquisas.

Os dados paleoambientais utilizados na elaboração da tese foram coletados durante o desenvolvimento do projeto "*A resposta da dinâmica sedimentar dos rios Xingu e Tapajós às* *mudanças climáticas e barragens de usinas hidrelétricas: riscos para conservação da biodiversidade e produção de energia na Amazônia*" financiado pela FAPESP, Fundação de Amparo à Pesquisa do Estado de São Paulo (processo nº 2016/02656-9), que teve a colaboração destacada de pesquisadores, funcionários e estudantes do Instituto de Geociências da Universidade de São Paulo, do Instituto de Botânica e de outras instituições parceiras.

SUMÁRIO

INTRODUÇÃO GERAL

O Holoceno é definido como uma época (ou série) dentro do Período Quaternário, que cobre o intervalo de tempo de 11,7 ka aos dias de hoje (Walkers *et al*. 2018). Os registros estratigráficos pertencentes a essa época encontram-se extremamente bem preservados e podem fornecer evidências geomorfológicas, sedimentólogicas, climáticas, hidrológicas, biológicas e arqueológicas de alta resolução (IPCC 2001, Melo & Marengo 2008, Walkers *et al*. 2018, 2019). Além disso, de acordo com Walkers (2005) muitos métodos geocronológicos podem ser aplicados aos registros holocênicos e, portanto, suas sucessões podem ser frequentemente datadas e correlacionadas com precisão e exatidão.

Atualmente, o Holoceno é divido em três Idades: Greenlandiana (correspondendo ao Holoceno inicial: 11.700 anos b2k ou 11.700 anos a.C., isto é, antes de 2000), Northgrippiana (Holoceno médio: 8.326 anos b2k) e Meghalayana (Holoceno tardio: 4.200 anos b2k). Tal divisão foi definida através de marcadores físicos e químicos, que refletiram eventos climáticos abruptos entre ~11,7 ka, ~8,2 ka e ~4,2 ka em escala global ou quase global (Walker *et al*. 2019). Este último evento (~4,2 ka, Idade Meghalayana), base da presente pesquisa, refletiu mudanças climáticas abruptas e uma reorganização signitivativa nos padrões de circulação atmostérica e oceânica (Walker *et al*. 2018). Foi também durante este período que as sociedades experimentaram o impacto de secas e resfriamento do Globo, levando ao colapso de várias civilizações (Silva *et al*. 2018).

Uma das formas de compreender as principais mudanças ocorridas durante o Holoceno é estudar remanescentes biológicos preservados em sedimentos aquáticos continentais e oceânicos. Um testemunho bem conservado pode conter uma sequência cronológica completa e contínua de informação sendo, portanto, considerado verdadeira “memória” dos ambientes que os contêm (Mozeto *et al*. 2004, Smol 2008).

A paleolimnologia é uma ciência multidisciplinar que utiliza informação física, química e biológica preservada em testemunhos para reconstruir condições ambientais passadas (Smol 2008). Desempenha papel importante e crucial, pois possibilita compreender os processos de eutrofização, acidificação, estresse e resiliência dos ecossistemas em escala anual e até milenar (Battarbee *et al*. 2005, Burge *et al*. 2018). Constitui, enfim, uma ferramenta absolutamente indispensável para a gestão e conservação desses ambientes e seus recursos, bem como dos serviços que eles fornecem (Saulnier-Talbot 2016).

A utilização de *registros representativos* (Suguio & Sallun 2017) como esporos, espículas de esponjas, pólen, frústulas de diatomáceas e fotólitos, entre outros (Battarbee *et al*. 2005, Smol 2008, Rasbold *et al*. 2016) constitui ferramenta empregada na paleolimnologia para interpretação e compreensão das mudanças climáticas (Lotter & Birks 2003). Entre tais registros, as diatomáceas compõem o melhor e mais bem-sucedido grupo de organismos presente nos ambientes aquáticos (Medlin & Kaczmarska 2004, Bennion *et al.* 2011).

Por apresentarem alta sensibilidade às variações físicas e químicas ocorridas nos ambientes e exibirem boa preservação nos sedimentos, as diatomáceas vêm se tornando, nas últimas décadas, em uma importante ferramenta nas reconstruções paleoambientais, atuando como arquivos naturais das principais modificações ocorridas no ambiente (Smol 2017, Burge *et al*. 2017). Estudos visando a estes microrganismos em sedimentos aquáticos estão diretamente ligados a condições limnológicas específicas, tais como pH, alcalinidade, estado trófico, salinidade e temperatura (Bigler & Hall 2002, Smol 2008, 2017).

Algumas feições conferem particularidades a esse grupo de algas, como segue: (1) ampla distribuição geográfica e grande diversidade taxonômica; (2) natureza resistente de seu exoesqueleto composto por sílica polimerizada ($S_iO_2.nH_2O$); (3) ciclo de vida curto que responde prontamente às mudanças físicas, químicas e biológicas do meio; (4) são bons indicadores ecológicos utilizados na micropaleontologia e na geoquímica; e (5) possuem características ecológicas distintas e bastante bem estudadas, tornando-as extremamente úteis nas reconstruções do passado (Wetzel 1993, Bennion 1995, Moro & Bicudo 2002, Flower & Ryves 2009).

Nas regiões tropicais e subtropicais do Globo, os estudos relacionando diatomáceas às condições pretéritas, embora ainda sejam bastante escassos, vêem mostrando um aumento crescente nas últimas décadas (Lamb *et al*. 1995, Urrutia *et al.* 2000, Barker *et al*. 2001). Particularmente para o Brasil, os estudos intensificaram somente a partir da década dos anos 1980. Atualmente, constam na literatura trabalhos utilizando diatomáceas em reconstruções paleolimnológicas e paleoambientais (ex. Rasbold *et al*. 2016, Ruwer *et al*. 2019) e histórico de eutrofização em reservatórios (ex. Costa-Böddeker *et al*. 2012, Fontana *et al*. 2014, Wengrat *et al*. 2017).

Para a bacia Amazônica, alguns trabalhos utilizaram temáticas paleoambientais para conhecer e caracterizar ambientes pretéritos (ex. Cordeiro *et al*. 2008, Moreira *et al*. 2009, Silveira & Chaan 2010), contudo, no leste amazônico a contribuição utilizando diatomáceas como paleoindicadores ambientais ainda é pequena. Para o rio Xingu, o segundo maior rio de águas claras do país, ainda não há trabalho realizado exclusivamente com esta abordagem. Destaquem-se aqui apenas os trabalhos de Sawakuchi *et al*. (2016) e Bertassoli *et al*. (2017) que citaram algumas espécies de diatomáceas encontradas no rio Iriri (localizado próximo à Volta Grande do Xingu) e forneceram informação ecológica importante sobre o local.

Nesse contexto, o presente estudo teve como objetivo central utilizar as diatomáceas na reconstrução paleoambiental do Xingu *ria* desde os últimos ~4.000 cal anos AP até os dias atuais. A presente contribuição está vinculada ao projeto denominado "*A resposta da dinâmica sedimentar dos rios Xingu e Tapajós às mudanças climáticas e barragens de usinas hidrelétricas: riscos para conservação da biodiversidade e produção de energia na Amazônia*" (processo FAPESP nº 16/02656-9). Saliente-se que parte do referido projeto contribui para seu propósito maior que consiste em prever cenários futuros e definir estratégias de conservação da biodiversidade.

MATERIAIS E MÉTODOS GERAIS

Área de Estudo

A Bacia Hidrográfica Amazônica (Fig. 1a) representa cerca de 40% do território nacional brasileiro e possui mais de 60% da disponibilidade hídrica do país (PNRH 2006). Ocupando uma área total de 6.925.674 km², a região hidrográfica amazônica está situada sobre terreno de origem mista, com uma área recente de terras baixas no centro e duas grandes áreas periféricas de rochas metamórficas Pré-Cambrianas e ígneas cristalinas, o Escudo Brasileiro (que abrange as bacias dos rios Tapajós e Xingu) e o Escudo das Guianas (bacias dos rios Trombetas e Branco) e a oeste os Andes (Reis 2013). No território brasileiro, a bacia situa-se em sete Estados da Federação (Acre, Amapá, Amazonas, Mato Grosso, Pará, Rondônia e Roraima) e é considerada uma das maiores bacias hidrográficas do mundo (Salomão *et al*. 2007).

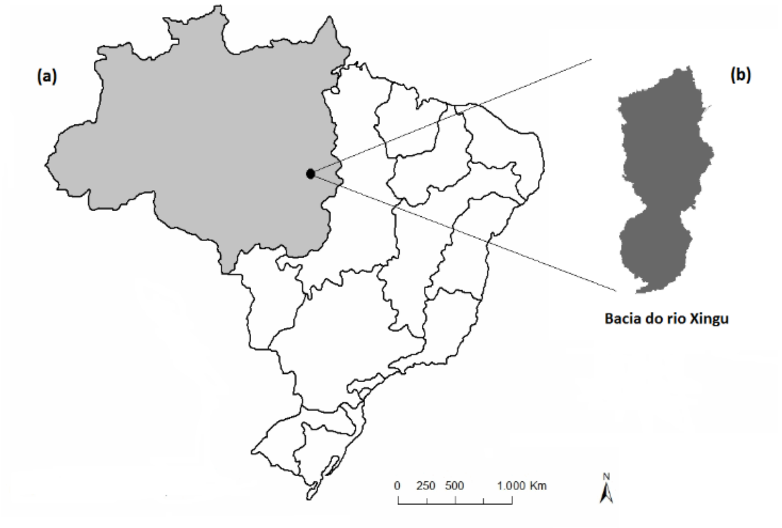


Figura 1. (a) Localização da bacia Amazônica (Fonte: adaptado de IBGE 2017) e (b) Localização da bacia do rio Xingu (Fonte: adaptado de Prado *et al*. 2017).

A precipitação anual média é entre 2.000 e 3.000 mm por ano, com estimativas de evapotranspiração na faixa de 3-5 mm diários (Werth & Avissar 2004). O clima varia de úmido a super-úmido, com temperaturas médias anuais entre 25-29ºC. O solo é do tipo laterítico e a cobertura vegetal varia desde uma cobertura baixa (na porção dos Andes) até uma floresta tropical úmida amazônica (PNRH 2006).

Para fins de gestão de recursos hídricos, a Bacia Hidrográfica Amazônica está dividida em nove sub-regiões hidrográficas ou sub-bacias hidrográficas (PNRH 2006), quais sejam: sub-região hidrográfica do Solimões, sub-região do Negro, sub-região do Madeira, sub-região do Purus, sub-região do Tapajós, sub-região do Xingu (correspondente aos rios Iriri e Xingu), sub-região do Paru, sub-região da Foz do Amazonas e, por fim, a sub-região hidrográfica do Amapá litoral.

A sub-bacia hidrográfica do rio Xingu (Fig. 1b) é uma forte referência da diversidade socioambiental da Amazônia brasileira (Villas-Bôas 2012). Ocupa área de ca. 509.000 km² e desenvolve-se no sentido sul-norte desde a Região Centro-Oeste (Estado do Mato Grosso), aproximadamente no paralelo 15º S até o paralelo 13º N. Limita-se a oeste com a bacia hidrográfica do rio Tapajós e a leste com a bacia dos rios Araguaia-Tocantins (AAI 2009).

O rio Xingu foi classificado por Sioli (1950) como de águas claras que percorrem áreas de drenagem e afloram sob rochas pertencentes ao Embasamento Cristalino da Plataforma Amazônica (AAI 2009). Tem sua cheia durante a estação chuvosa entre os meses março e abril e períodos de águas baixas entre os meses agosto a dezembro (Reis 2013). Contudo, algumas enchentes podem durar até setembro em alguns afluentes de sua margem norte (Goulding *et al*.

2003). O rio Xingu é o terceiro maior tributário do rio Amazonas e o segundo maior rio de águas claras do país (Sawakuchi *et al*. 2015). Possui cerca de 1.600 km de extensão e sua bacia ocupa a área de 51 milhões de hectares (Prado 2017), sendo responsável por cerca de 5% da vazão do rio Amazonas.

Ao longo do rio, a transparência das águas varia de 0,6 a 4 m com pH entre 4,5 e 7,8. O rio e seus principais afluentes nascem no Norte do Estado do Mato Grosso, nos terrenos situados ao sul da Chapada dos Parecis, sob influência dos rios Culuene e Sete de Setembro. No curso médio inferior da bacia, o rio Xingu recebe seu principal afluente, o rio Iriri, nas mediações da cidade de Altamira. As planícies fluviais são estreitas nesse trecho, com canais abandonados, lagoas e alagadiços e a vegetação é de florestas ombrófilas com encraves de savanas ou contatos de savana/floresta. É nesse trecho que o rio sofre uma acentuada deflexão, a chamada Volta Grande do Xingu (AAI 2009). No fim, próximo à localidade de Belo Monte, o rio se alarga e apresenta baixa declividade até sua foz, sofrendo efeitos de quietude (semelhante a um lago) promovido pelo rio Amazonas (CNEC 1988).

Amostragem e coleta do material

O testemunho foi amostrado durante a estação seca de 2014 com auxílio de tubos cilíndricos de PVC. A parte superior do tubo foi vedada com rolha e reforçado com cotovelo a fim de não ressecar as amostras. Em seguida, o material foi lacrado e levado intacto ao Instituto de Geociências da Universidade de São Paulo (IGC-USP) onde foi armazenado até à abertura e amostragem.

Cronologia

Para a cronologia do testemunho através da datação por radiocarbono (^{14}C) em espectrometria em massa acelerada (AMS) foram utilizados folhas e fragmentos de carvão de sete profundidades diferentes (11 cm, 51 cm, 96 cm, 173 cm, 235 cm, 275 cm e 307 cm), conforme detalhado por Bertassoli *et al*. (2017).

As datas foram calibradas usando o programa Calib 7.0 e a curva de calibração IntCal13 (Stuiver & Reimer 1993, Reimer *et al*. 2013).

Diatomáceas

As subamostras destinadas ao estudo das diatomáceas foram segmentadas a cada 2 cm do topo para a base do testemunho. Todas as subamostras foram acondicionadas em cilindros de volume conhecido (10 ml) com auxílio de espátulas, sendo etiquetadas de acordo com a profundidade amostrada (Fig. 2). As amostras assim preparadas foram transportadas em caixas térmicas até o Laboratório de Ecologia Aquática do Núcleo de Pesquisa em Ecologia do Instituto de Botânica, em São Paulo (IBt-SP).

Figura 2. Subamostras de diatomáceas acondicionadas em frascos acrílicos de 10 ml.

Oxidação e preparação das amostras

Parte das amostras foi pesada em balança analítica correspondente a 1-1,5 g por tubo de ensaio. Em seguida, as subamostras foram oxidadas conforme o método de Battarbee *et al*. (2011), no qual foi utilizado peróxido de hidrogênio (H_2O_2 PA) e ácido clorídrico (HCl) adicionados em blocos digestores a uma temperatura de 80ºC durante 12 h (Fig. 3). Esse método teve por finalidade eliminar toda a matéria orgânica encontrada nas frústulas. Finalmente, as amostras foram lavadas com água ultrapura e centrifugadas durante 10 min a 1200 rpm. Para confecção das lâminas permanentes foi utilizado Naphrax (IR = 1,73) como meio de inclusão.

Figura 3. Oxidação das subamostras de diatomáceas em blocos digestores a 80°C.

Análise quantitativa e qualitativa de diatomáceas

Análise ao microscópio óptico e quantificação das diatomáceas foram conduzidas a uma ampliação de 1000x usando um microscópio óptico Zeiss Axio-Imager A2 equipado com Contraste de Interferência Diferencial (DIC) e câmera digital de alta resolução Axiocam ERc5s.

Foram contadas pelo menos 400 valvas em cada lâmina ou até atingir a eficiência de 90%, de acordo com Pappas & Stoermer (1996). Identificação e classificação das diatomáceas seguiram trabalhos clássicos e recentes, além de publicações para alguns táxons específicos. A nomenclatura dos táxons seguiu o catálogo ‘online’ dos nomes de diatomáceas da Academia de Ciências da Califórnia (http://researcharchive.calacademy.org/research/diatoms/names/index.asp) compilado por Fourtanier & Kociolek (2011). A informação ecológica foi obtida a partir da revisão da literatura (van Dam *et al*. 1994, Moro & Fürstenberg 1997), da consulta ao programa OMNIDIA (Lecointe *et al*. 1993) e de endereços especializados (www.diatoms.org).

REFERÊNCIAS CITADAS

AAI, 2009. Avaliação Ambiental Integrada (AAI) da bacia do rio Xingu. Disponível: http://www.eletrobras.gov.br/ELB/data/documents/storedDocuments/%7BA75346D4-8DCD-4ADF-AB2A689A3CB5629C%7D/%7B1BF6069A-2E51-4C7C-91F7 BC21CA1BCF0D%7D/Sumario%20AAI%20Xingu.pdf (acesso em: 10-I-2017).

Barker, P.A., Street-Perrott, F.A., Leng, M.J., Greenwood, P.B., Swain, D.L., Perrott, R.A., Telford, R.J. & Ficken, K.J. 2001. A 14,000-year oxygen isotope record from diatom silica in two alpine lakes on Mt. Kenya. Science 292: 2307-2310.

Battarbee, R.W., John-Anderson, N., Jeppsen, E. & Laevitt, P.R. 2005. Combining paleolimnological and limnological approaches in assessing lake ecosystem response to nutrient reduction. Freshwater Biology 50: 1772-1780.

Bennion, H. 1995. Surface-sediment diatom assemblages in shallow, artificial, enriched ponds and implications for reconstructing trophic status. Diatom Research 10(1): 1-19.

Bennion, H., Battarbee, R.W., Sayer, C.D., Simpson, G.L. & Davidson, T. 2011. Defining reference conditions and restoration targets for lake ecosystems using Paleolimnology: a synthesis. Journal of Paleolimnology 45: 533-544.

Bertassoli Jr., D., Sawakuchi, A.O., Sawakuchi, H.O., Pupim, F.N., Hartmann, G.A., McGlue, M.M., Chiessi, C.M., Zabel, M., Schfub, E., Pereira, T.S., Santos, R.A., Faustino, S.B., Oliveira, P.E. & Bicudo, D.C. 2017. The fate of Carbon in Sediments of the Xingu and Tapajós Clearwater Rivers, Eastern Amazon. Frontiers in Marine Science 4. DOI:10.3389/fmars.2017.00044

Bigler, C. & Hall, R.I. 2002. Diatoms as indicators of climatic and limnological change in Swedish Lapland: a 100-lake calibration set and its validation for paleoecological reconstructions. Journal of Paleolimnology 27: 97-115.

Burge, D.R.L., Edlund, M.B. & Frisch, D. 2017. Paleolimnology and resurrection ecology: the future of reconstructing the past. Evolutionary Applications. doi:10.1111/eva.12556

Cordeiro, R.C., Turcq, P.F.M., Turcq, B.J., Moreira, L.S., Rodrigues, R.C., Costa, R.L., Sideddine, A. & Filho, F.F.L.S. 2008. Acumulação de carbono em lagos amazônicos como indicador de eventos paleoclimáticos e antrópicos. Oecologia Brasiliensis12(1): 130-154.

Costa-Böddeker, S., Bennion, H., Jesus, T.A., Albuquerque, A.L.S., Figueira, R.C.L. & Bicudo, D.C. 2012. Paleolimnologically inferred eutrophication of a shallow tropical, urban reservoir in southeast Brazil. Journal of Paleolimnology 48: 751-766.

Flower, R.J. & Ryves, D.B. 2009. Diatom preservation: differential preservation of sedimentar diatoms in two saline lakes. Acta Botanica Croatica 68(2): 381-399.

Fontana, L., Albuquerque, A.L.S., Brenner, M., Bonotto, D.M., Sabaris, T.P.P., Pires, M.A.F., Cotrim, M.E.B. & Bicudo, D.C. 2014. The eutrophication history of a tropical water supply reservoir in Brazil. Journal Paleolimnology 51: 29-43.

Fourtanier, E. & Kociolek, J.P. 2011. Catalogue of diatom names. California Academy of Sciences. Available from: http://researcharchive.calacademy.org/research/diatoms/names/index.asp (access: 15 April 2020).

Goulding, M., R. Barthem & E. J. G. Ferreira. 2003. The Smithsonian atlas of the Amazon. Smithsonian Books, Washington

IBGE, 2017. Estado do Pará. Disponível em: http://cidades.ibge.gov.br/xtras/perfil.php?lang=&codmun=150680&search=||infogr%E1ficos:informa%E7%F5es-completas (acesso em 20-II-2017).

Lamb, H.F., Gasse, F., Benkaddour, A., El Hamouti, N., van der Kaars, S., Perkins, W.T., Pearce, N.J. & Roberts, C.N. 1995. Relation between century-scale Holocene arid intervals in tropical and temperate zones. Nature 373(12): 134-137.

Leite, J.C. 2015. Do mistério das eras do gelo às mudanças climáticas abruptas. Scientia e Studia 13(4): 11-39.

Lotter, A.F. & Birks, H.J.B. 2003. The Holocene paleolimnology of Sagistalsee and its environmental history: a synthesis. Journal of Paleolimnology 30: 333-342.

Medlin, L.K. & Kaczmarska, I. 2004. Evolution of the diatoms, 5: morphological and cytological support for the major clades and a taxonomic revision. Phycologia 43: 245-270.

Moreira, L.S., Turcq, P.F.M., Cordeiro, R.C. & Turcq, B.J. 2009. Reconstituição paleoambiental do Lago Santa Ninha, Várzea do Lago Grande de Curuaí, Pará, Brasil. Acta Amazonica 39(3): 609-616.

Moro, R. & Bicudo, C.E.M. 2002. Estimativa da densidade valvar de diatomáceas em lâminas permanentes e em câmaras de sedimentação: qual método utilizar? Acta Limnologica Brasiliensia 14(1): 53-57.

Moro, R.S. & Fürstenberger, C.B. 1993. Diatomáceas (Bacillariophyceae) da Lagoa Dourada (Parque Estadual de Vila Velha), Paraná, Brasil. Acta Biologica Paranaense 22(1-4): 15-30. doi:10.5380/abpr.v22i0.718

Mozeto, A.A., Silvério, P.F. & Soares, A. 2001. Estimates of benthic fluxes of nutrients across the sediment-water interface (Guarapiranga reservoir, São Paulo, Brazil). The Science of Total Environment 266: 135-142.

Prado, M.C.R., Rodriguez, D.A. & Tomasella, J. 2017. Reposta hidrológica a cenários de mudanças globais na bacia do Rio Xingu. Disponível em: http://www.iwra.org/congress/resource/PAP00-5773.pdf (acessado em: 22-II-2017).

Rasbold, G.G., Parolin, M. & Caxambu, M.G. 2016. Reconstrução paleoambiental de um depósito sedimentar por análise multiproxy, Turvo, Estado do Paraná, Brasil. Revista Brasileira de Paleontologia 19(2): 315-324.

Reimer, P.J., Bard, E., Bayliss, A., Beck, J.W., Blackwell, P.G., Bronk Ramsey, C., Buck, C.E., Chenge, H., Eduards, R.L., Friedrich, M., Grootes, P.M., Guilderson, T.P., Haflidason, H., Hajdas, I., Hatté, C., Heaton, T.J., Hoffmann, D., Hogg, A.G., Hughen, K.A., Kaiser, K.F., Kromer, B., Manning, S.W., Niu, M., Reimer, R.W., Richards, D.A., Scott, E.M., Southon, J.R., Staff, R.A., Turney, C.S.M. & Plicht, J.V.D. 2013. IntCal13 and Marine 13 Radiocarbon Age Calibration Curves 0-50,000 Years cal BP. Radiocarbon 55(4): 1869-1887. doi: 10.2458/azu_js_rc.55.1694

Reis, R.E. 2013. Projeto gestão integrada e sustentável dos recursos hídricos transfronteiriços na Bacia do Rio Amazonas, considerando a variabilidade e a mudança climática. Relatório Parcial – Produto 1: As cabeceiras do rio Xingu. Disponível em: http://otca.info/gef/uploads/documento/91934ATIVID.II.1.1_III.1.1_ROBERTO.E.REIS_RELATORIO_1.pdf (acesso em: 01-II-2017).

Ruwer, D.T., Bernardes, M.C. & Rodrigues, L. 2018. Diatom responses to environmental changes in the Upper Paraná River floodplain (Brazil) during the last ~1000 years. Journal of Paleolimnology. doi:10.1007/s10933-018-0039-7

Salomão, R.P., Vieira, I.C.G., Suemitsu, C., Rosa, N.A., Almeida, S.S., Amaral, D.D. & Menezes, M.P.M. 2007. As florestas de Belo Monte na grande curva do rio Xingu, Amazônia Oriental. Bol. Mus. Para. Emílio Goeldi. Ciências Naturais, Belém, v.2, n.3, p. 57-153.

Saulnier-Talbot, E. 2016. Paleolimnology as a tool to achieve environmental sustainability in the Anthropocene: an overview. Geosciences 26(6): 1-11.

Sawakuchi, A.O., Hartmann, G.A., Sawakuchi, H.O., Pupim, F.N., Bertassoli, D.J., Parra, M., Antinao, J.L., Sousa, L.M., Pérez, M.H.S., Oliveira, P.E., Santos, R.A., Savian, J.F., Grohmann, C.H., Medeiros, V.B., McGlue, M.M., Bicudo, D.C. & Faustino, S.B. 2015. The Volta Grande do Xingu: reconstruction of past environments and forecasting of future scenarios of a unique Amazonian fluvial landscape. Scientific Drilling 20: 21-32.

Silva, C.M., Arbilla, G., Soares, R. & Machado, W. 2018. A nova Idade Meghalayan: o que isso significa para a Época do Antropoceno? Ver. Virtual Quim. 10 (6): 1648-1658.

Silveira, M.I. & Schaan, D.P. 2010. A vida nos manguezais: a ocupação humana da Costa Atlântica Amazônica durante o Holoceno. *In*: Pereira, E. & Guapindaia, V. (Orgs), Arqueologia Amazônica. Museu Paraense Emílio Goeldi, Belém vol. 1, p. 35-48.

Sioli, H. 1950. Das Wasser in Amazonasgebiet. Forsh. Fortschr, v. 26, p. 274-280.

Smol, J.P. 2008. Pollution of lakes and rivers: a paleoenvironmental perspective. Library of Congress Cataloging. 2ª ed. 361 p.

Smol, J.P. 2017. Paleolimnology, reference module in Earth Systems and Environmental Sciences, Elsevier. doi: 10.1016/B978-0-12-409548-9.10537-8.

Stuiver, M. & Reimer, P.J. 1993. Extended ^{14}C data base and revised CALIB 3.0 ^{14}C age calibration program. Radiocarbon 35: 215-230. doi: 10.1017/S0033822200013904

Suguio, K. & Sallun, A.E.M. 2004. Geologia do Quaternário e geologia ambiental. *In*: Ameida, F.F.M. (Org.), Geologia do Continente Sul-Americano. Editora Beca, São Paulo. 673 p.

Urrutia, R., Sabbe, K., Cruces, F., Pozo, K., Araneda, A., Vyverman, W. & Parra, O. 2000. Paleolimnological studies of Laguna Chica of San Pedro (VIII Region): diatoms, hydrocarbons and fatty acid records. Revista Chilena de Historia Natural 73(4): 717-728.

van Dam, H., Mertens, A. & Sinkeldam, J. 1994. A coded checklist and ecological indicator values of freshwater diatoms from the Netherlands. Netherlands Journal of Aquatic Ecology 28: 117-133.

Villas-Bôas, A. 2012. De olho na Bacia do Xingu. Instituto socioambiental, v.5. 61p.

Walker, J.D. & Geissman, J.W. 2009. GSA Geologic Time scale. GSA Today. doi:10.1130/1052-5173-19.4-5.60.

Walker, M. 2005. Quaternary Dating Methods. John Wiley: Chichester.

Walker, M., Head, M.J., Berkelhammer, M., Björck, S., Cheng, H., Cwynar, L., Fisher, D., Gkinis, V., Long, A., Lowe, J., Newnham, R., Rasmussen, S.O. & Weiss, H. 2018. Formal ratification of the subdivision of the Holocene Series/Epoch (Quaternary System/Period): two new Global Boundary Stratotype Sections and Points (GSSPs) and three new stages/subseries. J Gel Soc India 93: 135-141. https://doi.org/10.1007/s12594-019-1141-9

Walker, M., Head, M. J., Lowe, J. Berkelhammer, M., Björck, S., Cheng, H., Cwynar, L.C., Fisher, D., Gkinis, V., Long, A., Newnham, R., Rasmussen, S. O. & Weiss, H. 2019. Subdiving the Holocene Series/Epoch: formalization of stages/ages and subseries/subepochs, and designation of GSSPs and auxiliary stratotypes. Journal of Quaternary Science 34 (3): 173-186. https://doi.org/10.1002/jqs.3097

Wengrat, S., Padial, A.A., Jeppesen, E., Davidson, T. A., Fontana, L., Costa-Böddeker, S. & Bicudo, D.C. 2017. Paleolimnological records reveal biotic homogenization driven by eutrophication in tropical reservoirs. Journal of Paleolimnology. doi:10.1007/s10933-017-9997

Werth, D. & Avissar, R. 2004. The regional Evapotranspiration of the Amazon. Journal of Hydrometerology, Boston, v.5, n.1, p.100-109.

Wetzel, R.G. 1993. Limnologia. Fundação Calouste Gulbenkian, Lisboa. 2ª ed.

Capítulo 1

A resposta das diatomáceas às mudanças paleohidrológicas ocorridas no Xingu *ria* (bacia Amazônica) durante a Idade Meghalayana

Krysna S. de Morais[1]* & Carlos E. de M. Bicudo[1]

1. Instituto de Botânica, Núcleo de Pesquisa em Ecologia, Av. Miguel Estéfano 3687, 04301-902
São Paulo, SP, Brazil. *Autor para correspondência: krysnamorais@gmail.com

RESUMO

Um testemunho (XC-03) foi coletado em área de *ria* no baixo Xingu com auxílio de um tubo de PVC durante a estação seca de 2014. Após coleta, o testemunho foi transportado para o Instituto de Geociências da Universidade de São Paulo (IGC-USP), onde foi armazenado até o momento da amostragem. A cronologia do testemunho foi determinada pelo método de radiocarbono (^{14}C) usando espectrometria em massa acelerada (AMS). As amostras de diatomáceas foram oxidadas com auxílio de H_2O_2 e HCl e lâminas permanentes montadas utilizando Naphrax como meio de inclusão. A análise ao microscópio óptico e a quantificação das diatomáceas foram conduzidas no aumento de 1000x. Em cada amostra pelo menos 400 valvas foram contadas ao longo de uma transeção definida ou até atingir a eficiência de contagem de 90%. Identificação e classificação das diatomáceas seguiram trabalhos clássicos e recentes, além de publicações específicas para certos materiais. A informação ecológica foi obtida a partir da revisão de literatura específica. Com base em modelos de idade, o período entre a base e o topo do testemunho correspondeu a cerca de 4.000 a 300 cal anos AP, equivalentes à Idade Meghalayana. Como resultado, o total de 141 táxons entre espécies e variedades distribuídos em 41 gêneros foi identificado no testemunho. Contudo, apenas 39 do total de táxons apresentou abundância ≥ 2%. A análise de agrupamento indicou a formação de quatro zonas ambientais baseadas nas mudanças das assembleias de diatomáceas. A zona 1 foi caracterizada pela presença de diatomáceas fragilarioides que indicaram águas rasas, porém, fortemente instáveis. Tais condições também favoreceram a presença de gêneros constituídos por espécies de hábito bentônico prostrado adaptáveis a ambientes perturbados por fortes correntes de água. A zona 2 apresentou características semelhantes às da zona 1, indicando a permanência das mesmas condições ecológicas. Mudanças na hidrologia do Xingu foram observadas com maior intensidade na zona 3. Durante este período, *Aulacoseira granulata* dominou quase que toda a assembleia de diatomáceas indicando condições de turbulência e alta concentração de nutrientes. A partir de 779 cal anos AP (zona 4), as diatomáceas bentônicas voltaram a dominar o ambiente, indicando o retorno de uma maior hidrodinâmica do rio, além de uma ampla zona eufótica. Por fim, os resultados apresentados mostraram a baixa descarga do Xingu entre 2.500 a 1.500 cal anos AP. Tal mudança pode ter sido influenciada pelo deslocamento, mais ao norte, da Zona de Convergência Intertropical (ZCIT), que enfraqueceu as chuvas relacionadas ao Sistema de Monção da América do Sul (SMAS) na Amazônia e que, por fim, levou à diminuição da vazão do rio Amazonas na área de estudo.

Palavras-chave: baixo Xingu, diatomácea, *ria* amazônica

INTRODUÇÃO

As reconstruções paleoclimáticas na região Amazônica revelaram a existência de diferentes padrões climáticos durante o Holoceno (Moreira *et al*. 2009). Em estudos realizados na Amazônia Oriental, Behling & Costa (2000), por exemplo, observaram aumento no nível do Lago Curuá, região de Caxiuanã, por volta de 2.500 cal anos AP através de registos polínicos. Resultados bastante semelhantes foram observados mais tarde por Moreira *et al*. (2003) e Cordeiro *et al*. (2008) devidos ao aumento da produção lacustre a partir de 3.000 cal anos AP no Lago Calado e na Serra dos Carajás. Para a Costa Amazônica, Behling *et al*. (2001, 2004) relataram aumento no acúmulo de sedimentos de mangue e formação de manguezais no período entre 2.750-670 cal anos AP, o que resultou na substituição da floresta tropical costeira amazônica. Toledo & Bush (2008) relataram, por sua vez, a existência de um período de transição da floresta em savana durante 1.620 cal anos AP para o Lago Tapera, no Amapá, através de análises polínicas.

Para os maiores tributários do rio Amazonas na região leste, Irion *et al*. (2006) observaram não haver ocorrido mudanças substanciais no bioma ao redor do rio Tapajós ao longo de todo o Holoceno. Os mesmos resultados foram observados por Bertassoli *et al*. (2019) para o Xingu *ria*, embora os dados '*multiproxy*' revelassem diminuição na vazão do rio Amazonas em relação à do rio Xingu entre 2.600-1.400 cal anos AP. Segundo os últimos autores, a descarga anômala de águas no caso de ambos os rios foi ativada pelo aumento da intensidade do SMAS, o que afetou as cargas de sedimentos e as proporções relativas de descarga.

Em estudos recentes realizados sobre o lago Arapujá, médio Xingu, Azevedo *et al*. (2019) citaram a presença de uma maior taxa de concentração de palinomorfos arbóreos entre 1.150-925 cal anos AP, indicando a existência de um período úmido durante a Anomalia Climática Medieval (MCA). Este período úmido foi seguido por condições climáticas mais secas ocorridas durante o período 1.150-1.350 cal anos AP. Segundo os referidos autores, as transições precoces entre uma pronunciada fase úmida para condições mais secas apresentaram características antifásicas ao serem comparadas a registros conhecidos para o Brazil central-oriental. A fim de contribuir e ampliar a discussão a respeito da paleohidrologia da região Amazônica, principalmente para a Amazônia oriental, o presente estudo combinou análises de diatomáceas preservadas nos sedimentos do Xingu *ria* durante os últimos 4.000 cal anos AP com resultados já publicados para a região.

MATERIAIS E MÉTODOS

Area de estudo

O rio Xingu abrange a área aproximada de 500.000 km^2 e é o terceiro maior afluente do rio Amazonas e o segundo maior rio de águas claras da América do Sul (Dias *et al*. 2005, Sawakuchi *et al*. 2015). O rio Xingu tem origem no Estado de Mato Grosso e flui com águas claras, neutras a levemente alcalinas e de baixa concentração de sedimentos até encontrar o rio Amazonas, no Estado do Pará (Sioli 1984, 1950, Sawakuchi *et al*. 2015). Devido à sua grande extensão, o rio apresenta geomorfologia complexa, além de vastas diversidades biológica e cultural. No seu baixo curso, o Xingu sofre uma acentuada deflexão conhecida como Volta Grande do Xingu. Neste trecho, o rio apresenta corredeiras e múltiplos canais retilíneos sendo, por isso, único entre os grandes rios tropicais (Sawakuchi *et al*. 2015). Próximo à confluência com rio Amazonas, o Xingu apresenta uma baixa elevação (5-20 m) mudando para um rio amazônico de planície (Fig. 1C). Nesta parte, o rio exibe características semelhantes às de lagos e reservatórios que recebem o nome de lagos-*rias* ou páleo-*rias* (Dean & Gorham 1998, Bertassoli *et al*. 2017). As *rias* são resquícios de sistemas fluviais que ocupam as seções inferiores de rios e lagos e conectam (total ou parcialmente) todos seus afluentes aos sistemas amazônicos (Irion *et al*. 2010). Segundo Bertassoli *et al*. (2017), as *rias* desempenham função importante no transporte e na deposição de sedimentos no sistema fluvial, podendo ser usadas para inferir condições ambientais passadas em escala decadal e até milenar em grandes rios amazônicos.

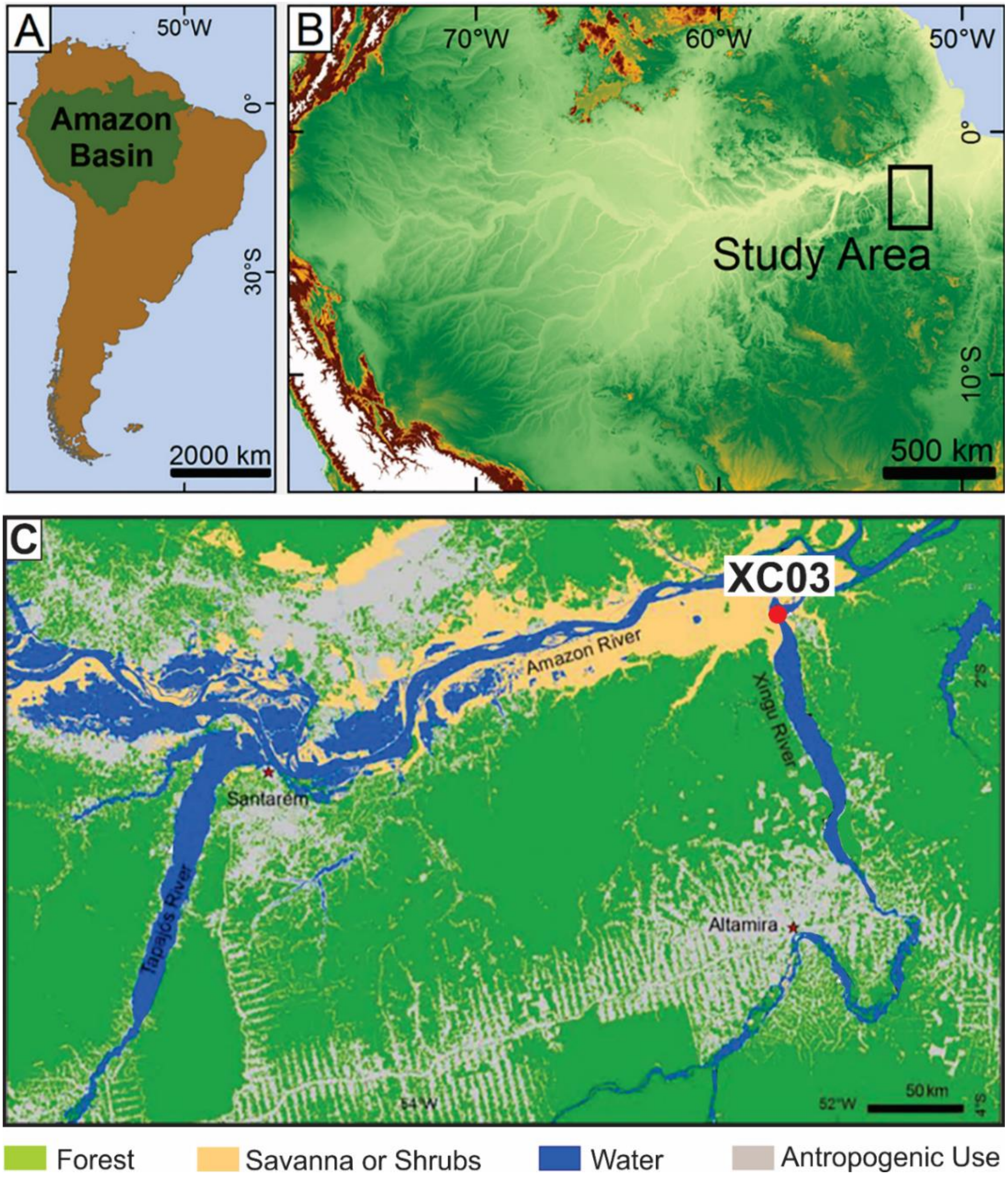


Figura 1. Localização da área de estudo. (A) bacia Amazônica. (B) bacia do rio Xingu. (C) Localização do Xingu *ria*. Mapas adaptados de Sawakuchi *et al*. (2015), Almeida *et al*. (2016) e Bertassoli *et al*. (2017).

Amostragem e cronologia

Um testemunho de 370 cm de comprimento (XC-03) foi coletado no Xingu *ria* (01°42’32,12”S, 52°16’47,42”W) usando um tubo de PVC de 6 m de comprimento. Após a coleta, o núcleo foi lacrado e transportado para o Instituto de Geociências da Universidade de São Paulo (IGC-USP), onde foi armazenado até a abertura para amostragem. As características gerais da estação de amostragem constam na tabela 1. Os dados geocronológicos do testemunho foram determinados pelo método do radiocarbono (^{14}C) em espectrometria em massa acelerada (AMS) utilizando folhas e fragmentos de carvão recuperados de sete profundidades diferentes (11 cm, 51 cm, 96 cm, 173 cm, 235 cm, 275 cm e 307 cm), conforme detalhado por Bertassoli *et al*. (2017). Todas as amostras foram tratadas no laboratório da Universidade Federal Fluminense (LAC-UFF) e as datas calibradas usando o programa Calib 7.0 e a curva de calibração IntCal13 (Stuiver & Reimer 1993, Reimer *et al*. 2013).

Diatomáceas

Amostras para estudar as diatomáceas foram oxidadas com auxílio de H_2O_2 (peróxido de hidrogênio) e HCl (ácido clorídrico) seguindo Battarbee *et al* (2001). Lâminas permanentes foram montadas com Naphrax (I.R. = 1,73). A análise ao microscópio óptico e a quantificação das diatomáceas foram realizadas no aumento de 1000x usando um microscópio óptico Zeiss Axio-Imager A2 equipado com Contraste de Interferência Diferencial (DIC) e câmera digital de alta resolução Axiocam ERc5s. Em cada lâmina permanente, pelo menos 400 valvas foram contadas ao longo de transeções definidas (Battarbee *et al*. 2001) ou até atingir a eficiência de 90%, de acordo com Pappas & Stoermer (1996). Identificação e classificação das diatomáceas seguiram trabalhos clássicos e recentes (Round *et al*. 1990, Metzeltin & Lange-Bertalot 2007, Ribeiro *et al*. 2010, Faustino *et al*. 2016), além de publicações para alguns táxons específicos (Morales 2006, Bicudo *et al*. 2016, Costa *et al*. 2017, Wetzel *et al*. 2019, Kulikovskiy *et al*. 2020). A nomenclatura dos táxons seguiu o catálogo ‘online’ dos nomes de diatomáceas da Academia de Ciências da Califórnia (http://researcharchive.calacademy.org/research/diatoms/names/index.asp) compilado por Fourtanier & Kociolek (2011). A informação ecológica foi obtida a partir da revisão da literatura (van Dam *et al*. 1994, Moro & Fürstenberg 1997), da consulta ao programa OMNIDIA (Lecointe *et al*. 1993) e de endereços especializados (www.diatoms.org).

Dados de abundância relativa (%) foram utilizados para gerar o diagrama de diatomáceas usando o programa TILIGRAPH 1.7.16 (Grim 1991). As principais fases de mudança das comunidades foram identificadas pelo CONISS (Soma Incremental Limitada de Quadrados).

Além disso, todos os táxons de diatomáceas foram classificados e separados de acordo com a forma de vida planctônica ou bentônica.

RESULTADOS

Cronologia e características físicas e químicas do testemunho XC-03

Com base em modelos de idade, o período compreendido entre a base e o topo do testemunho corresponde a cerca de 4.000 a 300 cal anos AP, o que corresponde, geologicamente, a Idade Meghalayana. De acordo com Bertassoli *et al*. (2019), as taxas de sedimentação variaram de 0,5 mm a 1,4 mm ano^{-1} e forneceram uma resolução temporal de 20 anos para os registros geoquímicos, susceptibilidade magnética e diatomáceas. Também de acordo com os mesmos autores, o testemunho consiste, basicamente, de sedimentos homogêneos de granulação fina, cinza e, principalmente, de argila e silte.

Composição e abundância das diatomáceas ao longo do tempo

O total de 141 táxons distribuídos em 41 gêneros foi identificado. Contudo, apenas 39 desses táxons apresentaram abundância ≥ 2%. Os gêneros mais representativos foram: *Aulacoseira* Thwaites (1848), *Staurosirella* D.M.Willians & Round (1988) e *Achnanthidium* Kützing (1844). A análise de agrupamento (CONISS) indicou a formação de quatro zonas ambientais baseadas nas mudanças das assembleias de diatomáceas (Fig. 2). As informações sobre cada zona estão detalhadas abaixo.

Zona 1: 346-206 cm, 4.000-3.260 cal anos AP

A zona 1 foi composta 83% por espécies bentônicas e 17% planctônicas. Das espécies bentônicas, *Staurosirella subcapitata* (Frenguelli) E.A.Morales foi a mais abundante, cuja densidade relativa variou entre 6% e 15% da densidade total das espécies bentônicas. *Staurosirella crassa* (Metzeltin & Lange-Bertalot) F.C.P.Ribeiro & Torgan e *Staurosirella* sp. também apresentaram valores elevados (entre 2% e 11%) em comparação com as demais espécies bentônicas. Apesar de *Gogorevia exilis* (Kützing) Kulikovskiy & Kociolek, *Psammothidium* sp. e *Pseudostaurosira* sp. 1 mostrarem-se constantes nessa fase, não ultrapassaram valores de abundância acima de 6%. Espécies como *Lacuneolimna* cf. *novagallia* Tudesque & Le Cohu, *Pinnularia acrosphaeria* W.Smith, *Sellaphora renata* Metzeltin & Lange-Bertalot, *Achnanthidium* sp. 1, *Achnanthidium* sp. 2, *Coconeis* sp., *Rimoneis* sp. 1 e *Rimoneis* sp. 2 foram observadas apenas nesta fase do testemunho.

Apesar de pouco frequentes, as espécies planctônicas também apresentaram valores significativos neste período, principalmente *Aulacoseira granulata* (Ehrenberg) Simonsen que atingiu valores máximos de abundância de até 35%. *Aulacoseira ambigua* (Grunow) Simonsen e *A. granulata* (Ehrenberg) Simonsen var. *australiensis* (Grunow) Moro atingiram valores máximos de 4%.

Zona 2: 258-206 cm, 3.241-2.566 cal anos AP

Esta zona foi caracterizada por um breve aumento do número de espécies planctônicas (23%) em relação à zona anterior. *Aulacoseira granulata* apresentou abundância máxima de 61%, enquanto que *A. ambigua* e *A. granulata* var. *australiensis* não apresentaram abundância maior do que 7%.

Em relação às espécies bentônicas, *Staurosirella subcapitata* apresentou abundância de 19%, valor este maior do que o da zona anterior. *Staurosirella* sp. também apresentou um breve aumento nesta zona (15%), enquanto que o contrário foi observado com *Staurosirella crassa* (9%). *Psammothidium* sp. manteve os valores de abundância constantes até 3.030 cal anos AP, depois disso a abundância caiu para valores abaixo de 2%, voltando a apresentar maior abundância em 2.725 cal anos AP. O contrário foi observado com *Pseudostaurosira* sp. 1 que atingiu a abundância máxima (8%) a partir dessa data. *Gogorevia exilis* e *Rimoneis* sp. 1 não ultrapassaram valores máximos de 2%. *Staurosirella martyii* (Héribaud) E.A.Morales & K.M.Manoylov surgiu pela primeira vez nesta zona sem, contudo, alcançar abundância superior a 3%. *Eunotia neomundana* Metzeltin & Lange-Bertalot foi observada apenas nesta zona do testemunho.

Zona 3: 200-32 cm, 2.472-779 cal anos AP

A zona 3 é a maior do núcleo sedimentar. Nesta zona foi observado o aumento significativo dos valores de abundância das espécies planctônicas (38%) se comparados com aqueles das duas zonas anteriores. *Aulacoseira granulata* atingiu os valores máximos em todo o testemunho (85%), assim como *A. ambigua* (11%) e *A. granulata* var. *australiensis* (8%). Algumas espécies planctônicas foram observadas pela primeira vez, tais como: *Aulacoseira crassipunctata* Krammer, *A. granulata* (Ehrenberg) Simonsen var. *angustissima* (O.Müller) Simonsen, *A. herzogii* (Lemmermann) Simonsen, *Discostella stelligera* (Cleve & Grunow) Houk & Klee e *Fragilaria tenera* (W.Smith) Lange-Bertalot. No que tange à abundância dessas espécies, somente *D. stelligera* e *A. granulata* var. *angustissima* apresentaram valores acima de 5%. *Fragilaria tenera* e *A. herzogii* foram observadas apenas nesta fase, entre 2.400 cal anos AP e 1.261 cal anos AP, respectivamente.

Em relação às espécies bentônicas, apenas *Staurosirella subcapitata* permaneceu constante ao logo desta zona, contudo, foi detectado decréscimo nos valores de abundância desta espécie (13%) quando comparado com aqueles das zonas 1 e 2. *Staurosirella crassa*, *Staurosirella* sp. e *Pseudostaurosira* sp. também tiveram seus valores de abundância reduzidos, contudo, nenhuma dessas espécies permaneceu constante ao longo do testemunho. O contrário foi observado com *Psammothidium* sp. e *Rimoneis* sp., que tiveram aumento em suas abundâncias (6% e 3%, respectivamente), quando comparadas com as duas primeiras zonas. *Diploneis elliptica* var. *elliptica*, *Diploneis* sp., *Achnanthidium minutissimum* (Kützing) Czarnecki, *Gomphonema brasiliensoides* Metzeltin & Lange-Bertalot, *Nitzschia pusilluhasta* Lehmkuhl & C.E.M.Bicudo, *Ulnaria ulna* (Nietzsche) Compère e *Navicula notha* J.H.Wallace foram observadas pela primeira vez nesta zona, contudo, apenas *N. notha* apresentou valores de abundância superiores a 5% no total.

Zona 4: 30-0 cm, 744-298 cal anos AP

A zona 4 foi a última observada no testemunho e também a mais recente. A relação entre espécies bentônicas e planctônicas apresentou nesta fase valores iguais (50%), porém, diferentes daqueles em todas as zonas descritas anteriormente. Com relação às espécies planctônicas, foi observado decréscimo nos valores de *A. granulata* até ~359 cal anos AP, mas que voltou a atingir abundância máxima de 68%. Picos de abundância também foram observados para outras espécies planctônicas, tais como *A. granulata* var. *angustissima* (17%) em ~463 cal anos AP, *A. ambigua* (12%) e *A. crassipunctata* (6%) em ~298 cal anos AP. *Discostella stelligera* foi a única espécie planctônica que manteve a abundância constante nesta zona, embora tais valores não houvessem ultrapassado 7% no total.

Em relação às espécies bentônicas, *Staurosirella subcapitata* e *Staurosirella* sp. apresentaram abundâncias semelhantes (13% e 12%, respectivamente) e mantiveram-se constantes ao longo de toda a zona 4. *Pseudostaurosira* sp. e *Staurosirella crassa* também apresentaram valores semelhantes, contudo, decadentes a partir de ~463 cal anos AP. *Diploneis elliptica* var. *elliptica* e *Staurosirella martyi* apresentaram picos de abundância máxima somente em ~569 cal anos AP, enquanto que *Gogorevia exilis* atingiu sua abundância máxima (3%) somente a partir de ~308 cal anos AP.

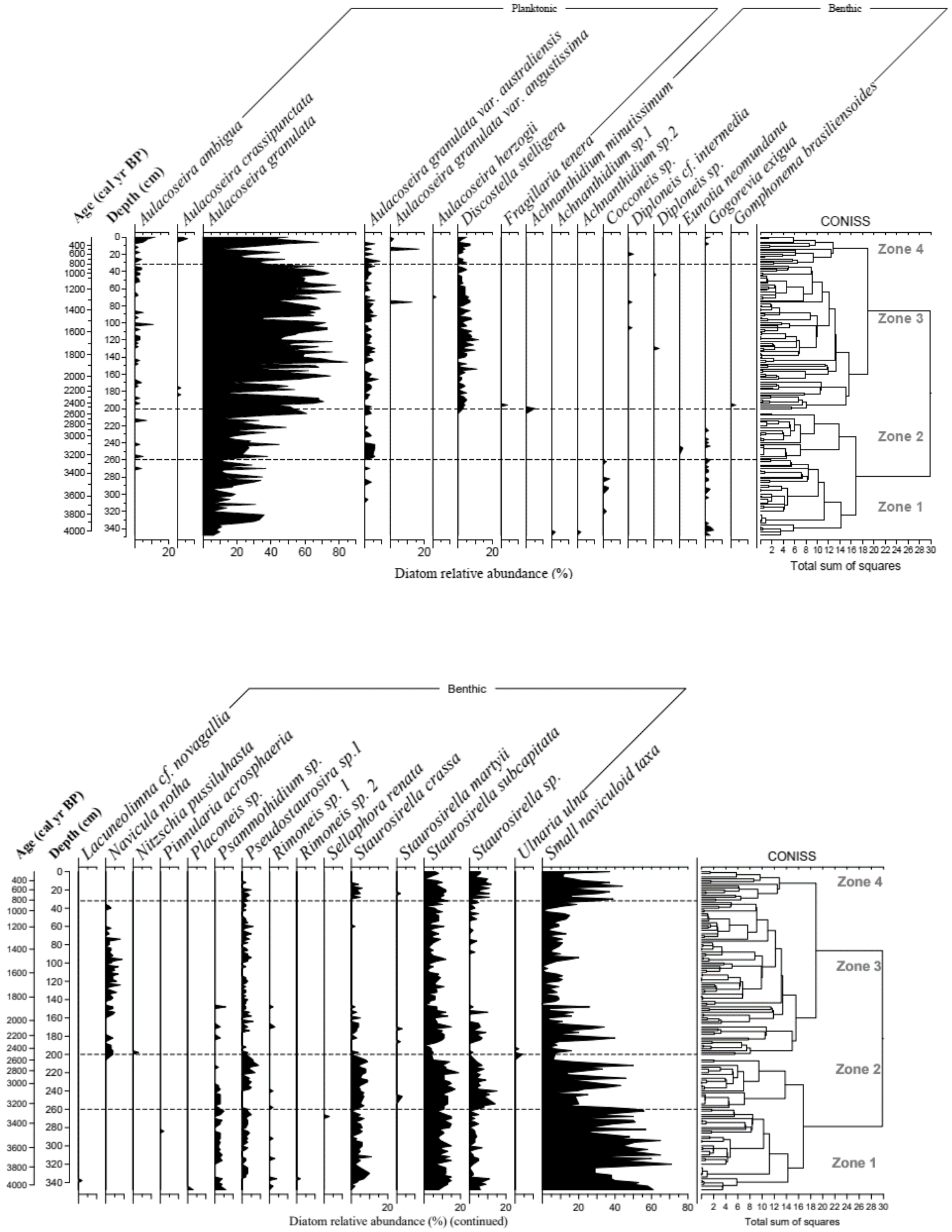


Figura 2. Diagrama do CONISS com as principais zonas e espécies de diatomáceas (abundância relativa ≥ 2%) identificadas no testemunho.

DISCUSSÃO

O início da Idade Meghalayana está representado na *ria* do Xingu pela zona 1 (4.000-3.260 cal anos AP) do testemunho. Nesta zona, a assembleia das diatomáceas foi composta por espécies arrafídeas e monorrafídeas de água doce, embora membros do gênero *Aulacoseira* também estivessem presentes (Fig. 2). *Staurosirella subcapitata* e *Staurosirella crassa* foram as espécies mais abundantes nesta fase. A primeira, *S. subcapitata*, é comumente encontrada em rios da América do Norte e, em geral, associada a águas com baixa concentração de ortofosfato e pH alcalino (Morales & Manoylov 2006). A segunda, *S. crassa*, possui hábito epipsâmico (Metzeltin & Lange-Bertalot 1998) e sua presença já foi documentada em sedimentos estuarinos rasos, com alta deposição de areia e forte energia hidrodinâmica (Ribeiro *et al*. 2010). De maneira similar, materiais de *Fragilaria* '*sensu lato*' e *Pseudostaurosira* sp. também indicam condições de águas rasas e abertas, cujas características físicas e químicas são instáveis (Leira *et al*. 2005). De acordo com Cardozo *et al*. (2014), a presença de indivíduos fragilarioides pode indicar águas rasas, porém, fortemente instáveis. Tais condições ambientais também podem favorecer a presença de representantes de pequenos gêneros bentônicos de hábito prostrado (*Achnanthidium*, *Cocconeis* e *Psammothidium*), adaptáveis a ambientes perturbados por fortes correntes aquáticas (Rühland *et al*. 2003). A presença de espécimes de *Aulacoseira* nesta zona, principalmente de *A. granulata*, reforça a dedução sobre as condições do sistema, uma vez que esta espécie requer intensa turbulência para se manter na zona eufótica de rios e lagos (Bicudo *et al*. 2014, Cardozo *et al*. 2014, Fayó *et al*. 2014).

A zona 2 (3.241-2.566 cal anos AP) foi definida pelo predomínio das mesmas espécies observadas na zona anterior, o que indica a permanência das condições ambientais. *Aulacoseira granulata* atingiu valores de densidade superiores a 60%, co-ocorrendo com dois outros materiais: *A. granulata* var. *australiensis* e *A. ambigua*. Segundo Bicudo *et al*. (2016), *A. granulata* var. *australiensis* é usualmente encontrada em ambientes lênticos, oligo-mesotróficos, com baixo teor de nutrientes. Além disso, esta espécie está associada a condições de baixa condutividade e águas de temperaturas relativamente baixas. *Aulacoseira ambigua* é, por sua vez, encontrada em um amplo gradiente de produtividade e junto com *A. granulata* pode estar associada à mistura da coluna d'agua e à baixa disponibilidade de luz (van Dam 1994, Anderson 2000, Reynolds 2006, Leira *et al*. 2005, Bicudo *et al*. 2016, Brugam & Munoz 2018). A ocorrência de indivíduos bentônicos nesta fase também indica a presença de águas rasas, contudo, menos instáveis do que na zona anterior.

Mudanças na hidrologia do Xingu foram observadas com maior intensidade no período 2.472-779 cal anos AP, as quais estão representadas no gráfico pela zona 3. Neste período, *A. granulata* dominou quase que totalmente a assembleia de diatomáceas, atingindo valores de abundância cima de 80%. Os materiais fragilarioides ainda permanecem constantes nesta zona, porém, menos abundantes se comparados com as duas zonas anteriores (Fig. 2). De acordo com Leira *et al*. (2005), valvas altamente silicificadas de *A. granulata* são comuns em condições de alta turbulência. Além disso, a presença dessa espécie em corpos d'agua é, geralmente, um indicativo de alta concentração de nutrientes (Leira *et al*. 2015, Bicudo *et al*. 2016) e baixa disponibilidade de luz e pH (van Dam 1994, Anderson 2000, Reynolds 2006, Brugam & Muñoz 2018). A presença de variedades taxonômicas dessa espécie (*A. granulata* var. *australiensis* e *A. granulata* var. *angustissima*), além do aparecimento de outras espécies do gênero, como *A. herzogii* e *A. crassipunctata*, permite inferir que o período foi caracterizado por um aumento na produtividade da *ria*.

A persistência de materiais bentônicos neste período, em especial de *Fragilaria*, indica também a presença de ambientes rasos, porém, menos perturbados do que nas zonas anteriores. De acordo com Lotter & Biggler (2000), táxons fragilarioides são altamente adaptados e, por isso, capazes de colonizar ambientes onde as alterações ambientais sejam frequentes. Além disso, os mesmos táxons competem bem com representantes de *Aulacoseira* spp., principalmente em condições ambientais flutuantes (Schmidt *et al*. 2004).

A partir de 779 cal anos AP (zona 4), as diatomáceas bentônicas voltaram a dominar o testemunho, embora picos de abundância de espécies planctônicas ainda tenham sido observados entre 298-358 cal anos AP. Este período apresentou uma assembleia de diatomáceas semelhante àquela da zona 2 descrita há pouco. A dominância de espécies bentônicas neste período pode inferir o retorno de uma maior hidrodinâmica do rio, além de uma ampla zona fótica.

Bertassoli *et al*. (2019) e Sawakuchi *et al*. (2015) observaram alta diversidade de espécies arbóreas de florestas de Terra Firme e Igapó na região do Xingu, além do armazenamento significativo de carbono nas *rias* desde a Idade Nortegripiana (antigo Holoceno Médio). Em relação às diatomáceas, ambos os autores apontaram para a presença de uma assembleia constituída de espécimes bem adaptados a águas oligotróficas e ácidas. Além disso, os mesmos autores observaram uma assembleia taxonomicamente uniforme, com pouca variação entre os gêneros, o que pode ocorrer em ambientes relativamente uniformes de águas paradas. Em nossas investigações sobre a *ria* do Xingu, a principal mudança observada ocorreu na zona 3 (2.472 e 779 cal anos AP) devido aos altos valores de abundância de representantes de *Aulacoseira*, apontando para uma mudança na hidrodinâmica do rio. Em contrapartida, a persistência de diatomáceas bentônicas observada em todo o núcleo sedimentar pode indicar uma baixa lâmina d'agua, uma característica típica das *rias* Amazônicas (Irion *et al*. 2010).

Em resumo, os resultados ora apresentados mostraram uma baixa descarga do Xingu ao longo deste período, com maior intensidade entre 2.500 e 1.500 cal anos AP. Tal mudança pode ter sido influenciada pelo deslocamento mais ao norte da Zona de Convergência Intertropical (ZCIT), enfraquecendo as chuvas relacionadas ao Sistema de Monções da América do Sul (SMAS) na Amazônia e que, por fim, diminuiu a vazão do rio Amazonas na área do presente estudo (Bertassoli *et al*. 2019).

REFERÊNCIAS

Anderson N.J. 2000. Miniview: diatoms, temperature and climatic change. European Journal of Phycology 35: 307-314.

Battarbee, R.W., Jones, V.J., Flower, R.J., Cameron, N.G., Bennion, H., Carvalho, L. & Juggins, S. 2001. Diatoms. *In*: Smol, J.P, Birks, H.J.B. & Last, W.M. (eds), Tracking environmental change using lake sediments. Vol. 3: terrestrial, algal, and siliceous indicators. Kluwer Academic Publishers, Dordrecht. p. 155-202.

Behling, H., Cohen, M.C.L. & Lara, R.J. 2004. Late Holocene mangrove dynamics of Marajó Island in Amazonia, northern Brazil. Vegetation History and Archaeobotany 13: 73-80.

Behling, H. & Costa, M.L. 2000. Holocene environmental changes from the rio Curuá record in the Caxiuanã region, eastern Amazon basin. Quaternary Research 53: 369-377. doi:10.1006/qres.1999.2117

Behling, H. & Hooghiemstra, H. 2000. Holocene Amazon rainforest-savanna dynamics and climatic implications: high-resolution pollen record from Laguna Loma Linda in eastern Colombia. Journal of Quaternary Science 15: 687-695.

Behling, H., Keim, G., Irion, G., Junk, W. & Nunes-Mello, J. 2001. Holocene environmental changes in the Central Amazon Basin inferred from Lago Calado (Brazil). Palaeogeography Palaeoclimatology, Palaeoecology 173: 87-101.

Bertassoli Jr., D.J., Sawakuchi, A.O., Sawakuchi, H.O., Pupim, F.N., Hartmann, G.A., McGlue, M.M., Chiessi, C.M., Zabel, M., Schefuß, E., Pereira, T.S., Santos, R.A., Faustino, S.B., Oliveira, P.E. & Bicudo, D.C. 2017. The fate of carbon in sediments of the Xingu and Tapajós clearwater rivers, eastern Amazon. Frontiers in Marine Science 44(4): 1-14. doi:10.3389/fmars.2017.00044

Bicudo, D.C., Tremarin, P.I, Almeida, P.D., Zorzal-Almeida, S., Wengrat, S., Faustino, S.B., Costa, L.F., Bartozek, E.C.R., Rocha, A.C.R., Bicudo, C.E.M. & Morales, E.A. 2016. Ecology and distribution of

Aulacoseira species (Bacillariophyta) from tropical reservoirs in Brazil. Diatom Research 36: 199-215. doi: 10.1080/0269249X.2016.1227376

Brugam, R.B. & Munoz, S.E. 2018. A 1600-year record of human impacts on a floodplain lake in the Mississippi River Valley. Journal of Paleolimnology 60: 445-460 https://doi.org/10.1007/s10933-018-0033-0

Bush, M.B., Silman, M.R. & Listopad, C.M.C.S. 2007. A regional study of Holocene climate change and human occupation in Peruvian Amazonia. Journal of Biogeography 34: 1342-1356.

Bustamante, M.G., Cruz, F.W., Vuille, M., Apaéstegui, J., Strikis, N., Panizo, G., Novello, F.V., Deininger, M., Sifeddine, A., Cheng, H., Moquet, J.S., Guyot, J.L., Santos, R.V., Segura, H. & Edwards, R.L. 2016. Holocene changes in monsoon precipitation in the Andes of NE Peru based on δ^{18}O speleothem records. Quaternary Science Reviews. doi:10.1016/j.quascirew.2016.05.023

Cardozo, A.Y.V., Gomes, D.F., da Silva, E.M., Duque, S.R.E., Rangel, J.O.Ch., Sifeddine, A., Turcq, B. & Albuquerque, A.L.S. 2014. Holocene paleolimnological reconstruction of a high altitude Colombian tropical lake. Palaeogeography, Palaeoclimatology, Palaeoecology 415: 127-136. doi:10.1016/j.palaeo.2014.03.013

Castro, D.F., Oliveira, P.E., Rossetti, D.F. & Pessenda, L.C.R. 2012. Late Quaternary landscape evolution of northeastern Amazonia from pollen and diatom records. Anais da Academia Brasileira de Ciências Printed version ISSN 0001-3765/Online version ISSN 1678-2690

Cohen, M.C.L., Behling, H., Lara, R.J., Smith, C.B., Matos, H.R.S. & Vedel, V. 2009. Impact of sea-level and climatic changes on the Amazon coastal wetlands during the late Holocene. Vegetation History and Archaeobotany 18: 425-439.

Cohen, M.C.L., Rossetti, D.F., Passenda, L.C.R., Friaes, Y.S. & Oliveira, P.E. 2014. Late Pleistocene glacial forest of Humaitá, Western Amazonia. Palaeogeography, Palaeoclimatology, Palaeoecology 415(1): 37-47. doi: 10.1016/j.palaeo.2013.12.025

Colinvaux, P.A. & Liu, K. 1987. The Late-Quaternary climate of the Western Amazon basin. Abrupt Climatic Change 216: 113-122.

Cordeiro, R.C., Turcq, B., Suguio, K., Oliveira da Silva, A., Sifeddine, A. & Volkmer-Ribeiro, C. 2008. Holocene fires in East Amazonia (Carajás): new evidences, chronology and relation with paleoclimate. Global and Planetary Changes 61: 49-62. doi:10.1016/j.gloplacha.2007.08.005

Costa, L.F., Wengrat, S. & Bicudo, D.C. 2017. Diatoms from distinct habitats of a highly heterogeneous reservoir, Billing Complex, southeastern Brazil. Hoehnea 44(4): 559-579. doi: 10.1590/2236-8906-12/2017

Dean, W.E. & Gorham, E. 1998. Magnitude and significance of carbon burial in lakes, reservoirs, and peatlands. Geology 26: 535-538. doi:10.1130/0091-7613(1998)026<0535:MASOCB>2.3.CO;2

Dias, L.C.P., Macedo, M.N., Costa, M.H., Coe, M.T. & Neill, C. 2015. Effects of land cover change on evapotranspiration and streamflow of small catchments in the Upper Xingu River Basin, Central Brazil. Journal of Hydrology: Regional Studies 4: 108-122. doi:10.1016/j.ejrh.2015.05.010

European Committee for Standardization. 2003. EN 13946. Water quality: guidance standard for the routine sampling and pretreatment of benthic diatoms from rivers. Available from: http://www.safrass.com/partners_area/BSI%20Benthic%20diatoms.pdf (access: 27 March 2020).

Faustino, S.B., Fontana, L., Bartozek, E.C.R., Bicudo, C.E.M. & Bicudo, D.C. 2016. Composition and distribution of diatom assemblages from core and surface sediments of a water supply reservoir in Southeastern Brazil. Biota Neotropica 16(2): 2-23. doi: 10.1590/1676-0611-BN-2015-012

Fayó, R., Espinosa, M.A., Vélez-Agudelo, C.A., Pan, J. & Isla, F.I. 2018. Diatom-based reconstruction of Holocene hydrological changes along the Colorado River floodplain (northern Patagonia, Argentina). Journal of Paleolimnology. doi:10.1007/s10933-018-0031-2

Fourtanier, E. & Kociolek, J.P. 2011. Catalogue of diatom names. California Academy of Sciences. Available from: http://researcharchive.calacademy.org/research/diatoms/names/index.asp (access: 15 April 2020).

França, M.C., Francisquini, M.I., Cohen, M.C.L., Pessenda, L.C.R., Rossetti, D.F., Guimarães, J.T.F. & Smith, C.B. 2012. The last mangroves of Marajó Island-Eastern Amazon: impact of climate and/or relative sea-level changes. Review of Palaeobotany and Palynology 187: 50-65. doi:10.1016/j.revpalbo.2012.08.007

Freitas, H.A., Pessenda, L.C.R., Gouveia, S.E.M., Ribeiro, A.S. & Boulet, R. 2001. Late Quaternary vegetation dynamics in the Southern Amazon Basin inferred from Carbon isotopes in soil organic matter. Quaternary Research 55: 39-46.

Grimm, W. 1991. TILIA version 1.11. TILIGRAPH version 1.18. *In*: Gear, A. (ed.), A user notebook. Illinois State Museum, Springfield, USA.

Guimarães, J.T.F., Cohen, M.C.L., Pessenda, L.C.R., França, M.C., Smith, C.B. & Nogueira, A.C.R. 2011. Mid- and late-Holocene sedimentary process and palaeovegetation changes near the mouth of the Amazon River. The Holocene: 1-12. doi:10.1177/0959683611423693

Intergovernmental Panel on Climate Change IPCC. 2001. Climate Change 2001: the scientific basis IPCC WG I TAR. Cambridge University Press, Cambridge. p. 881.

Irion, G., Mello, J.A.S.N., Morais, J., Piedade, M.T.F., Junk, W.J. & Garming. L. 2010. Development of the Amazon Valley during the Middle to Late Holocene Quaternary: sedimentological and climatological observations. *In*: Junk, W., Piedade, M., Wittmann, F., Schöngart, J. & Parolin, P. (eds), Amazonian Floodplain Forests. Ecological Studies (Analysis and Synthesis) 210. Springer, Dordrecht. doi: 10.1007/978-90-481-8725-6_2

Kützing, F.T. 1944. Die Kieselschalingen Bacillarien oder Diatomeen. W. Köhne, Nordhausen. 152 p.

Kulikovskiy, M., Maltsev, Y., Glushchenko, A., Kuznetsova, I., Kapustin, D., Gusev, E., Lange-Bertalot, H., Genkal, S. & Kociolek, J.P. 2020. *Gogorevia*, a new monoraphid diatom genus for *Achnanthes exigua* and allied taxa (Achnanthidiaceae) described on the basis of an integrated molecular and morphological approach. Journal of Phycology. doi:10.1111/jpy.13064

Lecointe, C., Coste, M. & Prygiel, J. 1993. “Omnidia”: software for taxonomy, calculation of diatom indices and inventories management. Hydrobiologia 269-270: 509-513.

Leira, M. 2005. Diatom responses to Holocene environmental changes in a small lake in northwest Spain. Quaternary International 140-141: 90-102. doi: 10.1016/j.quaint.2005.05.005

Leira, M., Filippi, M.L. & Cantonati, M. 2015. Diatom community response to extreme water-level fluctuations in two Alpine lakes: a core case study. Journal of Paleolimnology 53: 289-307. doi:10.1007/s10933-015-9825-7

Lotter, A. & Bigler, C. 2000. Do diatoms in the Swiss Alps reflect the length of ice-cover? Aquatic Science 62: 125-141

Metzeltin, D. & Lange-Bertalot, H. 2007. Tropical Diatoms of South America, 2: special remarks on biogeography disjunction. Iconografia Diatomologica 18: 1-877.

Morales, E.A. & Manoylov, K.M. 2006. Morphological studies on selected taxa in the genus *Staurosirella* Williams et Round (Bacillariophyceae) from rivers in North America. Diatom Research 21(2): 343-364. doi: 10.1080/0269249X.2006.9705674

Moreira, L.S., Moreira-Turcq, P., Cordeiro, R.C., Turq, B., Caquineau, S., Viana, J.C.C. & Brandini, N. 2013. Holocene paleoenvironmental reconstruction in the Eastern Amazonian basin: Comprido Lake. Journal of South American Earth Sciences 44: 55-62. doi:10.1016/j.jsames.2012.12.012

Moro, R.S. & Fürstenberger, C.B. 1993. Diatomáceas (Bacillariophyceae) da Lagoa Dourada (Parque Estadual de Vila Velha), Paraná, Brasil. Acta Biologica Paranaense 22(1-4): 15-30. doi:10.5380/abpr.v22i0.718

Murray, A.S. & Wintle, A.G. 2000. Luminescence dating of quartz using an improved single-aliquot regenerative-dose protocol. Radiation Measurements 32: 57-73. doi: 10.1016/S1350-4487(99)00253-X.

Pappas, J.L. & Stoermer, E.F. 1996. Quantitative method for determining a representative algal count. Journal of Phycology 32: 693-696.

Piperno, D.R. & Becker, P. 1996. Vegetational history of a site in the Central Amazon Basin derived from phytolith and charcoal records from natural soils. Quaternary Research 45: 202-209.

Prado, L.F., Wainer, I., Chiessi, C.M., Ledru, M.P. & Turcq, B. 2013. A mid-Holocene climate reconstruction for eastern South America. Climate of the Past 9: 2117-2133. doi:10.5194/cp-9-2117-2013

Reimer, P.J., Bard, E., Bayliss, A., Beck, J.W., Blackwell, P.G., Bronk Ramsey, C., Buck, C.E., Chenge, H., Eduards, R.L., Friedrich, M., Grootes, P.M., Guilderson, T.P., Haflidason, H., Hajdas, I., Hatté, C., Heaton, T.J., Hoffmann, D., Hogg, A.G., Hughen, K.A., Kaiser, K.F., Kromer, B., Manning, S.W., Niu, M., Reimer, R.W., Richards, D.A., Scott, E.M., Southon, J.R., Staff, R.A., Turney, C.S.M. & Plicht, J.V.D. 2013. IntCal13 and Marine 13 Radiocarbon Age Calibration Curves 0-50,000 Years cal BP. Radiocarbon 55(4): 1869-1887. doi: 10.2458/azu_js_rc.55.1694

Ribeiro, F.C.P., Senna, C.S.F. & Torgan, L.C. 2010. The use of diatoms for paleohydrological and paleoenvironmental reconstructions of Itupanema Beach, Pará State, Amazon Region, during the last millennium. Revista Brasileira de Paleontologia 13(1): 21-32. doi:10.4072/rbp.2010.1.03

Rigsby, C.A., Hemric, E.M. & Baker, P.A. 2009. Late Quaternary Paleohydrology of the Madre de Dios River, Amazon Basin, Peru. Geomorphology 113: 158-172.

Rossetti, D.F., Valeriano, M.M., Goés, A.M. & Thales, M. 2008. Palaeodrainage on Marajó Island, northern Brazil, in relation to Holocene relative sea-level dynamics. Holocene 18(5): 01-12.

Round, F.E., Crawford, R.M. & Mann, D.G. 1990. The Diatoms: biology and morphology of the genera. Cambridge University Press, Cambridge.

Rühland, K., Priesnitz, A. & Smoll, J.P. 2003. Paleolimnological evidence from diatoms for recent environmental changes in 50 lakes across Canadian Arctic Treeline. Arctic, Antartic, and Alpine Research 35(1): 110-123.

Saldarriaga J.G. & West, D.C. 1986. Holocene fires in the Northern Amazon Basin. Quaternary Research 26: 358-366.

Saulnier-Talbot, E. 2016. Paleolimnology as a tool to achieve environmental sustainability in the Anthropocene: an overview. Geosciences 26(6): 2-11.

Sawakuchi, A.O., Hartmann, G.A., Sawakuchi, H.O., Pupim, F.N., Bertassoli, D.J., Parra, M., Antinao, J.L., Sousa, L.M., Sabaj-Pérez, M.H., Oliveira, P.E., Santos, R.A., Savian, J.F., Grohmann, C.H., Medeiros, V.B., McGlue, M.M., Bicudo, D.C. & Faustino, S.B. 2015. The Volta Grande do Xingu: reconstruction of past environments and forecasting of future scenarios of a unique Amazonian fluvial landscape. Scientific Drilling 20: 21-32. doi:10.5194/sd-20-21-2015

Schmidt, R., Kamenik, C., Lange-Bertalot, H. & Klee, R. 2004. *Fragilaria* and *Staurosira* (Bacillariophyceae) from sediment surfaces of 40 lakes in the Austrian Alps in relation to environmental variables, and their potential for paleoclimatology. Journal of Limnology 63: 171-189.

Sioli, H. 1950. Das Wasser im Amazonasgebiet. Forschungen und Fortschritte 26(21-22): 274-280.

Sioli, H. 1984. The Amazon and its main effluents: 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. Monographiae biologicae 56. Dr W. Junk Publishers. Dordrecht, p. 127-165.

Smith, C.B., Cohen, M.C.L., Pessenda, L.C.R., França, M.C., Guimarães, J.T.F., Rossetti, D.F. & Lara, R.J. 2011. Holocene coastal vegetation changes at the mouth of the Amazon River. Review of Palaeobotany and Palynology 168: 21-30.

Stuiver, M. & Reimer, P.J. 1993. Extended ^{14}C data base and revised CALIB 3.0 ^{14}C age calibration program. Radiocarbon 35: 215-230. doi: 10.1017/S0033822200013904

Thwaites, G.H.K. 1848. Further observations on the Diatomaceae with descriptions of new genera and species. Annals and Magazine of Natural History, sér. 2, 1: 161-172.

Toledo, M.B. & Bush, M.B. 2008. Vegetation and hydrology changes in Eastern Amazonia inferred from a pollen record. Anais da Academia Brasileira de Ciências 80(1): 191-203.

van Dam, H., Mertens, A. & Sinkeldam, J. 1994. A coded checklist and ecological indicator values of freshwater diatoms from the Netherlands. Netherlands Journal of Aquatic Ecology 28: 117-133.

Weng, C., Bush, M. B. & Athens, J. S. 2002. Holocene climate change and hydrarch succession in lowland Amazonian Ecuador. Review of Palaeobotany and Palynology 120: 73-90.

Wetzel, C.E., van de Vijver, B., Blanco, S. & Ector, L. 2019. On some common and new cavum-bearing *Planothidium* (Bacillariophyta) species from freshwater. Fottea 19(1): 50-89. doi:10.5507/fot.2018.016

William, D.M. & Round, F.E. 1988. Revision of the genus *Fragilaria*. Diatom Research 2: 267-288.

Wintle, A.G. & Murray, A.S. 2006. A review of quartz Optically Stimulated Luminescence characteristics and their relevance in single-aliquot regeneration dating protocols. Radiation Measurements 41(4): 369-391. doi: 10.1016/j.radmeas.2005.11.001

Capítulo 2

Subfossil diatoms from Xingu River, Amazon Basin, Brazil

Krysna Stephanny de Morais[1*] & Carlos Eduardo de Mattos Bicudo[1]

1. Instituto de Botânica, Ecology Department, Avenida Miguel Estéfano, nº 3687, 04301-012 São Paulo, SP, Brazil. * Corresponding author: krysnamorais@gmail.com

ABSTRACT

(Subfossil diatoms from Xingu River, Amazon Basin, Brazil). Studies involving diatoms and sediment ecological variables are very valuable for reconstruction of past environmental conditions. However, sediment cores' floristic surveys still are quite scarce. Present study aimed at providing a floristic survey and the distribution of diatoms along a sediment core ~4.000 yr BP, in the Xingu *Ria*, near to the city Porto de Moz. Core (XC-03) was collected at the river deepest portion, with support of divers using a PVC tube. After sampling, sediment core was opened for description and sub-samplings at 2 cm intervals. For diatom observation, organic matter was cleaned using hydrogen peroxide (H_2O_2 35%) and hydrochloric acid (HCl 37%). Immediately after, permanent slides were mounted with Naphrax for analysis under a light microscope. Taxonomy, nomenclature and ecological information followed classic works, recent publications, and online directories of valid names. Sediment samples were deposited at the "Herbário Científico do Estado Maria Eneyda P. Kauffmann Fidalgo" (SP) in the city São Paulo, Brazil. Overall, 15 taxa distributed along nine genera were identified, from which 53.3% were from periphytic habitats. *Aulacoseira granulata* presented the greatest abundance in the whole sediment core, whereas *Aulacoseira herzogii*, *Eunotia reichardtii*, *Ulnaria* sp., *Gomphonema* sp. and *Pinnularia* sp. were of rare occurrence, their abundances never exceeding 5%.

Keywords: bioindicator, floristic survey, paleolimnology

RESUMO

(Diatomáceas subfósseis do rio Xingu, Bacia Amazônica, Brasil). Estudos envolvendo diatomáceas e variáveis físicas e químicas dos sedimentos são extremamente valiosos para a reconstrução de condições ambientais passadas. Contudo, levantamentos florísticos em perfis sedimentares são ainda bastante escassos. O presente estudo teve como objetivo realizar o levantamento florístico e conhecer a distribuição das diatomáceas obtidas de um testemunho de aproximadamente 4.000 cal anos BP localizado na *ria* Xingu, próximo da cidade de Porto de Moz. O testemunho (XC-03) foi coletado com um tubo de PVC e auxílio de mergulhadores. Após coleta, o testemunho foi aberto, descrito e seccionado a cada 2 cm. Para possibilitar a análise das diatomáceas, utilizou-se peróxido de hidrogênio (H_2O_2 35%) e ácido clorídrico (HCl 37%) para remoção da matéria orgânica. Em seguida, lâminas permanentes foram montadas com auxílio de Naphrax e submetidas a análises ao microscópio óptico. Taxonomia, nomenclatura e informação ecológica seguiram trabalhos clássicos e recentes, além de endereços eletrônicos especializados. Todo o material examinado foi depositado no Herbário Científico do Estado “Maria Eneyda P. Kauffmann Fidalgo” (SP), em São Paulo, Brasil. Foram catalogados, no total, 15 táxons distribuídos em nove gêneros, dos quais 53,3% possuem hábito perifítico. Em relação ao estado trófico e ao pH, 66,7% das espécies preferiram ambientes com baixa concentração de nutrientes e 44% mostraram preferência por águas alcalinas. *Aulacoseira granulata* foi a espécie que apresentou a máxima abundância em todo o testemunho, enquanto que *Aulacoseira herzogii*, *Eunotia reichardtii*, *Ulnaria* sp., *Gomphonema* sp. e *Pinnularia* sp. apresentaram abundância rara, não excedendo a 5%.

Palavras-chave: bioindicador, estudo florístico, paleolimnologia

INTRODUCTION

Diatoms (Bacillariophyceae) constitute one of the most abundant and common microfossils integrated to the aquatic sediments (Bradbury 1988). Because of their silicified cell wall (frustules), they are easily recognizable (Sims *et al*. 2006), their distribution and abundance in aquatic environments being associated to specific limnological conditions (Anderson 2000, Smol 2017). Due to this, diatoms are excellent bioindicators used in investigations of the past.

In Brazil, paleoenvironmental investigations using diatoms successfully explained the eutrophication history of reservoirs in the state São Paulo (Costa-Böddeker *et al*. 2012, Fontana *et al*. 2014, Wengrat *et al*. 2017), physical and hydrological changes in the Upper Paraná River floodplain (Ruwer *et al*. 2018), and paleoenvironmental reconstruction in rivers and coastal plains of Rio Grande do Sul (Medeanic *et al*. 2009, Hermany *et al*. 2013).

Regarding the Brazilian Amazon, studies using diatoms associated with some sediment variables were of utmost importance for the reconstruction of past environmental conditions in estuarine systems during the Quaternary Period (*e.g.* Ribeiro *et al*. 2008, Castro *et al*. 2012). However, taxonomic studies of the subfossil diatom flora over a long timescale are rare (*e.g.* Ribeiro *et al*. 2008). For the Xingu River (Fig. 1b), Sawakuchi *et al*. (2015) and Bertassoli *et al*. (2019) reported changes in the diatom flora assemblage of a floodplain lake located in the Arapujá Island (Xingu Big Back). Previous results showed a well-adapted diatom assemblage to oligotrophic and acidic waters at least since the Northgripian Age. Only one sediment core was observed (code named XC-05 in both articles), but no floristic survey was ever achieved using the core material.

Considering the large dimensions and the high complexity that the Xingu River presents, current study aimed at carrying out a floristic survey of a sediment core ~4.000 yr BP from a *Ria* area near to Porto de Moz city. The *Ria* shows a sedimentation dynamic similar to those of lakes and reservoirs (Dean & Gorham 1998), and plays a significant role during the sediments transportation and deposition in fluvial systems (Bertassoli *et al*. 2019). Due to a low sediment load, the *Ria* may be used to infer past environmental conditions.

MATERIAL AND METHODS

The Xingu River basin covers the total area of 509.685 km^2 corresponding to 13% of the Brazilian Amazon basin (Eletrobrás 2009). The drainage basin is composed by Amazonic floodplains and Xingu-Tocantins low tablelands (Silva *et al*. 2014) with ombrophilous open forest and pioneer herbaceous communities near the river mouth (Camargo *et al*. 2004). Climate is tropical with an average temperature between 25ºC-27ºC (Instituto Socioambiental 2012).

Clear waters with a bed load dominated by fine to coarse sand, low concentration of suspended sediments, and slightly alkaline waters (Sioli 1950, Sawakuchi *et al*. 2015) characterize the Xingu River. Near the confluence of the Amazon, the Xingu River shifts a lowland under influence of tides (Sawakuchi *et al*. 2015). In this region, sedimentary dynamic is similar to that of lakes and reservoirs, and is called *Rias* or *paleo-Rias* (Dean and Gorham 1998, Bertassoli *et al*. 2019).

The XC-03 core was collected in Xingu *Ria* (10 m deep) during the dry season of 2014, with a 6 m long PVC tube. After sampling, the sediment core was carried out to the Geosciences Institute of the São Paulo University (IGC-USP), and was opened for description and sub-sampling every 2 cm. Core chronology was determined by Optically Stimulated Luminescence (OSL) and ^{14}C dating as detailed in Bertassoli *et al*. (2017) Based on the OSL and ^{14}C dating, the base of the XC-03 core corresponded to about ~4,000 cal yr. BP, that covers the Meghalayan Age.

For diatom analyses, organic matter was washed using hydrogen peroxide (H_2O_2 35%) and hydrochloric acid (HCl 37%), following the standard procedures in Battarbee *et al.* (2001). Oxidized subsamples were rinsed with deionized water and permanent slides were mounted with Naphrax (R.I. = 1.6). Optical microscopy analysis and counts were conducted at a magnification of 1,000x using a light microscope Zeiss Axio Imager A2 with DIC (Differential Interference Constrast) and Axiocam ERc5s high-resolution digital camera. At least 400 valves were counted per slide along defined transects (Battarbee *et al*. 2001), and until reaching an efficiency of 90%, according to Pappas & Stoermer (1996). Species abundance was calculated by dividing the individual species count by the total count and expressed as percentage for each subsample. In the present study, we included all taxa with relative abundance $\geq$ 2%.

Taxonomy and nomenclature followed classic works and recent publications (*e.g*. Metzeltin & Lange-Bertalot 1998, 2007, Bicudo *et al*. 2016) as well as an on-line catalog of valid names (California Academy of Sciences site 2020). Ecological preferences and species habitats were classified according to the literature (van Dam *et al*. 1994, Moro & Fürstenberger 1997, Padisák *et al*. 2009). The classification system followed Medlin & Kaczmarska (2004) for supra-ordinal taxa and Round *et al*. (1990) for subordinal ones. For every taxon identified, valve measurements were provided (D: valve diameter, H: mantle height, L: valve length, W: valve width, S: striae, F: fibulae, and A: areolae). Sediment samples are deposited at the Herbário Científico do Estado "Maria Eneyda P. Kauffmann Fidalgo" (SP) in the city São Paulo, Brazil (herbarium access numbers SP513792 to SP513834).

RESULTS

Aulacoseiraceae

Aulacoseira Thwaites

Aulacoseira ambigua (Grunow) Simonsen, Bacillaria 2: 56. 1979.

Figures 2-4

Morphometry: D: 9-13.6 µm; H: 5.3-8 µm; D/H ratio: 1.1-2.5; A: 9-14 in 10 µm; S: 9-14 in 10 µm.

Population found in the Xingu *Ria* agree with the type material in Simonsen (1979). The species is characteristic in its frustules cylindrical and the valve mantle composed by small areolae curved to the right. Separation spines are small and pointed, whereas linking spines are short, triangular or bifurcate (Potapova & English 2010). *Aulacoseira ambigua* differs from other *Aulacoseira* taxa by its hollow U-shaped narrow ringleist (Bicudo *et al*. 2016).

Ecology and distribution: *Aulacoseira ambigua* is a cosmopolitan species reported from a large nutritional preferences range living in alkaliophylic to slightly acidic waters (Moro & Fürstenberger 1997, Taylor *et al*. 2007, Bicudo *et al*. 2016). In Brazil, the species is commonly found in plankton samples from lotic and lentic environments (Dunck *et al*. 2012, Cavalcante *et al*. 2013, Almeida & Bicudo 2014, Costa *et al*. 2017). It may also be found in aquatic sediments and periphytic samples (Bere & Tundisi 2010, Bertolli *et al*. 2010, Faustino *et al*. 2016, Bartozek *et al*. 2018). During the present investigation, *A. ambigua* was detected in ~3,222 cal. yr BP to ~318 cal. yr BP, and had its maximum abundance around 11%.

Material examined: BRASIL, PARÁ: Porto de Moz, Rio Xingu, 2014, A.O. Sawakuchi, core XC-03 (SP513833).

Aulacoseira granulata (Ehrenberg) Simonsen var. ***granulata***, Bacillaria 2: 58. 1979.

Figures 5-6

Morphometry: D: 8-13 µm; H: 6.5-13 µm; D/H ratio: 0.8-1.5; A: 4-11 in 10 µm; S: 6-10 in 10 µm.

Aulacoseira granulata presents cylindrical frustules linked by small spines to form filamentous colonies. Valvar mantle is ornamented with coarse and round areolae, curved or not to the right. Presence of two long spines in the separation valve and of a narrow and solid ringleist are two important taxonomic features of this species (Potapova & English 2010, Bicudo *et al*. 2016).

Ecology and distribution: worldwide distributed, this planktonic diatom is present in acid to alkaliphilous waters (Moro & Fürstenberger 1997, Bicudo *et al*. 2016). In general, *A. granulata* supports a large range of trophic conditions, but prefers nutrient-rich waters (Gómez *et al*. 1995, Taylor *et al*. 2007). In some publications, the species was reported living in high abundance during periods of mixing under light-limited conditions (van Dam *et al*. 1994, Siver & Kling 1997, Bicudo *et al*. 2016). *Aulacoseira granulata* is widely cited in Brazilian publications, both in floristic surveys and ecological studies (*e.g*. Fontana & Bicudo 2009, Laux & Torgan 2011, Moresco *et al*. 2011, Lobo *et al*. 2015, Faustino *et al*. 2016, Costa *et al*. 2017). During the present investigation, it was present in the entire sediment core (~4,000 cal. yr BP to ~300 cal. yr BP) with a maximum abundance of 84%.

Material examined: BRASIL, PARÁ: Porto de Moz, Rio Xingu, 2014, A.O. Sawakuchi, core XC-03 (SP513792, SP513824, SP513825, SP513826, SP513827, SP513828, SP513829, SP513830, SP513831, SP513832, SP513834).

Aulacoseira granulata (Ehrenberg) Simonsen var. ***angustissima*** (O.Müller) Simonsen, Bacillaria 2: 58. 1979.
Figures 7-8
Morphometry: D: c. 3.6 µm; H: 23.7-24.1 µm; D/H ratio: 6.6-6.7.

Individual specimens of *A. granulata* var. *angustissima* have frustules cylindrical, narrow, joined by short bifurcate spines to form straight chains. In their valvar mantle, round and delicate areolae are observed forming a curved to the right row. This variety differs from other *Aulacoseira* species in valve diameter, their longer than wide valves, and the presence of one or two elongate spines in the separation valve (English & Potapova 2010).

Ecology and distribution: Aulacoseira granulata var. *angustissima* is widely distributed in nutrient-rich waters (Bicudo *et al*. 2016, Costa *et al*. 2017). It occurs in high abundance in alkaline with low transparency waters (Moro & Fürstenberger 1997). This variety is commonly found co-occurring with other *Aulacoseira* taxa (Domingues & Torgan 2011, Nardelli *et al*. 2014, 2016, Marra *et al*. 2016). In the present study, *A. granulata* var. *angustissima* was found in ~1,330 cal. yr BP to ~300 cal. yr BP, and had a maximum abundance of 13%.

Material examined: BRASIL, PARÁ: Porto de Moz, Rio Xingu, 2014, A.O. Sawakuchi, core XC-03 (SP513833).

Aulacoseira granulata (Ehrenberg) Simonsen var. ***australiensis*** (Grunow) Moro, Arquivos de Biologia e Tecnologia 34(2): 353-359. 1991.

Figures 9-10

Morphometry: D: 7-18 µm; H: 14-21 µm; D/H ratio: 0.5-1.1; A: 9-15 in 10 µm; S: 5-10 in 10 µm.

Present variety has frustules cylindrical, wide, linked by short spines to form chains. Valvar mantle composed by coarse round or square areolae, forming a straight or slightly curved row visible at the LM. Unlike the type variety, *A. granulata* var. *australiensis* has greater diameter and 1-4 separation spines. Furthermore, this variety presents a conspicuous rimorportulae visible in the valvar mantle (Moro 1991, Bicudo *et al*. 2016).

Ecology and distribution: *Aulacoseira granulata* var. *australiensis* is a planktonic variety found in different regions of Brazil under oligo to eutrophic conditions (Nardelli *et al*. 2014, 2016, Faustino *et al*. 2016, Costa *et al*. 2017). In a revision of the *Aulacoseira* material from São Paulo reservoirs, Bicudo *et al*. (2016) reported this variety living in systems with low conductivity and temperature, and slightly acidic waters. *Aulacoseira granulata* var. *australiensis* occurs in the sequence ~3,150 cal. yr BP to ~380 cal. yr BP, and had its maximum abundance 13%.

Material examined: BRASIL, PARÁ: Porto de Moz, Rio Xingu, 2014, A.O. Sawakuchi, core XC-03 (SP513792, SP513826).

Aulacoseira herzogii (Lemmermann) Simonsen, Bacillaria 2: 59. 1979.

Figures 11-12

Morphometry: D: 12-17 µm; H: 4.4-6.5 µm; D/H ratio: 2.1-2.8.

Aulacoseira herzogii has frustules cylindrical, straight, narrow, forming short colonies. Valvar mantle is composed by small, delicate areolae, visible or not at LM. The species representative specimens have two grooves, without areolae, extending along the entire valve length. One or two spines are present at opposite sides (Potapova & English 2010).

Ecology and distribution: this species is found in lentic and lotic environments of different regions of Brazil (Laux & Torgan 2011, Dunck *et al*. 2012, Cavalcante *et al*. 2013, Nardelli *et al*. 2014, Marra *et al*. 2016), under a wide range of trophic conditions, but preferring mesotrophic waters (Bicudo *et al*. 2016). *Aulacoseira herzogii* is present only at the stratum ~1,278 cal. yr BP and had an abundance of 2%.

Material examined: BRASIL, PARÁ: Porto de Moz, Rio Xingu, 2014, A.O. Sawakuchi, core XC-03 (SP513792).

Stephanodiscaceae

Discostella Houk & Klee

Discostella stelligera (Cleve & Grunow) Houk & Klee, Diatom Research 19(2): 208. 2004.

Figures 13-17

Morphometry: D: 7-10 µm; S: 13-19 in 10 µm.

Frustules of *Discostella stelligera* have circular valves and a distinct central area with radial alveolar striae forming a rosette, striae at the marginal region equal in length (Lowe 2015).

Ecology and distribution: this cosmopolitan species has been associated with thermally stable environments (Cardozo *et al*. 2014), clear water and neutral to slightly basic pH (Bradbury 1988, Moro & Fürstenberger 1997). In Brazil, the species occur in lentic and lotic environments and different types of habitats (Laux & Torgan 2011, Dunck *et al*. 2012, Marra *et al*. 2016, Costa *et al*. 2017). *Discostella stelligera* is present in ~2,316 cal. yr BP to ~380 cal. yr BP, and had a maximum abundance of 12%.

Material examined: BRASIL, PARÁ: Porto de Moz, Rio Xingu, 2014, A.O. Sawakuchi, core XC-03 (SP513828, SP513830, SP513831, SP513832, SP513833).

Fragilariaceae

Fragilaria Lyngbye

Fragilaria fragilarioides (Grunow) Cholnoky, Nova Hedwigia 2: 168. 1963.

Figures 18-20

Morphometry: L: 25-60 µm; W: 2.8-3.1 µm; L/W ratio: 8.2-21.8; S: 14-16 in 10 µm.

Fragilaria fragilarioides is characterized by linear to lanceolate valves with inflate central area and apices capitate to subcapitate. The striae are uniseriate, alternate throughout the valve; ghost striae are observed in central area. This species resembles *Fragillaria pectinalis* (O.F.Müller) Lyngbye and *Fragillaria microvaucheriae* C.E.Wetzel & Ector in valve outline. However, both species presents smaller length and greater width valve (*F. pectinalis*: L: 12-36.2µm; W: 2.8-4.7 µm and *F. microvaucheriae*: L: 5.7-23.2 µm; W: 2.5-3.8 µm) and a large and unilateral central area.

Ecology and distribution: planktonic species found in lentic to lotic environments with neutral to alkaline waters (Raupp & Torgan 2006, Nardelli *et al*. 2016, Faustino *et al*. 2016). In the present study, *Fragilaria fragilarioides* is present in ~1.885 cal. yr BP to ~1.579 cal. yr BP and had the maximum abundance of 5%.

Material examined: BRASIL, PARÁ: Porto de Moz, Rio Xingu, 2014, A.O. Sawakuchi, core XC-03 (SP513792).

Staurosirella D.M.Williams & Round

Staurosirella cf. ***confusa*** E.A.Morales, Phycological research 53(2): 122. 2005.

Figures 21-24

Morphometry: L: 8-13 µm; W: 2.8-3.1 µm; L/W ratio: 2.9-4.8; S: 8-15 in 10 µm.

Specimens found in Xingu have linear to lanceolate valves with acuminate apices. Sternum narrow, linear. Striae parallel and alternate. The specimens found in Xingu ria agree with type material of *Staurosirella confusa*, however, it presents a lower width and a greater striae density (*S. confusa*, W: 3.5-4.5 µm; S: c. 11 in 10 µm). The taxa also resemble *Staurosirella subcapitata* (Frenguelli) E.A.Morales regard to the valve shape, however, both species differs in valve dimensions and striae pattern. According to Morales & Manoylov (2006), *S. subcapitata* presents a length of 8-27 µm, width of 4–5.5 µm; and refractive and thick striae.

Ecology and distribution: this species is found in alkaline waters with high conductivity, low concentrations of orthophosphate and tolerant to high nitrogen concentrations (Morales 2005). In our study, *S. confusa* is present from ~3.900 cal. yr BP to ~358 cal. yr BP and had a maximum abundance of 9%.

Material examined: BRASIL, PARÁ: Porto de Moz, Rio Xingu, 2014, A.O. Sawakuchi, core XC-03 (SP513792).

Staurosirella crassa (Metzeltin & Lange-Bertalot) F.C.P.Ribeiro & Torgan *in* Ribeiro *et al*., Revista Brasileira de Paleontologia 13(1): 24. 2010.

Figures 25-26

Morphometry: L: 11-30 µm; W: 4-6 µm; L/W ratio: 2.5-4.7; S: 6-9 in 10 µm.

This species presents valve linear with rounded apices. Their axial area is linear to lanceolate, with striae alternate through the valve. The population found shares measurements similar to *Staurosira* *acutirostrata* (Metzeltin & Lange-Bertalot) Metzeltin & Lange-Bertalot (2005), however, the last one presents attenuate ends.

Ecology and distribution: epipsammic species reported in sediments samples from estuarine shallow lakes (Ribeiro *et al*. 2008, 2010) and floodplains (Ruwer & Rodrigues 2018). It also found in planktonic and periphytic materials from lentic and lotic systems (Dunck *et al*. 2012, Marra *et al*. 2016). *Staurosirella crassa* is present from ~4.000 cal. yr BP to ~533 cal. yr BP and had a maximum abundance of 11%.

Material examined: BRASIL, PARÁ: Porto de Moz, Rio Xingu, 2014, A.O. Sawakuchi, core XC-03 (SP513792).

***Staurosirella* sp.**

Figures 27-28

Morphometry: L: 4.5-8 µm; W: 3-5 µm; L/W ratio: 1.3-1.8; S: 3-5 in 10 µm.

This taxon presents small and ovoid valves, with sternum linear to lanceolate and striae parallel, alternate. The specimens share several similarities with *Staurosirella pinnata* (Ehrenberg) Williams & Round regarding to valve shape and measures. However, in a recent review about the species, Morales *et al*. (2013) demonstrated that the type material of *S. pinnata* corresponds to *Denticula* sp., and thus, taxonomical and ecological analysis of this species should be carefully handled. For this reason, we decided to identify this taxon in genus level.

Ecology and distribution: *Staurosirella* sp. is present from ~4.000 cal. yr BP to ~380 cal. yr BP and had the maximum abundance of 15%.

Material examined: BRASIL, PARÁ: Porto de Moz, Rio Xingu, 2014, A.O. Sawakuchi, core XC-03 (SP513792, SP513824, SP513829, SP513832, SP513834).

Ulnariaceae

Ulnaria (Kützing) Compère

***Ulnaria* sp.**

Figures 29-30

Morphometry: L: 86.5-97.3 µm; W: c. 4.6 µm; L/W ratio: 18.8-20.9; S: 9-10 in 10 µm.

Valves longer than wide, lanceolate, isopolar with subcapitate apices. Sternum central and distinctive. Central area rectangular, slightly raised. Striae broad, parallel, radiating towards the poles; ghost striae are observed throughout in the central area.

Ecology and distribution: It is present only at ~2.473 cal. yr BP and had a maximum abundance of 5%.

Material examined: BRASIL, PARÁ: Porto de Moz, Rio Xingu, 2014, A.O. Sawakuchi, core XC-03 (SP513792).

Eunotiaceae

Eunotia Ehrenberg

Eunotia reichardtii Meltzeltin & Lange-Bertalot, Iconographia Diatomologica 5: 76, pl. 20, fig. 4-5, pl. 23, fig. 9-14. 1998.

Figures 31-32

Morphometry: L: 61.1-70 µm; W: c. 14.1 µm; L/W ratio: 4.3-4.9; S: c. 10 in 10 µm.

The species presents valves slightly arched, dorsal margins slightly convex, ventral margins straight to slightly concave and cuneate ends. Striae parallel becoming radiate at the apices. Areolae visible in LM. Terminal nodule conspicuous close to the poles. Because of large gradient of forms, it resembles other *Eunotia* species, such *Eunotia didyma* Hustedt *ex* Zimmermann and *Eunotia neomundana* Metizeltin & Lange-Bertalot since they also exhibit undulations in their dorsal margins. However, *E. didyma* presents less median swollen, mainly in small valves, whereas *E. neomundana* presents elongated valves (Costa *et al*. 2017, Metzeltin & Lange-Bertalot 1998).

Ecology and distribution: this species is reported in periphytic samples in wetlands from the Cerrado, Brazilian central-west (Dunk *et al*. 2016). *Eunotia rechardtii* is present only at ~3.127 cal. yr BP and had a maximum abundance of 2%.

Material examined: BRASIL, PARÁ: Porto de Moz, Rio Xingu, 2014, A.O. Sawakuchi, core XC-03 (SP513792).

Gomphonemataceae

Gomphonema Ehrenberg

***Gomphonema* sp.**

Figures 33-35

Morphometry: L: 38.6-42.7 µm; W: 8.5-8.7 µm; L/W ratio: 4.4-4.9; S: 9-12 in 10 µm.

Valves rhombic-lanceolate with apical and basal ends rounded. Sternum linear and narrow. Central area asymmetric, expanded unilaterally, limited by shortened striae. Raphe straight to slightly curved to the same side, toward the stigma. Striae radiate. Stigma opposed at the shortened striae. The taxon resembles *Gomphonema gracile* Ehrenberg in the valve format, sternum format and central area, however, differs in the striae pattern: radiate throughout the valve, whereas *G. gracile* presents striae slightly radiate becoming parallel at central region.

Distribution: It is present only at ~2.410 cal. yr BP and had the maximum abundance 4%.

Material examined: BRASIL, PARÁ: Porto de Moz, Rio Xingu, 2014, A.O. Sawakuchi, core XC-03 (SP513830).

Achnanthidiaceae

Achnanthidium Kützing

Achnanthidium minutissimum (Kützing) Czarnecki, Memoirs of the California Academy of Sciences 17: 157. 1994.

Figures 36-39

Morphometry: L: 8-16 µm; W: 2.7-3.7 µm.

The analyzed population has linear to lanceolate valves with rostrate to subcapitate apices, striae delicate and a small axial area. It resembles *Achanthidium jackii* Rabenhorst in valve shape. However, *A. jackii* differs in morphometric values (L: 10.5-17.6 µm; W: 2.9-3.9 µm) and by a visible central area without a shortened striae.

Ecology and distribution: according to Potapova & Hamilton (2007), this species is one of the most common benthic diatoms living in aquatic ecosystems. Because of its great abundance, *A. minutissimum* is widely used in ecological studies and monitoring. In Brazil, this species is reported in floristic survey and ecological studies under oligotrophic to eutrophic conditions (Bartozek *et al*. 2013, Marra *et al*. 2016, Costa *et al*. 2017, Silva-Lehmkuhl *et al*. 2019). In our investigations, *A. minutissimum* is present from ~3.768 cal. yr BP to ~1.869 cal. yr BP and had a maximum abundance of 6%.

Material examined: BRASIL, PARÁ: Porto de Moz, Rio Xingu, 2014, A.O. Sawakuchi, core XC-03 (SP513829).

Pinnulariaceae

Pinnularia Ehrenberg

***Pinnularia* sp.**

Figure 40

Morphometry: L: c. 126.5µm; W: c. 20 µm; S: c. 17 in 10 µm.

Valves linear, inflated at the middle part with prominent cuneate apices. Axial area linear, narrow, widening to the central area. Central area asymmetric. Raphe straight with sickled-shaped polar ends; and proximal ends expanded, deflected to the same side. Striae radiate in the valvar center becoming weakly parallel near the apices. A longitudinal line crosses the striae. *Pinnularia* sp. share several characteristics with *Pinnularia crassa* described by F.Meister (1937: pl. 7, fig. 1) of samples from the Pará river. However, according to Guiry & Guiry (2017), a different holotype was introduced in the same year by Skvortow (1937) and thus, the priority about the name has not been established. For this reason and the absence of detailed analyses such SEM, we decided to identify this taxon in genus level.

Distribution: *Pinnularia* sp. is present only at ~3.470 cal. yr BP and reached the maximum abundance of 2%.

Material examined: BRASIL, PARÁ: Porto de Moz, Rio Xingu, 2014, A.O. Sawakuchi, core XC-03 (SP513792).

DISCUSSION

Altogether, 16 taxa distributed in nine genera were identified from the Xingu *Ria* XC-03 core. Families Aulacoseiraceae R.M.Crawford and Fragilariaceae Kützing included the greatest number of taxa (5 species each). Concerning the different habitats, periphyton accounted for 53.3% of total taxa identified, followed by the phytoplankton with 47%.

Regarding trophic preferences and pH, 66.7% of the species identified preferred environments with low nutrient concentration, whereas 44% waters with alkaline pH, thus corroborating the limnological information described for the Xingu River (Sioli 1984, Sawakuchi *et al*. 2015).

Although periphyton contributed with the highest number of taxa, *Aulacoseira granulata* presented the highest abundance (maximum abundance 84%) along the whole sediment core. During the present investigation, all species collected presented their valves intact for over ~4,000 years. *Aulacoseira granulata* is the species that best responded to the environmental changes occurred during the Meghalanyan Age.

In the present study, five species (*Aulacoseira herzogii*, *Eunotia reichardtii*, *Ulnaria sp.*, *Gomphonema sp.* and *Pinnularia sp.*) were of rare occurrence, occurring only once each in the entire sediment core, their abundances not exceeding 5%.

CONCLUSION

To conclude, present study contributes to the knowledge of the ecology and distribution of the 16 species in the Holocene sediments, and highlights the crucial need for floristic surveys to really improve the knowledge of biodiversity of diatoms in Amazonian rivers.

ACKNOWLEDGMENTS

This study was carried out within the framework of the project “A resposta da dinâmica sedimentar dos rios Xingu e Tapajós às mudanças climáticas e barragens de usinas hidrelétricas: riscos para conservação da biodiversidade e produção de energia na Amazônia”, supported by funds from FAPESP (Fundação de Amparo à Pesquisa do Estado de São Paulo, grant nº 2016/02656-9), and was carried out as part of KSM PhD dissertation (CAPES, Coordenação de Aperfeiçoamento de Pessoal de Nível Superior fellowship). CEMB thanks CNPq (Conselho Nacional de Desenvolvimento Científico e Tecnológico) for Research Fellowship (305031/2016-3).

REFERENCES

Almeida, P.D.; Bicudo, D.C.2014. Diatomáceas planctônicas e de sedimento superficial em represas de abastecimento da Região Metropolitana de São Paulo, SP, Sudeste do Brasil. *Hoehnea* 41 (2): 187-207.

Anderson, N.J. 2000. Mini review: diatoms, temperature and climatic change. *European Journal of Phycology* 35: 307-314.

Bartozek, E.C.R.; Zorzal-Almeida, S.; Bicudo, D.C. 2018. Surface sediment and phytoplankton diatoms across a trophic gradient in tropical reservoirs: new records for Brazil and São Paulo State. *Hoehnea* 45 (1): 69-92. http://dx.doi.org/10.1590/2236-8906-51/2017

Battarbee, R.W.; Jones V.; Flower, R.J.; Cameron, N.; Bennion, H.; Carvalho, L.; Juggins, S. 2001. Diatoms. In: Smol, J.P; Birks, H.J.B.; Last, W.M. (ed.). *Tracking Environmental Change using Lake Sediments*. London.

Bere, T.; Tundisi, J.G. 2010. Epipsammic diatoms in streams influenced by urban pollution, São Paulo, SP, Brazil. *Brazilian Journal of Biology* 70 (4): 921-930.

Bertassoli, D.J.; Sawakuchi, A.O.; Chiessi, C.M.; Schefuβ, E.; Hartmann, G.A.; Häggi, C.; Cruz, F.W.; Zabel, M.; McGlue, M.M.; Santos, R.A.; Pupim, F.N. 2019. Spatiotemporal variations of riverine discharge within the Amazon Basin during the Late Holocene coincide with Extratropical Temperature Anomalies. *Geophysical Research Letters* 10.1029/2019GL082936.

Bertolli, L.M.; Tremarin, P.I.; Ludwig, T.A.V. 2010. Diatomáceas perifíticas em Polygonum hydropiperoides Michaux, reservatório do Passaúna, Região Metropolitana de Curitiba, Paraná, Brasil. *Acta Botanica Brasilica* 24 (4): 1065-1081.

Bicudo, D.C.; Tremarin, P.I.; Almeida, P.D.; Zorzal-Almeida, S.; Wengrat, S.; Faustino, S.B.; Costa, L.F.; Bartozek, E.C.R.; Rocha, A.C.R.; Bicudo, C.E.M.; Morales, E.A. 2016. Ecology and distribution of *Aulacoseira* species (Bacillariophyta) in tropical reservoirs from Brazil. *Diatom Research* http://dx.doi.org/10.1080/0269249X.2016.1227376.

Bradbury, J.P. 1988. Fossil diatoms and Neogene paleolimnology. *Palaeogeography, Palaeoclimatology, Palaeoecology* 62: 299-316.

Camargo, M.; Giarrizzo, T.; Isaac, V. 2004. Review of the geographic distribution of fish fauna of the Xingu river basin, Brazil. *Ecotropica* 10: 123-147.

Cardozo, A.Y.V.; Gomes, D.F.; Silva, E.M.; Duque, S.R.E.; Rangel, J.O.C.; Sifeddine, A.; Turcq, B.; Albuquerque, A.L.S. 2014. Holocene paleolimnological reconstruction of a high altitude Colombian tropical lake. *Palaeogeography, Palaeoclimatology, Palaeoecology* 415: 127-136.

Castro, D.F.; Oliveira, P.E.; Rossetti, D.F.; Pessenda, L.C.R. 2012. Late Quaternary landscape evolution of northeastern Amazonia from pollen and diatom records. *Anais da Academia Brasileira de Ciências*. Printed version ISSN 0001-3765 / Online version ISSN 1678-2690www.scielo.br/aabc

Catalogue of Diatom Names, California Academy of Sciences, on-line version updated 01-08-2020. Compiled by Elisabeth Fourtanier and J. Patrick Kociolek. Available online at http://research.calacademy.org/research/diatoms/names/index.asp

Cavalcante, K.P.; Tremarin, P.I.; Ludwig, T.A.V. 2013. Taxonomic studies of centric diatoms (Diatomeae): unusual nanoplanktonic forms and new records for Brazil. *Acta Botanica Brasilica* 27 (2): 237-251.

Costa, L.F.; Wengrat, S.; Bicudo, D.C. 2017. Diatoms from distinct habitats of a highly heterogeneous reservoir, Billings Complex, southeastern Brazil. *Hoehnea* 44 (4): 559-579.

Costa-Böddeker, S.; Bennion, H.; Jesus, T.A.; Albuquerque, A.L.S.; Figueira, R.C.L.; Bicudo, D.C. 2012. Paleolimnologically inferred eutrophication of a shallow tropical, urban reservoir in southeast Brazil. *Journal of Paleolimnology* 48: 751-766.

Dean, W.E.; Gorham, E. 1998. Magnitude and significance of carbon burial in lakes, reservoirs, and peatlands. *Geology* 26: 535-538. doi: 10.1130/0091-7613(1998)026<0535:MASOCB>2.3.CO;2

Domingues, C.D.; Torgan, L.C. 2011. Fitoplâncton (exceto Chlorophyceae) de um lago artificial urbano no Sul do Brasil. *Revista Brasileira de Botânica* 34(3): 463-480.

Dunck, B.; Nogueira, I.S.; Machado, M.G. 2012. Planktonic diatoms in lotic and lentic environments in the Lago dos Tigres hydrologic system (Britânia, Goiás, Brazil): Coscinodiscophyceae and Fragilariophyceae. *Brazilian Journal of Botany* 35 (2): 181-193.

Eletrobrás, 2009. AAI- *Avaliação ambiental integrada, aproveitamentos hidroelétricos da bacia hidrográfica do Rio Xingu*. São Paulo: Eletrobrás, v.1, 204 p.

English, J.; Potapova, M. 2010. Aulacoseira granulata var. angustissima. In Diatoms of North America. Available on: https://diatoms.org/species/aulacoseira_granulata_angustissima access in: 14 August 2020

Faustino, S.B.; Fontana, L.; Bartozek, E.C.R.; Bicudo, C.E.M.; Bicudo, D.C. 2016. Composition and distribution of diatoms assemblages from core and surface sediments of a water supply reservoir in Southeastern Brazil. *Biota Neotropica* 16(2): 320150129

Fontana, L.; Albuquerque, A.L.S.; Brenner, M.; Bonotto, D.M.; Sabaris, T.P.P.; Pires, M.A.F.; Cotrim, M.E.B.; Bicudo, D.C. 2014. The eutrophication history of a tropical water supply reservoir in Brazil. *Journal of Paleolimnology* 51: 29-43.

Fontana, L.; Bicudo, D.C. 2009. Diatomáceas (Bacillariophyceae) de sedimentos superficiais dos reservatórios em cascata do Rio Paranapanema (SP/PR, Brasil): Coscinodiscophyceae e Fragilariophyceae. *Hoehnea* 36(3): 375-386.

Gómez, N.; Riera, J.L.; Sabater, S. 1995. Ecology and morphological variability of *Aulacoseira granulata* (Bacillariophyceae) in Spanish reservoirs. *Journal of Plankton Research* 17 (1): 1-16.

Guiry, M.D.; Guiry, G.M. 2020. AlgaeBase. World-wide electronic publication, National University of Ireland, Galway. Available on: https://www.algaebase.org access in 14 August 2020.

Hermany, G.; Souza, P.A.; Torgan, L.C. 2013. Paleoecologia do Sistema Pinguela-Palmital-Malvas, Holoceno da Bacia de Pelotas, RS, Brasil: uma abordagem focada na utilização de análises multivariadas para obtenção de diatomáceas descritoras. *Pesquisas em Geociências* 40 (1): 31-49.

Instituto Socioambiental. 2012. Access at www.socioambiental.org/sites/blog.socio

Laux, M.; Torgan, L.C. 2011. Diatomáceas com plastídeos no plancton da foz dos rios do Deita do Jacuí, sul do Brasil: um complemento à taxonomia tradicional. *Iheringia* 66 (1): 109-132.

Lobo, E.A.; Schuch, M.; Heinrich, C.G.; Costa, A.B.; Düpont, A.; Wetzel, C.E.; Ector, L. 2015. Development of the Trophic Water Quality Index (TWQI) for subtropical temperate Brazilian lotic systems. Environmental Monitoring and Assessment 187: 354 DOI 10.1007/s10661-015-4586-3

Lowe, R. 2015. *Discostella stelligera*. *In*: Diatoms of North America. Available on: https://diatoms.org/species/discostella_stelligera. Access in 14 August 2020

Marra, R.C.; Tremarin, P.I.; Algarte, V.M.; Ludwig, T.A.V. 2016. Epiphytic diatoms (Diatomeae) from Piraquara II urban reservoir, Paraná state. *Biota Neotropica* 16(4): e20160200

Medeanic, S.; Torgan, L.C.; Clerot, L.C.P.; Santos, C.B. 2009. Holocene marine transgression in the Coastal Plain of Rio Grande do Sul, Brazil: palynomorph and diatom evidence. *Journal of Coast Research* 25 (1): 224-233.

Medlin, L.K.; Kaczmarkska, I. 2004. Evolution of the diatoms, 5: morphological and cytological support for the major clades and a taxonomic revision. *Phycologia* 43 (3): 245-270.

Meister, F. 1937. Seltene und neue Kieselalgen. II. *Berichte der Schweizerischen Botanischen Gessellschaft* 47: 258-276.

Metzeltin, D.; Lange-Bertalot, H. 1998. Tropical Diatoms of the South America, 1. *Iconographia Diatomologica*, Annotated diatom micrographs. H. Lange-Bertalot, (ed.). Stuttgart, Koeltz Scientific Books, v. 5, 695 p.

Metzeltin, D.; Lange-Bertalot, H. 2007. Tropical diatoms of South America, 2. Special remarks on biogeographic disjunction. *Iconographia Diatomologica*, Annotated diatom micrographs. H. Lange-Bertalot (ed.) Stuttgart: Koeltz Scientific Books, v. 18, 877 p.

Morales, E.A. 2005. Observations of the morphology of some known and new fragilarioid diatoms (Bacillariophyceae) from rivers in the USA. *Phycological Research* 53 (2):113-133.

Morales, E.A.; Guerrero, J.M.; Wetzel, C.E.; Sala, S.; Ector, L. 2013. Unraveling the identify of Fragilaria pinnata Ehrenberg and Staurosira pinnata Ehrenberg: research in progress on a convoluted story. *Cryptogamie, Algologie* 34: 89-102.

Morales, E.A.; Manoylov, K.M. 2006. Morphological studies on selected taxa in the genus *Staurosirella* Williams et Round (Bacillariophyceae) from rivers in North America. *Diatom Research* 21 (2): 343-364.

Moresco, C.; Tremarin, P.I.; Ludwig, T.A.V.; Rodrigues, L. 2011. Diatomáceas perifíticas abundantes em três córregos com diferentes ações antrópicas em Maringá, PR, Brasil. *Revista Brasileira de Botânica* 34 (3): 359-373.

Moro, R.S. 1991. Morphology of *Aulacoseira granulata* (Ehrenberg) var. *australiensis* (Grunow) nov. comb. Under light microscopy. *Arquivos de Biologia e Tecnologia* 34 (2): 353-359.

Moro, R.S.; Fürstenberger, C.B. 1997. *Catálogo dos principais parâmetros ecológicos de diatomáceas não-marinhas*. Editora da Universidade Estadual de Ponta Grossa, Ponta Grossa.

Nardelli, M.S.; Bueno, N.C.; Ludwig, T.A.V.; Guimarães, A.T.B. 2016. Structure and dynamics of the planktonic diatom community in the Iguassu River, Paraná State, Brazil. *Brazilian Journal of Biology* 21 (2): 374-386. https://doi.org/10.1590/1519-6984.16114

Nardelli, M.S.; Bueno, N.C.; Ludwig, T.A.V.; Tremarin, P.I.; Bartozek, E.C.R. 2014. Coscinodiscophyceae and Fragilariophyceae (Diatomeae) in the Iguaçu River, Paraná, Brazil. Acta Botanica Brasilica 28(1):127-140.

Padisák, J.; Crossetti, L.O; Naselli-Flores, L. 2009. Use and misuse in the application of the phytoplankton functional classification: a critical review with updates. *Hydrobiologia* 621: 1-19.

Pappas, J.L.; Stoermer, E.F. 1996. Quantitative method for determining a representative algal count. *Journal of Phycology* 32: 693-696.

Potapova, M.; English, J. 2010. *Aulacoseira ambigua*. *In*: Diatoms of North America. Available on: https://diatoms.org/species/aulacoseira_ambigua. Access in 14 August 2020.

Potapova, M.; Hamilton, P.B. 2007. Morphological and ecological variation within the *Achnanthidium minutissimum* (Bacillariophyceae) species complex. *Journal of Phycology* 43: 561-575.

Raupp, S.V.; Torgan, L.C.; Baptista, L.R.M. 2006. Composição e variação temporal de diatomáceas (Bacillariophyta) no plâncton da represa de Canastra, sul do Brasil. *Iheringia* 61 (1-2): 105-134.

Ribeiro, F.C.P.; Senna, C.S.F. 2010. The use of diatoms for palaeohydrological and paleoenvironmental reconstructions of Itupanema beach, Pará state, Amazon region, during the last millennium. *Revista brasileira de Paleontologia* 13 (1): 21-32.

Ribeiro, F.C.P.; Senna, C.S.F.; Torgan, L.C. 2008. Diatomáceas em sedimentos superficiais na planície de maré da praia de Itupanema, Estado do Pará, Amazônia. *Rodriguesia* 59 (2): 309-324.

Round, F.E.; Crawford, R.M; Mann, D.G. 1990. *The Diatoms: biology & morphology of the genera.* Cambridge University Press, Cambridge, 747 p.

Ruwer, D.T.; Bernardes, M.C.; Rodrigues, L. 2018. Diatom responses to environmental changes in the Upper Parana River floodplain (Brazil) during the last ~1000 years. *Journal of Paleolimnology* https://doi.org/10.1007/s10933-018-0039-7

Ruwer, D.T.; Rodrigues, L.R. 2018. Subfossil and periphytic diatoms from the upper Paraná River, Brazil: last ~1000 years of a transition period. *Hoehnea* 45(3): 1-19. http://dx.doi.org/10.1590/2236-8906-89/2017

Sawakuchi, A.O.; Hartmann, G.A.; Sawakuchi H.O; Pupim, F.N.; Bertassoli D.J.; Parra, M.; Antinao, J.L.; Sousa, L.M.; Sabaj-Pérez, M.H.; Oliveira, P.E.; Santos, R.A.; Savian, J.F.; Grohmann, C.H.; Medeiros, V.B.; McGlue, M.M.; Bicudo, D.C.; Faustino, S.B. 2015. The Volta Grande do Xingu: reconstruction of past environments and forecasting of future scenarios of a unique Amazonian fluvial landscape. *Scientific Drilling* 3: 1-12.

Silva, J.P.; Rodrigues, C.; Pereira, D.I. 2014. Mapping and analysis of Geodiversity Indices in the Xingu River Basin, Amazonia, Brazil. *Geoheritage* DOI 10.1007/s12371-014-0134-8

Simonsen, R. 1979. The diatom system: ideas on phylogeny. *Bacillaria* 2: 9-71.

Sims, P.A.; Mann, D.G.; Medlin, L.K. 2006. Evolution of the diatoms: insights from fossil, biological and molecular data. *Phycologia* 45 (4): 361-440.

Sioli, H. 1950. *Das Wasser in Amazonasgebiet*. Fortschrift: Ein Gedicht in fünfzehn Würfen 26: 274-280.

Sioli, H. 1984. The Amazon: limnology and landscape ecology of a mighty tropical river and its basin. *Internationale Revue der Gesmten Hidrobiologie und Hidrographie* 56: 1-762.

Siver, P.A.; Kling. H. 1997. Morphological observations of *Aulacoseira* using scanning electron microscopy. *Canadian Journal of Botany* 75: 1807-1835.

Skvortzov, B.V. 1937. Bottom diatoms from Olhon Gate of Baikal Lake, Siberia. *Philippine Journal of Science*, Sect. C 62 (3): 293-377.

Smol, J.P. 2017. Paleolimnology: reference module in Earth Systems and Environmental Sciences http://dx.doi.org/10.1016/B978-0-12-409548-9.10537-8

Taylor, J.C.; Harding, W.R.; Archibald, G.M. 2007. *An illustrated guide to some common diatom species from South Africa*. WRC report TT 282/07. 224 p.

van Dam, H.; Mertens, A.; Sinkeldam, J. 1994. A coded checklist and ecological indicator values of freshwater diatoms from the Netherlands. *Netherlands Journal of Aquatic Ecology* 28: 117-133.

Wengrat, S.; Padial, A.A.; Jeppsen, E.; Davidson, T.A.; Fontana, L.; Costa-Boddoker, S.; Bicudo, D.C. 2017. Paleolimnological records reveal biotic homogenization driven by eutrophication in tropical reservoirs. *Journal of Paleolimnology* DOI 10.1007/s10933-017-9997-4.

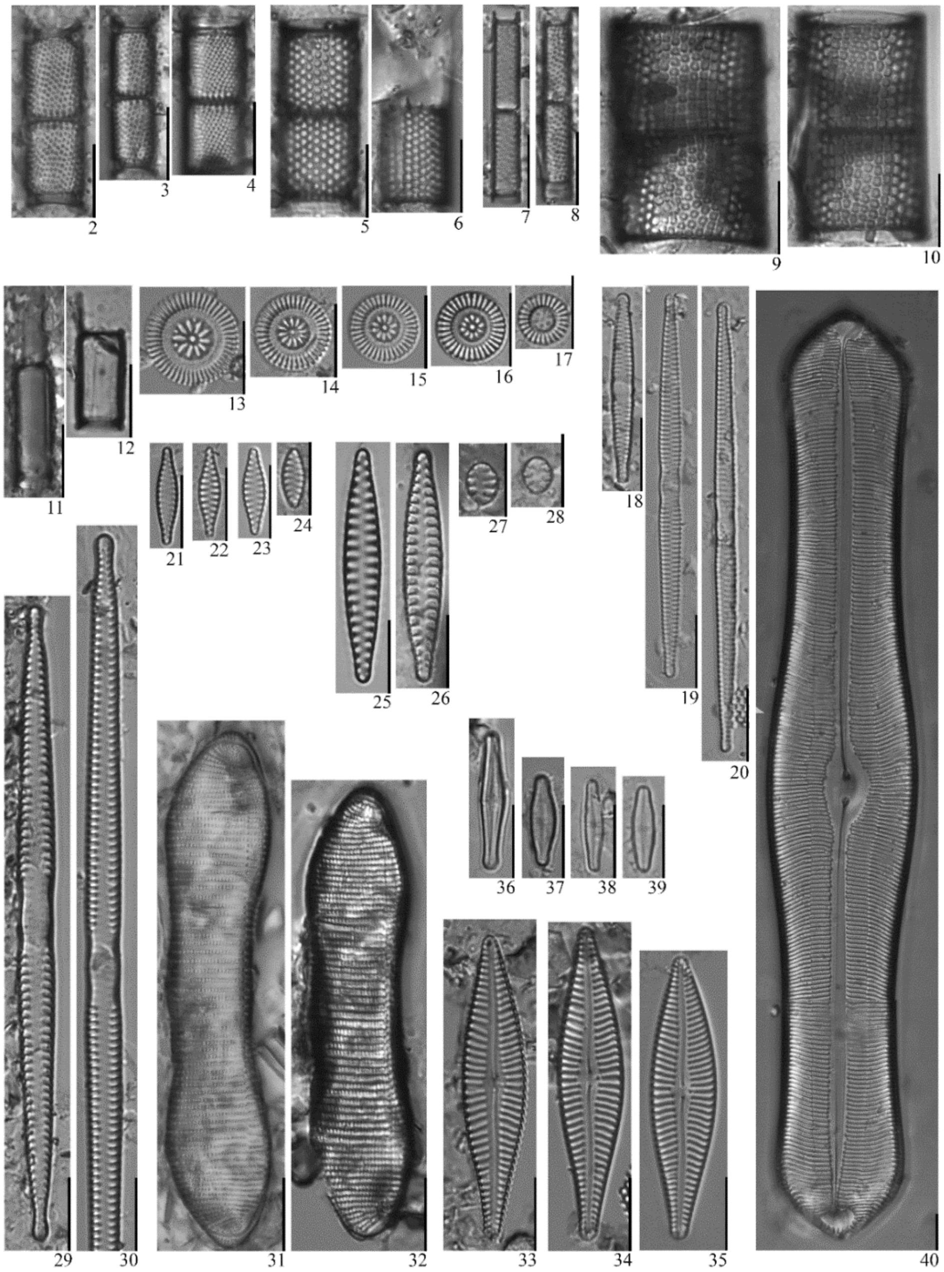


Figure 2-40. Diatoms of Xingu core. 2–4. *Aulacoseira ambigua*, 5-6. *Aulacoseira granulata*, 7-8. *Aulacoseira granulata* var. *angustissima*, 9-10. *Aulacoseira granulata* var. *australiensis*, 11-12. *Aulacoseira herzogii*, 13-17. *Discostella stelligera*, 18-20. *Fragillaria fragilarioides*, 21-24. *Staurosirella* cf. *confusa*, 25-26. *Staurosirella crassa*, 27-28. *Staurosirella* sp., 29-30. *Ulnaria* sp., 31-32. *Eunotia reichardtii*, 33-35. *Gomphonema* sp., 36-39. *Achnanthidium minutissimum*, 40. *Pinnularia* sp. Scale bar: 10 µm.

Capítulo 3

A new *Planothidium* species (Achnanthidiaceae, Bacillariophyceae) from Xingu *Ria*, Amazon River basin, Brazil

KRYSNA S. MORAIS[1*], LÍVIA F. COSTA[1], CARLOS E. DE M. BICUDO[1],
LUC ECTOR[2] & CARLOS E. WETZEL[2]

[1] *Instituto de Botânica, Department of Ecology, Av. Miguel Estéfano 3687, 04301-902 São Paulo, SP, Brazil.*

[2] *Luxembourg Institute of Science and Technology (LIST), Environmental Research & Innovation Department (ERIN), 41 rue du Brill, L-4422 Belvaux, Luxembourg.*

ABSTRACT

A new *Planothidium* species was found in sediment samples (~4.000 yr BP) from the Xingu *Ria* (Xingu River), Brazilian Amazon. The new species morphology was analyzed using light and scanning electron microscopy. *Planothidium xinguensis* sp. nov., is mainly characterized by its elliptical, slightly asymmetrical valves, with strongly marked short rostrate ends in the small specimens, whereas long and strongly rostrate apices in the larger valves. The taxon belongs to the group of species bearing a cavum on the rapheless valves around the name "*Planothidium rostratum* sensu lato". Morphology and ecology of the new species are compared with those of morphologically related taxa. Information of core chronology and the co-occurrence of other diatom species in the sample are also provided.

Keywords: Amazon basin, diatom, sediment samples, taxonomy

INTRODUCTION

Originally proposed by Round & Bukhtiyarova (1996), the so-called ‘monoraphid’ genus *Planothidium* includes around 126 taxonomically accepted species (Kociolek *et al*. 2020), therefore being one of the most species-rich genus in the family Achnanthidiaceae D.G.Mann.

Planothidium Round & Bukhtiyarova (1996: 351) is characterized by heterovalvar frustules usually solitary, with elliptic to lanceolate valves, slightly concave raphe valve (RV) and convex rapheless sternum valve (SV) (N’Guessan *et al*. 2014, Wetzel *et al*. 2019). The RV has usually radiate striae, central raphe with terminal ends curved and unilaterally deflected (Round & Bukhtiyarova 1996, van de Vijver & Bosak 2019). The SV, an asymmetrical central area is observed in several species (Wetzel *et al*. 2019), described sometimes as a “horseshoe” zone (Round & Bukhtiyarova 1996). Internally, the SV may present a shallow depression (sinus) or a hood (cavum), and often requires detailed scanning electron microscopy for a complete description of the structure, or the lack of it (Wetzel *et al*. 2019). Detailed observation of the central area, the shape and form of the “horseshoe” structure, and the striae pattern are of utmost importance for description of new taxa within this group (*e.g*. Morales 2006, Potapova 2012, Jahn *et al*. 2017, Wetzel *et al*. 2019).

Planothidium cells are often epilithic or epipsammic and live attached to a substratum by the RV (Spaulding *et al*. 2008, Wetzel *et al*. 2019). Most known species described up to date occur in freshwater ecosystems (Morales 2006, Wetzel *et al*. 2013, Wetzel & Ector 2014a, 2014b, Stancheva 2019), with a few ones living in brackish and marine environments (Riaux-Gobin *et al*. 2018, van de Vijver *et al.* 2018, van de Vijver & Bosak 2019, Bąk *et al*. 2020).

In Brazil, the genus is mentioned in floristic surveys and ecology studies in a wide range of habitats and trophic conditions (*e.g*. Silva *et al*. 2010, Costa-Böddeker *et al*. 2012, Fontana & Bicudo 2012, Bartozek *et al*. 2013, Nardelli *et al*. 2016, Costa *et al*. 2017, Ruwer & Rodrigues 2018, Silva-Lehmkuhl *et al*. 2019). Furthermore, new species were recently described to science, as new such as *Planothidium bagualensis* C.E.Wetzel & Ector (2014a: 203), *Planothidium brasiliense* C.E.Wetzel & S.Blanco in Wetzel *et al.* (2019: 58) and *Planothidium incuriatum* C.E.Wetzel, van de Vijver & Ector in Wetzel *et al.* (2013: 49), demonstrating the importance and the need for detailed studies on monoraphid taxa of Brazilian ecosystems. However, due to the large Brazilian territorial area and the great aquatic diversity, many species of *Planothidium* remain undescribed and, consequently, information about their richness and distribution remains poorly known, especially for the Amazonian ecosystems.

As part of the diatom survey of core sediments from the Xingu River, a pristine river in the Amazon basin, one unknown *Planothidium* species was frequently observed along the sediment core. Based observations made using light (LM) and scanning electron microscopy (SEM), the new species is described and compared with morphologically similar taxa.

MATERIAL AND METHODS

Study area

Localized in the eastern Amazon, Xingu River basin covers the total area of 509,685 km^2 and it is approximately 2,600 km long, corresponding to 13% of the Amazon River basin in the Brazilian territory (Eletrobrás 2009). The drainage basin comprises the Amazon floodplain and the Xingu-Tocantins low tablelands, with a wide variety of rocks of recent geological units, such as the Tertiary and Quaternary alluvium (Silva *et al.* 2015). Dominant vegetation is the ombrophilous open forest and pioneer herbaceous communities near to the river mouth (Camargo *et al.* 2004). Climate is tropical with an average temperature between 25ºC and 27ºC (Latrubesse *et al.* 2005).

Xingu is a clearwater river (‘*sensu*’ Sioli 1984) with a bed load dominated by fine to coarse sand, characterized by a low concentration of suspended sediments and slightly alkaline waters (Sioli 1950, Sawakuchi *et al.* 2015). Close to its mouth (Fig. 1C), the river shifts to a lowland Amazonian River under the influence of freshwater tides (Sawakuchi *et al.* 2015). In this region, the Xingu River shows a sedimentary dynamic similar to that of lakes and reservoirs, known as *rias*-lake or *paleorias* (Dean & Gorham 1998, Bertassoli *et al.* 2017). The *rias* consists of channels localized in the lower sections of Amazonian rivers or creeks, and connects (entirely or partially) all the tributaries to the Amazon River (Irion *et al.* 2010, Bertani *et al.* 2014, Bertassoli *et al.* 2017). Furthermore, *rias* accumulate fine-grained sediments, and play an important role as sink or source of carbon (Sawakuchi *et al.* 2015, Bertassoli *et al.* 2017).

Sampling and sample treatment

The new species was detected in a 362 cm long core collected at the deepest portion of the Xingu *Ria* (01°42’32.12” S, 52°16’47.42” W), close to the confluence to the Amazon River. The sediment core XC-03 (Fig. 1C) was retrieved by divers with a 6 m long PVC tube. After sampling, the sediment core was transferred to the Geosciences Institute of the São Paulo University (IGC-USP), where it was opened for description and subsampled at each 2 cm.

Optically Stimulated Luminescence (OSL) and ^{14}C dating determined the core chronology as detailed in Sawakuchi *et al*. (2015). Based on the OSL and ^{14}C datings, the base of the XC-03 core has about ~4.000 yr. BP, corresponding on geological scale, the Meghalayan Age.

Diatom samples were digested with concentrated 35% H_2O_2 (hydrogen peroxide) and 37% HCl (hydrochloric acid) following the standard procedures (European Committee for Standardization 2003). Oxidized subsamples were rinsed with deionized water, and permanent slides were mounted with Naphrax mounting medium (R.I. = 1.6). Optical microscopy analysis and counting were processed at a magnification of 1,000x using a Zeiss Axio Imager A2 light microscope equipped with DIC (Differential Interference Contrast) and Axiocam ERc5s high-resolution digital camera. At least 400 valves per slide were counted along defined transects (Battarbee *et al*. 2001), until reaching a 90% efficiency according to Pappas & Stoermer (1996).

For scanning electron microscopy (SEM), small aliquots of the oxidized samples were filtered through a polycarbonate membrane filter (3 µm mesh), and washed with deionized water. Then, the filters were mounted on aluminum stubs and coated with platinum. Pictures were taken with a Hitachi SU-70 equipment operated at 5 kV and 10 mm working distance. Plates containing light and scanning electron microscopy images were created using CorelDRAW X8.

Morphological terminology followed Barber & Haworth (1981) and Round & Bukhtiyarova (1996) for valve features and the genus morphology, respectively, and Round *et al*. (1990) for ultrastructure and SEM. Also the new taxon was morphologically compared with other *Planothidium* species (Bąk & Lange-Bertalot 2014, Wetzel *et al*. 2019). The holotype slide is deposited at the Herbário Científico do Estado “Maria Eneyda P. Kauffmann Fidalgo” (SP) of the Instituto de Botânica, São Paulo, Brazil, and an isotype slide at the Botanic Garden Meise (BR), Belgium.

RESULTS

Class Bacillariophyceae Haeckel
  Subclass Bacillariophycidae D.G.Mann
    Order Cocconeidales E.J.Cox
      Family Achnanthidiaceae D.G.Mann
        Genus *Planothidium* Round & Bukhtiyarova

Planothidium xinguensis K.S.Morais, C.E.Wezel & C.E.M.Bicudo, sp. nov. (Figs 2-25 LM; 26-29 SEM)

Morphological observations in LM (Figs 2-25):—Valves elliptic, asymmetric, with protracted, rostrate to subcapitate ends. Valve dimensions: length 12–14 µm, width 6.7-8.2 µm. Raphe valve (Figs 2-4, 8-12, 15-20): axial area narrow, linear. Central area irregular, rectangular to slightly rounded, bordered by 2 or 3 shortened striae on each side. Raphe straight, with expanded drop-like proximal raphe endings. Terminal raphe fissures deflected to the same side. Striae strongly radiate throughout the entire valve, 12-14 in 10 µm. Rapheless valve (Figs 5-7, 13-14, 21-25): axial area narrow, linear to lanceolate, expanded in the central area, in opposition to the cavum. Central area with a unilateral large, horseshoe-shaped, hyaline area with a visible cavum; on the opposite side, striae slightly shortened in the axial area. Striae radiate, more strongly radiate towards the apices, 12-14 in 10 µm measured at the central part of the valve, opposite to the cavum.

Morphological observations in SEM (Figs 26-29):—Raphe valve (Figs 26-27): striae composed of 3-4 rows of small rounded areolae (Fig. 26). Central striae short, gradually narrowing towards the axial area. Proximal raphe endings straight, terminating in expanded pores. Terminal raphe fissures unilaterally bent, continuing short onto the valve mantle. Internally: central area slightly raised. Striae sunken between virgae (Fig. 27). Areolae covered by individual hymenes (Fig. 27). Proximal raphe endings slightly deflected to opposite sides. Rapheless valve (Figs 28-29): striae composed of 1-3 rows of larger, rounded, sometimes elongated areolae, at the valve margins. Striae near the axial area composed of 2-5 rounded areolae, larger than the areolae near to the margins. Areolae on the valve mantle usually composed by groups of 6 or 7. Irregular shallow depressions present in the central area (Fig. 28) and slit-like depressions in the axial area. Internally, the cavum has a narrow aperture (Fig. 29). Virgae raised between striae.

Holotype (here designated):—Slide (SP! 365550) deposited at the Herbário Científico do Estado “Maria Eneyda P. Kauffmann Fidalgo” (SP), Instituto de Botânica, São Paulo, Brazil.

Isotype:—Slide BR-4603, Botanic Garden Meise (BR), Belgium.

Type locality:—BRAZIL, Pará State, Porto de Moz, Xingu River (01º42’32.12” S, 52º16’47.42” W), A.O. Sawakuchi *et al.*, sediment core XC-03 (SP365550).

Etymology:—From Xingu river, where the original material was collected.

Distribution and associated diatom flora:—*Planothidium xinguensis* was collected in somewhat low abundance (< 2%) throughout the entire XC-03 core. The greatest abundance value (1.9%) was detected at approximately ~3.950 yr BP. Xingu River included at that moment a period with shallow, but wide photic zone, and the diatom assemblage was composed by *Gogorevia exilis* (Kützing 1844: 105) Kulikovskiy & Kociolek *in* Kulikovskiy *et al.* (2020), *Psammothidium* sp., *Pseudostaurosira* cf. *brevistriata* (Grunow *in* van Heurck 1885: 157) D.M.Williams & Round

(1987: 276), *Staurosirella crassa* (Metzeltin & Lange-Bertalot 1998: 89-90) F.C.P.Ribeiro & Torgan in Ribeiro *et al.* (2010: 24), *S. subcapitata* (Frenguelli 1930: 199), *Staurosirella* sp. and *Lacuneolimna* cf. *novagallia* Tudesque & Le Cohu *in* Tudesque *et al.* (2015: 24).

DISCUSSION

Planothidium xinguensis belong to the genus *Planothidium* by having heterovalvar cells and its typical cavum structure in the rapheless valve. The unique features of *P. xingu*ensis such as strongly marked irregular lines along the axial area including shallow rounded and irregular depressions that are concentrated at the central area are not knowns in the most recent revision of the species around *Planothdium rostratum* by Wetzel *et al*. (2019). While *Planothidium xinguensis* show some degree of similarity regarding general valve outline to *P. rostratum* (Østrup 1902: 35) Lange-Bertalot (1999: 285) illustrated in Wetzel *et al*. (2019, figs 11-61) since they exhibit elliptical valves, rostrate apices, rectangular to rounded central area and similar striae density (see Table 1). However, both species area easily distinguished in LM in relation to breadth values and striae organization: *P. xinguensis* has slightly wider cells with strongly radiate striae in both valves, whereas *P. rostratum* has narrower valves with radiate to weakly radiate striae pattern. Furthermore, in SV, the striae of *P. rostratum* reaches the central area, and such characteristic was not observed in *P. xinguensis*. The main difference however, are observable in SEM: the number of striae and morphology of areolae on the SV are different in these two taxa, with those of *P. xinguensis* being composed by striae with 2-3 rows of rounded areolae, terminating with 2-5 areolae towards the central area whereas *P. rostratum* has striae composed of 3-4 rows of small rounded areolae, with the middle two rows smaller than the others. Near to the central area, the later species has three rows of areolae, and near to the mantle four discontinuous areolae are observed (see Wetzel *et al*. 2019: figs 109-113, 116-117). On the mantle, *P. rostratum* has lower areolae density (4-5) with the last areolae longer than the others; *P. xinguensis* has a set of areolae composed by groups of 6-7, approximately. The new species may also be differentiated by the presence of irregular depressions on the surface of axial and central areas (Fig. 29), in addition to the smaller cavum aperture.

Smaller representatives of *P. xinguensis* may be compared to *P. rostratoholarcticum* Bąk & Lange-Bertalot (2014: 354), species from the Central Europe. However, the latter species has smaller valve dimensions and a greater density of striae (L: 8-12 µm, W: 4.5-5.5 µm, S: 14-18 in

10 µm). Additionally, *P. rostratoholarcticum* presents subrostrate rather than rostrate apices whereas in the specimens from Xingu *Ria*, the apices remain rostrate, even in the smaller valves.

Another similar taxon is *Planothidium piaficum* (J.R.Carter & Denny 1982: 286) C.E.Wetzel & Ector in N'Guessan *et al*. (2014: 460), a tropical species from Western Africa. Nevertheless, in general features the new species *P. xinguensis* has smaller length and slight greater width (12-14 µm and 6.7-8.2 µm) compared to *P. piaficum* (12-20 µm and 6-8 µm), besides the presence of an axial area more lanceolate in SV. Moreover, in SEM analysis is possible to notice some other distinct features, as the shape and size of cavum apertures, larger in *P. xinguensis*; the number of areolae rows in the RV, being 3-5 in *P. piaficum* and 3-4 in our specimens; in SV, the larger rounded areolae, sometimes elongated in *P. xinguensis*; and the distinct shape of the depressions found in SV surface of both taxa. Moreover, the small areolae of *Planothidium piaficum* are located in an elevated structure similar to a costa (interstriae). *Planothidium brasiliense* C.E.Wetzel & S.Blanco in Wetzel *et al.* (2019: 58) differs in all metric features as well as in its striae density (*P. brasiliense*: L: 20-28 µm; W: 7.0-8.0 µm; S: 15-17 in 10 µm). Moreover, the areolae composing the striae of the raphe valve in *P. brasiliense* show 2 to 3 rows (Wetzel, pers. observ.).

CONCLUSION

Despite the increasing number of diatom's new species and genera descriptions for the Brazilian Amazon (Metzeltin & Lange-Bertalot 1998, Wetzel *et al*. 2010, 2011, 2012a, 2012b, Burliga *et al*. 2007, 2013, Burliga & Kociolek 2010, 2012, Pereira *et al*. 2014, 2015), areas such as the Xingu *Ria* are still rather poorly studied. It is also noteworthy that, so far the diversity and abundance of *Planothidium* species reported to this region (the Amazon basin as a whole) is usually low, being the water usually acidic and with a great richness of acidobiontic taxa such as *Actinella* Lewis (1964: 343), *Eunotia* Ehrenberg (1837: 44), *Fragilariforma* D.M.Williams & Round (1988: 265), *Nupela* Vyverman & Compère (1991: 175) and *Pinnularia* Ehrenberg (1843: 45) just to mention a few examples, as already noted by Hustedt (1952, 1965), Metzeltin & Lange-Bertalot (1998, 2007) and Wetzel *et al*. (2012). Up to date, very few *Planothidium* species were reported to the Brazilian Amazon basin, i.e. *Planothidium heteromorphum* (Grunow in Cleve & Grunow 1880: 23) Lange-Bertalot (1999: 276) [= *Achnanthes heteromorpha* (Grunow in Cleve & Grunow 1880: 23)] in Metzeltin & Lange-Bertalot (1998) from Tapajós River and *Planothidium lanceolatum* (Brébisson *ex* Kützing 1846: 247) Lange-Bertalot (1999: 287) in Ribeiro *et al*. (2008), from sediment samples retrieved from Itupanema beach, Pará State. However, the above authors did not include any illustration, description nor ultrastructural details of the species to confirm its presence.

In this way, description of *Planothidium xinguensis* contributes to the knowledge of the diatom diversity in *rias* ecosystems, adding a new record for the Amazonian clearwater rivers. Furthermore, the present study highlights the importance of an accurate taxonomy in paleoenvironmental investigations, thus aiming to find out new potential ecological indicators.

REFERENCES

Almeida, C.A., Coutinho, A.C., Esquerdo, J.C.D.M., Adami, M., Venturieri, A., Diniz, C.G., Dessay, N., Dirieux, L. & Gomes, A.R. (2016) High spatial resolution land use and land cover mapping of the Brazilian Legal Amazon in 2008 using Landsat-5/TM and MODIS data. *Acta Amazonica* 46 (3): 291-302. https://dx.doi.org/10.1590/1809-4392201505504

Bąk, M., Halabowski, D., Kryk, A., Lewin, I., & Sowa, A. (2020). Mining salinisation of rivers: its impact on diatom (Bacillariophyta) assemblages. *Fottea* 20 (1): 1-16. https://doi.org/10.5507/fot.2019.010

Bąk, M. & Lange-Bertalot, H. (2014) Four small-celled *Planothidium* species from Central Europe proposed as new to science. *Oceanological and Hydrobiological Studies* 43 (4): 346-359. https://doi.org/10.2478/s13545-014-0152-9

Barber, H.G. & Haworth, E.Y. (1981) *A guide to the morphology of the diatom frustule with a key to the British freshwater genera*. Freshwater Biological Association, Scientific Publication No. 44. 112 p.

Bartozek, E.C.R., Bueno, N.C., Ludwig, T.A.V., Tremarin, P.I., Nardelli, M.S. & Righetti, A.C. (2013) Diatoms (Bacillariophyceae) of Iguaçu National Park, Foz do Iguaçu, Brazil. *Acta Botanica Brasilica* 27 (1): 108-123. https://doi.org/10.1590/S0102-33062013000100012

Battarbee, R.W., Jones, V.J., Flower, R.J., Cameron, N.G., Bennion, H., Carvalho, L. & Juggins, S. (2001) Diatoms. *In*: Smol, J.P, Birks, H.J.B. & Last, W.M. (eds), Tracking Environmental Change Using Lake Sediments. Volume 3: Terrestrial, Algal, and Siliceous Indicators. Kluwer Academic Publishers, Dordrecht. p. 155-202.

Bertani, T.C., Rossetti, D.F., Hayakawa, E.H. & Cohen, M.C.L. (2014) Understanding Amazonian fluvial rias based on a Late Pleistocene-Holocene analog. *Earth Surface Processes and Landforms* 40 (3): 285-292. https://doi.org/10.1002/esp.3629

Bertassoli Jr., D.J., Sawakuchi, A.O., Sawakuchi, H.O., Pupim, F.N., Hartmann, G.A., McGlue, M.M., Chiessi, C.M., Zabel, M., Schefuß, E., Pereira, T.S., Santos, R.A., Faustino, S.B., Oliveira, P.E. & Bicudo, D.C. (2017) The fate of carbon in sediments of the Xingu and Tapajós clearwater rivers, eastern Amazon. *Frontiers in Marine Science* 44 (4): 1-14. https://doi.org/10.3389/fmars.2017.00044

Burliga, A.L. & Kociolek, J.P. (2010) *Kobayasiella* species from Carajás National Forest, Amazonia, Brazil. *Diatom Research* 25 (2): 235-250. http://dx.doi.org/10.1080/0269249X.2010.9705848

Burliga, A.L. & Kociolek, J.P. (2012) Four new *Eunotia* Ehrenberg species (Bacillariophyceae) from pristine regions of Carajás National Forest, Amazonia, Brazil. *Nova Hedwigia, Beiheft* 141: 53-70.

Burliga, A.L., Kociolek, J.P., Salomoni, S.E. & Figueiredo, D. (2013) A new genus and species in the diatom family Eunotiaceae Kützing (Bacillariophyceae) from the Amazonian hydrographic region, Brazil. *Phytotaxa* 79 (2): 47-57. http://dx.doi.org/10.11646/phytotaxa.79.2.1

Burliga, A.L., Torgan, L.C. & Beaumord, A.C. (2007) *Eunotia ariengae* sp. nov., an epilithic diatom from Brazilian Amazon. *Diatom Research* 22 (2): 247-253 http://dx.doi.org/10.1080/0269249X.2007.9705714

Camargo, M., Giarrizzo, T. & Isaac, V. (2004) Review of the geographic distribution of fish fauna of the Xingu River basin, Brazil. *Ecotropica* 10: 123-147.

Carter, J.R. & Denny, P. (1982) Freshwater algae of Sierra Leone III. Bacillariophyceae: Part (i) Diatoms from the River Jong (Taia) at Njala. *Beihefte zur Nova Hedwigia* 73: 281-331.

Cleve, P.T. & Grunow, A. (1880) Beiträge zur Kenntniss der arctischen Diatomeen. *Kongliga Svenska Vetenskaps-Akademiens Handlingar* 17 (2): 1-121.

Costa, L.F., Wengrat, S. & Bicudo, D.C. (2017) Diatoms from distinct habitats of a highly heterogeneous reservoir, Billing Complex, southeastern Brazil. *Hoehnea* 44 (4): 559-579. https://doi.org/10.1590/2236-8906-12/2017

Costa-Böddeker, S., Bennion, H., Araújo de Jesus, T., Albuquerque, A.L.S., Figueira, R.C.L. & Bicudo, D.C. (2012) Paleolimnologically inferred eutrophication of a shallow, tropical, urban reservoir in southeast Brazil. *Journal of Paleolimnology* 48 (4): 751-766. https://doi.org/10.1007/s10933-012-9642-1

Dean, W.E. & Gorham, E. (1998) Magnitude and significance of carbon burial in lakes, reservoirs, and peatlands. *Geology* 26 (6): 535-538. https://doi.org/10.1130/0091-7613(1998)026<0535:MASOCB>2.3.CO;2

Eletrobrás (2009) *AAI - Avaliação Ambiental Integrada: aproveitamentos hidroelétricos da bacia hidrográfica do Rio Xingu*. Eletrobrás, São Paulo. v.1, 204 p.

Ehrenberg, C.G. (1837) Über ei naus fossilen Infusorien bestehendes, 1832 zu Brod verbacknes Bergmehl von den Grenzen Lapplands in Schweden. *Bericht über die zur Bekanntmachung geeigneten Verhandlugen der Königl. Preuß. Akademie der Wissenschaften zu Berlin* 1837: 43-45.

Ehrenberg, C.G. (1843) Mittheilungen über 2 neue asiatische Lager fossiler Infusorien-Erden aus dem russischen TransKaukasien (Grusien) und Sibirien. *Bericht über die zur Bekanntmachung geeigneten Verhandlungen der KöniglichPreussischen Akademie der Wissenschaften zu Berlin* 1843: 43-49.

European Committee for Standardization (2003) EN 13946. Water quality - Guidance standard for the routine sampling and pretreatment of benthic diatoms from rivers. Available from: http://www.safrass.com/partners_area/BSI%20Benthic%20diatoms.pdf (accessed: 27 March 2020).

Fontana, L. & Bicudo, D.C. (2012) Diatomáceas (Bacillariophyceae) de sedimentos superficiais dos reservatórios em cascata do Rio Paranapanema (SP/PR, Brasil): Coscinodiscophyceae e Fragilariophyceae. *Hoehnea* 36 (3): 375-386. https://doi.org/10.1590/S2236-89062009000300001

Frenguelli, J. (1930) Diatomeas contenidas en una muestra de trípoli de Calama, en Chile. *Revista Chilena de Historia Natural* 34: 195-199.

Hustedt, F. (1952) Neue und wenig bekannte Diatomeen, 4. *Botaniska Notiser* 4: 366-410.

Hustedt, F. (1955) Zellteilungsfolge und Variabilität bei Diatomeen. *Archiv für Mikrobiologie* 21: 391-400.

Hustedt, F. (1965) Neue und wenig bekannte Diatomeen, 9: Süßwasserdiatomeen aus Brasilien, insbesondere des Amazonasgebietes. *International Review of Hydrobiology* 50: 391-410.

Irion, G., de Mello, J.A.S.N., Morais, J., Piedade, M.T.F., Junk, W.J. & Garming, L. (2010) Development of the Amazon valley during the Middle to Late Quaternary: sedimentological and climatological observations. *In*: Junk, W.J., Piedade, M., Wittmann, F., Schöngart, J. & Parolin, P. (eds), Amazonian Floodplain Forests: Ecophysiology, Biodiversity and Sustainable Management. Ecological Studies (Analysis and Synthesis), vol. 210. Springer, Dordrecht. https://doi.org/10.1007/978-90-481-8725-6_2

Jahn, R., Abarca, N., Gemeinholzer, B., Mora, D., Skibbe, O., Kulikovskiy, M., Gusev, E., Kusber, W.H. & Zimmermann, J. (2017) *Planothidium lanceolatum* and *Planothidium frequentissimum* reinvestigated with molecular methods and morphology: four new species and the taxonomic importance of the sinus and cavum. *Diatom Research* 32 (1): 75-107. https://dx.doi.org/10.1080/0269249X.2017.1312548

Kociolek, J.P., Blanco, S., Coste, M., Ector, L., Liu, Y., Karthick, B., Kulikovskiy, M., Lundholm, N., Ludwig, T., Potapova, M., Rimet, F., Sabbe, K., Sala, S., Sar, E., Taylor, J., van de Vijver, B., Wetzel, C.E., Williams, D.M., Witkowski, A. & Witkowski, J. (2020): DiatomBase. Available from: http://www.diatombase.org (accessed: 21 April 2020).

Kulikovskiy, M., Maltsev, Y., Glushchenko, A., Kuznetsova, I., Kapustin, D., Gusev, E., Lange-Bertalot, H., Genkal, S. & Kociolek, J.P. (2020) *Gogorevia*, a new monoraphid diatom genus for *Achnanthes exigua* and allied taxa (Achnanthidiaceae) described on the basis of an integrated molecular and morphological approach. *Journal of Phycology*. https://doi.org/10.1111/jpy.13064

Kützing, F.T. (1844) Die Kieselschaligen. Bacillarien oder Diatomeen. Nordhausen. 152 p.

Kützing, F.T. (1846) Kurze Mittheilung uber einige kieselschalige Diatomeen. *Botanische Zeitung* 4 (14): 247-248.

Lange-Bertalot, H. (1999) Neue Kombinationen von Taxa aus *Achnanthes* Bory (sensu lato). *Iconographia Diatomologica* 6: 276-289.

Latrubesse, E.M., Stevaux, J.C. & Sinha, R. (2005) Tropical rivers. *Geomorphology* 70 (3-4): 187-206. https://doi.org/10.1016/j.geomorph.2005.02.005

Lewis, F.W. (1864) On some new and singular intermediate forms of Diatomaceae. *Proceedings of the Academy of Natural Sciences of Philadelphia* 15: 336-346.

Metzeltin, D. & Lange-Bertalot, H. (1998) Tropische Diatomeen in Südamerika I. 700 überwiegend wenig bekannte oder neue Taxa repräsentativ als Elemente der neotropischen Flora [Tropical Diatoms of South America I. About 700 predominantly rarely known or new taxa representative of the neotropical flora]. *Iconographia Diatomologica* 5: 1-695.

Metzeltin, D. & Lange-Bertalot, H. (2007) Tropical Diatoms of South America II. Special remarks on biogeography disjunction. *Iconographia Diatomologica* 18: 1-877.

Morales, E.A. (2006) Small *Planothidium* Round et Bukhtiyarova (Bacillariophyceae) taxa related to *P. daui* (Foged) Lange-Bertalot from the United States. *Diatom Research* 21 (2): 325-342. https://doi.org/10.1080/0269249X.2006.9705673

Nardelli, M.S., Bueno, N.C., Ludwig, T.A.V. & Guimarães, A.T.B. (2016) Structure and dynamics of the planktonic diatom community in the Iguassu River, Paraná State, Brazil. *Brazilian Journal of Biology* 76 (2): 374-386. https://doi.org/10.1590/1519-6984.16114

N'Guessan, K.R., Wetzel, C.E., Ector, L., Coste, M., Cocquyt, C., van de Vijver, B., Yao, S.S., Ouattara, A., Kouamelan, E.P. & Tison-Rosebery, J. (2014) *Planothidium comperei* sp. nov. (Bacillariophyta), a new diatom species from Ivory Coast. *Plant Ecology and Evolution* 147 (3): 455-462. https://doi.org/10.5091/plecevo.2014.981

Østrup, E. (1902) Freshwater diatoms. In: Flora of Koh Chang. Contributions to the knowledge of the vegetation in the Gulf of Siam. Part VII. Johs. Schmidt (ed.). *Botanisk Tidsskrift* 25 (1): 28-41.

Pappas, J.L. & Stoermer, E.F. (1996) Quantitative method for determining a representative algal sample count. *Journal of Phycology* 32 (4): 693-696. https://doi.org/10.1111/j.0022-3646.1996.00693.x

Pereira, A.C., Torgan, L.C., Burliga, A.L., Kociolek, J.P., Wetzel, C.E., Ector, L. & Melo, S. (2015) *Pinnularia caprichosa* sp. nov.: a diatom from a black water Brazilian Amazon system. *Phytotaxa* 239 (3): 280-286. http://dx.doi.org/10.11646/phytotaxa.239.3.9

Pereira, A.C., Torgan, L.C. & Melo, S. (2014) Four new *Pinnularia* Ehrenberg (Bacillariophyta, Pinnulariaceae) species from Amazonian black water (Tupé Lake, Amazonas State, Brazil). *Phytotaxa* 158 (2): 154-168. http://dx.doi.org/10.11646/phytotaxa.158.2.3

Potapova, M.G. (2012) New species and combinations in monoraphid diatoms (family Achnanthidiaceae) from North America. *Diatom Research* 27 (1): 29-42. http://dx.doi.org/10.1080/0269249X.2011.644636

Riaux-Gobin, C., Witkowski, A., Igersheim, A., Lobban, C.S., Al-Handal, A.Y. & Compère, P. (2018) *Planothidium juandenovense* sp. nov. (Bacillariophyta) from Juan de Nova (Scattered Islands, Mozambique Channel) and other tropical environments: a new addition to the *Planothidium delicatulum* complex. *Fottea* 18 (1): 106-119. https://doi.org/10.5507/fot.2017.019

Ribeiro, F.C.P., Senna, C.S.F. & Torgan, L.C. (2008) Diatomáceas em sedimentos superficiais na planície de maré da Praia de Itupanema, estado do Pará, Amazônia. *Rodriguesia* 59 (2): 309-324.

Ribeiro, F.C.P., Senna, C.S.F. & Torgan, L.C. (2010) The use of diatoms for paleohydrological and paleoenvironmental reconstructions of Itupanema Beach, Pará State, Amazon Region, during the last millennium. *Revista Brasileira de Paleontologia* 13 (1): 21-32. https://doi.org/10.4072/rbp.2010.1.03

Round, F.E. & Bukhtiyarova, L. (1996) Four new genera based on *Achnanthes* (*Achnanthidium*) together with a re-definition of *Achnanthidium*. *Diatom Research* 11 (2): 345-361. https://doi.org/10.1080/0269249X.1996.9705389

Round, F.E., Crawford, R.M. & Mann, D.G. (1990) *The diatoms*: *biology & morphology of the genera.* Cambridge University Press, Cambridge. 747 p.

Ruwer, D.T. & Rodrigues, L. (2018) Subfossil and periphytic diatoms from the upper Paraná river, Brazil: last ~1000 years of a transition period. *Hoehnea* 45 (3): 431-449. http://dx.doi.org/10.1590/2236-8906-89/2017

Sawakuchi, A.O., Hartmann, G.A., Sawakuchi, H.O., Pupim, F.N., Bertassoli, D.J., Parra, M., Antinao, J.L., Sousa, L.M., Sabaj Pérez, M.H., Oliveira, P.E., Santos, R.A., Savian, J.F., Grohmann, C.H., Medeiros, V.B., McGlue, M.M., Bicudo, D.C. & Faustino, S.B. (2015) The Volta Grande do Xingu: reconstruction of past environments and forecasting of future scenarios of a unique Amazonian fluvial landscape. *Scientific Drilling* 20: 21-32. https://doi.org/10.5194/sd-20-21-2015

Silva, A.M., Ludwig, T.A.V., Tremarin, P.I. & Vercellino, I.S. (2010) Diatomáceas perifíticas em um sistema eutrófico brasileiro (Reservatório do Iraí, estado do Paraná). *Acta Botanica Brasilica* 24 (4): 997-1016. https://doi.org/10.1590/S0102-33062010000400015

Silva, J.P., Rodrigues, C. & Pereira, D.I. (2015) Mapping and analysis of geodiversity indices in the Xingu River basin, Amazonia, Brazil. *Geoheritage* 7: 337-350. https://doi.org/10.1007/s12371-014-0134-8

Silva-Lehmkuhl, A.M., Tremarin, P.I., Vercellino, I.S. & Ludwig, T.A.V. (2019) Periphytic diatoms from an oligotrophic lentic system, Piraquara I reservoir, Paraná state, Brazil. *Biota Neotropica* 19 (2): e20180568. http://dx.doi.org/10.1590/1676-0611-BN-2018-0568

Sioli, H. (1950) Das Wasser im Amazonasgebiet. *Forschungen und Fortschritte* 26 (21-22): 274-280.

Sioli, H. (1984). The Amazon and its main effluents: 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*. Monographiae biologicae. v. 56. Dr W. Junk Publishers. Dordrecht., p. 127-165.

Spaulding, S., Edlund, M. & Metzeltin, D. (2008) *Planothidium*. *In:* Diatoms of North America. Available from: https://diatoms.org/genera/planothidium (access: 21 April 2020).

Stancheva, R. (2019) *Planothidium sheathii*, a new monoraphid diatom species from rivers in California, USA. *Phytotaxa* 393 (2): 131-140. https://doi.org/10.11646/phytotaxa.393.2.4

Tudesque, L., Le Cohu, R., Coste, M. & Lange-Bertalot, H. (2015) *Lacuneolimna* gen. nov., *Lacuneolimna zalokariae* comb. nov. and *Lacuneolimna novagallia* spec. nov. (Bacillariophyceae) from the French Guiana diatom freshwater flora. *Phytotaxa* 231 (1): 19-30. https://doi.org/10.11646/phytotaxa.231.1.2

van de Vijver, B. & Bosak, S. (2019) *Planothidium kaetherobertianum*, a new marine diatom (Bacillariophyta) species from the Adriatic Sea. *Phytotaxa* 425 (2): 105-112. https://doi.org/10.11646/phytotaxa.425.2.5

van de Vijver, B., Wetzel, C.E., & Ector, L. (2018). Analysis of the type material of *Planothidium delicatulum* (Bacillariophyta) with the description of two new *Planothidium* species from the sub-Antarctic Region. *Fottea* 18 (2): 200-211. https://doi.org/10.5507/fot.2018.006

van Heurck, H. (1885) *Synopsis des Diatomées de Belgique. Texte*. Martin Brouwers & Co., Anvers. 235 p.

Vyverman, W. & Compère, P. (1991) *Nupela giluwensis* gen & spec. nov. a new genus of naviculoid diatoms. Diatom Research 6 (1): 175-179.

Wetzel, C.E. (2011) *Biodiversidade e distribuição espacial de diatomáceas (Bacillariophyceae) na bacia hidrográfica do rio Negro, Amazonas, Brasil*. Tese de doutorado, Instituto de Botânica, São Paulo, p. 1-1876.

Wetzel, C.E. & Ector, L. (2014a) Taxonomy, distribution and autecology of *Planothidium bagualensis* sp. nov. (Bacillariophyta) a common monoraphid species from southern Brazilian rivers. *Phytotaxa* 156 (4): 201-210. https://doi.org/10.11646/phytotaxa.156.4.2

Wetzel, C.E. & Ector, L. (2014b) *Planothidium lagerheimii* comb. nov. (Bacillariophyta, Achnanthales) a forgotten diatom from South America. *Phytotaxa* 188 (5): 261-267. https://doi.org/10.11646/phytotaxa.188.5.3

Wetzel, C.E., Ector, L., Hoffmann, L., Lange-Bertalot, H. & Bicudo, D.C. (2011) Two new periphytic *Eunotia* species from the neotropical Amazonian 'black waters', with a type analysis of *E. braunii*. *Diatom Research* 26 (1): 135-146. https://doi.org/10.1080/0269249X.2011.587644

Wetzel, C.E., Lange-Bertalot, H., Morales, E.A., Bicudo, D.C., Hoffmann, L. & Ector, L. (2012a) *Bicudoa amazonica* gen. nov. et sp. nov. (Bacillariophyta): a new freshwater diatom from the Amazon basin with a complete raphe loss in the Eunotioid lineage. *Phytotaxa* 75: 1-18. https://doi.org/10.11646/phytotaxa.75.1.1

Wetzel, C.E., van de Vijver, B., Blanco, S. & Ector, L. (2019) On some common and new cavum-bearing *Planothidium* (Bacillariophyta) species from freshwater. *Fottea* 19 (1): 50-89. https://dx.doi.org/10.5507/fot.2018.016

Wetzel, C.E., van de Vijver, B., Cox, E.J., Bicudo, D.C. & Ector, L. (2012b) *Tursiocola podocnemicola* sp. nov., a new epizoic freshwater diatom species from the Rio Negro in the Brazilian Amazon Basin. *Diatom Research* 27 (1): 1-8. https://doi.org/10.1080/0269249X.2011.642498

Wetzel, C.E., van de Vijver, B. & Ector, L. (2010) *Luticola deniseae* sp. nov. a new epizoic diatom from the Rio Negro (Amazon hydrographic basin). *Vie et Milieu-Life and Environment* 60 (3): 177-184.

Wetzel, C.E., van de Vijver, B., Hoffmann, L. & Ector, L. (2013) *Planothidium incuriatum sp. nov*. a widely distributed diatom species (Bacillariophyta) and type analysis of *Planothidium biporomum*. *Phytotaxa* 138 (1): 43-57. https://dx.doi.org/10.11646/phytotaxa.138.1.6

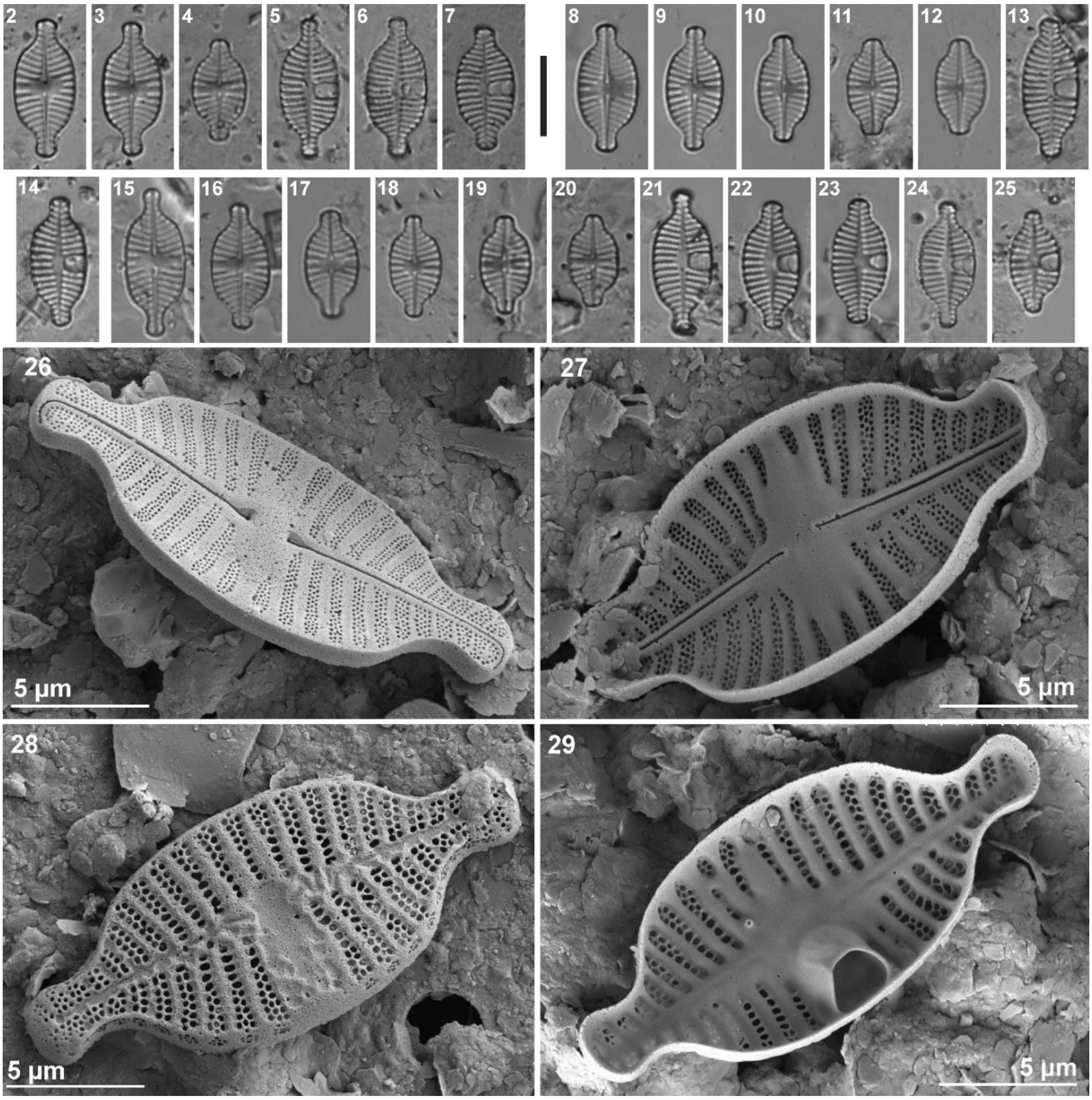
Williams, D.M. & Round, F.E. (1987) Revision of the genus *Fragilaria*. *Diatom Research* 2 (2): 267-288. https://doi.org/10.1080/0269249X.1987.9705004

Williams, D.M. & Round, F.E. (1988) *Fragilariforma*, nom. nov., a new generic name for *Neofragilaria* Williams & Round. *Diatom Research* 3 (2): 265-267.

TABLE 1. Morphological features and metrical variations of *Planothidium xinguensis* sp. nov. and other similar *Planothidium* taxa. Nd: no data.

	***Planothidium xinguensis* sp. nov.**	***P. rostratum***	***P. rostratoholarcticum***	***P. piaficum***	***P. brasiliense***
References	This study	Wetzel *et al*. (2019: figs 11–61)	Bąk & Lange-Bertalot (2014: figs 8a–s)	N’Guessan *et al*. (2014: figs 3a–g)	Wetzel *et al*. (2019: figs 211–217)
Valve outline	Elliptical, asymmetrical	Elliptical	Elliptical	Elliptic, lanceolate to oval	Lanceolate, elliptic-lanceolate
Apices	Short to long rostrate	Short to long rostrate	Short, protracted, subrostrate than rostrate	Protracted to capitate	Rostrate
Length (µm)	12–14	6.5–15.0	8–12	12–20*	20–28
Width (µm)	6.7–8.2	4.0–6.5	4.5–5.5	6–8*	7.0–8.0
Raphe valve (RV)					
Axial area	Narrow, linear	Narrow, linear, widening towards the central area	Narrow, linear*	Narrow, linear	Narrow, linear
Central area	Irregular, rectangular to slightly rounded	Rectangular to slightly round	Irregular*	Rectangular	Rectangular
Striae near to central area	2–3 shortened striae on each side	2–3 shortened striae on each side	1–2 shortened striae on each side*	1–2 shortened striae on each side	2–3 shortened striae on each side
Raphe	Straight	Straight	Straight*	Straight	Straight
Raphe endings					
Proximal ends	Expanded, drop-like	Expanded, drop-like	Expanded, drop-like*	Expanded, drop-like	Straight
Distal ends	Deflected, unilateral	Deflected, unilateral	Nd	Nd	Nd
Striae	Strongly radiate throughout the valve	Radiate throughout the valve	Radiate*	Radiate	Weakly radiate throughout the entire valve
Density in 10 µm	12–14	12–16	14–18	12*	Nd
Rapheless Valve (SV)					
Axial area	Narrow, linear, expanded in the central area opposite to the cavum	Narrow, straight, linear	Narrow, straight*	Narrow, straight	Narrow, linear, expanded in the central area opposite to the cavum
Central area	Unilateral, large horseshoe-shaped	Unilateral, large horseshoe-shaped	Unilateral, large horseshoe-shaped*	Unilateral, horseshoe-shaped	Unilateral, large horseshoe-shaped
Horseshoe-shaped	Cavum	Cavum	Cavum*	Cavum	Cavum
Striae opposite the cavum	Striae lightly shortened in axial area	Reaching the axial area	Reaching the axial area*	Shortened in axial area	Nd
Striae	Radiate, more strongly radiate towards the apices	Weakly radiate throughout the valve	Radiate towards the apices*	Parallel to radiate	Weakly radiate throughout the entire valve
Density in 10 µm	12–14	12–14	Nd	12–15*	15–17

*Personal information taken for population of the study cited



FIGURES 2-29. *Planothidium xinguensis* K.S.Morais, C.E.Wezel & C.E.M.Bicudo, sp. nov., LM images: Figs 2-4, 8-12, 15-20. Raphe valve. Figs 5-7, 13-14, 21-25. Rapheless valve. SEM images: Fig. 26. External view of raphe valve. Fig. 27. Internal view of raphe valve. Fig. 28. External view of rapheless valve. Fig. 29. Internal view of rapheless valve. LM scales: 10 µm.

Capítulo 4

Psammothidium sp. nov. (Achnanthidiaceae, Bacillariophyta) a subfossil diatom from Xingu River, Amazon Basin

Krysna S. Morais, Lívia F. Costa, Carlos E. de M. Bicudo and Carlos E. Wetzel

ABSTRACT

An unknown species of *Psammothidium* (Achnanthidiaceae) was found in core sediments (~4,000 yr BP) collected from Xingu *Ria*, located in eastern Amazon Basin. *Psammothidium* sp. nov. is mainly characterized by small valve dimensions, an irregular and expanded central area in SV clearly visible in LM. Under SEM observations, the new species has radiate striae with rectangular to rounded areolae present both on the surface and the valve mantle. The species description is based on light (LM) and scanning electron microscopy (SEM). Moreover, morphology the new species are compared with those already described for the genus. Information of core chronology and the co-occurrence of other diatom species in the sample are also provided.

Keywords: Amazon basin; biodiversity; diatoms; new taxa; paleolimnology; *ria* sediments

INTRODUCTION

The genus *Psammothidium* was proposed by Bukhtiyarova and Round (1996) to accommodate different *Achnanthes* Bory (1822) species found in epipsammic samples from British rivers. According to the original description, *Psammothidium* is mainly characterized by their heterovalvar frustule with convex raphe valve (RV), valves oval to elliptic or slightly capitate in shape; striae reaching the sternum and the raphe fissures lying in a channel (Bukhtiyarova and Round 1996). Moreover, members of this genus also present a rectangular central area on the RV and more expanded on the rapheless valve (SV). The areolae arrangement also differs as well as the terminal raphe fissures (Bukhtiyarova and Round 1996, Spaulding and Edlund 2008, Liu et al. 2014, Blanco et al. 2017).

Currently, *Psammothidium* comprises around 80 species (Kociolek et al. 2020), commonly found in lentic to lotic ecosystems, usually abundant in periphyton, living attached to the substrate (e.g. sand, rocks, moss and others) by the raphe valve face (Wojtal 2004, Enache et al. 2013, Blanco et al. 2017). Moreover, this genus is often reported in lake sediments, being, therefore, important to paleolimnological investigations (Enache et al. 2013, Blanco et al. 2017, Potapova 2018).

In the last decade, *Psammothidium* has experienced an increase number of new records (e.g. Bukhtiyarova and Stanislavskaya 2013, Potapova 2012, 2014, 2018, Liu et al. 2014, Kopalová, Zidarova and van de Vijver 2016, van de Vijver, Kopalová and Zidarova 2016, Blanco et al. 2017, van de Vijver 2019). However, the knowledge and distribution of *Psammothidium* in tropical and subtropical regions still remain underestimated. For Brazil, for instance, only two species were reported, a very small number considering the large brazilian territorial area and the rich aquatic diversity. Regarding species, *Psammothidium subtamoides* (Hustedt) Bukhtiyarova and Round (1996) is the most registered species (Schneck, Torgan and Schwarzbold, 2007, 2008) although sometimes just listed with no illustration (e.g. Santos, Tremarin and Ludwig 2011). Additional records includes *Psammothidium hustedtii* (Krasske) S.Mayama (2002), mentioned as *Coconeis hustedtii* Krasske (1923) in Moro and Furstenberger (1993) and Calegaro, Silva and Salomoni (1993). However, the above authors did not include ultrastructural details of the material studied. Moreover, it is important to note that all these records referred to lentic and lotic systems from the southern region of the country and until the present study, no *Psammothidium* specimens were mentioned for the Brazilian Amazon basin.

As part of a diatom survey in sediment samples from Xingu River, an unknown *Psammothidium* taxon was found and it is proposed as a new species: *Psammothidium elnatanii* sp. nov. Based on observations made by using light (LM) and scanning electron microscopy (SEM) the new species is described and compared with morphologically similar taxa.

MATERIAL AND METHODS

Study area

Xingu is a clearwater river located in the eastern Brazilian Amazonia. Its covers an area of about 500,000 km^2, being the 3th largest tributary of Amazon River (Dias et al. 2005, Sawakuchi et al. 2015). Xingu originates in Mato Grosso state and flows under neutral to slightly alkaline waters with low concentration of sediments to the Amazon River in Pará state (Sioli 1984, 1950, Sawakuchi et al. 2015). Near to the confluence of Amazon River, Xingu shifts to a lowland river with elevations between 5-20 m, and shows a sedimentary dynamic similar to lakes and reservoirs, known as *rias*-lake or *Paleorias* (Dean and Gorham 1998, Bertassoli et al. 2017). *Rias* are relict of river systems (Irion et al. 2010) that occupy the lower sections or rivers and creeks, and connect (entirely or not) all their tributaries to the Amazon system (Bertani et al. 2014, Bertassoli et al. 2017). Moreover, *rias*-lake accumulate fine-grained sediments, playing an important role as sink or source of carbon (Sawakuchi et al. 2015, Bertassoli et al. 2017).

Sampling and sample treatment

We investigated a 362 cm long-core of Xingu *Ria* (01°42’32.12”S, 52°16’47.42”W), close to the confluence of the Amazon River. The sediment core named XC-03 was retrieved by divers with a 6 m long PVC tube. After sampling, the XC-03 core was sealed and transported to the Geosciences Institute of the São Paulo University (IGC-USP) where it was stored until subsampling.

The core chronology was determined by analyses of radiocarbon (^{14}C) dating as detailed by Bertassoli et al. (2019). Based on the Age Model, the period between the base and the top of XC-03 corresponds to about ~4,000 cal yr. BP to 300 cal yr. BP respectively, what corresponds on the time scale, the Meghalayan Age (see Bertassoli et al. 2019 for more details).

Diatom samples were digested with concentrated 35% H_2O_2 (hydrogen peroxide) and 37% HCl (hydrochloric acid) following the standard procedures of the European Committee for Standardization (2003). Oxidized subsamples were rinsed with deionized water and permanent slides were mounted with Naphrax mounting medium (R.I. = 1.6). Optical microscopy analysis and counting were processed at a magnification of 1,000x using a light microscope Zeiss Axio Imager A2 equipped with Differential Interference Contrast (DIC) and Axiocam ERc5s high-resolution digital camera. At least 400 valves per slide were counted along a defined transect (Battarbee et al. 2001) or until reaching a 90% efficiency, according to Pappas and Stoermer (1996).

For scanning electron microscopy (SEM) analysis, small aliquots of oxidized samples were filtered through a polycarbonate membrane filter (3 µm mesh) and washed with deionized water. Filters were mounted on aluminum stubs and coated with platinum. SEM images were taken with a Hitachi SU-70 equipment operated at 5 kV and 10 mm working distance. Plates containing LM and SEM images were prepared using CorelDraw X8.

Morphological terminology followed Barber and Haworth (1981) and Buhktiyarova and Round (1996) respectively, for valve features and genus morphology, and Round, Crawford and Mann (1990) for ultrastructure and SEM. Moreover, the new taxon was morphologically compared with other *Psammothidium* species (Buktiyarova and Round 1996, Lange-Bertalot 1999, Manaylov 2007, Potapova 2012, Enache et al. 2013 and Blanco et al. 2017). The Holotype slide was deposited in the Herbário Científico do Estado “Maria Eneyda P. Kauffmann Fidalgo” of the Instituto de Botânica, São Paulo, Brazil (SP) and an isotype slide was deposited in the Botanic Garden Meise, Belgium (BR).

RESULTS AND DISCUSSION

Psammothidium **sp. K.S.Morais, L.F.Costa & C.E.Wetzel, sp. nov.** (Figures 2-37 LM; 38-41 SEM)

Description

LM observations (Figures 2-37). Valves small, elliptical to linear-elliptical with rounded apices. Valve dimensions: length 9.6-10.2 µm, width 4.6-5.2 µm. Raphe valve (Figures 2-8; 19-24; 31-33): axial area narrow, linear near the apices and gradually widening towards the central area. Central area irregular, assuming a rectangular shape. Raphe straight. Proximal raphe endings terminating slightly enlarged. Distal raphe endings not discernible in LM. Rapheless valve (Figures 9-18; 25-30; 34-37): axial area linear, narrow near the apices and distinctly widening towards the central area. Central area asymmetrical with an expanded area on side, the opposite side smaller and straight. Striae are not discernible in both valves.

SEM observations (Figures 38-41). Raphe valve (Figures 38 and 39): axial area narrow, widening towards the central area. Central area large, bow-tie-shaped expanding to the margin. Striae are uniseriate, radiating and spaced throughout the entire valve, 28-35 in 10 µm. Areolae foramina small, rectangular to rounded shape. A row of rounded areolae presents on the mantle near to the apices (Figure 38, arrow). Raphe straight, filiform. Proximal raphe endings straight slightly expanded. Distal raphe endings elongated, hooked to the same side, extending onto the mantle (Figure 38). Internally, the central area is heavily raised and silicified. Proximal raphe endings short, bent into opposite directions (Figure 39). Rapheless valve (Figures 40 and 41): axial area is linear, narrow, slightly depressed, forming a weak pseudoraphe (Figure 40, arrow). Central area assymetrical, expanded towards the margins, with one side larger than other (Figure 40). Striae uniseriate, radiate and spaced, 37-40 in 10 µm. Areolae foramina small, rectangular to rounded. A row of silt-like areolae is present on the valve mantle (Figure 40, arrow). Internally, the central area is slightly raised (Figure 41). Virgae slightly raised.

Type

Holotype. Slide SP513.832, Herbário Científico do Estado Maria Eneyda P. Kauffmann Fidalgo (SP), Instituto de Botânica, São Paulo, Brazil.

Isotype. Slide no. BR-4603, Botanic Garden Meise (BR), Belgium.

Type locality

Brazil, Pará, Porto de Moz, Xingu River, 01º42’32.12”S, 52º16’47.42”W. Collected from sediment core XC-03 by A.O. Sawakuchi et al. 2014.

Distribution and associated diatom flora

Psammothidium sp. nov. was present in reasonable abundance (2-6.3%) in the bottom sediments, mainly between 348-170 cm (ca. 4,000-2,040 cal yr BP, respectively). Then, it returned to show higher values (6%) around 1870 yr BP (148 cm). After that, it did not display values above 2% towards the top sediments. During the present observation, the high values of *P. elnatanii* coincided with decreasing water discharge observed in Xingu *Ria*, during 2,600-1,400 yr BP as observed by Bertassoli et al. (2019).

Diatom assemblage in this period was composed by centric and monoraphid taxa, such as: *Aulacoseira granulata* (Ehrenberg) Simonsen (1979), *Aulacoseira ambigua* (Grunow) Simonsen (1979), *Aulacoseira granulata* var. *australiensis* (Grunow) Moro (1991), *Gogorevia exilis* (Kutzing) Kulikovskiy and Kociolek (2020), *Staurosirella crassa* (Metzeltin and Lange-Bertalot) F.C.P.Ribeiro and Torgan (2010), *Staurosirella subcapitata* (Frenguelli) E.A.Morales (2006) and *Staurosirella* sp., *Pseudostaurosira* sp. and *Coconeis* sp.

Taxonomic remarks

Psammothidium sp. nov. is quite similar to *Psammothidium lauenburgianum* (Hustedt) Bukhtiyarova and Round (1996) in the valve outline. However, the new species has comparatively longer and slightly narrower valves (L: 9.6-10.2 µm, W: 4.6-5.2 µm) when compared to *P. lauenburgianum* (L: 1-4.5 µm, W: 3-6 µm). Other important difference lies in the shape of the central area in SV: *P. elnatanii* has an irregular, expanded central area with one side larger than the other, whereas *P. lauenburgianum* has a one side swelling, clearly visible in LM. Under SEM analysis, both species are completely different in the shape and size of areolae, since they are small and rectangular in *Psammothidium* sp. nov. and rounded in *P. lauenburgianum*. Furthermore, the latter has a row of slit-like areolae on the mantle, whereas *Psammothidium* sp. nov. has a row of small and rounded areolae in RV and slit-like areolae in SV. The new species can also differentiate by the raphe fissures, straight and slightly expanded near to the central area, and hooked, deflected to the same side near to the apices.

Psammothidium sp. nov. also can be compared to *Psammothidium daonense* (Lange-Bertalot) Lange-Bertalot (1999), *P. childanos* (M.H.Hohn and Hellerman) Lange-Bertalot (1999), *P. marginulatum* Buhktiyarova and Round (1999), *P. alpinum* M.Potapova and M.D.Enache (2013), and *P. nivale* M.Potapova and M.D.Enache (2013), since they all also exhibit elliptical to linear valves. However, *Psammothidium* sp. nov. has smaller dimensions when compared to all previously mentioned species (see Table 1).

Regarding to the shape of central area on the raphe valve, *Psammothidium* sp. nov. differs from *P. daonense* by the small and rectangular shape whereas the latter has a rectangular and expanded, bordered by 1-4 short striae on each side (Table 1). The same morphological features are also observed in *P. marginulatum*, although the latter presents a greater number of striae at the margins (approximately 8–11 striae). *Psammothidium childanos* also resembles *Psammothidium* sp. nov. in the shape of the central area, but differs by an elliptical to rectangular central area in SV, different from that of *Psammothidium* sp. nov. that has an irregular and expanded shape.

Smaller representatives of *Psammothidium alpinum and P. nivale*, species found in sediment samples from Cascade Mountains (USA), resembles *Psammothidium* sp. nov. However, the latter has radiate striae with greater density (S: 28-35 in 10 µm). Moreover, both *P. alpinum* and *P. nivale* have coarse areolae, visible in LM. In SEM observations, it is possible to notice some other distinct features as the shape and size of areolae as well as its organization on the valve mantle: *Psammothidium* sp. nov. has a row of small and rounded areolae in RV while *P. alpinum* displays a double row of areolae (see Enache et al. 2013, figures 40 and 41). Already in SV, *P. nivale* shows a more elongate slits than those observed on the mantle of the new species (Figure 39, arrow).

The length ranges of *P. toroi* Blanco, Pla-Rabes, Wetzel and Granados (2017) overlap with *Psammothidium* sp. nov. (Table 1). Moreover, both species also share similarities in the valve outline and striae arrangement. However, *P. toroi* has a valve slightly smaller (L: 5.3-10.1 µm) than the new species. Also, the *P. toroi* displays a distinctive central area in both valves; and its striae are clearly visible in LM. Finally, *P. pennsylvanicum* Potapova (2012) also has metric features that overlap with *Psammothidium* sp. nov., although the former has specimens slightly larger (L: 9-13 µm; W: 5-5.4 µm). Another morphological features that differ both species are present in the arrangement and density of striae: radiate and denser in *Psammothidium* sp. nov. (28-35 striae in 10 µm).

FINAL REMARKS

We currently highlight the importance of a precise analysis of the genus, since they have small valve dimensions and a great morphologic variability within species (Wojtal 2004, Blanco et al. 2017). Moreover, the SEM analysis is indispensable, since the shape of areolae and raphe fissures are also variable, as pointed by Bukhtiyarova and Round (1996).

Despite the increasing number of floristic studies (Ferrari et al. 2007, Melo, Torgan and Raupp 2010, Pereira, Torgan and Melo 2012), new records (Burliga, Torgan and Beaumord 2007,Wetzel, Van de Vijver and Ector 2010, Wetzel et al. 2010a,b, 2012a, Burliga and Kociolek 2010, 2012, Pereira et al. 2014, 2015, Almeida et al. 2018) and even new diatom genera descriptions (Wetzel et al. 2012b, Burliga et al. 2013, Wetzel and Kociolek 2018) for the Brazilian Amazon basin, few publications are directed to monoraphid taxa (e.g. Metzeltin and Lange-Bertalot 1998, Tudesque et al. 2016), making their knowledge, distribution and ecology poorly known in this region. Therefore, the description of *Psammothidium* sp. nov. emphasizes the importance of a detailed investigation of these taxa, especially in Amazonia *rias*.

Finally, the present study also highlights the importance of a precise taxonomy in paleoenvironmental studies, aiming to find new potential indicators and improve the accuracy of ecological diagnostic tools.

REFERENCES

Almeida, C.A., A.C. Coutinho, J.C. D.M. Esquerdo, M. Adami, A. Venturini, C.G. Diniz, N. Dessay, L. Dirieux, and A.R. Gomes. 2016. High spatial resolution land use and land cover mapping of the Brazilian Legal Amazon in 2008 using Landsat-5/TM and MODIS data. *Acta Amazonica* 46 (3): 291-302. doi:10.1590/1809-4392201505504

Almeida, F.F., E.N. Santos-Silva, L. Ector, and C.E. Wetzel. 2018. *Eunotia amazonica* sp. nov. (Bacillariophyta) a common stalk-forming species from the Rio Negro basin (Brazilian Amazon). *European Journal of Phycology* 53 (2): 166-179. doi:10.1080/09670262.2017.1402372

Barber, H.G., and E.Y. Haworth. 1981. *Guide to the morphology of diatom frustule*. Freshwater Biological Association.

Battarbee, R.W., V. Jones, R.J. Flower, N. Cameron, H. Bennion, L. Carvalho, and S. Juggins. 2001. Diatoms. *In*: Smol, J.P, Birks, H.J.B. & Last, W.M. (eds), *Tracking environmental change using lake sediments.*

Bertani, T. C., D. F. Rossetti, E. H. Hayakawa and M. C. L. Cohen. 2014. Understanding Amazonian fluvial rias based on a Late Pleistocene-Holocene analog. *Earth Surface Processes and Landforms* 40 (3): 285-292. doi:10.1002/esp.3629

Bertassoli Jr., D.J., A.O. Sawakuchi, C.M. Chiessi, E. Schefuß, G.A. Hartmann and C. Häggi. 2019. Spatiotemporal variations of riverine discharge within the Amazon basin during the late Holocene coincide with extratropical temperatures anomalies. *Geophysical Research Letters* 46. doi:10.1029/2019GL082936.

Bertassoli Jr., D.J., A.O. Sawakuchi, H.O. Sawakuchi, F.N. Pupim, G.A. Hartmann, M.M McGlue, C.M. Chiessi, M. Zabel, E. Schefuß, T.S. Pereira, R.A. Santos, S.B. Faustino, P.E. Oliveira, and D.C. Bicudo. 2017. The fate of Carbon in sediments of the Xingu and Tapajós clearwater rivers, Eastern Amazon. *Frontiers in Marine Science* 44 (4): 1-14. doi:10.3389/fmars.2017.00044

Blanco, S., S. Plá-Rabés, C.E. Wetzel, and I. Granados. 2017. A new *Psammothidium* species (Bacillariophyta, Achnanthidiaceae) from Cimera Lake (Gredos Mountain Range), Central spain. *Cryptogamie, Algologie* 38 (1): 17-29. doi:0.7872/crya/v38.iss1.2017.17

Bory de Saint-Vincent, J.B.G.M. 1822. *Achnanthes*. *Dictionnaire Classique d'Histoire Naturelle* 1: 79-80.

Bukhtiyarova, L., and F.E. Round. 1996. Revision of the genus *Achnanthes* sensu lato. *Psammothidium*, a new genus based on *A. Marginulatum*. *Diatom Research* 11 (1): 1-30. doi: 10.1080/0269249X.1996.9705361

Bukhtiyarova, L., and E.V. Stanislavskaya. 2013. *Psammothidium vernadskyi* sp. nov. (Bacillariophyta) from the Blue lake, East Siberia, Russia. *Algologia* 23 (1): 96-107. doi:10.15407/alg23.01.096

Burliga, A.L., and J.P. Kociolek. 2010. *Kobayasiella* species from Carajás National Forest, Amazonia, Brazil. *Diatom Research* 25 (2): 235-250. doi:10.1080/0269249X.2010.9705848

Burliga, A.L., and J.P. Kociolek. 2012. Four new *Eunotia* Ehrenberg species (Bacillariophyceae) from pristine regions of Carajás National Forest, Amazonia, Brazil. *Nova Hedwigia* 141: 53-70.

Burliga, A.L., J.P. Kociolek, S.E. Salomoni, and D. Figueiredo. 2013. A new genus and species in the diatom family Eunotiaceae Kützing (Bacillariophyceae) from the Amazonian hydrographic region, Brazil. *Phytotaxa* 79 (2): 47-57. doi:10.11646/phytotaxa.79.2.1

Burliga, A.L., L.C. Torgan, and A.C. Beaumord. 2007. *Eunotia ariengae* sp. nov., an epilithic diatom from Brazilian Amazon. *Diatom Research* 22 (2): 247-253. doi:10.1080/0269249X.2007.9705714

Callegaro, V.L.M., K.R.L.M. Silva, and S.E. Salomoni. 1993. Flórula diatomológica de ambientes lênticos e lóticos do Parque Florestal Estadual do Turvo, Rio Grande do Sul, Brasil. *Iheringia* (43): 89-134.

Dean, W.E., and E. Gorham. 1998. Magnitude and significance of carbon burial in lakes, reservoirs, and peatlands. *Geology* 26: 535-538. doi:10.1130/0091-7613(1998)026<0535:MASOCB>2.3.CO;2

Dias, L.P.C., M.N. Macedo, M.H. Costa, M.T. Coe, and C. Neill. 2015. Effects of land cover change on evapotranspiration and streamflow of small catchments in the Upper Xingu River Basin, Central Brazil. *Journal of Hydrology* 4: 108-122. doi:10.1016/j.ejrh.2015.05.010

Enache, M.D., M. Potapova, R. Sheibley, and P. Moran. 2013. Three new *Psammothidium* species from Lakes of Olympic and Cascade Mountains in Washington State, USA. *Phytotaxa* 127 (1): 49-57. doi:10.11646/phytotaxa.127.1.8

European Committee for Standardization (ECS). 2003. “Water Quality– Guidance Standard for the Routine Sampling and Pretreatment of Benthic Diatoms from Rivers”. *British Standard*. http://www.safrass.com/partnears_area/BSI%20Benthic%20diatoms.pdf

Ferrari, F., L.K. Procopiak, Y.B. Alencar and T.A.V. Ludwig. 2007. Eunotiaceae (Bacillariophyceae) from central Amazon rivers, Manaus and Presidente Figueiredo districts, Brasil. *Acta Amazonica* 37 (1): 1-16. doi:10.1590/S0044-59672007000100001

Heudre, D., C.E. Wetzel, L. Moreau and L. Ector. 2017. Diatoms of Gérardmer lake (Vosges, France). *Nova Hedwigia* 146: 253-277. doi: 10.1127/1438-9134/2017/253

Irion, G., J.A.S.N. de Mello, J. Morais, M.T.F. Piedade, W.J. Junk, and L. Garming. 2010. Development of the Amazon Valley during the Middle to Late Holocene Quaternary: Sedimentological and Climatological Observations. *In*: Junk, W., Piedade, M., Wittmann, F., Schöngart, J., Parolin, P. (eds), Amazonian Floodplain Forests. Ecological Studies (Analysis and Synthesis), vol. 210. Springer, Dordrecht. doi: 10.1007/978-90-481-8725-6_2

Kociolek, J.P., S. Blanco, M. Coste, L. Ector, Y. Liu, B. Karthick, M. Kulikovskiy, N. Lundholm, T. Ludwig, M. Potapova, F. Rimet, K. Sabbe, S. Sala, E. Sar, J. Taylor, B. van de Vijver, C.E. Wetzel, D.M. Williams, A. Witkowski, J. Witkowski. 2020. DiatomBase. *Psammothidium* L. Bukhtiyarova and F. E. Round 1996. 28 September. http://diatombase.org/aphia.php?p=taxdetails&id=574026

Kopalová, K., J. Veselá, J. Elster, L. Nedbalová, J. Komárek, and B. van de Vijver. 2012. Benthic diatoms (Bacillariophyta) from seepages and streams on James Ross Island (NW Weddell Sea, Antarctica). *Plant Ecology and Evolution* 145 (2): 190-208. doi:10.5091/placevo.2012.639

Kopalová, K., R. Zidarova, and B. van de Vijver. 2016. Four new monoraphid diatom species (Bacillariophyta, Achnanthaceae) from the Marine Antarctic Region. *European Journal of Taxonomy* 217: 1-19. doi:10.5852/ejt.2016.217.

Krasske, G. 1923. Die Diatomeen des Casseler Beckens und seiner Randgebirge nebst einigen wichtigen Funden aus Niederhessen. Botanisches Archv 3: 185-209.

Kulikovskiy, M., Y. Maltsev, A. Glushchenko, I. Kuznetsova, D. Kapustin, E. Gusev, H. Lange-Bertalot, S. Genkal and J.P. Kociolek. 2020. *Gogorevia*, a new monoraphid diatom genus for *Achnanthes exigua* and allied taxa (Achnanthidiaceae) described on the basis of an integrated molecular and morphological approach. *Journal of Phycology*. doi:10.1111/jpy.13064.

Lange-Bertalot, H. 1999. Neue Kombinationen von Taxa aus *Achnanthes* Bory (sensu lato). *Iconografia Diatomologica* 6: 270-283.

Liu, Y., J.P. Kociolek, Q. Wang, X. Tan, and Y. Fan. 2014. Two new species of monoraphid diatom (Bacillariophyceae) from South of China. 2014. *Phytotaxa* 188 (1): 031-037. doi:10.11646/phytotaxa.188.1.4

Manoylov, K.M. 2007. On some *Psammothidium* species from rivers in the United States. *Diatom Research* 22 (2): 317-327. doi:10.1080/0269249X.2007.9705718

Mayama, S., M. Idei, K. Osada, and T. Nagumo. 2002. Nomenclatural changes for 20 diatom taxa occurring in Japan. *Diatom. The Japanese Journal of Diatomology* 18: 89-91. doi:10.11464/diatom1985.18.0_89

Melo, S., L.C. Torgan, and S.V. Raupp. 2010. *Actinella* species (Bacillariophyta) from Amazon black water floodplain lake (Amazonas-Brasil). *Acta Amazonica* 40 (2): 269-274. doi:10.1590/S0044-59672010000200004

Metzeltin, D. and H. Lange-Bertalot. 1998. Tropische Diatomeen in Südamerika, 1: 700 überwiegend wenig bekannte oder neue Taxa repräsentativ als Elemente der neotropischen Flora [Tropical diatoms of South America, 1: about 700 predominantly rarely known or new taxa representative of the neotropical flora]. *Iconographia Diatomologica* 5: 1-695.

Morales, E., and K.M. Manoylov. 2006. Morphological studies on selected taxa in the genus *Staurosirella* Williams et Round (Bacillariophyceae) from rivers in North America. *Diatom Research* 21 (2): 343-364. doi:10.1080/0269249X.2006.9705674

Moro, R.S. 1991. Morphology of *Aulacoseira granulata* (Ehrenberg) var. *australiensis* (Grunow) nov. comb. under light microscopy. *Arquivos de Biologia e Tecnologia* 34 (2): 353-359.

Moro, R.S., and C.B. Fürstenberger. 1993. “Diatomáceas (Bacillariophyceae) da Lagoa Dourada (Parque Estadual de Vila Velha), Paraná, Brasil.” *Acta Biológica Paranaense* 22 (1-4): 15-30. doi:10.5380/abpr.v22i0.718

Pappas, J.L., and E.F. Störmer. 1996. Quantitative method for determining a representative algal count. *Journal of Phycology* 32: 693-696. doi: 10.1111/j.0022-3646.1996. 00693.x

Pereira, A.C., L.C. Torgan, A.L. Burliga, J.P. Kociolek, C.E. Wetzel, L. Ector, and S. Melo. 2015. *Pinnularia caprichosa* sp. nov.: a diatom from a black water Brazilian Amazon system. *Phytotaxa* 239 (3): 280-286. doi:10.11646/phytotaxa.239.3.9

Pereira, A.C., L.C. Torgan and S. Melo. 2012. *Pinnularia* (Bacillariophyta) do curso inferior do rio Negro, Amazonas, Brasil: taxonomia e distribuição temporal. *Acta Amazonica* 42 (3): 305–314. doi:10.1590/S0044-59672012000300001

Pereira, A.C., L.C. Torgan, and S. Melo. 2014. Four new *Pinnularia* Ehrenberg (Bacillariophyta, Pinnulariaceae) species from Amazonian black water (Tupé Lake, Amazonas State, Brazil). *Phytotaxa* 158 (2): 154-168. doi:10.11646/phytotaxa.158.2.3

Potapova, M.G. 2012. New species and combination in monoraphid diatoms (family Achnanthidiaceae) from North America. *Diatom Research* 27 (1): 29-42. doi: 10.1080/0269249X.2011.644636

Potapova, M.G. 2014. Diatoms of Bering Island, Kamchatka, Russia. *Nova Hedwigia* 143: 63-102. doi:10.1127/1438-9134/2014/004

Potapova, M. 2018. New and rare *Psammothidium* species (Bacillariophyta, Achnanthidiaceae) from Northeastern Siberia. *Cryptogamie, Algologie* 39 (4): 465-479. doi: 10.7872/crya/v39.iss4.2018.465

Ribeiro, F.C. P., C.S.F. Senna and L. C. Torgan. 2010. The use of diatoms for paleohydrological and paleoenvironmental reconstruction of Itupanema Beach, Pará State, Amazon Region, during the last millennium. *Revista Brasileira de Paleontologia* 13 (1): 21-32. doi: 10.4072/rbp.2010.1.03

Round, F.E., R.M. Crawford, and D.G. Mann. 1990. *The Diatoms: Biology and Morphology of the Genera*. Cambridge: Cambridge University Press.

Sabbe, K., E. Verleyen, D.A. Hodgson, K. Vanhoutte, and W. Vyverman. 2003. Benthic diatom flora of freshwater and saline lakes in the Lasermann Hills and Rauer Islands. *Antartic Science* 15 (2): 227-248. doi:10.1017/S095410200300124X

Santos, E.M., P.I. Tremarin, and T.A.V. Ludwig. 2011. Diatomáceas perifíticas em *Potamogeton polygonus* Cham. & Schltdl.: citações pioneiras para o estado do Paraná. *Biota Neotropica* 11 (3): 304-315. doi: 10.1590/S1676-06032011000300025

Sawakuchi, A.O., G.A. Hartmann, H.O. Sawakuchi, F.N. Pupim, D.J. Bertassoli, M. Parra, J.L. Antinao, L.M. Sousa, M.H.S. Pérez, P.E. Oliveira, R.A. Santos, J.F. Savian, C.H. Grohmann, V.B. Medeiros, M.M. McGlue, D.C. Bicudo, and S.B. Faustino. 2015. The Volta Grande do Xingu: reconstruction of past environments and forecasting of future scenarios of a unique Amazonian fluvial landscape. *Scientific Drilling* 3: 1-12. doi:10.5194/sd-20-21-2015

Schneck, F., L.C. Torgan and A. Schwarzbold. 2007. Epilithic diatom community in a high altitude stream impacted by fish farming in southern Brazil. *Acta Limnologica Brasiliensia* 19 (3): 341-355.

Schneck, F., L.C. Torgan and A. Schwarzbold. 2008. Diatomáceas epilíticas em riacho de altitude no sul do Brasil. *Rodriguésia* 59 (2): 325-338. doi:10.1590/2175-7860200859205

Simonsen, R. 1979. The diatoms systems: ideas on phylogeny. *Bacillaria* 2: 9-71.

Sioli, H. 1984. The Amazon and its main effluents: 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*. Monographiae biologicae. v. 56. Dr W. Junk Publishers. Dordrecht., p. 127-165.

Sioli, H. 1950. Das Wasser in Amazonasgebiet. *Fortschrift: ein Gedicht in fünfzehn Würfen* 26: 274-280.

Spaulding. S. and M. Edlund. 2008. *Psammothidium*. In "*Diatoms of North America*". 20 September. https://diatoms.org/genera/psammothidium

Tudesque, L., R. Le Cohu, and C.E. Wetzel. 2016. Two new *Platessa* (Bacillariophyceae) from Amazonia: *Platessa guianensis* spec. nov., and *P. itoupensis spec. nov*. *Phytotaxa* 267 (4): 237-255. doi:10.11646/phytotaxa.267.4.1

van de Vijver, B. 2019. Revision of the *Psammothidium manguinii* complex (Bacillariophyta) in the sub-Antarctic Region with the description of four new taxa. *Fottea* 19 (1): 90-106. doi:10.5507/fot.2019.001

van de Vijver, B., K. Kopalová, and R. Zidarova. 2016. Revision of the *Psammothidium germanii* complex (Bacillariophyta) in the Maritime Antarctic Region. *Fottea* 16 (2): 145-156. doi:10.5507/fot.2016.008.

Wetzel, C.E., B. van de Vijver, and L. Ector. 2010a. *Luticola deniseae* sp. nov. a new epizoic diatom from the Rio Negro (Amazon hydrographic basin). *Vie et Milieu* 60 (3): 177-184.

Wetzel, C.E., L. Ector, L. Hoffmann, and D.C. Bicudo. 2010b. Colonial planktonic *Eunotia* (Bacillariophyceae) from Brazilian Amazon: taxonomy and biogeographical considerations on the *E. asterionelloides* species complex. *Nova Hedwigia* 91 (1-2): 49-86. doi:10.1127/0029-5035/2010/0091-0049

Wetzel, C.E., and P. Kociolek. 2018. *Burliganiella* gen. nov. (Bacillariophyta, Eunotiales): another case of raphe reduction based on the type material of *Fragillaria sioli* Hustedt. *Cryptogamie, Algologie* 39 (2): 255-265. doi: 10.7872/crya/v39.iss2.2018.255

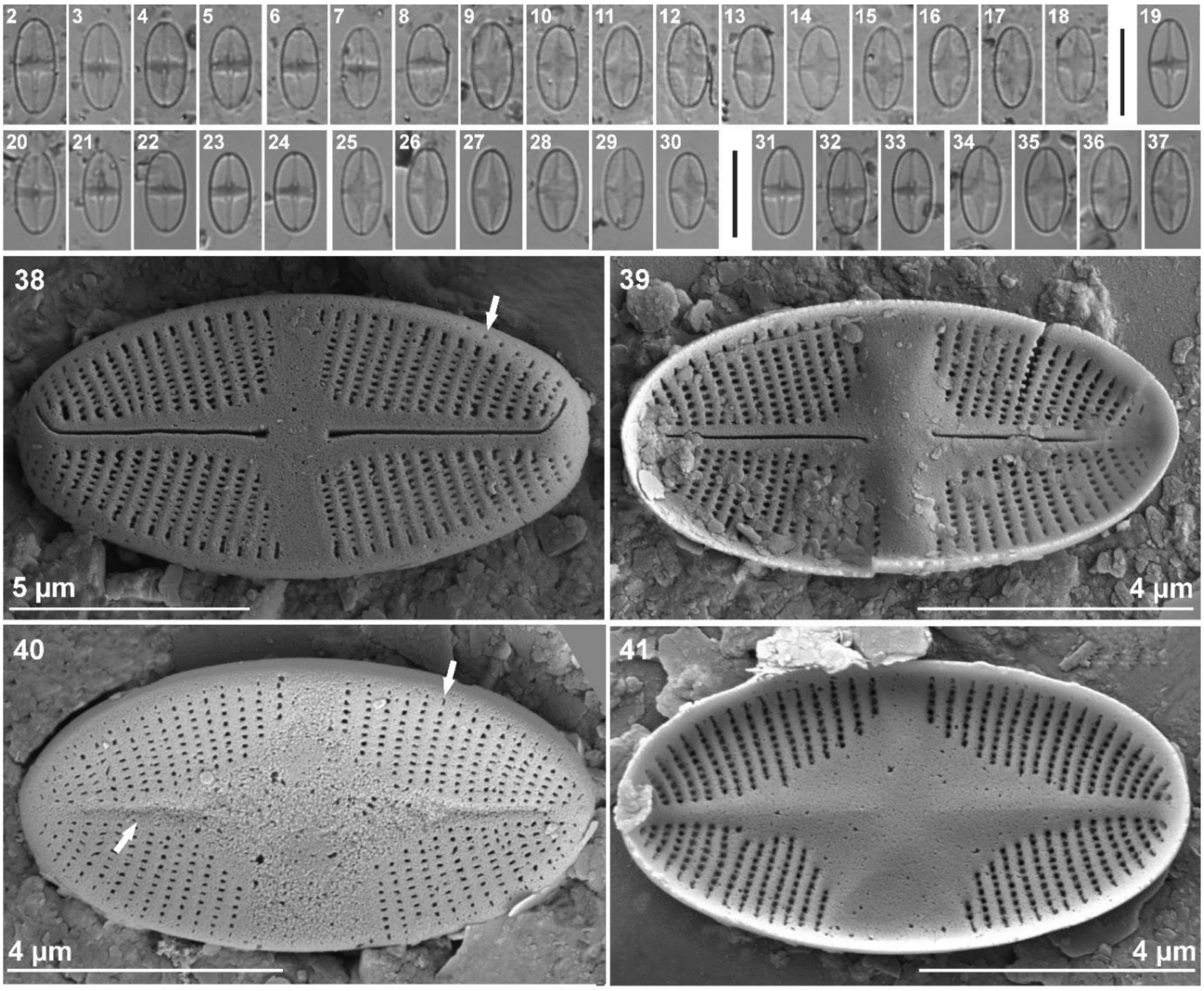
Wetzel, C.E., H. Lange-Bertalot, E.A. Morales, D.C. Bicudo, L. Hoffmann, and L. Ector. 2012a. *Bicudoa amazonica gen. nov. et sp. nov*. (Bacillariophyta): a new freshwater diatom from the Amazon basin with a complete raphe loss in the Eunotidioid lineage. *Phytotaxa* 75: 1-18. doi: 10.11646/phytotaxa.75.1.1

Wetzel, C.E., B. van de Vijver, E.J. Cox, D.C. Bicudo, and L. Ector. 2012b. *Tursicola podocnemicola* sp. nov., a new epizoic freshwater diatom species from the Rio Negro in the Brazilian Amazon Basin. *Diatom Research* 27 (1): 1-8. doi:10.1080/0269249X.2011.642498

Wojtal, A. 2004. New or rare species of the genera *Achnanthidium* and *Psammothidium* (Bacillariophyceae) in the diatom flora of Poland. *Polish Botanical Journal* 49 (2): 215-220.

Table 1. Comparison between *Psammothidium* sp. nov. and other similar *Psammothidium* taxa. Nd: no data

Species	Dimensions*	Valve outline	Striae	Density*	RV central area	SV central area	References
Psammothidium sp. nov.	L: 9.6-10.2 W: 4.6-5.2	Elliptical/linear-elliptical	Radiate	RV:28-35 SV:37-40	Rectangular	Assymetrical, expanded in one side	This study
P. alpinum	L: 14.6-30 W: 6.3-9.1	Linear-elliptic/ oval	Slightly radiate	22-25	Rectangular-irregular	Rounded, ½ of valve width	Enache et al. (2013)
P. nivale	L: 11.5-15 W: 5.6-6	Elliptical	Slightly radiate	RV: 30-32 SV: 26-32	Rectangular to oval	Rhombic-lanceolate, 2/3 of valve width	Enache et al. (2013)
P. childanos	L: 13-18 W: 5.2-6.2	Elliptical, parallel sides	Radiate, straight	27-33	Transversal rectangular	Elliptic, rectangular	Manoylov (2007)
P. daonense	L: 10-26 W: 5-8	Elliptical/linear elliptical	Radiate	27-32	Rectangular, expanded	Irregular, rhombic	Lange-Bertalot (1999)
P. lauenburgianum	L: 1-4.5 W: 3-6	Elliptical/linear elliptical	Radiate	24-28	Butterfly-shaped	Triangular, asymmetrical	Buhktiyarova and Round (1996)
P. marginulatum	L: 11-15 W: 5-6	Lanceolate/elliptical	Nd.	27-30	Rectangular	Nd.	Buhktiyarova and Round (1996)
P. pennsylvanicum	L: 9-13 W: 5-5.4	Elliptical	Uniseriate, slightly radiate	25-29	Rectangular or elliptical	Assymetrical, one side	Potapova (2012)
P. toroi	L: 5.3-10.1 W: 3.4-4.3	Linear-elliptic to broadly elliptic	Radiate, denser towards the apices	22-26	Irregular, oblong-elliptical/diamond shaped	Wide, 2/3 of valve width	Blanco et al. (2017)



Figures 2-41. *Psammothidium* sp. nov. K.S.Morais, L.F.Costa & C.E.Wetzel sp. nov. LM images: 2-8, 19-24, 31-33. Raphe valve. 9-18, 25-30, 34-37. SV. Rapheless valve. SEM images: 38. External view of raphe valve. 39. Internal view of raphe valve. 40. External view of rapheless valve. 41. Internal view of rapheless valve. LM scales: 10 µm

Considerações finais

A análise das diatomáceas associada à de outros traçadores ambientais (litologia, geoquímica orgânica e inorgânica e dados isotópicos) permitiu expandir o conhecimento sobre as principais mudanças ambientais ocorridas na *ria* do Xingu, Amazônia Oriental, durante a Idade Meghaliana (~4.000 cal anos BP). Em síntese, inferimos que:

- No início da Idade Meghalayana (346-206 cm; ~4.000-3.260 cal anos AP representado pela zona 1), diatomáceas bentônicas associadas aos materiais de *Aulacoseira* indicaram a existência de um sistema de águas rasas e abertas, contudo, fortemente instáveis e com elevado fluxo hidrológico.
- Entre 206-258 cm (~3.241-2.566 cal anos AP, representado pela zona 2), a comunidade de diatomáceas permaneceu a mesma, porém, houve um leve aumento de produtividade da *ria*, devido ao fato de que *Aulacoseira* apresentou quase que o dobro da abundância da fase anterior.
- O período de maior mudança ambiental foi observado entre 200-32 cm (~2.472-779 cal cal anos AP, caracterizando a zona 3). *Aulacoseira granulata* dominou quase que todo testemunho permitindo inferir que, durante este período, o Xingu *ria* apresentou um aumento em sua produtividade.
- A zona 4 (*30-0 cm*; ~744-298 cal cal anos AP) foi representada pelo retorno das condições anteriores. A presença de materiais bentônicos indicou águas rasas, abertas e fortemente instáveis.
- Em relação ao levantamento florístico das diatomáceas, 16 táxons entre espécies e variedade taxonômicas distribuídos em nove gêneros foram registrados no testemunho. Este levantamento complementou outros estudos já realizados no Xingu e contribuiu para ampliar e aprofundar o conhecimento da diatomoflórula de regiões ainda pouco estudadas. Além disso, forneceu base mais consistente para o melhor conhecimento das populações dessas algas em regiões tropicais.
- Entre as novas ocorrências, duas espécies foram identificadas como novas para a Ciência: *Planothidium xinguensis* e *Psammothidium* sp. nov. A descrição dessas duas espécies novas para o Xingu *ria* reforçou a importância de estudar detalhadamente esses compartimentos, uma vez que são potenciais indicadores ecológicos. Por fim, os presentes

resultados reforçam o papel da paleolimnologia como uma excelente ferramenta para avaliar a biodiversidade florística de ambientes até então pouco estudados.

ANEXOS

HOLOCENE DIATOMS FROM XINGU RIVER: NEW RECORDS FOR THE AMAZON AND BRAZIL

Samantha Borges Faustino (0000-0003-3531-2082)[1,3], Krysna S. de Morais (0000-0002-9745-015X)[1], Carlos Eduardo de Mattos Bicudo (0000-0003-4030-9961)[2] and Denise C. Bicudo (0000-0002-4248-3261)[2]

NOTA: Artigo aceito para publicação em 08 de setembro de 2020

ABSTRACT: (Holocene diatoms from Xingu River: new records for the Amazons and Brazil). Present study is the floristic survey and the distribution of diatoms observed in two sediment cores of the Xingu River, Pará State, north Brazil, and represents the past ~6,000 cal yr BP. Thirty-eight taxa distributed in twenty genera were recorded, among which five were new records for Brazil and nineteen new for the Brazilian Amazon. The most representative genus based on species number was *Gomphonema* Ehrenberg with six species. In brief, present new records represent a 75% increase in the total number of records for the Brazilian Amazons, and indicates that this region has not only been poorly investigated, but also suggests that its biodiversity assessment is underestimated. These findings highlight the efficacy of the paleolimnological approach as a tool for assessing biodiversity before the human impacts begin to affect the pristine conditions of the area.

Keywords: biodiversity, diatoms, core, floristic survey, paleolimnology

RESUMO: (Diatomáceas holocênicas do rio Xingu: novos registros para a Amazônia e o Brasil). O presente estudo visou ao levantamento florístico e à distribuição de diatomáceas obtidas de dois perfis sedimentares do rio Xingu, Pará, Brasil, e representa os últimos ~6.000 anos de idade. Trinta e oito táxons distribuídos em vinte gêneros foram documentados, entre os quais cinco são novos registros de ocorrência no Brasil e dezenove na Amazônia brasileira. *Gomphonema* Ehrenberg foi o gênero mais representado com seis espécies. Sintetizando, as novas ocorrências representam um aumento de 75% do número total de registros para a Amazônia brasileira e indicam que essa região ainda se encontra mal investigada, mas também sugere que a avaliação da biodiversidade está subestimada. Finalmente, os resultados destacam a utilidade da abordagem paleolimnológica como uma ferramenta de peso na avaliação da biodiversidade antes que os impactos humanos comecem a afetar as condições pristinas da área.

Palavras-chave: biodiversidade, diatomáceas, levantamento florístico, paleolimnologia, testemunho

INTRODUCTION

Holocene is the most recent interval of Earth history encompassing the present day. Together with the Pleistocene series it forms the Quaternary period, and possibly is the most intensively studied interval of recent geological time (Suguio 1999). Despite being a relatively short geological period, sedimentary evidence from the Holocene are sufficiently well preserved, thus enabling comparisons with data of the same nature in current processes (Walkers & Geissman 2009).

Paleolimnological studies have proved to be a valuable tool for the increase of environmental biodiversity and floristic changes reconstructions (*e.g.* Smol 2008, Bennion & Simpson 2011, Davidson & Jeppesen 2013, Wengrat *et al.* 2018). Moreover, past environmental communities are very often the only available source of information when researching biodiversity prior to human impacts (Smol 2002, Le Treut *et al.* 2007).

Diatoms have been widely used among the biological groups preserved in the sediments, because of their taxonomic distinction, abundance, preservation in the sediments, and rapid response to environmental changes (Reid 2005, Bennion & Simpson 2011). However, use of diatoms to indicate environmental changes requires high taxonomic precision (Birks 1994), since misidentifications may modify the interpretation in obtaining reliable data on modern diatom biodiversity (Buczko & Magyari 2007, Wetzel & Ector 2014).

In recent years, the number of studies for the Brazilian diatom flora showed a conspicuous increase (*e.g.* Souza & Senna 2009, Bertolli *et al.* 2010, Santos *et al.* 2011, Almeida & Bicudo 2014, Costa *et al.* 2017b, Bartozek *et al.* 2018). However, the increased number of newly described species in the Brazilian Amazon highlights the scant knowledge of diatoms for the region (Wetzel *et al.* 2010a, 2012a, Burliga *et al.* 2013, Tremarin *et al.* 2014, Pereira *et al.* 2014, 2015, 2017, Almeida *et al.* 2017, Almeida *et al.* 2018). Furthermore, floristic and taxonomical studies of sedimentary diatoms over a long timescale in Brazil and tropical regions are still very scarce. In fact, at the present time there are only four contributions to the subject, a floristic survey and the spatial-temporal distribution of diatoms from surface sediments and core samples (ca. 90 years) of an urban reservoir located in the São Paulo Metropolitan Region (Faustino *et al.* 2016), a study on the water level variations based on the abundance and distribution of two diatoms in core samples (~830 years) of a marsh located on the Mutum Island, in the Upper Parana River floodplain (Ruwer & Rodrigues 2018), a study to reconstitute paleoenvironments of the lacustrine Pinguela- Palmital- Malvas system during the Holocene (Hermany *et al.* 2013), and a study to infer the paleoecological and paleohydrological changes in five sedimentary cores of Itupanema Beach, Pará State (Ribeiro *et al.* 2010).

We presently documented the floristic survey and the diatoms distribution over the past ~6.000 years from two sediment cores of the Xingu River, Pará State, Brazil. The Amazon Basin represents about 40% of the national territory, and contains more than 60% of the water available to the country (PNRH 2006). Occupying two-fifths of South America and 5% of the Earth surface, the Amazon Basin covers a total area of approximately 7 million km², and represents the largest drainage basin in the world, thus playing a vital role in maintaining biodiversity (Wetzel *et al.* 2011). Within this context, present study aimed at expanding the knowledge of tropical diatoms biodiversity before human impacts, and highlighting its biodiversity by providing new records for Brazil and the Brazilian Amazon.

MATERIAL AND METHODS

The Xingu River Basin, one of the main eastern Amazonian River systems has an area of 531,250 km² and an average flow between 2,582 and 9,700 m^3 s^1. Climate is tropical with an average temperature between 25ºC and 27ºC (ISA 2012). The Xingu River downstream range is a region well known for its atypical river course and diversified morphology known as the Volta Grande do Xingu (*Xingu Great Bend*). Near to the mouth, the river shifts to a lowland Amazonian river with a single slack water channel under the influence of the tides (Sawakuchi *et al*. 2015). Samples used for the present investigation were collected in the Lower Xingu River, in a floodplain lake (3°12’51.24”S, 52°11’24.25”W) located in the Arapujá Island (Volta Grande do Xingu), in a *Ria* area (01°42’32.12”S, 52°16’47.42”W) near to Porto de Moz city.

During the dry season of 2014, the cores were collected by divers from a deep zone of both sites. The location was selected based on the water depth profile coupled with riverbed sediment sampling. Divers collected a 122 cm core (XC1-02) from the Arapujá Island, and a 362 cm core (XC-03) from the *Ria*, using a 6 m long PVC tube sectioned at 2 cm intervals. Core chronology was determined by Optically Stimulated Luminescence (OSL) and ^{14}C dating. Two samples for quartz OSL dating were collected and prepared in the Luminescence and Gamma Spectrometry Laboratory of the Institute of Geosciences at the University of São Paulo. Four samples were collected and prepared for ^{14}C dating at the Analytic Radiocarbon Dating in Miami and the Radiocarbon Laboratory at the Universidade Federal Fluminense (LAC-UFF). For more details, see Sawakuchi *et al.* (2015). Based on the OSL and ^{14}C dating, the base of the XC1-02 and XC-03 cores corresponded to about ~6.000 cal yr BP and 4.000 cal yr. BP, respectively, which covers the end of Mid-Holocene and the Late Holocene.

For diatom analyses, organic matter was oxidized to be removed, using hydrogen peroxide (H_2O_2 35%) and hydrochloric acid (HCl 37%), according to standard procedures (Battarbee *et al.* 2001). Permanent slides were prepared using Naphrax (R.I. = 1.6) as the mounting medium. Optical observations, measurements and photomicrographs were taken at 1.000× magnification, with a Zeiss Axioskop 2 plus microscope equipped with an Axiocam ERc5s high-resolution digital camera. At least 400 valves per slide were counted (Battarbee *et al.* 2001). Species abundance was calculated by dividing the individual species count by the total count expressed as percentages for each slide (subsample). Taxonomy and nomenclature followed specific publications (*e.g.* Lange-Bertalot 1993, Metzeltin & Lange-Bertalot 1998, Morales & Manoylov 2006, Garcia 2010, Lange-Bertalot *et al.* 2011, Wetzel 2011, Reichardt 2015, Almeida *et al.* 2015, Tyree & Vaccarino 2016, Costa *et al.* 2017b, Bartozek *et al.* 2018) and the valid names on-line catalog (Fourtanier & Kociolek 2011). Classification systems followed Medlin & Kaczmarska (2004) for supra-ordinal taxa and Round *et al.* (1990) for the subordinal ones, with the only exception of genera published after this work. After consulting the published literature (books and articles), the new records for Brazil and the Brazilian Amazon (Amazons, Amapá, Mato Grosso, western Maranhão, Pará, Rondônia, Roraima, Acre, and Tocatins states) were indicated. Furthermore, morphometric information is provided for the new records (M: valve mantle, D: diameter, L: length, W: width, L/W: length/width ratio, S: striae, A: areolae, and F: fibulae). Sediment samples are deposited at the "Herbário Científico do Estado Maria Eneyda P. Kauffmann Fidalgo" (SP) in the city São Paulo, Brazil (access numbers SP470331 to SP513834).

RESULTS

The diatom flora of the Xingu river over the past ~6.000 cal yr BP includes 38 taxa (30 species and varieties, and eight at the genus level, distributed in 20 genera). Eight taxa were identified only to the genus level because no similar taxon was found in the literature, and they probably represent taxonomic novelties. Taxa preceded by one asterisk represent new records for the Brazilian Amazon, and those preceded by two asterisks are first citations for Brazil. All taxa above mentioned are listed below.

Aulacoseiraceae R.M.Crawford

Aulacoseira Thwaites

****Aulacoseira crassipunctata** Krammer, Nova Hedwigia 52(1-2): 490, figs 71-79. 1991.

Figures 2-3

Morphometry: M: 12.6-16.6 µm; D: 5.4-7.1 µm; S: 5-10 in 10 µm; A. 2-8 in 10 µm.

The species differs from *Aulacoseira canadensis* (Hustedt) Simonsen (1979: 57) in the shape of the ringleist that is very solid and thick at the middle of the column. Another difference is in the areolae outline that is small and rounded in *Aulacoseira crassipunctata* Krammer (Bahls *et al*. 2009). It was present in only 2% of the core samples, and had a maximum abundance of 6%. The species is present in samples from the Late Holocene, ~2.200 cal. yr BP to ~320 cal. yr BP. This is the first record of the species occurrence in Brazil.

Material examined: BRASIL. PARÁ: Porto de Moz, Rio Xingu, 2014, *A.O. Sawakuchi et al.*, core XC-03 (SP513792).

Fragilariaceae Greville

Rimoneis M.Garcia

***Rimoneis* sp.**

Figures 4-6

Morphometry: L: 8-17µm; W: 2.5-7.1 µm.

Valves linear-lanceolate, hyaline, with rounded ends. Axial area wide, occupying all the valve face. Striae not observed in LM. This taxon resembles *Rimoneis inanis* M.Garcia (2010) in the valve shape, although its valve ends are more pronounced and less rounded. Moreover, *Rimoneis* sp. present smaller valve dimensions (*R. inanis*, L:17-25 µm, W:2.7-3.3 µm). Currently, the genus *Rimoneis* presents only two species registered in the world, being *R. inanis* restricted to freshwater/brackish waters in sandy beaches of the Lagoa dos Patos lagoon and Guaíba river, located in Southern Brazil.

Rimoneis sp. occurred in 5% of the core samples, with maximum abundance of 4%. It is present in samples from the Late Holocene, ~3.750 cal. yr BP to 1.450 cal. yr BP.

Material examined: BRASIL. PARÁ: Porto de Moz, Rio Xingu, 2014, *A.O. Sawakuchi et al.*, core XC-03 (SP513824).

Staurosira Ehrenberg

***Staurosira* sp.**

Figures 7-8

Morphometry: L: 12.0-16.0 µm; W: 8.0-12.0 µm; S: 16-17 in 10 µm.

The population found resembles *Staurosira construens* Ehrenberg (1843) in its valve outline. However, it is distinct by presenting narrower ends. *Staurosira* sp. was identified in 82% of the core samples, and had a maximum abundance of 24%. The species is present in samples from the end of the Mid-Holocene, ~6.000 cal. yr BP up to the core top.

Material examined: BRASIL. PARÁ: Altamira, Rio Xingu, 2014, *A.O. Sawakuchi et al.*, core XC1-02 (SP470331 to SP470349, SP470351, SP470352, SP470354, SP470357, SP470358, SP470361 to SP470365, SP470368 to SP470375, SP470377 to SP470383, SP470386 to SP470392).

Staurosirella D.M.Williams & Round

****Staurosirella acidophila*** P.D.Almeida, C.E.Wetzel, E.A.Morales, L.Ector & D.C.Bicudo, Cryptogamie Algologie 36(3): 260, figs 2-41. 2015.

Figures 9-10

Morphometry: L: 16.6-20.6 µm; W: 4.0-5.5 µm; S: 8-9 in 10 µm.

The species was proposed by Almeida *et al.* (2015) from material collected from the Cachoeira da Graça Reservoir (São Paulo state), and according to those authors, *S. acidophila* is similar to *Staurosirella confusa* E.A.Morales (2005: 54-58), however, there are some clear differences in the arrangement and density of the striae (ca. 11 in 10 µm). This species also differs from *Staurosirella oldenburgiana* (Hustedt) E.A.Morales (2005: 118) in the width of the valve center and the presence of small areolae. It was reported from 52% of the core samples, reaching 4% maximum abundance. The species is present in samples corresponding to the end of the Mid-Holocene, from ~6.000 cal. yr BP up to the core top. Current study represents the first report of this species occurrence in the Brazilian Amazon.

Material examined: BRASIL. PARÁ: Altamira, Rio Xingu, 2014, *A.O. Sawakuchi et al.*, core XC1-02 (SP470335 to SP470342, SP470345 to SP470356, SP470358, SP470360 to SP470366, SP470377, SP470378, SP470379, SP470392).

Staurosirella* cf. *acutirostrata (Metzeltin & Lange-Bertalot) Almeida & Wetzel, Cryptogamie Algologie 36(3): 267. 2015.

Figure 11

Morphometry: L: 16.0-23.3 µm; W: 5.3-6.0 µm; S: 7-8 in 10 µm.

This species was identified as *Staurosirella* cf. *acutirostrata* (Metzeltin & Lange-Bertalot) Almeida & Wetzel (2015: 267) due to presenting less tapered extremities and shorter valve length (L: 22-36 µm) than the ones described in Metzeltin & Lange-Bertalot (1998: 89, pl. 1, fig. 18-19, pl. 2) It was reported in 48% of all core samples, thus reaching a 4.3% maximum abundance. The species is identified from samples collected toward the end of the Mid-Holocene, from ~5.760 cal. yr BP up the core top.

Material examined: BRASIL. PARÁ: Altamira, Rio Xingu, 2014, *A.O. Sawakuchi et al.*, core XC1-02 (SP470331, SP470332 to SP470337, SP470352 to SP470356, SP470359, SP470362, SP470364 to SP470367, SP470371, SP470372, SP470375 to SP470380, SP470382, SP470383, SP470387 to SP470391).

****Staurosirella dubia*** (Grunow) E.A.Morales & K.M.Manoylov, Diatom Research 21(2): 348. 2006.

Figures 12-13

Morphometry: L: 14.0-16.0 µm; W: 5.0-6.0 µm; S: 7-8 in 10 µm.

Staurosirella dubia (Grunow) E.A.Morales & K.M.Manoylov has a similar valve outline when compared to *Staurosirella pinnata* (Ehrenberg) D.M.Williams & Round (1988: 274). However, *S. dubia* differs by having larger valves, lanceolate valve outline in the greater specimens, elliptical in the smaller ones, and wider striae (Morales 2010). It was found in 56% of the core samples, reaching 6% maximum abundance. Current species were present in samples from the end of the Mid-Holocene (~6.000 cal. yr BP) up to the core top. Current survey is the first report of this species occurrence in the Brazilian Amazon.

Material examined: BRASIL. PARÁ: Altamira, Rio Xingu, 2014, *A.O. Sawakuchi et al.*, core XC1-02 (SP470332 to SP470336, SP470338, SP470339, SP470344 to SP470353, SP470356, SP470357, SP470360 to SP470364, SP470377, SP470378, SP470380 to SP470385, SP470387, SP470388, SP470392).

****Staurosirella subcapitata*** (Frenguelli) E.A.Morales, Diatom Research 21(2): 358, figs 57-79. 2006.

Figures 14-15

Morphometry: L: 8.0-22.0 µm; W: 3.0-5.0 µm; S: 6-9 in 10 µm.

Present species resembles *S. dubia* (Grunow) Morales & Manoylov, however according to the authors *S. subcapitata* (Frenguelli) E.A.Morales has less lanceolate and silicified valves than the second species. It occurred in 98% of all core, with a maximum abundance of 15%. *S. subcapitata* was identified in all subsamples from the Late Holocene (~4.000 cal. yr BP) up to the core top (~300 cal. yr BP). Despite the species was already reported for Brazilian Amazon, in the Negro River (Wetzel 2011), the present is to be considered the first publish citation for the Brazilian Amazon.

Material examined: BRASIL. PARÁ: Porto de Moz, Rio Xingu, 2014, *A.O. Sawakuchi et al.*, core XC-03 (SP513792, SP513824, SP513825, SP513826, SP513827, SP513828, SP513829, SP513830, SP513831, SP513832, SP513833, SP513834).

Eunotiaceae Kützing

Eunotia Ehrenberg

Eunotia camelus Ehrenberg, Bericht über die zur Bekanntmachung geeigneten Verhandlungen der Königlich-Preussischen Akademie der Wissenschaften zu Berlin 1841: 413 [125], pl. 2/1, fig. 1. 1843.

Figure 16

Morphometry: L: 22.0-62.5 µm; W: 6.0-7.0 µm; S: 9-12 in 10 µm.

According to Costa *et al*. (2017b), the type material of *Eunotia camelus* Ehrenberg illustrated in Reichardt (1995) included a population composed of two different species, a fact that brings some confusion regarding the classification of the species. In the southeastern Brazil, most of the populations identified as *E. camelus* actually are *Eunotia longicamelus* L.F.Costa, D.C.Bicudo & C.E.Wetzel. It was reported in 15% of the core samples, and reached 3%

maximum abundance. The species is found in samples from the early Late Holocene (~1.514 cal. yr BP) to the core top.
Material examined: BRASIL. PARÁ: Altamira, Rio Xingu, 2014, *A.O. Sawakuchi et al.*, core XC1-02 (SP470348, SP470350 to SP470355, SP470357 to SP470360).

***Eunotia longicamelus** L.F.Costa, D.C.Bicudo & C.E.Wetzel, Bibliotheca Diatomologica 64: 32, pl. 73, pl. 74, figs 1-8, pl. 75, pl. 76. 2017.
Figure 17
Morphometry: L: 35.0-48.0 µm; W: 6.0-7.3 µm; S: 10-14 in 10 µm, A: 20-22 in 10 µm.

Eunotia longicamelus L.F.Costa, D.C.Bicudo & C.E.Wetzel was established by Costa *et al.* (2017b) on the basis of material gathered from the Ponte Nova Reservoir (Southeastern Brazil). *E. longicamelus* is widely identified and cited as *E. camelus* Ehrenberg, however, the first species shows narrower valves, dorsal margin with two or four major undulations, and less concave ventral margin (Costa *et al.* 2017b). The species was reported from 11% of the core samples, reaching 2.5% maximum abundance, and occurring since the end of the Mid-Holocene, from ~5.192 cal. yr BP up to the core top. Current survey is the first report of this species occurrence in the Brazilian Amazon.
Material examined: BRASIL. PARÁ: Altamira, Rio Xingu, 2014, *A.O. Sawakuchi et al.*, core XC1-02 (SP470352, SP470356, SP470357, SP470359, SP470384, SP470385, SP470388).

Eunotia rabenhorstii** Cleve & Grunow var. ***monodon Cleve & Grunow, Synopsis des Diatomées de Belgique Atlas. pl. 35, fig. 12 [A-B]. 1881.
Figures 18-19
Morphometry: L: 18.0-22.0 µm; W: 5.3-6.0 µm; S: 15-16 in 10 µm.

This variety is quite similar to *Eunotia rabenhorstii* Cleve & Grunow var. *triodon* Cleve & Grunow (1881: 12a), but, having a single undulation on the dorsal margin is unique for the var. *monodon* Cleve & Grunow (Patrick & Reimer 1966, Costa *et al.* 2017b). The species was rare, occurring in just 2% of the core samples, reaching 1% maximum abundance. It is found in samples from the Late Holocene (~408 cal. yr BP). This is the first report of the occurrence of the variety *monodon* in the Brazilian Amazon.
Material examined: BRASIL. PARÁ: Altamira, Rio Xingu, 2014, *A.O. Sawakuchi et al.*, core XC1-02 (SP470334).

***Eunotia superbidens** Lange-Bertalot, Diatoms of Europe 6: 229, pl. 81, figs 1-10, pl. 82, figs 1-6. 2011.

Figure 20

Morphometry: L: 57.0-67.0 µm; W: 11.0-11.9 µm at the swellings, 6.0-10.0 µm at the apices; S: 8-12 in 10 µm.

Eunotia superbidens Lange-Bertalot is very similar to *Eunotia praerupta* Ehrenberg (1843: 414), regarding their size, but differ in the presence of a single undulation on the dorsal margin, and the greater striae density. The species also differs from *Eunotia bigibba* Kützing (1849: 6) mainly by the more depressed undulations and its larger valves. This species was rarely met during the present investigation, being distributed in 2% of the core samples and reaching 1% maximum abundance. It is present in samples from the Late Holocene (~1.514 cal. yr BP). Current investigation is the first report of the presence of the species in the Brazilian Amazon.

Material examined: BRASIL. PARÁ: Altamira, Rio Xingu, 2014, *A.O. Sawakuchi et al.*, core XC1-02 (SP470360).

***Eunotia* sp.**

Figures 21-22

Morphometry: L: 119-137 µm; W: 12-13 µm; S: 8-11 in 10 µm.

Eunotia sp. resembles *Eunotia myrmica* Lange-Bertalot (2011), but the latter has narrower and cuneate apices, as well as smaller valve dimensions (Pavlov & Levkov 2013: L: 58.8-67 µm). The taxon was rarely observed, occurring in 2% of the core samples and reaching 1% maximum abundance. It is present in samples from the Late Holocene (~811 cal. yr BP).

Material examined: BRASIL. PARÁ: Altamira, Rio Xingu, 2014, *A.O. Sawakuchi et al.*, core XC1-02 (SP470342).

Placoneis Mereschkowsky

*** *Placoneis exigua*** (Gregory) Mereschkovsky, Beihefte zum Botanischen Centralblatt 15(1), p. 1-30, pl.1, 1903.

Figure 23

Morphometry: L: 33-34 µm; W: 10.6-11.3 µm; S: 11-13 in 10 µm.

Present species resembles *Placoneis constans* (Husted) Cox var. *symmetrica* (Hustedt) Kobayasi in its valves and rostrate ends. However, *P. exigua* differs by having larger valves than *P. constans* and presents a central area with a shorter striae surrounded by longer striae

(Bartozek *et al.* 2018). The species was reported for 6% of the core samples, thus reaching 1.5% maximum abundance. This taxon is met in samples from the end of the Mid-Holocene to the core top (~5.479 cal. yr BP to the present day).

Material examined: BRASIL. PARÁ: Altamira, Rio Xingu, 2014, *A.O. Sawakuchi et al.*, core XC-03 (SP470346, SP470352, SP470372, SP470388).

Gomphonemataceae F.T.Kützing

****Gomphonema auritum*** A.Braun *ex* Kützing, Species algarum. 68. 1849.

Figures 24-25

Morphometry: L: 18-22 µm; W: 4.9-5.1 µm; L/W: 3.6-4.3; S: 13-15 in 10 µm.

The species was found in 21% of the core samples surveyed, and reached 2.5% maximum abundance. The species is found in samples from the end of the Mid-Holocene to the core top (~5.479 cal. yr BP to the present day). Current study represents the first report of this species occurrence in the Brazilian Amazon.

Material examined: BRASIL. PARÁ: Altamira, Rio Xingu, 2014, *A.O. Sawakuchi et al.*, core XC1-02 (SP470351, SP470354 to SP470356, SP470365, SP470375, SP470377, SP470378, SP470382, SP470384 to SP470386, SP470390).

****Gomphonema acuminatum*** Ehrenberg, Abhandlungen der Königlichen Akademie Wissenschaften zu Berlin, Physikalische Klasse 1831: 88. 1832

Figure 26

Morphometry: L: ca. 44.0 µm; W: ca. 8.0 µm at the center; ca. 12 µm at apices; L/W: ca. 5.5; S: ca. 11 in 10 µm.

Based on the valve outline, *Gomphonema acuminatum* C.G.Ehrenberg is extremely similar to *Gomphonema brebissonii* F.T.Kützing (1849: 66) and *Gomphonema coronatum* C.G.Ehrenberg (1841: 211). However, *G. brebissoni* has a well reduced apical inflation, and *G. coronatum* a smaller inflation near the headpole (Kociolek 2011). Occurrence of *G. acuminatum* was rare, since it is found in only 2% of the core samples, reaching 1% maximum abundance. The species is found in samples from the Late Holocene up to the core top (~1.757 cal. yr BP to the present day). Present research is the first report of this species occurrence in the Brazilian Amazon.

Material examined: BRASIL. PARÁ: Altamira, Rio Xingu, 2014, *A.O. Sawakuchi et al.*, core XC1-02 (SP470362).

***Gomphonema brasiliensoides** Metzeltin, Lange-Bertalot & García-Rodríguez, Iconographia Diatomologica 15: 80, pl. 149, figs 1-10. 2005
Figures 27-28
Morphometry: L: 32.0-40.0 µm; W: 5.3-7.3 µm; L/W: 5.7-6.0; S: ca. 11 in 10 µm.

Dimensions of *Gomphonema brasiliensoides* Metzeltin, Lange-Bertalot & García-Rodriguez are greater than those of *Gomphonema brasiliense* Grunow (Metzeltin *et al.* 2005: L: 24.0-60.0 µm, W: 6.6-9 µm and L: 22.0-44.0 µm, W: 5.5-6.7 µm; respectively). It was found in 13% of the core samples and reached 2% maximum abundance. The species is identified from samples from the end of the Mid-Holocene to the core top (~3.774 cal. yr BP to the present day). Present investigation represents the first report of this species occurrence in the Brazilian Amazon.

Material examined: BRASIL. PARÁ: Altamira, Rio Xingu, 2014, *A.O. Sawakuchi et al.*, core XC1-02 (SP470342, SP470349, SP470350, SP470352, SP470353, SP470359, SP470362, SP470377).

***Gomphonema curvipedatum** H.Kobayasi *ex* Osada, Atlas of Japanese diatoms based on electron microscopy 1: 10, pl. 122, figs 1-13. 2006.
Figure 29
Morphometry: L: 24.5-34.0 µm; W: 4.5-6.0 µm; L/W: 5.4-5.6; S: ca. 14 in 10 µm.

Its differs from *Gomphonema hawaiiense* Reichardt (2005: 119) by having smaller valves dimensions (L: 24.5-34.0 µm; W: 4.5-6.0 µm and L: 32.6-55.0 µm; W:6.3-9.5 µm respectively). (Tremarin *et al.* 2009) and curved subcapitate apices. The taxon was found in 5% of the core samples, reaching 1% maximum abundance. This species is present in samples from the end of the Mid-Holocene (~4.345 cal. yr BP). Current investigation represents the first report of this species occurrence in the Brazilian Amazon.

Material examined: BRASIL. PARÁ: Altamira, Rio Xingu, 2014, *A.O. Sawakuchi et al.*, core XC1-02 (SP470337, SP470355, SP470381).

****Gomphonema pseudosphaerophorum** H.Kobayasi, Proceedings of the International Diatom Symposium 9: 452, pl. 1, figs 1-10. 1988.
Figure 30
Morphometry: L: 50-62.6 µm; W: 8.6-9.3 µm; S: 10-12 in 10 µm.

Gomphonema pseudosphaerophorum H. Kobayasi has slightly narrower valves than *Gomphonema sphaerophorum* Ehrenberg (1845: 78, Tyree & Vaccarino 2016: W: 8.1-9.4 µm and W: 12.8-13.2 µm, respectively). Additionally, *G. pseudosphaerophorum* has dimly punctate striae radiating throughout the valve, whereas *G. sphaerophorum* has nearly parallel striae at the mid-valve, becoming radiate toward the apices. Occurrence of representative specimens of this species was rare and only found in 2% of the core samples, reaching 1% maximum abundance. It is present in samples corresponding to the Late Holocene (~456 cal. yr BP). Current study is the first citation of the occurrence of this species in Brazil.

Material examined: BRASIL. PARÁ: Altamira, Rio Xingu, 2014, *A.O. Sawakuchi et al.*, core XC1-02 (SP470342).

***Gomphonema* sp.**

Figures 31-32

Morphometry: L: 43.8-55.8 µm; W: 7.8-8.3 µm; L/W: 5.6-6.7 µm, S: 11-12 in 10 µm.

Valves lanceolate to rhombic-lanceolate, apices rostrate, axial area narrow, linear, and slightly widened in the central area. Raphe slightly curved. Striae parallel, slightly radiating towards the ends. Stigma positioned at the end of the longest central striae.

This taxon presents morphological features similar to *Gomphonema naviculoides* W.Smith, regarding the valve shape. However, both species differ in valve dimensions and striae density. According to Reichardt (2015), *G. naviculoides* presents 35-45 µm in length, and 7.8-9.5 µm in width, with 12-14 striae in 10 µm. Due to the absence of ultrastructural details (SEM), we decided to retain *Gomphonema* sp. as a distinct taxon. It was present in 8% of the core samples, and reached 2.3% maximum abundance. It occurs during the Late Holocene from ~1.322 cal. yr BP.

Material examined: BRASIL. PARÁ: Altamira, Rio Xingu, 2014, *A.O. Sawakuchi et al.*, core XC1-02 (SP470350, SP470352, SP470353, SP470355, SP470359).

Achnanthidiaceae D.G.Mann

Achnanthidium Kützing

****Gogorevia exilis*** (Kützing) Kulikovskiy & Kociolek, Journal of Phycology 56(5): 2020

Figures 33-34

Morphometry: L: 14.0-15.0 µm; W: 7.3-8.0 µm; S: 22-23 in 10 µm.

This species was described as *Achnanthes exigua* by Grunow (1880: 21) and later on transferred to *Achnanthidium exiguum* by Czarnecki (1994: 157). However, according to Taylor *et al.* (2014) the type of *A. exiguum* have significant morphological differences as compared with members of *Achnanthidium*, suggesting that the transfer based on the structure of the raphe was not correct. Due to the presence of morphological features, such as sigmoid raphe, where the distal raphe ends curve to the different sides, uniseriate striae, and shape of the valves the species was transferred to *Gogorevia* by Kulikovskiy *et al.* (2020). The species is present in 5% of all core samples, reaching 1.5% maximum abundance. It occurred in the Late Holocene (~1.514 cal. yr BP). The species was already reported for Brazilian Amazon, in the Negro River, as *Achnanthidium exiguum* (Grunow) Czarnecki, however, the present is to be considered the first report for the country using its correct name.

Material examined: BRASIL. PARÁ: Altamira, Rio Xingu, 2014, *A.O. Sawakuchi, et al.*, core XC1-02 (SP470350, SP470351, SP470360), Porto de Moz, core XC-03 (SP513827, SP513829).

Planothidium Round & Bukhtiyarova

****Planothidium pulcherrimum*** (Hustedt) Coste, Essai de biotypologie et application au diagnostic du bon état écologique. 9, fig. 6. 2010.

Figures 35-36

Morphometry: L: 23.3-30.0 µm; W: 10.0-14.0 µm; S: 9-10 in 10 µm.

This species was described by Hustedt (1952: 392, fig. 99-100) as *Cocconeis pulcherrima* and later on transferred to *Achnanthes pulcherrima* by Metzeltin & Lange-Bertalot (1998: 18, pl. 69, fig. 9-14, pl. 70, fig. 1, 4, p. 366, pl. 66, fig. 1-9). However, that transference was considered not valid because the basionym was not mentioned (Coste *et al.* 2010). Due to the presence of a cavum (rimmed depression at the valve central area), which is a distinguishing character for species in the genus, it was later transferred to *Planothidium* by Coste *et al*. (2010). It was present in just 2% of the core samples, and reached 1% maximum abundance. It occurred in samples that corresponded to the end of the Mid-Holocene (~5.479 cal. yr BP). This is the first record of the presence of this species in Brazil using its correct name, and the first citation for the species occurrence in the Brazilian Amazon.

Material examined: BRASIL. PARÁ: Altamira, Rio Xingu, 2014, *A.O. Sawakuchi et al.*, core XC1-02 (SP470389).

Achnanthaceae Kützing

Achnanthes* cf. *inflata (Kützing) Grunow *in* Fenzl, E. *et al.* Reise der österreichischen Fregatte Novara um die Erde in den Jahren 1857, 1858, 1859 unter den Befehlen des Commodore B. von Wüllerstorf-Urbair. Botanischer Theil. Erster Band. Sporenpflanzen. 7. 1868.

Figures 37-38

Morphometry: L: 54.0-57.0 µm; W: 13.0-14.0 µm; S: 12-13 in 10 µm; A: 10-13 in 10 µm

This material is identified as *Achnanthes* cf. *inflata* (Kützing) Grunow due to its representative specimens show slightly less rounded ends than the ones described by Grunow (1868). However, other morphological characteristics coincided with Grunow (1868) original description. Our specimens have wider valve ends than *Achnanthes inflata* var. *elata* (Leuduger-Fortmorel) Hustedt (1937: 206), and differ from *Achnanthes coarctata* (Brébisson *ex* W.Smith) Grunow (1880: 20) by the presence of a central inflation at the valve margin and by being not constricted as is the latter. The species was found in just 2% of the core samples, and reached 1% maximum abundance in samples corresponding to the Late Holocene (~625 cal. yr BP). This is the first report for the Brazilian Amazon.

Material examined: BRASIL. PARÁ: Altamira, Rio Xingu, 2014, *A.O. Sawakuchi et al.*, core XC1-02 (SP470348).

Diadesmidaceae D.G.Mann

Luticola D.G.Mann

****Luticola intermedia*** (Hustedt) Levkov, Meltzeltin & A.Palov, Diatoms of Europe 7: 138, pl. 20, figs 1-16, pl. 21, figs 28-40. 2013.

Figures 39-40

Morphometry: L: 27.0-28.0 µm; W: ca. 8.0 µm; S: 17-20 in 10 µm.

Present species resembles *Luticola acidoclinata* Lange-Bertalot (1996) in its valve outline and dimensions (L: 10-30 µm, W: 5.0-8.5 µm). However, *Luticola intermedia* (Hustedt) Levkov, Meltzeltin & A.Palov exhibits a narrow and linear axial area, with 4-5 isolate areolae at the valve margin (Levkov *et al*. 2013). It was present in only 3% of the core samples, and reached 1% maximum abundance. The species is present in samples corresponding to the Late Holocene (~689 cal. yr BP). Current inventory is the first report of this species presence in the Brazilian Amazon.

Material examined: BRASIL, PARÁ: Altamira, Rio Xingu, 2014, *A.O. Sawakuchi et al.*, core XC1-02 (SP470340, SP470350).

Caloneis Cleve

***Caloneis* sp.**

Figures 41-42

Morphometry: L: 33.0-49.0 µm; W: 8.0-9.0 µm; S: 19-20 in 10 µm.

Caloneis sp. resembles *Caloneis* sp. Nº. 163/14 in Metzeltin & Lange-Bertalot (1998: 560, pl. 163, fig. 14). However, the specimens from Xingu River present slightly panduriform valves. Further studies are required to confirm if this taxon is a new species. During the present study, the taxon was present in 11% of the core samples, and reached 2.5% maximum abundance, occurring in samples corresponding to the end of the Mid-Holocene (~5.192 cal. yr BP).

Material examined: BRASIL. PARÁ: Altamira, Rio Xingu, 2014, *A.O. Sawakuchi et al.*, core XC1-02 (SP470336, SP470350, SP470354, SP470357, SP470358, SP470380, SP470387).

Diploneidaceae D.G.Mann

****Diploneis elliptica*** (Kützing) Cleve var. ***elliptica***, Kongliga Svenska Vetenskapsakademiens Handlingar, séries 4, 26(2): 92. 1894.

Figures 43-45

Morphometry: L: 18.3-30.0 µm; W: 13-18 µm; S: 9-11 in 10 µm, A: ca. 14 in 10 µm.

The population of *Diploneis elliptica* (Kützing) Cleve var. *elliptica* showed valve morphology and striae density similar to the ones illustrated by Krammer & Lange-Bertalot (1986: fig. 108: 1-4). However, samples analyzed from the Xingu River showed specimens smaller than those described for the species (L: 20-130 µm). It was present in 2.6% of the core samples, and reaches 3% maximum abundance. *D. elliptica* var. *elliptica* was identified from samples corresponding to the Late Holocene (~1.730 to 560 cal. yr BP).This is the first citation of the species presence in the Brazilian Amazon.

Material examined: BRASIL. PARÁ: Porto de Moz, Rio Xingu, 2014, *A.O. Sawakuchi et al.*, core XC1-02 (SP513826).

Naviculaceae Kützing

Navicula Bory

*__*Navicula notha*__ Wallace, Notulae Naturae Bacillarien order Diatomeen. 4, pl. 1, fig. 4A-D. 1960.

Figures 46-47

Morphometry: L: ca. 26.9 µm; W: ca. 5.0 µm; S: ca. 15 in 10 µm.

Considering the valve shape, *Navicula notha* Wallace resembles *Navicula cryptocephala* Kützing (1844: 95), but differs in having smaller valves, with an inconspicuous central area in the smaller specimens, and rhombic shape in the larger ones (Potapova 2011). The species occurred only in 3% of the core samples, and reaches 1.3% maximum abundance. It is present in samples corresponding to the Late Holocene (~2.909 cal. yr BP). This is the first report of its occurrence in the Brazilian Amazon.

Material examined: BRASIL. PARÁ: Altamira, Rio Xingu, 2014, *A.O. Sawakuchi et al.*, core XC1-02 (SP470358, SP470371).

Sellaphoraceae Mereschkowsky

Sellaphora Mereschkowsky

**__*Sellaphora emilia*__ Metzeltin & Lange-Bertalot, Iconographia Diatomologica 18: 234, pl. 159, figs 3-6. 2007.

Figure 48

Morphometry: L: 52.0-55.0 µm; W: 12.0-12.6 µm; S: 19-20 in 10 µm.

Sellaphora emilia Metzeltin & Lange-Bertalot belongs to the group *bacillum* of genus *Sellaphora* (Mann *et al.* 2008). Differs from *Sellaphora renata* Metzeltin & Lange-Bertalot in having valves with consistently straight margins, less broadly rounded ends and by the smaller valve dimensions (2007: L: 45.0-124.0 µm, W: 12.0-14.0 µm and L: 45.0-140.0 µm, W: 15.0-21.0 µm; respectively). The species was present in only 2% of the core samples, and reaches 1% maximum abundance. It is also present in samples corresponding to the Late Holocene (~1.757 cal. yr BP). Current study is the first report of the species occurrence in Brazil.

Material examined: BRASIL. PARÁ: Altamira, Rio Xingu, 2014, *A.O. Sawakuchi et al.*, core XC1-02 (SP470363).

*__*Sellaphora rectangularis*__ (Gregory) Lange-Bertalot & D.Metzeltin, Iconographia Diatomologica 2: 102, pl. 25, figs 10-12, pl. 125, fig. 7. 1996.

Figures 49-50

Morphometry: L: 29.0-36.0 µm; W: 7.0-8.0 µm; S: ca. 23 in 10 µm.

This species belongs to the group "*pupula*" of *Sellaphora* and differs from *Sellaphora pupula* (Kützing) Mereschkovsky (1902: 187) in its linear elliptical valves, with broadly rounded poles (Mann *et al.* 2008). It was present in 35% of the core samples, reaching 6% maximum abundance. The species was identified from samples corresponding to the end of the Mid-Holocene to the core top (~6.000 cal. yr BP to the present day). Current study is the first communication of this species occurrence in the Brazilian Amazon.

Material examined: BRASIL. PARÁ: Altamira, Rio Xingu, 2014, *A.O. Sawakuchi et al.*, core XC1-02 (SP470332 to SP470340, SP470342 to SP470344, SP470348, SP470351, 470358, SP470371, SP470377, SP470382, SP470390, SP470392).

Sellaphora renata Metzeltin & Lange-Bertalot, Iconographia Diatomologica 18: 1-877, incl. 296 pl. 2007.

Figures 51-52

Morphometry: L: 76.0-88.0 µm; W: 10.0-14.0 µm; S: 19-20 in 10 µm.

Based on the valve outline, *Sellaphora renata* Metzeltin & Lange-Bertalot is quite similar to *Sellaphora lambda* (Cleve) Metzeltin & Lange-Bertalot (1998: 206). However, *S. renata* lack of marginal spines present in *S. lambda* (Metzeltin & Lange-Bertalot 2007). The species was found in 5% of the core samples and reached 1.5% maximum abundance. It was identified in samples corresponding to the early Late Holocene (~1.322 cal. yr BP).

Examined material: BRASIL. PARÁ: Altamira, Rio Xingu, 2014, *A.O. Sawakuchi et al.*, core XC1-02 (SP470342; SP4703587; SP470358).

****Sellaphora sassiana*** (Metzeltin & Lange-Bertalot) C.E.Wetzel, Fottea 15(2): 228. 2015.

Figures 53-54

Morphometry: L: 14.0-15.0 µm; W: 1.2-1.3 µm; S: ca. 30 in 10 µm.

According to Wetzel *et al.* (2015), *Naviculadicta sassiana* Metzeltin & Lange-Bertalot (1998) was first described for the Amazonian region (Tapajós River, Brasil), and was later on transferred to *Sellaphora* based on the LM illustrations in Metzeltin & Lange-Bertalot (1998). *Sellaphora sassiana* was present in 5% of the core samples, reaching 9.6% maximum abundance. It occured in samples corresponding to the Late Holocene (~408 cal. yr BP). The species was already reported for Brazil, from the Tapajós River, as *Naviculadicta sassiana* (*e.g.*

Metzeltin & Lange-Bertalot 1998), however, the present is to be considered the first report for the country using its correct name.

Material examined: BRASIL. PARÁ: Altamira, Rio Xingu, 2014, *A.O. Sawakuchi et al.*, core XC1-02 (SP470331 to SP470333).

****Sellaphora ventraloconfusa*** (Lange-Bertalot) Metzeltin & Lange-Bertalot, Iconographia Diatomologica 5: 212. 1998.

Figure 55

Morphometry: L: ca. 21.0 µm; W: ca. 6.0 µm.

In a review of several *Sellaphora* materials, Mann *et al.* (2004) mentioned that *Sellaphora ventraloconfusa* (Lange-Bertalot) Metzeltin & Lange-Bertalot should be included in the *Sellaphora seminulum* (Grunow) D.G.Mann group, but all information available to date is still insufficient to confirm it. This species was present at only 2% of the core samples, and reached 1% maximum abundance. It occurred from samples corresponding to the Late Holocene (~408 cal. yr BP). Current investigation is the first document of the occurrence of the species in the Brazilian Amazon.

Material examined: BRASIL. PARÁ: Altamira, Rio Xingu, 2014, *A.O. Sawakuchi et al.*, core XC1-02 (SP470341).

Lacuneolimna Tudesque, Le Cohu & Lange-Bertalot

*****Lacuneolimna novagallia*** Tudesque & Le Cohu, Phytotaxa 231(1): 24, figs 43-71. 2015.

Figure 56

Morphometry: L: 16.2-16.6 µm; W: 7.7-8.6 µm; S: 15-18 in 10 µm.

Lacuneolimna novagallia Tudesque & Le Cohu is distinguished from *Lacuneolimna zalokariae* Tudesque & Le Cohu (2015: 21) in its continuous depressions in valve face, wider costae, and more expanded “cross-bar network” (Tudesque *et al*. 2015). It was present in 0.6% of the core samples, reaching 2% maximum abundance. The species was identified from samples corresponding to the Late Holocene (~1.790 cal. yr BP). This is the first citation of the species presence in Brazil.

Material examined: BRASIL. PARÁ: Porto de Moz, Rio Xingu, 2014, *A.O. Sawakuchi et al.*, core XC-03 (SP513828).

Pinnulariaceae D.G. Mann

Pinnularia Ehrenberg

Pinnularia* cf. *liyanlingae Metzeltin & Lange-Bertalot, Iconographia Diatomologica 18. p.207, pl. 238-239, figs 1-4; 1-3. 2007.

Figure 57

Morphometry: L: 86.0 µm; W: 22.0 µm; S: 9 in 10 µm.

In the present study, this taxon was identified as *Pinnularia* cf. *liyanlingae*, because the specimens presented smaller dimensions than those described by Metzeltin & Lange-Bertalot (2007, L: 94-200 µm, W: 24-32 µm). The taxon was found in 15% of the core samples and reached 1.5% maximum abundance. It was identified in samples corresponding to the early Late Holocene to the core top (~1.322 cal. yr BP to the present day).

Examined material: BRASIL. PARÁ: Altamira, Rio Xingu, 2014, *A.O. Sawakuchi et al.*, core XC1-02 (SP470340 to SP470342; SP470344; SP470347; SP470356 to SP470359).

Stauroneidaceae D.G.Mann

Stauroneis Ehrenberg

Stauroneis* cf. *sylviabonillae Meltzeltin, Lange-Bertalot & García-Rodriguez, Iconografia Diatomologica 15: 224, pl. 106, figs 1-2. 2005.

Figures 58-59

Morphometry: L: 84.0-88.0 µm; W: 17.0-18.0 µm; S: 19-20 in 10 µm; A: 21-22 in 10 µm.

In the current study, this species was identified as *Stauroneis* cf. *sylviabonillae* because the individual specimens had smaller and narrower valves and present higher striae density than those described in Meltizeltin *et al*. (2005: 224, pl. 106, fig. 1-215-16). Material examined is different from *Stauroneis amphicephala* Kützing (1844: 105) due to its narrow, rostrate, not protracted and nor subcapitate apices (Bahls 2011). The species was present in 5% of the core samples, reaching 2% maximum abundance. It occurred in samples corresponding to the Late Holocene (~2.909 cal. yr BP). Current study is the first report of the presence of the species in the Brazilian Amazon.

Material examined: BRASIL. PARÁ: Altamira, Rio Xingu, 2014, *A.O. Sawakuchi et al.*, core XC1-02 (SP470378, SP470380, SP470388).

***Stauroneis* sp.**

Figures 60-62

Morphometry: L: 108.0-124.0 µm; W: 14.0-15.0 µm; S: 18-19 in 10 µm.

This material resembles that of *Stauroneis schinzii* (Brun) Cleve (1894: 146), however, the latter has very broadly rounded valve apices and greater cell dimensions (Patrick & Reimer 1966: L: 130-221 µm, W: 17-19 µm, S: 15-18 in 10 µm) than *Stauroneis* sp. The latter material is further characterized by having linear valves, obtusely rounded subrostrate apices, broad linear slightly irregular axial area that suddenly turns ovoid at the terminal ends, relatively small fascia that slightly expands toward the margin, broad raphe that somewhat narrows near by the proximal and distal ends, branched distal raphe ends that form semicircular hooks bending to the same direction, and radiate striae at the valve center that become parallel toward the ends. It is present in 35% of the core samples, and reached 2.6% maximum abundance. The taxon was identified from samples corresponding to the end of the Mid-Holocene to the core top (~5.760 cal. yr BP to present).

Material examined: BRASIL. PARÁ: Altamira, Rio Xingu, 2014, *A.O. Sawakuchi et al.*, core XC1-02 (SP470331, SP470332, SP470336, SP470339, SP470342, SP470345, SP470349, SP470350, SP470352 to SP470357, SP470359, SP470362, SP470364, SP470375, SP470376, SP470382, SP470388, SP470390).

Bacillariaceae Ehrenberg

****Nitzschia pusilluhasta*** E.A.Lehmkhul & C.E.M.Bicudo, Phytotaxa 339(1): 86, figs 2-21, 53-58. 2019.

Figures 63-64

Morphometry: L: ca. 20 µm; W: ca. 3 µm; F: ca. 11 in 10 µm, S: ca. 20 in 10 µm.

Nitzschia pusilluhasta E.A.Lehmkhul & C.E.M.Bicudo differs from *Nitzschia amphibia* Grunow (1862: 574) because the latter species has lanceolate valves with slightly protracted ends, and a gap between the central fibulae (Lehmkuhl *et al*. 2019: 25-26). It can be also misidentified as *Nitzschia semirobusta* Lange-Bertalot (1993: 149), however, *N. pusilluhasta* has greater valve dimensions and rectangular, short to slightly extend fibulae. It was present in 0.6% of the core samples and reaches 3% maximum abundance. In the current study, *N. pusilluhasta* was identified from samples corresponding to the Late Holocene (~2.400 cal. yr BP). This is the first report of the species occurrence in the Amazon basin.

Material examined: BRASIL. PARÁ: Porto de Moz, Rio Xingu, 2014, *A.O. Sawakuchi et al.*, core XC-03 (SP513827).

Surirellaceae Kützing

Surirella Turpin

***Surirella* sp.**

Figure 65-66

Morphometry: L: 40.0-45.0 µm; W: 10.0-10.6 µm; S: 25-27 in 10 µm; AC: 3-4 in 10 µm.

Surirella sp. resembles *Surirella terryi* D.B.Ward *ex* W.A.Terry (1907: 127) in its heteropolar valves and the cuneate valve apices. However, the latter species has a more pronounced central area along the apical axis and greater valve dimensions (Ferreira & Bicudo 2017: L: 67-176 µm, W: 23-35 µm). The species is also characterized by its asymmetric linear valves with a rounded headpole and a cuneate footpole, a narrow hyaline axial area, lack of costae, nonvisible fibulae, and low keel and alar canals parallel to each other. This taxon was present in 5% of the core samples, reaching 1% maximum abundance. It was identified from samples corresponding to the Late Holocene (~973 cal. yr BP).

Material examined: BRASIL. PARÁ: Altamira, Rio Xingu, 2014, *A.O. Sawakuchi et al.*, core XC1-02 (SP470331, SP470332, SP470343).

DISCUSSION

Present study included five new records of diatom species for Brazil, as well as an additional nineteen new records of occurrence in the Brazilian Amazon.

The increasing number of newly described species for the Brazilian Amazon (Wetzel *et al.* 2010a, 2010b, 2011, 2012a, 2012b, Burliga *et al.* 2013, Tremarin *et al.* 2013a, 2014a, 2014b, Pereira *et al.* 2014, 2015, 2017, Almeida *et al.* 2017, Almeida *et al.* 2018, Canani *et al.* 2018) suggests how scant knowledge of the diatoms of the region is. Furthermore, the present new records for the Brazilian Amazon represent a 75% increase in the total number of records for the region, and strengthen that the region remains poorly investigated and its biodiversity assessment is considerably underestimated.

Overall, 38 taxa from 20 genera were recorded along the study period (~6.000 years). *Gomphonema* was the most represented genus in species number (6 species), followed by *Eunotia* (5 species), *Sellaphora* (5 species) and *Staurosirella* (4 species).

Regarding the five new records for the Brazilian territory (*Aulacoseira crassipunctata, Gomphonema pseudosphaerophorum, Sellaphora emilia, S. sassiana* e *Lacuneolimna* *novagallia*), all were exclusively found during the Late Holocene (~2.000 cal. yr. BP), suggesting that in this period the Xingu River probably had a well illuminated water column, low conductivity, oligotrophic and acidic waters (Moro & Fürstenberger 1993, Van Dam et al. 1994, Metzeltin & Lange-Bertalot 2007, Bahls *et al.* 2009, Tudesque *et al.* 2015).

Overall, considering the periods, 4 species exclusively occurred during the end of the Mid-Holocene, 20 in the Late Holocene, and an additional 14 species were indistinctly distributed throughout the core. The results indicate that this variation in diatoms species indicates water level changes in the Xingu River, so that at the end of the Mid-Holocene the system presented deep waters that gave way to shallower waters in the Late Holocene.

During the end of the Mid-Holocene, low abundance of diatoms species may be related to the deeper waters with hydrological flow. This finding is consistent with the results in studies in the Amazon Basin (*eg.* Cordeiro *et al.*, 2008, Moreira *et al.* 2013, Brugger *et al.* 2016, Fontes *et al.* 2017). In the Late Holocene the high abundance of diatoms species mainly benthic species suggest a shallower water conditions. Similar result was registered by Cardozo *et al.* (2014), in Lake Tota, Colombia during the Late Holocene and was attributed to a drier period with high temperatures and low precipitation.

These findings reinforce the use of the paleolimnological approach, which in many cases is the only tool available for assessing biodiversity over long time scale and pristine conditions prior to human impacts (Bennion & Simpson 2011, Gregory-Eaves & Beisner 2011).

LITERATURE CITED

Almeida, C.A., Coutinho, A.C., Esquerdo, J.C.D.M., Adami, M., Venturieri, A., Diniz, C.G., Dessay, N., Dirieux, L. & Gomes, A.R. 2016. High spatial resolution land use and land cover mapping of the Brazilian Legal Amazon in 2008 using Landsat-5/TM and MODIS data. Acta Amazonica 46(3): 291-302. doi:10.1590/1809-4392201505504

Almeida, F.F., Santos-Silva, E.N., Ector, L. & Wetzel, C.E. 2018. *Eunotia amazonica* sp. nov. (Bacillariophyta), a common stalk-forming species from the Rio Negro basin (Brazilian Amazon), European Journal of Phycology. doi: 10.1080/09670262.2017.1402372

Almeida, P.D. & Bicudo, D.C. 2014. Diatomáceas planctônicas e de sedimento superficial em represas de abastecimento da Região Metropolitana de São Paulo, SP, Sudeste do Brasil. Hoehnea 41(2): 187-207. doi: 10.1590/S2236-89062014000200004

Almeida, P.D., Wetzel, C.E., Morales, E.A., Ector, L. & Bicudo, D.C. 2015. *Staurosirella acidophila* sp. nov., a new araphid diatom (Bacillariophyta) from southeastern Brazil: ultrastructure, distribution and autecology. Cryptogamie, Algologie 36(3): 255-270. doi: 10.7872/crya/v36.iss3.2015.255

Almeida, P.D., Wetzel, C.E., Morales, E.A., Ector, L. & Bicudo, D.C. 2017. New species and combinations on *Fragilariforma* (Bacillariophyta) from tropical freshwater environments. Fottea 17(2): 277-292. doi:10.5507/fot.2017.006

Bahls, L. 2011. *Stauroneis anceps*. *In*: Diatoms of North America. Available in https://www.diatoms.org/species/stauroneis_anceps (last access on 28/03/2018).

Bahls, L., Potapova, M., Fallu, M.A. & Pienitz, R. 2009. *Aulacoseira canadensis* and *Aulacoseira crassipunctata* (Bacillariophyta) in North America. Nova Hedwigia 135: 167-184.

Bartozek, E.C.R., Bueno, N.C., Ludwig, T.A.V., Tremarin, P.I., Nardelli, M.S. & Rocha, A.C.R. 2013. Diatoms (Bacillariophyceae) of Iguaçu National Park, Foz do Iguaçu, Brazil. Acta Botanica Brasilica 27(1): 108-123. doi:10.1590/S0102-33062013000100012

Bartozek, E.C.R., Zorzal-Almeida, S. & Bicudo, D.C. 2018. Surface sediment and phytoplankton diatoms along a trophic gradient in tropical reservoirs: new records for Brazil and São Paulo State. Hoehnea 45(1): 69-92. doi:10.1590/2236-8906-51/2017

Battarbee, R.W., Jones, V.J., Flower, R.J., Cameron, N.G., Bennion, H., Carvalho, L. & Juggins, S. 2001. Diatoms. *In*: Smol, J.P., Birks, H.J.B. & Last, W.M. (eds.) Tracking environmental change using lake sediments, 3: terrestrial, algal, and siliceous indicators. Kluwer, Dordrecht. p. 155-202.

Bennion, H. & Simpson, G.L. 2011. The use of diatom records to establish reference conditions for UK lakes subject to eutrophication. Journal of Paleolimnology 45(4): 469-488. doi:doi.org/10.1007/s10933-010-9422-8

Bertassoli, D.J.Jr., Sawakuchi, A.O., Sawakuchi, H.O., Pupim, F.N., Hartmann, G.A., McGlue, M.M., Chiessi, C.M., Zabel, M., Schefuß, E., Pereira, T.S., Santos, R.A., Faustino, S.B., Oliveira, P.E. & Bicudo, D.C. 2017. The fate of carbon in sediments of the Xingu and Tapajós clearwater rivers, eastern Amazon. *Frontiers in Marine Science* 44 (4): 1-14. doi:10.3389/fmars.2017.00044

Bertolli, L.M., Tremarin, P.I. & Ludwig, T.A.V. 2010. Diatomáceas perifíticas em *Polygonum hydropiperoides* Michaux, reservatório do Passaúna, Região Metropolitana de Curitiba, Paraná, Brasil. Acta Botanica Brasilica 24(4): 1065-1081. doi: 10.1590/S0102-33062010000400022

Birks, H.J.B. 1994. The importance of pollen and diatom taxonomic precision in quantitative paleoenvironmental reconstructions. Review of Palaeobotany and Palynology 83: 107-117. doi:10.1016/0034-6667(94)90062-0

Brugger, S.O., Gobet, E., van Leeuwen, J.F.N., Ledru, M.P, Colombaroli, D., van der Knaap, W.O., Lombardo, U., Escobar-Torres, K., Finsinger, W., Rodrigues, L., Giesche, A., Zarate, M., Veit, H. & Tinner, W. 2016. Long-term man-environment interactions in the Bolivian Amazon: 8000 years of vegetation dynamics. Quaternary Science Reviews 132: 114-128. doi: 10.1016/j.quascirev.2015.11.001

Buczko, K. & Magyari, E. 2007. The Holocene diatom flora of Lake Saint Anna (Eastern Carapathians, Europe). Algological Studies 124: 1-28. doi: 10.1127/1864-1318/2007/0124-0001

Burliga, A.L., Kociolek, J.P., Salomoni, S.E. & Figueiredo, D. 2013. A new genus and species in the diatom Family Eunotiaceae Kützing (Bacillariophyceae) from the Amazonian hydrographic region, Brazil. Phytotaxa 79(2): 47-57.

Canani, L.G.C., Fraia, R.S. & Melo, S. 2018. Periphytic *Actinella* Lewis (Ochrophyta, Bacillariophyceae) species from an Environmental Protection Area in the Brazilian Amazon. Acta Limnologica Brasiliensia 30: e209. doi: 10.1590/s2179-975x7417

Cardozo, A.Y.V., Gomes, D.F., Silva, E.M., Duque, S.R.E., Rangel, J.O.C., Siffedine, A., Turcq, B. & Albuquerque, A.L.S. 2014. Holocene paleolimnological reconstruction of a high altitude Colombian tropical lake. Palaeogeography, Palaeoclimatolology, Palaeoecology. doi: 10.1016/j.palaeo.2014.03.013.

Cleve, P.T. 1894. Synopsis of the Naviculoid Diatoms, 1. Kongliga Svenska-Vetenskaps Akademiens Handlingar 26(2): 1-194.

Cleve, P. T. & Grunow, A. 1880. Beiträge zur Kenntniss der arctischen Diatomeen. Kongliga Svenska Vetenskaps-Akademiens Handlingar 17(2): 1-121.

Cordeiro, R.C., Turcq, B., Suguio, K., Silva, A.O., Sifeddine, A. & Volkmer-Ribeiro, C. 2008. Holocene fires in east Amazonia (Carajás), new evidences, chronology and relation with palaeoclimate. Global and Planetary Change 61: 49e62. doi: 10.1016/j.gloplacha.2007.08.005

Costa, L.F., Wengrat, S. & Bicudo, D.C. 2017a. Diatoms from distinct habitats of a highly heterogeneous reservoir, Billings Complex, southeastern Brazil. Hoehnea 44(4): 559-579. doi:10.1590/2236-8906-12/2017

Costa, L.F., Wetzel, C.E., Lange-Bertalot, H., Ector, L. & Bicudo, D.C. 2017b. Taxonomy and ecology of *Eunotia* species (Bacillariophyta) in southeastern Brazilian reservoirs. *In:* Lange-Bertalot, H. & Kociolek, J.P. (eds). Bibliotheca Diatomologica 64: 1-302.

Coste, M., Boutry, S., Delmas, F., Merona, B.D.E. & Cerdan, P. 2010. Diatomées des eaux courantes de Guyane: essai de biotypologie et application au diagnostic du bon état écologique. Cemagref U.R. 41 p.

Czarnecki, D.B. 1994. The freshwater diatoms culture collection at Loras College, Dubuque, Iowa. *In:* Kockiolek, J.P. (ed.). Proceedings of the 11th International Diatom Symposium. Memoirs of the California Academy of Sciences 17: 155-174.

Davidson, T.A. & Jeppesen, R. 2013. The role of palaeolimnology in assessing eutrophication and its impact on lakes. Journal of Paleolimnology 49: 391-410. doi: 10.1007/s10933-012-9651-0

Ehrenberg, C.G. 1832. Über die Entwickelung und Lebensdauer der Infusionsthiere; nebst ferneren Beiträgen zu einer Vergleichung ihrer organischen Systeme. Abhandlungen der Königlichen Akademie Wissenschaften zu Berlin, Physikalische Klasse, 1831: 1-154.

Ehrenberg, C.G. 1838. Die Infusionsthierchen als vollkommene Organismen. Ein Blick in das tiefere organische Leben der Natur. Leipzig: Verlag von Leopold Voss. pp. i-xviii, 1-4, 1-547.

Ehrenberg, C.G. 1840. Characteristik von 274 neuen Arten von Infusorien. Bericht über die zur Bekanntmachung geeigneten. Verhandlungen der Königlich-Preussischen Akademie der Wissenschaften zu Berlin 1840: 197-219.

Ehrenberg, C.G. 1841. Über Verbreitung und Einflufs des mikroskopischen Lebens in Süd-und Nordamerika: Bericht über die zur Bekanntmachung geeigneten. Verhandlungen der Königlich-Preussischen Akademie der Wissenschaften zu Berlin 1841: 139-144.

Ehrenberg, C.G. 1843. Verbreitung und Einfluss des mikroskopischen Lebens in Süd-und Nord-Amerika. Abhandlungen der Königlichen Akademie der Wissenschaften zu Berlin 1841: 291-466.

Ehrenberg, C.G. 1845. Neue Untersuchungen über das kleinste Leben als geologisches Moment. Bericht über die zur Bekanntmachung geeigneten. Verhandlungen der Königlich-Preussischen Akademie der Wissenschaften zu Berlin 1845: 53-87.

Faustino, S.B., Fontana, L., Bartozek, E.C.R., Bicudo, C.E.M. & Bicudo, D.C. 2016. Composition and distribution of diatom assemblages from core and surface sediments of water supply reservoir in Southeastern Brazil. Biota Neotropica 16(2): e20150129. doi: 10.1590/1676-0611-BN-2015-0129

Ferreira, K.S.M. & Bicudo, C.E.M. 2017. Criptógamos do Parque Estadual das Fontes do Ipiranga, São Paulo, SP. Algae, 42: Bacillariophyceae (Surirellales). Hoehnea 44(1): 10-28. doi:10.1590/2236-8906-34/2016

Fontes, D., Cordeiro, R.C., Martins, G.S., Behling, H., Turcq, B., Sifeddine, A., Seoane, J.C.S., Moreira, L.S. & Rodrigues, R.A. 2017. Paleoenvironmental dynamics in South Amazonia, Brazil, during the last 35,000 years inferred from pollen and geochemical records of Lago do Saci. Quaternary Science Reviews 173: 161-180. doi:10.1016/j.quascirev.2017.08.021

Fourtanier, E. & Kociolek, J.P. 2011. Catalogue of Diatoms Names. California Academy of Sciences. Available in http://researcharchive.calacademy.org/research/diatoms/names/index.asp (access in 28-III-2018).

Garcia, M. 2010. A new diatom genus: *Rimoneis* M.Garcia (Fragillariaceae, Bacillariophyceae): a new hyaline araphid genus based on observations of frustules from Southern Brazil. Diatom 26: 1-9. doi: 10.11464/diatom.26.1

Gregory-Eaves, I. & Beisner, B.E. 2011. Palaeolimnological insights for biodiversity science: an emerging field. Freshwater Biology 56: 2653-2661. doi:10.1111/j.1365-2427.2011.02677.x

Grunow, A. 1862. Die Österreichischen Diatomaceen nebst Anschluss einiger neuen Arten von andern Lokalitäten und einer kritischen Uebersicht der bisher bekannten Gattungen und Arten. Verhandlungen der kaiserlich-königlichen zoologisch-botanischen Gesellschaft in Wien 12: 315-472 (Abt 1), 545-588 (Abt. 2).

Grunow, A. 1868. Algae. *In* Reise der österreichischen Fregatte Novara um die Erde in den Jahren 1857, 1858, 1859 unter den Befehlen des Commodore B. von Wüllerstorf-Urbair. Botanischer Theil. Sporenpflanzen. (Fenzl, E. et al. Eds). Aus der Kaiserlich Königlichen Hof- und Staatsdruckeri in Commission bei Karl Gerold's Sohn. pp. 1-104.

Hermany, G., Souza, P.A. & Torgan, L.C. 2013. Paleoecologia do sistema Pinguela-Palmital-Malvas, Holoceno da Bacia de Pelotas, RS, Brasil: uma abordagem focada na utilização de análises multivariadas para obtenção de diatomáceas descritoras. Pesquisa em Geociências 40(1): 31-49. doi:10.22456/1807-9806.40833

Hustedt, F. 1937. Systematische und ökologische Untersuchungen über die Diatomeen-Flora von Java, Bali und Sumatra nach dem Material der Deutschen Limnologischen Sunda-Expedition. Archiv für Hydrobiologie (Supplement) 15(2): 178-295.

Hustedt, F. 1952. Neue und wenig bekannte Diatomeen, 4. Botaniska Notiser 1952: 366-410.

Instituto Socioambiental (ISA). 2012. De olho na Bacia do Xingu. Série Cartô Brasil Socioambiental 5. 63. Available in: https://www.socioambiental.org/sites/blog.socioambiental.org/files/publicacoes/de-olho-bacia-xingu_150dpi.pdf (access on 08-VIII-2018).

Kobayashi, H., Idei, M., Mayama, S., Nagumo, T. & Osada, K. 2006. Kobayashi hiromu keiso zukan. H.Kobayasi's atlas of Japanese diatoms based on electron microscopy. Tokyo: Uchida Rokakuho Publishing Co., Ltd. 531 p.

Krammer, K. 1991. Morphology and taxonomy of some taxa in the genus *Aulacoseira* Thwaites (Bacillariophyceae), 1: *Aulacoseira distans* and similar taxa. Nova Hedwigia 52(1-2): 89-112, pl. 1-10.

Krammer, K. & Lange-Bertalot, H. 1986. Bacillariophyceae, 1: Naviculaceae. *In*: Ettl, H., J. Gerloff, H. Heynig and D. Mollenhauer (eds.) Süsswasserflora von Mitteleuropa, Band 2-1. Gustav Fisher Verlag, Jena. 876 p.

Kociolek, P. 2011. *Gomphonema acuminatum*. *In*: Diatoms of North America. https://diatoms.org/species/gomphonema_acuminatum (access in 08-VIII-2018).

Kulikovskiy, M., Maltsev, Y., Glushchenko, A., Kuznetsova, I., Kapustin, D., Gusev, E., Lange-Bertalot, H., Genkal, S. & Kociolek, J.P. 2020. *Gogorevia*, a new monoraphid diatom genus for *Achnanthes exigua* and allied taxa (Achnanthidiaceae) described on the basis of an integrated molecular and morphological approach. Journal of Phycology. 10.1111/jpy.13064-20-010.

Kützing, F.T. 1844. Die Kieselschaligen Bacillarien oder Diatomeen. Nordhausen: zu finden bei W. Köhne pp. i-vii, 1-152.

Kützing, F.T. 1849. Species algarum. Leipzig F.A. Brockhaus pp. i-vi, 1-922.

Lange-Bertalot, H. 1993. 85 Neue Taxa und über 100 weitere neu definierte Taxa ergänzend zur Süßwasserflora von Mitteleuropa. Bibliotheca Diatomologica 27: 1-454.

Lange-Bertalot, H. & Metzeltin, D. 1996. Indicators of oligotrophy. 800 taxa representative of three ecologically distinct lake types, carbonate buffered-Oligodystrophic-weakly buffered soft water with 2428 figures on 125 plates. Oligotrophie-Indikatoren. Iconographia Diatomologica 2: 1-390.

Lange-Bertalot, H., Bak, M. & Witkowski, A. 2011. Diatoms of the European inland water and comparable habitats: *Eunotia* and some related genera. *In:* Lange-Bertalot, H.(ed.). Diatoms of Europe 6: 1-747.

Lehmkuhl, E.A., Morales, E.A., Tremarin, P.I., Bartozek, E.C.R., Zorzal-Almeida, S., Ludwig, T.A.V. & Bicudo, C.E.M. 2009. Two new species of *Nitzschia* (Bacillariaceae, Bacillariophyta) from tropical reservoirs of southeastern Brazil. Phytotaxa 399: 83-99. doi:10.11646/phytotaxa.399.1.9

Le Treut, H., Somerville, R., Cubasch, U., Ding, Y., Mauritzen, C., Mokssit, A., Peterson, T. & Prather, M. 2007. Historical overview of climate change. In Climate Change 2007: the physical science basis. *In:* Solomon, S., Qin, D., Manning, M., Chen, Z., Marquis, M., Averyt, K.B., Tignor, M. & Miller, HL. (eds.). Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge. p. 94-122.

Levkov, Z., Metzeltin, D. & Pavlov, A. 2013. Diatoms of Europe: Diatoms of the European inland waters and comparable habitats. Vol. 7. Koeltz Scientific Books.

Mann, D.G., McDonald, S.M., Bayeri, M.M., Droop, S.M., Chepurnovi, V.A., Loke, R.E., Ciobanu, A. & Du Buf, J.M.H. 2004. The *Sellaphora pupula* species complex (Bacillariophyceae): morphometric analysis, ultrastructure and mating data provide evidence for five new species. Phycologia 43(4): 459-482. doi: 10.2216/i0031-8884-43-4-459.1

Mann, D.G., Thomas, S.J. & Evans, K.M. 2008. Revision of the diatom genus *Sellaphora*: a first account of the larger species in the British Isles. Fottea 8(1): 15-78. doi:10.5507/fot.2008.002

Medlin, L.K. & Kaczamarska, I. 2004. Evolution of the diatoms, 5: morphological and cytological support for the major clades and taxonomic revision. Phycologia 43: 245-270. doi: 10.2216/i0031-8884-43-3-245.1

Mereschkowsky, C. 1902. On *Sellaphora,* a new genus of diatoms. Annals and Magazine of Natural History: Series 7, 9: 185-195.

Metzeltin, D. & Lange-Bertalot, H. 1998. Tropical Diatoms of South America, 1: about 700 predominantly rarely know or new taxa representative of the neotropical flora. *In*: Lange-Bertalot, H. (ed). Iconographia Diatomologica 5: 1-695.

Metzeltin, D. & Lange-Bertalot, H. 2007. Tropical diatoms of South America, 2: annotated diatom micrographs. Lange-Bertalot, H. (ed). Iconographia Diatomologica 18: 1-877.

Metzeltin, D., Lange-Bertalot, H. & Garcia-Rodríguez, F. 2005. Diatoms of Uruguay compared with other taxa from South America and elsewhere. *In:* Lange-Bertalot. (ed). Iconographia Diatomologica 15: 1-736.

Morales, E.A. 2005. Observations of the morphology of some known and new fragilarioid diatoms (Bacillariophyceae) from rivers in the USA. Phycological Research 53: 113-133. doi: 10.1111/j.1440-183.2005.00378.x

Morales, E.A. 2010. *Staurosira construens*. *In*: Diatoms of North America. Available in https://diatoms.org/species/staurosira_construens (access in 03-IV-2018).

Morales, E. & Manoylov, K. M. 2006. Morphological studies on selected taxa in the genus *Staurosirella* Williams et Round (Bacillariophyceae) from rivers in North America. Diatom Research 21(2): 343-364. doi: 10.1080/0269249X.2006.9705674

Moreira, L.S., Moreira-Turcq, P., Cordeiro, R.C., Turcq, B., Caquineau, S., Viana, J.C.C. & Brandini, N. 2013. Holocene palaeoenvironmental reconstruction in the eastern Amazonian basin: Comprido lake. Journal of South America Earth Sciences 44: 55e62. doi: 10.1016/j.jsames.2012.12.012

Moro, R.S. & Fürstenberg, C.B. 1993. Diatomáceas (Bacillariophyceae) da Lagoa Dourada (Parque Estadual de Vila Velha), Paraná, Brasil. Acta Biológica Paranaense 22(1-4): 15-30.

Patrick, R. & Reimer, C.W. 1966. The Diatoms of the United States. Vol. 1. The Academy of Natural Sciences of Philadelphia, 688 p.

Pavlov, A. & Levkov, Z. 2013. Diversity and distribution of taxa in the genus *Eunotia* Ehrenberg (Bacillariophyta) in Macedonia. Phytotaxa 86(1): 1-117. doi: 10.11646/phytotaxa.86.1.1

Pereira, A.C., Torgan, L.C., Burliga, J.P.K., Wetzel, C.E., Ector, L. & Melo, S. 2015. *Pinnularia caprichosa* sp. nov.: a diatom from a black water Brazilian Amazon system. Phytotaxa 239(3): 280-286. doi:10.11646/phytotaxa.239.3.9

Pereira, A.C., Torgan, L.C. & Melo, S. 2013. *Pinnularia* Ehrenberg (Bacillariophyceae) de um lago de inundação amazônico (lago Tupé, Amazonas, Brasil). Iheringia: Série Botânica 68(1): 91-101.

Pereira, A.C., Torgan, L.C. & Melo, S. 2014. Four new *Pinnularia* Ehrenberg (Bacillariophyta, Pinnulariaceae) species from Amazonian black water (Yupé Lake, Amazonas State, Brazil). Phytotaxa 158(2): 154-168. doi:10.11646/phytotaxa.158.2.3

Pereira, A.C., Torgan, L.C. & Melo, S. 2017. *Pinnularia* (Bacillariophyta, Pinnulariaceae) dos cursos superior e médio do rio Negro e de tributários, Amazonas, Brasil. Boletim do Museu Paraense Emilio Goeldi, Ciências Naturais 12(1): 49-74.

Plano Nacional de Recursos Hídricos PNRH. 2006. Síntese Executiva. Ministério do Meio Ambiente, Secretaria de Recursos Hídricos. Brasília: MMA. 135 p.

Potapova, M. 2011. *Navicula notha. In:* Diatoms of North America. Available in https://diatoms.org/species/navicula_notha (access in 03-IV-2018).

Reichardt, E. 1995. Die Diatomeen (Bacillariophyceae) in Ehrenberg's material von Cayenne, Guyana Gallica (1843). *In:* Lange-Bertalot (ed.). Iconographia Diatomologica. Koeltz Scientific Books. Königstein. Vol. 1: 7-99.

Reichardt, E. 2005. Die Identität von *Gomphonema entolejum* Østrup (Bacillariophyceae) sowie Revision änlicher Arten mit weiter Axialarea. Nova Hedwigia 81(1-2): 115-144. doi:10.1127/0029-5035/2005/0081-0115

Reichardt, E. 2015. Gomphonema gracile Ehrenberg sensu stricto et sensu auct. (Bacillariophyceae): A taxonomic revision. Nova Hedwigia 101(3-4): 367-393. doi: 10.1127/nova_hedwigia/2015/0275

Reid, M. 2005. Diatom based models for reconstructing past water quality and productivity in New Zealand Lakes. Journal of Paleolimnology 33(1): 13-38. doi:doi.org/10.1007/s10933-004-0424-2

Ribeiro, F.C.P., Senna, C.S.F. & Torgan, L.C. 2010. The use of diatoms for paleohydrological and paleoenvironmental reconstructions of Itupanema beach, Pará state, Amazon region, during the last millennium. Revista Brasileira de Paleontologia 13(1): 21-32. doi:10.4072/rbp.2010.1.03

Round, F.E., Crawford, R.M. & Mann, D.G. 1990. The diatoms: biology and morphology of the genera. Cambridge University Press, New York.

Ruwer, D.T. & Rodrigues, L. 2018. Abundance of *Diadesmis confervacea* Kützing and *Eunotia camelus* Ehrenberg indicates the historical water level variation in a marsh. Brazilian Journal of Botany 41: 241. doi:10.1007/s40415-017-0438-4

Santos, E.M.,Tremarin, P.I. & Ludwig, T.A.V. 2011. Diatomáceas perifíticas em *Potamogeton polygonus* Cham. & Schltdl.: citações pioneiras para o Estado do Paraná. Biota Neotropica 11(3): 303-315. doi:10.1590/S1676-06032011000300025.

Sawakuchi, A.O., Hartmann, G.A., Sawakuchi, H.O., Pupim, F.N., Bertassoli, D.J., Parra, M., Antinao, J.L., Sousa, L.M., PérezSabaj, M.H., Oliveira, P.E., Santos, R.A., Savian, J.F., Grohmann, C.H., Medeiros, V.B., Mcglue, M.M., Bicudo, D.C. & Faustino, S.B. 2015. The Volta Grande do Xingu: reconstruction of past environments and forecasting of future scenarios of a unique Amazonian fluvial landscape. Scientific Drilling 3: 1-12. doi: 10.5194/sd-20-21-2015

Simonsen, R. 1979. The diatom system: ideas on phylogeny. Bacillaria 2: 9-71.

Smol, J.P. 2002. Pollution of lakes and rivers: a paleolimnological perspective. Arnold, London, 280 p.

Smol, J.P. 2008. Pollution of lakes and rivers: a paleoenvironmental perspective. 2nd ed. 383 p.

Souza, M.G.M. & Senna, P.A.C. 2009. Diatomáceas epilíticas da subordem Sellaphorineae do rio do Monjolinho, São Carlos, SP, Brasil. Acta Botanica Brasilica 23: 618-629. doi:10.1590/S0102-33062009000300002

Suguio, K. 1999. Geologia do Quaternário e mudanças ambientais: passado + presente = futuro? São Paulo, Paulo Comunicação e Artes Gráficas. 366 p.

Taylor, J. C., Cocquyt, C., Karthick, B. & van de Vijver, B. 2014. Analysis of the type of Achnnathes exigua Grunow (Bacillariophyta) with the description of a new Antarctic diatom species. Fottea 14: 43-51. doi:10.5507/fot.2014.003

Terry, W.A. 1907. A partial list of Connecticut diatoms with some account of their distribution in certain parts of the state. Rhodora 9(104): 125-140.

Tremarin, P.I., Bertolli, L.M., Faria, D.M., Costin, J.C. & Ludwig, T.A.V. 2009. *Gomphonema* Ehrenberg e *Gomphosphenia* Lange-Bertalot (Bacillariophyceae) do Rio Maurício, Paraná, Brasil. Biota Neotropica 9: 111-130. doi:10.1590/S1676-06032009000400013

Tremarin, P.I., Ludwig, T.A.V. & Torgan, L.C. 2014a. Four new *Aulacoseira* species (Coscinodiscophyceae) from Matogrossense Pantanal, Brazil. Diatom Research 29(2): 183-199. Aquatic Ecology 28: 117-133. doi:10.1080/0269249X.2014.880072

Tremarin, P.I., Ludwig, T.A.V. & Torgan, L.C. 2014b. *Aulacoseira veraluciae* sp. nov. (Coscinodiscophyceae, Aulacoseiraceae): a common freshwater diatom from Brazil. Phytotaxa 184: 208-222. doi:10.11646/phytotaxa.184.4.2

Tremarin, P.I., Paiva, R.S., Ludwig, T.A.V. & Torgan, L.C. 2013. *Aulacoseira calypsi* sp. nov. (Coscinodiscophyceae) from an Amazonian lake, northern Brazil. Phycological Research 61: 292-298. doi:10.1111/pre.12031

Tudesque, L., Le Cohu, R., Coste, M. &Lange-Bertalot, H. 2015. *Lacuneolimna* gen. nov., *Lacuneolimna zalokariae* comb. nov. and *Lacuneolimna novagallia* spec. nov. (Bacillariophyceae) from the French Guiana diatom freshwater flora. Phytotaxa 231(1): 019-030. doi:10.11646/phytotaxa.231.1.2

Tyree, M. & Vaccarino, M. 2016. *Gomphonema pseudosphaerophorum*. *In:* Diatoms of North America. https://diatoms.org/species/gomphonema_pseudosphaerophorum (access on 08-VIII-2018).

van Dam, H., Mertens, A. & Sinkeldam, J. 1994. A coded checklist and ecological indicator values of freshwater diatoms from the Netherlands. Netherlans Journal of Aquatic Ecology 28: 117-133. Doi: http://dx. doi.org/10.1007/BF02334251.

Walkers, J.D. & Geissman, J.W. 2009. GSA geologic time scale. GSA Today 19: 60-61

Wallace, J.H. 1960. New and variable diatoms. Notulae Naturae (Philadelphia) 331: 1-8.

Wengrat, S., Padial, A.A., Jeppesen, E., Davidson, T.A., Fontana, L., Costa-Böddeker, S. & Bicudo, D.C. 2018. Paleolimnological records reveal biotic homogenization driven by eutrophication in tropical reservoirs. Journal of Paleolimnology 60(2): 299-309. doi:10.1007/s10933-017-9997-4

Wetzel, C.E., Ector, L., Hoffmann, L. & Bicudo, D.C. 2010a. Colonial planktonic *Eunotia* (Bacillariophyceae) from Brazilian Amazon: taxonomy and biogeographical considerations on the *E. asterionelloides* species complex. Nova Hedwigia 91: 49-86. doi:10.1127/0029-5035/2010/0091-0049

Wetzel, C.E., Ector, L., Hoffmann, L., Lange-Bertalot, H. &Bicudo, D.C. 2011. Two new periphytic *Eunotia* species from the neotropical Amazonian ‘black waters’, with a type analysis of *E. braunii*. Diatom Research 26: 135-146. doi:10.1080/0269249X.2011.587644

Wetzel, C.E., Lange-Bertalot, H., Morales, E.A., Bicudo, D.C., Hoffmann, L. & Ector, L. 2012a. *Bicudoa amazonica* gen. nov. et sp. nov. (Bacillariophyta): a new freshwater diatom from the Amazon basin with a complete raphe loss in the *Eunotioid* lineage. Phytotaxa 75: 1-18. doi:10.11646/phytotaxa.75.1.1

Wetzel, C.E., van De Vijver, B., Cox, E.J., Bicudo, D.C. & Ector, L. 2012b. *Tursiocola podocnemicola* sp. nov., anew epizoic freshwater diatom species from the Rio Negro in the Brazilian Amazon Basin. Diatom Research 27: 1-8. doi:10.1080/0269249X.2011.642498

Wetzel, C.E., van de Vijver, B. & Ector, L. 2010b. *Luticola deniseae* sp. nov.: a new epizoic diatom from the Rio Negro (Amazon hydrographic Basin). Vie et Milieu 60: 177-184.

Wetzel, C.E. & Ector, L. 2014. Taxonomy, distribution and autecology of *Planothidium bagualensis* sp. nov. (Bacillariophyta) a common monoraphid species from southern Brazilian rivers. Phytotaxa 156(4): 201-210. doi:10.11646/phytotaxa.156.4.2

Wetzel, C.E., Ector, L., van de Vijver, B., Compère, P. & Mann, D.G. 2015. Morphology, typification and critical analysis of some ecologically important small naviculoid species (Bacillariophyta). Fottea 15(2): 203-234. doi:10.5507/fot.2015.020

Williams, D.M. & Round, F.E. 1988. Revision of the genus *Fragilaria*. Diatom Research 2: 267-288. doi:10.1080/0269249X.1987.9705004

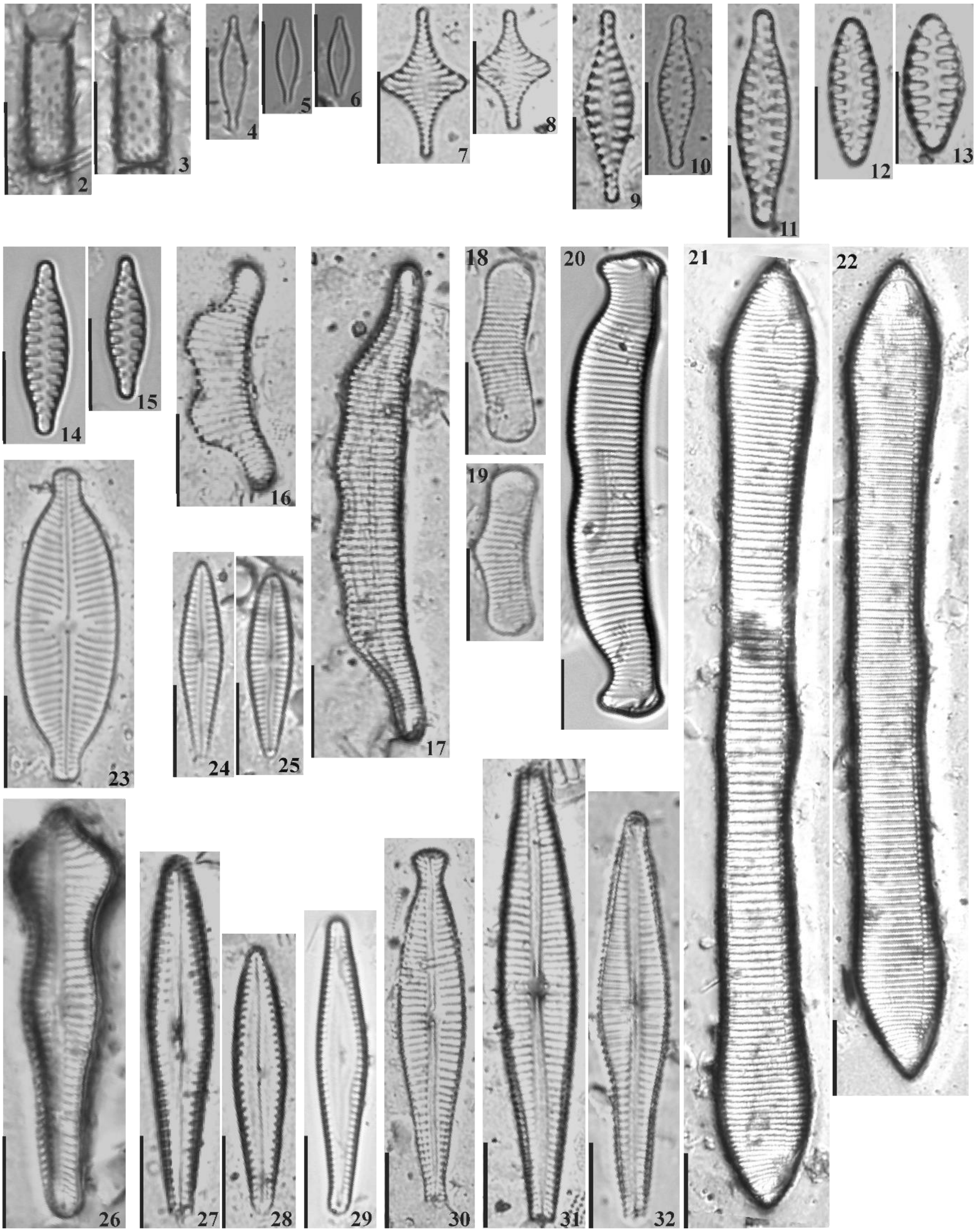
Legends of figures

Figure 1A-C. Location of the sampling site. A. Amazon basin, B. Xingu River basin, C. Location of the floodplain lake on Arapujá island (XC1-02) and Xingu *ria* (XC-03). Maps adapted from Sawakuchi *et al*. (2015), Almeida *et al*. (2016) and Bertassoli *et al*. (2017).

Figures 2-32. Diatoms of Xingu core. 2-3. *Aulacoseira* cf. *crassipunctata*. 4-6. *Rimoneis* sp. 7-8. *Staurosira* sp. 9-10. *Staurosirella acidophila*. 11. *Staurosirella* cf. *acutirostrata*. 12-13. *Staurosirella dubia*. 14-15. *Staurosirella subcapitata*. 16. *Eunotia camelus*. 17. *Eunotia longicamelus*. 18-19. *Eunotia rabenhorstii* var. *monodon*. 20. *Eunotia superbidens*. 21-22. *Eunotia* sp. 23. *Placoneis* sp. 24-25. *Gomphonema auritum*. 26. *Gomphonema acuminatum*. 27-28. *Gomphonema brasiliensoides*. 29. *Gomphonema curvipedatum*. 30. *Gomphonema pseudosphaerophorum*. 31-32. *Gomphonema* sp. Scale bar = 10 µm.

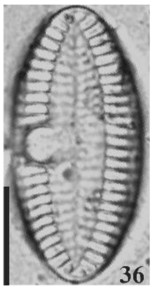
Figures 33-50. Diatoms of Xingu core. 33-34. *Gogorevia exilis*. 35-36. *Planothidium pulcherrimum*. 37-38. *Achnanthes* cf. *inflata*. 39-40. *Luticola intermedia*. 41-42. *Caloneis* sp. 43-45. *Diploneis elliptica* var. *elliptica*. 46-47. *Navicula notha*. 48. *Sellaphora emilia*. 49-50. *Sellaphora rectangularis*. Scale bar = 10 µm.

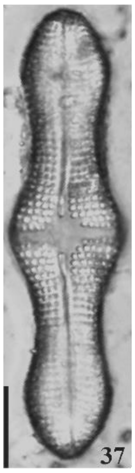
Figures 51-66. Diatoms of Xingu core. 51-52. *Sellaphora renata*. 53-54. *Sellaphora sassiana*. 55. *Sellaphora ventraloconfusa*. 56. *Lacuneolimna novagallia*. 57. *Pinnularia* cf. *liyanlingae*. 58-59. *Stauroneis* cf. *sylviabonillae*. 60-62. *Stauroneis* sp. 63-64. *Nitzschia pusilluhasta*. 65-66. *Surirella* sp. Scale bar = 10 µm.

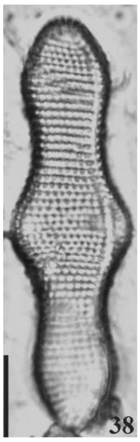

2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32


33


35

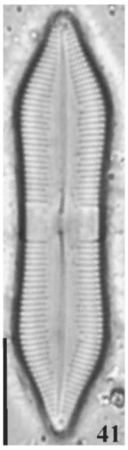

36

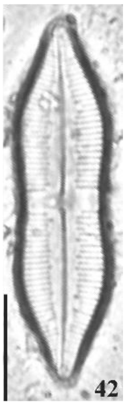

37

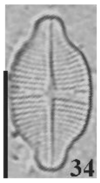

38

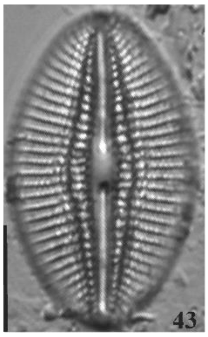

39

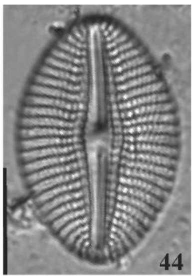

40

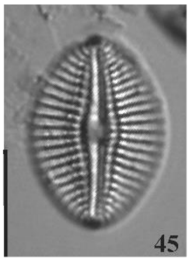

41

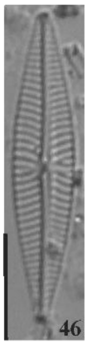

42


34


43

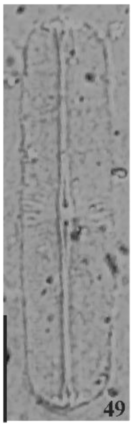

44

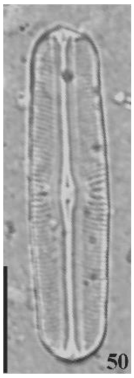

45

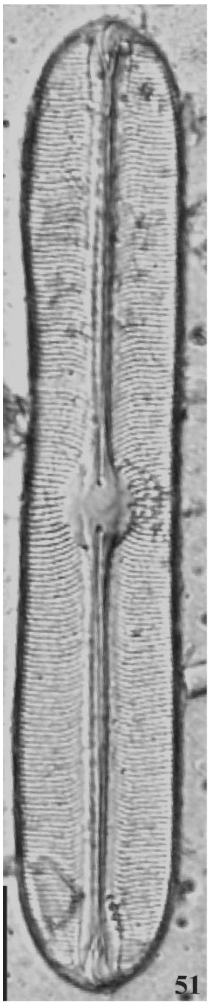

46

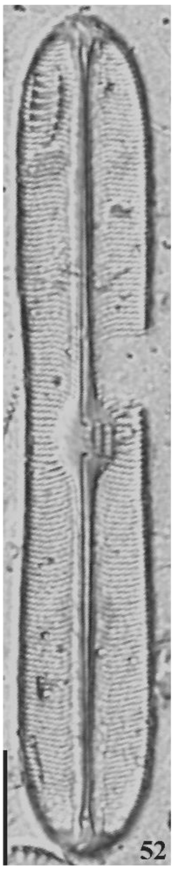

47


48


49

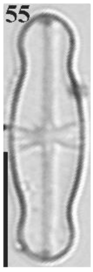

50


51

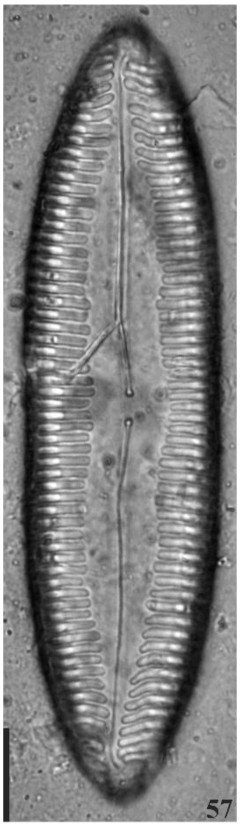

52

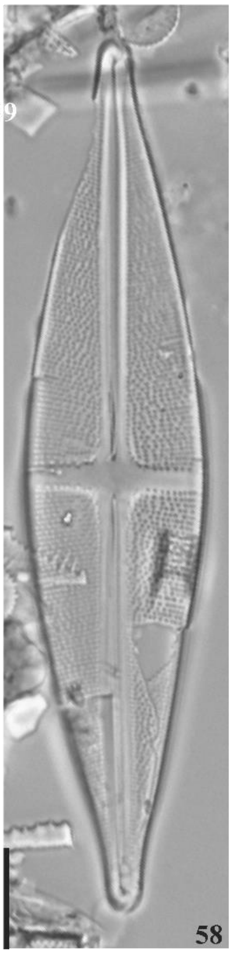

53

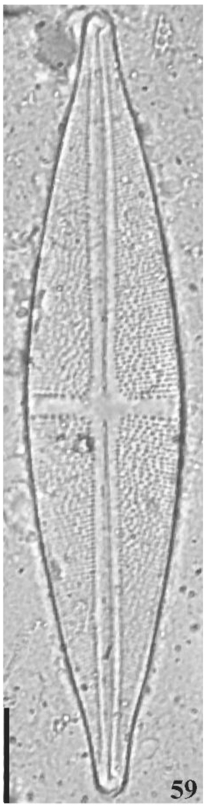

54

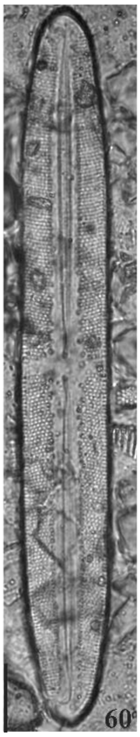

55


56

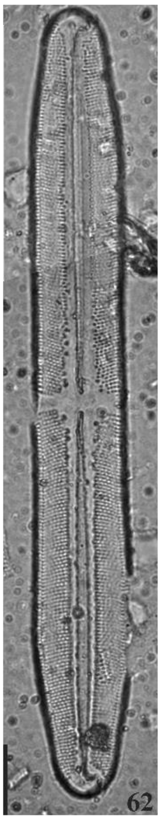

57

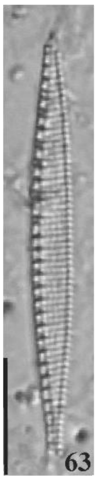

58


59


60

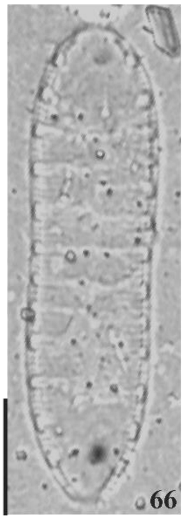

61


62


63


64


65


66