

# Morphological variation and distribution of the freshwater diatom *Aulacoseira ambigua* (Grunow) Simonsen in Brazilian continental environments

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**ABSTRACT** – *Aulacoseira ambigua* has a worldwide distribution and its occurrence and ultrastructure are well documented, mainly for North America and Europe. Very few studies on the morphology from Brazilian specimens have been developed. The aim of this paper is to describe the morphological variability and ultrastructure of *A. ambigua* based on the analysis of 123 samples from different Brazilian geographic regions, compare their morphology with that of similar species presents in the literature and to extend the knowledge of its distribution in the country. *Aulacoseira ambigua* is characterized mainly by the obliquely-curved striae in the mantle, areolae occluded by vola, external slit of rimoportula oblique and near the collum, and a hollow and narrow ringleist.

**Key-words:** *Coscinodiscophyceae*, taxonomy, ultrastructure

**RESUMO** – **Varição morfológica e distribuição da diatomácea de água doce *Aulacoseira ambigua* (Grunow) Simonsen em ambientes continentais brasileiros.** *Aulacoseira ambigua* é uma espécie de ampla distribuição mundial, cuja ocorrência e ultraestrutura foram bem documentadas, principalmente, para a América do Norte e Europa. Raros estudos sobre a morfologia da espécie foram desenvolvidos no Brasil. O presente trabalho descreve a ultraestrutura de *A. ambigua* com base na análise de 123 amostras de diferentes regiões brasileiras, compara sua morfologia com a de espécies semelhantes presentes na literatura e amplia sua distribuição no país. *Aulacoseira ambigua* caracteriza-se, principalmente, por apresentar estrias do manto oblíquo-curvadas, aréolas ocluídas por vola, abertura externa da rimopórtula oblíqua próxima ao colo, ringleist oco e pouco profundo.

**Palavras-chave:** *Coscinodiscophyceae*, taxonomia, ultraestrutura

## INTRODUCTION

The genus *Aulacoseira* Thwaites is exclusive of continental waters and has worldwide distribution. Generally, it represents an important component of the phytoplankton of eutrophic lakes, lagoons and rivers, and it is also present in oligotrophic waters (Haworth, 1988; Denys *et al.*, 2003).

The genus is mainly characterized by having cylindrical frustules united in chains by means of linking spines of varying size and number (Round

*et al.*, 1990). Recent studies have defined important characters for distinguishing species and varieties of *Aulacoseira* as mantle height, ultrastructure and shape of spines, density, size and distribution pattern of the areolae, as well as location, number and shape of rimoportulae (Siver & Kling, 1997; Crawford & Likhoshway, 1998; Likhoshway & Crawford, 2001, Edgar & Theriot, 2003; Houk, 2003; Houk & Klee, 2007; Potapova *et al.*, 2008).

*Aulacoseira ambigua* was described by Grunow in Van Heurck (1882) and has since been commonly

found in various regions of the world. In Brazil, the species was reported for the states of Bahia, Ceará, Distrito Federal, Goiás, Mato Grosso do Sul, Minas Gerais, Paraná, Pernambuco, Rio Grande do Sul, Rio de Janeiro, Santa Catarina and São Paulo (Patrick, 1940; Costa & Torgan, 1991; Rodrigues, 1991; Bicudo *et al.*, 1993; Torgan *et al.*, 1999; Silva *et al.*, 2001; Cardoso & Motta-Marques, 2004; Algarte *et al.*, 2006; Henry *et al.*, 2006; Raupp *et al.*, 2006; Perbiche-Neves *et al.*, 2007, 2011; Tremarin *et al.*, 2009; Bertolli *et al.*, 2010; Eskinazi-Leça *et al.*, 2010; Silva *et al.*, 2010; Silva *et al.*, 2011; Dunk *et al.*, 2012; Cavalcante *et al.*, 2013).

The ultrastructure of the frustule of *A. ambigua* is well documented, mainly from temperate environments of North America and Europe (e.g. Kobayasi & Nozawa, 1981, Krammer & Lange-Bertalot, 1991; Le Cohu, 1991; Siver & Kling, 1997; Houk & Klee, 2007). Papers documenting details on the morphology of the species based on Brazilian samples are scarce (e.g. Raupp *et al.*, 2006). The present study describes the ultrastructure of *A. ambigua* based on 123 samples collected from different Brazilian regions and compares its morphology with that of similar species, such as *A. italica* (Ehrenberg) Simonsen and *A. valida* (Grunow) Krammer.

## MATERIAL AND METHODS

Six periphyton samples and 117 phytoplankton samples were collected from different Brazilian regions (Table 1). The phytoplankton material was collected at the water subsurface with a Van Dorn bottle and fixed with Lugol solution (1%). Further samples were collected with the aid of a plankton net or scraping the stems and roots of submerged

macrophytes to obtain periphyton, later preserved in Transeau solution (1:1) (Bicudo & Menezes, 2006). The organic material was removed by addition of KMnO<sub>4</sub> and HCl according to Simonsen (1974) modified by Moreira-Filho & Valente-Moreira (1981). Slides were mounted with Naphrax® (R.I. 1.74) and examined with an Olympus BX40 light microscope (LM). Illustrations of the specimens examined were obtained with an Olympus DP71 image capture equipment. Some material was used in the preparation of supported aluminum coated with gold palladium at 1 kV for 5 min. in a Balzers SCD030 sputter coater. The samples were analyzed by scanning electron microscope (SEM) JEOL JSM 6360LV operated at 15 kV and 8 mm WD. The slides and material studied were deposited in the Herbariums HAS, UPGB, INPA, SP and UFG in Brazil (Table 1). The terminology used in the species description was based on Round *et al.* (1990), Siver & Kling (1997), Houk (2003) and Houk & Klee (2007).

## RESULTS AND DISCUSSION

*Aulacoseira ambigua* (Grunow) Simonsen, Bacil. 2: 56, 1979. *Melosira crenulata* var. *ambigua* Grunow in Van Heurck, Syn. Diat. Belg., pl. 88, figs 12-15, 1882. *Melosira granulata* var. *ambigua* (Grunow) Thum, Inst. Mikros., 1889. *Melosira ambigua* (Grunow) Otto Müller, Ber. Deut. Bot. Gess., 1903. *Melosira italica* f. *ambigua* (Grunow) Balachonzew, Ber. Mag. St. Peters., 1909. *Melosira italica* var. *ambigua* (Grunow) A. Cleve-Euler in Backmann & Cleve-Euler, Acta Forest. Fenn., 1922. *Melosira italica* subsp. *ambigua* (Grunow) Cleve-Euler, Botaniska Notiser, 1938. *Melosira italica* var. *ambigua* (Grunow) Cleve-Euler, Kongl. Sven. Vet.-Akad. Handl., 1951.

**Table 1.** Data of the analyzed samples and register numbers in Herbariums of the Research Institutions in Brazil.

State	Municipality	Site	Sampling date	Collector	Register number
Alagoas	.....	São Francisco river	22.V.2004	Brasil das Águas Project	slide nº. 6.298
Alagoas	Marechal Deodoro	Manguaba lake	17.V.2004	Brasil das Águas Project	slide nº. 6.297
Amazonas	Santarém	Tupé lake	XII.2003	A.C. Pereira, s.n.	INPA 223.907
Amazonas	Itacoatiara	Madeira river	21.X.2004	Brasil das Águas Project	slide nº. 6.270
Amazonas	Borba	Canumã river	02.XII.2004	Brasil das Águas Project	slide nº. 6.276
Amazonas	Novo Aripuanã	Aripuanã river	09.XI.2004	Brasil das Águas Project	slide nº. 6.278
Amazonas	Codajás	Piorini river	18.XI.2004	Brasil das Águas Project	slide nº. 6.271
Amazonas	Codajás	Acará lake	18.XI.2004	Brasil das Águas Project	slide nº. 6.272
Amazonas	Codajás	Badajós lake	18.XI.2004	Brasil das Águas Project	slide nº. 6.268
Amazonas	Coari	Urucu river	04.VIII.2008	P.Mera, s.n.	UPCB 72.503
Amazonas	Anamá	Anamá lake	04.VIII.2008	P.Mera, s.n.	UPCB 72.506
Amazonas	Barcelos	Jaú river	04.VIII.2008	P.Mera, s.n.	UPCB 72.510
Amazonas	Badajós	Badajós river	04.VIII.2008	P.Mera, s.n.	UPCB 72.502
Amazonas	Coari	Aruã lake	04.VIII.2008	P.Mera, s.n.	UPCB 72.509
Amazonas	Coari	Coarizão lake	04.VIII.2008	P.Mera, s.n.	UPCB 72.508
Amazonas	Manaus	Solimões river	04.VIII.2008	P.Mera, s.n.	UPCB 72.511
Amazonas	Santarém	Tapajós river	14.X.2010	A.M. Silva, s.n.	UPCB 72.260
Bahia	Curaçá	São Francisco river	17.V.2004	Brasil das Águas Project	slide nº. 6.296
Ceará	Acaratú	Acaratú river	31.VII.2004	Brasil das Águas Project	slide nº. 6.338
Distrito Federal	Brasília	Paranoá lake	06.V.2009	M.G.M. Souza, s.n.	UPCB 72.266

continue

Table 1. Continuation

State	Municipality	Site	Sampling date	Collector	Register number
Goiás	Britânia	Vermelho river	VIII.2004	I. Nogueira, s.n.	UFG 29.905
Goiás	Britânia	Tigres lake	2004	I. Nogueira, s.n.	UFG 29.865
Maranhão	Conceição do Lago Açu	Açu lake	27.VII.2004	Brasil das Águas Project	slide n°. 6.277
Mato Grosso	Cocalinho	Cristalino river	19.VI.2004	Brasil das Águas Project	slide n°. 6.306
Mato Grosso	Pium	Tavaés river	21.VI.2004	Brasil das Águas Project	slide n°. 6.299
Mato Grosso	São Félix do Araguaia	Araguaia river	19.VI.2004	Brasil das Águas Project	slide n°. 6.300
Mato Grosso	Aquidauana	bay Pantaneira lake	27.XII.2004	Brasil das Águas Project	slide n°. 6.322
Mato Grosso	Barão do Melgaço	Sinhá Mariana lake	IX.1997- VIII.2008	S.M. Loverde-Oliveira, s.n.	UPCB 67.019
Mato Grosso	Nossa Senhora do Livramento	Coqueiro lake	IV.2002 -V.2003	S.M. Loverde-Oliveira, s.n.	UPCB 67.020
Mato Grosso do Sul	Maracaju	reservoir of a farm	28.XII.2003	Brasil das Águas Project	slide n°. 6.323
Minas Gerais	Pompeu	Três Marias reservoir	03.X.2004	Brasil das Águas Project	slide n°. 6.308
Minas Gerais	Guaicui/Várzea da Palma	Vêlhas river	29.V.2009	J.M. Lopes, s.n.	UPCB 72.270
Pará	Marabá	Parauapebas river	25.VII.2004	Brasil das Águas Project	slide n°. 6.341
Pará	Altamira	Curuá river	20.VIII.2004	Brasil das Águas Project	slide n°. 6.342
Pará	Belterra	Topajós river	22.VIII.2004	Brasil das Águas Project	slide n°. 6.266
Pará	Altamira	Iriti river	20.VIII.2004	Brasil das Águas Project	slide n°. 6.280
Pará	Parauapebas	Parauapebas river	25.VII.2004	Brasil das Águas Project	slide n°. 6.334
Pará	Altamira	Xingu river	27.VIII.2004	Brasil das Águas Project	slide n°. 6.289
Pará	Belém	Murutucu fluvial island	16.VII.2003	P.I. Tremarin, F.Ferrari, s.n.	UPCB 58.045

continue

Table 1. Continuation

State	Municipality	Site	Sampling date	Collector	Register number
Pará	Belém	Água Preta lake	29.VIII.2007	R.S. Paiva, s.n.	UPCB 72.036
Pará	Belém	mouth of the Guamá river	31.VIII.2009	R.S. Paiva, s.n.	UPCB 72.273
Pará	Santarém	Mapiri lake	15.II.2003	R.S. Paiva, s.n.	UPCB 72.274
Pará	Barcarena	Caripi beach	29.II.2008	R.S. Paiva, s.n.	UPCB 72.275
Pará	Belém	Tucanduba stream	01.VI.2010	R.S. Paiva, s.n.	UPCB 72.278
Pará	Santarém	Açai lake	17.III.2004	I. Nogueira, s.n.	UFG 46.265
Pará	Santarém	.....	18.III.2004	I. Nogueira, s.n.	UFG 46.264
Paraná	Morretes	Nhundiaguara river	25.III.2000	M. Landucci, E.L. Corrêa, s.n.	UPCB 44.536
Paraná	Antonina	Nunes river	25.III.2000	M. Landucci, E.L. Corrêa, s.n.	UPCB 44.538
Paraná	Paranaguá	Cambará river	01.IV.2000	M. Landucci, E.L. Corrêa, s.n.	UPCB 44.544
Paraná	Guaratuba	Cabaraquara river	02.IV.2000	M. Landucci, D. Atab, s.n.	UPCB 44.548
Paraná	Quitandinha	Várzea river	06.VII.2000	N.D. Visinoni, T. Ludwig, L. Ludwig, M. Landucci, s.n.	UPCB 44.554
Paraná	Fazenda Rio Grande	Maurício river	20.XI.2000	N.D. Visinoni, T. Ludwig, L. Ludwig, M. Landucci, s.n.	UPCB 44.556
Paraná	Quatro Barras	Timbu river	20.XI.2000	N.D. Visinoni, T. Ludwig, s.n.	UPCB 44.559
Paraná	Almirante Tamandaré	Barigui river	10.I.2001	N.D. Visinoni, T. Ludwig, s.n.	UPCB 44.562
Paraná	Itaperuçu	Tacaniça river	10.I.2001	N.D. Visinoni, T. Ludwig, s.n.	UPCB 44.564
Paraná	Rio Branco do Sul	Santaria river	10.I.2001	N.D. Visinoni, T. Ludwig, s.n.	UPCB 44.566
Paraná	Balsa Nova	Papagaio river	11.I.2001	N.D. Visinoni, T. Ludwig, L. Ludwig, s.n.	UPCB 44.568

continue

Table 1. Continuation

State	Municipality	Site	Sampling date	Collector	Register number
Paraná	Campo Magro	Verde river	11.I.2001	N.D. Visinoni, T. Ludwig, L. Ludwig, s.n.	UPCB 44.570
Paraná	Curitiba	Passaúna river	11.I.2001	N.D. Visinoni, T. Ludwig, L. Ludwig, s.n.	UPCB 44.572
Paraná	Doutor Uliisses	Ribeira river	11.I.2001	N.D. Visinoni, T. Ludwig, s.n.	UPCB 44.574
Paraná	Campo Magro	Cachoeirinha river	11.I.2001	N.D. Visinoni, T. Ludwig, s.n.	UPCB 44.576
Paraná	Bocaiúva	Capivari river	11.I.2001	N.D. Visinoni, T. Ludwig, s.n.	UPCB 44.580
Paraná	São José dos Pinhais	Una river	11.I.2001	N.D. Visinoni, T. Ludwig, s.n.	UPCB 44.582
Paraná	Araucária	Onças river	11.I.2001	N.D. Visinoni, T. Ludwig, s.n.	UPCB 44.584
Paraná	Pontal do Paraná	Guaraguaçu river	16.IV.2003	P.I. Tremarin, T. Ludwig, A. Campos, s.n.	UPCB 47.495
Paraná	Guaramiaçu	dam in the Ponto Certo farm	20.X.2007	L.L. Wolff, s.n.	UPCB 59.500
Paraná	Guarapuava	Cascavel river	25.X.2007	L.L. Wolff, s.n.	UPCB 59.502
Paraná	Guarapuava	Guabioba river	26.x.2007	L.L. Wolff, s.n.	UPCB 59.503
Paraná	Guarapuava	lake of the Parque do Lago	25.X.2007	L.L. Wolff, s.n.	UPCB 59.505
Paraná	Piraquara	Iraí reservoir	31.VII.2007	A.M. Silva, T. Ludwig, s.n.	UPCB 59.509
Paraná	Piraquara	Piraquara reservoir	27.IX.2007	T. Ludwig, s.n.	UPCB 59.513
Paraná	Piraquara	Piraquara reservoir	16.I.2008	A.M. Silva, T. Ludwig, E.A. Lehmkuhl, s.n.	UPCB 59.514
Paraná	Curitiba	lake of the Jardim Botânico	2008	P.I. Tremarin, s.n.	UPCB 60.529
Paraná	São José dos Pinhais	Itaqui reservoir	15.II.2008	D.M. Faria, s.n.	UPCB 63.478

continue

Table 1. Continuation

State	Municipality	Site	Sampling date	Collector	Register number
Paraná	Curitiba	lake of the Parque Tingui	13.IX.2008	E.K.F. Santos, s.n.	UPCB 65.978
Paraná	General Carneiro	Reflora II lake	II.2005	E.M. Santos, s.n.	UPCB 67.014
Paraná	Antonina	U.H.E. Capivari reservoir	2011	COPEL equip. s.n.	UPCB 72.237
Paraná	São José dos Pinhais	U.H.E. Chaminé reservoir	2011	COPEL equip. s.n.	UPCB 72.239
Paraná	Guaratuba	U.H.E. Guaricana reservoir	2011	COPEL equip. s.n.	UPCB 72.245
Paraná	Ponta Grossa	U.H.E. Pitangui reservoir	2011	COPEL equip. s.n.	UPCB 72.249
Paraná	Ponta Grossa	U.H.E. São Jorge reservoir	2011	COPEL equip. s.n.	UPCB 72.254
Paraná	Candói	U.H.E. Santa Clara reservoir	2011	COPEL equip. s.n.	UPCB 72.254
Paraná	Curitiba	lake of the Jardim Botânico	15.IX.2010	L.K. Procopiak, s.n.	UPCB 72.298
Paraná	Curitiba	lake of the Ópera de Arame	27.IX.2010	L.F. Fernandes, s.n.	UPCB 75.517
Paraná	Curitiba	lake of the Ópera de Arame	27.X.2010	L.F. Fernandes, s.n.	UPCB 75.518
Paraná	Curitiba	lake of the Passeio Público	27.X.2010	L.F. Fernandes, s.n.	UPCB 75.519
Rio Grande do Sul	Tapes e Mostardas	Patos lagoon	08.XII.1987	L.C. Torgan, s.n.	HAS 16.893
Rio Grande do Sul	Tapes e Mostardas	Patos lagoon	09.I.1988	L.C. Torgan, s.n.	HAS 16.900
Rio Grande do Sul	Tapes e Mostardas	Patos lagoon	08.IV.1988	L.C. Torgan, s.n.	HAS 16.968
Rio Grande do Sul	Santa Vitória do Palmar	Mangueira lagoon	06.II.2004	Brasil das Águas Project	slide nº. 6.321
Rio Grande do Sul	Porto Alegre	Guaíba river	07.II.2004	Brasil das Águas Project	slide nº. 6.330
Rio Grande do Sul	Barra do Quaraí	Quaraí river	18.I.2004	Brasil das Águas Project	slide nº. 6.316
Rio Grande do Sul	Uruguaiana	Uruguai river	16.I.2004	Brasil das Águas Project	slide nº. 6.314
Rio Grande do Sul	Rosário do Sul	Santa Maria river	20.I.2004	Brasil das Águas Project	slide nº. 6.317
Rio Grande do Sul	Santa Vitória do Palmar	Pacheco lake	06.II.2004	Brasil das Águas Project	slide nº. 6.319

continue

Table 1. Continuation

State	Municipality	Site	Sampling date	Collector	Register number
Rio Grande do Sul	Uruguaiana	Touro Passa river	18.I.2004	Brasil das Águas Project	slide nº. 6.325
Rio Grande do Sul	São Francisco de Assis	Ibicuí river	20.I.2004	Brasil das Águas Project	slide nº. 6.315
Rio Grande do Sul	Palmares do Sul	Casamento lagoon	04.II.2004	Brasil das Águas Project	slide nº. 6.327
Rondônia	Guajará Mirim	Guaporé river	03.VII.2004	Brasil das Águas Project	slide nº. 6.346
Rondônia	Costa Marques	Guaporé river	04.VII.2004	Brasil das Águas Project	slide nº. 6.304
Rondônia	São Francisco do Guaporé	Guaporé river	04.VII.2004	Brasil das Águas Project	slide nº. 6.347
Rondônia	Machadinho D'Oeste	Jiparana/Machado river	02.VII.2004	Brasil das Águas Project	slide nº. 6.294
Santa Catarina	São Francisco do Sul	Acará lake	11.II.2004	Brasil das Águas Project	slide nº. 6.309
Santa Catarina	São Martinho	Capivari river	09.IX.2007	E.A. Lehmkühl, s.n.	UPCB 59.511
Santa Catarina	Pedras Grandes	Azambuja river	2008	A.M. Silva, s.n.	UPCB 72.284
São Paulo	Pindamonhangaba	lake with macrophytes	24.IV.1990	A.A.J. Castro, C.E.M. Bicudo, s.n.	SP 188.520
São Paulo	São Pedro	lake of the Restaurante do Lago	20.III.1990	A.A.J. Castro, C.E.M. Bicudo, s.n.	SP 188.436
São Paulo	Piracicaba	Piracicaba river	29.X.1991	A.A.J. Castro, s.n.	SP 239.095
São Paulo	Batatais	reservoir with macrophytes	16.XI.1991	A.A.J. Castro, s.n.	SP 239.096
São Paulo	Vargem Grande Paulista	dammed stream in the Ise farm	18.II.1992	A.A.J. Castro, s.n.	SP 239.138
São Paulo	Capivari	pond with macrophytes	20.III.1990	A.A.J. Castro, C.E.M. Bicudo, s.n.	SP 255.723
São Paulo	Itu	reservoir with macrophytes	20.III.1990	A.A.J. Castro, C.E.M. Bicudo, s.n.	SP 255.725

continue



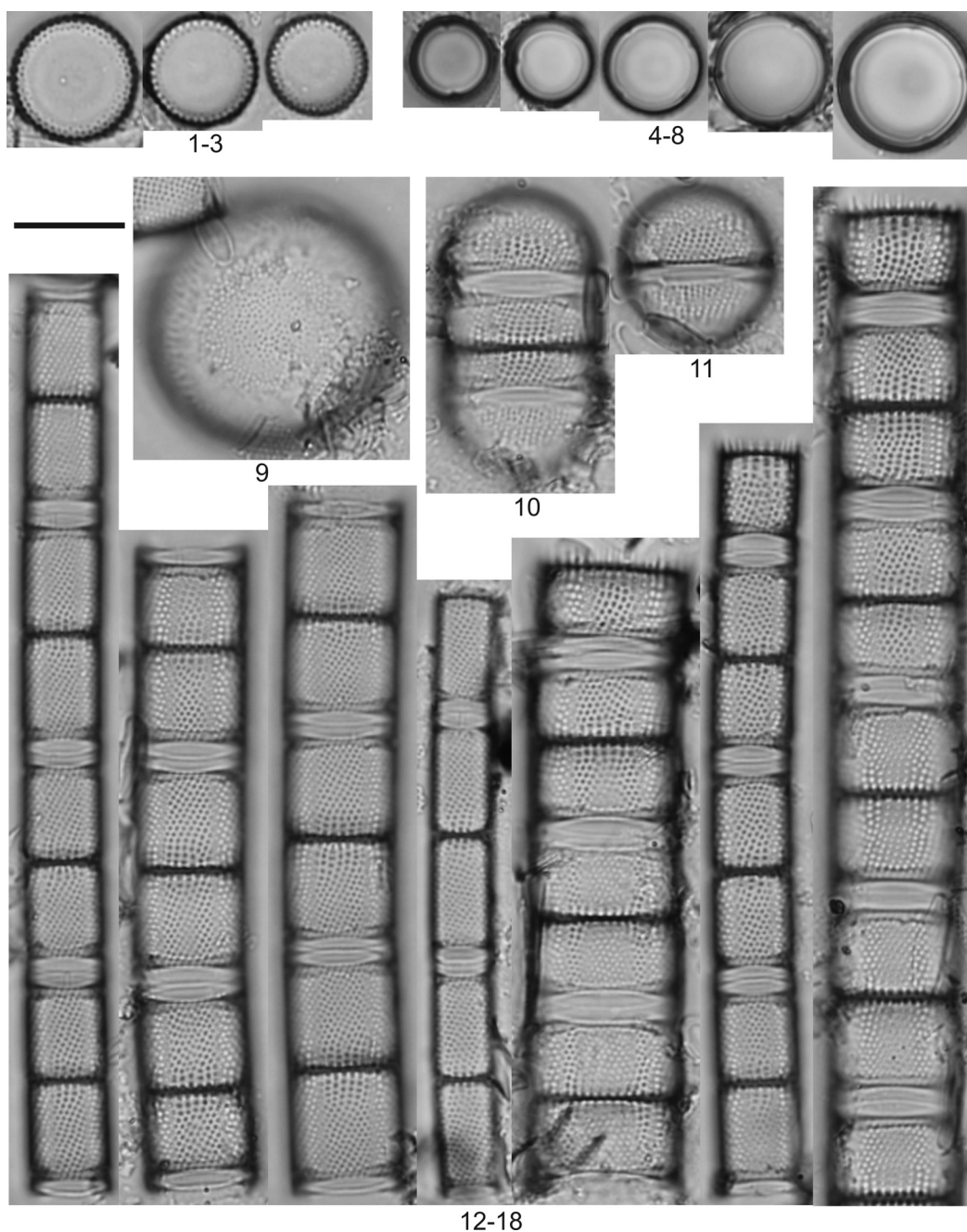
Table 1. Continuation

State	Municipality	Site	Sampling date	Collector	Register number
São Paulo	Barra Bonita	Tietê river	02-I.1991	L.B. Zanini, s.n.	SP 255.742
São Paulo	Avaré	Jurimirim reservoir	10.IX.1991	A.A.J. Castro, C.E.M. Bicudo, M.R.M. Lopes s.n.	SP 255.759
São Paulo	Piedade	dammed stream	30.XII.1991	D.C. Bicudo, C.E.M. Bicudo, s.n.	SP 255.766
São Paulo	São Paulo	Garças lake	14.I.1997	D.C. Bicudo, L.L. Morandi, s.n.	SP 294.905
São Paulo	Salto Grande	Salto Grande reservoir	X.2005-VII.2006	G.P. Neves, s.n.	UPCB 72.288
Sergipe	São Cristóvão	Vaza Barris river	22.V.2004	Brasil das Águas Project	slide n°. 6.302
Tocantins	Pium	Araguaia river	21.VI.2004	Brasil das Águas Project	slide n°. 6.288
Tocantins	Bernardo Sayão	Araguaia river	22.VII.2004	Brasil das Águas Project	slide n°. 6.295
Tocantins	Lajeado e Miracema do Tocantins	downstream of U.H.E. Lajeado reservoir	X.2009	A.K. Marques, s.n.	UPCB 72.291
Tocantins	Lajeado e Miracema do Tocantins	U.H.E. Lajeado reservoir	X.2009	A.K. Marques, s.n.	UPCB 72.292
To cantins	Dianópolis	P.C.H. Porto Franco reservoir	IX.2009	A.K. Marques, s.n.	UPCB 72.293

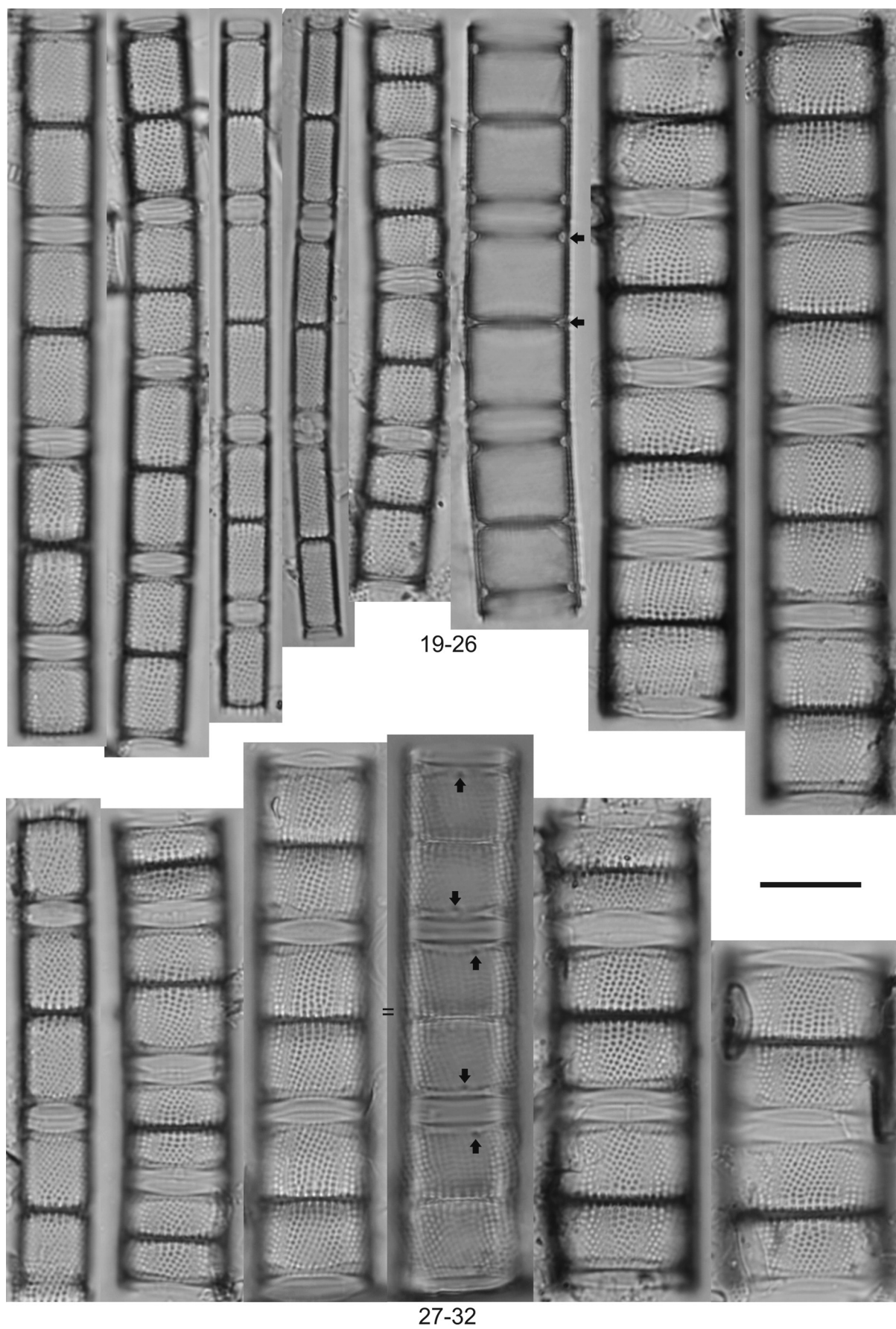
### Observations in LM (Figs. 1-32)

Frustules cylindrical joined by small linking spines forming long straight chains (Figs. 12-32). Heterovalvarity present: chains composed of separation and linking valves (Figs. 16-18, 21, 27). Separation valve with elongated marginal spines, acute and equal length. Linking valves with short marginal spines of equal length. Valve face flat with one or two irregular rows of rounded marginal areolae (Figs. 1-3). Mantle ornamented by oblique

and dextrorse, slightly curved striae (Figs. 10-32). Mantle areolae rounded to elliptical near the base of the spines, coarser in the separation valves (Figs. 16-18). Sulcus U-shape and pseudosulcus deep, V-shaped (Fig. 24). One to four rimoportulae near the collum (Figs. 4-8, 30). Ringleist narrow (Figs. 4-8). Diameter 4-23  $\mu\text{m}$ ; mantle height 6-17  $\mu\text{m}$ ; 14 striae/10  $\mu\text{m}$  in the separation valves; 14-18 striae/10  $\mu\text{m}$  in the linking valves; 10-14 areolae/10  $\mu\text{m}$  in the separation valves; 12-20 areolae/10  $\mu\text{m}$  in the linking valves. Auxospore 21-26  $\mu\text{m}$  in diameter (Fig. 9).



**Figs. 1-18.** *Aulacoseira ambigua* (LM). **1-3.** Valve view of the linking cells. **4-8.** View of the cell lumen showing the rimoportulae. **9.** Auxospore. **10, 11.** Initial cells. **12-18.** Aspect of the chains. Note the terminal cell of chain with separating spines in the **Figs. 16-18.** Bars = 10  $\mu\text{m}$ .



**Figs. 19-32.** *Aulacoseira ambigua*: aspect of chains (LM). **24.** Note the sulcus and pseudosulcus (arrows). **30.** Disposition of the rimoportulae in the cells of chains (arrows). Bars = 10  $\mu$ m.

### Observations in SEM (Figs. 33-47)

Linking valves with valve face flat to slightly concave, ornamented with one or two irregular rows of rounded areolae near the margins (Figs. 33, 36, 37). Separation valves with elongated and acute spines, of equal length, protruding from 1-2 interestriae and with elongated elliptical areolae at the valve face/mantle junction (Figs. 34, 35). Linking valve with small spines, spatulate to strongly bidentate, protruding from each interestria (Figs. 36, 37). Mantle ornamented by oblique striae, slightly curved, comprised by rounded or square areolae in larger specimens (Fig. 38). Areolae occluded by vola. Ringleist hollow and narrow, ca. 1.0-1.2  $\mu\text{m}$  projecting into the valve (Fig. 41). One to four rimoportulae present near the collum, taking the place of one areola. External slit-like opening of rimoportula large, rectangular and oblique, located at the end of striae, usually take the place of more than one areola (Figs. 41, 43). Rimoportula internally sessile, on the ringleist, disposed perpendicularly to the edge of the valve. Collum and mantle often ornamented with irregularly spaced siliceous knobs. Girdle composed of broad and open bands with evident ligulae and antiligulae, ornamented by small rounded pores (Figs. 45- 47).

A wide morphological and metric variation was found in the populations of *Aulacoseira ambigua* studied, but this was within the limits of observations for the species from the published literature (e.g. Kobayasi & Nozawa, 1981; Le Cohu, 1991; Houk & Klee, 2007).

The occurrence of separation valves in *A. ambigua* was documented by Kobayasi & Nozawa (1981) and Le Cohu (1991). And although less frequent than in some other species, they were present in most of our samples. Siver & Kling (1997) report that the face of the linking valve is usually smooth, but in the material we have studied the valves always had two marginal rings of discontinuous areolae.

*Aulacoseira ambigua* was widespread throughout the 17 Brazilian states (Fig. 48) and it occurred in lakes, reservoirs and rivers, usually presenting

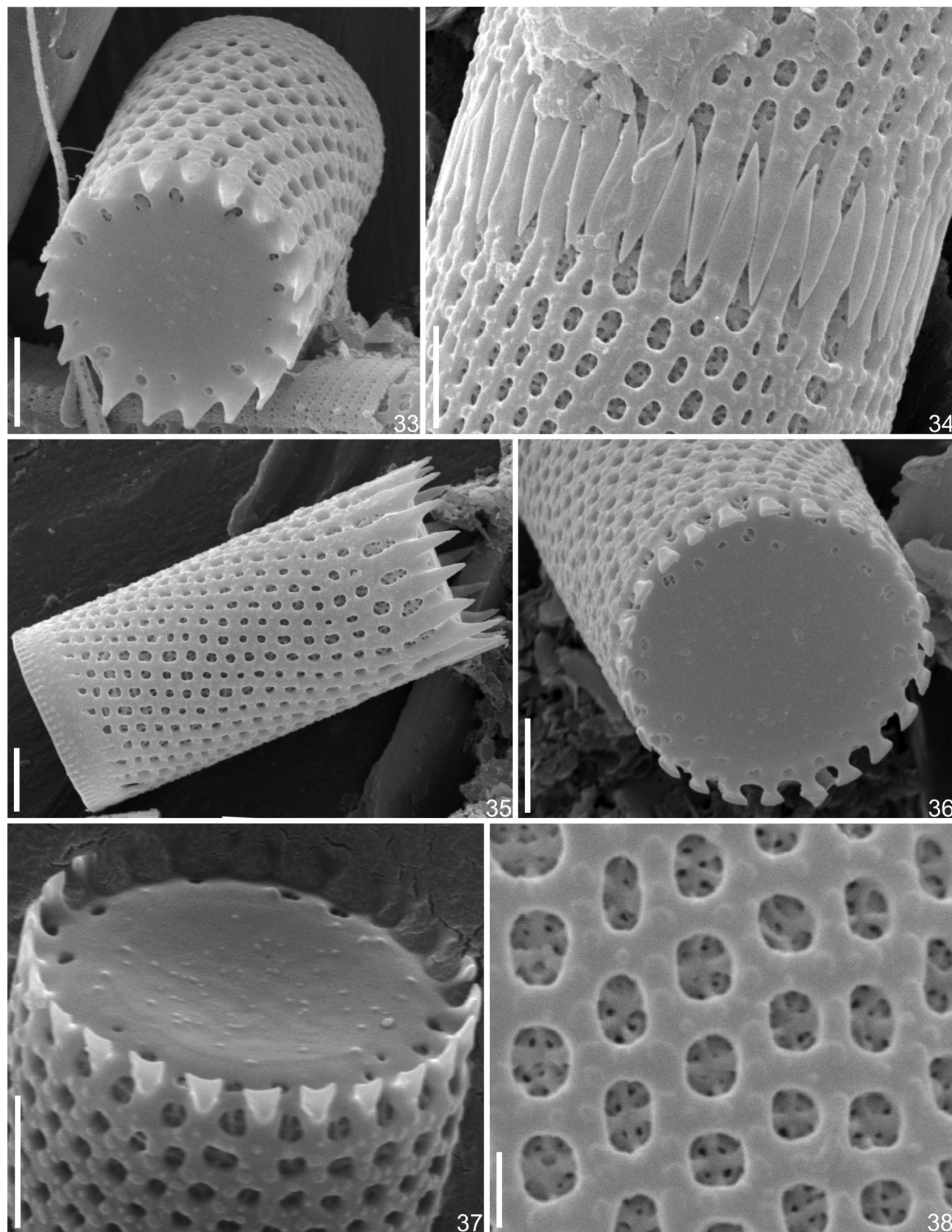
thin frustules ( $\approx 8 \mu\text{m}$  in diameter). Wider chains (diameter up to 23  $\mu\text{m}$ ) with or without auxospores were only found in samples with larger numbers of individuals from lentic sites.

*Aulacoseira ambigua* was previously found dominant in Peri Lagoon, Santa Catarina, by Souza-Mosimann (1983, fig. 7) who recorded the species as *Melosira italica* (Ehrenberg) Kützing [= *Aulacoseira italica* (Ehrenberg) Simonsen]. The two species can be distinguished mainly by the morphology of linking spines, areolar pattern of the valve face and mantle, and by the ringleist structure (Table 2). Subsequently, Souza-Mosimann *et al.* (2011) documented exemplars of *A. ambigua* as *A. granulata* (Ehrenberg) Simonsen for Conceição Lake, Santa Catarina. However, *A. granulata* has 1 or 2 long separation spines, higher density of striae and areolae (7-15/10  $\mu\text{m}$  and 8-12/10  $\mu\text{m}$ , respectively), and solid ringleist (Hustedt, 1930; Siver & Kling, 1997; Houk, 2003).

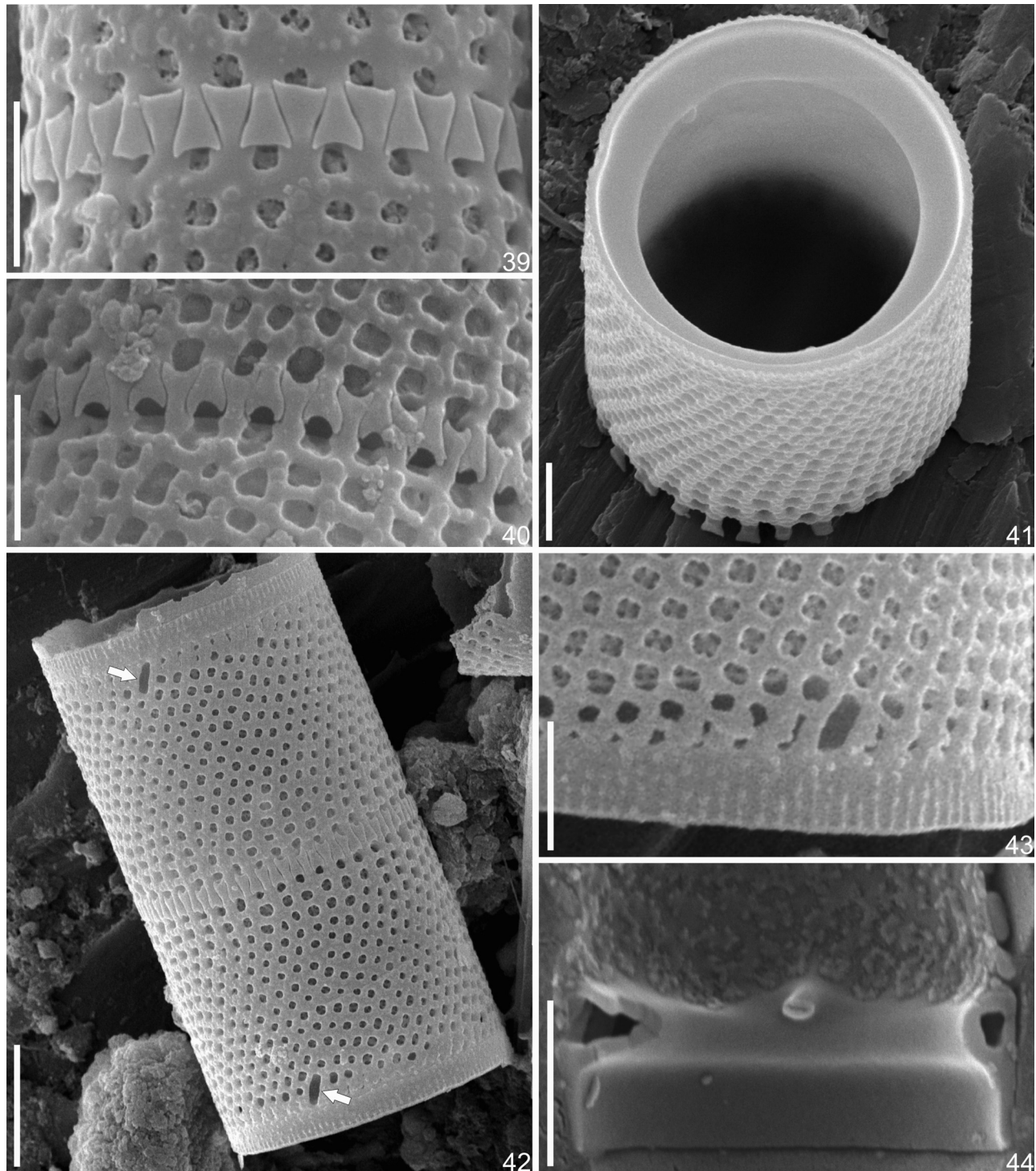
The specimens recorded for Jucurui Lake, state of Pará, by Metzeltin & Lange-Bertalot (2007, pl. 3, figs. 1-3) as *Aulacoseira cf. valida* (Grunow) Krammer probably correspond to larger cells of *A. ambigua* because they possess a more shaded region near the collum, as a result of the hollow channel (ringleist) of the species and do not seem to have linking spines as elongate as those in *A. valida*. Moreover, the two species differ in the valve face ornamentation and ringleist structure (Table 2).

*Aulacoseira ambigua* is distinguished from other species of the genus mainly by the hollow ringleist, a feature that can be observed in the light microscope as a structure in a "U" (Fig. 31) found in the mantle near the collum. Siver & Kling (1997) report that this structure, generally described as the sulcus, actually corresponds to the shape of the internal cavity of the ringleist.

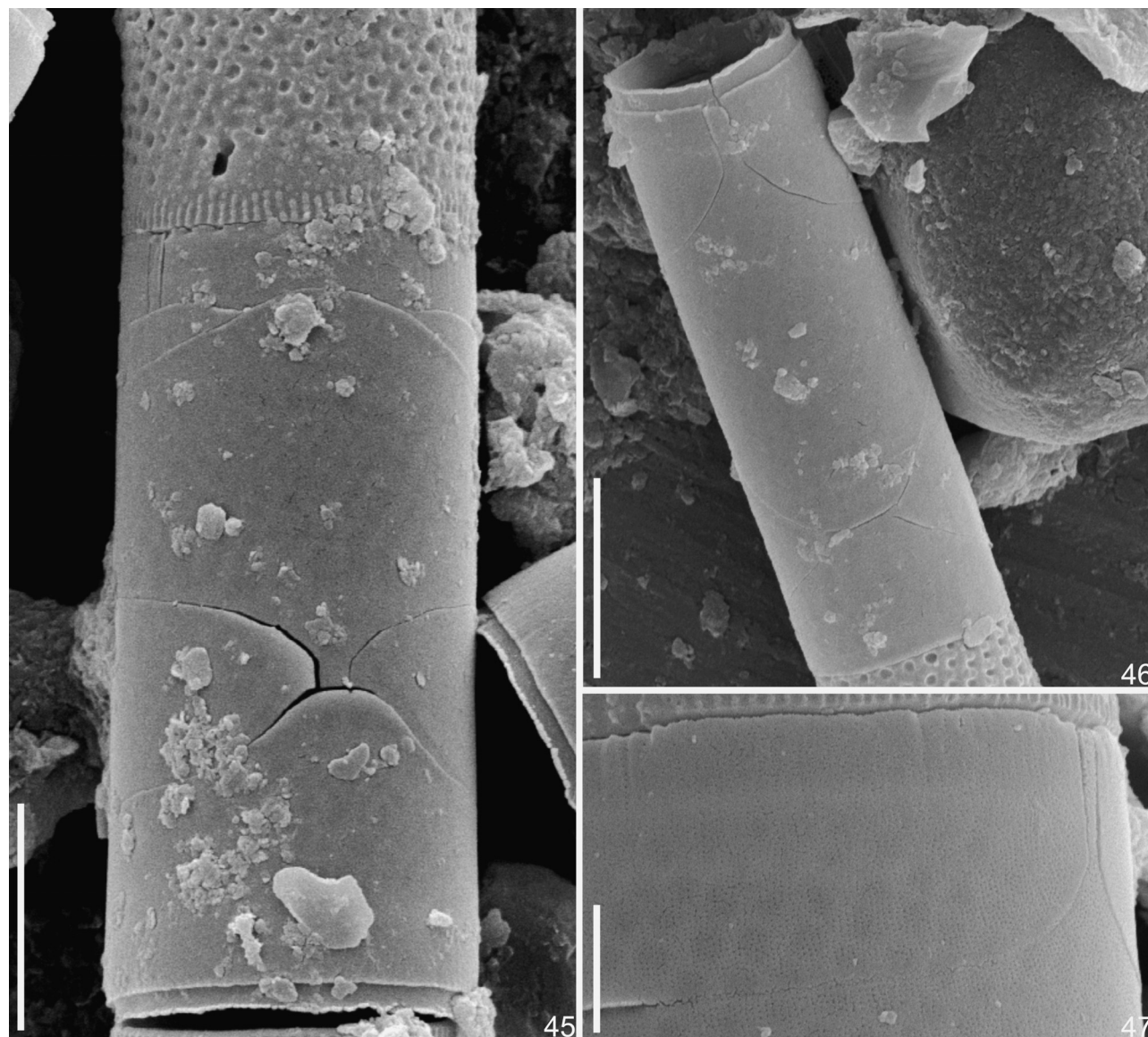
This study has expanded the knowledge of the geographic distribution of *Aulacoseira ambigua* in Brazil, presenting the pioneering record of this species for the states of Alagoas, Amazonas, Distrito Federal, Maranhão, Mato Grosso, Rondônia, Sergipe and Tocantins.



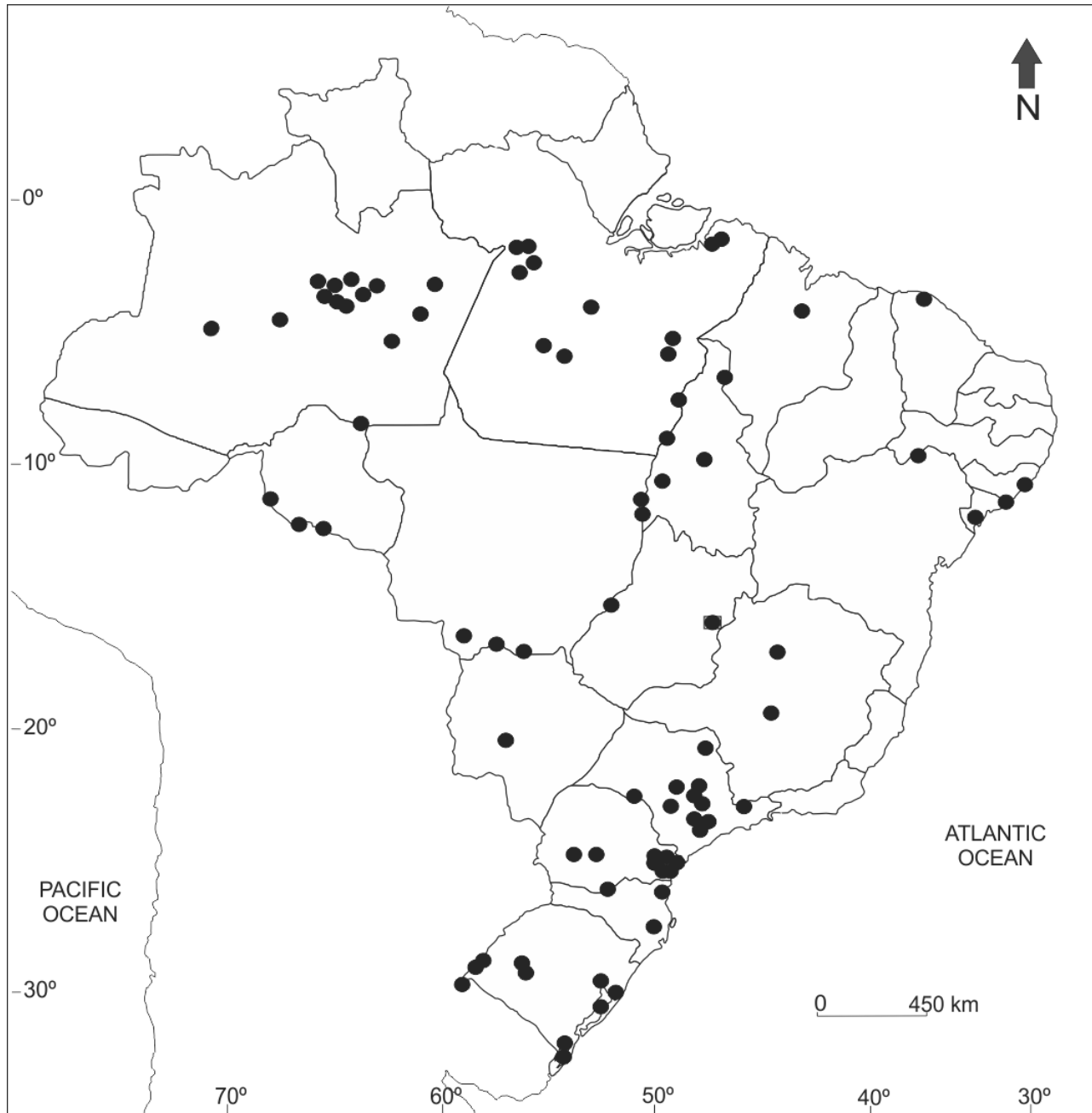
**Figs. 33-38.** *Aulacoseira ambigua*: external view (SEM). **33.** Valve view of the terminal cell of chain. **34, 35.** Girdle view of the separation valve, note the spines. **36, 37.** Valve face of the linking cell. **38.** Detail of the mantle areolae. Bars: **Figs. 33-37** = 2  $\mu$ m; **Fig. 38** = 0.5  $\mu$ m



**Figs. 39-44.** *Aulacoseira ambigua* (SEM). **39-40.** Detail of the linking spines. **41.** Aspect of the ringleist. **42.** Mantle of the linking valves and location of external rimoportulae opening (arrows). **43.** Detail of the collum and external rimoportulae opening. **44.** Internal view of the rimoportulae opening and ringleist. Bars: **Figs. 39-41, 43, 44** = 2  $\mu$ m; **Fig. 42** = 5  $\mu$ m.



**Figs. 45-47.** *Aulacoseira ambigua*: aspect of the girdle bands (MEV). Bars: **Figs. 45, 46** = 5  $\mu\text{m}$ ; **Fig. 47** = 2  $\mu\text{m}$ .



**Fig. 48.** Distribution of *Aulacoseira ambigua* on different Brazilian geographic regions.



**Table 2.** Morphologic and metric variation of *Aulacoseira ambigua* and related species. References: <sup>1</sup>Le Cohu (1991), <sup>2</sup>Houk (2003), <sup>3</sup>Huber-Pestalozzi (1942), <sup>4</sup>Siver & Kling (1997), <sup>5</sup>Crawford *et al.* (2003), <sup>6</sup>Krammer (1991), <sup>7</sup>Krammer & Lange-Bertalot (1991).

Characteristics	<i>A. ambigua</i> <sup>1,2,3,4</sup>	<i>A. italica</i> <sup>1,2,5</sup>	<i>A. valida</i> <sup>2,6,7</sup>
Diameter (µm)	4-15	3-23	10-25
Mantle height (µm)	3.5-15	8-20	10-18
Valve face	flat with marginal areolae	flat to slightly convex with few areolae scattered	slightly convex, completely areolated
Linking spines	short, spatulate, bidentate	long, spatulate, tridentate	long, T-shaped
Striation pattern	oblique, dextrorse	parallel to oblique, sinistrorse	oblique, curved, dextrorse
Striae (in 10 µm)	14-26	13-18	12-15
Shape of the mantle areolae	round to elongated close to valve face	subcircular, elongated around the mantle	round to elongated close to valve face
Areolae (in 10 µm)	18-20	20	18-22
Number and shape of the rimoportulae	1-3, sessile, under ringleist	transversally elongated in relation to striae, close to ringleist	----
Ringleist	hollow and narrow	solid and narrow	solid and broad

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