ARTICLE

PENNATE DIATOMS (BACILLARIOPHYCEAE) FLORA FROM TWO TROPICAL ESTUARIES IN PERNAMBUCO STATE, BRAZIL

Flora de diatomáceas penadas (Bacillariophyceae) de dois estuários tropicais no Estado de Pernambuco, Brasil

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ABSTRACT

Pennate diatoms' taxonomic composition in many estuaries and coastal areas worldwide remains unknown. To better understand the biodiversity of planktonic pennate diatoms (Bacillariophyceae) in Northeast Brazil, we conducted a floristic survey in two tropical estuaries in Pernambuco state. Fifty-one species were identified, with Naviculales and Bacillariales being the most representative orders. *Gyrosigma subtile* was reported for the first time in Brazil; besides, eleven species are new records for Northeast Brazil, and one is for Pernambuco. For the first time, the genera *Cymatoneis*, *Pinnunavis*, and *Staurophora* are described for Northeast Brazil. The results of the work expand the information on the richness of pennate diatoms for tropical estuaries in Northeastern Brazil, presenting descriptions, comments, and illustrations using optical and scanning electron microscopy of the taxa identified in the estuaries of the Botafogo and Paripe rivers - PE.

Keywords: Atlantic Ocean. Floristic survey. New records. Bacillariophyta. Phytoplankton.

RESUMO

A composição taxonômica de diatomáceas penadas de diversos estuários e áreas costeiras no mundo ainda é pouco conhecida. Para melhor compreender a biodiversidade de diatomáceas planctônicas penadas (Bacillariophyceae) no Nordeste do Brasil, realizamos o levantamento florístico em dois estuários tropicais no estado de Pernambuco. Cinquenta e uma espécies foram identificadas, sendo Naviculales e Bacillariales as ordens mais representativas. *Gyrosigma subtile* é referida pela primeira vez para costa brasileira, enquanto 11 espécies são novos registros para o Nordeste do Brasil e uma para Pernambuco. Os gêneros *Cymatoneis*, *Pinnunavis* e *Staurophora* são registrados pela primeira vez para o nordeste brasileiro. Os resultados do trabalho ampliam as informações sobre a riqueza de diatomáceas penadas para estuários tropicais do Nordeste do Brasil, apresentando descrições, comentários e ilustrações usando microscopia ótica e eletrônica de varredura dos táxons identificados nos estuários dos rios Botafogo e Paripe – PE.

Palavras-chave: Oceano Atlântico. Levantamento florístico. Novos registros. Bacillariophyta. Fitoplâncton.

1 INTRODUCTION

Coastal environments are among the most explored and degraded natural ecosystems worldwide (Halpern et al. 2008). Estuaries are transition zones that connect freshwater and marine environments, offering numerous ecosystem services with high ecological relevance and economic value (Barbier et al. 2011). In estuaries, photosynthetic microorganisms play an essential role in primary production, exhibiting wide spatial-temporal variability influenced by several factors, such as nutrients, light, grazing, tidal regimes, and salinity (Underwood & Kromkamp 1999). Around 50% of primary production in the oceans and coastal areas, and 25% of global carbon fixation, is attributed to diatoms (Nelson et al. 1995), which are the most abundant algal group in estuarine areas worldwide (Aquino et al. 2015; Cavalcanti et al. 2020). In tropical estuaries, such as those in Northeast Brazil, diatoms are mainly influenced by the salinity gradient (Santiago et al. 2010; Melo-Magalhães et al. 2011). In addition to primary production, diatoms are essential indicators of water quality (Koening et al. 2003) and serve as a food source for herbivorous organisms, such as copepods (Kumar & Krishnan 2021).

Diatom floristic studies may serve as references for detecting natural or anthropogenic environmental impacts. Diatom taxonomic richness is often used as an index to monitor ecological impacts since diatom populations are sensitive to changes in physiochemical and trophic states (Chariton et al. 2015). Moreover, diatoms can be used as environmental indicators to help characterize environments contaminated by pollutants (Siqueiros-Beltrones et al. 2014).

Within diatoms, the pennate group can be divided into raphids and araphids (Round et al. 1990). The raphe system in diatoms allows for active movement, and raphid diatoms are usually attached to substrates. In contrast, araphid diatoms do not have a raphe but possess tiny pores and labial processes (rimoportula) that facilitate their buoyancy in the water column (Sato & Medlin 2006; Kooistra et al. 2009). Pennate diatoms are mostly benthic (Montresor et al. 2016) and are thus also tychoplanktonic. Furthermore, the presence of pennate diatoms in the plankton is related to their evolutionary adaptation and morphological adjustments, such as reducing the thickness of their valves to limit sinking (Kooistra et al. 2009). In estuaries, pennate diatoms in plankton are related to tidal fluctuations, which promote their resuspension and keep them in the water column (Leles et al. 2014; Affe et al. 2019). Although less abundant in plankton than centric diatoms, pennate diatoms are still ecologically significant, and some species are also potentially toxic, especially in marine environments (Kooistra et al. 2009).

Brazil exhibits a wide diversity of marine and freshwater diatoms, with 1,247 species recorded (Menezes et al. 2015). However, most studies on marine diatoms have been concentrated in the southern region of the country (e.g., Donadel & Torgan 2016; Dutra & Garcia 2016; Donadel & Torgan 2018; Bertolli et al. 2019). Only a few studies have been conducted in Northeast Brazil, most of which are ecological or checklist studies (e.g., Zimmermann 1914; Sassi 1991; Moreira-Filho et al. 1995; Ferrari et al. 2009; Cavalcante et al. 2013; Santana et al. 2018; Cavalcanti et al. 2020, 2018; Cutrim et al. 2024).

Although Pernambuco state has a high number of diatom species recorded in its estuarine regions, to date, few taxonomic studies have been conducted and published for its coastal areas (e.g., Eskinazi-Leça & Satô 1963; Moura et al. 2007). Besides this, only ecological or floristic studies have been published (e.g., Moreira-Filho et al. 1968; Neumann-Leitão et al. 1999, 2001; Lacerda et al. 2004; Macedo et al. 2005; Koening et al. 2009; Santos et al. 2010; Aquino et al. 2014, 2015; Silva et al. 2017; Borges et al. 2020).

Considering the scarcity of studies on diatom taxonomy in the region, we hypothesized that the studied estuaries would have high Bacillariophyceae diatom richness, with new records for local, regional, and national flora. To test this hypothesis, we report on the planktonic pennate diatom (Bacillariophyceae) and occasionally tychoplanktonic flora of two tropical estuaries in Pernambuco state, Brazil.

2 MATERIALS AND METHODS

Water samples were collected on April 4th, 2019, in two tropical estuaries: the Botafogo River estuary and the Paripe River estuary, located in Pernambuco state, Northeast Brazil. The complete location of the collection points (latitude and longitude) is shown in Table 1. The Botafogo River estuary is characterized by a salinity ranging from approximately 4.7 to 37.9 PSU and a temperature ranging from 21.5 to 39.8°C, with tidal variation between 0 and 2.5 m (Otsuka et al. 2014; Noriega et al. 2015). Meanwhile, the Paripe River estuary has temperatures ranging from 26.5 to 35.5°C, a salinity of approximately 32 to 40 PSU, and tidal variation from 0.9 to 1.9 m (Medeiros et al. 2018;

Silva et al. 2017). Water samples were collected from each station during high tide and low tide, totaling seven samples (Table 1).

The phytoplankton material was collected with a 25 µm mesh size plankton net, which can occasionally include tychoplanktonic species (Supplementary Table 1). Samples were stored in amber flasks (150 mL) and preserved with 4% formaldehyde for later identification. Permanent slides were prepared according to Carr et al. (1986). Both fresh and permanent slides were analyzed under a light microscope at 400× and 1,000× magnification, where at least ten individuals were evaluated whenever possible. All samples and permanent slides were deposited in the Professor Vasconcelos Sobrinho herbarium - PEUFR at the Federal Rural University of Pernambuco, Brazil, under the vouchers 55493-55499 (Table 1).

Additionally, we analyzed the samples under a scanning electron microscope (SEM) to better visualize morphological and ultrastructural characters. Aliquots of each sample were prepared according to Moreira-Filho & Valente-Moreira (1981) and transferred to the stubs until dry. They were then vacuum-coated with gold and analyzed using a Vega Tescan scanning electron microscope operated at 15 kV and a distance of 10 mm. The SEM analyses were performed at CENAPESQ/UFRPE. Whenever possible, at least ten individuals of the species *Frustulia interposita*, *Vanheurckia lewisiana*, *Caloneis permagna*, *Gyrosigma subtile*, *Navicula* sp., *Pinnunavis yarrensis*, *Plagiotropis lepidoptera*, *Plagiotropis* sp., *Epithemia adnata*, *Coronia decora*, *Surirella febigeri*, and *Plagiogramma pulchellum* were photographed and measured. Identification keys and specialized bibliography were used, including Jensen & Hustedt (1985), Krammer & Lange-Bertalot (1986, 1988, 1991), Lange-Bertalot (1996), and additional bibliography for specific taxa, as cited in the taxonomic comments for each species.

The taxonomic classification of the species followed the classification system of Medlin & Kaczmarska (2004) at the Class level, with updates according to Medlin (2016) and nomenclature updates according to Guiry & Guiry (2021). Species distribution in the Brazilian states was verified on the online platform Flora do Brasil 2020 (Flora e Funga do Brasil 2024) and supplemented with taxonomic articles (e.g., Andrade & Teixeira 1957; Moreira-Filho & Valente-Moreira 1981; Moreira-Filho et al. 1999; Fernandes et al. 2002; Villac et al. 2008).

Table 1. Details of sampling sites in the Paripe and Botafogo estuarine rivers, indicating the tide height at the time of sampling and the Herbarium Vouchers deposited at the PEUFR Herbarium.

Sample	Voucher	Estuaries	Sampling sites	Tide height
ERPH1	PEUFR 55493	Paripe River	7° 48' 39.65" S; 34° 51' 22.21" W	High tide
ERPL1	PEUFR 55494	Paripe River	7° 48' 39.65" S; 34° 51' 22.21" W	Low tide
ERBL2	PEUFR 55495	Botafogo River	7° 46' 26.94" S; 34° 53' 23.15" W	Low tide
ERBL3	PEUFR 55496	Botafogo River	7° 46' 36.16" S; 34° 53' 27.06" W	Low tide
ERBH2	PEUFR 55497	Botafogo River	7° 46' 31.04" S; 34° 53' 25.91" W	High tide
ERBH3	PEUFR 55498	Botafogo River	7° 46' 26.94" S; 34° 53' 23.15" W	High tide
ERBL4	PEUFR 55499	Botafogo River	7° 46' 31.04" S; 34° 53' 25.91" W	Low tide

3 RESULTS

Fifty-one infrageneric taxa of pennate diatoms (Bacillariophyceae) were identified across three subclasses. The subclass Bacillariophycidae had the highest number of species (41), followed by Fragilariophycidae and Urneidophycidae, with six and four species, respectively. In total, 14 orders, 21 families, and 35 genera were identified. Naviculales and Bacillariales, followed by Lyrellales and Surirellales, showed the highest number of species, with *Tryblionella* and *Lyrella* being the richest genera (four and three species, respectively). Greater species richness was recorded in the Botafogo estuary, with 50 taxa, while the Paripe estuary presented 40 taxa. Moreover, 39 species were recorded in both estuaries. In total, 35 taxa were present at both low and high tides, 15 were exclusive to low tide periods and only *Gyrosigma subtile* was exclusive to high tide periods.

This study marks the first record of *Gyrosigma subtile* in Brazil. *Staurophora soodensis*, *Lyrella approximata*, *Achnanthes grunowii, Frustulia interposita, Diploneis gruendleri, Cymatoneis sulcata, Pinnunavis yarrensis, Seminavis robusta, Epithemia adnata, Surirella robusta,* and *Plagiogramma staurophorum* were recorded for the first time in Northeast Brazil, and *Trachyneis aspera* in Pernambuco state.

Taxonomic descriptions

Bacillariophyceae Haeckel
Bacillariales Hendey
Bacillariaceae Ehrenberg

Bacillaria paxillifera (O.F.Müller) T.Marsson, 1901: 254 **(Fig. 1A.)**
Valves linear, apices slightly lanceolate; frustules forming tabular colonies with individuals positioned towards the apices, rectangular aspect in girdle view. Length: 90–110 µm; Width: 4–5 µm.
Characteristics and dimensions according to Fernandes (1996) and Souza-Mosimann et al. (2001).
Material examined: ERPL1, ERBL2, ERBH2.

Nitzschia* cf. *obtusa W.Smith (1853: 39) **(Fig. 1B.)**
Valves sigmoid, apices scalpelliform and rounded, slightly curved in opposite directions; raphe keel-shaped with central flexion; 4–6 fibulae in 10 µm; striae inconspicuous. Length: 50–66 µm; Width in the central area: 7–8 µm; Width in the apices: 6 µm.
Characteristics and dimensions according to Smith (1856) and Fernandes (1996). The analyzed specimens have similar morphology to the original description; however, they lack width measurements. The literature describes populations with widths of 10—12 µm, differing from the studied specimens.
Material examined: ERBL2, ERBL3, ERBH3, ERBL4.

Nitzschia sigmoidea (Nitzsch) W.Smith (1853: 38) **(Fig. 1C–D.)**
Valves sigmoid in valve view, apices rounded, slightly curved in opposite directions; 3–6 fibulae in 10 µm; 16–18 striae in 10 µm. Length: 216–375 µm; Width in the central area: 9.5–19.5 µm; Width in the apices: 6 µm.
Characteristics and dimensions according to Knattrup et al. (2007).
Material examined: ERPL1, ERBL2, ERBL3.

Pseudo-nitzschia* aff. *pungens (Grunow ex Cleve) Hasle (1993: 319) **(Fig. 1E.)**
Valves linear to lanceolate; rectangular frustules in girdle view, forming colonies with individuals connected parallelly by the apices. Length: 82.6–90 µm; Width in the central area: 5–7.5 µm, Width in the apices: 3.8 µm.
The examined material shows morphological and size similarities to *P. pungens*, a cosmopolitan species complex divided into three genetically and ecophysiologically distinct clades, described as different varieties (Kim et al. 2015). However, Giulietti et al. (2021), showed through molecular data that these distinctions are not evident, with the same variety appearing in different clades. Characteristics and dimensions similar to *P. pungens,* according to Ajani et al. (2013).
Material examined: ERBL2, ERBL3, ERBH2.

Tryblionella coarctata (Grunow) D.G.Mann in Round, R.M.Crawford & D.G.Mann (1990: 678) **(Fig. 1F.)**
Valves linear-elliptical to lanceolate, constricted at the middle, apices apiculate; 13–14 striae in 10 µm, punctate and parallel. Length: 33–56 µm; Width: 10–21 µm.
Characteristics and dimensions according to Fernandes (1996) and Moura et al. (2007).
Material examined: ERPH1, ERPL1, ERBL2, ERBL3, ERBH3, ERBL4.

Tryblionella compressa (Bailey) Poulin in Poulin et al. (1990: 96) **(Fig. 1G.)**
Valves elliptical to lanceolate, apices apiculate; 9–10 striae in 10 µm, punctate and parallel. Length: 19–30 µm; Width: 6–14 µm.
Characteristics and dimensions according to Fernandes (1996) and Bertolli et al. (2019).
Material examined: ERPL1, ERBL2, ERBL3, ERBH2.

Tryblionella granulata (Grunow) D.G.Mann in Round, R.M.Crawford & D.G.Mann (1990: 678) **(Fig. 1H.)**
Valves elliptical, apices rounded; 3–9 striae in 10 µm, punctate and parallel. Length: 25–59 µm; Width: 11–28 µm.
Characteristics and dimensions according to Souza-Mosimann et al. (2001); Moura et al. (2007) and López-Fuerte et al. (2010).
Material examined: ERPL1, ERBL2, ERBL3, ERBH3.

Tryblionella lanceola Grunow in Cleve (1878: 14) **(Fig. 1I.)**

Valves lanceolate, apices slightly rounded; 10 striae in 10 µm, punctate and parallel. Length: 25–35 µm; Width: 7.5–8.2 µm.
Characteristics and dimensions according to Fernandes (1996).
Material examined: ERBL2, ERBL3, ERBH3.

Cocconeidales E.J.Cox
Cocconeidaceae Kützing

Campyloneis grevillei (W.Smith) Grunow & Eulenstein in Grunow (1868: 10) **(Fig. 1J.)**
Valves elliptical; raphe narrow, almost imperceptible in the raphe valve; 2 costae in 10 µm, thick, not reaching the valve center; 6 rows of coarsely punctate striae over the costae; 10–13 striae in 10 µm. Length: 36–58 µm; Width: 25–46 µm.
Characteristics and dimensions according to De Stefano et al. (2003).
Material examined: ERPH1, ERPL1, ERBL2, ERBL3, ERBH3.

Cocconeis scutellum Ehrenberg (1838: 194) **(Fig. 1K-L.)**
Valves flat, elliptical; central hyaline area thick; 5–6 radial striae in 10 µm, punctate, 5 poroid areolas in 10 µm. Length: 44 µm; Width: 30 µm.
Characteristics and dimensions according to De Stefano et al. (2008).
Material examined: ERPH1, ERPL1, ERBL2, ERBL3, ERBH2, ERBH3.

Cymbellales D.G.Mann
Anomoeoneidaceae D.G.Mann

Staurophora soodensis (Krasske) Bahls (2013: 10) **(Fig. 1M.)**
Valves linear-elliptical, apices rounded; raphe linear; central hyaline area with a transverse fascia reaching the valve margin; 18–20 striae in 10 µm. Length: 23.5 µm; Width: 7.8 µm.
First record for Northeast Brazil. The species has been previously described in the Rio Grande do Sul state (Torgan et al. 1999, as *Navicula soodensis* Krasske). Moreover, this is also the first record of the genus *Staurophora* for Northeast Brazil (Flora e Funga do Brasil 2024). Characteristics and dimensions according to Bahls (2013) and Jensen & Hustedt (1985), as *Stauroneis legleri* Hustedt.
Material examined: ERBL3.

Lyrellales D.G.Mann
Lyrellaceae D.G.Mann

Lyrella approximata (Greville) D.G.Mann in Round, Crawford & Mann (1990: 671) **(Fig. 1N.)**
Valves elliptical-lanceolate, apices acuminate; raphe linear; 9–11 striae in 10 µm, interrupted by an H-shaped central hyaline area, not reaching the apical margin of the valve, central striae not reaching the raphe central nodule, creating a broad central hyaline area. Length: 65–97 µm; Width: 35–37 µm.
First record for Northeast Brazil. The species has been previously described in Santa Catarina state (Fernandes 1996). This species is similar to *L. lyra*, differing by the central hyaline area not reaching the apical margins and by the absence of constriction in the central hyaline area in the middle. Also, striae do not reach the central nodule of the raphe in *L. approximata*. Characteristics and dimensions according to Fernandes (1996).
Material examined: ERPL1, ERBL2.

Lyrella hennedyi (W.Smith) Stickle & D.G.Mann in Round, Crawford & D.G.Mann (1990: 672) **(Fig. 1O.)**
Valves elliptical, apices slightly flat; raphe linear; 8–12 striae in 10 µm, with small ramifications, interrupted by an H-shaped central hyaline area, not reaching the apical margins of the valve, central striae reach the central nodule of the raphe, marginal striae are almost of the same size across the entire length of the valve, creating a central hyaline area enlarged at the middle. Length: 52–62 µm; Width: 35–37 µm.
Characteristics and dimensions according to Fernandes (1996).
Material examined: ERBL2, ERBL3.

Lyrella lyra (Ehrenberg) Karayeva (1978: 1595) **(Fig. 1P.)**
Valves elliptical or elliptical-lanceolate, apices rounded; raphe linear; 8–10 striae in 10 µm, interrupted by an H-shaped central hyaline area, constricted at the middle, reaching the apical margins of the valve, central striae reach the central nodule of the raphe. Length: 79–100 µm; Width: 33–45 µm.

Characteristics and dimensions according to Moura et al. (2007) and López-Fuerte et al. (2010).
Material examined: ERPH1, ERPL1, ERBL2, ERBL3, ERBH2, ERBH3.

Petroneis humerosa (Brébisson ex W.Smith) Stickle & D.G.Mann in Round, R.M.Crawford & D.G.Mann (1990: 674) **(Fig. 2A.)**
Valves rectangular, apices rostrate; raphe linear; central hyaline area circular; 9–14 radial striae in 10 µm, punctate. Length: 42–63 µm; Width: 16–32 µm.
Characteristics and dimensions according to Garcia et al. (2012).
Material examined: ERPH1, ERPL1, ERBL2, ERBL3, ERBH2, ERBH3.

Petroneis marina (Ralfs) D.G.Mann in Round, R.M.Crawford & D.G.Mann (1990: 674) **(Fig. 2B.)**
Valves elliptical or elliptical-lanceolate, apices rounded; raphe linear; central hyaline area circular; 10 transversal striae in 10 µm, punctate. Length: 56–90 µm; Width: 20–38 µm.
Characteristics and dimensions according to López-Fuerte et al. (2010).
Material examined: ERPH1, ERPL1, ERBL2, ERBL3, ERBH2, ERBH3, ERBL4.

Mastogloiales D.G.Mann
Achnanthaceae Kützing

Achnanthes grunowii Toyoda & D.M.Williams (2005: 7) **(Fig. 2C-D.)**
Valves rhombic to elliptical, apices cuneate; raphe valve concave and araphid valve convex; two terminal orbiculi on both apices in the araphid valve; central hyaline area narrow in the apical axis; transversal hyaline area inside a depression in the raphe valve; siliceous thickness in the araphid valve; raphe linear; 5–6 transapical costae in 10 µm in the raphe valve, with ramifications towards the margins, 4–5 transapical costae in 10 µm in the araphid valve, interrupted by two longitudinal lines along the margins; 2-4 striae in between the transapical costae. Length: 41–67 µm; Width: 29–35 µm.
First record for Northeast Brazil. The species has been previously described in Paraná and Santa Catarina states (Fernandes et al. 2002) as *A. javanica* Grunow f. *rhombica* Grunow. Characteristics and dimensions according to Cleve (1983) and Toyoda et al. (2005), and length according to Fernandes et al. (2002).
The individuals are very similar to *A. subconstricta* (Meister) Toyoda according to Lee et al. (2013; Fig. 2j) and Toyoda et al. (2003). However, the specimens from our samples lack a central constriction that gives a panduriform appearance to this taxon. In addition, our individuals exhibit a wider diameter (29 – 35 µm) than *A. subconstricta* as described by Toyoda et al. (2003) (14–29 µm) and Lee et al. (2013) (13–26 µm). While the shape and dimensions our specimens overlap with those of *A. javanica* Cleve & Grunow as described by Lee et al. (2013), the latter species lacks the terminal orbiculi. Furthermore, Toyoda et al. (2005) acknowledge that *A. grunowii* is more closely related to *A. subconstricta* than to the type variety of *A. javanica.*
Material examined: ERBL2, ERBL3.

Naviculales Bessey
Amphipleuraceae Grunow

Frustulia interposita (Lewis) De Toni (1891: 278) **(Fig. 2E-F, 5A-B.)**
Valves linear, apices rounded; raphe linear, between two axial linear and narrow ribs; 18–23 striae in 10 µm, crossing each other in 90º angles. Length: 113–155 µm, Width: 24–32 µm.
SEM: Terminal nodules globular, striae radial at the apices (Fig.5); central nodule elliptical and elongate; axial ribs and longitudinal striae curved at the middle (Fig.5).
First record for Northeast Brazil. The species has been previously reported in Santa Catarina state (Fernandes 1996). *Frustulia interposita* has been cited for Northeast Brazil only in ecological studies, without illustration or description, such as in Maranhão state (Cavalcanti et al. 2018). The species is similar to *Vanheurckia lewisiana*; however, they differ in the absence of a siliceous thickness between the axial ribs and the striae pattern (Fernandes 1996). Characteristics and dimensions according to Fernandes (1996).
Material examined: ERPL1, ERBL2, ERBL3.

Vanheurckia lewisiana (Greville) Brébisson (1869: 202) **(Fig. 2G-H, 5C-D.)**
Valves linear, apices rounded; raphe linear, between two axial linear and narrow ribs; central nodule elliptical and elongate; axial ribs attenuate at the apices, not reaching the apical margins; 19–22 transversal striae in 10 µm. Length: 130.5 µm; Width: 28.5 µm.

SEM: Transversal striae delicate, punctate; central nodule hyaline (Fig.5); siliceous thickness bar-shaped, surrounded by radial striae in the apices (Fig.5).
Characteristics and dimensions according to Fernandes (1996).
Material examined: ERPL1, ERBL3.

Diploneidaceae D.G.Mann

Diploneis gruendleri (A.W.F.Schmidt) Cleve (1894: 89) **(Fig. 2I.)**
Valves panduriform, slightly heteropolar, apices rounded; longitudinal channels hyaline; central axis with an asymmetrical sternum; raphe linear with central nodules rounded; 7–9 rows of areolae in 10 µm, parallel in the central region and radial towards the apices. Length: 24–44 µm; Width in the wider semi-valve: 10–23 µm; Width in the narrower semi-valve: 9–21 µm; Width in the central area: 5–12 µm.
First record for Northeast Brazil. The species has been previously reported in Rio de Janeiro (Andrade & Teixeira 1957), Santa Catarina (Souza-Mosimann 1988), and Pará states (Moreira-Filho et al. 1999). *Diploneis gruendleri* has only been cited in ecological studies for Northeast Brazil , without photographs or descriptions, such as in Maranhão (Cavalcanti et al. 2018) and Bahia states (Castro et al. 2013). *Diploneis gruendleri* can be confused with *Diploneis bombus* (Ehrenberg) Ehrenberg, but it differs in having smaller cells and an asymmetrical sternum in the central axis, unlike *D. bombus* (Cleve 1894; Noh & Choi 1992). Upon reviewing the material illustrated and described by Moura et al. (2007), we believe that the specimens identified as *D. bombus* might actually be *D. gruendleri*, as the illustrated taxon exhibits the asymmetry characteristic of the latter species. Characteristics and dimensions are according to Andrade & Teixeira (1957), López-Fuerte et al. (2010) and Souza-Mosimann (1988).
Material examined: ERPH1, ERPL1, ERBL2, ERBL3, ERBH2, ERBL4.

Diploneis* cf. *smithii (Brébisson) Cleve (1894: 96) **(Fig. 2J.)**
Valves elliptical, apices rounded, central area rounded; longitudinal channels hyaline; raphe linear with central nodules rounded; 12 striae in 10 µm, radial towards the apices and parallel at the middle. Length: 25–42 µm; Width: 11–19 µm.
Characteristics and dimensions according to Fernandes (1996), Idei et al. (2018), and López-Fuerte et al. (2010).
Material examined: ERPL1, ERBL2, ERBL3.

Naviculaceae Kützing

Caloneis permagna (Bailey) Cleve (1894: 59) **(Fig. 2K, 5E-F.)**
Valves elliptical-lanceolate, apices acuminate, central hyaline area rounded; raphe linear with rounded central nodules, curved to one side; 11–13 striae in 10 µm, delicate, transversally, not reaching valve center. Length: 105–151 µm; Width: 22–43 µm.
SEM: Internally, presents short alveoli openings (Fig.5); central raphe nodule conspicuous and piriform, apical nodule slightly hook-like (Fig.5).
Characteristics according to Fernandes (1996) and Souza-Mosimann et al. (2001).
Material examined: ERPH1, ERPL1, ERBL2, ERBL3, ERBH2, ERBH3, ERBL4.

Cymatoneis sulcata (Greville) Cleve (1894: 75) **(Fig. 2L-M.)**
Valves rhombic-lanceolate, wavy, apices apiculate to rounded; raphe linear; median lines slightly sigmoid; 10–11 striae in 10 µm, punctate. Length: 46 µm; Width: 20 µm.
First record for Northeast Brazil. The species has been previously reported in Rio de Janeiro state (Andrade & Teixeira 1957). Moreover, this is the first record of the genus *Cymatoneis* for Northeast Brazil (Flora e Funga do Brasil 2024). Characteristics and dimensions according to Jensen & Hustedt (1985).
Material examined: ERPL1.

Gyrosigma fasciola (Ehrenberg) J.W.Griffith & Henfrey (1856: 303) **(Fig. 2N-O.)**
Valves sigmoid, elongate, apices narrow acuminate, curved to opposite sides; raphe sigmoid, central nodule elongate; 20–22 inconspicuous striae in 10 µm, crossing each other in 90º angles. Length: 101 µm; Width: 15.
Characteristics and dimensions according to Fernandes (1996).
Material examined: ERBH2.

Gyrosigma subtile (Brébisson) G.Reid in G.Reid & D.M.Williams (2003: 139) **(Fig. 2P-Q; 5G; 6A-B.)**

Valves sigmoid, apices rounded; raphe sigmoid, apical nodules thick in the valve curve; central area hyaline, wide and transapically offset; 16–20 striae in 10 µm, crossing each other in 90º angles, curved near the apices and at the middle. Length: 155–288 µm; Width: 19–31 µm.
SEM: Central area with S-shaped transapical elevations; central bars flat (Fig.6); 15–16 areoles in 10 µm in the longitudinal striae and 17–20 areoles in the transversal striae (Fig.6); raphe apices with wide globular nodule, apices with a row of 14 pores above apical nodule (Fig.6).
First record for Brazil. *Gyrosigma subtile* is similar to *G. balticum* (Ehrenberg) Rabenhorst. However, our specimens showed different lengths and ratios between length and width compared with the description in the protologue of *Gyrosigma balticum* (Ehrenberg 1834), and they exhibit different apex morphology than the illustration presented by Rabenhorst (1853) for *G. balticum*. The specimens in our study have morphological characteristics and dimensions more closely related to *G. subtile* than to the type material of *G. balticum* (revised by Reid & Williams 2003), including length, width, central area shape, central bars, and the number of striae per 10 µm. The population in the present study presented slightly smaller individuals (155–288 µm) compared to the type material from Calvados, France (240–400 µm) (Reid & Williams 2003).
Material examined: ERPH1, ERPL1, ERBL2, ERBL3, ERBH2, ERBH3, ERBL4.

Navicula longa (W.Gregory) Ralfs in Pritchard (1861: 906) **(Fig. 3A.)**
Valves lanceolate, apices rounded; raphe linear; 8 striae in 10 µm, slightly radial in central area and parallel near the apices. Length: 63–103 µm; Width: 15–16 µm.
Characteristics and dimensions according to Moura et al. (2007), and López-Fuerte et al. (2010).
Material examined: ERPH1, ERPL1, ERBL2, ERBL3.

***Navicula* sp. (Fig. 3B, 6C-D.)**
Valves lanceolate, apices acuminate-rounded; central hyaline area slightly wider on one side, with a butterfly-like fascia; raphe linear; 12–16 striae in 10 µm, radial in the central area and parallel to convergent near the apices. Length: 19–32 µm; Width: 5.5–6.5 µm.
SEM: Valve surface flat with a clear border between the valve face and the mantle (Fig.6C), valvar mantle with a thin row of areole and closest to each other than striae areoles; raphe central nodule slightly thickened, raphe ending strongly hooked, raphe-sternum slightly elevated in external valve and broader at the raphe endings (Fig.6C-D), striae with 32–36 areolae in 10 µm, elongate and parallel to the apical axis; Voigt discontinuity visible in internal view (Fig.6C-D).
Characteristics and dimensions were similar to those described by Seddon et al. (2011) for *N. phylleptosomaformis* Seddon & Witkowski: length: 15–25; width: 4–6; striae in 10 µm: 16; and most notable, the presence of a distinct border between the valve face and the mantle, with the raphe-sternum slightly elevated. The dimensions of our specimens also overlap with those of *N. phylleptosoma* Lange-Bertalot but differ because the latter species has more striae (17–20) and areolae (40–45) in 10 µm, a circular central area (instead of butterfly-like), and markedly thickened central nodules, in addition to lacking the hooked-shaped end of the raphe (Lange-Bertalot & Genkal 1999). Our specimens also resemble the globally distributed and cryptic *N. phyllepta* Kützing 1844, according to Cox (1995) in terms of measurements (length: 12–45; width: 4–9; striae in 10 µm: 13–20). However, *N. phyllepta* does not feature a separation between the valve surface and mantle or a butterfly-like fascia, similarly to what is described for *N. phylleptosomaformis.* Considering the similarities and differences with these taxa, we could not reliably identify our individuals at the species level.
Material examined: ERPL1, ERBL2.

Pinnunavis yarrensis (Grunow) H.Okuno (1975:111) **(Fig. 3C-D; 6E; 7A-F.)**
Valves elliptical to lanceolate, apices rounded; central hyaline area rounded; raphe linear toward the entire valve, central nodules curved to one side, or sometimes straight; 5–8 alveoli in 10 µm, radially disposed towards the valve center, except by 3–6 last alveoli that become convergent turning to the apices, decreasing in size towards the valve ends. The size of specimens varies widely within the population. Length: 43–91 µm; Width: 11–22 µm.
SEM: Central nodules oblique and elevated in the internal view of the valve (Fig.7); alveoli inflection point (i.e. point where radial alveoli become convergent turning to the apices) may differ between the sides of the valves (Fig.7), each alveoli are externally closed by a sieve membrane with multiseriate striae (Fig.7), while are freely open in the internal view (Fig.7); raphe ending hook-like, slightly curved near the mantle (Fig.7), forming a helictoglossa with a row of pores above the apical nodule (Fig.7).
First record for Northeast Brazil. *Pinnunavis yarrensis* has been previously cited in Santa Catarina (Souza-Mosimann et al. 2001) and Rio Grande do Sul states (Torgan et al. 1999) as *Navicula yarrensis* Grunow.

Moreover, this marks the first record of the genus *Pinnunavis* for Northeast Brazil (Flora e Funga do Brasil 2024). Characteristics and dimensions according to Okuno (1975) and Edgar et al. (2015).
Material examined: ERPH1, ERPL1, ERBL2, ERBL3, ERBH2, ERBH3, ERBL4.

Seminavis robusta Danielidis & D.G.Mann (2002: 440) **(Fig. 3E.)**
Valves semi-lanceolate, dorsiventral in valve view, elongate, apices acute; raphe linear; 16 striae in 10 µm, radial in the central region and parallel towards the apices. Length: 69–73 µm; Width: 11–13 µm.
First record of this morphospecies for Northeast Brazilian. The species has been previously reported in Paraná state by Moreira-Filho (1959), Moreira Filho & Kutner (1962), Fernandes et al. (1990), and Talgatti et al. (2014). This taxon was mentioned by Costa et al. (2016) for Pernambuco state in an ecological study; however, it lacks description, illustration, and voucher. Our specimens are similar to those described by Danielidis & Mann (2002) but with greater dimensions. Danielidis & Mann (2003) noted that these size variations may be confused with *Seminavis latior* (Schmidt) Danielidis & Mann, a closely related species. De Decker et al. (2018) recently reported that *S. robusta* is a species complex of morphologically undistinguishable taxa with incomplete reproductive barriers. Characteristics and dimensions are according to Wachnicka & Gaiser (2007).
Material examined: ERPL1, ERBL2, ERBL3, ERBH2, ERBH3.

Trachyneis aspera (Ehrenberg) Cleve (1894: 191) **(Fig. 3F.)**
Valves linear-elliptical, apices cuneate; central hyaline area expands towards the margins, forming a stauros; raphe linear in almost all its extension, curved near the apices; 10–15 striae in 10 µm, punctate, parallel near the apices and radial at the middle. Length: 65–125 µm; Width: 15–22 µm.
First record for Pernambuco state. The species has been previously described in e Maranhão state (Azevedo 1999) and Rio Grande do Norte (Flora e Funga do Brasil 2024). Characteristics and dimensions according to Jensen & Hustedt (1985) and Fernandes (1996).
Material examined: ERPH1, ERBL2.

Plagiotropidaceae D.G.Mann

Plagiotropis lepidoptera (W.Gregory) Kuntze (1898: 421) **(Fig. 3G, 7G; 8A.)**
Valves elliptical-lanceolate, apices acuminate; 17–24 striae in 10 µm, interrupted by a hyaline longitudinal line; 1–2 marginal longitudinal lines. Length: 87–127 µm; Width: 18–26 µm.
SEM: Raphe keel-shaped; 23–26 areolas in 10 µm in the striae (Fig. 7, 8); longitudinal lines correspond to the keels in the internal view of the valve (Fig. 8).
Characteristics and dimensions according to Fernandes (1996).
Material examined: ERPH1, ERPL1, ERBL2, ERBL3, ERBH2, ERBH3, ERBL4.

***Plagiotropis* sp. (Fig. 3H, 8B-C.)**
Valves elliptical-lanceolate; raphe keel-shaped; 5–6 striae in 10 µm, interrupted by a hyaline longitudinal line; 1–2 marginal longitudinal lines. Length: 143–168 µm; Width: 27.6–32 µm.
SEM: Raphe situated on a keel-shaped ridge; striae with different sizes, sometimes ending in the first third of the valve surface, 4–6 striae in 10 µm on the central nodule side, and 8–10 striae in 10 µm on the opposite side; striae with 23–25 areole in 10 µm (Fig. 8).
Material examined: ERBL3.

Pleurosigmataceae Mereschowsky

Pleurosigma angulatum (J.T.Quekett) W.Smith (1852: 7) **(Fig. 3I-J.)**
Valves slightly sigmoid, rhombic-lanceolate, apices rounded; raphe sigmoid; 22 transverse and diagonal striae in 10 µm, crossing each other in less than 60º angles. Length: 116–190 µm; Width: 25–32 µm.
Characteristics and dimensions according to Jensen & Hustedt (1985).
Material examined: ERPL1, ERBL2, ERBL3, ERBH2, ERBH3, ERBL4.

Pleurosigma elongatum W.Smith (1852: 6) **(Fig. 3K-L.)**
Valves slightly sigmoid, lanceolate, narrowing from the center to the apices, apices rounded; raphe slightly sigmoid; 17 oblique striae in 10 µm, crossing each other in less than 60º angles. Length: 213–303 µm; Width: 21–27 µm.
Species similar to *P. angulatum*, differing in size and number of striae in 10 µm. Characteristics and dimensions according to Jensen & Hustedt (1985), Hendey (1964), and Reid (2002).
Material examined: ERPL1, ERBL2, ERBL3, ERBH3, ERBL4.

Rhopalodiales D.G.Mann
Rhopalodiaceae (Karsten) Topachevs'kyj & Oksiyuk

Epithemia adnata (Kützing) Brébisson (1838: 16) **(Fig. 3M, 8D.)**
Valves slightly dorsiventral, apices rounded; raphe close to the ventral margin in almost all extension, expanding to the central area at the middle; 3 costae in 10 µm; 10–13 areolas in 10 µm. Length: 50–62 µm, Width: 7.5–12 µm.
SEM: 3–6 striae between adjacent costae, with a radial position near the apices and parallel in the middle (Fig. 8).
First record for Northeast Brazil. The species has been previously reported in Santa Catarina state (Souza-Mosimann et al. 2001). *Epithemia adnata* has been cited for Northeast Brazil only in freshwater ecological studies, without photographs or descriptions, such as for Pernambuco (Diniz et al. 2023), Ceará (Amorim et al. 2015, as *E. zebra* (Ehrenberg) Kützing)), and Paraíba states (Cordeiro et al. 2017). Characteristics and dimensions according to Souza-Mosimann et al. (2001).
Material examined: ERPL1, ERBL2, ERBL3, ERBH2, ERBH3, ERBL4.

Surirellales D.G.Mann
Surirellaceae Kützing

Campylodiscus brightwellii Stodder (1861: 26) **(Fig. 3N.)**
Valves circular-ovate, strongly convex; central hyaline area linear, surrounded by an elevated elliptical area, from where the costae come from; 4–6 costae in 10 µm, acuminate in the central area and dilated towards the margin. Length: 30-43 µm; Width: 23-39 µm.
Characteristics and dimensions according to Navarro (1983) and Navarro & Lobban (2009).
Material examined: ERPH1, ERPL1, ERBL2, ERBL3, ERBH2.

Campylodiscus neofastuosus Ruck & Nakov in Ruck et al. (2016: 3) **(Fig. 3O.)**
Valves elliptical-ovate, heteropolar; lanceolate hyaline central area; 2–3 costae in 10 µm, acuminate in the center and dilated towards the margin; 2 longitudinal lines of small striae in the central area that merge towards the apices; 11–13 striae in 10 µm. Length: 37–159 µm; Width: 26–90 µm.
Characteristics and dimensions are according to Gopinathan (1984) and López-Fuerte et al. (2010), as well as *Surirella fastuosa* (Ehrenberg) Ehrenberg.
Material examined: ERPH1, ERPL1, ERBL2, ERBL3, ERBH2, ERBH3, ERBL4.

Coronia decora (Brébisson) Ruck & Guiry (2016: 2) **(Fig. 3P, 8E-F.)**
Valves circular to sub-circular, slightly convex; central hyaline area narrow, lanceolate; 2–3 costae in 10 µm, acuminate in the center and expanded towards the margin. Length: 37–44 µm; Width: 37–48 µm.
SEM: Central area with short spines; valve perimeter surrounded by a sub-marginal raphe; costae branches ending in pyriform cups (Fig. 8).
This species is similar to *Campylodiscus fastuosus*, differing in the shape of the central area lacking an elevated area, and the number of costae in 10 µm. Characteristics and dimensions according to Al-Handal et al. (2018) and Park et al. (2014).
Material examined: ERPL1, ERBL2, ERBL3.

Surirella febigeri F.W.Lewis (1861: 63) **(Fig. 3Q, 4A, 8G.)**
Valves elliptical-ovate, heteropolar, margins wavy; 2 costae in 10 µm; 2 longitudinal lines of small striae in the central area that merge towards the apices; 11–14 striae in 10 µm. Length: 65–190 µm; Width: 30–75 µm.
SEM: Presence of small rounded punctuations, forming thin transverse lines in the fissures between the costae and in the concavity of the central lanceolate area (Fig. 8).
Characteristics and dimensions according to Fernandes (1996), López-Fuerte et al. (2010), and Souza-Mosimann et al. (2011).
Material examined: ERPL1, ERBL2, ERBL3, ERBH2, ERBH3, ERBL4.

Surirella robusta Ehrenberg (1841: 215) **(Fig. 4B.)**
Valves linear-lanceolate, slightly heteropolar; 2 costae in 10 µm; 2 parallel longitudinal lines of small striae in the central area; striae inconspicuous. Length: 78–115 µm; Width: 30–41 µm.
First record for Northeast Brazil. The species has been previously described in São Paulo state (Ferreira & Bicudo 2017). *Surirella robusta* has been mentioned for Northeast Brazil only in ecological studies, without

photographs or descriptions, such as for Bahia state (Severiano et al. 2012). Characteristics and dimensions according to Flôres et al. (1999).
Material examined: ERPL1, ERBL2, ERBL3, ERBH3.

Thalassiophysales D.G.Mann
Catenulaceae Mereschkowsky

Amphora ovalis (Kützing) Kützing (1844: 107) **(Fig. 4C.)**
Valves dorsiventral in valve view, apices rounded; raphe curved, close to the ventral margin and ending at the center of the valve apices, central nodules elongate; the presence of depression between the central nodules; 11–12 striae in 10 µm, radial near the apices and parallel at the middle. Length: 37–61 µm; Width: 11–12 µm.
Characteristics and dimensions according to Gopinathan (1984) and Souza-Mosimann et al. (2011).
Material examined: ERPL1, ERBL2, ERBL3, ERBH2.

Fragilariales P.C.Silva
Fragilariaceae Kützing

Podocystis adriatica (Kützing) Ralfs in Pritchard (1861: 772) **(Fig. 4D.)**
Valves piriform; pseudo-raphe median; 3–4 transversal costae in 10 µm; 2 striae in each costa. Length: 50–54 µm; Width: 34–36 µm.
Characteristics and dimensions according to Stidolph (1980), Fernandes et al. (2002), and Harper & Garbary (1994).
Material examined: ERPH1, ERBL3.

Licmophorales Round
Licmophoraceae Kützing

Licmophora abbreviata C.Agardh (1831: 42) **(Fig. 4E-F.)**
Valves heteropolar, cuneate in the girdle view and clavate in the valve view; central hyaline area narrow; 10–12 striae in 10 µm in the base and 13–15 striae in 10 µm in the apices. Length: 52–56 µm; Apical width: 8 µm; Basal width: 4 µm.
Characteristics and dimensions according to Lobban (2013).
Material examined: ERPL1, ERBL3.

Ulnariaceae E.J.Cox

Catacombas gaillonii (Bory) D.M.Williams & Round (1986: 315) **(Fig. 4G-H.)**
Valves linear, apices rounded, slightly acuminate; 8–10 transverse striae in 10 µm, interrupted by one median line and two lateral ones, striae less dense at the poles. Length: 333 µm; Width: 20 µm.
Characteristics according to Krammer & Lange-Bertalot (1991).
Material examined: ERBL3.

Rhabdonematales Round & R.M.Crawford
Grammatophoraceae Lobban & Ashworth

Grammatophora marina (Lyngbye) Kützing (1844: 128) **(Fig. 4I.)**
Valves linear, rectangular in girdle view; 2 wavy septa that extend to the central area. Length: 20–56 µm; Width: 12–18 µm.
Species similar to *Grammatophora oceanica* Ehrenberg in the girdle view, differing by the shape of the septa.
Characteristics and dimensions according to Gopinathan (1975), Fernandes (1996), and Moura et al. (2007).
Material examined: ERPH1, ERPL1, ERBL2, ERBL3, ERBH2, ERBH3.

Grammatophora oceanica Ehrenberg (1840: 161) **(Fig. 4J.)**
Valves linear, rectangular in girdle view; 2 septa slightly wavy in the first 1/3 upper and linear in the lower 2/3. Length: 32–112 µm; Width: 12–23 µm.
Characteristics according to Gopinathan (1975).
Material examined: ERPH1, ERPL1, ERBL2, ERBL3, ERBH2, ERBH3, ERBL4.

Rhabdonemataceae Round & R.M.Crawford

Rhabdonema adriaticum Kützing (1844: 126) **(Fig. 4K.)**
Valves linear, rounded apices, forming ribbon-shaped colonies; 15 striae in 10 µm; several septa in the girdle view. Length: 70–110 µm.
Characteristics according to Moura et al. (2007).
Material examined: ERPH1, ERPL1, ERBL2, ERBL3, ERBH2, ERBH3.

Plagiogrammales E.J.Cox
Plagiogrammaceae De Toni

Plagiogramma pulchellum Greville (1859: 209) **(Fig. 4L, 8H.)**
Valves linear-elliptical, apices rounded; central hyaline area delimited by two pseudo-septa; two subcircular apical areas, also delimited by pseudo-septa; 7–11 striae in 10 µm, punctate. Length: 28–54 µm; Width: 7–15 µm.
SEM: Subcircular apical areas ornamented with pores; striae with 10 pores in 10 µm (Fig. 8).
Characteristics and dimensions according to Fernandes (1996) and Moura et al. (2007).
Material examined: ERPL1, ERBL2, ERBL3.

Plagiogramma staurophorum (W.Gregory) Heiberg (1863: 55) **(Fig. 4M.)**
Valves lanceolate, apices rounded; central hyaline area fascia-shaped, delimited by two pseudo-septa; two subcircular apical areas, also delimited by pseudo-septa; 16 striae in 10 µm, punctate. Length: 31 µm; Width: 10 µm.
First record for Northeast Brazil. The species has been previously described in Santa Catarina state (Fernandes 1996, Souza-Mosimann et al. 2011). Characteristics and dimensions according to Fernandes (1996) and Souza-Mosimann et al. (2011).
Material examined: ERPL1, ERBL2, ERBL3, ERBH2.

Rhaphoneidales Round
Asterionellopsidaceae Medlin

Asterionellopsis glacialis *sensu lato* **(Fig. 4N.)**
Valves enlarged, base triangular, apices apiculate, forming starry colonies; striae delicate and inconspicuous. Length: 45–58 µm, Width: 9–15 µm.
Kaczmarska et al. (2014) discussed that *A. glaciallis* is a species complex composed of at least five genetically distinct species with cryptic morphology, four of which were described as new species by the authors. Three species of the *Asterionellopsis glacialis* complex are confirmed along the Brazilian coast based on molecular data: *A. tropicalis* A.O.R.Franco, *A. thurstonii* J.M.Erhman and *A. guyunusae* I.A.Luddington; with only *A. tropicalis* referred for Northeast Brazil (Franco et al. 2016; 2023). Characteristics and dimensions according to Souza-Mosimann et al. (2011).
Material examined: ERPL1, ERBL2, ERBL3, ERBH2.

Rhaphoneidaceae Forti

Rhaphoneis castracanei Grunow in Van Heurck (1881: 36) **(Fig. 4O.)**
Valves bipolar, margins wavy, forming six angles; central hyaline area lanceolate; 6–7 rows of areolas in 10 µm, radial near the apices, and parallel in the middle. Length: 35–39 µm, Width: 24–29 µm.
Characteristics and dimensions according to Fernandes (1996).
Material examined: ERBL2, ERBL3, ERBH2.

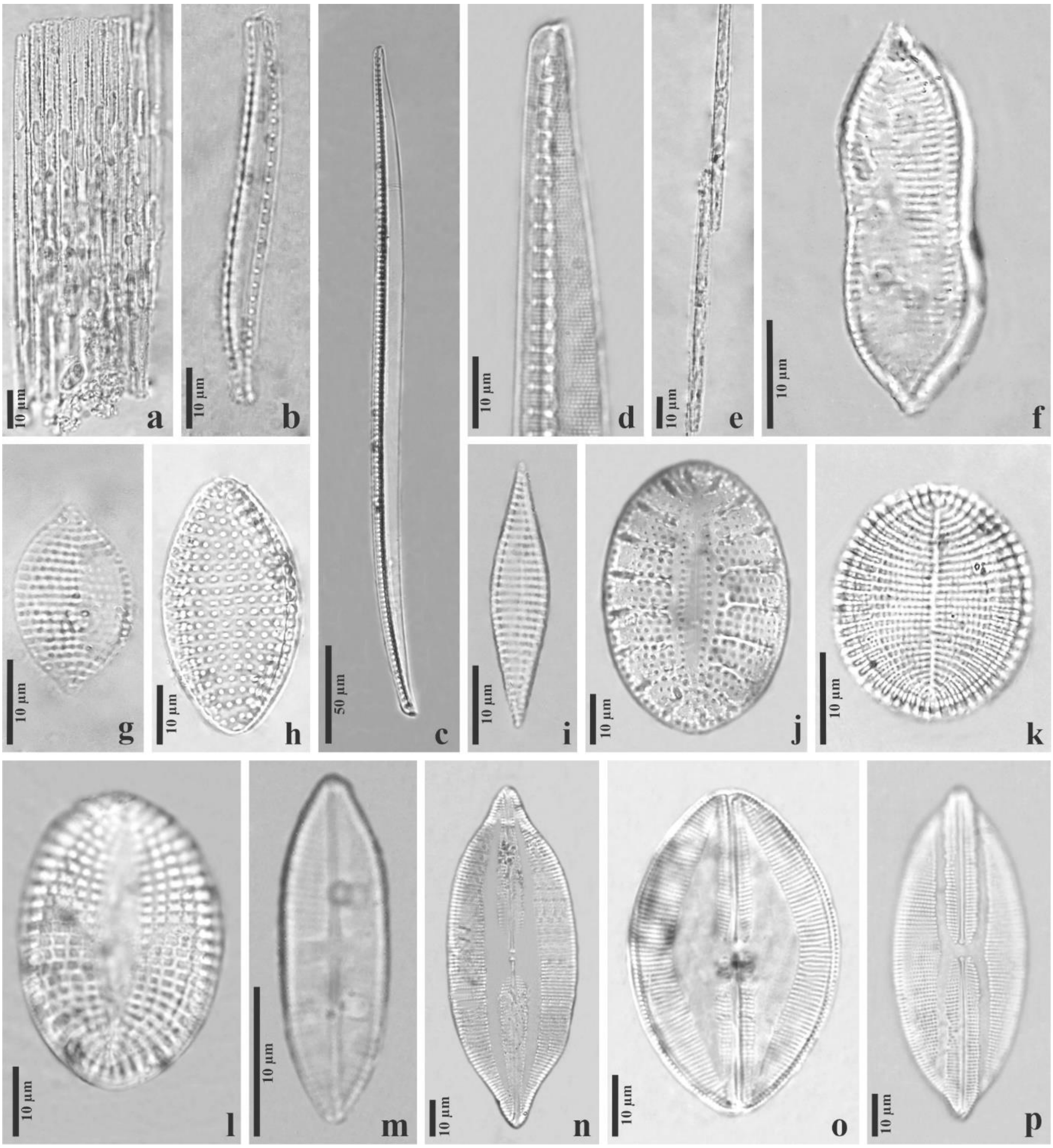

Figure 1a-p. a. ***Bacillaria paxillifera.*** b. ***Nitzschia*** **cf.** ***obtusa.*** c-d. ***Nitzschia sigmoidea.*** e. ***Pseudo-nitzschia pungens.*** f. ***Tryblionella coarctata.*** g. ***Tryblionella compressa.*** h. ***Tryblionella granulata.*** i. ***Tryblionella lanceola.*** j. ***Campyloneis grevillei.*** k-l. ***Cocconeis scutellum.*** m. ***Staurophora soodensis.*** n. ***Lyrella approximata.*** o. ***Lyrella hennedyi.*** p. ***Lyrella lyra.*** **Scale bars: 50 µm for Figure c; 10 µm for the others.**

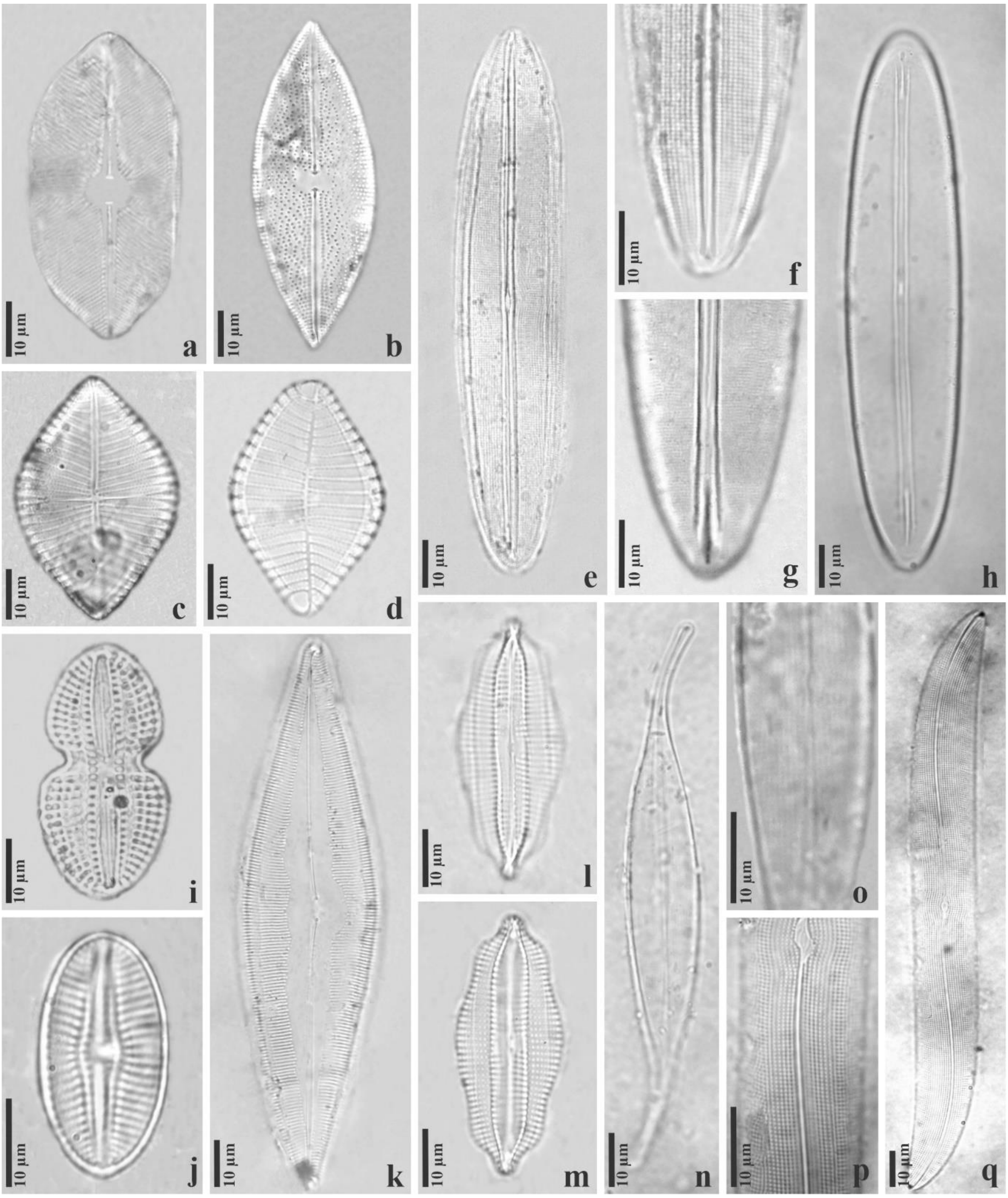

Figure 2a-q. a. *Petroneis humerosa*. b. *Petroneis marina*. c-d. *Achnanthes grunowii*. e-f. *Frustulia interposita*. g-h. *Vanheurckia lewisiana*. i. *Diploneis gruendleri* j. *Diploneis* cf. *smithii*. k. *Caloneis permagna*. l-m. *Cymatoneis sulcata*. n-o. *Gyrosigma fasciola*. p-q. *Gyrosigma subtile*. Scale bars: 10 µm.

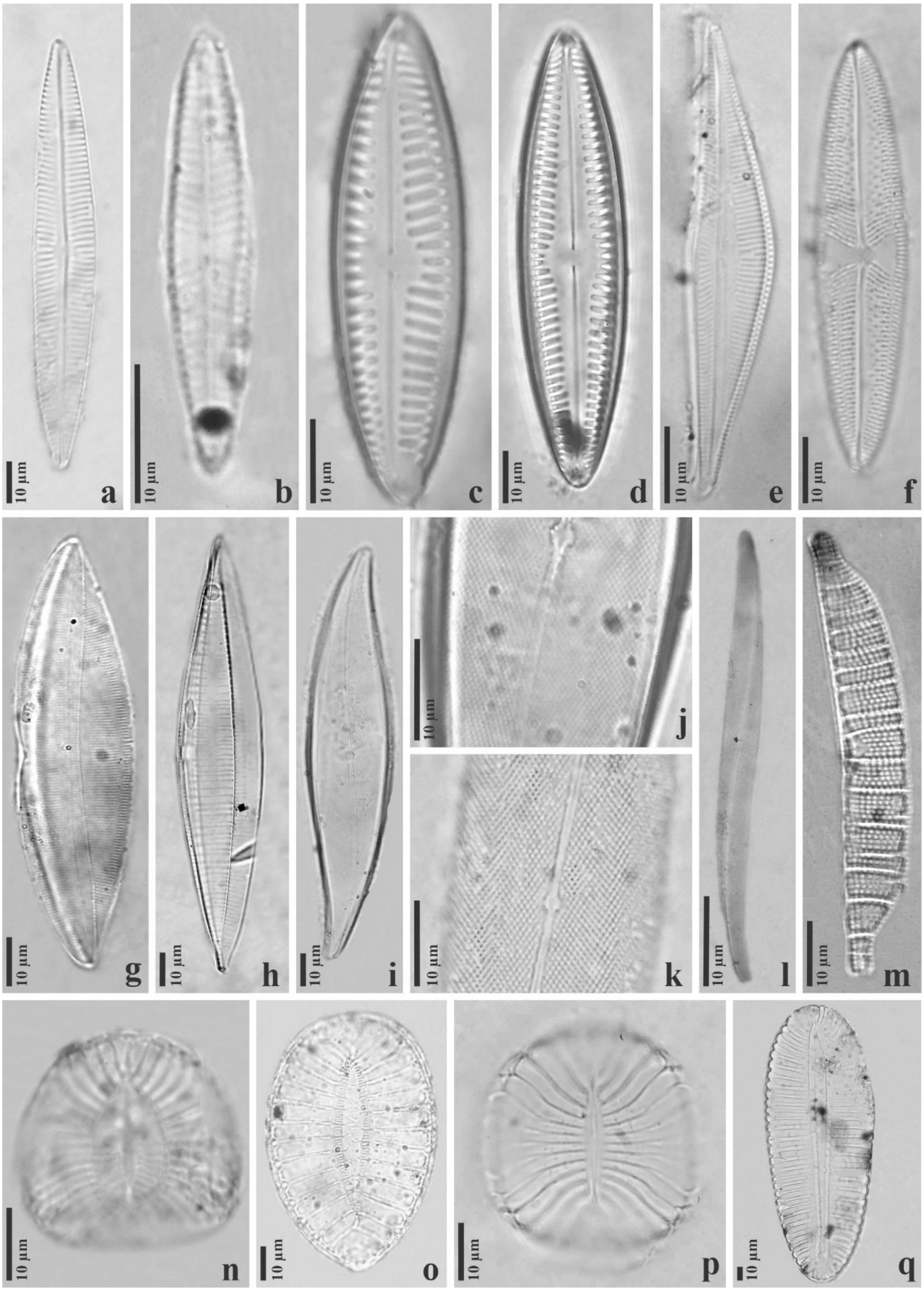

Figure 3a-q. a. *Navicula longa*. b. *Navicula* sp. c-d. *Pinnunavis yarrensis*. e. *Seminavis robusta* f. *Trachyneis aspera*. g. *Plagiotropis lepidoptera*. h. *Plagiotropis* sp.. i-j. *Pleurosigma angulatum*. k-l. *Pleurosigma elongatum*. m. *Epithemia adnata*. n. *Campylodiscus brightwelli*. o. *Campylodiscus neofastuosus*. p. *Coronia decora*. q. *Surirella febigeri*. Scale bars: 10 µm.

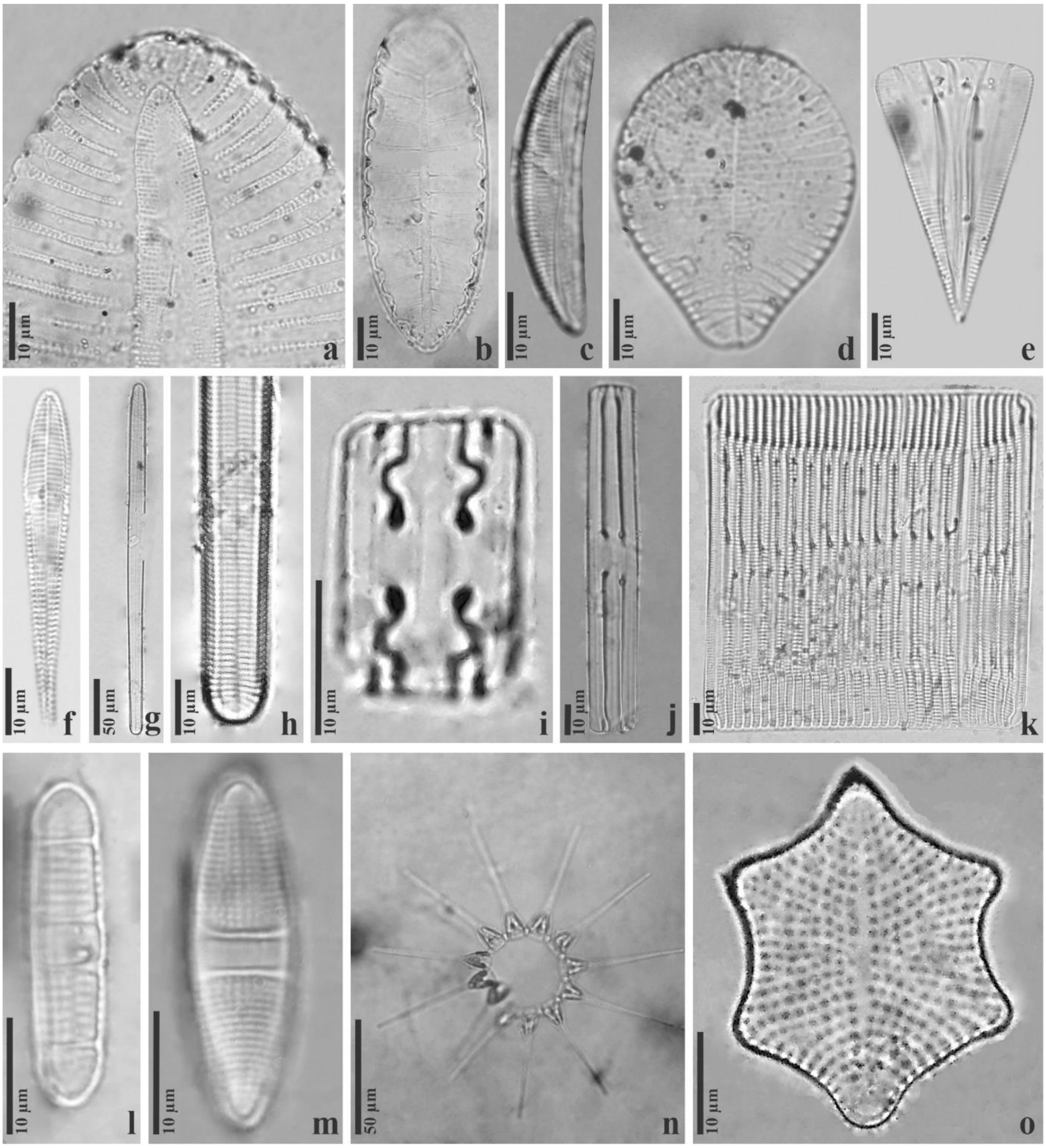

Figure 4a-o. a. *Surirella febigeri*. b. *Surirella robusta*. c. *Amphora ovalis*. d. *Podocystis adriatica*. e-f. *Licmophora abbreviata*. g-h. *Catacombas gaillonii*. i. *Grammatophora marina*. j. *Grammatophora oceanica*. k. *Rhabdonema adriaticum*. l. *Plagiogramma pulchellum*. m. *Plagiogramma staurophorum*. n. *Asterionellopsis glacialis*. o. *Rhaphoneis castracanei*. Scale bars: 50 µm for Figures g and n; 10 µm for the others.

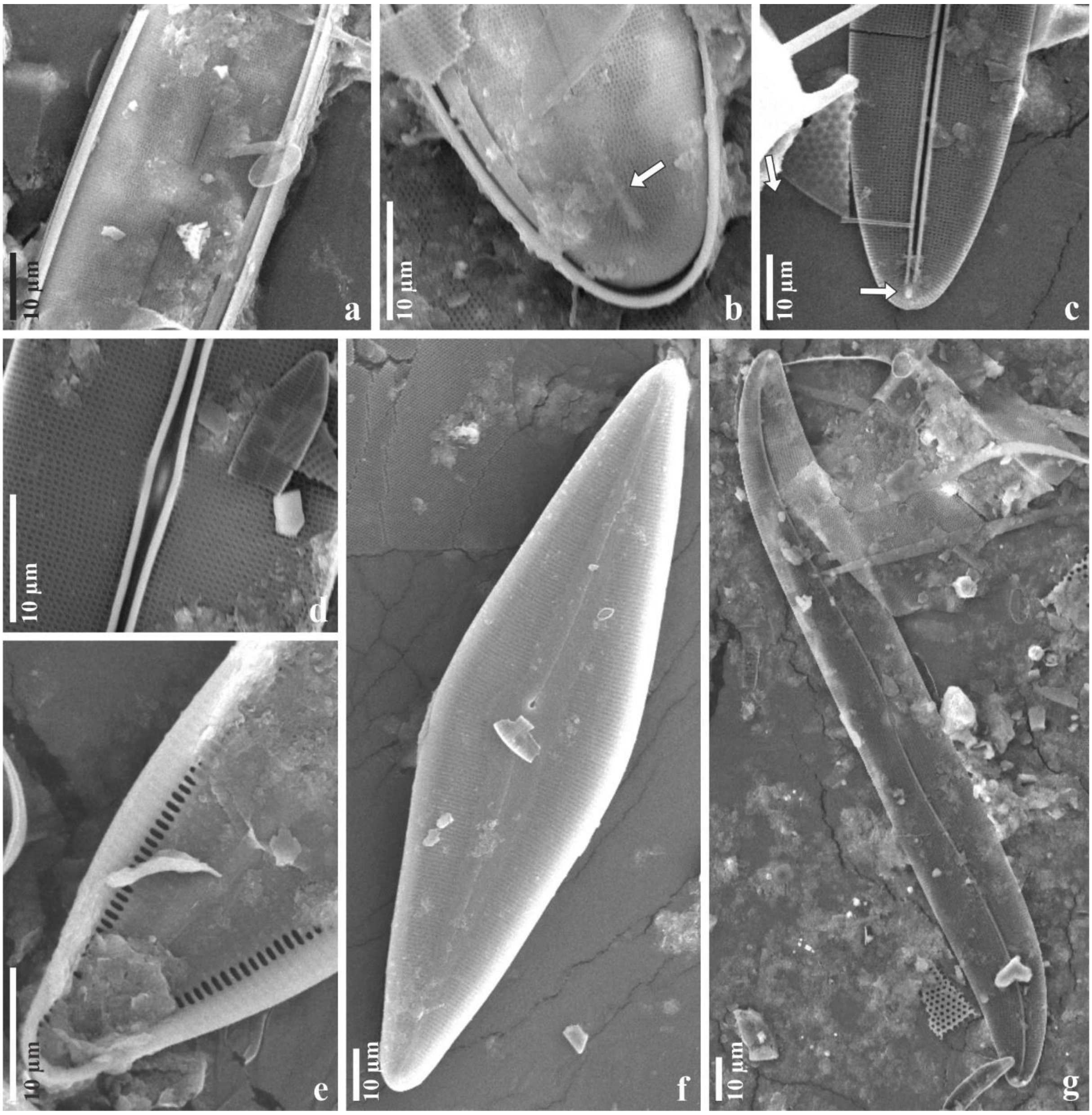

Figure 5a-g. a-b. *Frustulia interposita*. a. Valve apex, white arrow indicates the globular terminal nodule. b. Central valve area, showing the striae. c-d. *Vanheurckia lewisiana*. c. White arrow indicates the silica thickening. e-f. *Caloneis permagna*. e. Internal view of the valve, showing the opening of the alveoli. f. External view of the valve. g. *Gyrosigma subtile*, showing the external view of the valve. Scale bars: 10 µm.

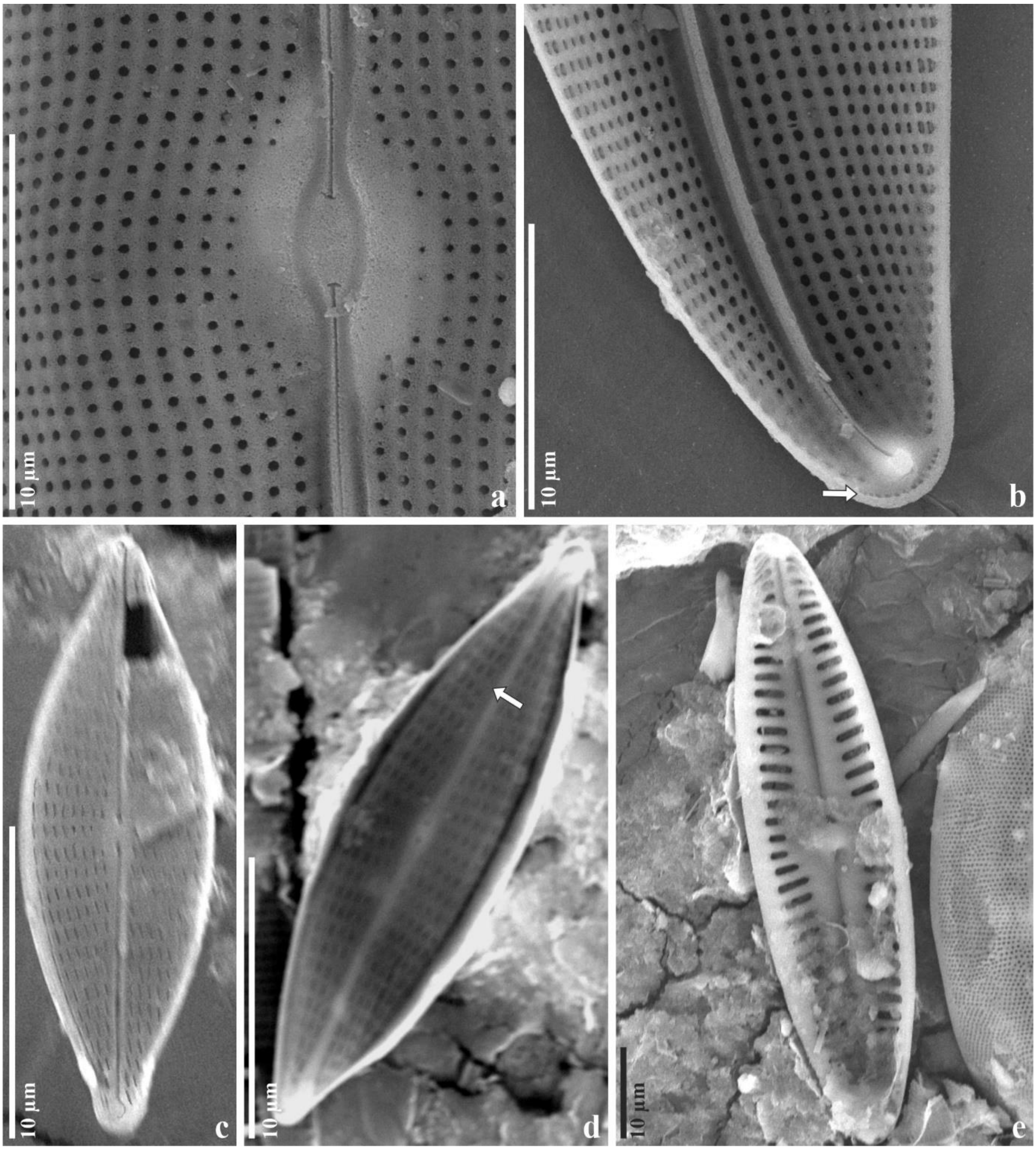

Figure 6a-e. a-b. *Gyrosigma subtile*. a. External view of the central valve area, showing the striae and central bars. b. Internal view of the valve apex, white arrow indicates the row of pores above the apical nodule. c-d. *Navicula* sp. c. External view of the valve. d. Internal view of the valve, white arrow indicates Voigt discontinuity. e. *Pinnunavis yarrensis*, showing the internal view of the valve. Scale bars: 10 µm.

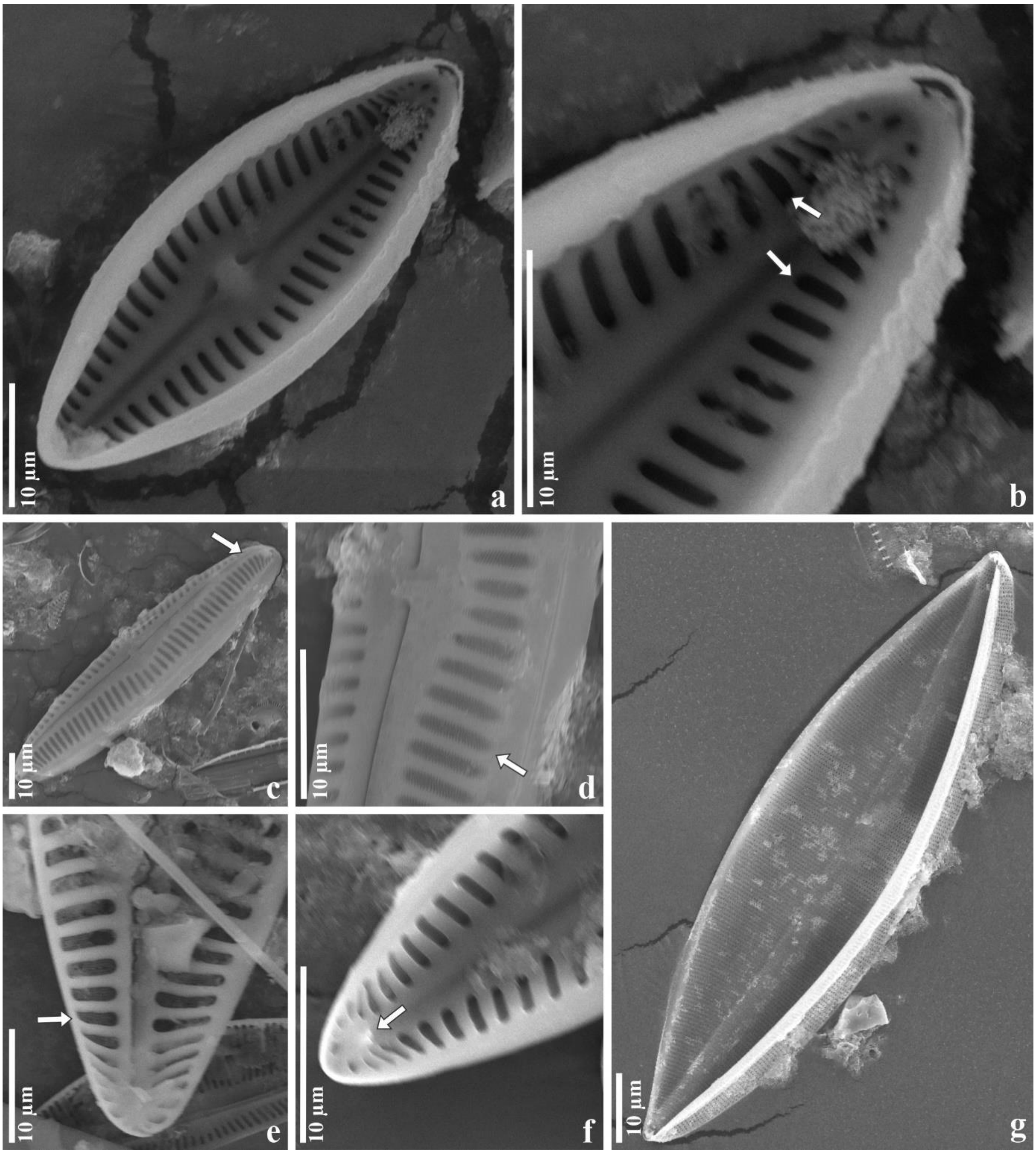

Figure 7a-g. a-f. *Pinnunavis yarrensis*. a. Internal view of the valve, showing the central nodules. b. Valve apex, white arrows indicate the alveoli inflection point, where radial alveoli become convergent turning to the apices. c. External view of the valve, white arrow indicates the raphe ending. d. External view of the valve, showing the central hyaline area, raphe, and central nodules, white arrow indicates the sieve membrane with multiseriate striae covering the alveoli. e. Valve apex, white arrow indicates the internal face of the alveoli showing the sieve membrane inside of them. f. Valve apex, white arrow indicates the helictoglossa with a row of pores above the apical nodule. g. *Plagiotropis lepidoptera*, showing the external view of the valve. Scale bars: 10 µm.

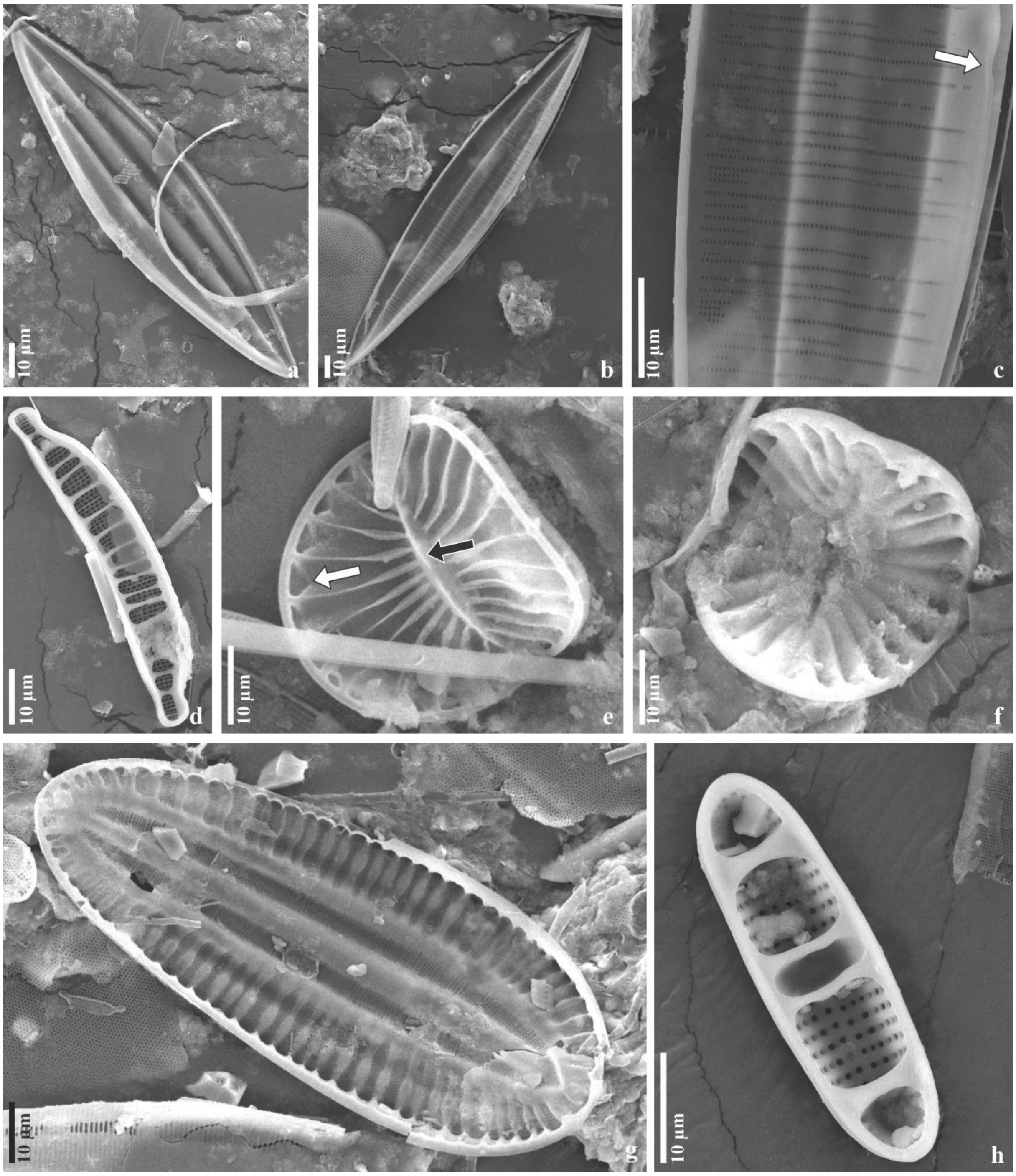

Figure 8a-h. a. *Plagiotropis lepidoptera*, showing the internal view of the valve and keels. b-c. *Plagiotropis zebra*. b. Internal view of the valve, showing the keels and the hyaline longitudinal line. c. Internal view of the valve, showing the striae, white arrow indicates the central nodule. d. *Epithemia adnata*. e-f. *Coronia decora*. e. External view of the valve, black arrow indicates the short spines in the central area, white arrow indicates piriform cups. f. Internal view of the valve. g. *Surirella febigeri*. h. *Plagiogramma pulchellum*. Scale bars: 10 µm.

4 DISCUSSION

This study identified 51 taxa of pennate diatoms in two estuaries, a species richness significantly higher than that reported by Moura et al. (2007), who documented only 33 infraspecific taxa across all diatom classes the benthic diatoms in the Paripe River estuary (the same as in the present study), 24 of which were pennate diatoms. Among the species identified by Moura et al. (2007), 15 are also reported in the present study, while eight species and one variety were absent. Overall, the diatoms found in this study were common to both the Paripe and Botafogo estuaries (39 spp.), highlighting their environmental similarities due to proximity. The Botafogo River estuary presented the highest species richness (50 taxa) when compared to the Paripe estuary (40 taxa). Most species were recorded in the samples collected during the low tide period.

This research provides the first report of *Gyrosigma subtile* for the Brazilian territory, contributing to the knowledge of its geographical distribution. Although *G. subtile* is often mistaken with *Gyrosigma balticum* due to morphological similarities, our specimens exhibited clear differences from the type material of *G. balticum* described by Ehrenberg (1834), such as shorter length and length-to-width ratio (15-16 for *G. balticum*; 8.2-9.3 for individuals in the present study). The morphometric characteristics of the specimens found in the present study are in accordance with the type material of *G. subtile*, and different from the type material of *G. balticum*, both analyzed by Reid & Williams (2003). *G. balticum* is distributed worldwide, with records from all continents (Guiry & Guiry 2021) and is known in the Northeastern, Southeastern, and Southern regions of Brazil (Flora e Funga do Brasil 2024). However, *G. balticum* is considered part of a cryptic species complex and has been studied for decades. Reid & Williams (2003) resolved this species complex through morphological analyses of the type material of *G. balticum* and related species. The authors separated 12 species closely related to *G. balticum*, including three new species, through cladistic analysis of morphological characters. Among these species, the authors combined *Pleurosigma subtile* (Brébisson) Ralfs into the genus *Gyrosigma* (*G. subtile*), distinguishing it from *G. balticum* by its smooth and flattened central bars, as opposed to thick in the central area.

For Northeast Brazil, 11 new records were added to the species level: *Staurophora soodensis*, *Seminavis robusta*, *Lyrella approximata*, *Diploneis gruendleri*, *Achnanthes grunowii*, *Frustulia interposita*, *Cymatoneis sulcata*, *Pinnunavis yarrensis*, *Epithemia adnata*, *Surirella robusta*, and *Plagiogramma staurophorum*. Additionally, *Trachyneis aspera* was recorded for the first time in the Pernambuco state. *T. aspera* can be confused with the variety *Trachyneis aspera* var. *intermedia* (Grunow ex A.W.F.Schmidt), as they share similar morphological characteristics, differing only in the central area. In *Trachyneis aspera*, the stauros in the central area is broad and truncated, extending to the valve's edge, and this species has a greater number of striae (Jensen & Hustedt 1985). Moreover, *Trachyneis aspera* var. *intermedia* has not been recorded in Northeast of Brazil, being registered only in South and Southeast regions (Flora e Funga do Brasil 2024).

Furthermore, the genera *Cymatoneis*, *Pinnunavis*, and *Staurophora* are reported for the first time in Northeast Brazil. They are not registered for this region in the list of "Flora do Brasil" (Menezes et al. 2015, Flora e Funga do Brasil 2024) and other taxonomic and floristic studies. These three genera were initially classified under *Navicula* and later segregated. Currently, *Cymatoneis* has five taxonomically accepted species and three species of uncertain status, while the genus *Pinnunavis* has ten accepted species and one variety, and *Staurophora* has 18 taxonomically accepted species (Guiry & Guiry 2024).

Our study presented a high number of pennate diatom species compared to other studies along the Brazilian coast, with 11 new records, confirming our hypothesis. A detailed description and high-quality images from optical and scanning electron microscopy of the registered species will aid future taxonomic and ecological studies of diatoms in coastal regions of Northeast Brazil. Furthermore, this study, which documents diatom diversity before the 2019 oil spills on the Brazilian coast, may assist future research on the impacts of this pollution event on pennate estuarine diatoms.

Traditionally, species richness is considered a useful biological index for monitoring the ecological integrity of marine communities and their response to environmental impacts, especially since richness is one of the most sensitive indexes (Johnston & Roberts 2009). Some studies have demonstrated a decrease in diatom species richness in response to environmental stressors (Weckström et al. 2007). In this context, taxonomic surveys such as the present study provide valuable baseline data for ecological studies by facilitating identification and providing a historical record of species composition and morphology.

Despite the high diversity and information available for some species in literature, others are underrepresented, with information sometimes limited to protologues, which are often unavailable or lack important information and illustrations, for example, for the genus *Plagiotropis*. Therefore, continuing floristic studies of microalgae are essential for understanding the diversity of Brazilian estuarine systems, especially for diatoms, which exhibit high diversity and remain relatively unknown in tropical estuaries.

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