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The occurrence of *Nitzschia martiana* (C.A. Agardh) Van Heurck (Nitzschiaceae - Bacillariophyta) in the southwestern Atlantic Ocean

Luciano Felício Fernandes[1,3], Enide Eskinazi-Leça[2], Ariadne do Nascimento Moura[2] and Gibson Gomes de Oliveira[2]

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ABSTRACT - (The occurrence of *Nitzschia martiana* (C.A. Agardh) Van Heurck (Nitzschiaceae - Bacillariophyta) in the southwestern Atlantic Ocean). The distribution of the marine tube-dwelling *Nitzschia martiana* in the southwestern Atlantic Ocean was studied, as well as the frustule morphology, from benthic communities collected in islands of Paraná and Santa Catarina States, and from an estuary in Pernambuco State. The cells live enclosed in macroscopic tubular colonies, growing on intertidal to infralittoral rocks. The diatom has typical features like raphe system running along the center of the entire valve, bearing a well-developed central conopeum. In internal view, the raphe system has a conspicuous raphe sternum, lacking central endings. Polar endings of the raphe are straight and bear a helictoglossa. Valvar surface is areolated. *N. martiana* was abundant or dominant in the localities studied. In southern Brazil, *Biddulphia pulchella* and *Parlibellus delognei* were abundant diatoms associated with *N. martiana,* while *Nitzschia* sp. and *Navicula* sp. were found attached on the colonies. Taxonomic and morphometric data on other epilithic diatoms found during the study are also given.
Key words: Bacillariophyta, periphyton, microphytobenthos, southern Brazil

RESUMO - (Ocorrência de *Nitzschia martiana* (C.A. Agardh) Van Heurck (Nitzschiaceae - Bacillariophyta) no Oceano Atlântico sul ocidental). A distribuição de *Nitzschia martiana* no Oceano Atlântico sul ocidental foi estudada bem como a morfologia da frústula, a partir de comunidades bênticas/perifíticas coletadas nos estados do Paraná, Santa Catarina e Pernambuco. As células vivem no interior de colônias tubulares macroscópicas, sobre rochas ou substratos artificiais na região de entremarés até o infralitoral. A diatomácea apresenta características típicas, como sistema de rafe localizado ao longo da região central da valva, com conopeum bem desenvolvido e um canal conopeal. Em vista interna, a rafe possui sternum da rafe evidente. A rafe é contínua, sem terminações centrais. As terminações polares da rafe são retas, apresentando helictoglossa. A superfície valvar é areolada. *N. martiana* foi abundante ou dominante nas localidades amostradas. No sul do Brasil, *Biddulphia pulchella* and *Parlibellus delognei* foram abundantes e estiveram associadas à *N. martiana*, enquanto que *Nitzschia* sp. e *Navicula* sp. apresentaram-se aderidas às colônias. Dados taxonômicos e morfométricos sobre outras espécies encontradas neste estudo também são fornecidos.
Palavras-chave: Bacillariophyta, perifíton, microfitobentos, Atlântico sul ocidental

Introduction

Marine tube-dwelling diatoms are widespread benthic microalgae recorded in temperate and cold waters of the world (McIntire & Moore 1977, Lobban 1989). In contrast, few reports on this characteristic group are found in the literature for warm oceans (Navarro 1982, 1983, 1987, Lobban & Mann 1987, Basson & Mohamed 1989). In the subtropical to tropical Brazilian waters, few taxonomic studies are found regarding benthic microalgae. In general, such works focused on epipelic, epipsammic or epiphytic communities from sandy beaches or mangroves, or epiphytic on macroalgae (see reviews of Moreira Filho et al. 1990, 1996, Cunha & Eskinazi-Leça 1990, and references therein).

Nitzschia martiana (C.A. Agardh) Van Heurck is a conspicuous tube-dwelling diatom, due to the formation of macroscopic mucilaginous tubes. Surprisingly, it has been scarcely reported since the original description by Agardh (1830). The species was recorded in Europe, Atlantic coast of United States (Navarro 1982, Navarro & Torres 1987), Pacific coast of Central America (Lobban & Mann 1987), Arabian

1. Departamento de Botânica, Setor de Ciências Biológicas, Centro Politécnico, Universidade Federal do Paraná, Caixa Postal 19031, 81531-990 Curitiba, PR, Brasil.
2. Universidade Federal Rural de Pernambuco, Rua Dom Manuel de Medeiros, s. n., Dois Irmãos, 52171-900 Recife, PE, Brasil.
3. Corresponding author: lucfel@bio.ufpr.br

Gulf (Basson & Mohamed 1989) and South Africa (Basson & Sims 1998).

Originally described under the name *Homoeocladia martiana* by Agardh (1830), the species was transferred to genus *Nitzschia* by Van Heurck (1896). *Nitzschia martiana* is included in the section *Spathulatae* within the subgenus *Nitzschia*. The section is characterized by straight frustules, central raphe system, lack of central raphe endings (that is, the raphe is continuous from pole to pole), well developed conopeum and its associated conopeal canal in both the sides of the raphe sternum, and rib-like fibulae (Lobban & Mann 1987, Mann 1987). All are marine species occurring in temperate to tropical seas.

The present work describes the occurrence of *N. martiana* in three localities of the Brazilian coast in the southwestern Atlantic Ocean, and provides a morphological study of colonies and frustules. In addition, some comments on the diatom species associated to the colonies are given.

Material and methods

The material was collected from three sites of the Brazilian coast: two from southern and one from the northern coast. In the clean waters of Campeche Island (27°35'S and 48°28'W), Florianópolis, Santa Catarina State, *Nitzschia martiana* was carefully collected through SCUBA diving at 4, 8 and 12 m depth attached to infralittoral rocks. Over the sampling period (January to March 1998), water temperature and salinity ranged from 15°C to 28°C, and 35.0 to 36.5, respectively.

In Coqueiros Beach (27°32'S and 48°32'W), Florianópolis, Santa Catarina State, the diatom was growing on rocks and oyster beds of the lower intertidal and infralittoral zones (maximum 1.5 m depth), in waters highly enriched with organic matter derived from domestic sewage. In the sampling period (January to March, and July 1998), values of temperature and salinity were 18.5°C-26.5°C, and 23.5-34.0, respectively.

In Currais Island (25°20'S and 48°15'W), Paraná State, two rock samples were collected in November 1997, at 8.0 m depth.

In River Paripe estuary (7°48'30"S and 34°51'21"W), Pernambuco State, *N. martiana* was found growing on fiber glass slides, placed at one meter depth. Average salinity value in the region is 30, and water temperature 29°C. Samples were collected every three days from September to October 1998 and from June to August 1999, all of them containing abundant cells of *N. martiana*. The estuary is surrounded by dense mangrove forests.

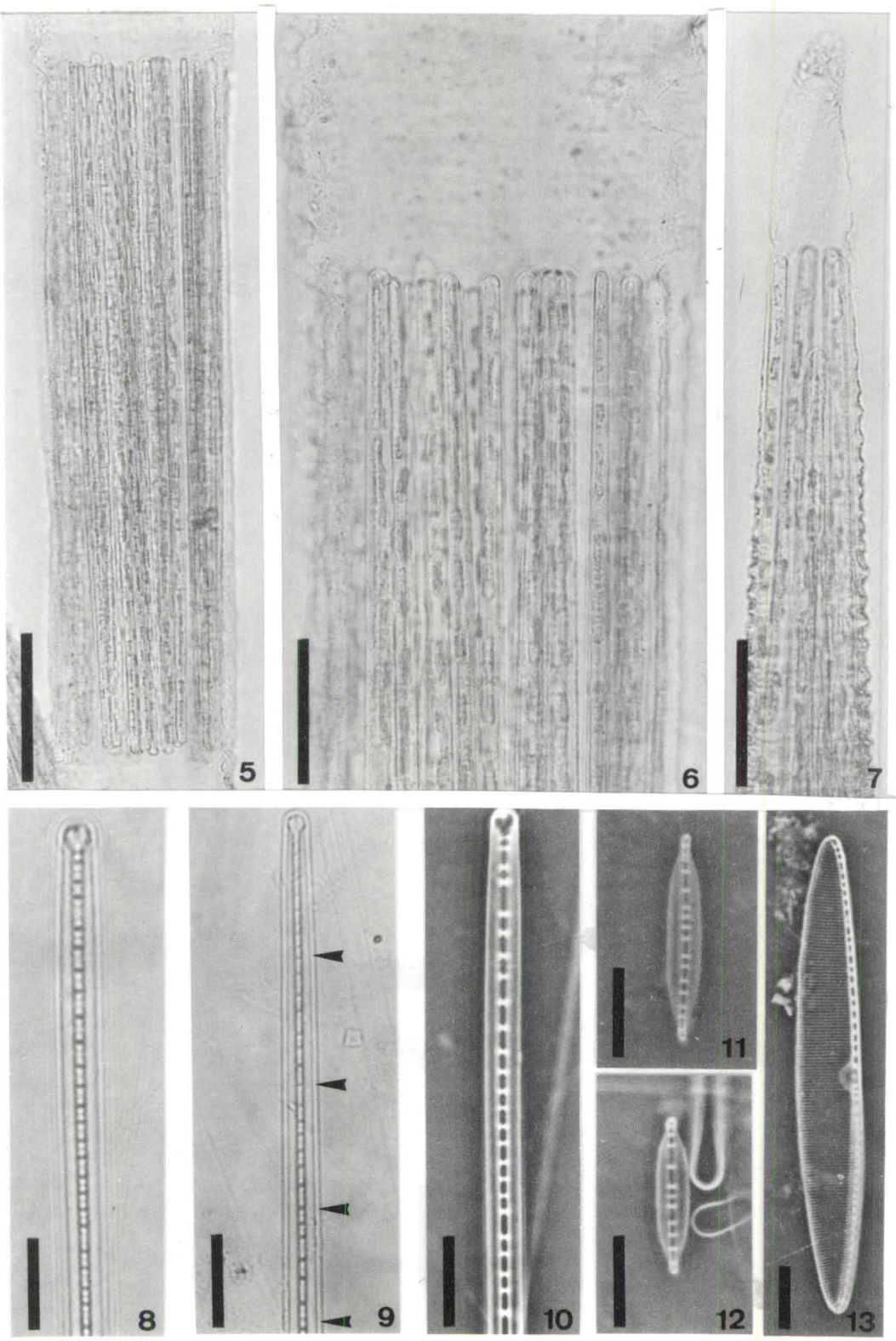
All samples were collected by scrapping of the substrate. Samples were cleaned following Hasle & Fryxell (1970) technique. Naphrax (Northern Biological Supplies, r = 1.74) was used as mounting medium. Specimens were identified and photomicrographed with an Olympus BX40 light microscope. Aliquots for electron microscopy were mounted on aluminum stubs, covered with gold 20 nm thick, and examined with a Phillips LX30 scanning electron microscope operated at 20-25 kV acceleration voltage. Permanent slides and liquid samples are deposited at the FLOR Herbarium of Horto Botânico of Federal University of Santa Catarina, Florianópolis, Santa Catarina State, under the numbers FLOR704 to 708 and FLOR12825 to 12836. Terminology follows Ross et al. (1979) and Mann (1987).

Results

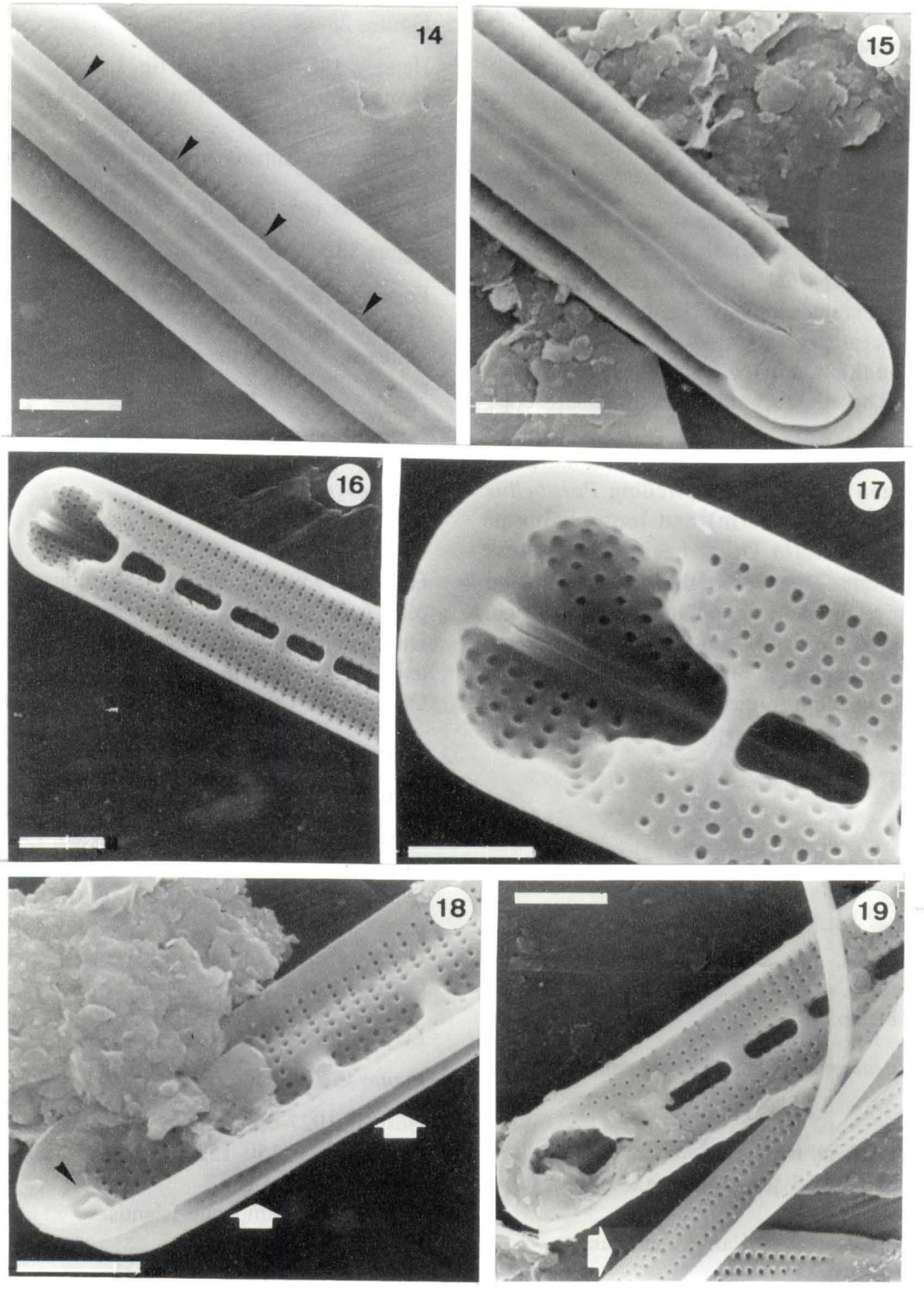
Nitzschia martiana (C.A. Agardh) Van Heurck
Figures 1-10, 14-19

The colonies of *Nitzschia martiana* are 3.0-45.0 mm in length, with a thickened tubular basal stalk that branches in little thinner tubes (figures 1-4). These latter may subdivide to give additional very long dichotomic branchings. Cells are enclosed in wrinkled mucilage tubes (figures 5-7), and form fascicles alternated with regions lacking cells, giving a stripped aspect to the tubes (figure 3). Chloroplasts are bacillar, 26-30 per cell, equally spaced one to another. Valves (n = 120) are long and narrow, 190-330 µm apical axis, and 4-6 µm transapical axis, with rounded apices. The valvar surface presents areolae in transverse rows, 34-40 in 10 µm (figure 16). The raphe system lies along the center of the entire valve (figures 8-10), with a well-developed central conopeum in both sides of the raphe (figure 14), visible under light microscopy (figure 9). This structure is projected parallel to the valvar surface (figures 14-15, 18), and extends towards the margin. Under the conopeum, the valve surface is concave, forming a space termed conopeal canal (Mann 1987). Polar raphe endings are simple, slightly thickened beneath the apices (figure 15). Inside, the raphe system has a conspicuous raphe sternum and the polar endings are straight and bear a helictoglossa (figures 16-17, 18). There are no central raphe endings;

Figures 1-4. General views of *Nitzschia martiana* colonies in different growth stages. 3. Detail of a tube, showing the cells side by side (arrows), and the stripped appearance of the colonies. Note the progressive development of branching from figure 1 to figure 3. 4. Detail of basal tube, showing wrinkled bands. Scales: figures 1-3 = 200 µm; figure 4 = 50 µm.



Figures 5-7. Details of *Nitzschia martiana* colonies; note chloroplasts in figure 6 and the mucilage apex in figure 7. Figures 8-10. *Nitzschia martiana*. 9. The conopeum is viewed lying near the margins (arrowheads). Figures 11-12. *Nitzschia* sp. Figure 13. *Nitzschia britonii*. Scales: figure 5 = 50 µm; figures 6-7 = 60 µm; figures 8-13 = 10 µm.



Figures 14-19. *Nitzschia martiana*, SEM. 14. Detail of central region of the valve in external view, showing the conopeum (arrowheads) borning in the raphe; note the absence of central nodules. 15. Apex of valve, external view; terminal fissure is straight, slightly thickened. 16. Apex of valve in internal view, showing the morphology of fibulae and arrangement of areolae. 17. Detail of internal valve apex, revealing helictoglossa and the raphe fissure. 18. Oblique view of valve apex; internal side; the conopeum (white arrows) is placed parallely with the valvar surface; note the projected helictoglossa (black arrow). 19. Valve view showing the apex on the inner side, and the bands of the cingulum (arrow). Scales: figures 14-16, 18-19 = 2 μm; figure 17 = 1 μm.

that is, the raphe fissure is continuous (figure 14). Fibulae are placed on a central position of the valve, easily viewed under light microscopy (figures 8-10); 6-8 in 10 μm, partially occluding a deep raphe channel (figures 16-17). The bands of the cingulum have 2-3 longitudinal rows of pores (figure 19).

Diatom species associated with *Nitzschia martiana*

A list of the most common species found in the epilithic communities studied, as well as their dimensions is given below, exclusively from Santa Catarina and Paraná samples. The diatoms found in Paripe river's estuary were studied by Oliveira et al. (2000). In addition, *Navicula* sp. and *Nitzschia* sp. are described based on scanning electron microscope observations.

In Currais and Campeche Islands, *N. martiana* was associated with the tube-dwelling *Parlibellus delognei* Cox (small form) and long chains of *Biddulphia pulchella* Gray, besides other less abundant diatoms. They formed the bulk of the diatom biomass during the study period. In Coqueiros Beach, the small *Nitzschia* sp. and *Navicula* sp. were dominant, attached to the tubes of *N. martiana*. In this site, *N. martiana* formed dense pale green mats on rocks and oyster beds, easily visible at naked eyes.

Achnanthes brevipes Agardh

Figure 34

Hustedt, 1927-66: 424, fig. 877a-c; Foged, 1978: 23, pl. 16, fig. 2.
Dimensions: 58-85 μm apical axis; 11-14 μm transapical axis.
Occurrence: Currais and Campeche Islands; Coqueiros beach.

Achnanthes javanica Grunow f. *rhombica* Grunow

Figures 35-36

Foged, 1978: 26, pl. 16, fig. 3-5.
Dimensions: 51-55 μm apical axis; 21-24 μm transapical axis.
Occurrence: Currais and Campeche Islands.

Anaulus sp.

Figure 31

Dimensions: 6.5-8.0 μm apical axis; 2.2-2.7 μm transapical axis.
Occurrence: Coqueiros beach.

Biddulphia pulchella Gray

Figures 28-30

Hendey, 1964: 101, pl. 25, fig. 1.
Dimensions: 35-82 μm apical axis; 23-41 μm transapical axis.
Occurrence: Currais and Campeche Islands.

Diploneis weissflogii (A. Schmidt) Cleve

Figure 38

Foged, 1978: 54, pl. 24, fig. 5-7; Fernandes et al., 1990: 41, pr. 3, fig. 35.
Dimensions: 26-34 μm apical axis; 8-9 μm transapical axis.
Occurrence: Currais and Campeche Islands; Coqueiros beach.

Diplonesis aestuari Hustedt

Figure 40

Hustedt, 1939: 612, fig. 41-42; Simonsen, 1987: 254, pl. 376, fig. 21-26.
Dimensions: 15-19 μm apical axis; 6-8 μm transapical axis, 10-12 estriae in 10 μm.
Occurrence: Currais and Campeche Islands.

Grammatophora oceanica (Ehrenberg) Grunow

Figures 33, 37

Hustedt, 1927-66: 46, fig. 573; Foged, 1975: 25, pl. 7, fig. 1-2.
Dimensions: 49-85 μm apical axis; 6-8 μm transapical axis.
Occurrence: Currais and Campeche Islands; Coqueiros beach.

Lyrella spectabilis Gregory

Figure 45

Hustedt, 1927-66: 476, fig. 1533.
Dimensions: 150-152 μm apical axis; 78-83 μm transapical axis.
Occurrence: Campeche Islands.

Navicula platyventris Meister

Figure 41

Witkowski et al., 1998: 92, fig. 15-22, 77, 78, 80; Fernandes et al., 1999: 20, fig. 39.
Dimensions: 11-17 μm apical axis; 6-8 μm transapical axis.

Occurrence: Coqueiros beach.

Navicula sp.

Figures 23-27, 39

Valves linear-lanceolate with slightly cuneate apices (figure 23). Valvar surface striated; striae radiate to transverse, but always transverse in the centre (figures 23-24, 26). The areolae are elongate (figures 24-25), occluded by hymenes (not illustrated). The raphe system is interrupted in the inner side of the valve (figure 27). In external view, the central fissures are deflected to the same side and are strongly hooked, also ending as a pore (figure 26). Terminal fissures are distinct, having large elongated hooks externally (figure 24); in internal view the fissure is straight, surrounded by a helictoglossa (figure 25). Raphe sternum is parallel and narrow, widening as a subquadrangular central area (figures 25, 27). At the apices, the sternum is thickened (figure 25), giving rise to a triangle-like figure around the helictoglossa.
Dimensions: 30-55 μm apical axis; 5-7 μm transapical axis.
Occurrence: Coqueiros beach.

Nitzschia britonii Hagelstein

Figure 13

Navarro, 1982: 52, pl. 34, fig. 7; Fernandes et al., 1990: 63, pr. 8, fig. 89-90.
Dimensions: 54-68 μm apical axis; 5-6 μm transapical axis.
Occurrence: Campeche Islands; Coqueiros beach.

Nitzschia sp. (Section *Spathulatae*)

Figure 11-12, 20-22

Valves narrowly elliptical with pronounced, rostrate apices (figures 11-12). Striae parallel (figure 20), with poroidal areolae. Raphe system continuous, placed in a central position along the valve (figure 20), within a deep raphe channel (figure 22). Terminal fissures are strongly hooked (figure 21) externally; and internally they are straight with a helictoglossa (not illustrated). A conspicuous conopeum is born from the raphe fissure, partially covering the areolae (figures 20-21). The conopeum abruptly narrows near the apices (figure 21). Fibulae are central, irregularly spaced one to another (figure 22).
Dimensions: 15-30 μm apical axis; 2-4 μm transapical axis; 24-27 striae in 10 μm; 4-6 fibulae in 10 μm.
Occurrence: Coqueiros beach.

Parlibellus delognei Cox

Figures 42-44

Hustedt, 1927-66: 302, fig. 1422 (as *Navicula grevillii* (Agardh ?) Heiberg); Cox, 1988: 9-38.
Dimensions: 16-50 μm apical axis; 8-16 μm transapical axis; 11-16 striae in 10 μm.
Occurrence: Currais and Campeche Islands.

Podocystis adriatica (Kützing) Ralfs *in* Pritchard

Figure 32

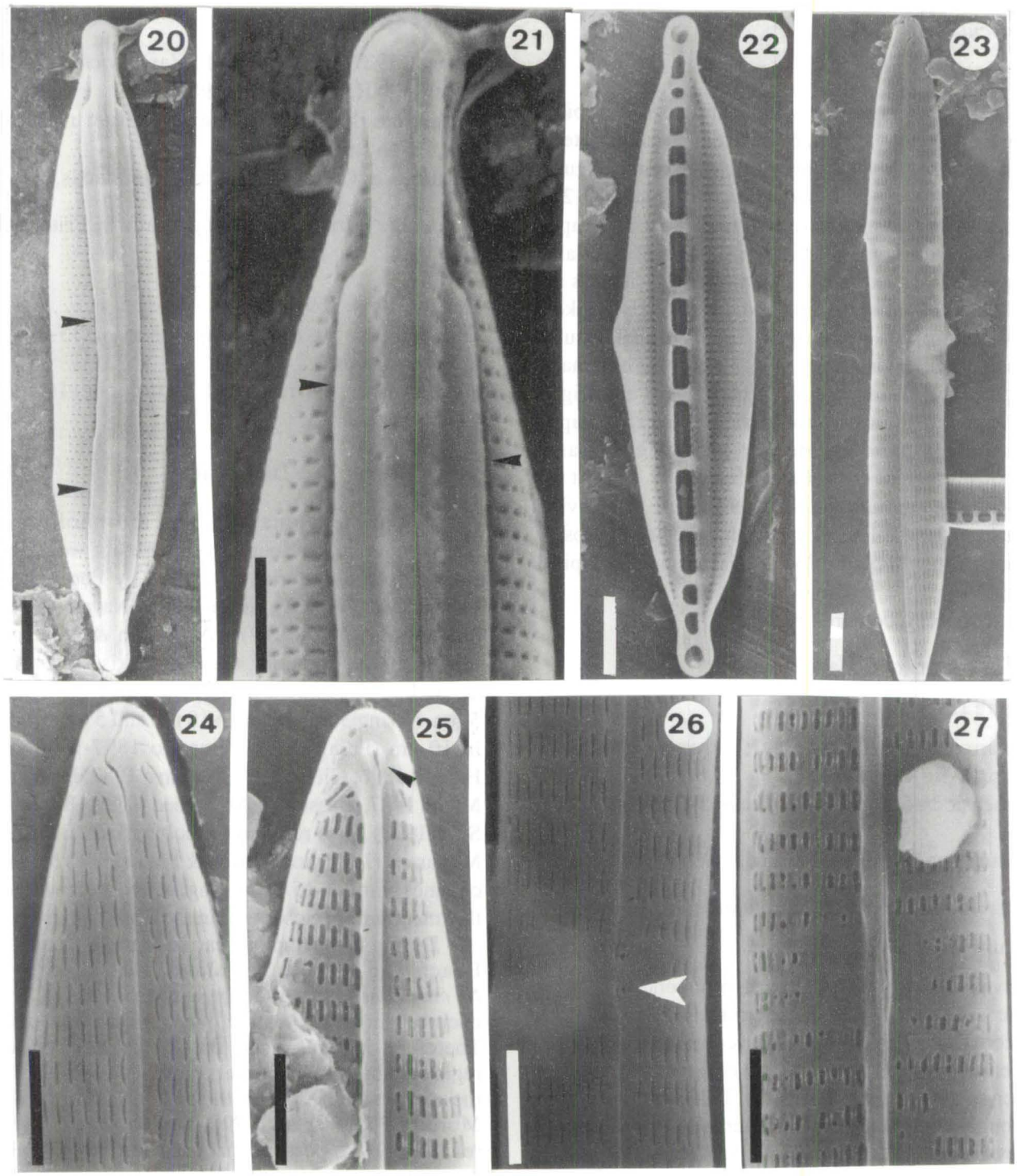
Hendey, 1964: 169, pl.27, fig. 4.
Dimensions: 50-108 μm apical axis; 35-66 μm transapical axis.
Occurrence: Currais and Campeche Islands; Coqueiros beach.

Discussion

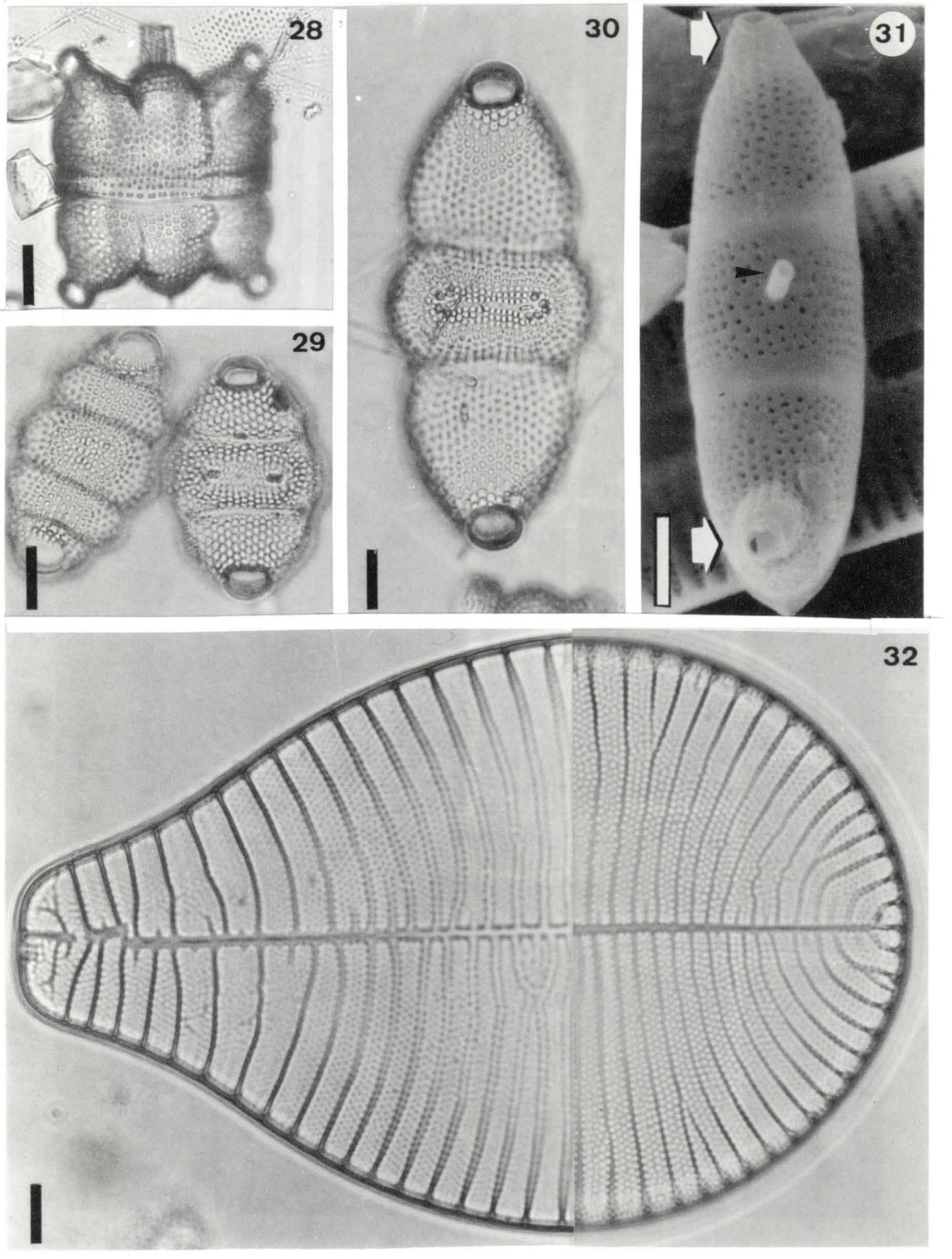
The dimensions and the morphology of *N. martiana* valves found in the present work were similar to the material described by Peragallo & Peragallo (1897-1908), Giffen (1971), Navarro (1982), Lobban & Mann (1987) and Basson & Mohamed (1989). In the literature, the apical axis varies from 120 to 280 μm, and the transapical axis from 3 μm to 5 μm, having 30-53 striae in 10 μm and 5 to 8 fibulae in 10 μm (Peragallo & Peragallo 1897-1908, Van Heurck 1896, Giffen 1971, Navarro 1982, Lobban & Mann 1987, Basson & Mohamed 1989, Basson & Sims 1998). Regarding to the colony size, Basson & Mohamed (1989) and Basson & Sims (1998) reported colonies with 1.8-15.7 mm long, which are lower than the maximum size observed in the Brazilian material.

During the sampling carried out in Coqueiros Beach and Campeche Island, the colonies of *N. martiana* were readily recognizable as they occurred in dense mats along the intertidal zone. Therefore, it is surprising the species has not been registered in Brazilian waters previously, considering the many works done in the region (see review of Moreira-Filho et al. 1990, for complete list of references). It is possible that the macroscopic thallus has rendered the species easily mistaken with other marine macroalgae.

Some diatoms have been found in close association with the mucilage tubes of *N. martiana*. Basson & Sims (1998) reported *Navicula ramosissima* (C. A. Agardh) Cleve as an abundant co-habitant of *N. martiana* colonies in shallow water pools of South Africa. We did not find *N. ramosissima*



Figures 20-22. *Nitzschia* sp., SEM. 20. General external view of valve, showing the conopeum (arrowheads) and areolae arrangement. 21. Detail of apex, showing the strongly hooked terminal fissure; the conopeum is also viewed (arrowheads) around the raphe fissure. 22. General internal view, fibulae and arrangement of areolae in detail. Figures 23-27: *Navicula* sp., SEM. 23. Whole valve, external view. 24. Detail of apex, external view; raphe with hooked terminal endings; note parallel striae. 25. Internal view of raphe; terminal ending with helictoglossa (arrowhead). 26. External view of central region, with hooked central endings with pores (arrowhead). 27. Internal view of central region of valve, showing the raphe fissure and the associated raphe sternum turn to the primary side of the valve. Scales: figures 20, 22-23 = 2.5 μm; figure 21 = 1 μm; figures 24-27 = 2 μm.



Figures 28-30. *Biddulphia pulchella*. 28. Lateral view. 30. Valvar view; note valves with 3-4 pseudosepta in figure 29. Figure 31. *Anaulus* sp., SEM, external view of valve, showing the external tube of rimoportula (arrowhead) and ocelli (arrows). Figure 32. *Podocystis adriatica*. Scales: figures 28-30 = 10 µm; figure 31 = 1 µm.

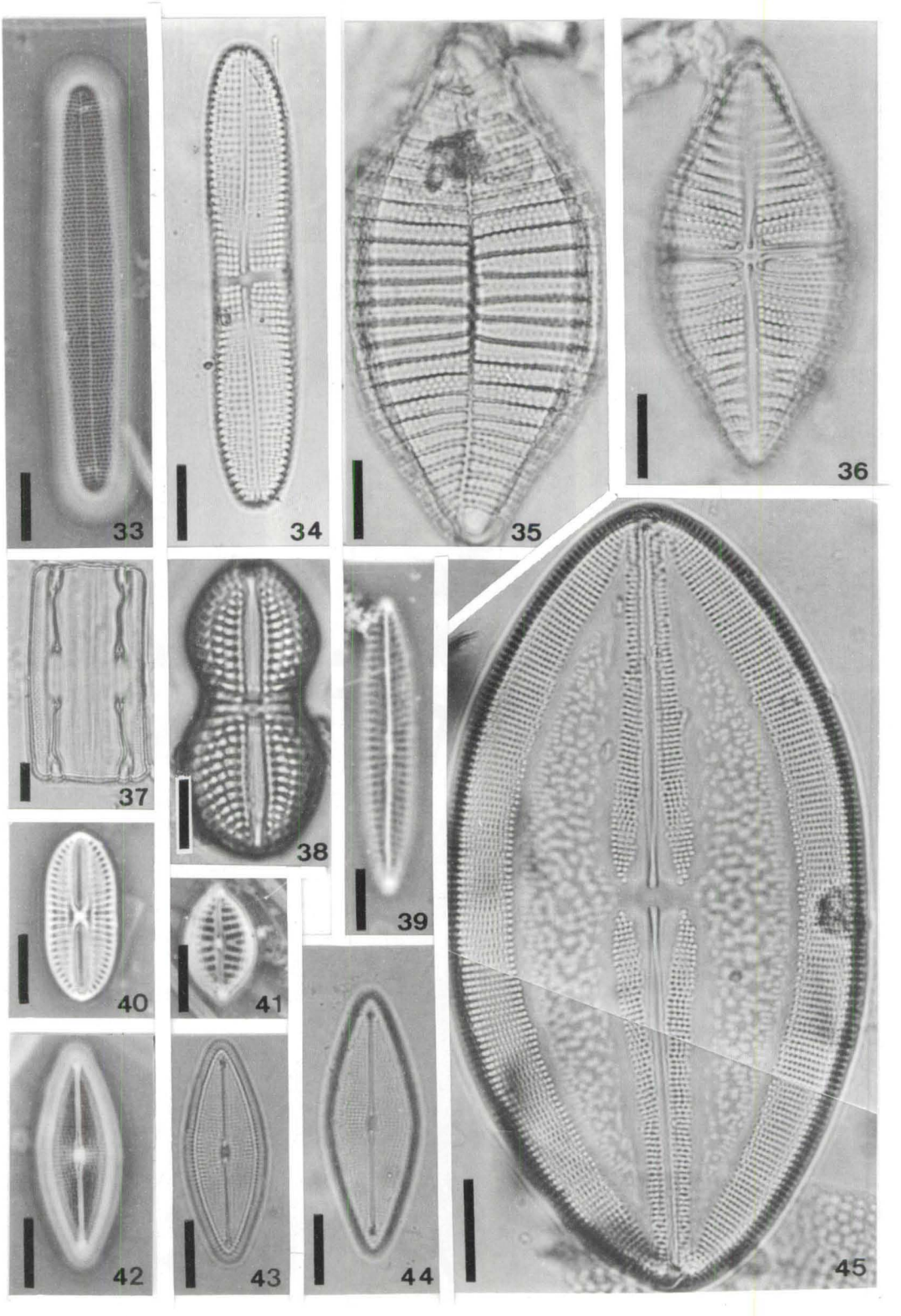


Figure 33. *Grammatophora oceanica*, valve view. Figure 34. *Achnanthes brevipes*. Figures 35-36. *Achnanthes javanica* f. *rhombica*. 35. Raphe valve. 36. Rapheless valve. Figure 37. *Grammatophora oceanica*, lateral view. Figure 38. *Diploneis weissflogii*. Figure 39. *Navicula* sp. Figure 40. *Diplones aestuari*. Figure 41. *Navicula platyventris*. Figures 42-44. *Parlibellus delognei*. Figure 45. *Lyrella spectabilis*. All scales = 10 μm.

in the material studied, but the related species *Navicula* sp. and *Nitzschia* sp. (Section *Spathulatae*) were abundant diatoms attached on the colonies.

The composition of tube-dwelling diatoms in other world regions varies from one region to another. In temperate seas, *Berkeleya rutilans* (Trentepohl) Grunow, *B. hyalina* (Round & Brooks) Cox, and *Parlibellus berkeleyi* (Kützing) Cox are the main representatives followed by *Gyrosigma* spp., *Navicula* spp. and *Nitzschia* spp. (Cox 1977a,b). Indeed, according to Lobban & Mann (1987), *N. martiana* was cited for Europe by Agardh in 1827 and 1830 (Italy), and by Grunow in 1862 (Adriatic). In Arctic and Antarctic waters, *Berkeleya rutilans*, *Nitzschia lecointei* Van Heurck and *Parlibellus delognei* are dominating species (Lobban 1984, 1989, Watanabe 1988, Watanabe et al. 1990, Klöser 1998). However, the majority of the Antarctic literature focused on the ice-algae community. Future studies in other habitats like sediments and rocks would certainly improve our knowledge on tube-dwellings diatoms from southern seas.

Tropical and subtropical seas show a different community. *Nitzschia martiana*, *Berkeleya hyalina* and *Parlibellus hamulifer* (Grunow) Cox were reported in Florida and/or Puerto Rico (Navarro 1982, 1983, 1987, Navarro & Torres 1987). In Arabian Gulf and South Africa, *N. martiana* were common in shallow waters (Basson & Mohamed 1989, Basson & Sims 1998). In Brazilian waters, *N. martiana* was first recorded in northeast Brazil by Oliveira et al. (2000), and appeared to be a common or a dominant taxon in the sites sampled, with a wide range of tolerance to temperature and salinity oscillations (this work, Oliveira et al. 2000). At mesohaline waters of Paripe River's estuary, Pernambuco State, the species occurred in high densities throughout the year (ranging from 5×10^3 cells cm^{-2} to 89×10^3 cells cm^{-2}) and sometimes it was the dominating species growing on fiber glass plates (Oliveira et al. 2000). Other important species inhabiting this substrate were *Cylindrotheca closterium* (Ehrenberg) Reimer and *Nitzschia longissima* (Brebisson) Grunow (Oliveira et al. 2000). However, Fernandes et al. (1999) and Brandini et al. (2000) found *Cylindrotheca closterium*, *Navicula phyllepta* Kützing, *Navicula* sp. (*ramosissima* ?), *N. platyventris* and *Nitzschia* spp. as the dominant forms growing on glass slides during an annual study in Paranaguá Bay, southern Brazil. *Gyrosigma* spp. and *Navicula platyventris* Meister appeared in lower numbers.

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