Epiphytic diatoms associated with red mangrove (*Rhizophora mangle*) prop roots in Bahía Magdalena, Baja California Sur, Mexico

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Received 30-I-2001. Corrected 26-VI-2002. Accepted 11-II-2003.

Abstract. The first floristic inventory of benthic diatoms is provided for the Bahía Magdalena-Bahía Almejas lagoon system. Samplings were carried out during November of 1999. The oxydized samples were mounted permanently. Eighty six diatom taxa were identified, out of which 59 are new records for the Bahía Magdalena area, and 12 taxa are new for the Baja California peninsula. Taxa recorded previously as rare in other substrata are common or abundant on the epiphytic macroalgae of mangrove prop roots. Other species are mainly epipelic forms, while 24 are commonly found as tychoplankton in the area. Certain taxa appear to be characteristic of mangrove systems in general. Rev. Biol. Trop. 54(2): 287-297. Epub 2006 Jun 01.

Key words: benthic diatoms, epiphytes, mangrove, Bahía Magdalena, macroalgae.

Much of the epiphytic flora growing on marine macrophytes are diatoms (Kita and Harada 1962, Jacobs and Noten 1980). These may contribute significantly to the primary production of mangrove systems where diatoms from different substrata are the main microalgae forms (Siqueiros Beltrones 2002). Epiphytes enter the second level of the food chain when they are grazed by invertebrates (Navarro 1987). However, information regarding other host-epiphyte relations in mangroves is lacking, only a few floristic inventories exist, with some remarks on possible interactions (Navarro 1988), while fewer yet intent to define the structure of the epibiosis (Inclán-Rivadeneyra 1989).

Biogeographycally the Bahía Magdalena system is located within a transitional zone where tropical and temperate elements coexist (Castro Aguirre and Torres Orozco 1993). Mangroves are characteristic of the Baja California Sur coasts and B. Magdalena represents the northern limit of their distribution in the north-eastern Pacific (Blasco 1984). Mangroves constitute one of the most conspicuous tropical components of the system, and along with the ichthyological component it may have persisted since the peninsula separated from the Mexican continent six to seven m.y. ago (Castro Aguirre and Torres Orozco 1993).

Currently this area is of great importance for the fishing industry of the state. Although ichthyological studies for Bahía Magdalena are available, which support some of the most important fisheries, research on the benthic microflora that relate to other resources is lacking. Recently the microflora related to abalone fishing sites just outside the lagoon system has been undertaken (Siqueiros Beltrones 2000), but for the lagoon itself only indirect observations of tychoplanktonic diatoms have been made (Gárate Lizárraga and Siqueiros Beltrones 1998) albeit lacking taxonomic precision.

In this study we show the first results of the taxonomic survey of diatoms found on red mangrove (*Rhizophora mangle* L.) prop roots in order to determine which diatom species may determine the structure of the epiphytic assemblage on mangrove prop roots.

MATERIALS AND METHODS

The sampling was carried out in Bahía Magdalena during November 1999. Twelve 30 cm^2 segments were peeled off from submerged and exposed prop roots of red mangrove plants. The epiphytic macroalgae found on submerged portions of the roots were separated under a dissecting microscope. The root segments were brushed using a toothbrush rinsing with water to obtain a concentrate of sediments, organic matter and diatoms that were observed in fresh mounts to determine the proportion of live cells. The diatom frustules from the roots and macroalgae were cleaned by oxydizing the organic matter using nitric acid and alcohol. Permanent preparations were mounted by triplicate using Meltmount (R.I. = 1.7) (Siqueiros Beltrones 2000).

Drawings were made of the observed taxa on curatorial cards which include information on location, habitat, frequency, and meristic and morphometric data. These were included along with the slides in the diatom collection (Diatomario) of the Museo de Historia Natural of the Universidad Autónoma de Baja California Sur. Microphotographs of representative taxa were taken under an Olympus CH-2 microscope with phase contrast illumination.

Taxonomic determinations were done following the classic works of Peragallo and Peragallo (1897-1908), Hustedt (1955, 1959, 1961-1966), Hendey (1964), Cleve-Euler (1968), McIntire and Reimer (1974), Foged (1975, 1984), Navarro (1982), Siqueiros Beltrones and Ibarra Obando (1985), Simonsen (1987), Moreno *et al.* (1996), Siqueiros-Beltrones and Sánchez Castrejón (1999), Siqueiros-Beltrones and Morzaria Luna (1999), Siqueiros Beltrones (2000), Siqueiros Beltrones (2002). Round *et al.* (1990) was used for updating generic nomenclature. The epiphytic macroalgae were identified following Abbot and Hollenberg (1976).

Study Area. Bahía Magdalena is a shallow lagoon located on the western coast of Baja California Sur, between 24º15' - 25º20' N and 111º30' - 112º12' W (Fig. 1). It is part of the Bahía Magdalena-Bahía Almejas lagoon system (Gárate Lizárraga and Siqueiros Beltrones 1998). The middle part of the Bahía Magdalena littoral where the sampling point was located (San Carlos docking area) is densely populated by mangroves mainly *Rhizophora mangle* and *Avicennia germinans* (black mangrove) bordering the coastline.

RESULTS

A total of 86 diatom taxa were identified as epiphytes of *Rhizophora mangle* prop roots (Table 1). 59 taxa are new records for the system.

Most of the taxa in this study were better represented on the macroalgae (*Ulva* sp., 1 species of the gelidiales, and a *Polysiphonia* species) separated from the root segments which appeared heavily epiphytized. *In vivo* observations of macroalgal thalli showed the presence of multispecific colonial growths in mucilaginous films (*Amphora bigibba*, *Amphora proteus*, *Amphora ventricosa*, *Caloneis elongata*, *Cocconeis dirupta*, *Cocconeis scutellum*,

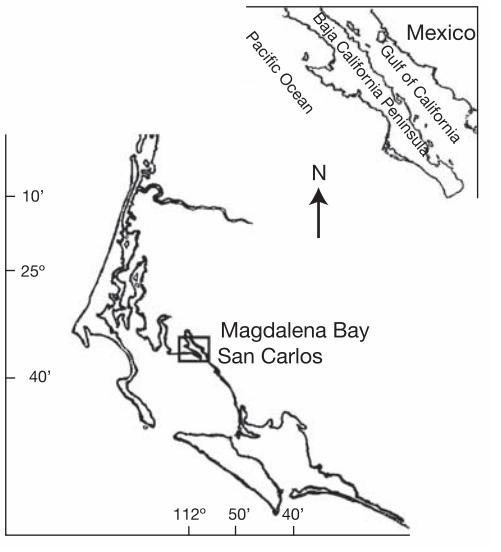

Fig. 1. Location of the Bahía Magdalena mangrove system and sampling site.

TABLE 1

*Epiphytic diatoms collected on red mangrove (*Rhizophora mangle*) prop roots in Bahía Magdalena, B.C.S., during November 1999*

Achnanthes brevipes var. *Intermedia* (Kütz.) Cleve E, T, O	Rare
Achnanthes delicatula (Kütz.) Grunow E	Rare
Achnanthes hauckiana Grunow	Abundant
Achnanthes kuwaitensis Hendey E	Common
Achnanthes manifera Brun E	Rare
Achnanthes pseudogroenlandica var. *Phineyii* E	Common
Achnanthes yaquinensis McIntire & Reimer E	Common
Actinoptychus aster Brun T	Rare
Actinoptychus vulgaris Schuman T, O	Rare
Amphora angusta Gregory E	Rare
Amphora bigibba Grunow E, T, O	Abundant
* *Amphora clevei* Grunow	Rare
Amphora coffeaeformis var. *salina* (Wm. Smith) A. Cleve	Common
* *Amphora obtusa* var. *typica* Paragallo & Paragallo T, O	Rare
* *Amphora ocellata* Donkin E, T	Rare
Amphora proteus Cleve E, T	Common
Amphora strigosa Hustedt E	Common
Amphora ventricosa (Greg.) Cleve T, O	Rare
Amphora sp. 1	Rare
* *Auliscus punctatus* Bailey	Rare
* *Caloneis elongata* (Grun.) Boyer E	Common
Caloneis linearis (Grun.) Boyer	Common
Campylodiscus thuretii Brébisson	Common
Catenula pelagica Mereshkowsky T, O	Abundant
Cocconeis dirupta Gregory O	Rare
Cocconeis placentula Ehrenberg	Rare
* *Cocconeis pseudomarginata* Gregory	Abundant
Cocconeis scutellum Ehrenberg E	Abundant
Cocconeis scutellum var. *Parva* Grun. Ex. Cleve E	Abundant
Cyclotella litoralis Lange & Syvertsen E, T, O	Rare
Denticula kuetzingii Grunow	Common
Denticula subtilis Grunow	Abundant
Dimeregramma maculatum (Cleve) Frenguelli	Rare
Dimeregramma minor var. *Genuina* A. Cleve	Common
Diploneis gravelleana Hagelstein T, O	Rare
Diploneis gruendleri (A. Schmidt) Cleve	Common
Diploneis obliqua (Brun.) Hustedt T, O	Rare
Diploneis suborbicularis var. *Intermedia* A. Cleve	Rare
Fallacia nummularia (Grev.) Mann T, O	Common
Fallacia approximatoides (Hust.) Mann	Common
Fallacia vittata (Cleve) Mann	Common
Gomphonemopsis pseudoexigua (Simonsen) Medlin E	Rare
Grammatophora marina Ehrenberg	Common
Lyrella clavata var. *subconstricta* (Greg.) Mann T, O	Common
Lyrella exsul (A.S.) Mann	Abundant
Melosira nummuloides (Dillwyn) Agardh E, T	Rare
Navicula cancellata Donkin	Rare
* *Navicula contenta* Grunow E	Abundant
* *Navicula ergadensis* Gregory T	Rare
* *Navicula gastrum* (Ehr.) Donkin	Rare
Navicula pennata Schmmidt E, T, O	Abundant
Navicula platyventris Meister E	Common
Navicula salinarum Grunow E	Common
Nitzschia angularis Wm. Smith	Rare

TABLE 1 (*Continued*)
*Epiphytic diatoms collected on red mangrove (*Rhizophora mangle*) prop roots in Bahía Magdalena, B.C.S., during November 1999*

Nitzschia brittoni Hagelstein	Rare
Nitzschia dissipata (Kütz.) Grunow	Abundant
Nitzschia frustulum var. *perminuta* Grunow	Rare
Nitzschia grossestriata Hustedt	Common
Nitzschia lanceolata var. *minor* Grunow	Common
Nitzschia obtusa var. *brevissima* Grunow	Common
Nitzschia sigma Wm. Smith	Rare
Nitzschia socialis Gregory	Rare
Nitzschia subhybrida Hustedt	Common
Nitzschia subtilis Grunow T, O	Common
Odontinium marinum Grunow O	Common
Opephora pacifica (Grun.) Petit	Abundant
Paralia sulacata (Ehr.) Cleve E, T, O	Common
Paralia sulacata var. *crenulata* Grunow T, O	Common
Paralia sulcata var. *radiata* (Grun.) Paragallo & Paragallo T, O	Rare
Petroneis granulata (Bail) Mann	Rare
Plagiotropis vitrea var. *genuina* A. Cleve	Rare
Psammodictyon constrictum (Kütz.) D.G. Mann	Abundant
Psammodictyon panduriformis var. *lata* (Greg.) Mann	Rare
Seminavis sp.	Common
Staurophora amphioxys (Greg.) Mann	Rare
Staurosirella pinnata (Ehr.) Mann	Common
Surirella fastuosa Ehrenberg	Common
Surirella fastuosa var. *cuneata* A. Schmidt	Common
Synedra tabulata var. *affinis* (Kütz.) A. Cleve	Abundant
* *Synedra gailloni* Ehrenberg E	Abundant
Terpsinoe americana (Bail.) Ralfs	Rare
* *Thallassiosira leptopus* (Grunow) Hasle & Fryxell E, O	Rare
Trachyneis aspera Ehrenberg E, T, O	Rare
Trachyneis clepsydra (Donk.) Cleve E	Common
* *Trachyneis velata* (A.S.) Cleve T, O	Common
Tryblionella acuminata W. Smith T, O	Common

Notes: * New records for the area.
E = Previously recorded as epiphytic on mangrove prop roots or as abundant in this study; T = recorded also as tychoplankton; O = also collected offshore.

Cocconeis scutellum var. *parva* and *Trachyneis* spp.), stalked chains (*Achnanthes yaquinensis*, *Cyclotella stylorum*, *Melosira nummuloides*, *Paralia sulcata*), or erect tufts of *Synedra gaillonii* (Fig. 2a, b, c, respectively).

Taxa such as *Navicula contenta, Navicula platyventris*, *Navicula pennata* and *Navicula salinarum* and most of the *Achnanthes* species had been recorded elsewhere as epiphytes (Table 1) either from macroalgae or mangrove prop roots (Navarro 1987). *Caloneis elongata*, *Navicula contenta*, *Navicula platyventris*, *Psammodyction constricta*, *Synedra gaillonii*, and *Trachyneis velata* were abundant in our samples, although they are recorded for the first time for the peninsula, along with 6 other taxa (Table 1).

A representative array of the diatom taxocoenosis in the study site is presented in Figs. 3-6.

Rev. Biol. Trop. (Int. J. Trop. Biol. ISSN-0034-7744) Vol. 54 (2): 287-297, June 2006

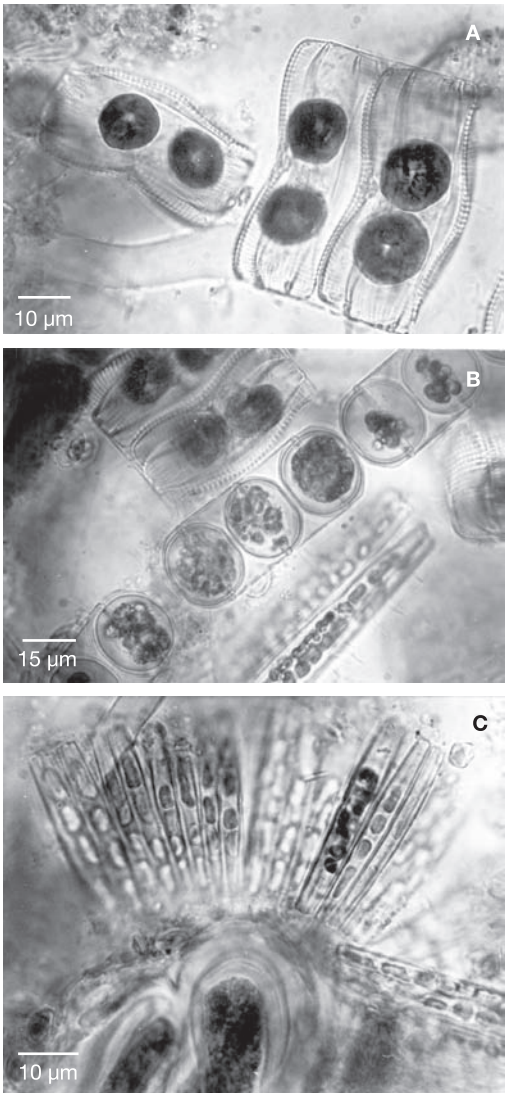

Fig. 2. Most conspicuous diatoms growing on epiphytic macroalgae collected from mangrove prop roots: a) Stalked chains of *Achnanthes yaquinensis*; b) Chains of *Melosira nummuloides*; c) Erect colonies of *Synedra gailloni*.

DISCUSSION

Previous studies on benthic diatoms in the system comprising only the rocky environment just outside Bahía Magdalena account for the remaining 27 taxa recorded in the system (Siqueiros Beltrones 2000, Siqueiros Beltrones and Valenzuela Romero 2001).

On the other hand, otherwise rare taxa from previous records in the region such as *Achnanthes yaquinensis*, *Amphora bigibba*, *Cyclotella stylorum*, and *Melosira nummuloides* (Siqueiros Beltrones 2002), were either common or abundant. Such observations have been made also on *Macrocystis pyrifera* in undergoing studies (Siqueiros Beltrones *et al.* 2002). All this indicates that host-epiphyte relations are important for the growth of certain benthic diatoms and some may be specific, mainly of the epiphytic macroalgae, but apparently not for the mangrove roots. However, the specificity of the macroalgae-prop root relation should be analyzed in order to determine if an indirect association exists between diatoms and mangrove roots.

Several species, although not abundant occur frequently enough to be considered epiphytes (*e.g. Amphora proteus*, *Amphora ocellata*, *Caloneis elongata*, *Caloneis linearis*) but further observations are required to confirm this. Other taxa, such as *Diploneis obliqua, Lyrella exsul, Petroneis granulata, Surirella fastuosa* and *Surirella fastuosa* var. *cuneata* occur principally in sediments of mangrove systems (Siqueiros-Beltrones and Sánchez-Castrejón 1999). These species may be opportunistic colonizers from the bottom sediments that migrate upward on the sediments covering the prop roots.

The epiphytic or epipelic taxa from the B.C.S. mangrove systems are somewhat similar to those from mangroves in different parts of the world (Foged 1975, 1984, Navarro 1987) and Sinaloa, México (Moreno *et al.* 1996, Siqueiros Beltrones and Martínez López unpublished.). The current inventory of benthic diatoms from mangrove systems, including this paper, has yielded 181 new records altogether for the Baja California peninsula since 1999 (Siqueiros-Beltrones and Sánchez Castrejón 1999, Siqueiros-Beltrones and Morzaria Luna 1999). Although the northern limit for most of them is not known certain taxa appear to be characteristic of the mangrove environment and have not been observed in other localities along the peninsula, especially on the northern part (Siqueiros Beltrones 2002).

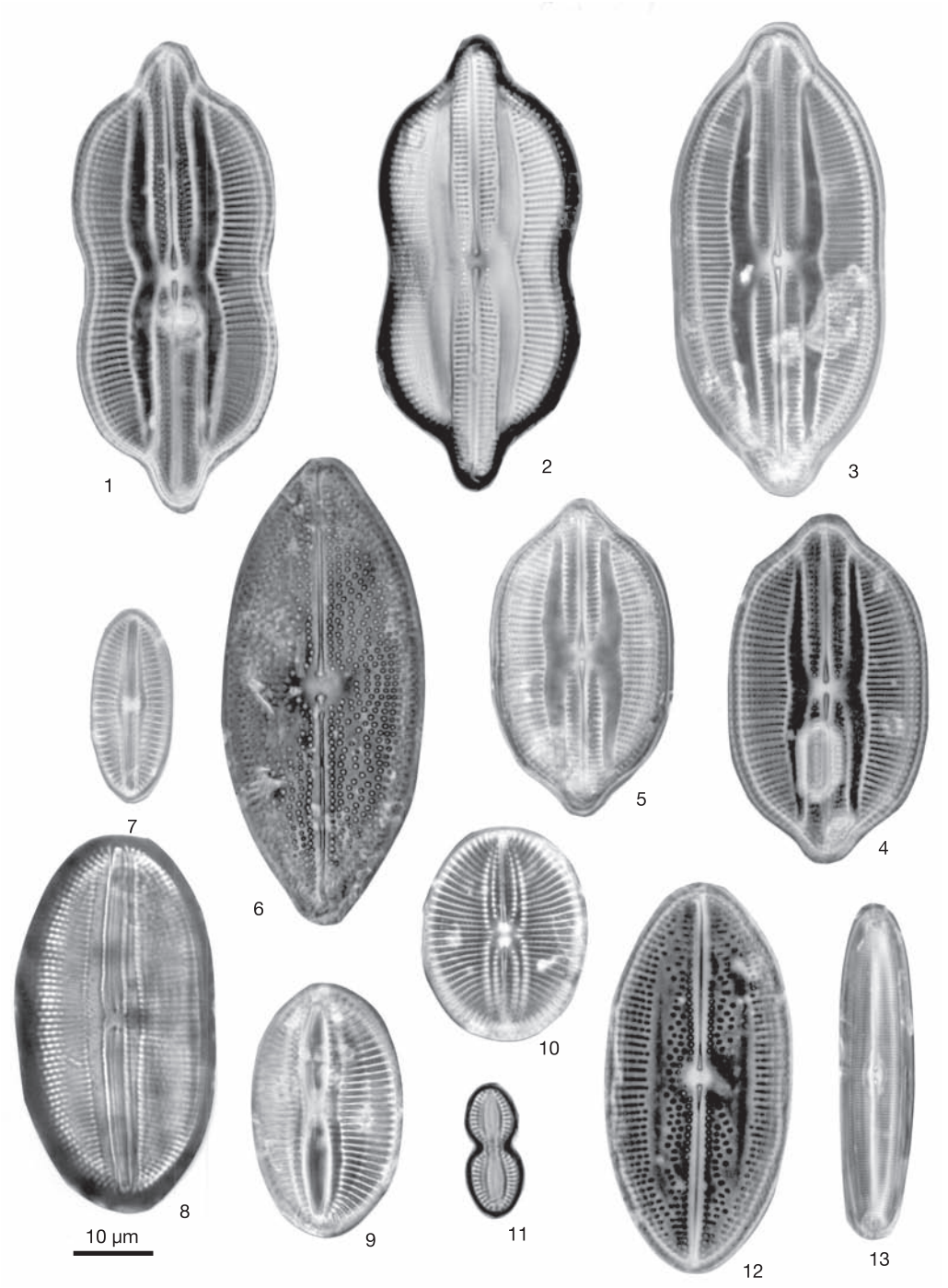

Fig. 3. 1) *Lyrella exsul* (A. Schmidt) Mann, 2) *Lyrella exsul* (A. Schmidt) Mann, 3) *Lyrella clavata* (Greg.) D.G. Mann, 4) *Lyrella clavata* var. *indica* (Grun.) Cleve, 5*) Lyrella clavata* (Greg.) D.G. Mann, 6) *Petroneis granulata* (Bailey) Mann, 7) *Diploneis subovalis* Cleve, 8) *Diploneis obliqua* (Brun) Hustedt, 9) *Diploneis suborbicularis* var. *intermedia* A. Cleve, 10) *Fallacia nummularia* (Greg.) Mann, 11) *Diploneis gravelleana* Hagelstein, 12) *Fallacia approximatoides* (Hust.) Mann, 13) *Caloneis elongata* (Grun.) Boyer.

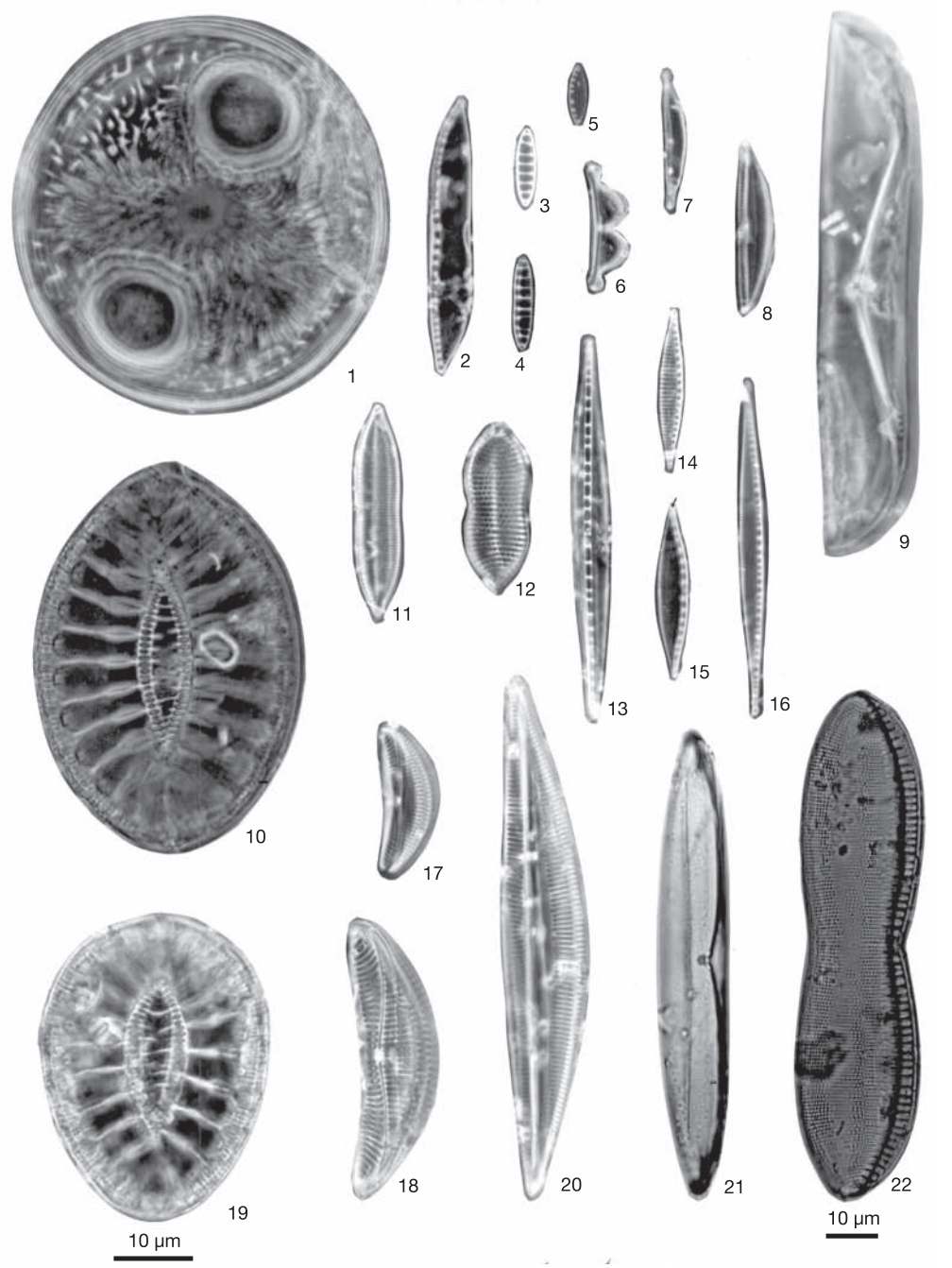

Fig. 4. 1) *Auliscus punctatus* Bailey, 2) *Nitzschia obtusa* var. *brevissima* Grunow, 3) *Odontinium marinum* Grunow, 4) *Denticula subtilis* Grunow, 5) *Nitzschia frustulum* var. *perminuta* Grunow, 6) *Amphora bigibba* Grunow, 7) *Amphora* sp. 1, 8) *Amphora strigosa* Hustedt, 9) *Amphora obtusa* var. *typica* Peragallo & Peragallo, 10) *Surirella fastuosa* Ehrenberg, 11) *Tryblionella acuminata* W. Smith, 12) *Psammodyction constrictum* (Kütz.) Mann, 13) *Nitzschia angularis* Wm. Smith, 14) *Nitzschia grossestriata* Hustedt, 15) *Nitzschia lanceolata* var. *minor* Grunow, 16) *Nitzschia subtilis* Grunow, 17-18) *Amphora proteus* Cleve, 19) *Surirella fastuosa* var. *cuneata* A. Schmidt, 20) *Amphora ventricosa* (Greg.) Cleve, 21) *Plagiotropis vitrea* var. *genuina* A. Cleve, 22) *Psammodyction panduriformis* var. *lata* (Greg.) Mann.

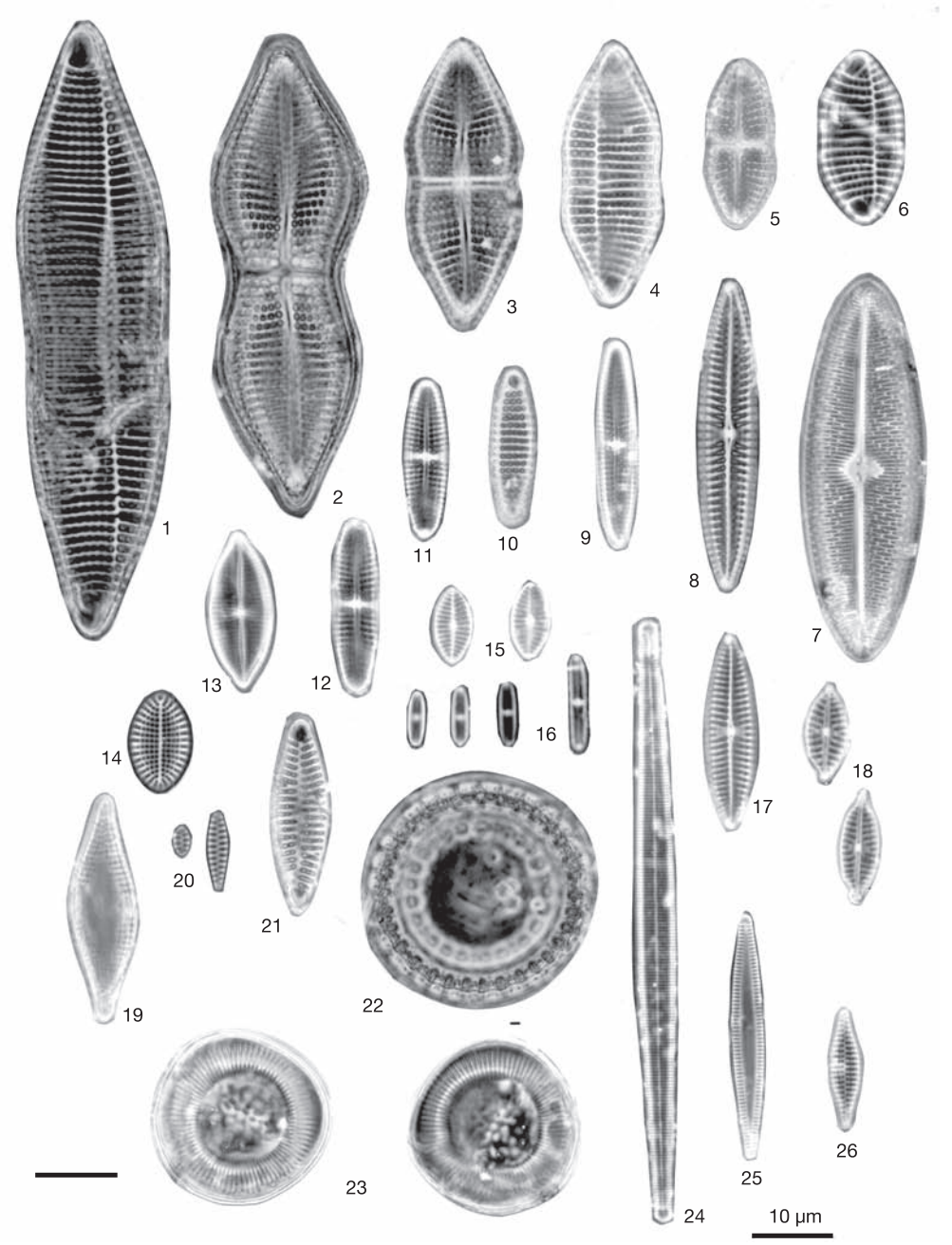

Fig. 5. 1-6) *Achnanthes yaquinensis* McIntire & Reimer, 7) *Trachyneis velata* (A.Schmidt) Cleve, 8) *Navicula pennata* Schmidt, 9) *Achnanthes pseudogroenlandica* var. *phinneyii* McIntire & Reimer, 10) *Achnanthes kuwaitensis* Hendey, 11) *Achnanthes kuwaitensis* Hendey, 12) *Achnanthes brevipes* var. *intermedia* (Kütz.) Cleve, 13) *Achnanthes manifera* Brun, 14) *Cocconeis scutellum* var. *parva* Grunow ex Cleve, 15) *Achnanthes hauckiana* Grunow, 16) *Navicula contenta* Grunow, 17) *Navicula pennata* Schmidt, 18) *Navicula platyventris* Meister, 19) *Dimeregramma maculatum* (Cleve) Frenguelli, 20) *Opephora pacifica* (Grun.) Petit, 21) *Dimeregrama minor* var. *genuina* A. Cleve, 22) *Paralia sulcata* (Ehr.) Cleve, 23) *Cyclotella litoralis* Lange & Syvertsen l, 24) *Synedra gailloni* Ehrenberg, 25) *Synedra tabulata* var. *affinis* (Kütz.) A. Cleve, 26) *Neodelphineis pelagica* Takano.

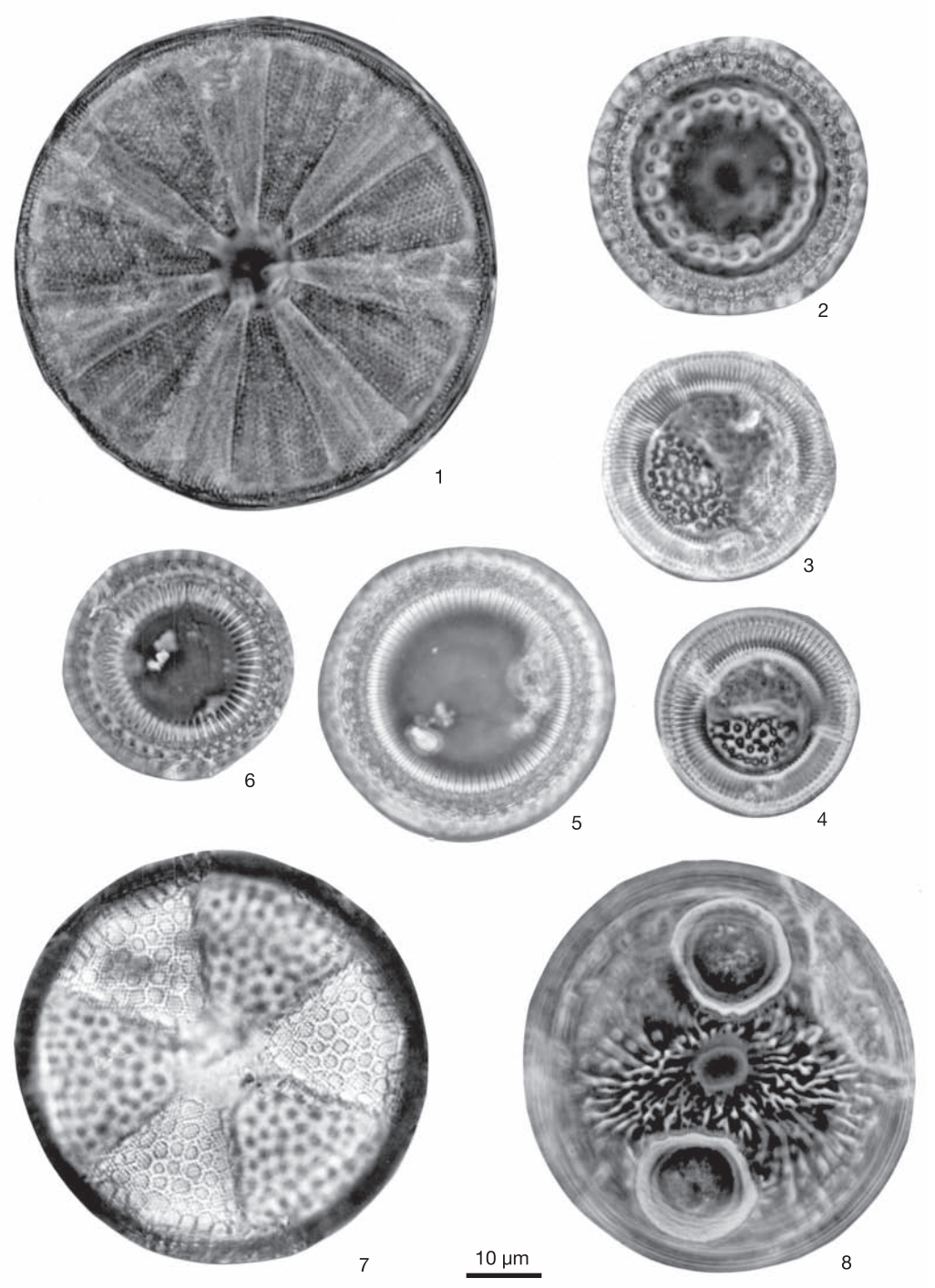

Fig. 6. 1) *Actinoptychus vulgaris* Schuman, 2) *Paralia sulcata* (Ehr.) Cleve, 3) *Cyclotella litoralis* Lange & Syvertsen, 4) *Cyclotella litoralis* Lange & Syvertsen, 5) *Paralia sulcata* var. *radiata* (Grunow) Peragallo & Peragallo, 6) *Paralia sulcata* var. *radiata* (Grunow) Peragallo & Peragallo, 7) *Actinoptychus aster* Brun, 8) *Auliscus punctatus* Bailey.

Twenty four taxa from our inventory (Table 1) have been collected previously in phytoplankton tows (tychoplankton) representing an important part of the estimated biomass (Gárate Lizárraga and Siqueiros Beltrones 1998). Although the species were not then identified, we observed them recently in samples collected by the above authors at the northern mouth of the Bahía Magdalena system, and can be considered as common tychoplankton. Also, 21 of the benthic diatom taxa in this study (Table 1) have been collected in deep water traps deployed 300 m offshore north-west of Bahía Magdalena. The occurrence of benthic diatoms in the traps and in the samples from phytoplankton tows suggests that organic material is exported offshore through the northern opening of the system (Martínez López *et al.* 2004).

Tidal mixing has been identified as an important factor causing the presence of abundant benthic diatoms in the water column (Gárate Lizárraga and Siqueiros Beltrones 1998). However, much work has to be done to complete the floristic inventory and analyze the association structure of benthic diatoms from the Bahía Magdalena-Bahía Almejas lagoon system. This information may provide important tools to explain oceanographic, ecological, and biogeographical phenomena in the area.

ACKNOWLEDGMENTS

The sampling for this study was carried out during field trips for the Microalgas Marinas course of the Departamento de Biología Marina of the Universidad Autónoma de Baja California Sur. The Museo de Historia Natural of the Universidad Autónoma de Baja California Sur financed laboratory material for processing the samples. Elisa Serviere from the Centro de Investigaciones Biológicas del Noroeste aided in the identification of the macroalgae.

RESUMEN

Se presenta el primer inventario florístico de diatomeas bénticas para el Sistema Lagunar Bahía Magdalena-Bahía Almejas. Se hicieron muestreos en noviembre de 1999. En las muestras oxidadas y montadas permanentemente, se identificaron 86 táxones, de los cuales 59 son nuevos registros para el área de Bahía Magdalena, y 12 son nuevos para la península de Baja California. Táxones previamente registrados como escasos en otros sustratos son comunes o abundantes sobre macroalgas epífitas de raíces primarias de mangle. Otras species son principalmente formas epipélicas, mientras que 24 son constituyentes comunes del ticoplancton del área. Ciertos táxones parecen ser característicos de sistemas de manglar en general.

Palabras clave: diatomeas bentónicas, epífitas, mangle, Bahía Magdalena, macroalgas.

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