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Taxonomy and systematics

First record of benthic diatoms (Bacillariophyceae and Fragilariophyceae) from Isla Guadalupe, Baja California, Mexico

Primer registro de diatomeas bentónicas (Bacillariophyceae y Fragilariophyceae) de isla Guadalupe, Baja California, México

Francisco Omar López-Fuerte [a], David A. Siqueiros-Beltrones [b,*], Ricardo Yabur [c]

[a] *Laboratorio de Sistemas Arrecifales, Departamento Académico de Economía, Universidad Autónoma de Baja California Sur, Carretera al Sur, Km. 5.5, 23080 La Paz, B.C.S., Mexico*

[b] *Departamento de Plancton y Ecología Marina, Centro Interdisciplinario de Ciencias Marinas, Intituto Politécnico Nacional, Av. Instituto Politécnico Nacional s/n, Col. Playa Palo de Santa Rita, 23096 La Paz, B.C.S., Mexico*

[c] *Departamento Académico de Biología Marina, Universidad Autónoma de Baja California Sur, Carretera al Sur, Km. 5.5, 23080 La Paz, B.C.S., Mexico*

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Abstract

Guadalupe Island represents a unique ecosystem. Its volcanic origin and remoteness from the Baja California peninsula have allowed for the successful establishment of its distinctive flora and fauna. However, the difficulty in accessing the island has precluded the study of its biotic communities, mainly the marine ones. Consequently, no studies on benthic or planktonic diatoms have been hitherto published. Thus, the first records of marine benthic diatom species (epiphytic, epilithic, epizoic) from Guadalupe Island in the NW Mexican Pacific are here provided. One hundred and nineteen diatom taxa belonging to the Bacillariophyceae and Fragilariophyceae were identified, including species and varieties. The former with 87 taxa was the most diverse. Thirteen taxa are new records for Mexico; photographic images of these are provided. Because this is the first study for the benthic diatoms of Isla Guadalupe, a particular bio-geographical affinity is not proposed. However, the best represented genus was *Mastogloia* which has tropical affinity, and *Cocconeis thalassiana* was also identified, a new species recently recorded for the Mexican Caribbean.
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Keywords: Insular; Bacillariophyta; Epiphytic; Epilithic; Epizoic; Eastern Pacific

Resumen

Isla Guadalupe es única como ecosistema; su origen volcánico y lejanía de la península de Baja California han permitido que el desarrollo evolutivo de sus distintivas flora y fauna haya sido exitoso. La dificultad para acceder a la isla es causa de que algunas comunidades, principalmente marinas, no hayan sido estudiadas aún. Consecuentemente, a la fecha no existía algún estudio publicado sobre diatomeas. Así, se presenta el primer registro de diatomeas bentónicas (epilíticas, epifitas y epizoicas) de isla Guadalupe en el noroeste de México. Se identificaron 119 taxa (incluyendo especies y variedades) de diatomeas pertenecientes a las clases Bacillariophyceae y Fragilariophyceae. Las primeras fueron más diversas con 87 taxa. Del total, 13 taxa son nuevos registros para México y se proveen imágenes fotográficas de ellos. Dado que se trata apenas del primer estudio para la flora de diatomeas bentónicas de isla Guadalupe, no se propone una afinidad biogeográfica. Sin embargo, uno de los géneros con mayor número de especies es de afinidad tropical, i.e., *Mastogloia* y se identificó *Cocconeis thalassiana*, una especie nueva recientemente registrada para el Caribe mexicano.
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Palabras clave: Insular; Bacillariophyta; Epifitas; Epilíticas; Epizoicas; Pacífico oriental

* Corresponding author.
E-mail address: dsiquei@gmail.com (D.A. Siqueiros-Beltrones).
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Introduction

Isla Guadalupe is a natural reserve that represents a unique ecosystem as other Mexican islands. Its volcanic origin and distance from the Baja California peninsula have allowed for a successful evolutionary development of both its particular land and marine flora and fauna, as can be inferred by the high number of cases of endemism recorded (Aguirre-Muñoz et al., 2003; García-Gutiérrez et al., 2005). However, studies on biodiversity, particularly of marine life, are lacking for Isla Guadalupe, mainly because of the difficulty to access the island. The available studies on marine flora of Isla Guadalupe date back to the late 1800s and were published by Setchell and Gardner (1930) in a list that included 90 species of macroalgae. The last review of the macroalgae of Isla Guadalupe was carried out by Stewart and Stewart (1984) and included 212 species, with 24 new records. Both studies recorded a large number of genera of subtropical affinity, indicating that the marine flora in the island is more characteristic of a subtropical than a temperate environment.

The difficulty in accessing an area such as Isla Guadalupe to carry out scientific research is the main cause that many marine communities are yet to be studied, even in their most basic aspects such as species composition. Thus, no published work existed hitherto on diatoms from that area, nor planktonic or benthic forms, in spite of being the most diverse, abundant and productive algal group in marine ecosystems.

In general, studies on benthic diatoms from the Mexican NW are scarce, and these are related either with their role in the feeding habits of abalone (*Haliotis* spp.) and grazing intertidal molluscs (Siqueiros-Beltrones & Valenzuela-Romero, 2004), or the structure of epiphytic forms assemblages found on macroalgae and marine plants (Argumedo-Hernández & Siqueiros-Beltrones, 2008; Siqueiros-Beltrones, Serviere-Zaragoza, & Argumedo-Hernández, 2002). Another study describes assemblages of epipelic diatoms characteristic of mangrove environments (López-Fuerte, Siqueiros-Beltrones, & Navarro, 2010).

In this study we begin the construction of a taxonomic basis that serves for monitoring and assessing the environmental health of any ecosystem, and provide the first floristic account of benthic diatoms from Isla Guadalupe.

Materials and methods

Isla Guadalupe is located in the Mexican Pacific Ocean approximately 256 km off the coast of the Baja California peninsula at 29° N, 118° W, within the Guadalupe Island Biosphere Reserve (Fig. 1). It is influenced by the California Current which is characterized by low temperature and salinity (Lynn & Simpson, 1987). Surficial water temperature ranges between 15 and 20 °C during winter and between 20 and 22 °C in summer. Its ocean volcanic nature and its remote distance from the coast confer it an abrupt topography and a unique biodiversity. The coastal zone physiography consists of loose basalts, blocks, dikes, cliffs, and few sandy beaches (Pierson, 1987).

Sample collection

Surficial temperature, salinity and pH were measured in situ using a field multi-sensor (Horiba U10). Benthic diatoms were collected at Guadalupe Island in one sampling site on January 18, 2013. Epiphytic diatoms were scraped off from specimens of *Eisenia desmarestioides* Setchell and N.L. Gardner, 1930 (Ochrophyta; Laminariales), and *Codium latum* subsp. *palmeri* (E.Y. Dawson) P.C. Silva, 1962 (Chlorophyta; Bryopsidales), using a glass slide for each sampling. Epilithic and epizoic diatoms from the shell of the sea-snail *Megastraea undosa*

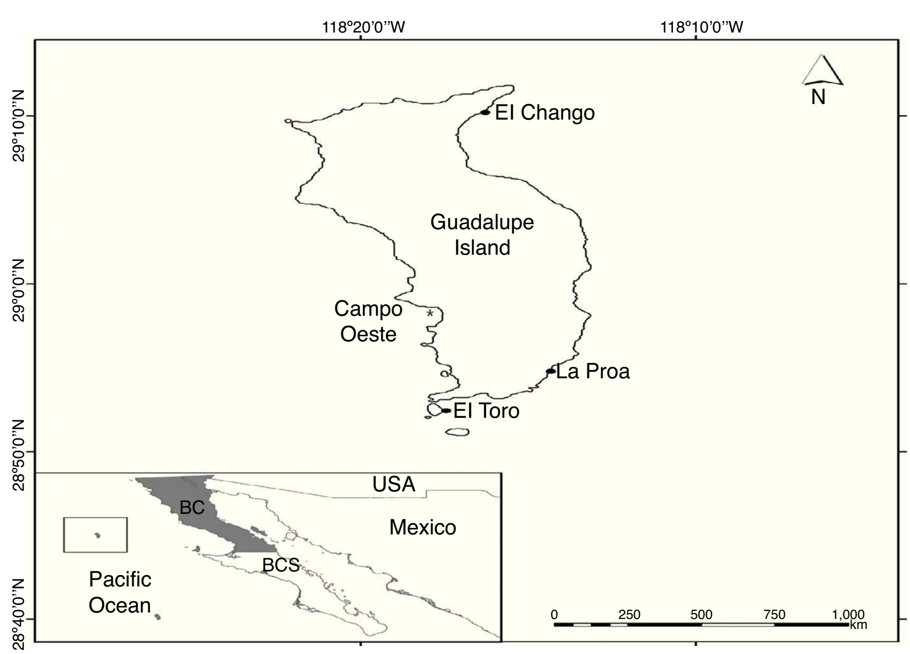
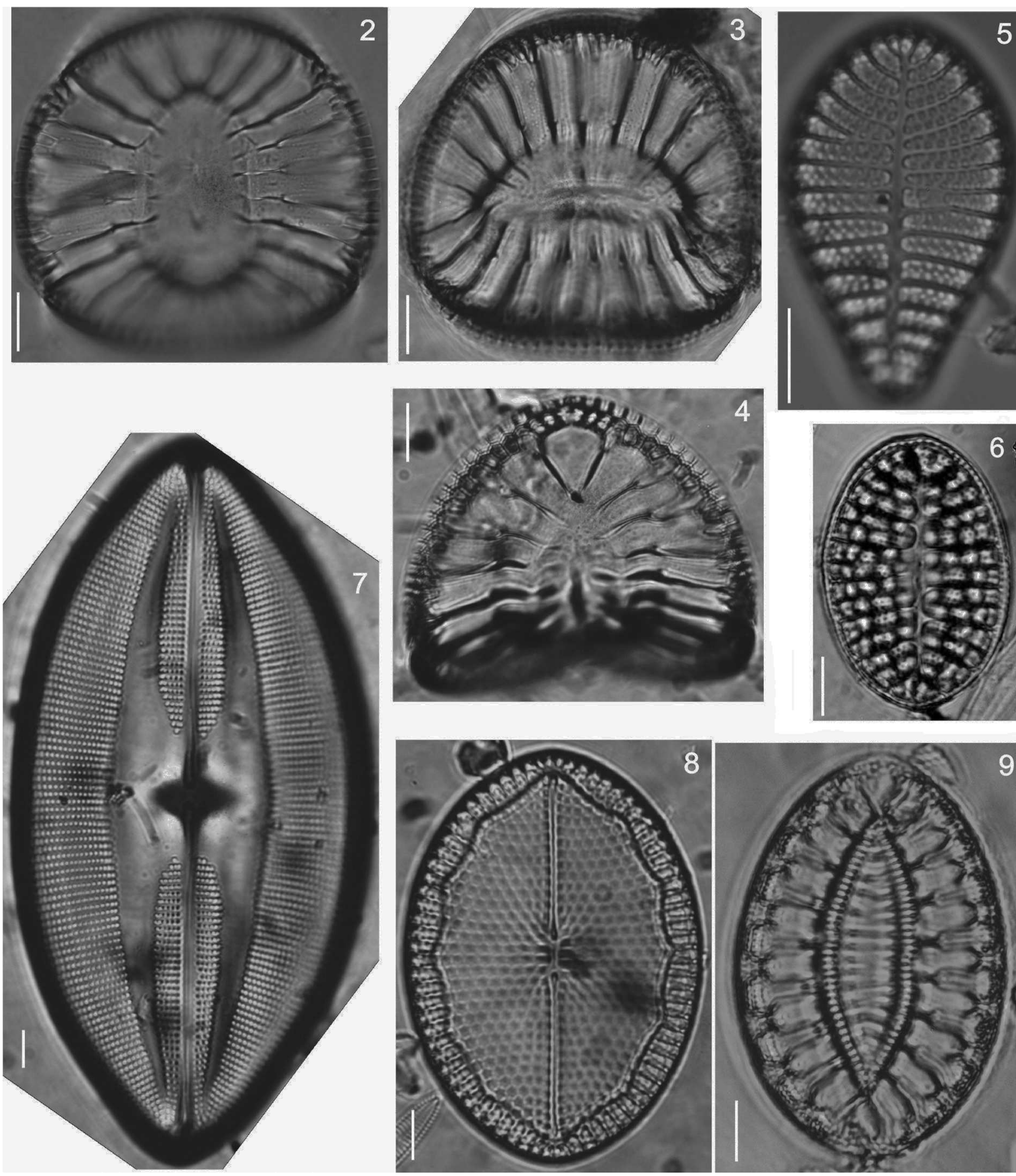


Figure 1. Location of Isla Guadalupe and sampling site.

W. Wood, 1828 were brushed off from an area of 5 cm^2 in each substrate using a toothbrush. Afterwards, a compound sample was formed for the site and preserved in commercial ethanol (70%); concomitant observations of fresh diatom samples were made. In order to clean the diatom frustules for identification the organic matter was oxidized with a mixture of sample, commercial ethanol and nitric acid at a 1:3:5 proportion (Siqueiros-Beltrones, 2002). The samples were then rinsed with drinking water until reaching a pH >6. From each compound sample three permanent slides were mounted for each substrate using Zrax® (RI: 1.7) as mounting medium. All species names and authorities were revised, and in certain cases nomenclatural updates were made, confirming all of the currently accepted taxonomic names. In order to revise the taxonomic names and their synonymies, we consulted Round, Crawford, and Mann (1990) along with the data bases on www.algaebase.org (Guiry & Guiry, 2014) and www.marinespecies.org (WoRMS Editorial Board, 2014). Taxonomic keys used for species identification

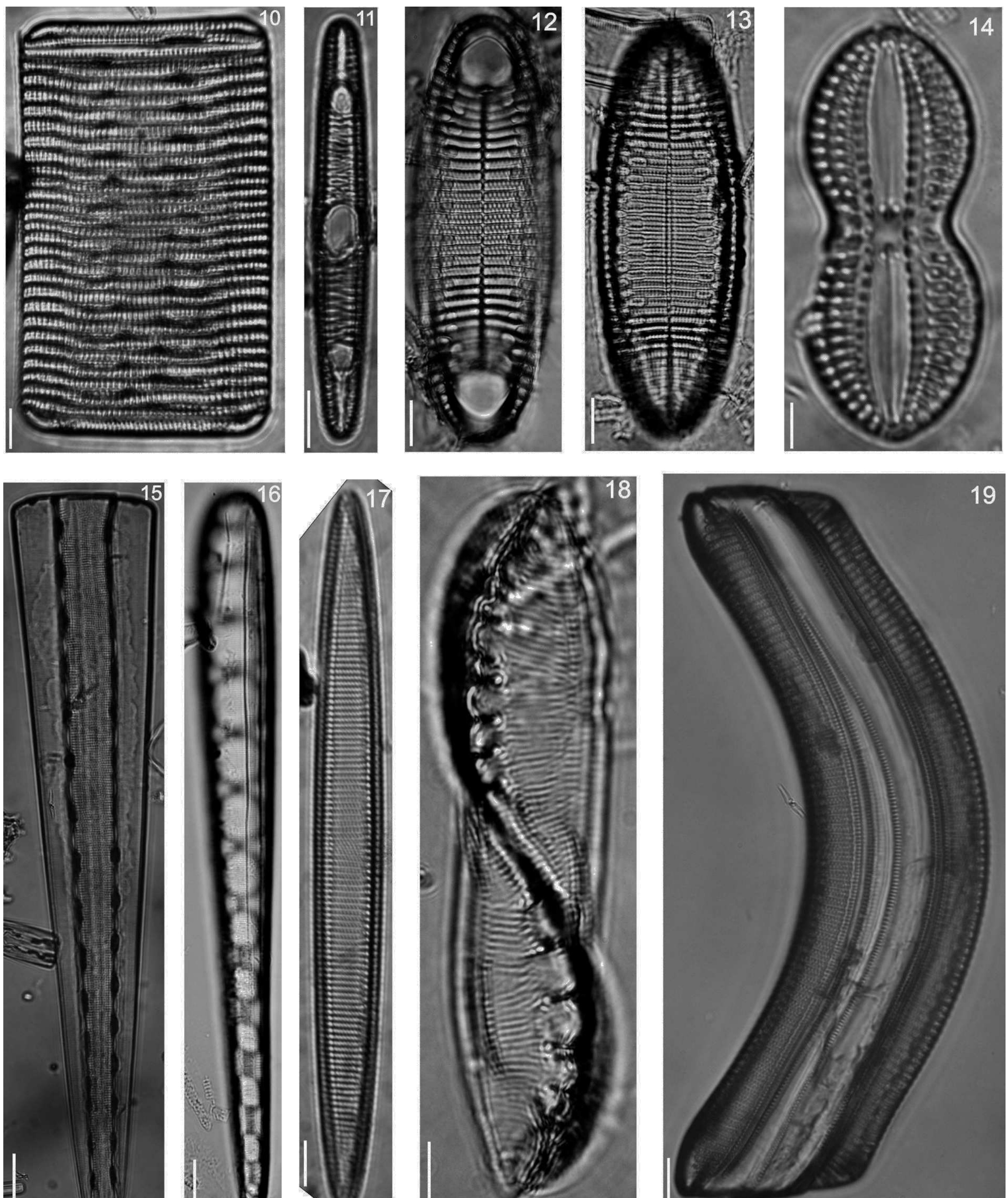


Figures 2–9. Iconographic sample of the diatoms observed on different coastal substrata from Isla Guadalupe. All images by Folf. Bar = 10 μm. (2) *Campylodiscus crebrecostatus* var. *speciosa*, (3) *Campylodiscus ambiguus*, (4) *Campylodiscus fastuosus*, (5) *Podocystis adriatica*, (6) *Campyloneis grevillei*, (7) *Lyrella approximata*, (8) *Mastogloia fimbriata*, (9) *Surirella fastuosa*.

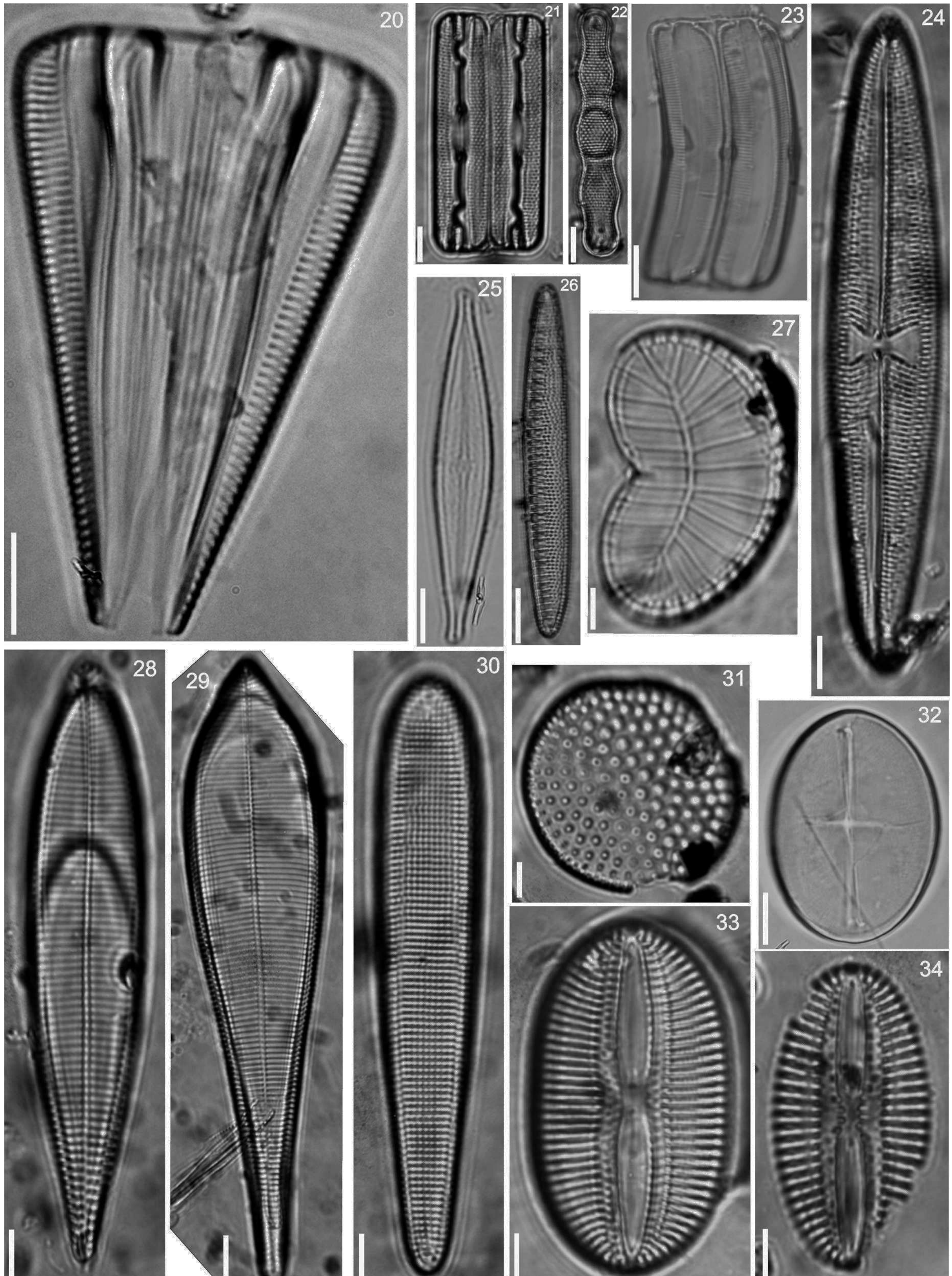
included: Schmidt et al. (1874–1959), Peragallo and Peragallo (1897–1908), Foged (1984), Witkowski, Lange-Bertalot, and Metzeltin (2000), Siqueiros-Beltrones (2002), and López-Fuerte et al. (2010). Photographic images of newly recorded taxa and others were acquired using an electronic ocular lens.

Results

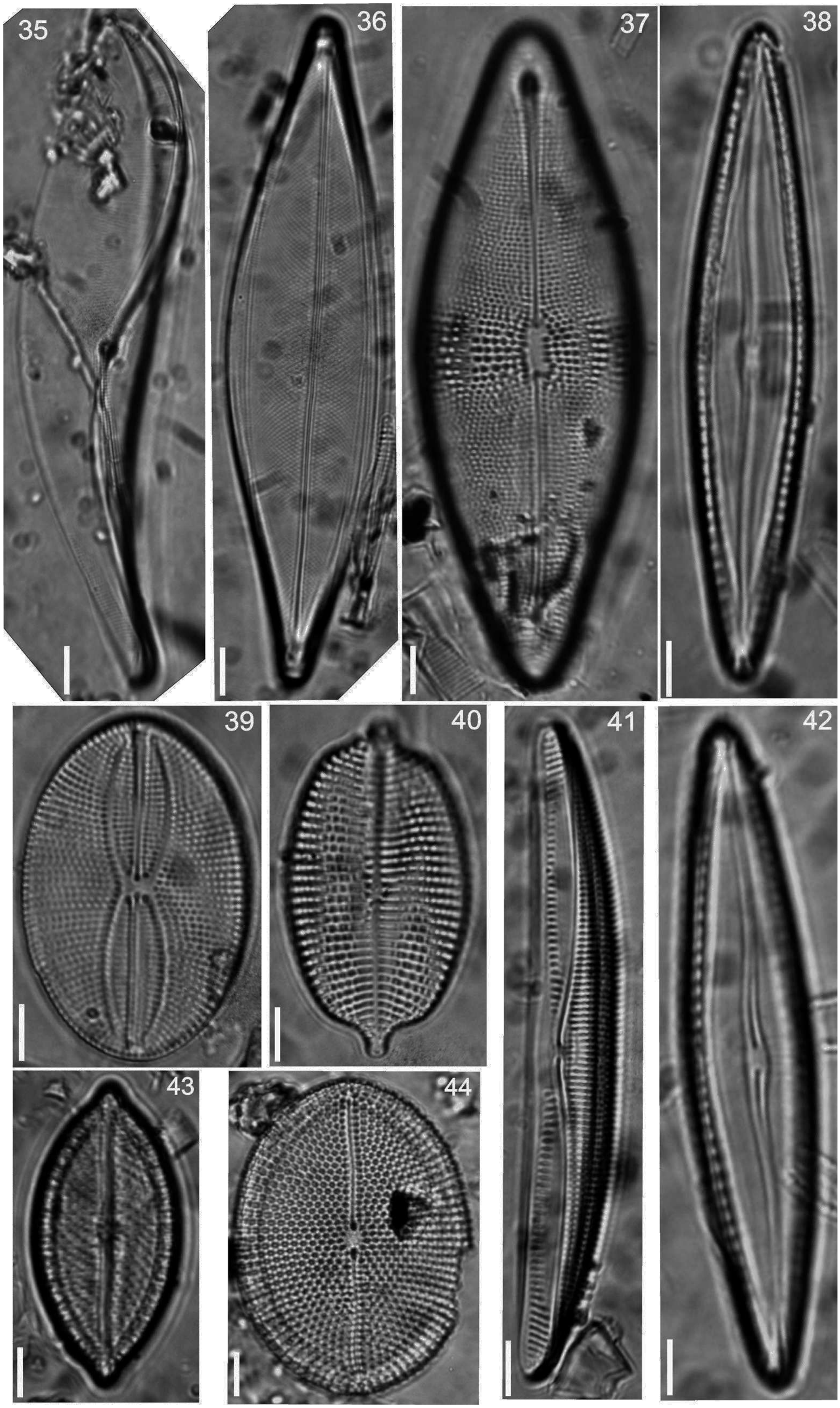
Surficial water temperature in the sampling site was measured at 17.7 °C; salinity was recorded at 38 psu, which renders the environment as polyhalobous. The measured pH was close to neutral at 7.4.



Figures 10–19. 10) Girdle view, (11) *Rhabdonema adriaticum*, (12 and 13) *Rhabdonema arcuatum*, (14) *Diploneis bombus*, (15) Girdle view, (16) *Climacosphenia moniligera*, (17) *Alveus marinus*, (18) *Amphiprora conspicua*, (19) *Gephyria media*.



Figures 20–34. (20) *Licmophora abbreviata*, (21) *Grammatophora marina*, (22) *Grammatophora undulata*, (23) *Campylopyxis garkeana*, (24) *Trachyneis aspera*, (25) *Brachysira* aff. *neoexilis*, (26) *Denticula kuetzingii*, (27) *Plagiodiscus nervatus*, (28) *Licmophora communis*, (29) *Licmophora ehrenbergii*, (30) *Licmosoma squamosum*, (31) *Psammodiscus calceatus*, (32) *Cocconeis molesta* var. *crucifera*, (33) *Diploneis suborbicularis* var. *constricta*, (34) *Diploneis coffaeiformis*.



Figures 35–44. (35) *Donkinia reticulata*, (36) *Striatella unipunctata*, (37) *Parlibellus delognei*, (38 and 42) *Mastogloia ciskeiensis*, (39) *Lyrella perplexoides*, (40) *Achnanthes citronella*, (41) *Amphora proteus* var. *oculata*, (43) *Mastogloia asperuloides*, (44) *Mastogloia punctatissima*.

Floristic analysis yielded 119 taxa including species and varieties of benthic diatoms, including epiphytic, epilithic and epizoic forms (Appendix). All diatoms appear alive in the fresh mountings (Fig. 2). The class Bacillariophyceae with 87 taxa was much more diverse than the Fragilariophyceae which yielded 32 taxa. Out of the 45 identified genera, those with higher number of species were *Mastogloia* (13), *Diploneis* (11 species), *Nitzschia* (10), *Cocconeis* (9), *Grammatophora* (6) and *Licmophora* (5). These represent 46% of the species recorded in this study. In contrast, 25 genera were represented by a single species. Thirteen taxa are new records for Mexico: *Achnanthes citronella* (A. Mann) Hustedt (Fig. 40), *Amphiprora conspicua* Greville (Fig. 18), *Amphora proteus* var. *oculata* H. Peragallo (Fig. 41), *Campylodiscus ambiguus* Greville (Fig. 3), *Diploneis coffaeiformis* (Schmidt) Cleve (Fig. 34), *D. suborbicularis* var. *constricta* Hustedt (Fig. 33), *Donkinia reticulata* Norm. (Fig. 35), *Lyrella perplexoides* (Hustedt) D.G. Mann (Fig. 39), *Mastogloia asperuloides* Hustedt (Fig. 43), *M. ciskeiensis* Giffen (Figs. 38 and 42), *M. punctatissima* (Greville) Ricard (Fig. 44), *Parlibellus delognei* (Van Heurck) E. J. Cox (Fig. 37) and *Psammodiscus calceatus* T. Watanabe, T. Nagumo and J. Tanaka (Fig. 31). Only 11 taxa occurred in all three surveyed substrates. The higher number of taxa was observed on the rocky substrate (57), and the lowest on the shell of *Megastraea undosa*. On the other hand, the higher number of exclusive taxa occurred on macroalgal substrate, particularly on *Eisenia desmarestioides* with 29 taxa, which renders it as a proper substrate for diatoms, while *M. undosa* had the lowest (6) number of taxa.

Discussion

Research on benthic marine diatoms in Mexico dates barely to the 1980s, and most studies have been carried out for the NW region. Recently, however, some have been carried out in the Mexican Caribbean area (Hernández-Almeida, Herrera-Silveira, & Merino-Virgilio, 2013; López-Fuerte, Siqueiros-Beltrones, & Hernández-Almeida, 2013; Siqueiros-Beltrones, Argumedo-Hernández, & Hernández-Almeida, 2013). Nonetheless, there are still extensive areas in the country where the most basic floristic studies on benthic diatoms are lacking and are badly needed.

Our present work falls within this category, inasmuch no research on diatoms, whether scientific or of any sort, existed for Mexican islands, in spite the fact that 1365 islands are distributed within the Mexican territory (Comité Asesor Nacional sobre el Territorio Insular Mexicano, 2012). Thus, this constitutes the first floristic list of benthic diatoms for any oceanic island located in the exclusive economic zone of Mexico, and it targets the Guadalupe Island Biosphere Reserve.

Although only three substrates were examined, the number of identified taxa is high, and over 11% are new records for the whole country. Some of the genera with a higher number of species are of tropical affinity, e.g., *Mastogloia*. Others such as *Cocconeis thalassiana*, primarily described for the Mexican Caribbean (Romero & López-Fuerte, 2013), leads us to suggest that, as with the terrestrial flora, Isla Guadalupe does not have a diatom flora with a particular biogeographical affinity, i.e., temperate, subtropical, or tropical. Moreover, due to the distance of the island with the continent it is likely that further observations based on a more exhaustive sampling may render new records of diatom species or varieties. This, and on the basis that Isla Guadalupe is not influenced by coastal upwelling, shows a biogeographically mixed macroalgal flora that includes species from California, the Mexican tropics, and the insular Indo-Pacific, plus a conspicuous group of endemic taxa derived from the California flora. All of these are evidence of their effective isolation and the ecological divergence in a process of speciation (Dawson, 1960).

In comparison with *E. desmarestioides* that stands out as a proper substrate for diatoms with 29 exclusive taxa and the second most number of taxa overall, Siqueiros-Beltrones et al. (2002) did not find diatom epiphytes on *Eisenia arborea* Areschoug, although recent research has shown that older blades may harbor monospecific proliferations of diatoms. Along the West coast of the Baja California Peninsula, *Macrocystis pyrifera* (Linnaeus) C. Agardh is considered the main food source of abalone (*Haliotis* spp.), together with its numerous epiphytic diatom species (Argumedo-Hernández & Siqueiros-Beltrones, 2008). However, in Isla Guadalupe *M. pyrifera* is absent, thus its ecological role may be replaced by *E. desmarestioides*, which is the largest macroalgae in the area and, according to the local fishermen, its abundance relate to the that of abalone.

Aside from this being the first publication on the diatom flora of Isla Guadalupe or any other Mexican island, the high number of new records either for the region or the whole country gives an insight to a highly diverse flora hitherto unknown as an assemblage. Thus, the generated information is relevant both in bio-geographical as well as in environmental health terms. We are confident that further exhaustive research will provide much valuable information that is hard to come by, given the remoteness of the studied area. The differential distribution of exclusive diatom taxa on distinct substrates strongly supports the expectation of increasing the species richness for the island as more substrates are examined.

Acknowledgements

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Appendix.

List of benthic diatoms recorded for the Biosphere Reserve Isla Guadalupe, Mexico. Symbols indicate the type of substrate from which it was sampled. Epiphytic (*Eisenia desmarestioides* *; *Codium latum* subsp. *palmeri* ■); epilithic ●; epizoic ▲ (*Megastraea undosa*); ♦ new records for Mexico.

Class Bacillariophyceae Haeckel, 1878					
Subclass: Bacillariophycidae D.G. Mann, 1990					
Order: Achnanthales Silva, 1962					
Family: Achnanthaceae Kützing, 1844					
Achnanthes Bory de Saint Vincent, 1822					
1. *Achnanthes brevipes* var. *angustata* (Greville) Cleve, 1894				●	▲
2. *Achnanthes brevipes* var. *intermedia* (Kützing) Cleve, 1895					▲
3. *Achnanthes citronella* (A. Mann) Hustedt, 1937	♦			●	
4. *Achnanthes yaquinensis* McIntire et Reimer, 1974				●	
Order: Bacillariales Hendey, 1937					
Family: Bacillariaceae Ehrenberg, 1831					
Alveus Kaczmarska et Fryxell, 1995					
5. *Alveus marinus* (Grunow) Kaczmarska et Fryxell, 1996 (Fig. 17)			■	●	
Denticula Kützing, 1844					
6. *Denticula kuetzingii* Grunow, 1862 (Fig. 26)		*			
Nitzschia Hassall, 1845					
7. *Nitzschia angularis* W. Smith, 1853			■		
8. *Nitzschia dissipata* (Kützing) Grunow, 1862		*	■	●	▲
9. *Nitzschia macilenta* W. Gregory, 1859		*	■	●	▲
10. *Nitzschia marginulata* var. *didyma* Grunow, 1880		*			
11. *Nitzschia punctata* var. *coarctata* (Grunow) Hustedt, 1921					▲
12. *Nitzschia sigma* (Kützing) W. Smith, 1853			■		
13. *Nitzschia spathulata* W. Smith, 1853				●	
14. *Nitzschia tryblionella* Hantzsch, 1860		*			
15. *Nitzschia ventricosa* Kitton, 1873				●	
Tryblionella W. Smith, 1853					
16. *Tryblionella hungarica* (Grunow) Frenguelli, 1942		*			
Order: Cymbellales D.G. Mann, 1990					
Family: Rhoicospheniaceae Chen et Zhu, 1983					
Campylopyxis L. K. Medlin, 1985					
17. *Campylopyxis garkeana* (Grunow) L. K. Medlin, 1985 (Fig. 23)		*			
Gomphonemopsis L.K. Medlin, 1986					
18. *Gomphonemopsis pseudexigua* cf. (R. Simonsen) L.K. Medlin, 1986		*			
Order: Lyrellales D.G. Mann, 1990					
Family: Lyrellaceae D.G. Mann, 1990					
Lyrella Karajeva, 1978					
19. *Lyrella approximata* (Greville) D.G. Mann, 1990 (Fig. 7)		*			
20. *Lyrella perplexoides* (Hustedt) D.G. Mann, 1990	♦			●	
Order: Mastogloiales D.G. Mann, 1990					
Family: Mastogloiaceae Mereschkowsky, 1903					
Mastogloia Thwaites ex W. Smith, 1856					
21. *Mastogloia asperuloides* Hustedt, 1933	♦			●	
22. *Mastogloia binotata* (Grunow) Cleve, 1895			■	●	
23. *Mastogloia borneensis* Hustedt, 1927		*			
24. *Mastogloia ciskeiensis* Giffen, 1967	♦			●	
25. *Mastogloia crucicula* (Grunow) Cleve, 1895				●	
26. *Mastogloia crucicula* var. *alternans* Zanon, 1948			■	●	
27. *Mastogloia erythraea* Grunow, 1860				●	
28. *Mastogloia fimbriata* (T. Brightwell) Grunow, 1863 (Fig. 8)		*	■	●	▲
29. *Mastogloia gieskesii* Cholnoky, 1963			■	●	
30. *Mastogloia mediterranea* Hustedt, 1933		*			
31. *Mastogloia obliqua* Hagelstein, 1939			■		
32. *Mastogloia punctatissima* (Greville) Ricard, 1975	♦			●	
33. *Mastogloia rostrata* (Wallich) Hustedt, 1933				●	
Order: Naviculales Bessey, 1907					
Family: Amphipleuraceae Grunow, 1862					
Amphiprora Ehrenberg, 1844					
34. *Amphiprora conspicua* Greville, 1861 (Fig. 18)	♦	*			
Family: Brachysiraceae D. G. Mann, 1990					
Brachysira Kützing, 1836					
35. *Brachysira* aff. *neoexilis* Lange-Bertalot, 1994 (Fig. 25)		*			

Appendix *(Continued)*

Family: Pinnulariaceae D.G. Mann, 1990					
Oestrupia Heiden ex Hustedt, 1935					
36. *Oestrupia musca* (Gregory) Hustedt, 1935			+		
Suborder: Diploneidineae D.G. Mann, 1990					
Family: Diploneidaceae D.G. Mann, 1990					
Diploneis Ehrenb. ex Cleve, 1844					
37. *Diploneis aestuarii* Hustedt, 1939		*			
38. *Diploneis bombus* (Ehrenb.) Ehrenberg, 1853 (Fig. 14)			■	●	
39. *Diploneis chersonensis* (Grunow) Cleve, 1894			■	●	
40. *Diploneis coffaeiformis* (Schmidt) Cleve, 1894	♦	*			
41. *Diploneis crabro* (Ehrenb.) Ehrenberg, 1854		*	■	●	▲
42. *Diploneis nitescens* (Gregory) Cleve, 1894		*			
43. *Diploneis papula* (A.W.F. Schmidt) Cleve, 1894			■	●	
44. *Diploneis papula* var. *constricta* Hustedt, 1937			■	●	
45. *Diploneis suborbicularis* var. *constricta* Hustedt, 1937	♦	*			
46. *Diploneis vacillans* var. *renitens* (A. Schmidt) Cleve, 1894		*	■		
47. *Diploneis vacillans* var. *vacillans* (A. Schmidt) Cleve, 1894		*	■		
Suborder: Naviculineae (Bessey) Hendey, 1937					
Family: Naviculaceae Kützing, 1844					
Caloneis Cleve, 1894					
48. *Caloneis excentrica* (Grunow) Boyer, 1927			■		
49. *Caloneis linearis* (Grunow) Boyer, 1927			■		
Navicula Bory de Saint-Vincent, 1822					
50. *Navicula agnita* Hustedt,1955			■		
51. *Navicula cancellata* Donkin, 1872		*			
52. *Navicula longa* var. *irregularis* Hustedt, 1955		*			
53. *Navicula zostereti* Grunow, 1860		*			
Trachyneis Cleve, 1894					
54. *Trachyneis aspera* (Ehrenb.) P.T. Cleve, 1894 (Fig. 24)		*	■	●	▲
55. *Trachyneis velata* A. Schmidt, 1876		*	■	●	▲
Family: Pleurosigmataceae Mereschkowsky, 1903					
Pleurosigma W. Smith, 1852					
56. *Pleurosigma salinarum* (Grunow) Grunow, 1880			■		
Family: Sellaphoraceae Mereschkowsky, 1902					
Fallacia Stickle et D.G. Mann, 1990					
57. *Fallacia forcipata* (Greville) Stickle et Mann, 1990		*			
Family: Berkeleyaceae D.G. Mann, 1990					
Parlibellus E. J. Cox, 1998					
58. *Parlibellus delognei* (Van Heurck) E. J. Cox, 1988	♦	*	■		▲
Family: Pleurosigmataceae Mereschkowsky, 1903					
Donkinia Ralfs, 1861					
59. *Donkinia reticulata* Norman, 1861	♦	*			
Order: Rhopalodiales D.G. Mann, 1990					
Family: Rhopalodiaceae (G. Karst.) Topachevs'kyj et Oksiyuk, 1960					
Rhopalodia Otto Müll., 1895					
60. *Rhopalodia pacifica* Krammer, 1987			■		
Epithemia Kützing, 1844					
61. *Epithemia turgida* (Ehrenb.) Kützing, 1844		*	■		
Order: Surirellales D. G. Mann, 1990					
Family: Surirellaceae Kützing, 1844					
Campylodiscus Ehrenb. ex Kützing, 1840					
62. *Campylodiscus ambiguus* Greville, 1860	♦	*			
63. *Campylodiscus crebrecostatus* var. *speciosa* T. Eulenstein, 1875 (Fig. 2)				●	
64. *Campylodiscus fastuosus* Ehrenberg, 1845 (Fig. 4)					▲
65. *Campylodiscus simulans* Gregory, 1857			■	●	
Family: Cocconeidaceae Kützing, 1844					
Campyloneis Grunow, 1862					
66. *Campyloneis grevillei* Petit, 1877 (Fig. 7)			■	●	
Cocconeis Ehrenberg, 1836					
67. *Cocconeis costata* var. *hexagona* Grunow, 1880			■	●	
68. *Cocconeis dirupta* var. *flexella* (Janisch et Rabenhorst) Grunow, 1880				●	
69. *Cocconeis discrepans* A.W.F. Schmidt, 1894			■	●	
70. *Cocconeis molesta* var. *crucifera* Grunow, 1880 (Fig. 32)			■	●	
71. *Cocconeis molesta* var. *molesta* Kützing, 1844			■	●	
72. *Cocconeis pediculus* Ehrenberg, 1838		*			
73. *Cocconeis* cf. *pseudomarginata* Gregory, 1857				●	

Appendix *(Continued)*

74. *Cocconeis scutellum* Ehrenberg, 1838		*	■	●	▲
75. *Cocconeis thalassiana* O.E. Romero et F.O. López-Fuerte, 2013		*	■	●	▲
Psammodictyon D.G. Mann, 1990					
76. *Psammodictyon panduriforme* (W. Gregory) D.G. Mann, 1990			■	●	▲
Order: Thalassiophysales D.G. Mann, 1990					
Family: Catenulaceae Mereschkowsky, 1902					
Amphora Ehrenb. ex Kützing, 1844					
77. *Amphora angusta* Gregory, 1857		*			▲
78. *Amphora clevei* Grunow, 1875					▲
79. *Amphora immarginata* Nagumo, 2003					▲
80. *Amphora laevissima* W. Gregory, 1857				●	
81. *Amphora libyca* Ehrenberg, 1840		*			
82. *Amphora proteus* Gregory, 1857					▲
83. *Amphora proteus* var. *oculata* H. Peragallo, 1898	♦				▲
84. *Amphora rhombica* var. *intermedia* Cleve, 1895				●	
Halamphora (Cleve) Levkov, 2009					
85. *Halamphora coffeaeformis* (C. Agardh) Levkov, 2009		*			
86. *Halamphora costata* (W. Smith) Levkov, 2009				●	
87. *Halamphora cymbifera* (Gregory) Levkov, 2009				●	
Class Fragilariophyceae Round et R.M. Crawford, 1990					
Order: Climacospheniales Round, 1990					
Family: Climacospheniaceae Round, 1990					
Climacosphenia Ehrenberg, 1843					
88. *Climacosphenia moniligera* Ehrenberg, 1843 (Figs. 15 and 16)		*	■	●	▲
Order: Cyclophorales Round, 1990					▲
Family: Entopylaceae Round, 1990					
Gephyria Arnott, 1858					
89. *Gephyria media* Arnott, 1860 (Fig. 19)		*	■	●	▲
Subclass Fragilariophycidae Round, 1990					
Order: Fragilariales Silva, 1962					
Family: Fragilariaceae Greville, 1833					
Hyalosynedra D.M. Williams et F.E. Round, 1986					
90. *Hyalosynedra laevigata* (Grunow) D.M. Williams et Round, 1986		*			
Opephora Petit, 1889					
91. *Opephora schwartzii* (Grunow) Petit ex Pelletan, 1889			■		
Podocystis J. W. Bailey, 1854					
92. *Podocystis adriatica* (Kützing) Ralfs, 1861 (Fig. 5)		*			▲
Synedra Ehrenberg, 1830					▲
93. *Synedra fulgens* (Greville) W. Smith, 1853		*	■	●	▲
94. *Synedra parva* Kützing, 1844				●	
Tabularia (Kützing) D.M. Williams et Round, 1986					
95. *Tabularia fasciculata* (C. Agardh) D.M. Williams et Round, 1986			■	●	
Order: Licmophorales Round et R.M. Crawford, 1990					
Family: Licmophoraceae Kützing, 1844					
Licmophora C. Agardh, 1827					
96. *Licmophora abbreviata* C. Agardh, 1831 (Fig. 20)		*	■		
97. *Licmophora communis* (Heiberg) Grunow, 1881 (Fig. 28)		*			
98. *Licmophora ehrenbergii* (Kützing) Grunow, 1867 (Fig. 29)		*			
99. *Licmophora gracilis* (Ehrenb.) Grunow, 1867		*			
100. *Licmophora paradoxa* (Lyngbye) C. Agardh, 1828				●	
Licmosoma Round & C.G. Alexander, 2002: 324					
101. *Licmosoma squamosum* Round & C.G. Alexander, 2002 (Fig. 30)				●	
Order: Rhaphoneidales Round, 1990					
Family: Psammodiscaceae Round et D.G. Mann, 1990					
Psammodiscus Round et D.G. Mann, 1980					
102. *Psammodiscus calceatus* T. Watanabe, T. Nagumo et J. Tanaka, 2013.	♦			●	
103. *Psammodiscus nitidus* (Gregory) Round et D.G. Mann, 1980				●	
Order: Rhabdonematales Round et R.M. Crawford, 1990					
Family: Rhabdonemataceae Round et R.M. Crawford, 1990					
Rhabdonema Kützing 1844					
104. *Rhabdonema adriaticum* Kützing, 1844 (Figs. 10 and 11)		*	■		
105. *Rhabdonema arcuatum* (Lyngbye) Kützing, 1844 (Figs. 12 and 13)		*			
Order: Striatellales Round, 1990					
Family: Striatellaceae Kützing, 1844					
Grammatophora Ehrenberg, 1840					
106. *Grammatophora angulosa* Ehrenberg, 1841			■		

Appendix *(Continued)*

107. *Grammatophora hamulifera* Kützing, 1844	*			
108. *Grammatophora marina* (Lyngbye) Kützing, 1844 (Fig. 21)	*	■	●	
109. *Grammatophora oceanica* Ehrenberg, 1840	*	■	●	
110. *Grammatophora oceanica* var. *macilenta* (W. Smith) Grunow, 1862	*	■		▲
111. *Grammatophora undulata* Ehrenberg, 1840 (Fig. 22)	*	■	●	▲
Striatella C. Agardh, 1832				
112. *Striatella interrupta* (Ehrenb.) Heiberg, 1863	*			
113. *Striatella unipunctata* (Lyngbye) C. Agardh, 1832 (Fig. 36)	*			
Order: Surirellales D.G. Mann, 1990				
Family: Surirellaceae Kützing, 1844				
Plagiodiscus Grunow et Eulenstein, 1867				
114. *Plagiodiscus nervatus* Grunow, 1867 (Fig. 27)			●	
Surirella Turpin, 1828				
115. *Surirella armoricana* H. Peragallo et M. Peragallo, 1899			●	
116. *Surirella fastuosa* (Ehrenb.) Ehrenberg, 1843 (Fig. 9)		■	●	▲
Order: Thalassionematales Round, 1990				
Family: Thalassionemataceae Round, 1990				
Thalassionema (Grunow) Grunow, 1881				
117. *Thalassionema frauenfeldii* (Grunow) Tempère et Peragallo, 1910		■		
118. *Thalassionema nitzschioides* (Grunow) Mereschkowsky, 1902		■		
Order: Toxariales Round, 1990				
Family: Toxariaceae Round, 1990				
Toxarium Bailey, 1854				
119. *Toxarium undulatum* J.W. Bailey, 1854		■		

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