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Diversity of Phytoplankton Collected During the Scientific Expedition to Pulau Perak, Pulau Jarak and the Sembilan Group of Islands

Aishah Salleh*, Sarini Ahmad Wakid and Iskandar Shah Bahnan

Institute of Biological Sciences, Faculty of Science, University of Malaya, 50603, Kuala Lumpur, Malaysia
*aishahsalleh@um.edu.my (Corresponding author)

ABSTRACT Preliminary studies on the phytoplankton in the Straits of Malacca were conducted during the 'Scientific Expedition to the Seas Of Malaysia' (SESMA). Phytoplankton samples were collected from Pulau Perak, Pulau Jarak and the Sembilan group of Islands. The quantitative analysis was carried out especially on the identification and calculation of the diversity of the phytoplankton. A total of 69 species of phytoplankton from 17 genera were recorded. The species were mainly from two major divisions namely Bacillariophyta (diatoms) and Pyrrophyta (dinoflagellates). Five species are new records for Malaysia: *Peridinium quinquecorne* Abé, *Protoperidinium cerasus* (Paulsen) Balech, *Protoperidinium nudum* (Meunier) Balech, *Ceratium arietinum* Cleve and *Ceratium compressum* Gran.

ABSTRAK Kajian awal mengenai fitoplankton di Selat Melaka telah dijalankan semasa 'Ekspedisi Saintifik ke lautan di Malaysia' (SESMA). Penyampelan telah dijalankan meliputi Pulau Perak, Pulau Jarak dan Kepulauan Sembilan. Analisis kuantitatif telah dijalankan terutamanya pada pengecaman dan pengiraan diversiti fitoplankton. Sejumlah 69 spesies fitoplankton daripada 17 genera telah direkodkan. Spesies terutamanya adalah terdiri daripada dua divisi Bacillariophyta (diatom) dan Pyrrophyta (dinoflagellata) diperolehi. Lima spesies baru merupakan rekod baru bagi Malaysia iaitu; *Peridinium quinquecorne* Abé, *Protoperidinium cerasus* (Paulsen) Balech, *Protoperidinium nudum* (Meunier) Balech, *Ceratium arietinum* Cleve dan *Ceratium compressum* Gran.

(phytoplankton, biodiversity, SESMA)

INTRODUCTION

The Straits of Malacca is located in a unique geographical position and its deep waters have enabled it to grow into one of the busiest straits in the world, with several thriving port cities along the coast. The challenge that coastal cities in Malaysia face is how to effectively manage the coastal impacts in such a way that sustainable development can be pursued.

The climate of Malaysia is typically wet equatorial, with high temperatures and large amounts of rainfall throughout the year. Although the local climate is relatively uniform, it is modified by the Southeast Asian monsoon regime, which introduces variations in wind speed and direction, cloudiness, rain and dry seasons over the year. The oceanic circulation patterns driven by the monsoon winds play an important role in determining the distribution of plankton and other environmental parameters in the Straits of Malacca.

Marine phytoplankton are known as the ocean's fundamental food web. Marine phytoplankton consist of an immense variety of single-celled plants found in the surface zone of the aquatic system. Phytoplankton have the ability to transform inorganic minerals and sea water, natural warmth, and the Earth's sunlight and carbon dioxide into usable vitamins, proteins, amino acids, and carbohydrates, in essence, creating food for the marine ecosystem. Marine phytoplankton are also responsible for creating much of our planet's oxygen. These phytoplankton, in the process of photosynthesis, also extract carbon dioxide from the atmosphere, and as a result, play an important role in the balance of greenhouse gases that control global climate. Though incredibly small as individual cells, their vast numbers influence both the primary production of the oceans and the world's climate.

Although the oceans cover 70% of the Earth's surface, our knowledge of biodiversity patterns in marine phytoplankton is very limited compared to that of the biodiversity of plants and herbivores in the terrestrial world. From this scientific expedition, we present biodiversity data for marine phytoplankton assemblages around different islands along the Straits of Malacca.

Phytoplankton size is important because it regulates phytoplankton growth and loss rates [1], thereby significantly affecting phytoplankton abundance [2] and its contribution to community biomass. The variability and distribution of the size fractionated phytoplankton biomass and productivity have important implications in the path of carbon produced in the euphotic zone, and in the pelagic food chain structure [3, 4].

One of the main environmental concerns is the occurrence of cultural eutrophication and harmful algal blooms. Cultural eutrophication is caused by excessive nutrient inputs which lead to the proliferation of phytoplankton. The incidence of eutrophication of coastal waters in Southeast Asia has increased dramatically in recent years, coinciding with increases in loading from domestic and industrial effluents [5]. For example, occurrences of harmful algal blooms have been reported in Hong Kong [6, 7], Philippines [8, 9], Brunei [10], Papua New Guinea [11], Sabah in East Malaysia [12] and possibly the Malacca Straits of West Malaysia [13] and Indonesia [14]. The strategy for preventing eutrophication problems in phytoplankton lies in the strict control of nutrient discharges coupled with comprehensive monitoring and numerical modelling capabilities for sound management of the coastal environment. As Malaysia's economy continues to expand, the successful management of Malaysia's marine environment is critical. Land reclamation, expanding coastal and port developments, ocean outfalls and damming of rivers and estuaries are expected to increasingly impact the coastal environment in future years. A field monitoring programme is needed together with cooperation of government agencies to allow for the continued successful management of Malaysia's coastal environment.

MATERIALS AND METHODS

Water samples were collected from 12 sampling stations using 500 ml polythene bottles and preserved in 4% formalin. Net samples were obtained using plankton net with mesh size of about 30 µm. In oceanic sampling, one of the plankton nets (Bongo net) with mesh size of 180 µm was used. The plankton net was towed obliquely at the (with speed of 5 knots) side of the ship for about 15 minutes to obtain a sufficient sample. The samples collected by the plankton net were examined to aid in the identification of life algae. Algae counts were made using the 'sedimentation-inverted microscope' technique. Results were expressed in the number of algae in cells/ml. Algal identification and enumerations were conducted using light microscope and Scanning Electron Microscope (SEM).

RESULTS

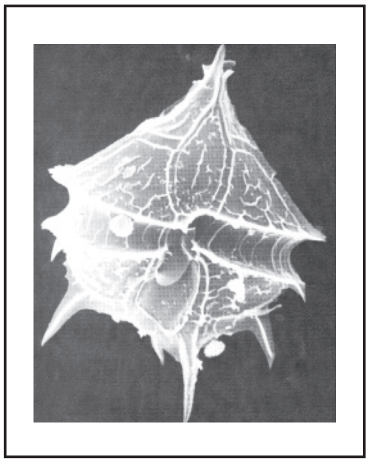
A total of 69 species of phytoplankton from 17 genera were recorded. The species are mainly from two major divisions namely Bacillariophyta (diatoms) and Pyrrophyta (dinoflagellates). About 50% from the total diatom population were from the genus *Chaetoceros* (*Chaetoceros constrictum* and *Chaetoceros leave*). Other common diatoms were *Rhizosolenia (Rhizosolenia alata var gracillima)* and *Bacteriastrum (Bacteriastrum varians)*. The dominant genera were *Chaetoceros* (21 taxa) and *Rhizosolenia* (14 taxa). Among the major phytoplankton species in these islands were *Chaetoceros constrictum, Chaetoceros laeve, Bacteriastrum varians, Rhizosolenia alata, Thalassiothrix nitzschioides* and *Thalassiothrix frauenfeldii.* Five species are new records for Malaysia; *Peridinium quinquecorne* Abé (Figure 1-a), *Protoperidinium cerasus* (Paulsen) Balech (Figure 1-b, *Protoperidinium nudum* (Meunier) Balech (Figure 1-c), *Ceratium arietinum* Cleve (Figure 1-d) and *Ceratium compressum* Gran (Figure 1-e).

The references used in identification are given for each species. The following abbreviations are used in the text :- L.= valve length of apical axis; B.= valve breadth of transapical axis; r.= radius of valve; Str.=number of striae. The samples were examined under a microscope and identification was based on published taxonomic treatments [15, 16, 17, 18].

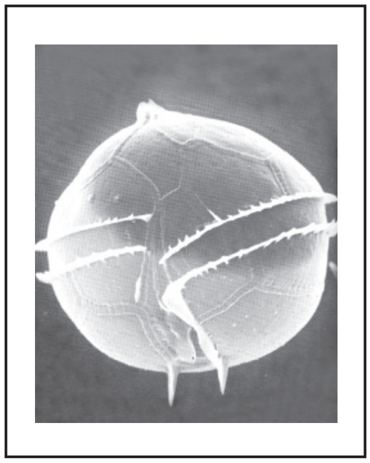
Refer to Figures at the Appendices.

1. *Asterionella japonica* Cleve.; Shamsudin 1991. *p. 154, f. 8.123* L. 75-130 µm.
2. *Asterolampra marylandica* Ehr.; Shamsudin 1991. *p. 106, f. 8.27* r. 70 µm, 13 areola in 10 µm.
3. *Asteromphalus hepaticus* Ralf.; Shamsudin 1991. *p. 106, f. 8.31* r. 40-145 µm.
4. *Bacteriastrum comosum* Pavillard.; Shamsudin 1991. *p. 121, f. 8.62* r. 7-10 µm.
5. *Bacteriastrum delicatulum* Cleve.; Shamsudin 1991. *p. 119, f. 8.58* r. 6-16 µm.
6. *Bacteriastrum hyalinum* Lauder.; Shamsudin 1991. *p. 120, f. 8.59* r. 24-36 µm.
7. *Bacteriastrum varians* Lauder.; Shamsudin 1991. *p. 120, f. 8.60* r. 30-36 µm.
8. *Biddulphia heteroceros* Grunow.; Shamsudin 1991. *p. 143, f. 8.99* L. 30-54 µm, 15-16 areola in 10 µm.
9. *Biddulphia longicruris* Greville.; Shamsudin 1991. *p. 145, f. 8.105* B. 90-250 µm.
10. *Biddulphia mobilensis* (Bail.) Grunow.; Shamsudin 1991. *p. 140, f. 8.97* L. 36-50 µm, 14-16 areola in 10 µm.
11. *Biddulphia reticulum* (Ehr.).; Shamsudin 1991. *p. 143, f. 8.100* L. 22-42 µm, 13-15 areola in 10 µm.
12. *Biddulphia sinensis* Greville.; Shamsudin 1991. *p. 143, f. 8.98* L. 54-245 µm, 14-16 areola in 10 µm.
13. *Ceratium arietinum* Cleve; Dodge 1985. *p. 93 ,* L. 270 µm B. 140 µm.
14. *Ceratium compressum* Gran.; Dodge 1985. *p. 95,* L. 250 µm, B. 150 µm.
15. *Ceratium hirundinella* O. F. Müller.; Dodge 1985. *p. 99,* L. 200 µm, B. 60 µm.
16. *Ceratium lineatum* (Ehrenberg) Cleve; Dodge 1985. *p.100 ,* L. 95 µm, B.30 µm.
17. *Ceratium platycorne* Daday.; Dodge 1985. *p. 101,* L. 100 µm, B. 160 µm.
18. *Chaetoceros affine* Lauder.; Shamsudin 1991. *p. 131, f. 8.76,* B. 22 µm.
19. *Chaetoceros breve* Schutt.; Shamsudin 1991. *p. 132, f. 8.80,* B. 24 µm.
20. *Chaetoceros coarctatum* Lauder.; Shamsudin 1991. *p. 124, f. 8.64,* B. 26-45 µm.
21. *Chaetoceros compressum* Lauder.; Shamsudin 1991. *p. 128, f. 8.70,* B. 12-34 µm.
22. *Chaetoceros constrictum* Gran.; Shamsudin 1991. *p. 131, f. 8.74,* B. 24-26 µm.
23. *Chaetoceros costatus* Pavillard.; Shamsudin 1991. *p. 134, f. 8.84,* B. 23-27 µm.
24. *Chaetoceros decipiens* Cleve.; Shamsudin 1991. *p. 137, f. 8.85,* B. 18-22 µm.
25. *Chaetoceros denticulatum* Lauder.; Shamsudin 1991. *p. 126, f. 8.65,* B. 24-30 µm.
26. *Chaetoceros didymum* Ehrenberg.; Shamsudin 1991. *p. 130, f. 8.71,* B. 20-32 µm.
27. *Chaetoceros didymum* var. *anglica* Gran .; Shamsudin 1991. *p. 130, f. 8.73,* B. 20-30 µm.
28. *Chaetoceros distans* Cleve.; Shamsudin 1991. *p. 132, f. 8.78,* B. 16-24 µm.
29. *Chaetoceros diversum* Cleve.; Shamsudin 1991. *p. 134, f. 8.81,* B. 7-12 µm.
30. *Chaetoceros hispidum* Brightwell.; Shamsudin 1991. *p. 137, f. 8.86,* B. 30-40 µm.
31. *Chaetoceros laciniosum* Schutt.; Shamsudin 1991. *p. 132, f. 8.79,* B. 12 µm.
32. *Chaetoceros laeve* Leudiger-Fortmorel.; Shamsudin 1991. *p. 134, f. 8.82,*B. 8-12 µm.
33. *Chaetoceros lauderii* Ralfs.; Shamsudin 1991. *p. 128, f. 8.69,* B. 19-30 µm.
34. *Chaetoceros lorenzianum* Grunow.; Shamsudin 1991. *p. 127, f. 8.68,* B. 18-60 µm.
35. *Chaetoceros paradoxum* Cleve.; Shamsudin 1991. *p. 132, f. 8.77,* B. 13-28 µm.
36. *Chaetoceros peruvianum var robusta* (Cleve) Hustedz.; Shamsudin 1991. *p. 126,*
37. *Chaetoceros pseudocurvisetum* Mangin.; Shamsudin 1991. *p. 134, f. 8.83,* B. 18-22µm.
38. *Chaetoceros siamense* Ostanfeld.; Shamsudin 1991. *p. 137, f. 8.87,* B. 25-60 µm.
39. *Chaetoceros van heurckii* Gran.; Shamsudin 1991. *p. 131, f. 8.75,* B. 24-28 µm.
40. *Climacodium biconcavum* Cleve.; Shamsudin 1991. *p. 138, f. 8.91,* L. 60µm, B. 35-65 µm.
41. *Corethron criophilum* Castr.; Shamsudin 1991. *p. 108 , f. 8.32,* L.30-50 µm, r. 30-33 µm.
42. *Coscinodiscus asteromphalus* Ehr.; Shamsudin 1991. *p. 99, f. 8.15,* r. 245-360 µm, 5-6 areola in 10 µm.
43. *Coscinodiscus curvatulus* Grunow.; Shamsudin 1991. *p.101 , f. 8.20 ,* r. 40-100 µm, 11-12 areola in 10 µm.
44. *Coscinodiscus excentricus* Ehr.; Shamsudin 1991. *p. 96, f. 8.7,* r. 20-66 µm, 5-6 areola in 10 µm.
45. *Coscinodiscus perforatus* Ehr.; Shamsudin 1991. *p. 101, f. 8.21,* r. 20-100 µm, 5-6 areola in 10 µm.
46. *Launderia annulata* Cleve.; Shamsudin 1991. *p. 108, f. 8.34*, r. 18-52 µm, L. 34-80 µm.
47. *Launderia borealis* Gran.; Shamsudin 1991. *p.*

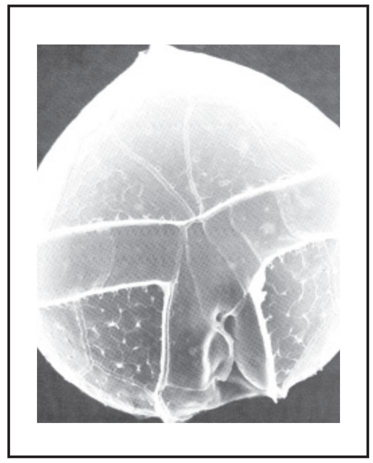
108, f. 8.35, r. 30-50 µm.
48. *Leptocylindricus danicus* Cleve.; Shamsudin 1991. *p. 111, f. 8.38*, r. 8 µm.
49. *Peridinium quinquecorne* Abé; Dodge 1985. *p. 37 ,* L. 26 µm, B. 20 µm.
50. *Protoperidinium ceracus* (Paulsen) Balech; Dodge 1985. *p.44,* r. 80 µm.
51. *Protoperidinium nudum* (Meunier) Balech; Dodge 1985. *p. 56,* L. 25 µm, B. 25 µm.
52. *Rhizosolenia alata var gracillima* (Cleve) Grunow.; Shamsudin 1991. *p. 116, f. 8.53*, r. 5-7 µm.
53. *Rhizosolenia alata var indica* (Paragallo) Ostenfeld.; Shamsudin 1991. *p. 116, f. 8.54*, r. 24-75 µm.
54. *Rhizosolenia araturensis* Castracane.; Shamsudin 1991. *p. 113, f. 8.45*, r. 65-95 µm.
55. *Rhizosolenia bergonii* Peragallo .; Shamsudin 1991. *p. 113, f. 8.44*, r. 34-36 µm, 18 puncta in 10 µm.
56. *Rhizosolenia calcor-avis* M. Schultze.; Shamsudin 1991. *p. 115, f. 8.50*, r. 20-45 µm, 18-20 puncta in 10 µm.
57. *Rhizosolenia clevei* Ostenfeld.; Shamsudin1991. *p. 113, f. 8.46*, r. 36-85 µm, L. 270-400 µm.
58. *Rhizosolenia cylindrus* Cleve.; Shamsudin 1991. *p. 111, f. 8.42*, r. 24 µm, L. 98 µm.
59. *Rhizosolenia delicatula* Cleve.; Shamsudin 1991. *p. 116, f. 8.57*, r. 10-20 µm, L. 30-100 µm.
60. *Rhizosolenia hebetata* (Bail) Gran.; Shamsudin 1991. *p. 115, f. 8.51*, r. 12-16 µm.
61. *Rhizosolenia imbriceta* Brightwell.; Shamsudin 1991. *p. 115, f. 8.47*, r. 30-70 µm, 18-20 puncta in 10 µm.
62. *Rhizosolenia robusta* Norman.; Shamsudin 1991. *p. 113, f. 8.43*, r. 75-97 µm.
63. *Rhizosolenia setigera* Brightwell.; Shamsudin 1991. *p. 115, f. 8.48*, r. 10-42 µm.
64. *Rhizosolenia stolterforthi* H. Peragallo.; Shamsudin 1991. *p. 111, f. 8.41*, r. 18-44 µm, L. 250 µm.
65. *Rhizosolenia styliformis* Brightwell.; Shamsudin 1991. *p. 115, f. 8.49*, r. 60-80 µm, 28-30 puncta in 10 µm.
66. *Schroderella schroderi* (Bergon).; Shamsudin 1991. *p.111, f. 8.37*, r. 13-40 µm.
67. *Thalassiothrix delicatula* Cupp.; Shamsudin 1991. *p. 154, f. 8.121*, B. 3-4 µm, L. 150-170 µm, Str. 9-12 in 10 µm.
68. *Thalassiothrix frauenfeldii* Grunow.; Shamsudin 1991. *p. 152, f. 8.120*, B. 8-12 µm, L. 160-260 µm, Str. 10-12 in 10 µm.
69. *Thalassiothrix nitzschioides* Grun.; Shamsudin 1991. *p. 152, f. 8.119*, B. 6-7 µm, L. 18-20 µm, Str. 12-14 in 10 µm**.**



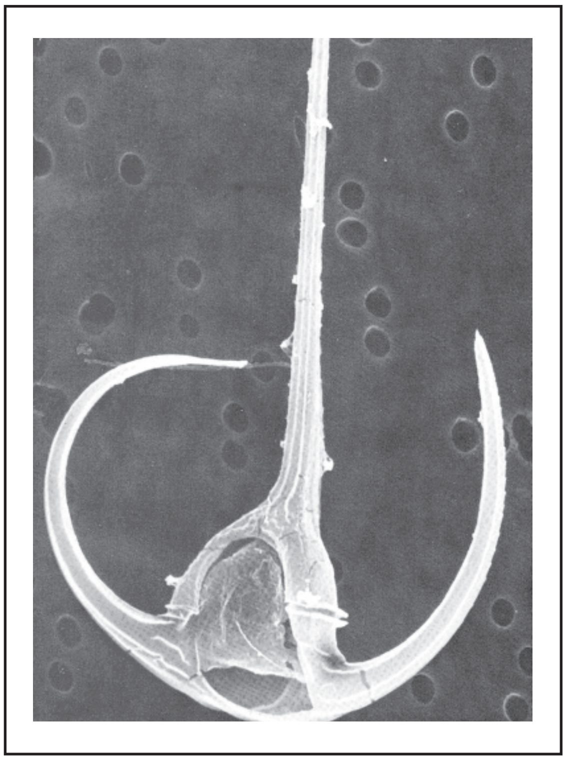
a. Peridinium quinquecorne Abé



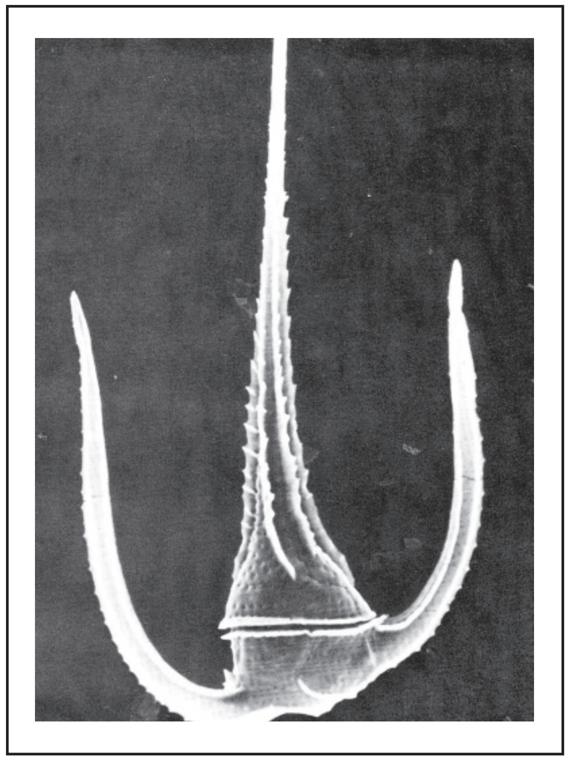
b. *Protoperidinium ceracus (Paulsen) Balech*



c. *Protoperidinium nudum (Meunier) Balech*



d. *Ceratium arietinum Cleve*



e. *Ceratium compressum Gran*

Figure 1 a-e. New record for Malaysia.

CONCLUSION

A total of 69 taxa from 17 genera were identified. About 50% from the total diatom populations are from *Chaetoceros*, i.e. *Chaetoceros constrictum* and *Chaetoceros laeve*. The dominant genera are *Chaetoceros* with 22 taxa. Most of the islands in the Straits of Malacca need to be conserved and protected from unmanaged human activities which will pollute the water and threaten the diversity of phytoplankton species.

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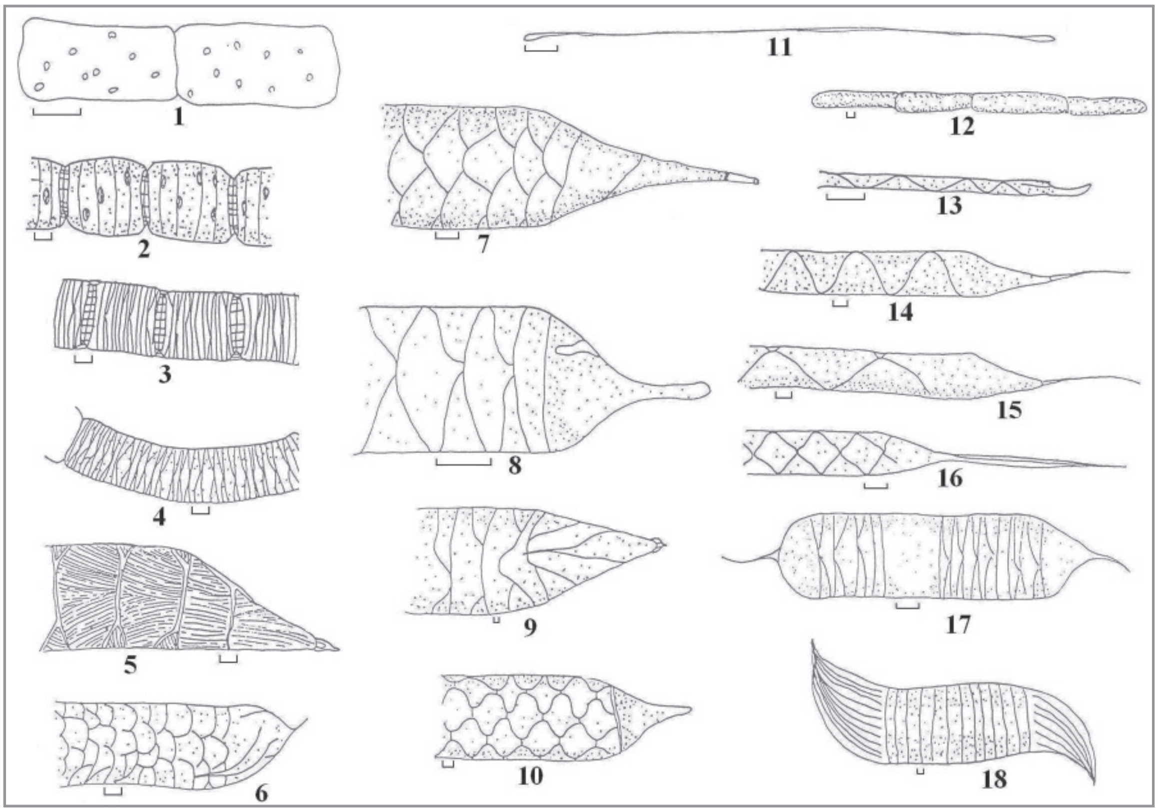

Plate 1. Scale bars = 10 µm.

Fig. 1. *Rhizosolenia delicatula* Cleve
Fig. 2. *Launderia borealis* Gran
Fig. 3. *Launderia annulata* Cleve
Fig. 4. *Rhizosolenia stolterforthi* H. Peragallo
Fig. 5. *Rhizosolenia imbriceta* Brightwell
Fig. 6. *Rhizosolenia clevei* Ostenfeld
Fig. 7. *Rhizosolenia bergonii* Peragallo
Fig. 8. *Rhizosolenia alata var indica* (Paragallo) Ostenfeld
Fig. 9. *Rhizosolenia styliformis* Brightwell
Fig. 10. *Rhizosolenia araturensis* Castracane
Fig. 11. *Thalassiothrix delicatula* Cupp
Fig. 12. *Leptocylindricus danicus* Cleve
Fig. 13. *Rhizosolenia alata var gracillima* (Cleve) Grunow
Fig. 14. *Rhizosolenia calcor-avis* M. Schultze
Fig. 15. *Rhizosolenia hebetata* (Bail) Gran
Fig. 16. *Rhizosolenia setigera* Brightwell
Fig. 17. *Rhizosolenia cylindrus* Cleve
Fig. 18. *Rhizosolenia robusta* Norman

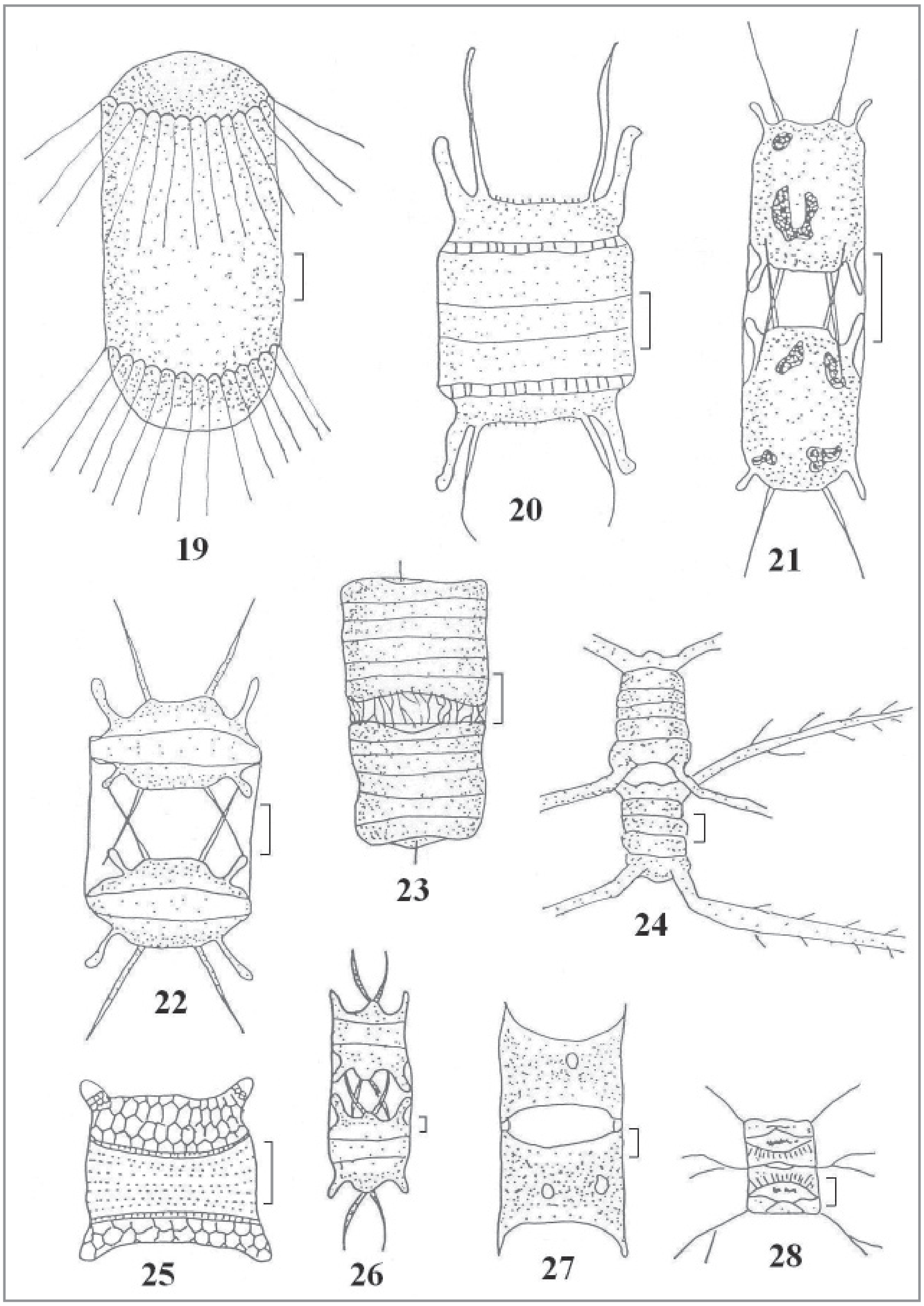

Plate 2. Scale bars = 10 µm.

Fig. 19. *Corethron criophilum* Castr
Fig. 20. *Biddulphia heteroceros* Grunow
Fig. 21. *Biddulphia sinensis* Greville
Fig. 22. *Biddulphia mobilensis* (Bail.) Grunow
Fig. 23. *Schroderella schroderi* (Bergon)
Fig. 24. *Chaetoceros denticulatum* Lauder
Fig. 25. *Biddulphia reticulum* (Ehr)
Fig. 26. *Biddulphia longicruris* Greville
Fig. 27. *Climacodium biconcavum* Cleve
Fig. 28. *Chaetoceros costatus* Pavillard

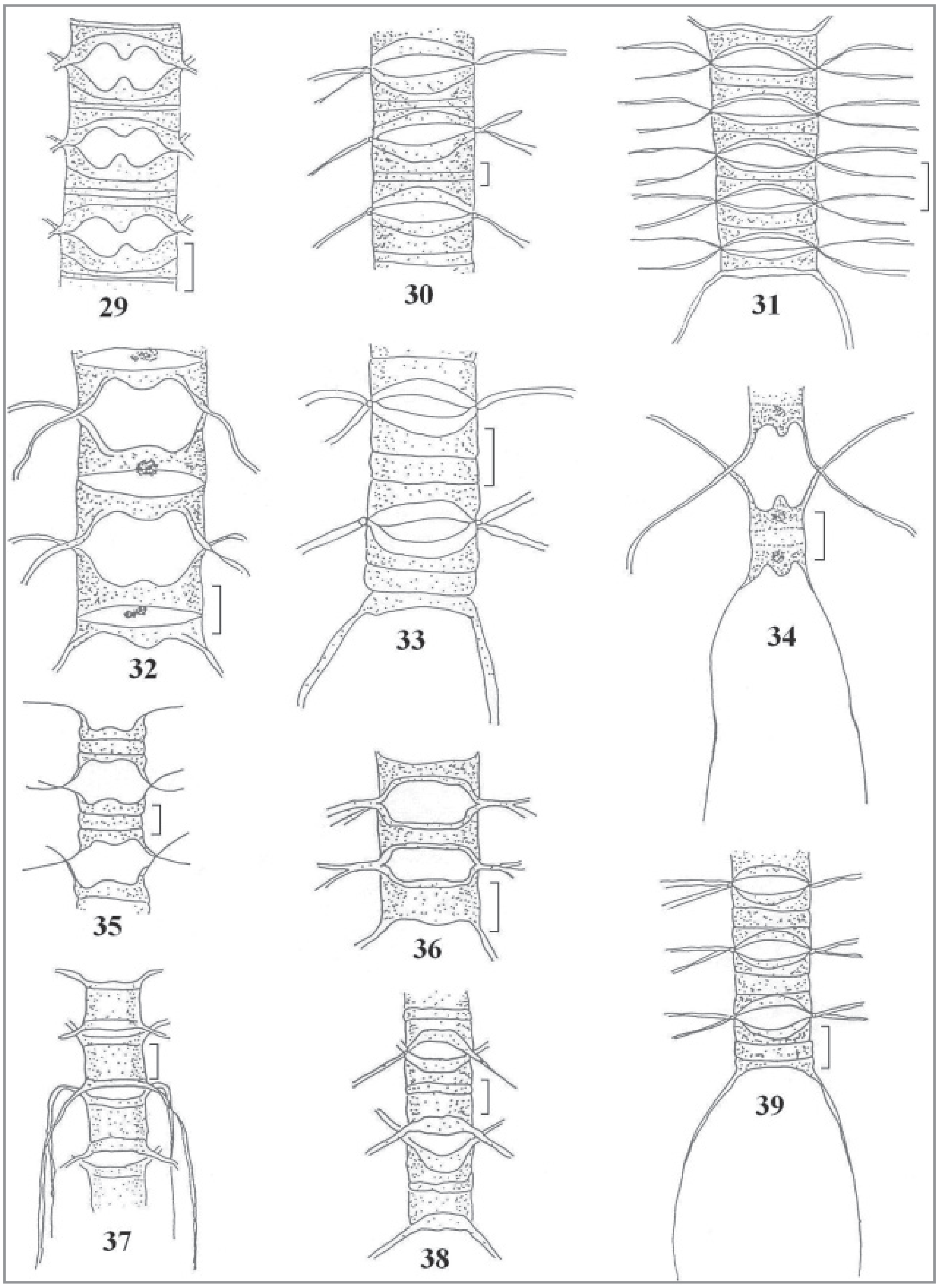

Plate 3. Scale bars = 10 μm.

Fig. 29. *Chaetoceros didymum* Ehrenberg
Fig. 30. *Chaetoceros van heurckii* Gran
Fig. 31. *Chaetoceros siamense* Ostanfeld
Fig. 32. *Chaetoceros lorenzianum* Grunow
Fig. 33. *Chaetoceros affine* Lauder
Fig. 34. *Chaetoceros didymum var. anglica* Gran
Fig. 35. *Chaetoceros breve* Schutt
Fig. 36. *Chaetoceros decipiens* Cleve
Fig. 37. *Chaetoceros compressum* Lauder
Fig. 38. *Chaetoceros constrictum* Gran
Fig. 39. *Chaetoceros pseudocurvisetum* Mangin

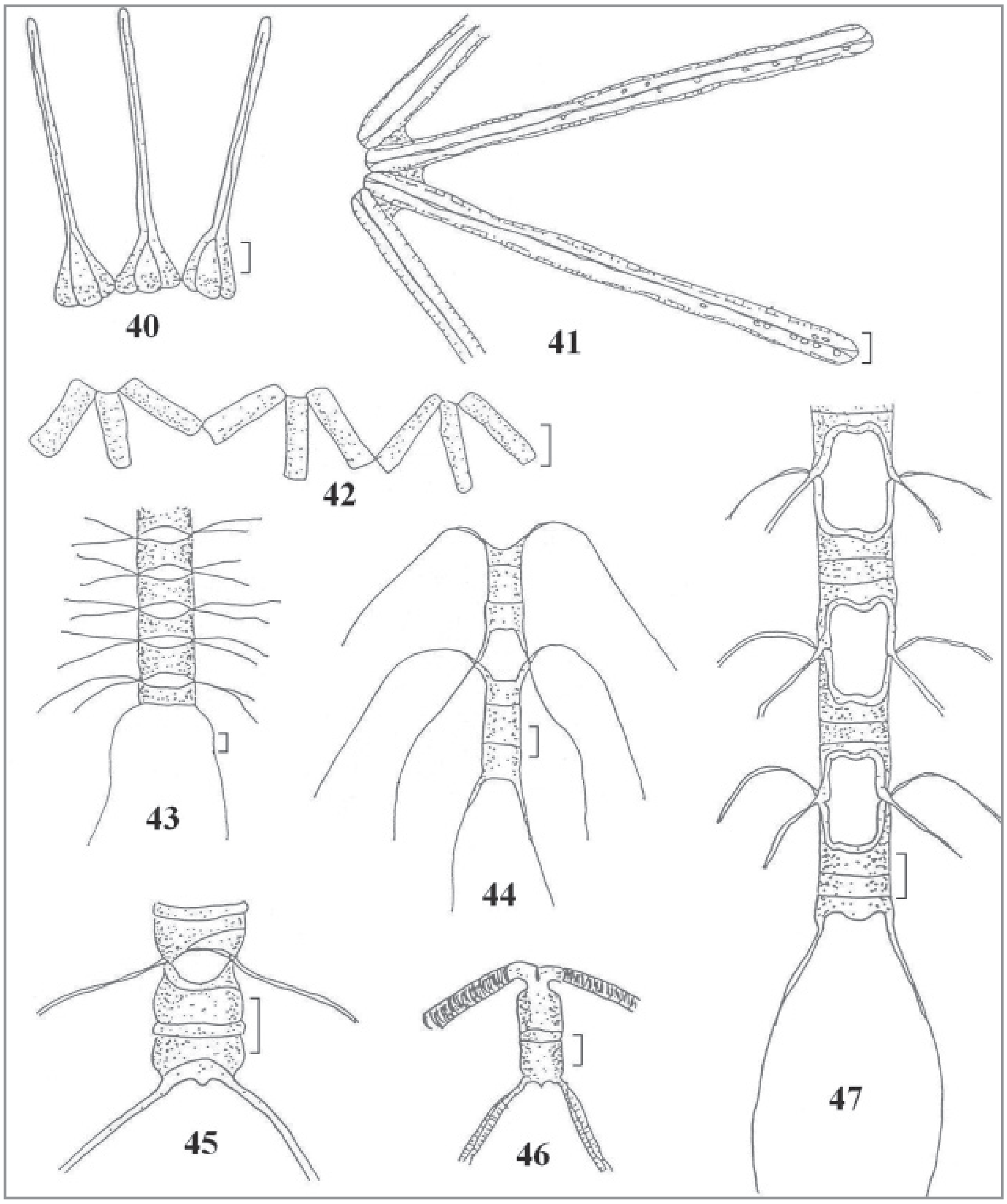

Plate 4. Scale bars = 10 µm.

Fig. 40. *Asterionella japonica* Cleve
Fig. 41. *Thalassiothrix frauenfeldii* Grunow
Fig. 42. *Thalassiothrix nitzschioides* Grun
Fig. 43. *Chaetoceros hispidum* Brightwell
Fig. 44. *Chaetoceros laciniosum* Schutt
Fig. 45. *Chaetoceros paradoxum* Cleve
Fig. 46. *Chaetoceros peruvianum var robusta* (Cleve) Hustedz
Fig. 47. *Chaetoceros distans* Cleve

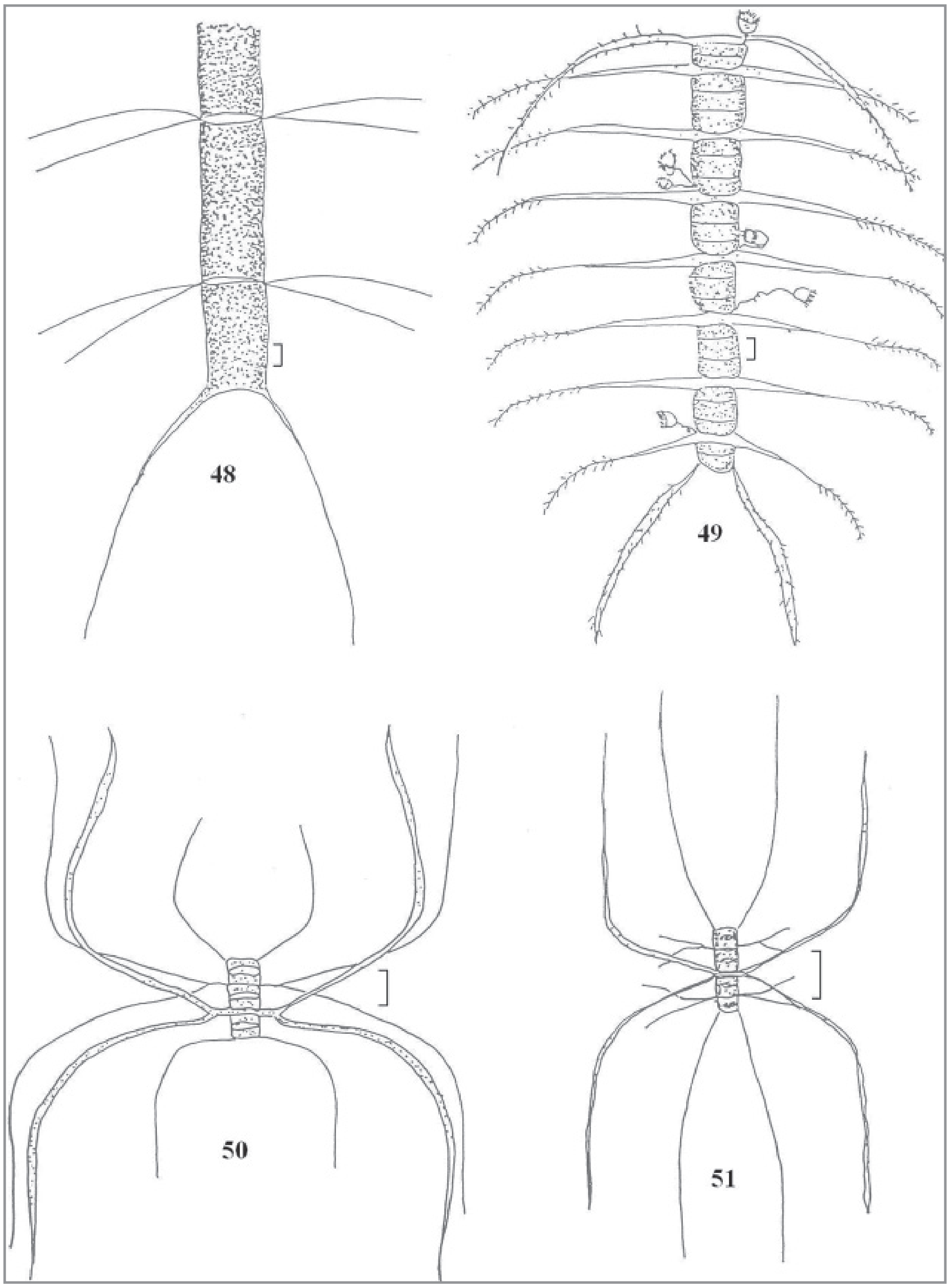

Plate 5. Scale bars = 10 µm.

Fig. 48. *Chaetoceros lauderii* Ralfs
Fig. 49. *Chaetoceros coarctatum* Lauder
Fig. 50. *Chaetoceros laeve* Leudiger - Fortmorel
Fig. 51. *Chaetoceros diversum* Cleve

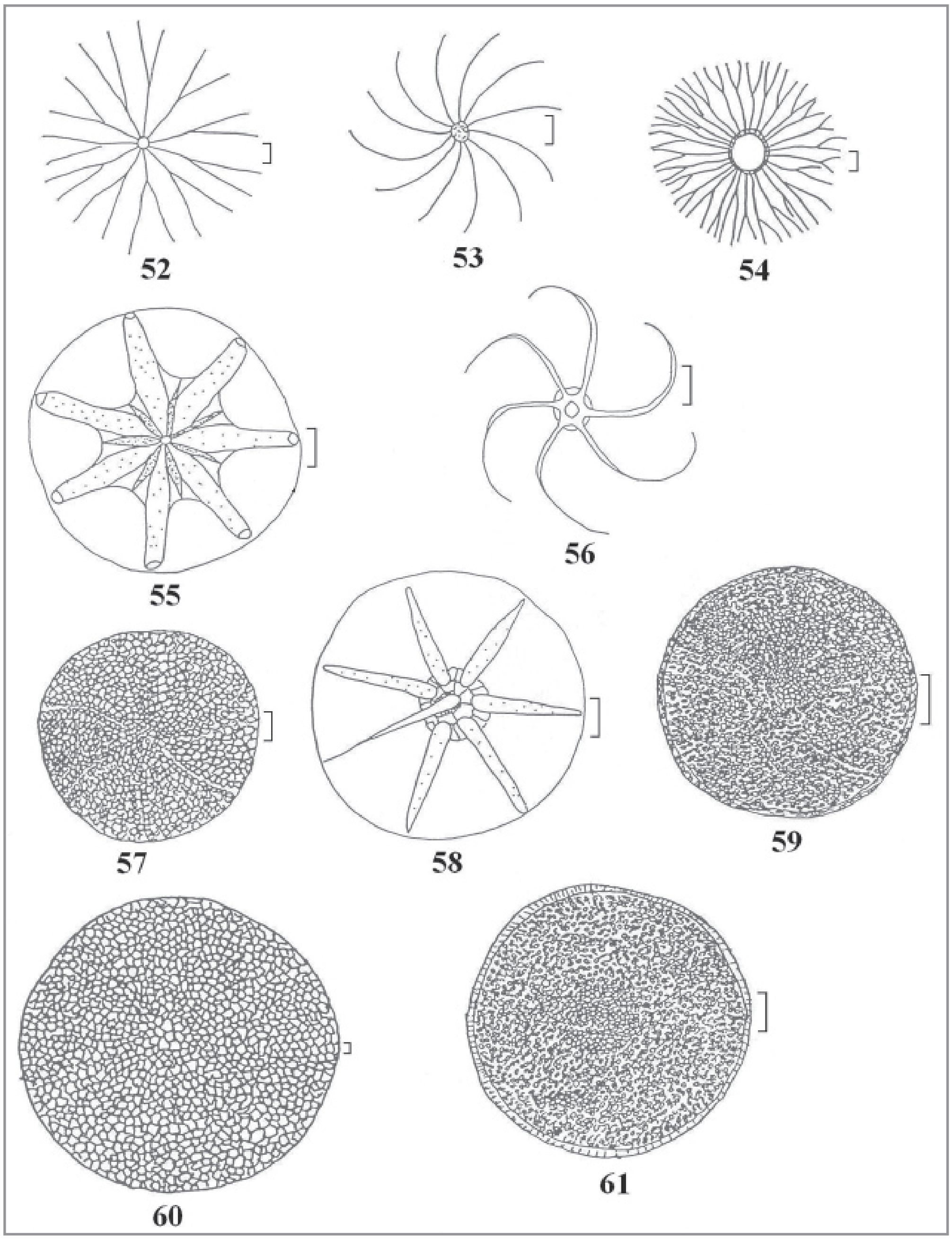

Plate 6. Scale bars = 10 μm.

Fig. 52. *Bacteriastrum delicatulum* Cleve
Fig. 53. *Bacteriastrum hyalinum* Lauder
Fig. 54. *Bacteriastrum varians* Lauder
Fig. 55. *Asterolampra marylandica* Ehr
Fig. 56. *Bacteriastrum comosum* Pavillard
Fig. 57. *Coscinodiscus curvatulus* Grunow
Fig. 58. *Asteromphalus hepaticus* Ralf
Fig. 59. *Coscinodiscus perforatus* Ehr
Fig. 60. *Coscinodiscus asteromphalus* Ehr
Fig. 61. *Coscinodiscus excentricus* Ehr

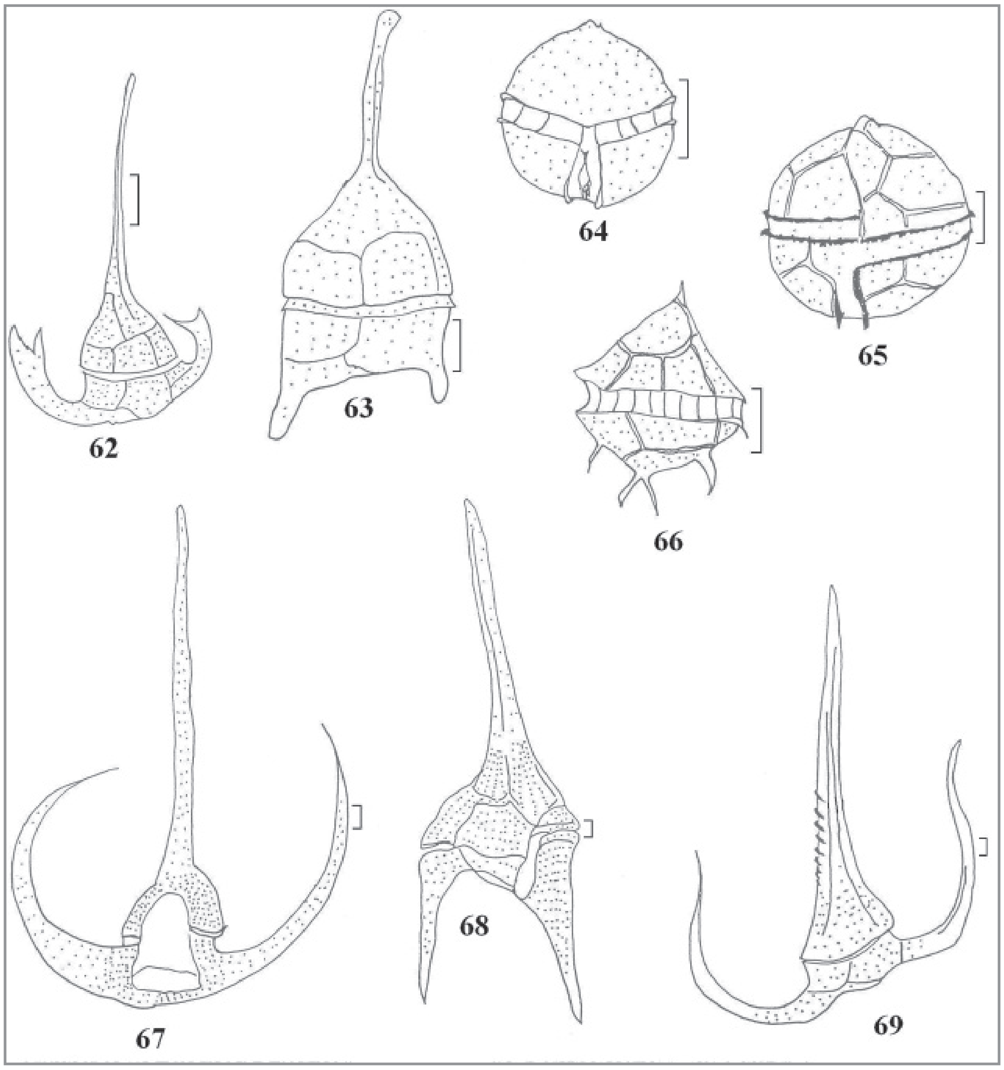

Plate 7. Scale bars = 10 µm.

Fig. 62. *Ceratium platycorne* Daday
Fig. 63. *Ceratium lineatum* (Ehrenberg) Cleve
Fig. 64. *Protoperidinium nudum* (Meunier) Balech
Fig. 65. *Protoperidinium ceracus* (Paulsen) Balech
Fig. 66. *Peridinium quinquecorne* Abé
Fig. 67. *Ceratium arietinum* Cleve
Fig. 68. *Ceratium hirundinella* O. F. Müller
Fig. 69. *Ceratium compressum* Gran