Malaysian Journal of Science **24**: 43 - 55 (2005)

Diversity of phytoplankton at Langkawi Island, Malaysia

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ABSTRACT A study on the biodiversity of phytoplankton was carried out at Langkawi Island for seven days from 4 to 10 April 2004. Thirteen samplings were done at selected sites, including Sungai Kilim, Sungai Banja, Sungai Itau, Tanjung Rhu, Sungai Belanga Pecah, Sungai Air Hangat, Sungai Padang Lalang and Sungai Kisap . A total of 106 species of phytoplankton from 29 genera were recorded. *Chaetoceros constrictum, Chaetoceros laeve, Bacteriastrum varians, Ditylium sol, Ditylium brightwelli, Rhizosolenia alata var gracillima, Thalassiothrix nitzschioides* and *Thalassiothrix frauenfeldii* were major phytoplankton species in this island area.

ABSTRAK Kajian mengenai ekologi dan biodiversiti fitoplankton telah dijalankan di Pulau Langkawi selama tujuh hari bermula daripada 4 hingga 10 April, 2004. Sebanyak 13 stesen penyampelan telah dibuat yang merangkumi Sungai Kilim, Sungai Banja, Sungai Itau, Tanjung Rhu, Sungai Belanga Pecah, Sungai Air Hangat, Sungai Padang Lalang dan Sungai Kisap. Keputusan telah menunjukkan sejumlah 106 spesies fitoplankton daripada 29 genus telah direkodkan. *Chaetoceros constrictum, Chaetoceros laeve, Bacteriastrum varians, Ditylium sol, Ditylium brightwelli, Rhizosolenia alata var gracillima, Thalassiothrix nitzschioides* dan *Thalassiothrix frauenfeldii* adalah spesies fitoplankton yang utama di kawasan pulau ini.

(phytoplankton, biodiversity, Langkawi)

INTRODUCTION

Langkawi Island is a recreational island in Malaysia. Langkawi Island has much potential for tourism, conservation and vacation based development. However, the development activities may disturb the phytoplankton communities in this area. Since the area has not been much exploited in terms of land development, the aim of this project is to obtain data for documenting the biodiversity and ecology of phytoplankton of this scientifically little known area. Phytoplankton comprises the photosynthetic microscopic organisms ranging in size and volume [1], and which can be considered as an important primer producer in the aquatic ecosystem food chain [2].

Photosynthetic phytoplankton is the "grass" of aquatic habitats. They are eaten by protoplankton, zooplankton (small invertebrate animals that swim), aquatic insects, fish, and other animals. Together with aquatic higher plants, they are the basis of freshwater food chains._Phytoplankton, together with other algae and plants, are the source of most of the oxygen in Earth's atmosphere.

The biodiversity of phytoplankton is very high. For example, experts think that there may be more than 10 million types (species) of diatoms, just one group of phytoplankton. But people still do not completely understand why there are so many species of these microscopic organisms in natural waters.

Ecologists suspect that high diversity confers ecological flexibility, the ability to handle climate and other environmental changes without dramatic impact on entire food chains and webs. If one food source declines, there are many potential substitutes. High diversity is Nature's fail-safe plan for emergencies. It is in our own best interests to preserve good water quality and fisheries. For this reason, humans need to understand, appreciate, and protect microbial diversity in natural waters.

These small plants are the beginning of the food chain for most of the planet. As phytoplankton grow and multiply, small fish and other animals eat them as food. Larger animals then eat these smaller ones. The ocean fishing industry often finds good fishing spots by looking at ocean color images to locate areas rich in phytoplankton.

Phytoplankton, as revealed by ocean color, frequently shows scientists where ocean currents provide nutrients for plant growth. In addition, the plants show where pollutants poison the ocean and prevent plant growth, and where subtle changes in the climate-warmer or colder more saline or less saline-affect phytoplankton growth. Since phytoplankton depends upon specific conditions for growth, they frequently become the first indicator of a change in their environment.

Ecologically, phytoplankton is the major source of primary production in the ocean, and one of the most important driving forces of global ecology. In fact, phytoplankton production influences all life by being at the lowest rings of the food chain, and even plays a role in global climate. In terms of their growth and ecology, they are in many cases most similar to bacteria. In fact, only bacteria share such similarities in size, growth rate ecological tolerance, and rapid response to nutrient enrichment [3].

MATERIALS AND METHODS

Water samples were collected from 13 sampling station using 500 ml polythene bottles and preserved in 4% formalin. Net samples were obtained using plankton net with mesh size of about 30μm. The samples collected by the plankton net were examined for the identification of live 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 enumeration was conducted using the light microscope and scanning electron microscope (SEM).

RESULTS

A total of 106 species of marine phytoplankton from 29 genera were recorded. 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 the taxonomic treatments by, for example, [4, 5 and 6].

Refer to Figures at the Appendices.

1. *Amphora lineata* Greg.; Shamsudin 1991. *p. 167, f. 8.154* L. 57μm, B. 13μm.
2. *Amphora lineolata* Grun.; Shamsudin 1991. *p. 163, f. 8.150* L. 40μm, B. 20μm, Str.10-12 in 10μm.
3. *Amphora quadrata* Breb.; Shamsudin 1991. *p. 163, f. 8.152* L. 67μm, B. 42μm, Str. 10-12 in 10μm.
4. *Amphora sp* Ehr., Salleh 1996. *p. 72, f. 3.18 (d)* L. 50-140μm, B. 32μm, Str. 10-12 in 10μm.
5. *Asterionella japonica* Cleve.; Shamsudin 1991. *p. 154, f. 8.123* L. 75-130μm.
6. *Asterolampra marylandica* Ehr.; Shamsudin 1991. *p. 106, f. 8.27* r. 70μm, 13 areola in 10μm.
7. *Asteromphalus hepaticus* Ralf.; Shamsudin 1991. *p. 106, f. 8.31* r. 40-145μm.
8. *Bacillaria paradoxa* Gmel.; Shamsudin 1991. *p. 167, f. 8.155* L. 156-250μm, B. 6μm, Str. radial, 20-21 in 10μm.
9. *Bacteriastrum comosum* Pavillard.; Shamsudin 1991. *p. 121, f. 8.62* r. 7-10μm.
10. *Bacteriastrum delicatulum* Cleve.; Shamsudin 1991. *p. 119, f. 8.58* r. 6-16μm.
11. *Bacteriastrum hyalinum* Lauder.; Shamsudin 1991. *p. 120, f. 8.59* r. 24-36μm.
12. *Bacteriastrum varians* Lauder.; Shamsudin 1991. *p. 120, f. 8.60* r. 30-36μm.
13. *Biddulphia heteroceros* Grunow.; Shamsudin 1991. *p. 143, f. 8.99* L. 30-54μm, 15-16 areola in 10μm.
14. *Biddulphia longicruris* Greville.; Shamsudin 1991. *p. 145, f. 8.105* B. 90-250μm.
15. *Biddulphia mobilensis* (Bail.) Grunow.; Shamsudin 1991. *p. 140, f. 8.97* L. 36-50μm, 14-16 areola in 10μm.
16. *Biddulphia regia* Ostenfeld.; Shamsudin 1991. *p. 145, f. 8.104* B. 90-310μm.
17. *Biddulphia reticulum* (Ehr.).; Shamsudin 1991. *p. 143, f. 8.100* L. 22-42μm, 13-15 areola in 10μm.
18. *Biddulphia sinensis* Greville.; Shamsudin 1991. *p. 143, f. 8.98* L. 54-245μm, 14-16 areola in 10μm.

19. *Campylodiscus daemelianus* Grun.; Shamsudin 1991. *p. 170, f. 8.173* L. 80-100µm.
20. *Cerataulina bergonii* H. Perag.; Shamsudin 1991. *p. 145, f. 8.106* r. 30-54µm, 22 puncta in 10µm.
21. *Ceratium compressum* Gran.; Dodge 1985. *p. 95,* L. 250µm, B. 150µm.
22. *Ceratium hirundinella* O.F. Müller.; Dodge 1985. *p. 99,* L. 200µm, B. 60µm.
23. *Ceratium platycorne* Daday.; Dodge 1985. *p. 101,* L. 100µm, B. 160µm.
24. *Chaetoceros affine* Lauder.; Shamsudin 1991. *p. 131, f. 8.76,* B. 22µm.
25. *Chaetoceros breve* Schutt.; Shamsudin 1991. *p. 132, f. 8.80,* B. 24µm.
26. *Chaetoceros coarctatum* Lauder.; Shamsudin 1991. *p. 124, f. 8.64,* B. 26-45µm.
27. *Chaetoceros compressum* Lauder.; Shamsudin 1991. *p. 128, f. 8.70,* B. 12-34µm.
28. *Chaetoceros constrictum* Gran.; Shamsudin 1991. *p. 131, f. 8.74,* B. 24-26µm.
29. *Chaetoceros costatus* Pavillard.; Shamsudin 1991. *p. 134, f. 8.84,* B. 23-27µm.
30. *Chaetoceros decipiens* Cleve.; Shamsudin 1991. *p. 137, f. 8.85,* B. 18-22µm.
31. *Chaetoceros denticulatum* Lauder.; Shamsudin 1991. *p. 126, f. 8.65,* B. 24-30µm.
32. *Chaetoceros didymium* Ehrenberg.; Shamsudin 1991. *p. 130, f. 8.71,* B. 20-32µm.
33. *Chaetoceros didymum* var. *anglica* Gran .; Shamsudin 1991. *p. 130, f. 8.73,* B. 20-30µm.
34. *Chaetoceros distans* Cleve.; Shamsudin 1991. *p. 132, f. 8.78,* B. 16-24µm.
35. *Chaetoceros diversum* Cleve.; Shamsudin 1991. *p. 134, f. 8.81,* B. 7-12µm.
36. *Chaetoceros hispidum* Brightwell.; Shamsudin 1991. *p. 137, f. 8.86,* B. 30-40µm.
37. *Chaetoceros laciniosum* Schutt.; Shamsudin 1991. *p. 132, f. 8.79,* B. 12µm.
38. *Chaetoceros laeve* Leudiger- Fortmorel.; Shamsudin 1991. *p. 134, f. 8.82,*B. 8-12µm.
39. *Chaetoceros lauderii* Ralfs.; Shamsudin 1991. *p. 128, f. 8.69,* B. 19-30µm.
40. *Chaetoceros lorenzianum* Grunow.; Shamsudin 1991. *p. 127, f. 8.68,* B. 18-60µm.
41. *Chaetoceros paradoxum* Cleve.; Shamsudin 1991. *p. 132, f. 8.77,* B. 13-28µm.
42. *Chaetoceros peruvianum var robusta* (Cleve) Hustedz.; Shamsudin 1991. *p. 126, f. 8.67,* B. 22-34µm.
43. *Chaetoceros pseudocurvisetum* Mangin.; Shamsudin 1991. *p. 134, f. 8.83,* B. 18-22µm.
44. *Chaetoceros siamense* Ostanfeld.; Shamsudin 1991. *p. 137, f. 8.87,* B. 25-60µm.
45. *Chaetoceros van heurckii* Gran.; Shamsudin 1991. *p. 131, f. 8.75,* B. 24-28µm.
46. *Climacodium biconcavum* Cleve.; Shamsudin 1991. *p. 138, f. 8.91,* L. 60µm, B. 35-65µm.
47. *Climacodium frauenfeldianum* Grunow.; Shamsudin 1991. *p. 138, f. 8.90,* L. 169-170µm, B. 169-170µm.
48. *Coscinodiscus asteromphalus* Ehr.; Shamsudin 1991. *p. 99, f. 8.15,* r. 245-360µm, 5-6 areola in 10µm.
49. *Coscinodiscus curvatulus* Grunow.; Shamsudin 1991. *p.101 , f. 8.20 ,* r. 40-100µm, 11-12 areola in 10µm.
50. *Coscinodiscus excentricus* Ehr.; Shamsudin 1991. *p. 96, f. 8.7,* r. 20-66µm, 5-6 areola in 10µm.
51. *Coscinodiscus perforatus* Ehr.; Shamsudin 1991. *p. 101, f. 8.21,* r. 20-100µm, 5-6 areola in 10µm.
52. *Ditylium brightwelli* Grunow.; Shamsudin 1991. *p. 140, f. 8.96,* L. 80µm, r. 25 µm.
53. *Ditylium sol* Grunow.; Shamsudin 1991. *p. 140, f. 8.95,* 19-20 puncta in 10µm, r. 36-158 µm.
54. *Euçampia cornuta* (Cleve) Grunow.; Shamsudin 1991. *p. 138, f. 8.89,* 13-16 puncta in 10µm, B. 54-61 µm.
55. *Eucampia zoodiacus* Ehr.; Shamsudin 1991. *p. 137, f. 8.88,* 16-20 puncta in 10µm, B. 36-46 µm.
56. *Guinardia blovyaria* Peragallo.; Shamsudin 1991. *p. 111, f. 8.40*, r. 40-80 µm.
57. *Guinardia flaccida* (Castr.) Peragallo.; Shamsudin 1991. *p. 111, f. 8.39*, r. 42-110 µm, 21-23 puncta in 10µm.
58. *Hemianulus indicus* Karsten.; Shamsudin 1991. *p. 147, f. 8.109*, r. 34-40µm.
59. *Hemianulus membranaceus* Cleve.; Shamsudin 1991. *p. 147, f. 8.110*, B. 67-97 µm, 17-23 puncta in 10µm.
60. *Hemianulus sinensis* Greville.; Shamsudin 1991. *p. 147, f. 8.108*, L. 18-75 µm, 21-23 puncta in 10µm, 7-9 areola in 10µm.
61. *Hemidiscus hardmanianus* Mann.; Shamsudin 1991. *p. 150, f. 8.112*, B. 250-

270 μm, L. 500-540μm, 13-14 areola in 10μm.

62. *Launderia annulata* Cleve.; Shamsudin 1991. *p. 108, f. 8.34*, r. 18-52 μm, L. 34-80μm.
63. *Launderia borealis* Gran.; Shamsudin 1991. *p. 108, f. 8.35*, r. 30-50 μm.
64. *Leptocylindricus danicus* Cleve.; Shamsudin 1991. *p. 111, f. 8.38*, r. 8μm.
65. *Navicula cancellata* Dank.; Shamsudin 1991. *p. 158, f. 8.131*, Str. 14 in 10μm, L. 52μm.
66. *Navicula elegans* W. Smith.; Shamsudin 1991. *p. 158, f. 8.132*, Str. 16 in 10μm, L. 60-115μm.
67. *Navicula lyra* Ehr.; Shamsudin 1991. *p. 158, f. 8.133*, Str. 15-18 in 10μm, L. 60-150μm.
68. *Nitzschia closterium* W. Smith.; Shamsudin 1991. *p. 167, f. 8.160*, B. 5-12 μm, L. 57-208μm, 15 puncta in 10μm.
69. *Nitzschia lanceolata* W. Smith.; Shamsudin 1991. *p. 169, f. 8.163*, B. 6-8μm, L. 100-200μm, Str. 11-14 in 10μm.
70. *Nitzschia longissima* (Breb). Ralfs.; Shamsudin 1991. *p. 167, f. 8.159*, B. 6μm, L. 253μm, Str. 5-7 in 10μm.
71. *Nitzschia pasifica* Cupp.; Shamsudin 1991. *p. 169, f. 8.164*, B. 5-7μm, L. 80-140μm, Str. 9-12 in 10μm.
72. *Nitzschia pungens* var atlantica Cleve.; Shamsudin 1991. *p. 169, f. 8.165*, L. 137μm, Str. 9-12 in 10μm.
73. *Nitzschia seriata* Cleve.; Shamsudin 1991. *p. 169, f. 8.162*, B. 6-8μm, L. 97-174μm, Str. 10-13 in 10μm.
74. *Nitzschia sigma* var indica Karsten.; Shamsudin 1991. *p. 167, f. 8.158*, B. 12μm, L. 520μm, Str. 7-10 in 10μm.
75. *Planktoniella sol* (Wallich) Schutt.; Shamsudin 1991. *p. 103, f. 8.25*, r. 40-50μm, 5-6 areola in 10μm.
76. *Pleurosigma aestuarii* W. Smith.; Shamsudin 1991. *p. 160, f. 8.140*, B. 8-14μm, L. 24-46μm, Str. 17-20 in 10μm.
77. *Pleurosigma angulatum* W. Smith.; Shamsudin 1991. *p. 160, f. 8.138*, B. 18-20μm, L. 110-115μm, Str. 18-21 in 10μm.
78. *Pleurosigma elongatum* W. Smith.; Shamsudin 1991. *p. 160, f. 8.136*, B. 36μm, L. 445μm, Str. 17-20 in 10μm.
79. *Pleurosigma naviculaceum* Breb.; Shamsudin 1991. *p. 158, f. 8.134*, B. 16μm, L. 79μm, Str. 17-18 in 10μm.
80. *Pleurosigma nicobaricum* Grun.; Shamsudin 1991. *p. 163, f. 8.144*, B. 8-14μm, L. 130μm, Str. 17-20 in 10μm.
81. *Pleurosigma normanii* Ralfs.; Shamsudin 1991. *p. 160, f. 8.137*, B. 12-14μm, L. 92-127μm, Str. 18-21 in 10μm.
82. *Pleurosigma rigidum* var *incurvata* Brun.; Shamsudin 1991. *p. 163, f. 8.145*, B. 12μm, L. 200μm, Str. 18-20 in 10μm.
83. *Pleurosigma salinarum* Grun. Patrick, R.& Reimer,C.W 1966. *p.353 , f. 2ac*, B. 13-17μm, L. 70-130μm, Str. 22-25 in 10μm.
84. *Pleurosigma spencerii* W. Smith.; Shamsudin 1991. *p. 160, f. 8.141*, B. 10μm, L. 120μm, Str. 18-22 in 10μm.
85. *Raphoneis amphiceros* Ehr.; Shamsudin 1991. *p. 152, f. 8.116*, B. 12μm, L. 24μm, 12 puncta in 10μm.
86. *Raphoneis surirella* Grun.; Shamsudin 1991. *p. 152, f. 8.117*, B. 7-8μm, L. 20-22μm, Str. 13 in 10μm.
87. *Rhizosolenia acuminata* Gran.; Shamsudin 1991. *p. 116, f. 8.55*, r. 35-225μm, L. 1000μm.
88. *Rhizosolenia alata var gracillima* (Cleve) Grunow.; Shamsudin 1991. *p. 116, f. 8.53*, r. 5-7μm.
89. *Rhizosolenia alata var indica* (Paragallo) Ostenfeld.; Shamsudin 1991. *p. 116, f. 8.54*, r. 24-75μm.
90. *Rhizosolenia araturensis* Castracane.; Shamsudin 1991. *p. 113, f. 8.45*, r. 65-95μm.
91. *Rhizosolenia calcor-avis* M. Schultze.; Shamsudin 1991. *p. 115, f. 8.50*, r. 20-45μm, 18-20 puncta in 10μm.
92. *Rhizosolenia clevei* Ostenfeld.; Shamsudin 1991. *p. 113, f. 8.46*, r. 36-85μm, L. 270-400μm.
93. *Rhizosolenia cylindrus* Cleve.; Shamsudin 1991. *p. 111, f. 8.42*, r. 24μm, L. 98μm.
94. *Rhizosolenia delicatula* Cleve.; Shamsudin 1991. *p. 116, f. 8.57*, r. 10-20μm, L. 30-100μm.
95. *Rhizosolenia hebetate* (Bail) Gran.; Shamsudin 1991. *p. 115, f. 8.51*, r. 12-16μm.
96. *Rhizosolenia imbriceta* Brightwell.; Shamsudin 1991. *p. 115, f. 8.47*, r. 30-70μm, 18-20 puncta in 10μm.
97. *Rhizosolenia robusta* Norman.; Shamsudin 1991. *p. 113, f. 8.43*, r. 75-97μm.*Rhizosolenia setigera* Brightwell.; Shamsudin 1991. *p. 115, f. 8.48*, r. 10-42μm.
98. *Rhizosolenia stolterforthi* H. Peragallo.; Shamsudin 1991. *p. 111, f. 8.41*, r. 18-44μm, L. 250μm.
99. *Rhizosolenia styliformis* Brightwell.; Shamsudin 1991. *p. 115, f. 8.49*, r. 60-80μm, 28-30 puncta in 10μm.

100. *Strephanophyxis palmeriana* (Grev).; Shamsudin 1991. *p. 93, f. 8.2*, r. 93-105μm, 7-9 areola in 10μm.
101. *Surirella gemma* Ehr.; Shamsudin 1991. *p. 169, f. 8.169*, L 102μm, Str. 18-21 in 10μm.
102. *Thalassiothrix delicatula* Cupp.; Shamsudin 1991. *p. 154, f. 8.121*, B. 7-10μm, L. 150-170μm, Str. 9-12 in 10μm.
103. *Thalassiothrix elongata* Grunow.; Shamsudin 1991. *p. 152, f. 8.118*, B. 3-4μm, L. 1050-1260μm, Str. 9-14 in 10μm.
104. *Thalassiothrix frauenfeldii* Grunow.; Shamsudin 1991. *p. 152, f. 8.120*, B. 8-12μm, L. 160-260μm, Str. 10-12 in 10μm.
105. *Thalassiothrix nitzschioides* Grun.; Shamsudin 1991. *p. 152, f. 8.119*, B. 6-7μm, L. 18-20μm, Str. 12-14 in 10μm.

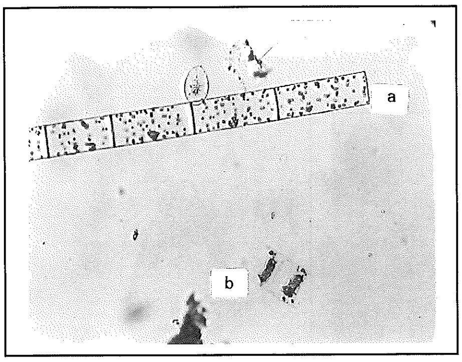

Figure 1 (a) *Launderia borealis*
(b) *Climacodium biconcavum*
(scale 1 bar = 20μm)

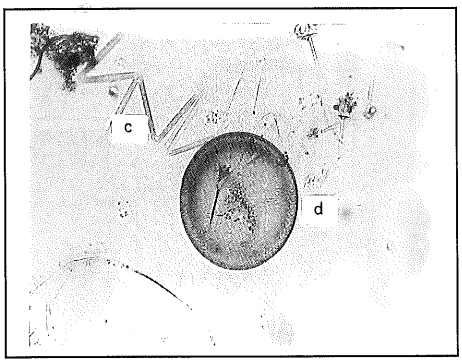

Figure 2 (c) *Thalassiothrix nitzschioides*
(d) *Coscinodiscus asteromphalus*
(scale 1 bar = 20μm)

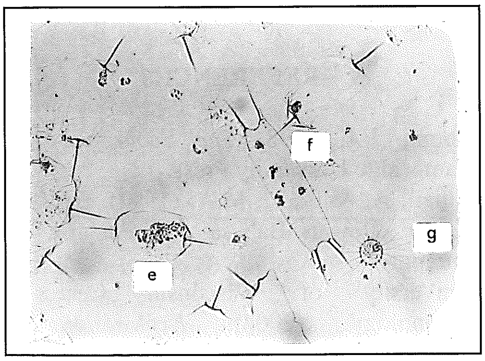

Figure 3 (e) *Ditylium brightwelli*
(f) *Biddulphia longicruris*
(g) *Bacteriastrum delicatulum*
(scale 1 bar = 20μm)

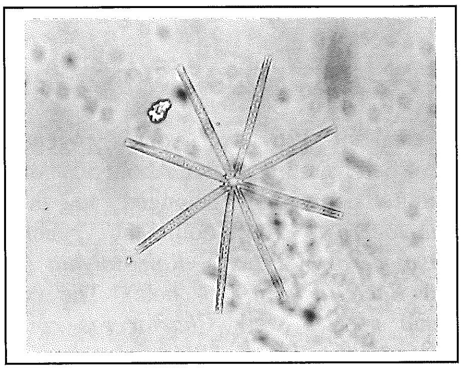

Figure 4 *Thalassiothrix frauenfeldii*
(scale 1 bar = 20μm)

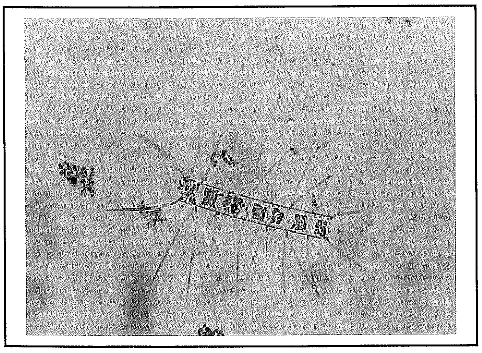

Figure 5 *Chaetoceros constrictum*
(scale 1 bar = 20μm).

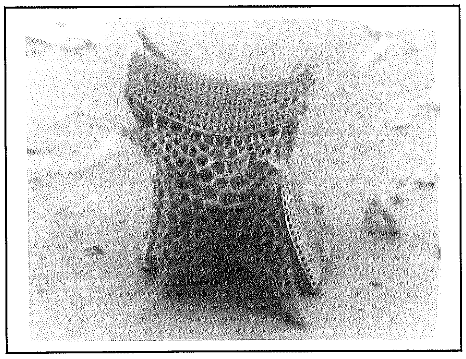

Figure 6 *Biddulphia mobilensis*
(valve view)

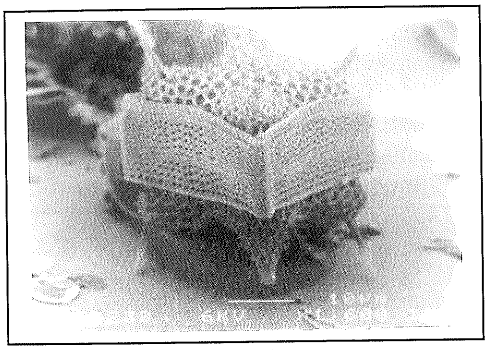

Figure 7 *Biddulphia mobilensis* (girdle view)

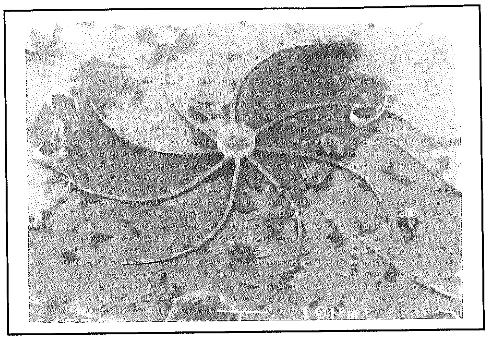

Figure 8 *Bacteriastrum comosum*

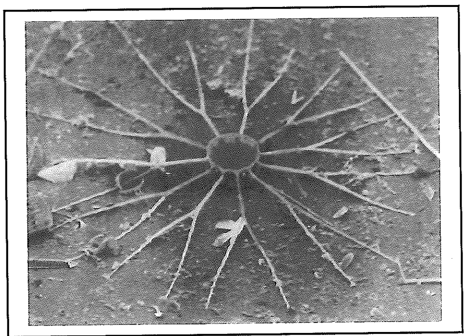

Figure 9 *Bacteriastrum delicatulum*

CONCLUSION

A total of 106 taxa from 29 genera were identified from Langkawi. About 50% of the total diatom population belonged to the genus *Chaetoceros*. The dominant genera were *Chaetoceros* (22 taxa), *Rhizosolenia* (14 taxa) and *Bacteriastrum* (4 taxa). The commonly found species were *Chaetoceros constrictum*, *Chaetoceros laeve*. *Rhizosolenia alata var gracillima* and *Bacteriastrum varians*.

Acknowledgements The authors would like to thank all the staff from the Institute of Biological Sciences, Faculty of Science, University of Malaya, Kuala Lumpur. We would like to convey our gratitude to the Malaysian government for the financial assistance (R&D 01-02-03-1003).

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EXPLANATION OF PLATES

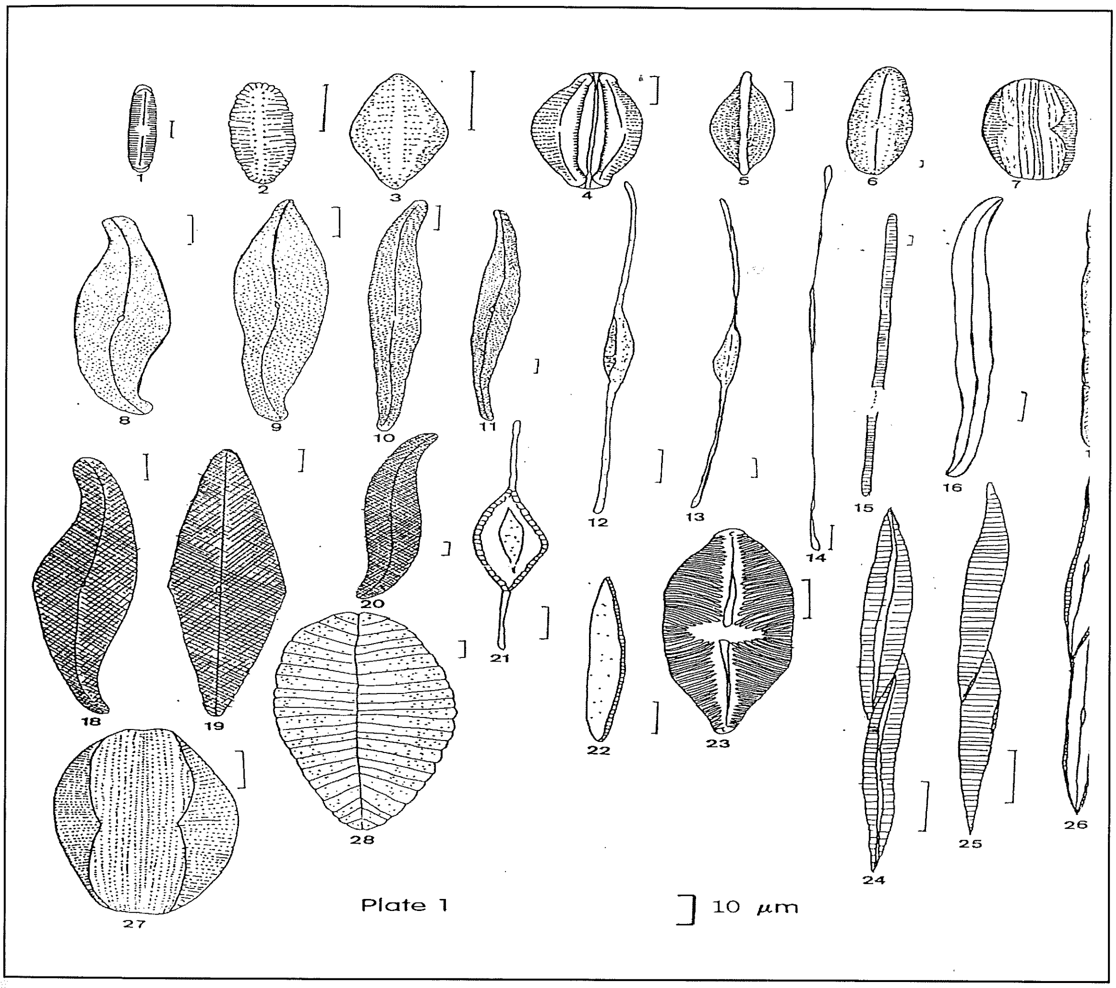

Plate 1. Scale bars = 10 μm.

Fig.1. *Navicula cancellata* Dank
Fig.2. *Raphoneis surirella* Grun
Fig.3. *Raphoneis amphiceros* Ehr
Fig.4. *Amphora sp* Ehr.
Fig.5. *Amphora lineata* Greg.
Fig.6. *Navicula lyra* Ehr
Fig.7. *Amphora quadrata* Breb.
Fig.8. *Pleurosigma naviculaceum* Breb
Fig.9. *Pleurosigma normanii* Ralfs
Fig.10. *Pleurosigma salinarum* Grun
Fig.11. *Pleurosigma angulatum* W. Smith
Fig.12. *Nitzschia longissima* (Breb). Ralfs
Fig.13. *Nitzschia sigma* var indica Karsten
Fig.14. *Thalassiothrix delicatula* Cupp
Fig.15. *Thalassiothrix elongata* Grunow
Fig.16. *Pleurosigma spencerii* W. Smith
Fig.17. *Leptocylindricus danicus* Cleve
Fig.18. *Pleurosigma elongatum* W. Smith
Fig.19. *Pleurosigma nicobaricum* Grun
Fig.20. *Pleurosigma rigidum* var *incurvata* Brun
Fig.21. *Nitzschia closterium* W. Smith
Fig. 22. *Nitzschia lanceolata* W. Smith
Fig. 23. *Navicula elegans* W. Smith
Fig. 24. *Nitzschia pungens* var atlantica Cleve
Fig. 25. *Nitzschia pasifica* Cupp
Fig. 26. *Nitzschia seriata* Cleve
Fig. 27. *Amphora lineolata* Grun.
Fig. 28. *Surirella gemma* Ehr.

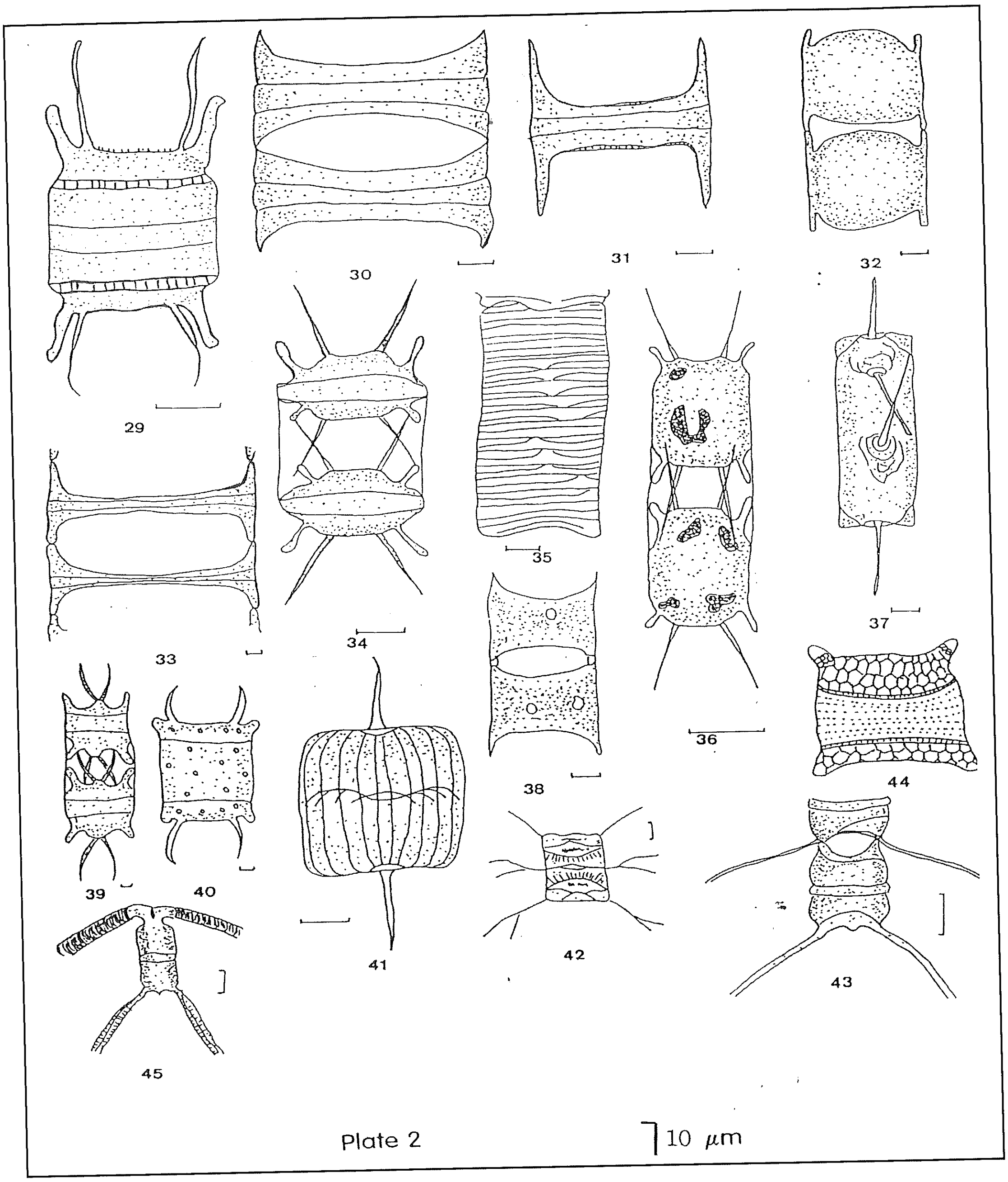

Plate 2. Scale bars = 10 μm.

Fig. 29. *Biddulphia heteroceros* Grunow
Fig.30. *Hemianulus membranaceus* Cleve
Fig. 31. *Hemianulus sinensis* Greville
Fig. 32. *Hemianulus indicus* Karsten
Fig.33. *Climacodium frauenfeldianum* Grunow
Fig.34. *Biddulphia mobilensis* (Bail.) Grunow
Fig.35. *Guinardia flaccida* (Castr.) Peragallo
Fig. 36. *Biddulphia sinensis* Greville
Fig. 37. *Ditylium brightwelli* Grunow
Fig.38. *Climacodium biconcavum* Cleve.
Fig.39. *Biddulphia longicruris* Greville
Fig.40. *Biddulphia regia* Ostenfeld.
Fig.41. *Ditylium sol* Grunow
Fig.42. *Chaetoceros costatus* Pavillard
Fig.43. *Chaetoceros paradoxum* Cleve
Fig.44. *Biddulphia reticulum* (Ehr.).
Fig.45. *Chaetoceros peruvianum var robusta* (Cleve) Hustedz

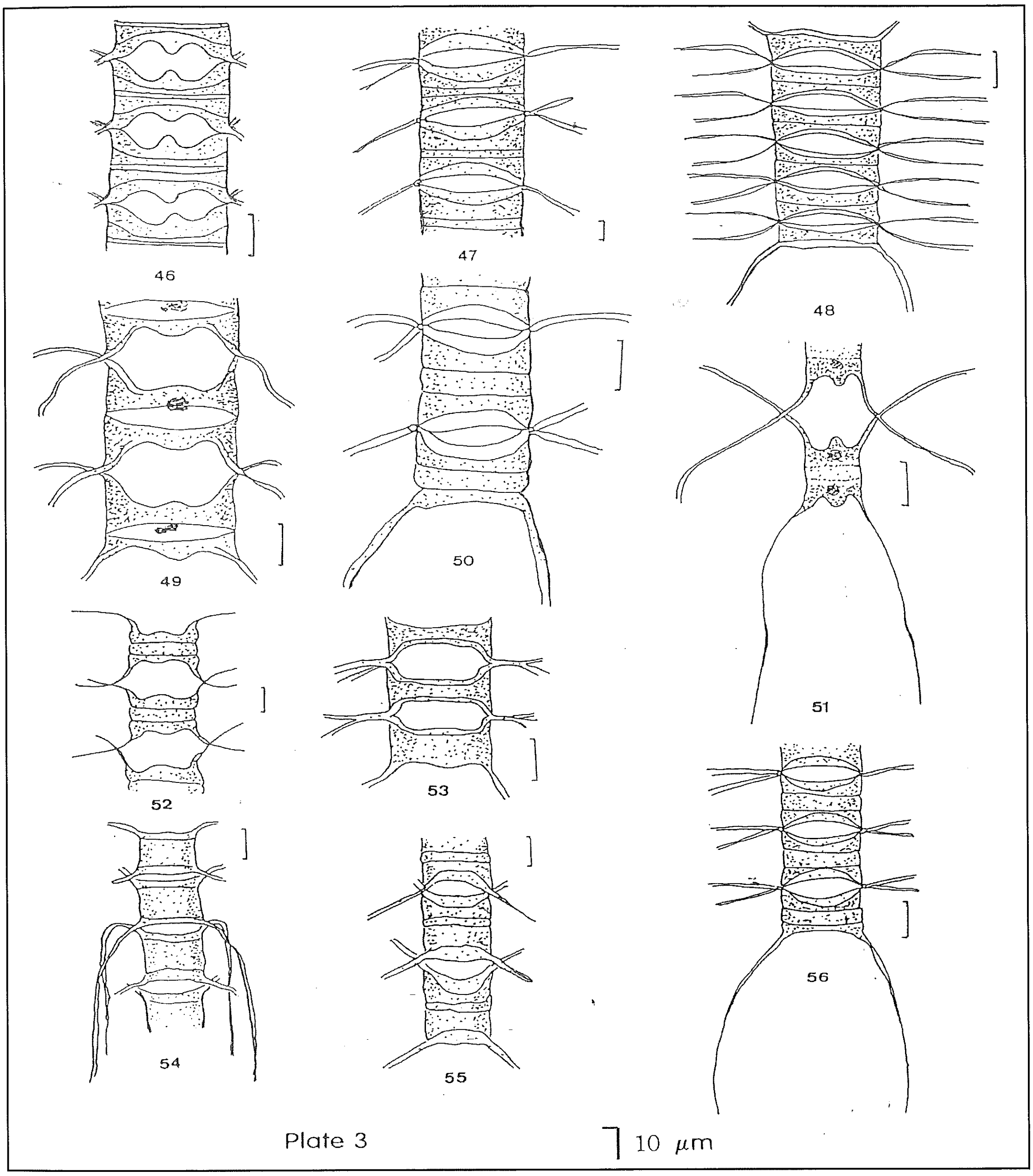

Plate 3. Scale bars = 10 μm.

Fig.46. *Chaetoceros didymum* Ehrenberg.
Fig.47. *Chaetoceros van heurckii* Gran
Fig.48. *Chaetoceros siamense* Ostanfeld
Fig.49. *Chaetoceros lorenzianum* Grunow
Fig.50. *Chaetoceros affine* Lauder.
Fig.51. *Chaetoceros didymum* var *anglica* Gran
Fig.52. *Chaetoceros breve* Schutt.
Fig.53. *Chaetoceros decipiens* Cleve
Fig.54. *Chaetoceros compressum* Lauder.
Fig.55. *Chaetoceros constrictum* Gran
Fig.56. *Chaetoceros pseudocurvisetum* Mangin

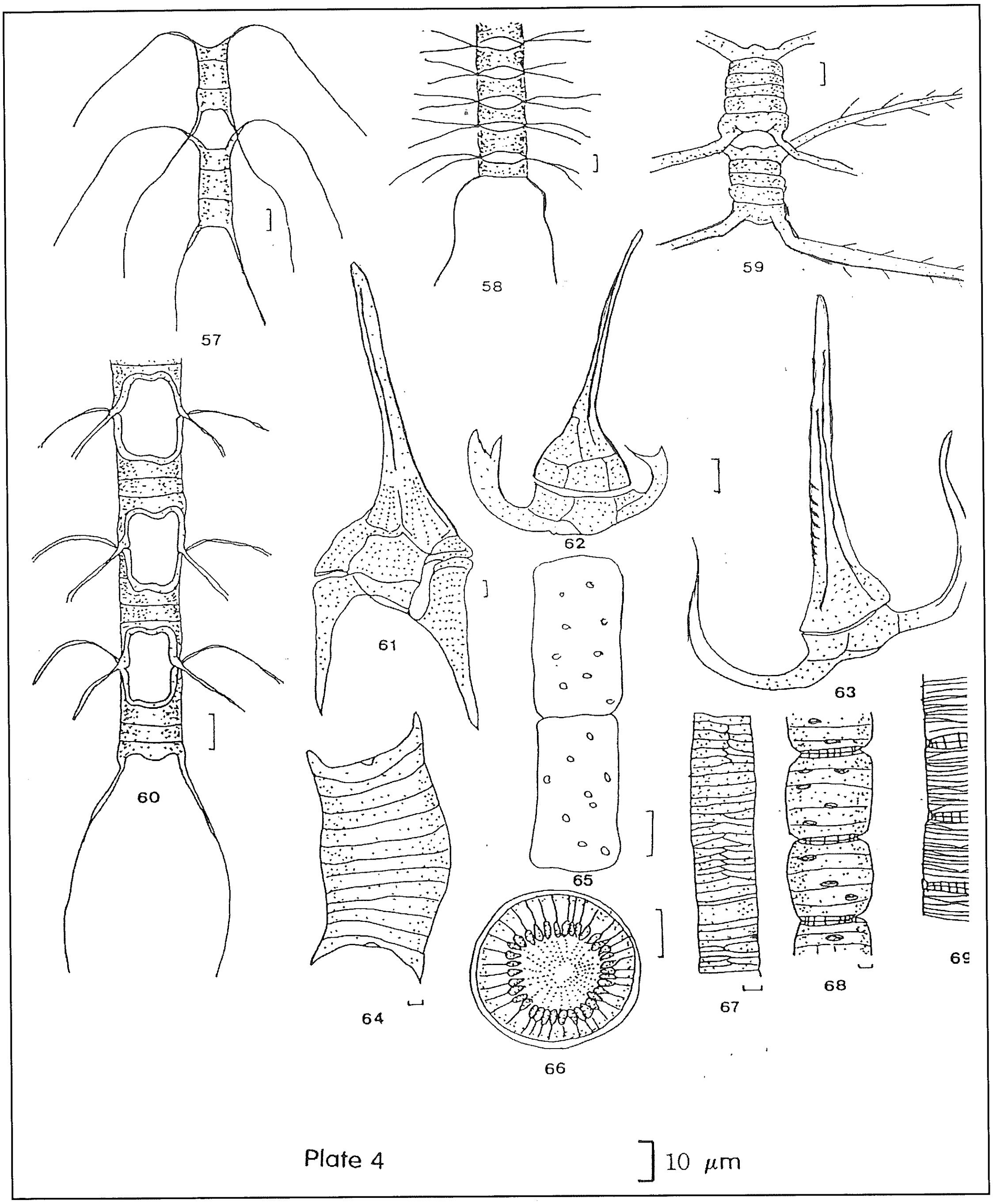

Plate 4. Scale bars = 10 μm.

Fig.57. *Chaetoceros laciniosum* Schutt
Fig.58. *Chaetoceros hispidum* Brightwell
Fig.59. *Chaetoceros denticulatum* Lauder
Fig.60. *Chaetoceros distans* Cleve
Fig.61. *Ceratium hirundinella* O. F. Müller
Fig.62. *Ceratium platycorne* Daday
Fig.63. *Ceratium compressum* Gran
Fig.64. *Eucampia cornuta* (Cleve) Grunow
Fig.65. *Rhizosolenia delicatula* Cleve
Fig.66. *Campylodiscus daemelianus* Grun
Fig.67. *Guinardia blovyaria* Peragallo
Fig.68. *Launderia borealis* Gran
Fig.69. *Launderia annulata* Cleve

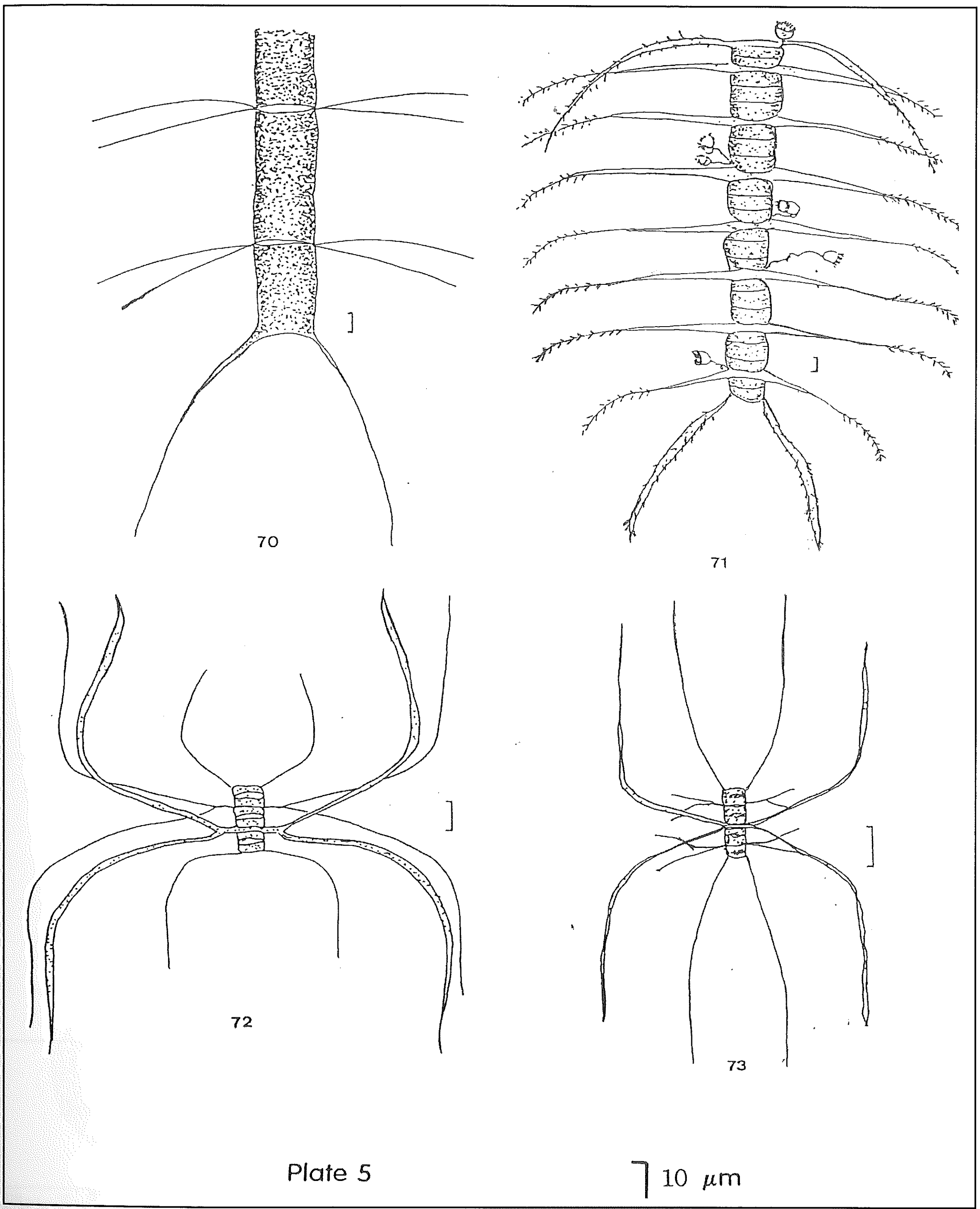

Plate 5. Scale bars = 10 μm.

Fig.70. *Chaetoceros lauderii* Ralfs
Fig.71. *Chaetoceros coarctatum* Lauder.
Fig.72. *Chaetoceros laeve* Leudiger- Fortmorel
Fig.73. *Chaetoceros diversum* Cleve

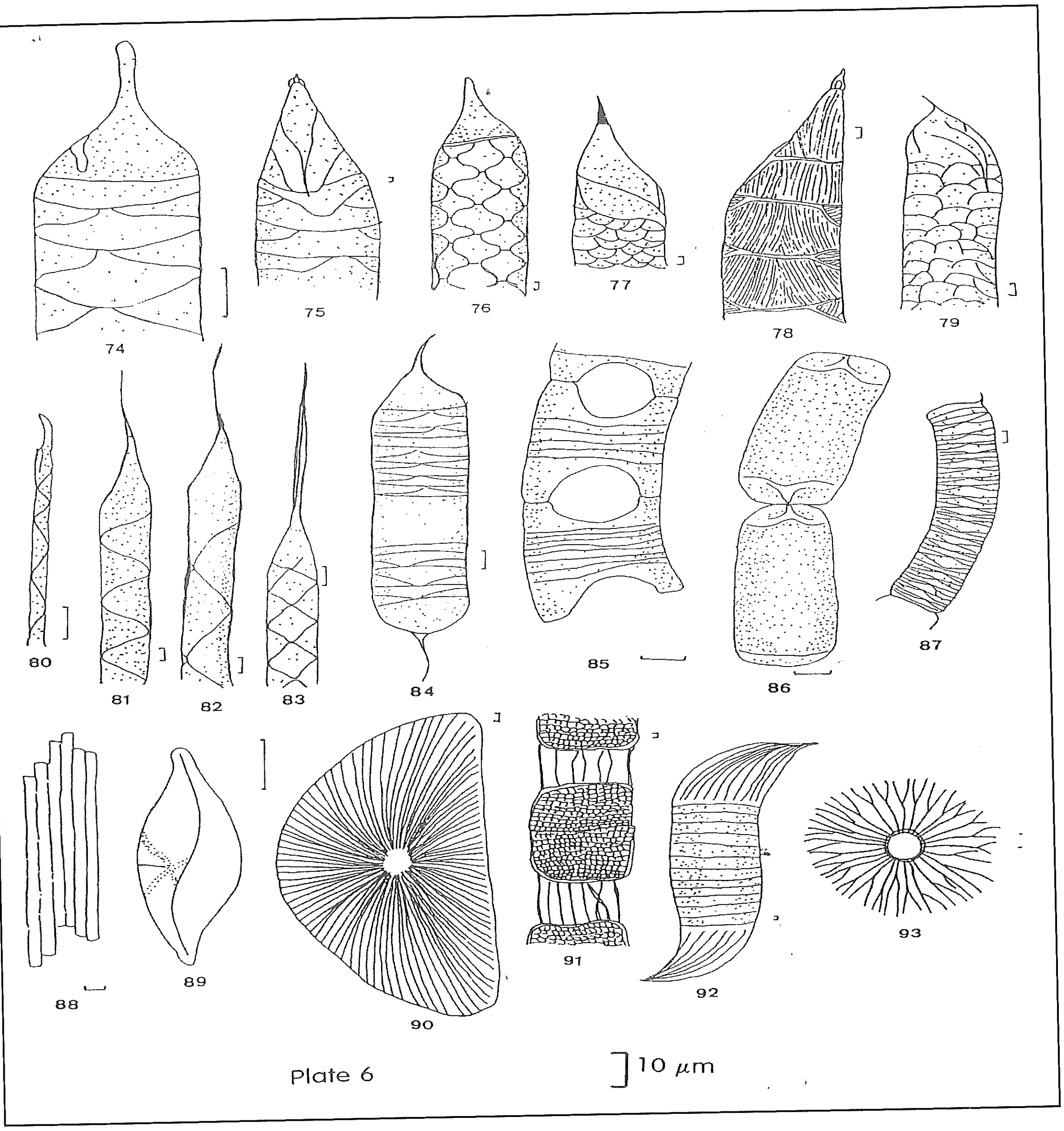

Plate 6. Scale bars = 10 µm.

Fig.74. *Rhizosolenia alata var indica* (Paragallo) Ostenfeld
Fig.75. *Rhizosolenia styliformis* Brightwell
Fig.76. *Rhizosolenia araturensis* Castracane
Fig.77. *Rhizosolenia acuminata* Gran
Fig.78. *Rhizosolenia imbriceta* Brightwell
Fig.79. *Rhizosolenia clevei* Ostenfeld
Fig.80. *Rhizosolenia alata var gracillima* (Cleve) Grunow
Fig.81. *Rhizosolenia calcor-avis* M. Schultze
Fig.82. *Rhizosolenia hebetata* (Bail) Gran
Fig.83. *Rhizosolenia setigera* Brightwell
Fig.84. *Rhizosolenia cylindrus* Cleve
Fig.85. *Eucampia zoodiacus* Ehr
Fig.86. *Cerataulina bergonii* H. Perag
Fig.87. *Rhizosolenia stolterforthi* H. Peragallo
Fig.88. *Bacillaria paradoxa* Gmel.
Fig.89. *Pleurosigma aestuarii* W. Smith
Fig.90. *Hemidiscus hardmanianus* Mann
Fig.91. *Strephanophyxis palmeriana* (Grev).
Fig.92. *Rhizosolenia robusta* Norman
Fig.93. *Bacteriastrum varians* Lauder.

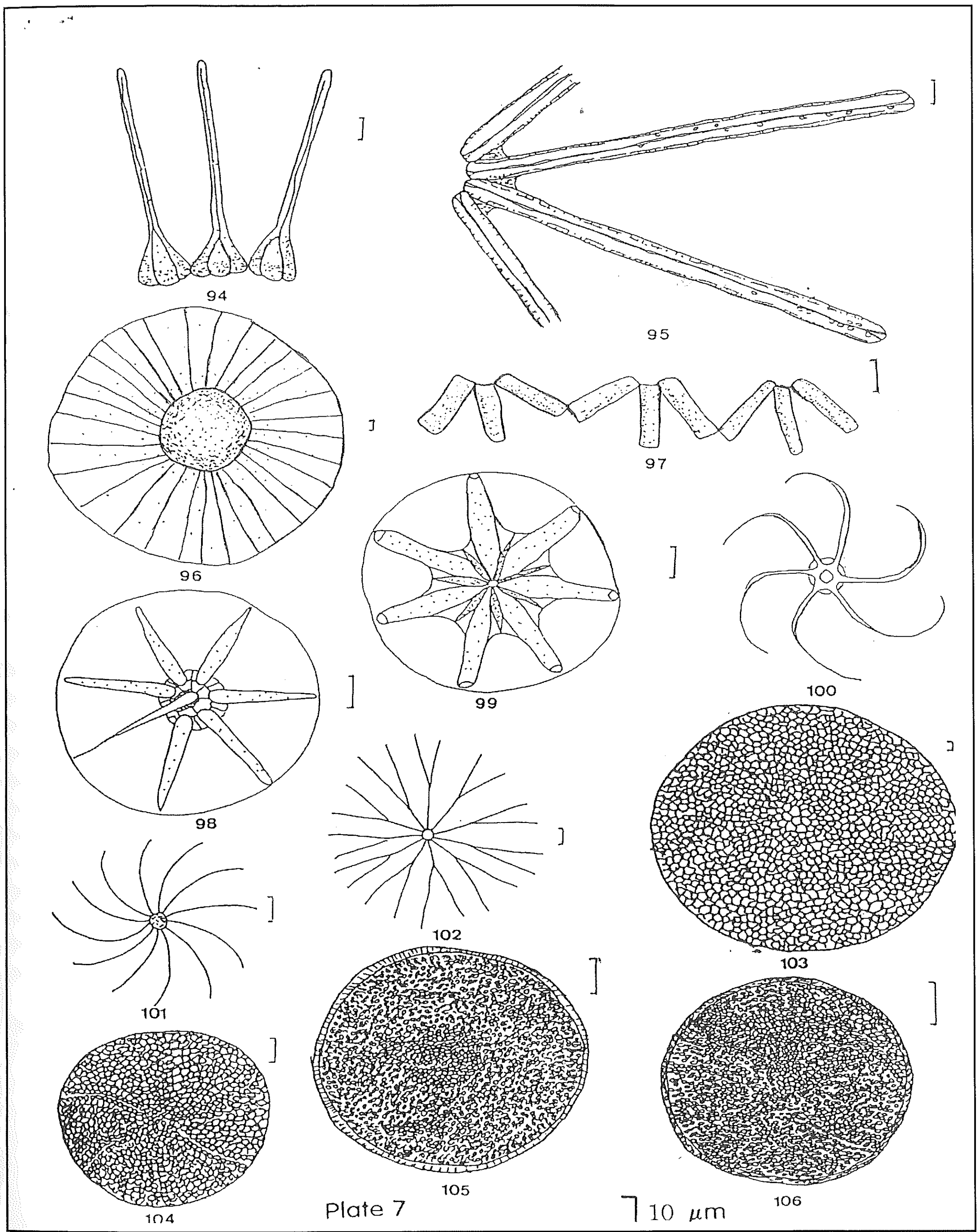

Plate 7. Scale bars = 10 µm.

Fig.94. *Asterionella japonica* Cleve.
Fig.95. *Thalassiothrix frauenfeldii* Grunow
Fig.96. *Planktoniella sol* (Wallich) Schutt
Fig.97. *Thalassiothrix nitzschioides* Grun
Fig.98. *Asteromphalus hepaticus* Ralf
Fig.99. *Asterolampra marylandica* Ehr.
Fig.100. *Bacteriastrum comosum* Pavillard.
Fig.101. *Bacteriastrum hyalinum* Lauder
Fig.102. *Bacteriastrum delicatulum* Cleve.
Fig.103. *Coscinodiscus asteromphalus* Ehr
Fig.104. *Coscinodiscus curvatulus* Grunow
Fig.105. *Coscinodiscus excentricus* Ehr
Fig.106. *Coscinodiscus perforatus* Ehr