Algae from Livingston Island (S Shetland Islands): a checklist

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Abstract. An investigation of the algal flora of Livingston Island was carried out during four consecutive Antarctic summer seasons (2003–2006). Direct microscopic analysis and culture studies revealed a diverse and rich algal flora of 302 taxa (286 species, 15 varieties and one form) from four divisions: *Cyanoprokaryota*, *Bacillariophyta*, *Ochrophyta*, and *Chlorophyta*. *Bacillariophyta* and *Cyanoprokaryota* dominate in terms of species diversity. One hundred and four species, 13 varieties and one form are reported for the first time for Livingston Island. Twenty-eight species are new records for the South Shetland Islands and 13 species are new records for Maritime Antarctica. Eighteen species and six varieties are new reports for Antarctica. A full list of algae found on Livingston Islands with their Antarctic and Sub-Antarctic distribution is presented. LM and SEM micrographs of some of the taxa and short descriptions of the new records for Antarctica are provided.

Key words: algal flora, Antarctica, diatoms, Livingston Island

Introduction

Livingston Island belongs to the South Shetland Archipelago, Maritime Antarctica. Although many studies have been made in different localities throughout the Antarctic continent and the surrounding islands, the algal flora of Livingston Island is still poorly known. Most of the reports refer to diversity, ecology and distribution of diatoms (Björck & al. 1991, 1993; Jones & al. 1993; Temniskova-Topalova & al. 1996; Chipev & Temniskova-Topalova 1999; Temniskova-Topalova & Chipev 2001). Preliminary investigations of the diversity and distribution of green and blue–green algae were carried out by Temniskova-Topalova & Kirjakov (2002) and Temniskova-Topalova & Zidarova (2004), respectively. Zidarova (2007) describes the distribution of algae in different aquatic and terrestrial habitats on Livingston Island. The current paper presents a full list of algae found in the samples between the years 2003 and 2006 with remarks on their Antarctic and Sub-Antarctic distribution and photomicrographs of some of them.

Materials and methods

Livingston Island (850 km^2) is the second largest island of the South Shetland Archipelago, Maritime Antarctica (see Temniskova-Topalova & Chipev 2001). Most of the area of the island is occupied by glaciers and only about 10 % are free of snow and ice during summer. The climate is mild in comparison to Continental Antarctica, with a mean annual temperature of –4 °C (winter minimum of –24 °C and summer maximum of +7.5 °C). Prevailing features of the weather are strong winds and high humidity (Chipev & Veltchev 1996).

Samples (153) were collected on the Hurd Peninsula during four consecutive Antarctic summer seasons (2003–2006). They were taken from different habitats: lakes and their outflows, ponds, puddles, streams, small brooks, rocks irrigated by melting snow, red and green snow, mosses, grass tufts of *Deschampsia antarctica* Desv., and soils. Samples from freshwater habitats and snow were immediately stored in 4 % formaldehyde.

Samples from mosses, soils and tufts of *D. antarctica* were transported "live" to Bulgaria. A small part of each sample was diluted or washed out in sterile distilled water. Part of the received sub-sample was stored in 4% formaldehyde and later used in the analysis of algae that occur in the studied habitats before culturing. The other part was used in the preparation of cultures. They were set in flasks and on agar plates. Initially, three inorganic media were used (Bold's Basal Medium, Allen-Arnon and Shetlik-Simmer) (Thompson & al. 1988). Since the preliminary results did not show large differences between the species growing in the different media, later only Bold's Basal Medium was used. Microscopic slides were prepared following the standard methods. For analysis of diatoms, samples were treated after Hasle & Fryxell (1970) and slides were prepared following Glezer & al. (1974).

Identifications of algae are based mainly on Gollerbach & al. (1953), Ettl (1978), Broady (1979a), Krammer & Lange-Bertalot (1986–1991), Lange-Bertalot & Krammer (1989), Ettl & Gärtner (1995), Komárek & Anagnostidis (1999), Krammer (2000), Lange-Bertalot (2001), and Van de Vijver & al. (2002, 2004).

The Antarctic (Continental and Maritime Antarctica) and Sub-Antarctic distribution of the identified taxa was consulted with many works conducted between the years of 1960 and 2007. Among them the most important are: Broady (1979a, b, 1982), Pankow & al. (1987), Mataloni & al. (2000), Vinocur & Pizarro (2000), Vinocur & Unrein (2000), Cavacini (2001), Mataloni & Pose (2001), Kellogg & Kellogg (2002), Mataloni & Tell (2002), Pizarro & al. (2002), Van de Vijver & al. (2002, 2004), Sabbe & al. (2003), Taton & al. (2003), Cremer & al. (2004), Scott & Thomas (2005), Fermani & al. (2007), etc.

SEM photographs were taken with SEM JEOL JSM 5510 by Dr. N. Dimitrov at the Faculty of Chemistry, University of Sofia.

Results and discussion

The analysis revealed a diverse and rich algal flora of 302 taxa (286 species, 15 varieties and one form) that belong to 106 genera from four divisions: *Cyanoprokaryota*, *Bacillariophyta*, *Ochrophyta,* and *Chlorophyta*. *Bacillariophyta* (156 species and 15 varieties) and *Cyanoprokaryota* (71 species) are the most diverse groups. *Chlorophyta* and *Ochrophyta* follow with 43 species and one form, and 16 species, respectively. Nearly one-fifth of *Cyanoprokaryota* (18.9%), half of *Chlorophyta* (47.7%) and almost all *Xanthophyceae* (86.7%) were discovered only in culture. Eighty-three taxa remained unidentified and need further investigations.

The highest species diversity was observed in the following genera: *Pinnularia* (16 species and 10 varieties), *Phormidium, Luticola, Navicula* and *Nitzschia* (10 species each), *Cocconeis* (nine species and three varieties), *Leptolyngbya, Muelleria* and *Stauroneis* (eight species each), *Xanthonema* and *Stichococcus* (seven species each).

One hundred and four species, 13 varieties and one form are new records for Livingston Island (species with uncertain identification are excluded): *Cyanoprokaryota* – 32 species; *Bacillariophyta* – 41 species and 13 varieties; *Ochrophyta* – eight species; *Chlorophyta* – 23 species and one form. Twenty-eight of them were discovered only in culture.

Twenty-eight species are reported for the first time from the South Shetland Archipelago (*Cyanoprokaryota* – 15 species, *Bacillariophyta* – four, *Ochrophyta* – four and *Chlorophyta* – five), and 13 species are new records for Maritime Antarctica (five of *Cyanoprokaryota*, one of *Bacillariophyta*, one of *Ochrophyta* and six of *Chlorophyta*). Eighteen species and six varieties are new reports for Antarctica (*Cyanoprokaryota* – four species, *Chlorophyta* – seven species, *Bacillariophyta* – seven species and six varieties).

In the list of taxa below the new records are marked as follows: * new to Livingston Island, ◊ new to the South Shetland Islands, • new to Maritime Antarctica, ° new to Antarctica. The species found only in culture are marked with '**c**'. For each taxon (species, variety or form) the habitat is also shown (**St** –stream; **B** – brook, **L** – lake; **P** – pond, **R** – rocks irrigated by melting snow, **S** – soil, **M** – moss, **D** – tufts of *Deschampsia antarctica*; **Sn** – snow) as well as its presence in Continetal Antarctica (**CA**), Maritime Antarctica (**MA**) and Sub-Antarctica (**sA**) according to the available literature. The presence of the taxa is marked with "**x**". Species with uncertain identification are excluded. The sign "**?**" is used when the exact distribution of a taxon in Antarctica is not specified in the literature or its presence is questionable, as in the case of *Stauroneis obtusa* (see Van de Vijver & al. 2004).

taxa	St	B	P	L	R	M	S	D	Sn	CA	MA	sA
Cyanoprokaryota (*Cyanophyta, Cyanobacteria*)												
Cyanophyceae												
Anabaena laxa (Rabenh.) A. Braun	x	x			x						x	
Anabaena sp. juv.		x		x								
Anabaena sp.					x							
[c]*Aphanocapsa* sp.								x				
◊*Aphanothece saxicola* Nägeli					x					x	x	x
◊*Calothrix parietina* (Nägeli) Thur.		x			x	x				x	x	x
◊*Chroococcus minutus* (Kütz.) Nägeli		x	x			x	x			x	x	x
◊*Ch. turgidus* (Kütz.) Nägeli					x	x	x			x	x	
Cyanothece aeruginosa (Nägeli) Komárek		x	x		x	x				x	x	x
◊*Eucapsis alpina* Clem. & Schantz					x					x	x	
Gloeocapsa sp. A			x		x							
Gloeocapsa sp. B					x							
Gloeocapsa sp. C		x			x							
**Gloeocapsopsis aurea* Mataloni & Komárek [Plate I, Fig. 1]					x						x	
◊*Geitlerinema* cf. *deflexa* (W. West & G.S. West)[1] Anagn .	x	x								x	x	
Jaaginema pseudogeminatum (G.W. Schmidt) Anagn. & Komárek	x	x		x	x						x	
◊*J. subtilissimum* (Kütz.) Anagn. & Komárek					x						x	
[c]◊*Leptolyngbya battersii* (Gomont) Anagn. & Komárek							x	x		x	x	
L. foveolarum (Rabenh. ex Gomont) Anagn. & Komárek	x	x	x	x	x	x	x	x		x	x	
**L. fragilis* (Gomont) Anagn. & Komárek	x	x		x	x	x	x	x		x	x	
**L. frigida* (F. E. Fritsch) Anagn. & Komárek	x	x	x	x	x	x	x	x		x	x	
[c]*L. scottii* (F. E. Fritsch) Anagn. & Komárek							x				x	
L. aff. *scotii* (F. E. Fritsch) Anagn. & Komárek	x	x										
•*L. subcapitata* (J.B. Petersen) Anagn.	x									x		
[c]◊*L. tenuis* (Menegh.) Anagn. & Komárek						x	x			x	x	
Lyngbya cf. *antarctica* Gain		x	x	x	x					?	?	
○*Merismopedia angularis* R.H. Thompson					x							
M. punctata Meyen			x								x	
M. tenuissima Lemmerm.			x							x	x	
◊*M. vaginatus* (Vaucher) Gomont [Plate I, Figs 3, 4]	x	x		x	x	x				x	x	
○*Microcystis smithii* Komárek & Anagn.					x							
[c]*Nostoc* cf. *microscopicum* Carmich.						x		x				
N. punctiforme (Kütz.) Har. [Plate I, Fig. 5]		x			x					x	x	x

[1] This species corresponds to the description of *Oscillatoria* cf. *deflexa* W. West & G.S. West found by Broady (1982) in a stream in Taylor Valley, Continental Antarctica.

taxa	St	B	P	L	R	M	S	D	Sn	CA	MA	sA
[c]*Nostoc* sp. juv. cf. *N. punctiforme* (Kütz.) Har.						x						
Nostoc sp. juv.		x			x							
[c]*Nostoc* sp. A							x					
[c]*Nostoc* sp. B						x						
◊*Oscillatoria amoena* (Kütz.) Gomont	x			x						x	x	x
O. cf. *sancta* (Kütz.) Gomont		x	x							x	x	
Phormidium aerugineo-coeruleum (Gomont) Anagn. & Komárek	x		x	x						x	x	
**Ph. ambiguum* Gomont					x	x	x	x		x	x	
Ph. autumnale (C. Agardh) Gomont [Plate I, Fig. 2]	x		x	x	x	x	x			x	x	x
•*Ph. bohneri* Schmidle					x					x		
◊*Ph. chalybeum* (Mertens) Anagn. & Komárek					x						x	
**Ph. chlorinum* (Kütz.) Anagn.					x					x	x	
**Ph. corium* (C. Agardh) Gomont					x	x	x	x		x	x	
[c]•*Ph. crouanii* Gomont						x	x	x		x		
[c]○*Ph. lividum* Nägeli						x	x	x				
**Ph. simplicissimum* (Gomont) Anagn. & Komárek		x		x						x		
Ph. tenuis (C. Agardh) Anagn. & Komárek	x	x	x	x						x	x	
◊*Planktothrix agardhii* (Gomont) Anagn. & Komárek	x			x						x	x	
[c]*P. cryptovaginata* (Schkorb.) Anagn. & Komárek								x			x	
◊*Porphyrosiphon martensianus* (Menegh. ex Gomont) Anagn. & Komárek		x		x						x	x	
**Schizothrix fragilis* (Kütz.) Gomont					x					x	x	
•*S. lenormandiana* Gomont				x						x		
[c]*Schizothrix* sp.						x	x					
•*Synechocystis aquatilis* Sauv.			x		x					x		
Synechocystis sp.			x		x	x						
○*Tolypothrix distorta* (Fl. Dan.) Kütz.			x		x							
[c]◊*T. tenuis* Kütz.								x			x	x
unidentified *Oscillatoriales* gen. sp. A–J												
unidentified *Nostocales* gen. sp.												
Bacillariophyta												
Coscinodiscophyceae												
Actinocyclus actinochilus (Ehrenb.) Simonsen							x		x	x	x	
**Asteromphalus hookeri* Ehrenb.									x	x	x	
A. parvulus G. Karst.									x	x	x	
**Coscinodiscus oculoides* G. Karst.									x	x	x	
**Cyclotella meneghiniana* Kütz. [Plate III, Fig. 2]						x				x	x	x
Eucampia antarctica (Castrac.) Manguin									x	x	x	
Melosira nummuloides (Dillwyn) C. Agardh									x		x	x
Orthoseira dendroteres (Ehrenb.) R.M. Crawford	x	x				x	x				x	

taxa	St	B	P	L	R	M	S	D	Sn	CA	MA	sA
O. roeseana (Rabenh.) O'Meara [Plate III, Fig. 1]	x			x	x	x	x	x			x	x
Thalassiosira gracilis (G. Karst.) Hust.					x		x	x	x	x	x	
Fragilariophyceae												
Diatoma vulgare Bory						x	x	x		x	x	x
D. vulgare *var. *ehrenbergii* (Kütz.) Grunow [Plate III, Fig.4]						x				x	x	x
Fragilaria capucina Desm.	x	x	x	x	x	x	x	x		x	x	x
F. ulna (Nitzsch) Lange-Bert.						x				x	x	x
Fragilaria sp.	x						x					
Hannaea arcus (Ehrenb.) R.M. Patrick						x				x	x	x
Licmophora antarctica Carlson									x		x	
Licmophora spp.					x				x			
**Meridion circulare* (Grev.) C. Agardh						x					x	x
Staurosira pinnata Ehrenb. [Plate III, Fig. 3]	x			x		x	x			x	x	x
**Synedropsis laevis* (Heiden) Hasle, Medlin & Syversten									x	x		
Tabellaria sp.						x	x					
Bacillariophyceae												
Achnanthes coarctata (Bréb.) Grunow [Plate III, Figs 6–7]	x		x		x	x	x			x	x	x
A. exigua Grunow	x			x	x		x				x	x
A. groenlandica (P.T. Cleve) Grunow									x	x	x	
A. muelleri Carlson [Plate III, Figs 8–9]	x	x			x	x	x				x	x
◊*A. parvula* Kütz.	x								x	x	x	
A. taylorensis D.A. Kellogg, Stuiver, T.B. Kellogg & Denton							x	x		x	x	x
Achnanthidium minutissimum (Kütz.) Czarn.		x								x	x	x
Amphora copulata (Kütz.) Schoeman & R.E. M. Archibald									x	x	x	x
A. oligotraphenta Lange-Bert.	x		x	x		x	x			x	x	x
°*Brachysira brebissonii* R. Ross						x	x	x				
**B. minor* (Krasske) Lange-Bert. & Moser	x	x	x	x	x	x	x				x	x
Caloneis bacillum (Grunow) P.T. Cleve	x		x	x	x		x			x	x	x
C. silicula (Ehrenb.) P.T. Cleve	x			x	x	x	x			x	x	x
C. tenuis (Greg.) Krammer		x								x	x	x
**Chamaepinnularia krookiformis* (Krammer) Lange-Bert. & Krammer [Plate IV, Figs 15–16]	x	x	x	x	x	x	x	x	x		x	x
Ch. krookii (Grunow) Lange-Bert. & Krammer	x		x	x		x	x			x	x	x
Chamaepinnularia sp. [Plate IV, Fig. 14]	x	x	x	x		x	x					
**Cocconeis californica* (Grunow) Grunow	x										x	x
C. costata Greg.	x				x	x	x		x	x	x	x
C. costata *var. *antarctica* Manguin		x							x	x	x	x
C. fasciolata (Ehrenb.) Brown									x	x	x	x

taxa	St	B	P	L	R	M	S	D	Sn	CA	MA	sA
**C. pediculus* Ehrenb.						x				?	?	x
C. placentula var. **euglypta* (Ehrenb.) P.T. Cleve						x				x	x	
C. placentula var. *lineata* (Ehrenb.) Van Heurck						x	x			x	x	x
**C. schuettii* Van Heurck									x	x	x	
Cocconeis sp. A									x			
Cocconeis sp. B									x			
Cocconeis sp. C							x					
Cocconeis sp. D							x					
**Craticula accomoda* (Hust.) D.G. Mann	x		x							x	x	
**Cymbella cistula* (Hemprich) Kirchner							x			x	x	x
Cymbella sp.						x						
Cymbopleura sp.						x						
Diadesmis aff. *arcuata* (Heiden) Lange-Bert.					x		x					
°*D. costei* Le Cohu & Van de Vijver					x							x
D. perpusilla (Grunow) D.G. Mann	x	x			x	x	x			x	x	x
D. tabellariaeformis (Krasske) Lange-Bert. & Wojtal [Plate VI, Fig. 1]	x			x		x	x	x			x	
Diadesmis sp.	x		x	x		x	x					
**Encyonema silesiacum* (Bleish) D.G. Mann [Plate IV, Fig. 13]						x	x				x	x
Encyonema sp.								x				
◊*Eunotia exigua* (Bréb.) Rabenh.						x	x				x	x
E. groenlandica (Grunow) Norpel-Schempp & Lange-Bert.						x	x				x	
°*E. paludosa* Grunow							x					x
E. praerupta Ehrenb.	x	x	x	x		x	x	x	x		x	x
°*E. tetraodon* Ehrenb. [Plate III, Fig. 5]						x						x
Fragilariopsis curta (Van Heurck) Hust.									x	x	x	x
F. kerguelensis (O'Meara) Hust.									x	x	x	x
F. cf. *rhombica* (O'Meara) Hust.									x			
Frustulia sp.						x	x	x				
Geissleria sp. [Plate III, Figs 19–20; Plate VI, Fig. 4]	x	x				x	x					
**Gomphonema signyensis* Kociolek & Jones [Plate IV, Fig. 3; Plate VI, Fig. 7]	x	x				x	x				x	x
Gomphonema sp. A [Plate IV, Figs 1–2]	x	x	x			x	x					
Gomphonema sp. B [Plate IV, Fig. 4]	x		x				x					
Gomphonema sp. C [Plate IV, Fig. 5]	x			x	x	x	x					
Hantzschia amphioxys (Ehrenb.) Grunow	x	x	x	x		x	x	x	x	x	x	x
Hantzschia sp. A	x	x	x	x	x	x	x					
Hantzschia sp. B	x	x	x		x	x	x					
Hippodonta hungarica (Grunow) Lange-Bert., Metzeltin & Witkowski	x			x	x		x			x	x	x

taxa	St	B	P	L	R	M	S	D	Sn	CA	MA	sA
Luticola cohnii (Hilse) D. G. Mann	x	x		x	x	x	x			x	x	x
**L. higleri* Van de Vijver, Van Dam & Beyens [Plate III, Fig. 29; Plate V, Fig. 8]	x	x	x		x	x	x				x	
L. mutica (Kütz.) D.G. Mann	x	x	x	x	x	x	x			x	x	x
L. muticopsis (Van Heurck) D.G. Mann [Plate III, Fig. 30]	x	x	x	x	x	x	x	x	x	x	x	x
L. nivalis (Ehrenb.) D. G. Man [Plate III, Fig. 32]			x			x	x			x	x	x
Luticola sp. A		x	x		x	x						
Luticola sp. B [Plate III, Fig. 33]				x	x	x	x					
Luticola sp. C [Plate III, Fig. 34]	x	x	x				x					
Luticola sp. D [Plate III, Fig. 31]							x					
Luticola sp. E [Plate V, Fig. 7]					x	x	x					
Mayamaea atomus *var. *permitis* (Hust.) Lange-Bert.			x							x	x	x
Mayamaea sp.	x		x		x							
Microcostatus naumanii (Hust.) Lange-Bert.	x									x	x	
**Muelleria algida* Spaulding & Kociolek [Plate III, Fig. 22]	x	x	x	x	x	x	x		x		x	
M. cf. *linearis* (O. Müll.) Freng. [Plate III, Fig. 23]		x				x	x				?	
**M. luculenta* Spaulding & Kociolek [Plate III, Fig. 26]	x					x	x				x	x
**M. rostrata* Van de Vijver & Spaulding (provisional name)[2] [Plate III, Fig. 21] R, S];		x			x		x				x	
Muelleria sp. A [Plate III, Fig. 28; Plate VI, Figs 2–3]			x			x	x					
Muelleria sp. B	x		x									
Muelleria sp. C [Plate III, Figs 24–25]					x		x					
Muelleria sp. D [Plate III, Fig. 27]						x						
**Navicula bicephala* Hust. [Plate III, Fig. 17]						x	x				x	x
◊*N. capitatoradiata* H. Germain						x	x			x	x	x
N. cincta (Ehrenb.) Ralfs	x	x	x		x		x			x	x	
N. directa (W.M. Smith) Ralfs									x	x	x	
N. glaciei Van Heurck									x	x	x	
N. gregaria Donkin	x		x	x		x	x			x	x	x
N. lanceolata (C. Agardh) Ehrenb.	x	x				x	x		x		x	x
N. cf. *vekhovii* Lange-Bert. & Genkal	x	x	x			x	x					
Navicula sp. A		x			x							
Navicula sp. B [Plate III, Fig. 18]			x		x		x					
Neidiopsis levanderi (Hust.) Lange-Bert., Metzeltin & Kusber eco-type *levanderi* ("acidophila")					x						x	
◊*Neidium affine* (Ehrenb.) Pfitzer	x			x			x				x	
N. bisulcatum (Lagerst.) P.T. Cleve							x				x	x
**Nitzschia acidoclinata* Lange-Bert.		x	x		x						x	x
N. debilis (Arnott) Grunow					x	x	x				x	x
N. frustulum (Kütz.) Grunow	x		x				x			x	x	x
N. gracilis Hantzsch [Plate IV, Fig. 28]	x	x	x	x	x	x	x			x	x	x
N. homburgiensis Lange-Bert. [Plate IV, Fig. 29]	x	x	x	x	x	x	x				x	x
**N. inconspicua* Grunow	x					x	x				x	x
N. paleacea (Grunow) Grunow	x	x	x	x	x	x	x				x	x
N. perminuta (Grunow) Perag.	x	x	x	x	x	x	x	x			x	x
Nitzschia sp. A							x					
Nitzschia sp. B						x						
Pinnularia borealis Ehrenb.	x	x	x	x	x	x	x	x	x	x	x	x
P. borealis var. *scalaris* (Ehrenb.) Rabenh.	x	x	x		x	x	x	x			x	x
P. borealis var. A							x					
P. divergens ○var. *media* Krammer [Plate IV, Fig. 24]	x		x				x					
P. divergens ○var. *biconstricta* (A. Cleve) A. Cleve		x			x	x						
P. divergens ○var. *sublinearis* P.T. Cleve [Plate IV, Figs 25–26; Plate VI, Fig. 8]	x		x	x	x	x	x					
P. divergentissima (Grunow) P.T. Cleve	x					x					x	x
P. diversa ○var. *subcapitata* Krammer & Lange-Bert. [Plate IV, Fig. 19]	x					x	x					
P. cf. *globiceps* Greg. [Plate IV, Fig. 20]	x			x		x	x					
**P. kolbei* Manguin					x						x	x
P. microstauron (Ehrenb.) P. T. Cleve	x	x	x			x	x			x	x	x
P. microstauron ○var. *rostrata* Krammer [Plate IV, Fig. 27];							x					x
P. obscura Krasske	x	x	x	x	x	x	x				x	x
○*P. peracuminata* Krammer						x						x
P. rabenhorstii ○var. *franconica* Krammer	x	x			x	x	x					x
P. rabenhorstii *var. *subantarctica* Van de Vijver & Le Cohu [Plate IV, Fig. 21]	x				x	x	x	x			x	x
**P. schoenfelderi* Krammer						x					x	x
P. subantarctica *var. *elongata* (Manguin) Van de Vijver & Le Cohu [Plate IV, Fig. 18]	x	x	x	x	x	x	x	x			x	x
•*P. viridiformis* Krammer						x				x		x
Pinnularia sp. A	x	x		x	x	x	x		x			
Pinnularia sp. B [Plate IV, Fig. 23]	x	x	x		x	x	x					
Pinnularia sp. C	x	x		x		x	x					
Pinnularia sp. D							x					
Pinnularia sp. E [Plate IV, Fig. 17]						x	x					
Pinnularia sp. F	x											
Pinnularia sp. G [Plate IV, Fig. 22]	x	x	x	x	x	x	x					
Placoneis elginensis (Greg.) Cox	x	x	x	x		x	x				x	x
Planothidium delicatulum (Kütz.) Round & Bukht. s. l.	x		x	x		x	x			x	x	x
P. lanceolatum (Bréb.) Lange-Bert.	x	x	x	x	x	x	x	x			x	x
**Psammothidium germainii* (Manguin) Sabbe [Plate III, Fig. 16; Plate V, Figs 4–5]	x	x	x	x	x	x	x			x	x	x

[2] The species appeared under this name in a poster presentation of Dr Van de Vijver and Dr Spaulding at the 18th North American Diatom Symposium, October 31–November 4, 2005, Alabama, USA.

taxa	St	B	P	L	R	M	S	D	Sn	CA	MA	sA
P. incognitum (Krasske) Van de Vijver [Plate III, Figs 10–12; Plate V, Figs 1–2]	x	x	x		x	x	x	x			x	x
**P. manguinii* (Hust.) Van de Vijver [Plate III, Fig. 13; Plate V, Fig. 6]	x		x		x	x	x	x			x	x
P. metakryophilum (Lange-Bert. & Schmidt) Sabbe [Plate III, Figs 14–15; Plate V, Fig. 3]	x	x	x	x		x	x			x	x	x
P. subatomoides (Hust.) Bukht. & Round	x		x				x				x	x
**Pseudogomphonema kamtschaticum* (Grunow) Medlin				x		x		x	x	x	x	
**Rhoicosphaenia abbreviata* (C. Agardh) Lange-Bert.	x									x	x	x
Sellaphora sp.						x						
Stauroneis aff. *acidoclinata* Lange-Bert. & Werum [3] [Plate IV, Fig. 6]	x	x	x		x	x	x				x	
**S. husvikensis* Van de Vijver & Lange-Bert. [Plate IV, Figs 8–9]	x	x				x	x				x	
S. cf. *husvikensis* Van de Vijver & Lange-Bert. [Plate IV, Fig. 7]							x	x				
**S. latistauros* Van de Vjiver & Lange-Bert.	x	x	x	x		x	x			x	x	x
S. cf. *pseudomuriella* Van de Vijver & Lange-Bert. [Plate IV, Fig. 12]	x	x	x		x		x					
**S. obtusa* Lagerst.					x					?	?	?
○*S. pseudoschimanskii* Van de Vijver & Lange-Bert. [Plate IV, Figs 10–11; Plate VI, Figs 5–6];	x	x	x		x	x	x	x				x
○*S. reichardtii* Lange-Bert., Cavacini, Tagliaventi & Alfinito	x	x			x	x	x					
Surirella sp.	x					x						
Trachyneis sp.	x											
Ochrophyta												
Dictyochophyceae												
**Distephanus speculum* (Ehrenb.) Haeckel									x	x	x	
Xanthophyceae												
◊*Chloridella simplex* Pascher	x										x	
c*Heterococcus* sp.						x	x					
c•*Monodus guttula* Pascher							x			x		
c**Monodopsis subterranea* (J.B. Petersen) D.J. Hibberd						x				x	x	x
c◊*Tribonema vulgare* Pascher						x					x	
c◊*T. viride* Pascher							x				x	
c*Tribonema* sp. A							x					
c*Tribonema* sp. B								x				
c*Xanthonema* aff. *antarcticum* (Broady) H. Ettl & G. Gärtner							x					
X. aff. *bristolianum* (Pascher) P.C. Silva									x			
c**X. debile* (Vischer) P.C. Silva [Plate II, Fig. 16]						x	x	x			x	
c◊*X. exile* (G.A. Klebs) P.C. Silva						x	x	x		x	x	
c*X.* cf. *solidum* (Vischer) P.C. Silva						x	x	x				
c*Xanthonema* sp. A						x	x	x				
c*Xanthonema* sp. B							x					
Chlorophyta												
Chlorophyceae												
c•*Coccomyxa gloeobotrydiformis* Reisigl						x	x	x		x		
c*Gloeocystis* sp.						x	x					
c•*Heterotetracystis akinetos* Cox & Deason [Plate I, Fig. 8]						x				x		
◊*Keratococcus bicaudatus* (A. Braun) J. B. Petersen [Plate I, Fig. 7]						x	x	x			x	
Monoraphidium sp.				x								
Prasiola crispa (Lightf.) Menegh.	x		x		x	x	x			x	x	x
c**Pseudococcomyxa simplex* (Mainx) Fott						x	x	x		x	x	
c•*Scotiellopsis oocystiformis* (J.W.G. Lund) Punčoch. & Kalina [Plate I, Fig. 6]						x	x	x		x		
c•*S. terrestris* (Reisigl) Punčoch. & Kalina						x	x	x		x		
resting stages (*Chlamydomonadaceae*)									x			
Klebsormidiophyceae												
c**Klebsormidium dissectum* (Gay) H. Ettl & G. Gärtner [Plate II, Fig. 15]						x	x	x			x	
K. flaccidum (Kütz.) P.C. Silva, Mattox & Blackwell	x					x	x	x			x	x
c○*K. klebsii* (G.M. Sm.) P.C. Silva, Mattox & Blackwell [Plate II, Fig. 5]						x	x	x				
○*K. scopulinum* (Hazen) H. Ettl & G. Gärtner							x					
K. subtile (Kütz.) Tracanna ex Tell	x			x	x	x		x		x	x	
Raphidonema brevisrostre Scherff.									x		x	
R. nivale Lagerh. [Plate II, Fig. 3]		x							x		x	
c**R. pyrenoidifera* Korschikov							x			x	x	
c◊*R. sempervirens* Chodat							x	x		x	x	
Trebouxiophyceae												
c○*Chlorella luteoviridis* Chodat							x					
Chlorella sp.								x				
c○*Choricystis minor* (Skuja) Fott						x	x	x				
c◊*Koliella tatrae* (Kol) Hindák							x				x	
c○*Stichococcus allas* Reisigl						x	x					
**S. bacillaris* Nägeli [Plate I, Fig. 10]						x	x	x	x	x	x	x
c◊*S. chlorelloides* Grintz. & Péterfi						x	x	x		x		
c•*S. exiguus* Gerneck [Plate I, Fig. 9]						x	x	x		x		
c◊*S. minutus* Grintz. & Péterfi						x	x	x		x	x	
c○*S. pelagicus* (Nygaard) Hindák							x					
c○*S. sequoieti* Arce							x					
Ulvophyceae												
c•*Hormidiopsis crenulata* (Kütz.) Heering						x	x	x		x		
Ulothrix sp.									x			

[3] This species corresponds to the description of *Stauroneis* aff. *acidoclinata* Lange–Bert. & Werum in Van de Vijver & al. (2004).

taxa	St	B	P	L	R	M	S	D	Sn	CA	MA	sA
Zygnematophyceae												
Actinotaenium cucurbita (Bréb.) Teiling		x			x	x				x	x	
A. curtum Teiling [Plate II, Fig. 14]		x			x	x					x	
Cosmarium subspeciosum *f. *antarcticum* Mrozińska, Olech & Massalski [Plate II, Fig. 17]		x			x						x	
Cosmarium sp. A					x							
Cosmarium sp. B [Plate II, Fig. 6]						x						
Cosmarium sp. C [Plate II, Figs 1, 2]					x							
Cylindrocystis brebissonii (Menegh.) de Bary [Plate II, Fig. 4]		x	x		x					x	x	x
C. crassa de Bary	x	x	x		x						x	
Spirogyra sp. ster.	x											
**Staurastrum punctulatum* (Bréb.) Ralfs [Plate II, Figs 7–13]		x	x		x						x	
Staurastrum sp.					x							
Zygnema spp. ster.	x	x	x		x							
unidentified algal cells												

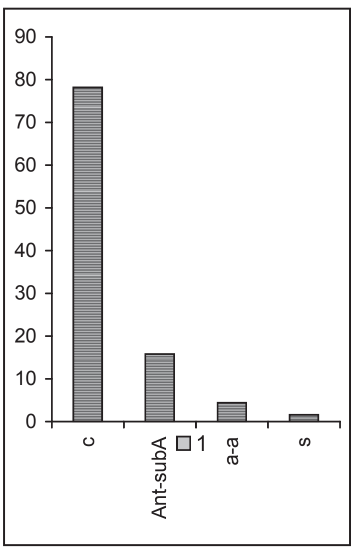


Fig. 1. Distribution of the identified species, varieties and form from Livingston Island.
c – cosmopolitans and widely distributed species and varieties across the world;
Ant-subA – typical Antarctic and Sub-Antarctic taxa;
a–a – arctic and north-alpine species;
s – species from the Southern Hemisphere.

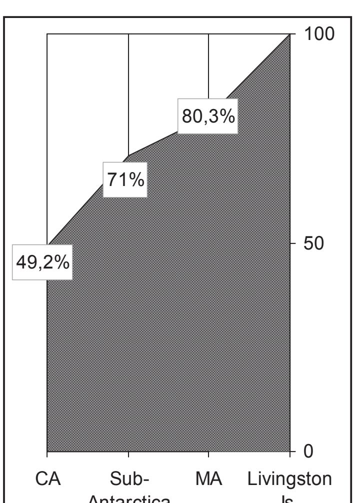


Fig. 2. Similarity of the diatom flora of Livingston Island to that of Continental Antarctica, other places in Maritime Antarctica and Sub-Antarctica (as percentage of common taxa). **CA** – Continental Antarctica; **MA** – Maritime Antarctica.

New records for Antarctica (short descriptions)

Cyanoprokaryota

Merismopedia angularis R.H. Thomps.
Aggregates of 4 to 32 cells, cell dimensions 4–6.2 × 4.2 μm, envelopes colourless.

Microcystis smithii Komárek & Anagn.
Cells rounded, 3.5 μm in diameter, enclosed in a colourless mucilage.

Phormidium lividum Nägeli
Trichomes 3–6 μm wide, cells 2–4 μm long. Apical cell rounded or slightly conical.
Remarks: The species was discovered only in cultures in a liquid medium.

Tolypothrix distorta (Fl. Dan.) Kütz.
Filaments 13.6–15 μm wide, sheaths yellow–orange. Trichomes 7.5–10 μm wide, cells 4.5–5 μm long. Heterocysts rounded, 7.5–10.5 μm in diameter.

Bacillariophyta

Brachysira brebissonii Ross
Dimensions: 19.5–34.8 μm L, 4.5–9 μm W. The number of the striae is difficult to resolve in LM.

Diadesmis costei Le Cohu & Van de Vijver
Dimensions: 20–20.8 μm L, 4–5 μm W, the number of the striae not resolvable in LM.
Remarks: Known from soils, Kerguelen, Sub-Antarctica (Le Cohu & Van de Vijver 2002).

Eunotia paludosa Grunow
Dimensions: 25.2–29.6 μm L, 1.9–2.7 μm W. Striae 19–20/10 μm.

E. tetraodon Ehrenb.
Dimensions: 30.2–34.7 μm L, 13.2–15.8 μm W, striae 7–8/10 μm.

Pinnularia divergens var. ***biconstricta*** (A. Cleve) A. Cleve
Dimensions: 82–102 μm L, 12–15.1 μm W, striae 10–12 /10 μm.
Remarks: The individuals from Livingston Island possess 10–12 striae in 10 μm instead of 9–10 as in the description of the variety in Krammer (2000).

P. divergens var. ***media*** Krammer
Dimensions: 47.9–54.3 µm L, 10.1–12 W, striae 9–10/10 µm.

P. divergens var. ***sublinearis*** P.T. Cleve
Dimensions: valves (46)62–76.9 µm L, 10.7–12.6 µm W, striae 10–12/10 µm.
Remarks: The individuals from Livingston Island are smaller and posses more striae, 10–12 instead of 8–10 in 10 µm as given in Krammer (2000), and somewhat larger fascia. Despite this, the overall combination of characters directed to the identification of the taxon as *P. divergens* var. *sublinearis.*

P. diversa var. ***subcapitata*** Krammer & Lange-Bert.
Dimensions: 23.9–36.6 µm L, 4–5.7 µm W, striae 12–14/10 µm.
Remarks: Arctic species (Krammer 2000).

P. microstauron var. ***rostrata*** Krammer
Dimensions: 44.1 µm L , 7.6 µm W, striae 11–13/ 10µm.

P. peracuminata Krammer
Dimensions: 50.4–65.5 µm L, 9.5–10 µm W, striae 11–12/10 µm.

P. rabenhorstii var. ***franconica*** Krammer
Dimensions: 50.4–65 µm L, 11.3–13.9 µm W, striae 5/10 µm.

Stauroneis pseudoschimanskii Van de Vijver & Lange-Bert.
Dimensions: 22.1–30.2 µm L, 5–7 µm W, striae 23–24 в 10 µm.
Remarks: Recently described species from Sub-Antarctica (Van de Vijver & al. 2004).

S. reichardtii Lange-Bert., Cavacini, Tagliaventi & Alfinito
Dimensions: 41.1–47.9 µm L, 9.5–10.7 µm W, striae 20–21/10 µm.
Remarks: Although this species is known from the Arctic region, according to Van de Vijver & al. (2004) it is possible that in Antarctica it has been erroneously identified as *S. anceps* Ehrenb.

Chlorophyta

Klebsormidium klebsii (G.M. Sm.) P.C. Silva, Mattox & Blackwell
Filaments of cylindrical cells, 4.5–7 µm wide, 5–17 µm long, one chloroplast with a prolonged pyrenoid.
Remarks: Discovered only in cultures.

K. scopulinum (Hazen) H. Ettl & G. Gärtner
Short filaments, cells 6.2–15 µm long and 4 µm wide.
Remarks: Found only in a soil culture in a liquid medium.

Chlorella luteoviridis Chodat
Cells rounded 10–11 µm in diameter. One of the autospores notably larger than the others.
Remarks: The species was discovered only in a soil culture on an agarized medium.

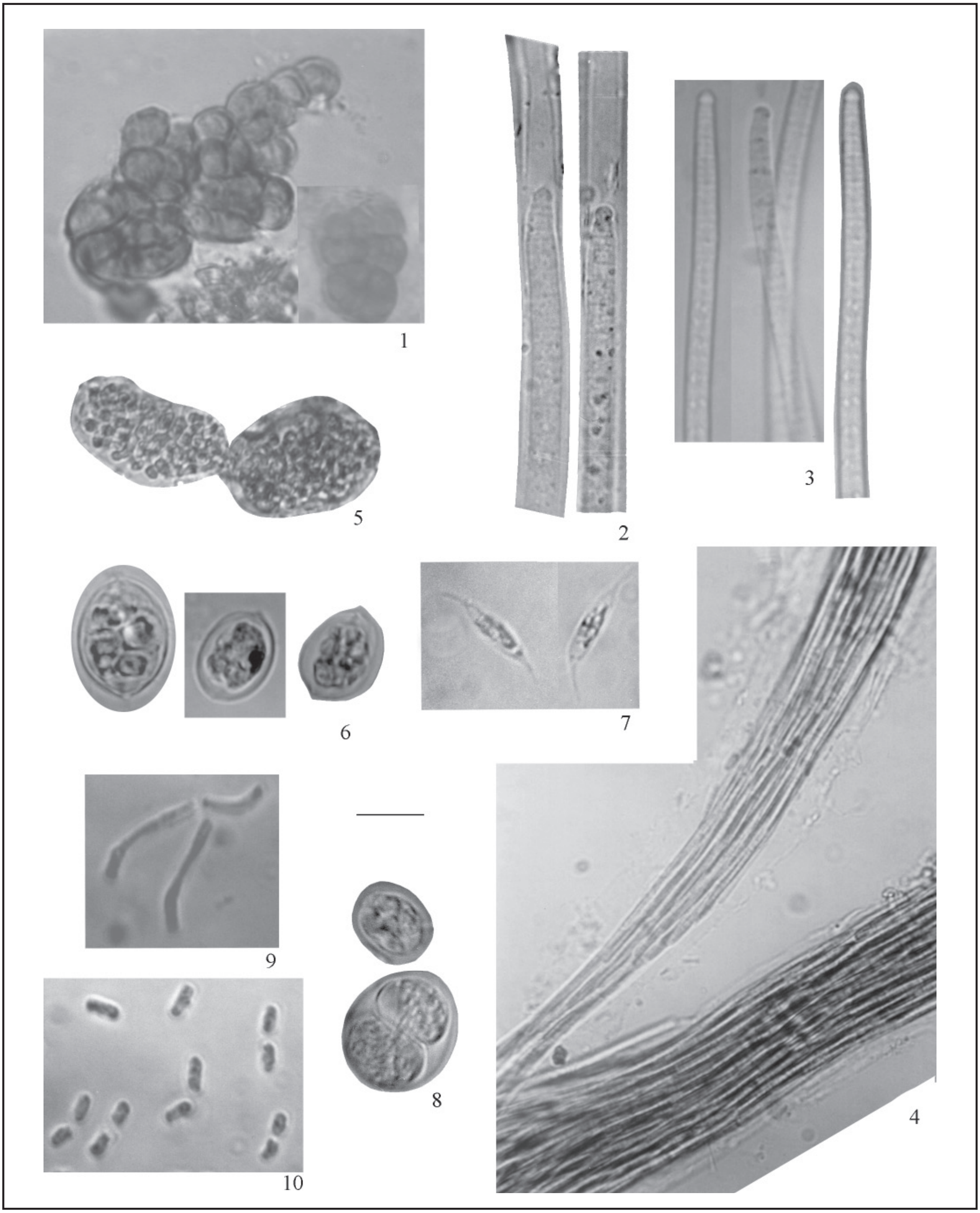
Choricystis minor (Skuja) Fott
Cells 4–9.4 µm long and 2.1–5.5 µm wide, ellipsoidal or slightly kidney–shaped with rounded ends, sometimes heteropolar. Reproduction by formation of two autospores.
Remarks: Found only in cultures. Cavacini (2001) reported from soils in northern Victoria Land two other species of the genus *Choricystis* – *Ch. chodatii* (Jaag) Fott and *Ch. guttula* Hindák. According to the hypothesis of Krienitz & al. (1996), it is possible that *Ch. chodatii* and *Ch. minor* are actually one species. Our investigations (Zidarova & al. in prepar.) have shown that *Ch. minor* and *Ch. chodatii* are karyologically very similar.

Stichococcus allas Reisigl
Short filaments of several cells. Cells twisted, 3 µm wide and 15 µm long, one chloroplast without a pyrenoid.
Remarks: The species is known from soil cultures in Europe (Ettl & Gärtner 1995). On Livingston Island it was only discovered in soil and moss samples, cultured on agarazied and liquid media.

S. pelagicus (Nygaard) Hindák
Filaments of 2–4 strongly twisted cells, 1.5 µm wide, 14–25 µm long, one chloroplast that covers ¾ of the cell.
Remarks: the species was found only in a soil culture in a liquid BBM medium.

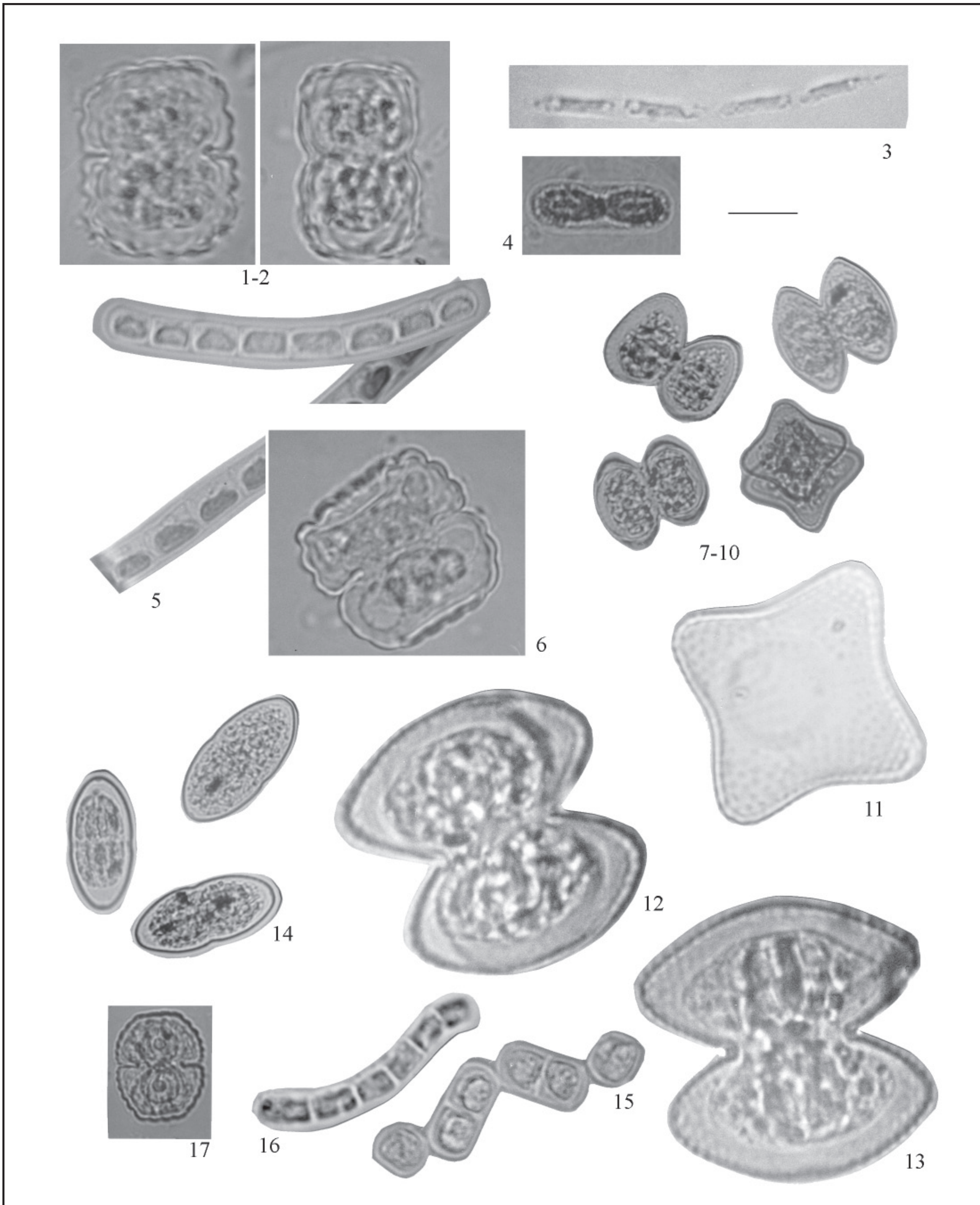
S. sequoieti Arce
Short filaments of 2–3 cells, cells cylindrical, 2.8 µm wide and 14 µm long. One chloroplast that covers almost the whole cell length.
Remarks: This species is known from soil cultures (Ettl & Gärtner 1995). On Livingston Island it was found in a soil culture on an agarized medium.

Plate I



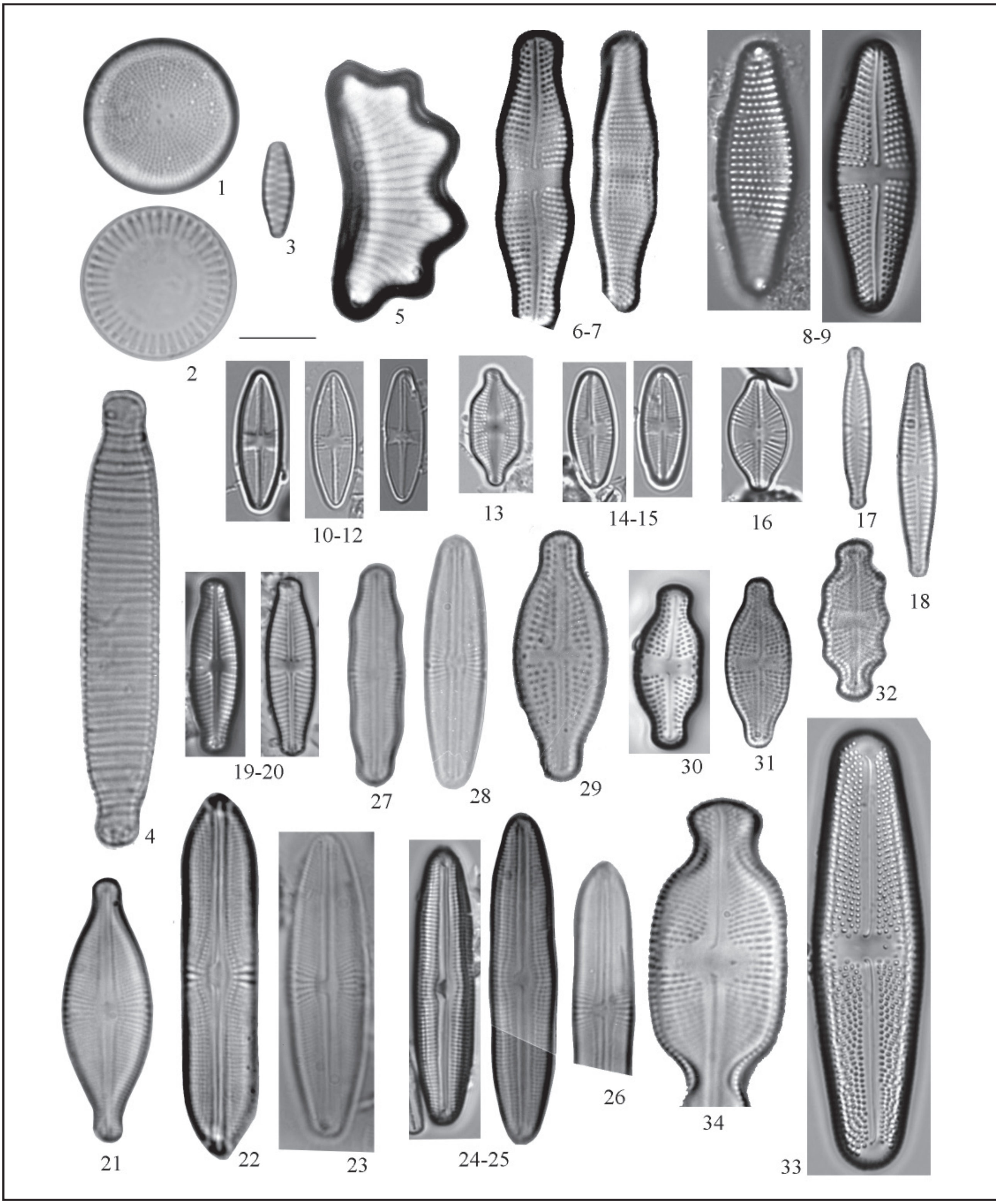
Figs 1–10. LM micrographs of:
1, *Gloeocapsopsis aurea*; **2**, *Phormidium autumnale*; **3–4**, *Microcoleus vaginatus*; **5**, *Nostoc punctiforme*; **6**, *Scotiellopsis oocystiformis*; **7**, *Keratococcus bicaudatus*; **8**, *Heterotetracystis akinetos*; **9**, *Stichococcus exiguus*; **10**, *S. bacillaris*. Scale bar = 10 µm for Figs 1–3, 6–10; scale bar = 25 µm for Figs 4, 5.

Plate II



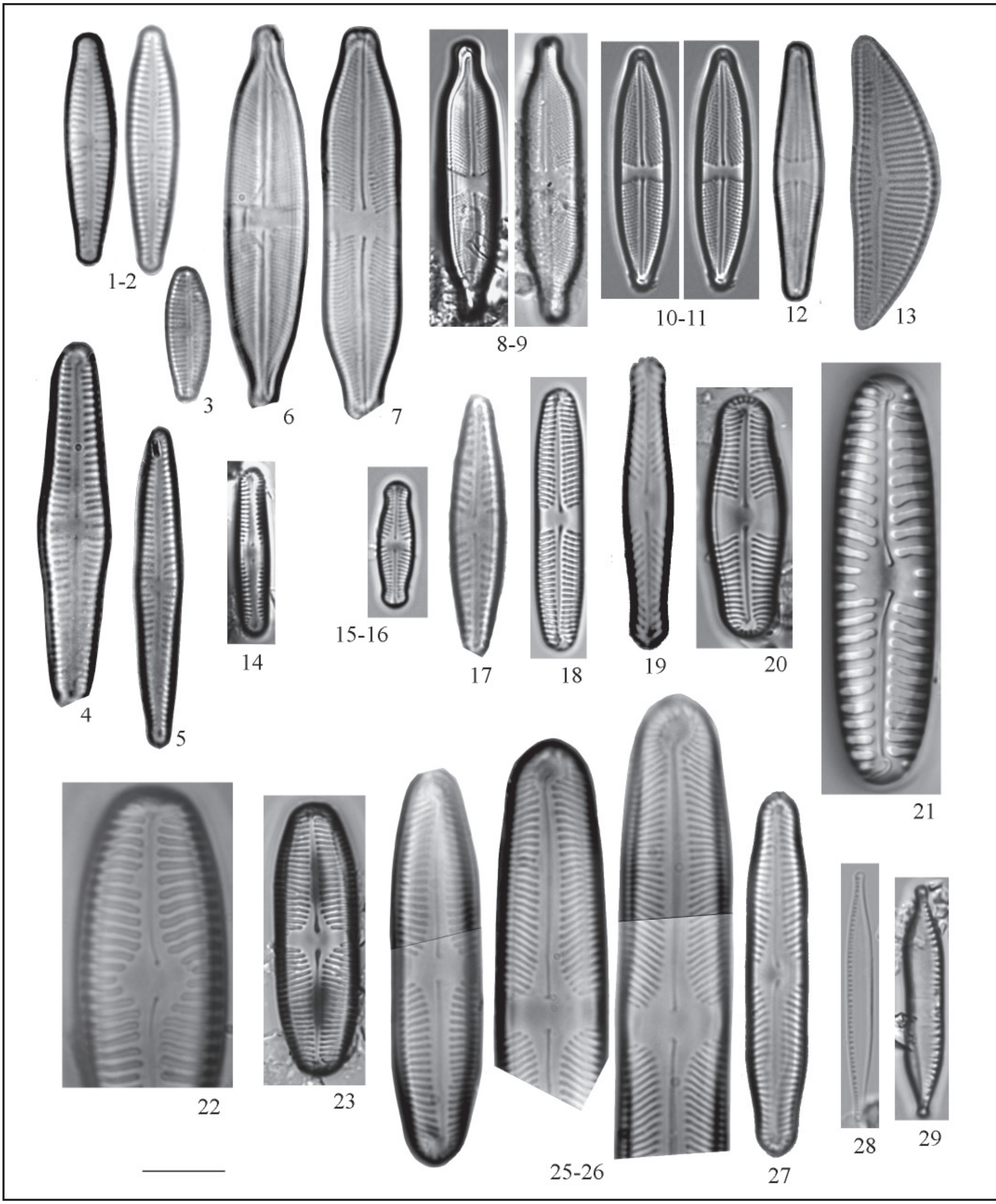
Figs 1–17. LM micrographs of:
1–2, *Cosmarium* sp. C; **3**, *Raphidonema nivale*; **4**, *Cylindrocystis brebissonii*; **5**, *Klebsormidium klebsii*; **6**, *Cosmarium* sp. B; **7–13**, *Staurastrum punctulatum*; **14**, *Actinotaenium curtum*; **15**, *Klebsormidium dissectum*; **16**, *Xanthonema debile*; **17**, *Cosmarium subspeciosum* f. *antarcticum*. Scale bar = 10 µm for Figs 1–3, 5–9, 11–13, 15; scale bar = 25 µm for Figs 4, 7–10, 14, 17.

Plate III



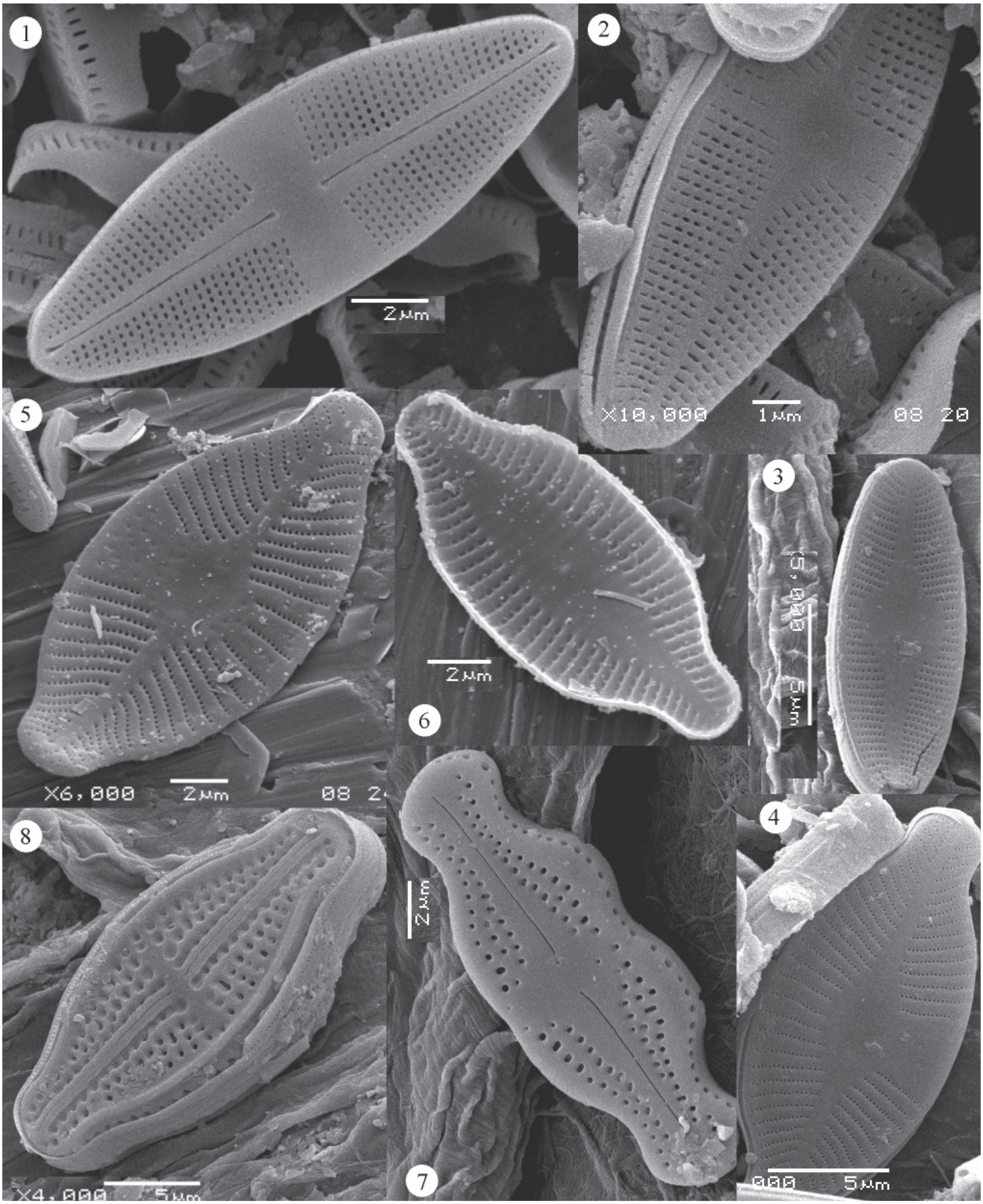
Figs 1–34. LM micrographs of:
1, *Orthoseira roeseana*; **2**, *Cyclotella meneghiniana*; **3**, *Staurosira pinnata*; **4**, *Diatoma vulgare* var. *ehrenbergii*; **5**, *Eunotia tetraodon*; **6–7**, *Achnanthes coarctata*; **8–9**, *A. muelleri*; **10–12**, *Psammothidium incognitum*; **13**, *P. manguinii*; **14–15**, *P. metakryophilum*; **16**, *P. germainii*; **17**, *Navicula bicephala*; **18**, *Navicula* sp. B; **19–20**, *Geissleria* sp.; **21**, *Muelleria rostrata* (provisional name, see p. 23); **22**, *M. algida*; **23**, *M.* cf. *linearis*; **24–25**, *Muelleria* sp. C; **26**, *M. luculenta*; **27**, *Muelleria* sp. D; **28**, *Muelleria* sp. A; **29**, *Luticola higleri*; **30**, *L. muticopsis*; **31**, *Luticola* sp. D; **32**, *L. nivalis*; **33**, *Luticola* sp. B; **34**, *Luticola* sp. C. Scale bar = 10 µm.

Plate IV



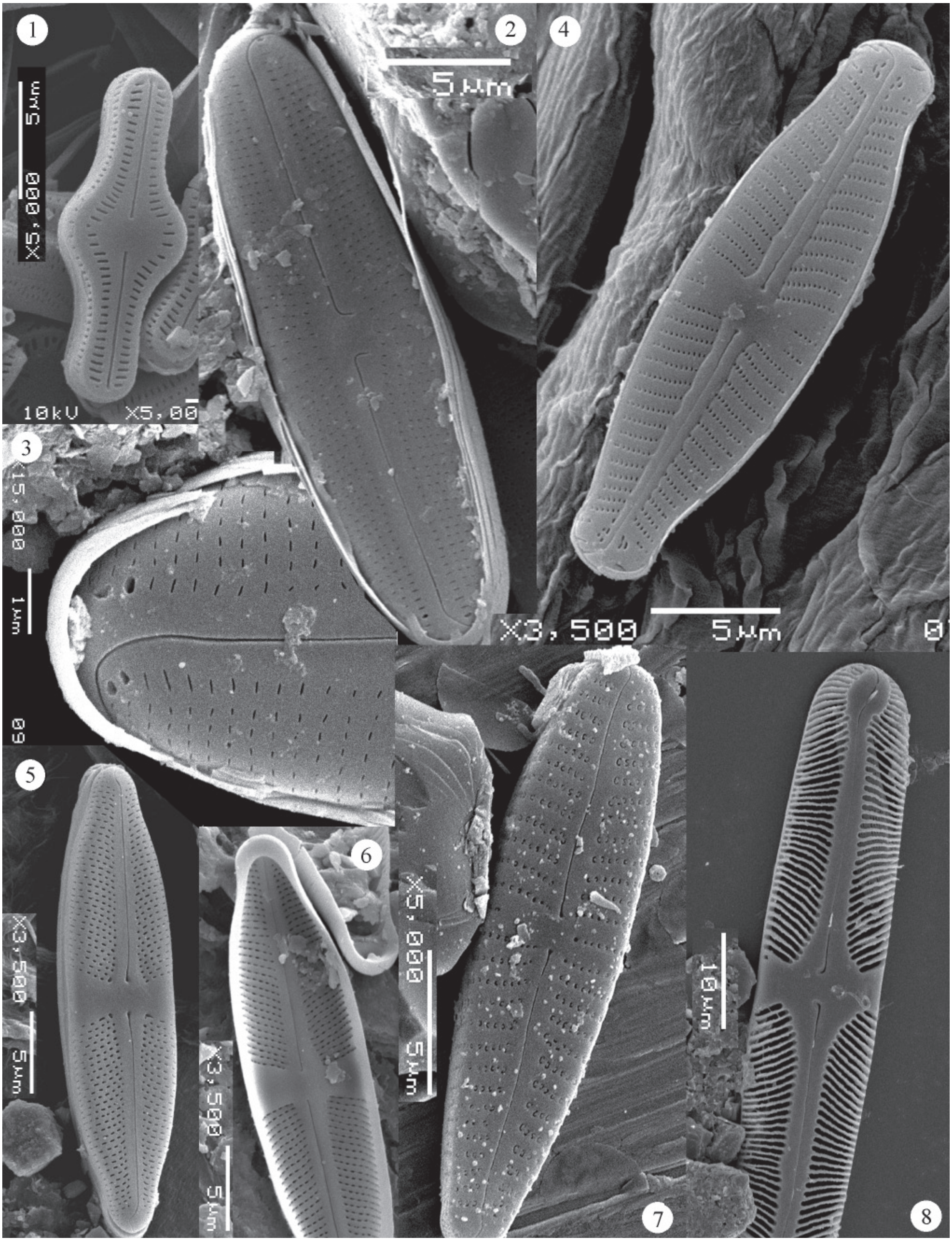
Figs 1–29. LM micrographs of:
1–2, *Gomphonema* sp. A; **3**, *G. signyensis*; **4**, *Gomphonema* sp. B; **5**, *Gomphonema* sp. C; **6**, *Stauroneis* aff. *acidoclinata*; **7**, *S.* cf. *husvikensis*; **8–9**, *S. husvikensis*; **10–11**, *S. pseudoschimanskii*; **12**, *S.* cf. *pseudomuriella*; **13**, *Encyonema silesiacum*; **14**, *Chamaepinnularia* sp.; **15–16**, *Ch. krookiformis* ; **17**, *Pinnularia* sp. E; **18**, *P. subantarctica* var. *elongata*; **19**, *P. diversa* var. *subcapitata*; **20**, *P.* cf. *globiceps*; **21**, *P. rabenhorstii* var. *subantarctica*; **22**, *Pinnularia* sp. G; **23**, *Pinnularia* sp. B; **24**, *P. divergens* var. *media*; **25–26**, *P. divergens* var. *sublinearis*; **27**, *P. microstauron* var. *rostrata*; **28**, *Nitzschia gracilis*; **29**, *N. homburgiensis*. Scale bar = 10 µm, with the exception of Fig. 19 (× 2000).

Plate V



Figs 1–8. SEM micrographs of:
1, *Psammothidium incognitum* (RV); **2**, *P. incognitum* (RLV); **3**, *P. metakryophilum* (RLV); **4–5**, *P. germainii* (RLV); **6**, *P. manguinii* (RLV, valve interior); **7**, *Luticola* sp. E; **8**, *L. higleri*.

Plate VI



Figs 1–8. SEM micrographs of:
1, *Diadesmis tabellariaeformis*; **2**, *Muelleria* sp. A; **3**, *Muelleria* sp. A (distal raphe ending); **4**, *Geissleria* sp.; **5**, *Stauroneis pseudoschimanskii*; **6**, *S. pseudoschimanskii* (valve interior); **7**, *Gomphonema signyensis*; **8**, *Pinnularia divergens* var. *sublinearis*.

Conclusion

Most of the taxa (76 %) found in this study have been reported earlier from Maritime Antarctica. As in previous studies on Livingston Island (e.g. Temniskova-Topalova & Chipev 2001, Temniskova-Topalova & Kirjakov 2002, Temniskova-Topalova & Zidarova 2004) cosmopolitans prevail (Fig. 1). Apart of several marine diatoms, Temniskova-Topalova & Chipev (2001), Temniskova-Topalova & Kirjakov (2002) and Temniskova-Topalova & Zidarova (2004) did not find any Antarctic taxa at all. However, the number of the Antarctic taxa here is notably higher – 29 taxa (16 % of the species with known geographic distribution) were recognized as typical for the Antarctic and/or Sub-Antarctic regions. With the exclusion of two blue-green algae (*Gloeocapsopsis aurea, Geitlerinema* cf. *deflexa*) and one green alga (*Cosmarium subspeciosum* f. *antarcticum*), most of them are diatoms. Since many species remained unidentified, it is possible that among them there are endemics as well.

An attempt was made to compare the Livingston Island algal flora with that of Continental Antarctica and Sub-Antarctica. When compared with Continental Antarctica, it is clear that almost all of the common taxa are widely distributed species throughout the world. Exceptions are *Geitlerinema* cf. *deflexa* (*Cyanoprokaryota*), which has not been recorded outside Antarctica (Mataloni & Pose 2001) and several diatoms that are regarded as endemic to the region (*Achnanthes taylorensis, Psammothidium germainii, P. metakryophilum, Stauroneis latistauros* and some marine species). On the other hand, the known Antarctic distribution of three southern diatom species – *Psammothidium incognitum, Brachysira minor* and *Diadesmis tabellarieformis,* and some Antarctic taxa (*Gloeocapsopsis aurea, Luticola higleri, Stauroneis husvikensis, Cosmarium subspeciosum* f. *antarcticum*) found on Livingston Island, seems to be restricted to the Maritime Antarctic region. They have not been reported from Continental Antarctica to date but as recently described taxa, it is possible that they have remained "hidden" in the previous studies.

A full comparison of the Livingston Island algal flora with the algal flora of Sub-Antarctica is difficult to make, since with the exception of diatoms data on Sub-Antarctic algae are almost lacking, e.g. few studies listed in Broady (1979a, b). Only 13 taxa of blue-green, yellow-green and green algae found on Livingston Island have been reported from Sub-Antarctica so far, and all of them are cosmopolitans. A comparison of the diatom flora of Livingston Island with that of Continental Antarctica and Sub-Antarctica reveals higher similarity with Sub-Antarctica (Fig. 2). As the species richness decreases with the increase of latitude (Jones 1996; Van de Vijver & Beyens 1999), higher species diversity is observed in Maritime Antarctica in comparison to Continental Antarctica. On Livingston Island 171 diatom taxa were found which number is comparable to that reported from Sub-Antarctica. For example, Van de Vijver & al. (2001) reported 170 taxa from Keurguelen and Van de Vijver & al. (2002) found 220 diatom taxa on Ile de la Possession. In addition, Sub-Antarctic and Maritime Antarctic region share a higher number of common probably endemic taxa that are not found in Continental Antarctica to date (e.g. *Achnanthes muelleri, Psammothidium manguinii, Diadesmis costei, Navicula bicephala, Muelleria algida, M. luculenta, Stauroneis husvikensis, S. pseudoschimanskii, Pinnularia kolbei, P. rabenhorstii* var. *subantarctica, P. subantarctica* var. *elongata*). These findings correspond to the observation of Van de Vijver & Beyens (1999) that the Antarctic continent has a distinct diatom flora and need to be separated from Maritime Antarctica and Sub-Antarctica.

The knowledge about the biogeography and the diversity of the Antarctic and Sub-Antarctic algae is far incomplete. There are problems surrounding the determination of algae. Most floristic studies traditionally use direct microscopic observations for the identification of algae on the basis of morphological criteria. While direct analysis could be applied for blue-green algae and diatoms, green and yellow-green algae need to be cultured and observations on their life cycles are often necessary in order to identify to a species level. This method is not frequently used in the Antarctic studies and perhaps many species remain unidentified. Moreover, the use of culture technique reveals higher and more complete diversity than the direct microscopic analysis (Cavacini 2001). In this study 47 species, mostly green and yellow-green algae, were discovered only after extensive culturing which supports the above opinion.

Many authors agree that the number of the Antarctic taxa is currently underestimated (Sabbe & al. 2003; Taton & al. 2003; Mataloni & Komárek 2004; Van de Vijver & al. 2005). Data in the literature regarding the species diversity and distribution of algae in Antarctica might be unreliable since it is possible that the species are erroneously identified. The use of unsuitable keys for the identification of the Antarctic algae often leads to a 'fitting' of the Antarctic taxa to taxa from other latitudes (Sabbe & al. 2003; Mataloni & Komárek 2004; Van de Vijver & al. 2005). As a result, the proportion of the endemic species is found to be very low and, conversely, the geographic range of the so called cosmopolitan taxa is expanded.

In future a revision of many cosmopolitan taxa that are reported from Antarctica and show high morphological variability is necessary. Also, investigations of the algal flora of Sub-Antarctica need to be extended in order to obtain more complete picture of the distribution of algae in the southern region.

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