Доклади на Българската академия на науките
Comptes rendus de l'Académie bulgare des Sciences
Tome 60, No 4, 2007

BIOLOGIE
Botanique

DIVERSITY AND DISTRIBUTION OF ALGAE ON LIVINGSTON ISLAND, ANTARCTICA

R. Zidarova

(*Submitted by Academician V. Golemansky on March 23, 2007*)

Abstract

The present study concerns algal diversity and distribution on Livingston Island. Direct microscopic examination and culture studies revealed a diverse and rich algal flora of 302 taxa that belong to three divisions: Cyanoprokaryota, Heterokontophyta (classes Bacillariophyceae, Xanthophyceae and Dictyochophyceae) and Chlorophyta (including class Zygnematophyceae). Bacillariophyceae is the most diverse group, followed by Cyanoprokaryota and Chlorophyta. Nearly 1/5 of Cyanoprokaryota, half of the Chlorophyta and almost all of Xanthophyceae were discovered only in culture. The distribution of algae in the studied habitats and some features of the algal flora on Livingston Island are briefly described.
Key words: algae, distribution, habitats, Maritime Antarctica

Introduction. Algae are widespread and occur in different habitats in Antarctica. They inhabit streams, lakes, ponds and puddles that are formed in summer but could be found among mosses and on soil as well. Although many studies have been made in different localities throughout Antarctica, the algal flora of Livingston Island is still poorly known. Most of the reports refer to diatoms and their diversity, ecology and distribution [1–3]. Preliminary data on the diversity and distribution of green and blue-green algae are included in [4,5]. No culture studies have been made to date.

This study aims to present a short review on the distribution of blue-green, yellow-green, green algae and diatoms in different habitats on Livingston Island. Preliminary data from cultures are also provided and some features of the algal flora on Livingston Island are described.

Materials and methods. Livingston Island (850 km^2) is the second largest island of the South Shetland Archipelago, Maritime Antarctica (Fig. 1). Most of the area of the island is occupied by glaciers and only about 10% are free of snow and ice during

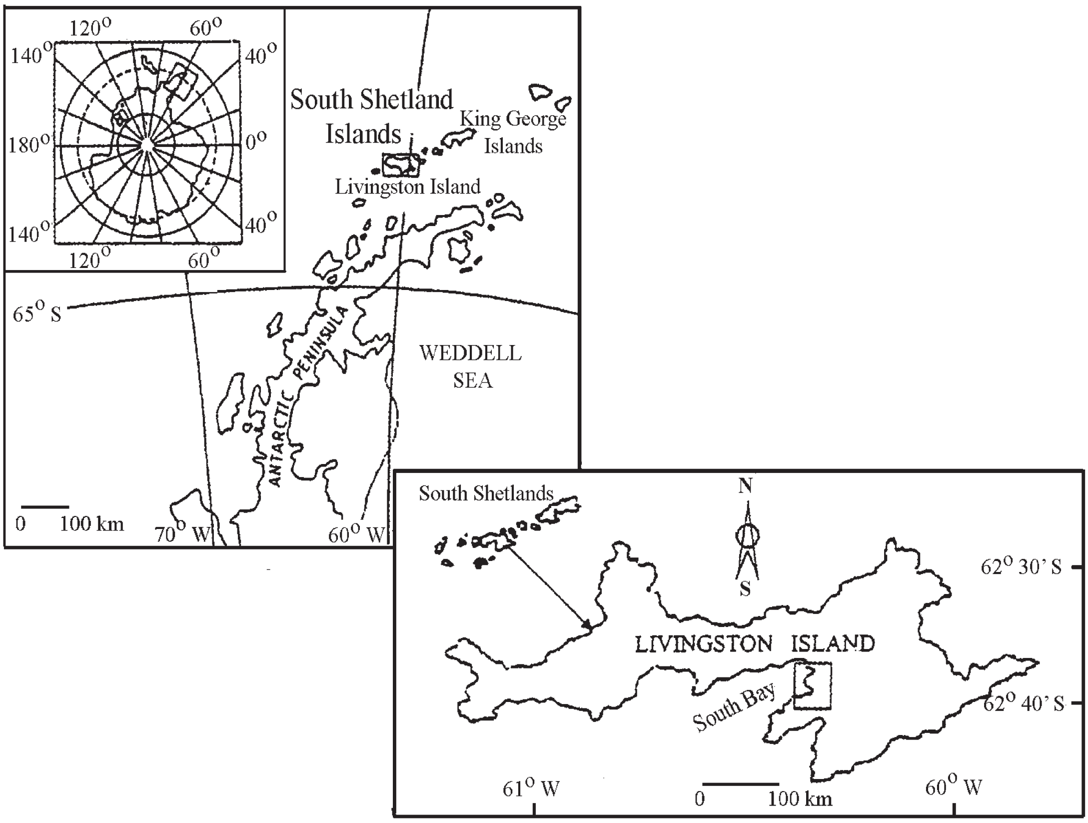

Fig. 1. Map of the region (according to TEMNISKOVA-TOPALOVA and CHIPEV [3])

summer. The climate is mild in comparison to continental Antarctica, with 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 [3].

Samples (152) were collected during four consecutive Antarctic summer seasons between 2003 and 2006. They were taken from lakes and their outflows, ponds, puddles, streams, small brooks, rocks irrigated by melting snow, red and green snow, mosses, tufts of the grass *Deschampsia antarctica* Desv. and soils. Samples from freshwater habitats and snow were stored immediately in 4% formaldehyde. Samples from mosses, soils and tufts of *D. antarctica* were transported "alive" to Bulgaria. A small part of each sample was diluted or "washed" in sterile distilled water. A part of the received subsample 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. Cultures were set in flasks and on agar plates. Initially three inorganic media were used (Bold's Basal Medium, Allen-Arnon and Shetlik-Simmer) [6]. Since the first 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 standard methods. For analysis of diatoms, samples were treated after HASLE and FRYXELL [7].

Average-linkage cluster analysis was applied by using `Primer` software package [8].

Results. The analysis revealed a diverse and rich algal flora of 302 taxa (287 species and 15 varieties) from three divisions: Cyanoprokaryota (Cyanophyta, Cyanobacteria), Heterokontophyta (classes Bacillariophyceae, Xanthophyceae and Dictyochophyceae) and Chlorophyta (including class Zygnematophyceae). Bacillariophyceae is the most diverse group (156 species and 15 varieties) followed by Cyanoprokaryota (71 species) and Chlorophyta (44 species). Xanthophyceae is represented by 15 species and Dictyochophyceae – by one of the two present-day species. Nearly 1/5 of Cyanoprokaryota (17.1%), the half of Chlorophyta (47.7%) and almost all of Xanthophyceae (86.7%) were revealed only in culture. A large proportion (40%) of all encountered taxa are new records for Livingston Island.

Pinnularia is the most diverse genus (16 species and 10 varieties). Among Bacillariophyceae the genera *Cocconeis* (9 species and 3 varieties), *Luticola* and *Nitzschia* (10 species each), *Muelleria* and *Stauroneis* (8 species each), also show high diversity. *Phormidium* and *Leptolyngbya* have the highest species richness within Cyanoprokaryota (10 and 8 species, respectively). *Xanthonema* (7 species) is the most diverse genus within Xanthophyceae and *Stichocococcus* (7 species) among Chlorophyta.

Three diatom species have the highest frequency of occurrence – *Luticola muticopsis* (Van Heurck) Mann (70.5%), *Pinnularia borealis* Ehr. (65.7%) and *Hantzschia amphioxys* (Ehr.) Grun. (58.9%). *Phormidium autumnale* (Ag.) Gom. (Cyanoprokaryota) and *Klebsormidium subtile* (Kütz.) Tracanna (Chlorophyta) follow with 21.2% and 14.4%, respectively.

Cluster analysis (Fig. 2) shows two main groups of algae: A – snow algae, and B – algae from all other studied habitats. Group B consists of two subgroups: B.1 – algae that occur among tufts of *Deschampsia antarctica*, and B.2 – algae among mosses and on soil (B.2A) and algae in habitats with availability of water (B.2B). The analysis of distribution of algae in different habitats revealed the following picture:

On Livingston Island green and red snow was observed (Fig. 2, cluster A). Green snow is characterized with the presence of widely distributed all over the world cryophilic algae (*Raphidonema nivale* Lagerh. and *R. brevirostre* Scherff.). At places, where snow melt has just been started, green filamentous algae of the genus *Ulothrix* develop abundantly. Red colouration of the snow comes from red-coloured resting stages of green algae. Since our attempts to establish cultures were unsuccessful, these algae remained unidentified.

A large number of marine diatoms (*Cocconeis costata* Greg., *C. schuetii* Van Heurck, *Navicula glaciei* Van Heurck, etc.) as well as the silicoflagellate *Distephanus speculum* (Ehr.) Haeck. and some algae, distributed in other habitats (*Stichococcus bacillaris* Näg., *Chamaepinnularia krookifromis* (Krammer) L.-Bert. et Krammer, *Pinnularia borealis*, *Hantzschia amphioxys*) are also found on snow.

The tufts of *Deschampsia antarctica* (Fig. 2, cluster B.1) differ with low species diversity. Most of the species were revealed only in culture and are green and yellow-green soil algae (e.g. *Stichococcus exiguus* Gerneck, *S. minutus* Grintz. et Petérfi, *Scotiellopsis oocystiformis* (Lund) Punčochářová et Kalina, *Xanthonema exile* (Klebs) Silva, etc.). Zygnematophyceae are completely absent. Among diatoms, species that are able to live in almost dry places prevail (*Pinnularia borealis*, *Hantzschia amphioxys*, *Psammothidium incognitum* (Krasske) Van de Vijver). Species known from both aquatic and terrestrial habitats have rare occurrence (e.g. *Fragilaria capucina* Desmaz. and *Planothidium lanceolatum* (Bréb.) L.-Bert.).

Soils and mosses (Fig. 2, cluster B.2A) have similar algal flora. It consists of algae distributed mainly in dry or temporary dry places (*Stichococcus bacillaris*, *Orthoseira roeseana* (Rabenh.) O'Meara, *Achnanthes coarctata* (Bréb.) Grun., *Diadesmis* *perpusilla* (Grun.) Mann, *Luticola cohnii* (Hilse) Mann, *Nitzschia debilis* (Arnott) Grun., etc.), soil algae (*Stichococcus minutus*, *Heterotetracystis akinetos* Cox et Deason, *Scotiellopsis oocystiformis*, *Xanthonema exile*, etc.) and a large number of species that grow in both aquatic and terrestrial habitats (*Leptolyngbya foveolarum* (Gom.) Anag. et Kom., *L. tenuis* (Menegh.) Anag. et Kom., *Phormidium autumnale*, *Ph. corium* (Ag.) Gom., *Tribonema vulgare* Pascher, *Xanthonema debile* (Vischer) Silva, *Klebsormidium flaccidum* (Kütz.) Silva et al., *Fragilaria capucina*, *Nitzschia perminuta* (Grun.) M. Peragallo, etc.). With exception of diatoms, most of the species here were also discovered only in culture. *Planothidium delicatulum* (Kütz.) Round et Bukht., *Psammothidium metakryophilum* (L.-Bert. et Schmidt) Sabbe, *Staurosira pinnata* Ehr., *Navicula gregaria* Donkin, *Placoneis elginensis* (Greg.) Cox, *Pinnularia* cf. *globiceps* Greg., *Nitzschia paleacea* (Grun.) Grun., are found on soil and among mosses in the close proximity of water bodies. In cultures some aquatic blue-green algae (e.g. *Chroococcus minutus* (Kütz.) Näg., *Phormidium crouanii* Gom.) have found suitable conditions for growth.

Rocks, irrigated by melting snow, and shallow temporary brooks share many common species (Fig. 2, cluster B.2-1). The algal flora of these habitats consists of algae that grow in terrestrial and aquatic habitats, and many aerophilic diatoms (*Achnanthes coarctata*, *Diadesmis perpusilla*, *Luticola cohnii*, *Hantzschia amphioxys*, etc.), which is

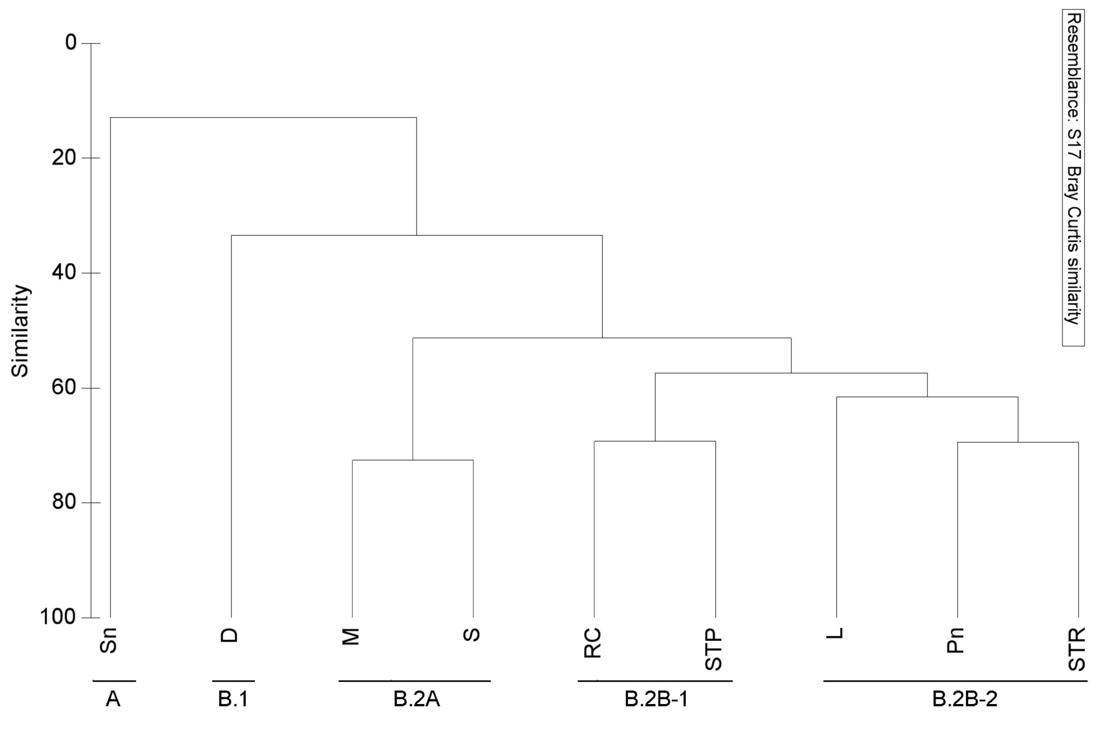

Fig. 2. Cluster dendrogram based on presence-absence of the species in studied habitats. The different clusters are marked in the bottom. Sn – snow; D – tufts of *Deschampsia antarctica*; M – mosses; S – soil; RC – rocks irrigated by melting water; STP – shallow temporary brooks; L – lakes; Pn – ponds and puddles; STR – streams and outflows

related to their irregular moistening and comparatively short existence, confined to the period of snow melt. Zygnematophyceae have high diversity (*Actinotaenium curtum* Teil., *A. cucurbita* (Bréb.) Teil., *Cylindrocystis brebissonii* (Menegh.) De Bary, *C. crassa* De Bary, *Staurastrum punctulatum* (Bréb.) Ralfs, *Cosmarium* spp.). Among Cyanoprokaryota characteristic species are *Cyanothece aeruginosa* (Näg.) Kom., *Nostoc punctiforme* (Kütz.) Hariot, *Leptolyngbya foveolarum*, *Phormidium autumnale*, *Tolypothrix distorta* (Fl. Dan) Kütz.

On wet rocks *Gloeocapsopsis aurea* Mataloni et Kom. forms extensive dark crusts. At places, influenced by the activity of birds, *Prasiola crispa* (Lightf.) Menegh. (Chlorophyta) and *Luticola muticopsis* (Bacillariophyceae) occur in abundance.

In lakes, their outflows, streams, ponds and puddles (Fig. 2, cluster B.2B-2) several diatoms (*Planothidium delicatulum*, *P. lanceolatum*, *Psammothidium metakryophilum*, *Fragilaria capucina*, *Stauroneis latistauros* Van de Vijver et L.-Bert., *Navicula gregaria*, *Nitzschia homburgiensis* L.-Bert., *N. gracilis*, *N. paleacea*) and blue-green algae (e.g. *Phoridium aerugineo-coeruleum*, *P. autumnale*, *P. tenuis* (Ag.) Anagn. et Kom., *Leptolyngbya foveolarum*, *L. fragilis* (Menegh.) Anagn. et Kom., *L. frigida* (Fritsch) Anagn. et Kom.) are most frequently observed. The algal flora of the lakes is similar to that of their outflows and streams but with lower diversity. In streams and lake outflows green filamentous algae (*Klebsormidium subtile* and *Zygnema* spp. ster.) are conspicuous and abundant. *Klebsormidium subtile* occurs in all types of water bodies, while *Zygnema* is absent in the lakes on Livingston Island. Rarely, *Spirogyra* sp. ster. is found in streams. In the fast-flowing and turbid glacier streams *Klebsormidium* prevails. In these streams the diversity of diatoms is also very low and mostly *Fragilaria capucina*, *Nitzschia homburgiensis* and *Psammothidium metakryophilum* are found in low numbers.

In puddles, surrounded by mosses, unicellular Zygnematophycean algae (*Cylindrocystis crassa*, *C. brebissonii* and *Staurastrum punctulatum*) are frequent. With the exception of rare occurrence of *Cylindrocystis crassa* in a stream, other species are not found in streams and lakes.

Discussion. The observed diversity of algae on Livingston Island is undoubtedly a result of the number of habitats investigated and the use of culture technique. Although this method probably leads to an overestimate of the abundance of algae, to date this is one of the methods that together with traditional microscopic analysis, allow us to receive a close to complete description of the algal flora [9]. The fact that many species, especially soil algae, were found only in culture, supports this opinion. As in other studies in Antarctica [9,10], these are mostly green and yellow-green algae (e.g. *Scotiellopsis oocystiformis*, species of the genera *Stichococus*, *Xanthonema*, *Tribonema*, etc.). It is presumed that in natural habitats these algae are in very low abundance and they could not be detected by the use of direct microscopic analysis or they exist as resting stages that could develop with the establishment of suitable conditions for their growth [9].

The number of diatoms is comparable to that reported by Temniskova-Topalova and Chipev [3] but in the composition of the diatom flora some differences could be found. An interesting feature is the comparatively high number of species of *Muelleria* and *Luticola*. The genus *Muelleria* is unique in its geographic distribution. Most of the known-to-date species are found in the high latitudes of both Northern and Southern hemisphere and are endemic [11]. The genus *Luticola* is represented with *L. muticopsis*, characteristic species for the Antarctic region, *L. higleri* Van de Vijver et al., which is known from the South Shetlands [12], with the cosmopolitans *L. cohnii*, *L. mutica* and *L. nivalis*, and five species that remained unidentified and perhaps some of them are knew to science. A diversity of *Luticola* species "with the presence of several unknown taxa" is also found by Van de Vijver et al. (poster presentation at the 18th North

American Diatom Symposium, Mobile, Alabama, 2005) on Deception Island, which is about 30 km away from Livingston Island.

Luticola muticopsis, the most frequent species on Livingston Island, was usually found in low abundance. Only on a rock where the nitrophilous species *Prasiola crispa* grows, it was abundant. This confirms the opinion of Van de Vijver and Beyens [13] that *L. muticopsis* dominates in diatom communities at places with higher concentration of nutrients.

The higher diversity in *Cocconeis* is due to the presence of marine species (*Cocconeis costata*, *C. fasciolata* (Ehr.) Brown, *Cocconeis schuetii*, etc.). Marine diatoms are occasionally found in all studied habitats. A large number was found on snow in the vicinity of the sea. These "immigrants" from the sea probably have "arrived" with the sea-sprays [3].

Unicellular algae from Zygnematophyceae are with rare occurrence and, as a rule, in low abundance. Their distribution seems to be related to mosses, as already mentioned by Broady [14] in his review on terrestrial algae in Antarctica. They were not found on soil and among tufts of *Deschampsia antarctica*, and in aquatic habitats occur in places with mosses in the proximity. Their higher diversity and abundance in shallow brooks and on irrigated rocks might be due to the transportation by water that trickles among mosses.

Several diatoms (*Fragilaria capucina*, *Nitzschia homburgiensis*, *Planothidium delicatulum*, *Nitzschia gracilis*) and blue-green algae (*Phormidium aerugineo-coeruleum*, *P. autumnale*, *Leptolyngbya fragilis*) are typical of the aquatic habitats on Livingston Island. *Nitzschia homburgiensis*, *Nitzschia gracilis* and *Planothidium delicatulum* are among the most frequent diatoms in ponds, puddles and slow-flowing waters on King George Island [15], and *Fragilaria capucina* is often a dominant species in different water bodies in the Antarctic and Sub-Antarctic [16]. *Phormidium aerugineo-coeruleum*, *P. autumnale* and *Leptolyngbya fragilis* are widely distributed in different habitats in Antarctica, the last one is abundant in streams [17]. The presence in the terrestrial habitats of some species, usually found in aquatic habitats on Livingston Island, could be explained with their transportation by water [3] from other habitats or from the water bodies in the vicinity.

Glacier streams have poor algal flora. This might be related to their turbid water. The turbidity of water is known to be one of the main factors that affect the abundance and distribution of algae in Antarctic streams [18].

Lakes are also characterized with comparatively low species diversity. This could be related to several factors. The bottom of the lakes is sandy and there are few stones for algae to attach. The later thaw of the lakes in summer shortens the period with favourable conditions for algae to grow. Lakes differ with lower water temperature. Our observations (still preliminary unpublished results) show that this factor influences the distribution of diatoms in aquatic habitats on Livingston Island.

In the seasonally stable water habitats (those that are formed every summer), same dominant species develop every year and there is a high percentage of similarity in the species that occur from year to year. Conversely, differences exist from year to year in the algal flora of mosses and soils from one site. They could be caused by differences in the concrete conditions [3]. An important factor that influences the distribution and abundance of algae in these habitats is the moister content [10], which may vary in summer and in different years in dependence of the concrete climate conditions and snow melt. Differences were also found in the species that develop in cultures from year to year. This could be related to heterogeneity of propagules that get into cultures [10].

The pattern of the distribution of algae in the studied habitats shows that many species are able to live in both aquatic and terrestrial habitats and clear boundaries between them do not exist. This confirms the observations made by Broady [14].

The algal flora of Livingston Island is typical of the Maritime Antarctic region. It consists of a large number of species with wide, cosmopolitan range and few Antarctic and Sub-Antarctic species. The prevalence of cosmopolitans in Maritime Antarctica has been observed in earlier studies on diatoms [1–3, 13]. In the reports of blue-green, yellow-green and green algae also widely distributed species predominate.

However, it is believed that the number of endemic species to Antarctica is higher than we actually know, but they remain "hidden" due to the use of unsuitable keys for determination of Antarctic algae, which often leads to "fitting" of the unknown Antarctic species to morphologically similar species from other latitudes [19, 20]. These species could be even ecologically different [19]. According to Mann and Droop [21] the real number of truly cosmopolitan and endemic species could be estimated only after extended studies with the use of more reliable taxonomy. This seems to be true not only for diatoms but for other algae as well.

Acknowledgments. We are grateful to the Bulgarian Antarctic Institute for the provided logistical support. Special thanks are due to Nikolay Stanchev for his help in the field work.

REFERENCES

[1] Temniskova-Topalova D., N. Chipev, K. Manoilova. Bulg. Antarc. Res., Life Sciences, **1**, 1996, 31–61.
[2] Chipev N., D. Temniskova-Topalova. Ibid., **2**, 1999, 32–42.
[3] Temniskova-Topalova D., N. Chipev. In: Proceedings of the 16th International Diatom Symposium (ed. Economou-Amilli), 25 Aug.–21 Sept. 2000, Athenes & Aegean Islands, Greece, 2001, 291–314.
[4] Temniskova-Topalova D., I. Kirjakov. Bulg. Antarc. Res., Life Sciences, **3**, 2002, 51–68.
[5] Temniskova-Topalova D., R. Zidarova. Ibid., **4**, 2004, 69–82.
[6] Thompson A. S., J. C. Rhodes, I. Pettman (eds). Culture Collection of Algae and Protozoa, Catalogue of Strains, Ferry House, 1988.
[7] Hasle G., G. Fryxell. T. Am. Microsc. Soc., **89**, 1970, 469–474.
[8] Clarke K. R., R. N. Gorley. Primer v5. Roborough, Plymouth, UK: Plymouth Marine Laboratory, 2002, `www.primer-e.com`
[9] Cavacini P. Polar Biosci., **14**, 2001, 45–60.
[10] Ohtani S., K. Suyama, H. Yamamoto, Y. Aridomi, R. Itoh, Y. Fukuoka. Polar Biosci., **13**, 2000, 113–132.
[11] Spaulding S. A., J. P. Kociolek, D. Wong. Phycologia, **38**, 1999, 314–341.
[12] Van de Vijver B., H. Van Dam, L. Beyens. Nova Hedwigia, **82**, 2006, 69–79.
[13] Van de Vijver B., L Beyens. Antarct. Sci., **9**, 1997, 418–425.
[14] Broady P. A. Biodivers. Conserv., **5**, 1996, 1307–1335.
[15] Kawecka B., M. Olech, M. Nowogrodzka-Zagórska, B. Wojtun. Polar Biol., **19**, 1998, 183–192.
[16] Van de Vijver B., Y. Frenot, L. Beyens. In: Bibliotheca Diatomologica **46** (eds H. Lange-Bertalot, P. Kociolek). J. Cramer, Berlin-Stuttgart, 2002.
[17] Izaguirre I., H. Pizarro. Polar Biol., **19**, 1998, 24–31.

[18] Hawes I., P. Brazier. Antarct. Sci., **3**, 1991, 265–271.
[19] Mataloni G., J. Komárek. Polar Biol., **27**, 2004, 623–628.
[20] Van de Vijver B., N. J. M. Gremmen, L. Beyens. J. Biogeogr., **32**, 2005, 1791–1798.
[21] Mann D. G., S. J. M. Droop. Hydrobiologia, **336**, 1996, 19–32.

Department of Botany
Faculty of Biology
St. Kl. Ohridski University of Sofia
8, Dr. Tsankov Blvd
1164 Sofia, Bulgaria
e-mail: `ralliez@abv.bg`