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Kateřina Kopalová

Taxonomy, ecology and biogeography of aquatic and limno-terrestrial diatoms (Bacillariophyta) in the Maritime Antarctic Region

Supervisors of the thesis

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Prague, June 2013

I thereby declare that this thesis has not been submitted in order to obtain the same or any other academic degree earlier or at another institution. My involvement in the research presented in this thesis is expressed in the authorship order of the included publications and manuscripts. All publications and other sources I used when writing this thesis have been properly cited.

In Prague, June 2013

Kateřina Kopalová

JUSTIFICATION OF THE CONTRIBUTION TO THE DIFFERENT PUBLISHED PAPERS

I declare that the contribution of the PhD-candidate, Mgr. Kateřina Kopalová, to the different published papers can be considered more than sufficient to justify the inclusion of these papers in this PhD thesis.

For the taxonomical chapters 2 and 4, for which Mgr. Kateřina Kopalová is first author, the PhD-candidate prepared part of the samples prior to microscopical analysis, made the microscopical observations, photographed and analysed the diatom flora and compared the unidentified species with known taxa from all over the world. The contribution of the co-authors has been limited to guidance, assistance to the formal descriptions of the new species, help with finding the appropriate literature and stimulating discussions during the writing of the manuscripts. She wrote the major part of the manuscripts.

For the taxonomical paper in chapter 3, Mgr. Kateřina Kopalová contributed in analysing the samples, photographing the unidentified diatoms, assembling plates for the publication and partly writing of the manuscript. Her contribution can be considered sufficient to warrant its inclusion in this PhD thesis.

The ecological papers (chapters 5, 6 and 7) for which Mgr. Kateřina Kopalová is first author, the PhD-candidate prepared part of the samples, analysed them and performed part of the statistical analyses. For some analyses, assistance was provided by the co-authors.

For the co-authors

Bart Van de Vijver
National Botanic Garden of Belgium

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PREFACE AND ACKNOWLEDGEMENTS

My name is Kateřina Kopalová and I was born 3. 7. 1984 in North Bohemia in the Czech Republic. After graduating from high school, in 2004 I started my Biology studies at Charles University in Prague, later at the Department of Ecology, focusing on Hydrobiology. In 2009, I obtained a Master´s Degree with the following thesis: 'Taxonomy, ecology and biogeography of limno-terrestrial diatoms in the Maritime Antarctic Region'. Already during my bachelor studies, I had the opportunity to work on biological material from the Antarctic region and I continued using this material up till now, in the framework of my PhD thesis. Since January 2011, I have been doing my PhD work mostly in the Algology lab at the National Botanic Garden of Belgium as an Erasmus student, based at the University of Antwerp. My work is mostly concentrated on area of James Ross Island, but I have been closely working with Bart Van de Vijver from the National Botanic Garden of Belgium, broadening my research area to other Antarctic localities such as Livingston Island. Recently, I have finished my Phd study with topic of ecology, taxonomy, diversity and biogeography of Limno-terrestrial and aquatic diatoms in the Antarctic region. Since 2011, I have collaborated also in an education and research program dealing with Arctic environment from Spitsbergen where I regularly go during summer periods. An important part of my studies was also definitely my trip to Antarctica in the austral summer 2012, where I had the opportunity to see myself the locality I have built my PhD on my own. Besides my interest in research and science, I devote most of my free time to classical music and for quite some time, I studied viola at the Conservatory and I regularly play in the symphonic orchestra at home and abroad. Apart from playing viola, my favourite hobby is horse riding - competition in show jumping and dressage, filling almost all my remaining free time.

Here, I would like to thank everyone who has had anything to do with this thesis and to everyone who supported me during my study. I am not able to mention everyone as it would make this chapter much longer than the thesis itself but will mention at least some of them:

My special thanks belong to my two great supervisors Linda and Bart for their enormous patience with my (not always easy) work. The first time I met Linda I was a bachelor student asking for a completely different limnological topic for my bachelor thesis and she offered me the ‘diatom topic from Antarctica’. I would lie if I claimed that I was interested in diatoms, *but to do something related to Antarctica was so exciting that I accepted. I am not sure whether she realized at that time that she would be stuck with me for so many years☺.*

In March 2007 as a student-diatomologist I was required to go to a meeting in Berlin to present my first results. When I put my poster on the wall I was informed by a man in a blue jacket (Bart Van de Vijver) that my identifications were completely wrong. Nevertheless, what followed was an invitation to correct my data in his lab in the National Botanic Garden of Belgium. I was asking myself all the time whether he would have done it again had he known that he would be my supervisor also for my master and Ph.D theses. But I am so grateful that I had the opportunity to learn diatom taxonomy correctly right from the beginning and that I could explore the Antarctic Science with a real specialist. To work in his lab was an invaluable experience and a real pleasure.

That this thesis has been written is thanks to these two amazing people and their big help and pleasurable cooperation during the past years, and therefore 'Thanks A LOT for your time, scientific, technical, financial and also personal advice which helped me enormously with my work and also in personal life'.

Talking about Antarctic Science, I would like to give a polar thanks to Daniel Nývlt who gave me the opportunity to go there via his project. Working with Antarctic material, I naturally wanted to go there and see it myself and he made my dream real. He is the third main person next to my supervisors who was always helping me and correcting all my texts, projects, ideas... and I am so glad I can collaborate with him on both hemispheres as is Antarctic and Arctic ground. Big Antarctic thanks also go to Bulgaria to my colleague Ralitsa Zidarova for a nice collaboration and big help with the diatom flora from Livingston Island. Other thanks go to Argentina to all my colleagues who were with me on James Ross Island in 2012 and also to all my friends who spent time with me in Marambio base while we were waiting for our helicopters. Especially to all pilots who taught me drink maté and made my time there unforgettable. Staying in polar region I would also like to mention my friends from the Centre of Polar Research (CPE) for a nice time in Petuniabukta (and not only there) and to thank people from Mendel station for their not only logistical support in Antarctica 2012. The last but not least polar thanks go to Professor Jiří Komárek and Josef Elster, who brought me *the first samples from James Ross Island. Furthermore, this thesis would not be there without support provided by my home Department of Ecology of the Charles University in Prague, the National Botanic Garden of Belgium, the University of Antwerp and also the Academy of Science in Třeboň. My thanks belong especially to Vojta Jarošík and Adam Petrusek as former and current heads of the Department of Ecology, to our great secretary Lenka, who had from time to time a lot of work with me and to Jan Rammeloo and Steven Dessein as former and current directors of the Botanic Garden in Meise in Belgium who gave me the opportunity to use their facilities and stay in their institute.*

I wish to acknowledge all colleagues from Botanic Garden, especially people from the Department of Cryptogamy led by Jérôme Degreef for the nice time I could spend with them during my stay in Belgium, especially for our common lunchtimes and coffee breaks. I would also like to thank Myriam for the assistance she offered to me at the laboratory work and many diatom hunting trips with the electron microscopy. Big thanks go to Ann for her constant happiness (she always made me smile again in times of troubles), to Wim (for his science fiction comments and zombie jokes) and also to Petra (for her calming effect and scientific help she offered me not only during last days of finishing this thesis). Many thanks go to Sven and Natasha for their enormous patience with most of my figures and tables in my papers and in this thesis as well. Also thanks to all participants of Spitsbergen trekking group for a nice holiday. Furthermore, I would like to thank people from the Protistology & Aquatic Ecology lab of Ghent University for the opportunity to participate in some of their projects and fruitful and useful conversations about science. I am especially grateful to Elie for his big help with analysing my data and Wim and Koen for nice moments during the Gent IDS meeting and not only that. It was always a pleasure to be in your department in all respects.

I would like to thank all my friends and huge thanks go to my best friend Evka for the time she always has for me when I need it. I am really glad that we got lost in one of the field excursions together and that we had to walk a lot to be able to find our way back home as it was THE moment when our great friendship had been built. We have had an amazing time together during excursions, field trips, exam periods.... and when I wanted to drop biology sometimes, she was always the reason why I had never done so. I am really happy to have *such a friend who supported the L-strategy so well. Big thanks go also to all my friends and colleagues from my home department. Thanks for all the great moments we spent together during our field courses and outside of university. Furthermore, I would like to give a big thanks to all my 'horse friends' especially Drahoš and Jitka for the nice time I always could have in the stable and for all care provided to Legenda. Thanks to all of them I could always go abroad, knowing that everything will be fine with her.*

The artistic musical thanks go to Mechelen to the orchestra led by Tom Van den Eynde. I cannot express what it meant to me that I could play there with you. At the beginning I was not able to speak any Dutch but I understood the music we played. It was always so relaxing for me and I found some nice friends as well. Thanks Mattijs for our common beers. Thanks to this orchestra everything what I knew from my studies at the conservatory has not been forgotten. When talking about music which occupies a large space in my life, I would like to thank my viola teacher Josef Fiala for all the lessons we had together and Gabriela Pechmannová for all the time she accompanied me on piano and the director Miroslav Brejcha for all things he 'did not see'in school rules. I was always a special student, old and needing special timing of my lessons, having special reasons of absences.... but everybody always did their best to give me the opportunity to study that school as well.

My extra-greatest thanks belong to my family, especially to my parents and my brother, who supported me all the time during my life in all possible ways. I really appreciated it, I still do and I always will! I will miss the incessant questions of my father: 'when are you going to study something normal or what are you actually doing? ' ☺ The enormous thanks for support provided during the last six years belong to my 'second Belgium family', who made my life abroad much easier, nicer and unforgettable. I will always remember the pleasant moments we spent together. From the beginning I felt as a real part of your family and I hope that our Belgium-Czech connections will not stop with finishing this Ph.D.

Thanks again to so many people that helped me on my (not always easy) path called Ph D and finally big thanks go to Adéla Balcarová and Kateřina Hronová for their English corrections.

Finally, I have been thinking a long time about the useful impacts of my PhD for the public ... and now I know it: it is the fact that more people in this world know what DIATOMS are and also that in Antarctica it is not possible to find a polar bear ☺

KATE

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ABSTRACT

Diatoms (Bacillariophyta) are one of the most diverse algal groups in the Antarctic Region and play a dominant role in almost all freshwater and terrestrial ecosystems. Despite this overall occurrence, little is known about the diversity, ecology and biogeography of this group in the Maritime Antarctic Region. The main objective of this thesis is therefore to define the taxonomical, ecological and biogeographical characterisation of aquatic, semi-aquatic and moss-inhabiting diatom communities from two islands in the Maritime Antarctic Region: James Ross Island and Livingston Island, located on opposite sides of the Antarctic Peninsula.

In this study, a total of 250 samples from three different habitat types (lakes, streams & seepage areas and mosses) from Byers Peninsula (Livingston Island) and Ulu Peninsula (James Ross Island) have been analysed. Using light and scanning electron microscopy, a rather diverse diatom flora composed of 178 taxa, belonging to 43 genera has been identified. Although even until recently, it was generally accepted that the Antarctic diatom flora was mostly composed of cosmopolitan taxa, several new species could be described as a new for science during this PhD study (a reflection of this work is presented in **chapters 2** & **3** and in **Appendices)**. Habitat type and geographical position of the islands seem to play a primary role in determining the composition of the diatom communities, apart from the impact of several physico-chemical parameters of their environment. The analyses of the different freshwater diatom communities on James Ross Island and Livingston Island are presented in **chapters 4, 5** & **6**. The obtained ecological preferences (in this case conductivity) were used to construct a transfer function for James Ross Island lakes diatom communities. Additionally, the moss vegetation on the islands form an important habitat for semi-aquatic and terrestrial diatoms influenced by the availability of moisture and the presence of larger marine animals. **Chapter 7** provides results of moss inhabiting diatom samples collected from Byers Peninsula and the area of Lagoons Mesa on James Ross Island.

Finally, in **chapter 8** all obtained results are discussed in an attempt to compare the diatom flora from both islands, showing a clear separation between the two islands. On a broader biogeographical scale, the Maritime Antarctic Region, as represented by the two studied islands, forms a separate and well-defined biogeographical entity with a highly specific diatom flora.

ABSTRAKT

Rozsivky (Bacillariophyta) představuji jednu z nejrozmanitějších skupin řas v antarktické oblasti, hrající dominantní roli téměř ve všech sladkovodních a suchozemských ekosystémech. Přestože se jedná o tak důležitou skupinu, její diverzitě, ekologii a biogeografii v oblasti maritimní Antarktidy bylo věnováno jen málo pozornosti. Hlavním cílem této práce je taxonomická, ekologická a biogeografická charakteristika sladkovodních, limno-terestrických a mechy osídlujících společenstev rozsivek ze dvou ostrovů v oblasti maritimní Antarktidy: z ostrova Jamese Rosse a ostrova Livingston, které se nacházejí na opačných stranách Antarktického poloostrova.

V této práci bylo analyzováno celkem 250 vzorků z různých typů habitatů (z jezer, potoků, mělkých mokřadů a mechů) poloostrova Byers na ostrově Livingston a poloostrova Ulu na ostrově Jamese Rosse. S využitím světelného a skenovacího elektronového mikroskopu byla popsána poměrně bohatá rozsivková flóra složená ze 178 druhů zastupujících 43 rodů. Ačkoli ještě donedávna bylo všeobecně uznáváno, že rozsivková flora antarktické oblasti se skládá z převážně kosmopolitních druhů, výsledky této práce a popis mnoha nových druhů (některé z nich prezentovány v **kapitolách 2**, **3** a **Appendixech 1-5**) tuto teorii vyvrací.

Zdá se, že vedle vlivu fyzikálně-chemických parametrů jednotlivých stanovišť, představuje významný faktor určující složení společenstev typ habitatu a geografická poloha jednotlivých ostrovů. V **kapitolách 4**, **5** a **6** této práce, jsou prezentovány výsledky analýz jednotlivých společenstev sladkovodních rozsivek z ostrova Jamese Rosse a ostrova Livingston. Zjištěné ekologické preference jezerních společenstev z ostrova Jamese Rosse byly použity k vytvoření kvantitativního modelu pro rekonstrukci konduktivity (´transfer function´). Dalším, pro rozsivky významným habitatem, je na studovaných ostrovech mechová vegetace, která je významně ovlivněna dostupností vlhkosti, případně přítomností velkých mořských živočichů. **Kapitola 7** shrnuje výsledky analýz společenstev rozsivek ze vzorků mechů odebraných na poloostrově Byers a v oblasti Lagoons Mesa na ostrově Jamese Rosse.

V závěru práce (**v kapitole 8**) jsou diskutována všechna získaná data ve snaze porovnat rozsivkovou flóru obou ostrovů. Jasné oddělení těchto lokalit je prezentováno i v širším biogeografickém měřítku. Oblast maritimní Antarktidy reprezentovaná dvěma studovanými ostrovy tvoří oddělenou a dobře definovanou biogeografickou jednotku s vysoce specifickou rozsivkovou flórou.

CHAPTER 1

General Introduction

Since the general public is rather unfamiliar with 'diatoms', a short introduction on the basic biology, (morphology, ecology and biogeography) of these organisms should ease the understanding and the interpretation of the results in this PhD thesis. The general characteristics of the Maritime Antarctic Region and more specifically of the two studied islands are described, with details on their geomorphology, climate, flora and fauna. A historical overview is presented of the diatom research so far done in this region. Furthermore, an overview is given of the main objectives and the contents of this thesis.

DIATOMS

General characteristics

Diatoms (Bacillariophyta) are probably the most species rich group of algae, with tens of thousands of species (Mann 1999) and have often been treated as a separate phylum, based on their unique features. Pascher (1914, 1921) suggested that diatoms share features with Chrysophyceae and Xanthophyceae and therefore placed these classes and the Bacillariophyceae in the phylum Chrysophyta. Ultrastructural and molecular sequence data have confirmed the general thrust of Pascher's idea, placing the diatoms unambiguously among the heterokont protists ('stramenopiles') within the chromalveolates (Adl et al. 2005).

The origin of diatoms may be related to the end-Permian mass extinction (~250 Ma), after which many marine niches were opened (Medlin et al. 2007). The earliest known diatom fossils date from the early Jurassic (~185 Ma), although molecular clock and sedimentary evidence suggest an earlier origin (Kooistra & Medlin 1996, Schieber et al. 2000).

The first certain observations of diatoms date back to the 17th century when early microscopists were fascinated by the mysterious world of diatoms. Later, mainly in 19th century, diatoms were admired for their various shapes and sizes. Due to the limitations of light microscopy (LM) and the late development of scanning electron microscopy (SEM), it lasted till the mid 20th century before the ultrastructure of the diatom cell walls was fully explored. This opened a new dimension of diatom taxonomy and led the way to a better classification and identification of diatoms.

Diatoms are pigmented, photosynthetic autotrophic organisms, with the exception of a few obligatory heterotrophic species mainly in the genera *Nitzschia* and *Hantzschia.* Their yellowish-brown chloroplasts are typical for heterokonts, with four membranes containing pigments such as the carotenoid fucoxanthin. Diatoms are characterized by a number of key features. They are most easily recognized by their siliceous cell wall (frustules). The biogenic silica of the cell wall is intracellularly synthesised by the polymerisation of silicic acid monomers. This material is then extruded to the cell exterior and added to the cell wall. The structure and ornamentation of this cell wall forms the basis of diatom identification (Round et al. 1990). A frustule consists of two equal halves called epivalve and hypovalve, connected by girdle elements (cingulum) encompassing the algal cell. (Fig 1.1). Two morphological groups are delineated: centric diatoms with a radial symmetry and pennate diatoms with bilaterally organized valves (Fig 1.1).

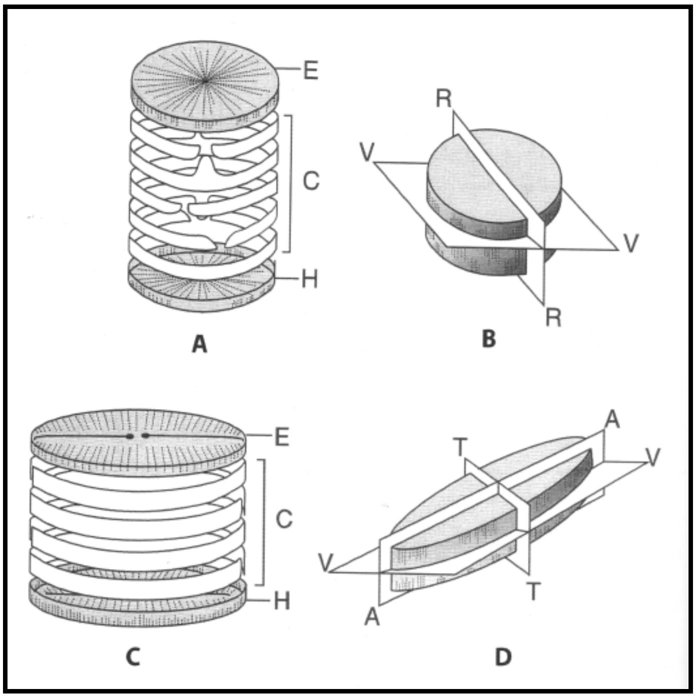


FIGURE 1.1 – Frustule structure and symmetry of diatoms. **A** – Centric diatom: *E* = epivalve, *C* = cingulum, *H* = hypovalve. The cingulum (girdle) consists of copulae (girdle bands). The copula adjacent to the valve is valvocopula. **B** – Centric diatom symmetry: *VV* = Valvar plane, *RR* = Radial plane. **C** – Pennate diatom: *E* = epivalve, *C* = cingulum with cingular elements (girdle bands), *H* = hypovalve. Valve face is the flat surface of the valve up to the margin; Mantle is the steep edge (side) of the valve. **D** – Pennate diatom symmetry: *VV* = valvar plane, *AA* = apical plane, *TT* = transapical plane. Apical axis connects the two poles through the median line. Perivalvar axis connects the centre of the epivalve to that of the hypovalve. (Figure taken from John 2012)

The Centrales (now called Biddulphiales) which have valve striae arranged basically in relation to a point, an annulus or a central areola and tend to appear radially symmetrical, and the Pennales (now called Bacillariales) which have valve striae arranged in relation to a line and tend to appear bilaterally symmetrical. The classification system developed by Simonsen (1979) and further developed by Round et al. (1990) is currently the most commonly accepted. Diatoms commonly found in the marine plankton may be divided into the centric diatoms including three sub-orders based primarily on the shape of the cells, the polarity and the arrangement of the processes. These are the Coscinodiscineae, with a marginal ring of processes and no polarity to the symmetry, the Rhizosoleniineae with no marginal ring of processes and unipolar symmetry, and the Biddulphiineae with no marginal ring of processes and bipolar symmetry. The pennate diatoms are divided into two sub-orders, the Fragilariineae which do not posses a raphe (araphid) and the Bacillariineae which posses a raphe.

Under favourable conditions diatoms can multiply quite rapidly, maintaining a dynamic population of variable cell size. Diatoms have a diploid life cycle and when a diatom divides to produce two daughter cells, each cell keeps one of the two halves and grows a smaller half within it. As a result, after each division cycle, the average size of diatom cells in the population gets smaller, which leads often to a considerable size and even shape variability within one species (Fig. 1.2). Once the cells reach a certain minimum in size, the cells will reproduce sexually reversing the size decline by forming an auxospore. This expands in size gives rise to a much larger cell, which then returns to size-diminishing divisions. Auxospore production is almost always linked to meiosis and sexual reproduction.

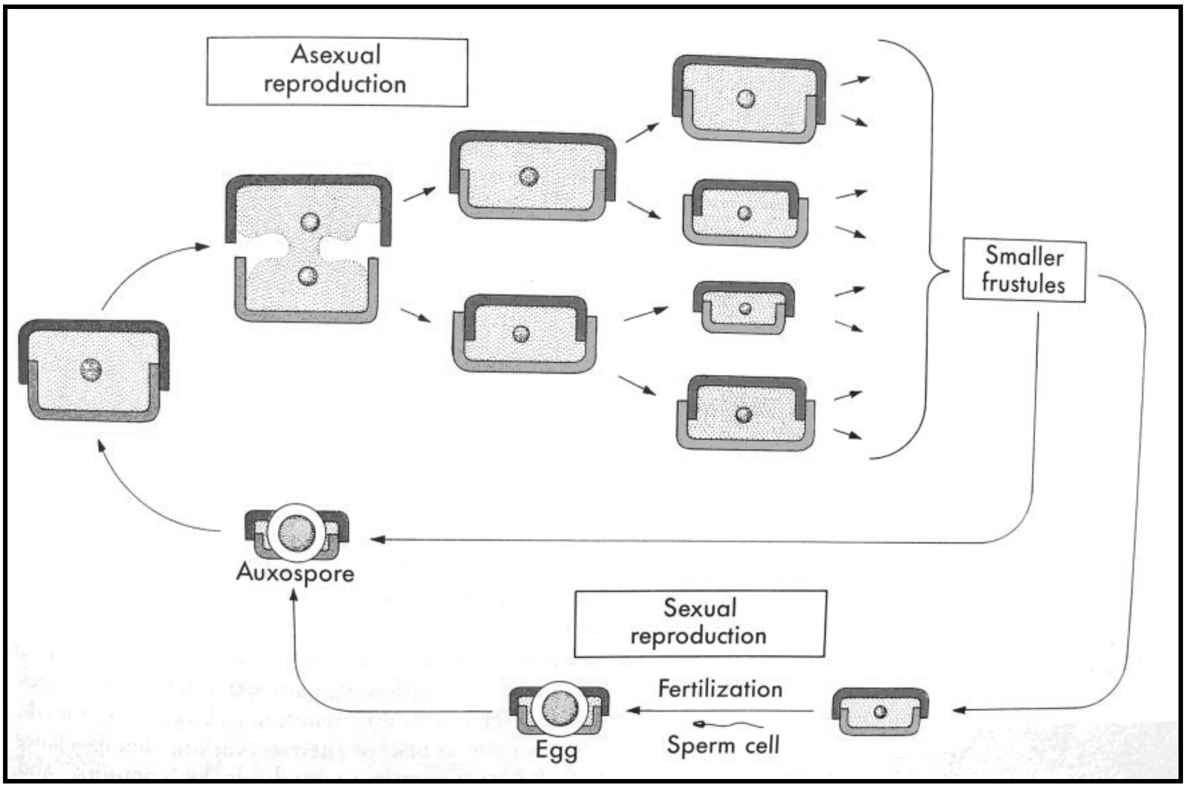


FIGURE 1.2 – Reproduction of diatoms showing diminution of cells in diatom populations. At each division, the new valve is always formed within the parental theca, causing the average size of the frustules in a population to slowly decrease. (Figure taken from www.bio.vu.nl)

Ecology

Diatoms inhabit a wide range of terrestrial and aquatic environments including marine, hyper-saline and freshwater habitats such as lakes, rivers, estuaries and oceans. They live in open water bodies as phytoplankton, but also as a surface film at the water-sediment interface (benthic), or even under damp atmospheric conditions. Diatoms are one of the most successful groups of unicellular algae and contribute significantly to the global carbon cycle. They play an important role in oceans, where they are estimated to contribute up to 45% of the total oceanic primary production (Werner 1977). Diatoms are unicellular, but can group together as filaments or colonies (e.g., *Aulacoseira, Melosira, Fragilaria*, *Meridion*, *Tabellaria*, *Asterionella*). While most centric and araphid diatoms occur in the plankton, raphid diatoms are especially diversified in benthic environments (in sediments or on various substrates) indicating the ecological advantages offered by the evolution of the raphe (Sims et al. 2006).

The principal factors controlling the distribution of the diatom flora are the physical and chemical characteristics of their habitats. Unfortunately, ecological data are lacking for a large part of the terrestrial diatoms since mostly marine and freshwater diatom species have been studied. Due to their characteristic silica outer cell wall and their significant responses to changes in their environment, they are often used as excellent bio-indicators or as proxies in paleoecological and biogeographical research and in water quality bio-monitoring. Nevertheless, the specific factors controlling diatom distribution are often unclear and the presence of several species complexes containing (pseudo)cryptic species complicates their use as indicators (Vanormelingen et al. 2008, Trobajo et al 2009). Breeding studies help to confirm whether cryptic species conform to a biological species concept and underscore the premise that the diatoms are underclassified as a group at the species level (Medlin 2010). Genetic diversity studies have shown that the diatoms have strongly structured populations both spatially and temporally (Medlin 2010). Several recent studies have questioned whether the geographical distribution of diatom species is only determined by species sorting, or by an interaction between local ecological and historical factors (Vyverman et al. 2007, Verleyen et al. 2009).

Biogeography and dispersal

Since diatoms tolerate a wide range of habitats and environmental conditions, they have been able to colonize all parts of the world, from the Tropics to the Polar Regions. In the Antarctic Region for instance, diatoms are one of the most common algal groups in terms of both species richness and number of individuals (Jones 1996, Van de Vijver & Beyens 1999a, Sabbe et al. 2003, Van de Vijver et al. 2005). For a long time, diatoms have been considered to be a group of protists with a cosmopolitan distribution according to the ubiquity hypothesis (Finlay 2002). This theory states that due to the vast population size of micro-organisms in combination with their small cell size, micro-organisms are easily dispersed (Baas-Becking 1934) making local extinction virtually impossible (Fenchel & Finlay 2004). Geographic isolation was therefore considered to be absent and as result, allopatric speciation was thought being rare or non-existent. In contrast, using a global freshwater diatom data set, Vyverman et al. (2007) were able to demonstrate that a latitudinal gradient is present in both local and regional genus richness which moreover differed between both hemispheres. This observation was explained by the degree of isolation and contradicted the idea that microbial dispersal should be considered to be virtually unlimited (Baas-Becking 1934, Finlay & Clarke 1999, Finlay 2002). In order to survive locally, diatoms have to be adapted to these extreme fluctuations in environmental conditions. Souffreau et al. (2010) investigated the tolerance of benthic diatoms to experimental desiccation and temperature stress. The results of these observations indicate that vegetative cells of benthic freshwater diatoms show a high sensitivity to desiccation, freezing and abrupt heating. This is in agreement with the high population differentiation observed in freshwater benthic diatoms and may explain the widespread endemism observed in freshwater diatoms.

In the past, Antarctic diatom taxa were often force-fitted into European and North American relatives (Tyler 1996), which led to the incorrect conclusion that the Antarctic diatom flora is mostly cosmopolitan (Toro et al. 2007, Vinocur & Maidana 2010). In contrast to previous studies, recent revisions of the non-marine diatom flora from the entire Antarctic Region based on a narrower species concept and a more fine-grained taxonomy, resulted in the description of a large number of (new) typical Antarctic taxa. Therefore, a high degree of endemism has been demonstrated in the Antarctic diatom flora (e.g., Sabbe et al. 2003, Kopalová et al. 2009, 2011, Van de Vijver et al. 2005, 2010a,b, 2011a, Zidarova et al. 2012).

Based on these new insights, a reconsideration of the Antarctic diatom biogeography was more than necessary and led to the statement that the Antarctic diatom flora is much more unique than previously accepted (Vyverman et al. 2007, 2010).

MARITIME ANTARCTIC REGION

Antarctica is Earth's southernmost continent. The term ‘Antarctic region‘ has traditionally been used for the entire southern region, later subdivided based on physical (Holdgate 1970) and biological (Longton 1988) differences into southern cold temperate, sub-Antarctic, Maritime Antarctic and Continental Antarctic Region. These ideas separated terrestrial habitats on the Antarctic Peninsula and the high latitude Southern Ocean islands from the main part of the Antarctic Continent where biogeographical zones differ significantly in climatic parameters and type of ecosystems (Walton 1984). These traditional terrestrial biogeographical zones in Antarctica are discussed in detail in Convey (2010) (Fig. 1.3). Recently this traditional concept was revised which led to the delimitation of 15 climatically and biologically distinct ice-free regions by combining the groups formed by the environmental domains and expert-defined bioregions (Terauds et al. 2012).

A generally accepted classification proposed by Holdgate (1970) defined the Maritime Antarctic Region as the zone concluded between the southern limit of the extensive, closed phanerogamic vegetation to the southern limit of the extensive cryptogamic (mainly bryophyte) communities, roughly comprising all landmasses between 70°S northwards to 55°S, including several islands and archipelagos (South Sandwich, South Orkney, South Shetland Islands, Palmer Archipelago), as well as the west coast of the Antarctic Peninsula south to Marguerite Bay. The Antarctic Peninsula is identified as a distinct bioregion separated from the Antarctic Continent (Chown & Convey 2007). Antarctic ice-free areas and surrounding islands are isolated pieces of lands with a different glaciological and geological history and this multi-scale spatial variation in the environment has profoundly affected the distribution of the biodiversity on the islands (Chown et al. 1998, 2002, Greve et al. 2005).

It has become clear that biogeographic (and historical structure) within the Antarctic terrestrial biota is far more complex than was previously thought. Inspections of patterns of species occurence in most of the major groups of terrestrial invertebrates (Acari, Collembola, Nematoda) occuring on the continent has identified a previously unrecognized but strong and ancient biogeographical boundary between communities of the Antarctic Peninsula and continental Antarctica, across which no species are shared in many of the groups present, has led to the naming of the 'Gressitt Line', a biogeographical boundary of similar significance to the Wallace Line of SE Asia (Chown & Convey 2007).

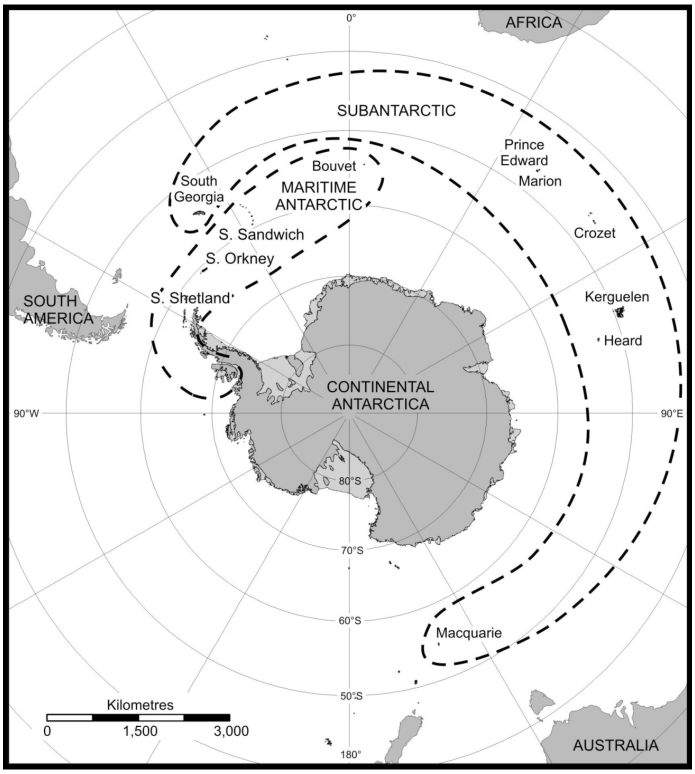


FIGURE 1.3 – Map of the Antarctic Continent and surrounding Southern Ocean, indicating the three commonly recognised terrestrial biogeographical zones within the region. Picture taken from Convey (2011)

South Shetland archipelago

The South Shetland Islands (61°00'–63°37'S, 53°83'–62°83'W) are part of the so-called Scotia Arc, a series of island groups that extends in the boundary between the northern tip of the Antarctic Peninsula and the southernmost part of South America. The islands are situated 940 km south of the Falkland Islands, and between 93 km (Deception Island) and 269 km (Clarence Island) northwest and north from the nearest point of the Antarctic Peninsula. The archipelago, covering a total area of about 4000 km^2, is located about 850 km of Cape Horn through the stormy Drake Passage. It comprises a ca. 500 km long chain of islands, islets and rocks, forming four major island groups with 11 main islands: Elephant (Mordvinov) and

Clarence (admiral Shishkov) Islands; King George and Nelson Islands; Robert, Greenwich, Livingston, Snow and Deception Islands; Smith and Low Islands. Livingston Island, the second largest of the South Shetland Islands, is one of the two target islands in the present PhD research and will therefore be presented in more detail.

Livingston Island

Geology and geomorphology

Livingston Island (LIV) is the second largest island of the South Shetland Islands, with a total surface area of about 950 km^2. The island (62°36′ S, 60°30′ W) is located approximately 110 km northwest of the Antarctic Peninsula and about 830 km southern of Cape Horn (Fig 1.4). It is almost entirely covered by a permanent icecap and several glaciers leaving only 10% of the land ice-free. The geology is mainly dominated by Upper Jurassic to Lower Cretaceous marine sedimentary, volcanic and volcaniclastic rocks. (Smellie et al. 1995). The terrain of the island is characterized by steep cliffs, moraine deposits and raised beaches reaching up to 20 m a.s.l. (Chipev & Veltchev 1996). The coastline (250 km long) is deeply indented and embayed of ice-cliffs or rocky headlands (Lindsay 1971). Based on geomorphological features, López-Martinez et al. (1996) divided Livingston Island into three main zones: an eastern mountainous area mainly covered by glaciers culminating at Mt. Friesland (1788 m a.s.l.); a central area with dome glaciers and an elevation of 200–400 m a.s.l. and a western lowland area (Byers Peninsula), the largest ice-free area of the island with a maximal elevation of only 80–100 m a.s.l.

Climate

Livingston Island has a typical maritime Antarctic climate, milder in comparison to the coastal areas of the Antarctic Continent. The mean annual temperature (measured at the Bulgarian Antarctic Base) is about –4 °C, with a winter minimum of –24 °C and a summer maximum of +7.5 °C (Chipev & Veltchev 1996), although in 2007, Toro et al. reported a maximum of +10 °C on Byers Peninsula. The relatively small air temperature amplitude can be explained by the influence of the ocean during wintertime and of the glaciers in summer. The thickness of the active permafrost layer is usually 30 cm. The most significant climatic features on Livingston Island include the cloudy summer days (less than 4% clear days in summer), high relative humidity with a minimum of 65% and strong pulsating winds with a velocity up to 28 m/s (Chipev & Veltchev, 1996). Precipitation is much higher than in any other Antarctic locality, with mean annual values of 700–1000 mm (Toro et al. 2007).

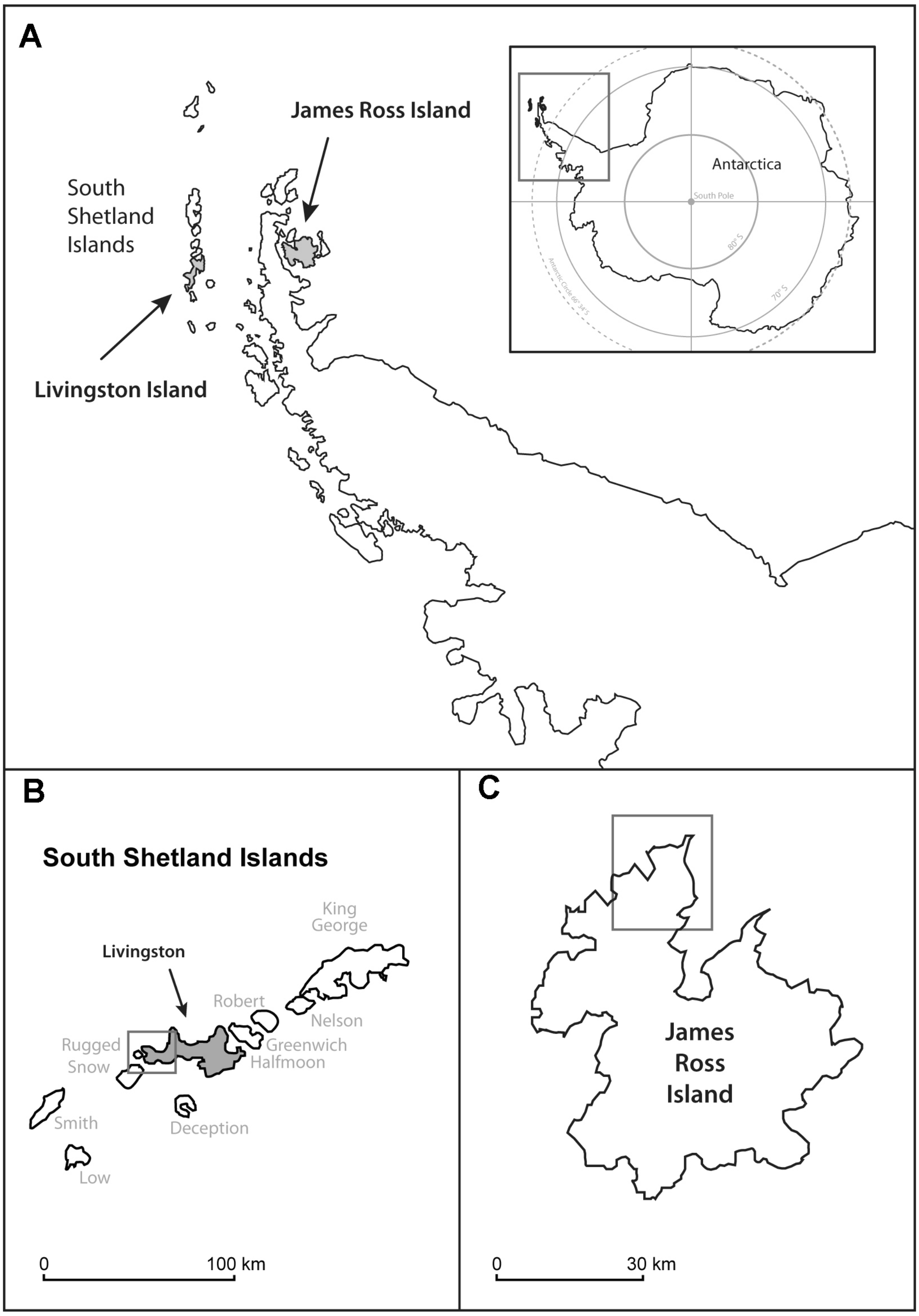


FIGURE 1.4 – Location of the South Shetland Islands and James Ross Island in the southern hemisphere close to the Antarctic Peninsula **(A).** Livingston Island (in grey) within the South Shetland Islands; Byers Peninsula in frame **(B).** Map of James Ross Island; Ulu Peninsula in frame **(C).**

Fauna and flora

Due to the harsh Antarctic climatic and light conditions as limiting factors for the vegetation, the vegetation cover on Livingston Island is scarce and has a mosaic structure. It is mainly formed by cryptogams, with lichens (more than 50 species) and mosses (over 29 species) (Sancho et al. 1999) being predominant and forming large carpets in the coastal areas (Toro et al. 2007). The presence of vascular plants is limited to only two species: the ´hair grass´ *Deschampsia antarctica* Desv. and the pearlwort *Colobanthus quitensis* (Kunth) Bartl. Fungal diversity is low with only three species of macromycetes currently reported (Guminska et al. 1994).

The invertebrate fauna on Byers Peninsula known at present comprises 23 taxa, (Usher & Edwards 1986, Richard et al. 1994, Block & Starý 1996, Convey et al. 1996). Larvae of the wingless midge *Belgica antarctica* (Jacobs) occur in limited numbers in moist moss vegetations, especially *Sanionia* carpets, although it is of very restricted distribution on Byers Peninsula (found especially near Cerro Negro) and may be near its northern geographical limit. The winged midge *Parochlus steinenii* (Gerke) and its larvae inhabit the margins of inland lakes and pools, notably Midge Lake and another near *Usnea* Plug, and are also found amongst the stones of many stream beds (Bonner & Smith 1985, Richard et al 1994).

The vertebrate fauna is rather poor and only composed of marine mammals and birds. On the shores of Livingston Island, only two medium-sized penguins (gentoo penguins (*Pygoscelis papua* Forster) and chinstrap penguins (*Pygoscelis antarctica* Forster)) breed annually in large rookeries of several thousand pairs. Apart from these penguins, several marine birds nest in the coastal areas of the island such as southern giant petrels (*Macronectes giganteus* Gmelin) or brown skua (*Catharacta lonnbergi* Mathews). Mammals are represented by five seal species of which the southern elephant seal (*Mirounga leonina* (L.)) is the most common one.

The human presence on the island is limited to two bases (occupied only in summertime) both on the coast of the South Bay: ‘St. Kliment Ohridski’ Base (Bulgaria) and ‘Juan Carlos I’ Base (Spain). Temporary field camps are regularly organized on Byers Peninsula.

Sampling area: Byers Peninsula

During the austral summer of 2009, fieldwork was conducted on Byers Peninsula (fig. 1.4A). A total of 71 surface sediment samples from 29 lakes, 18 pools and 8 streams together with 68 moss samples were collected. Byers Peninsula is the principal biodiversity hotspot on Livingston Island and is currently included within the list of the Antarctic Specially Protected Areas (ASPA No 126) because of its geological, biological and archaeological values. The peninsula is situated in the northwestern part of island and forms the largest ice-free area on the island and even on the entire Archipelago, covering almost 60 km^2 (Fig. 1.5). The central part of the Peninsula is a lowland plateau with an altitude of about 105 m a.s.l. The highest point is Cerro Start reaching 265 m a.s.l. The relatively flat relief of the plateau and the presence of over-deepened basins formed by glacial erosion have favoured water retention, and a large number of lakes and ponds were formed (Toro et al. 2007). Many inland lakes harbour aquatic ecosystems formed by aquatic mosses, cyanobacterial mats and populations of chironomids and crustaceans. The geology is mainly dominated by Upper Jurassic to Lower Cretaceous marine sedimentary, volcanic and volcaniclastic rocks (López-Martínez et al. 1996). A limnological survey was carried out and the hydrographic system and stream characteristics are described in detail in Toro et al. (2007).

No long-term meteorological records are available for Byers Peninsula. The climate is likely to be similar to that of Base Juan Carlos I on Hurd Peninsula, with a mean annual temperature of below 0 °C and temperatures rising above 0 °C for several summer months. Precipitation is relatively high with around 800 mm/yr, mostly falling as rain during summer. The peninsula is generally snow-covered during winter but becomes snow-free in January–March. Winds prevail from the Drake Passage in the north and northwest and Bransfield Strait to the south.

James Ross Island

Geology and geomorphology

James Ross Island (JRI) is a large island in the northwestern part of the Weddell Sea with an area of almost 2600 km^2. The island (64°10'S, 57°45'W) is located close to the northern tip of the Antarctic Peninsula, from which it is separated by the Prince Gustav Channel. Rising to 1,630 m a.s.l., it is irregularly shaped and extends (64 km) in a north–south direction. The island belongs to the transitory zone between the Maritime Antarctic and Continental Antarctic regions (Øvstedal & Lewis-Smith 2001). More than 80% of the island is covered by a permanent ice cap leaving only the northern part of the island, Ulu Peninsula, ice-free. The ice-free areas of James Ross Island are composed of two main geological units, namely Cretaceous marine sediments and subglacial Neogene to Quaternary volcanic rocks (e.g. Olivero et al. 2008, Smellie et al. 2008, Svojtka et al. 2009, Nývlt et al. 2011). Most of the volcanic eruptions took place during glacial periods under the ice cover (Smellie et al. 2008), which resulted in a specific volcanic landform, such as volcanic mesas that attain over 400 m a.s.l. (Lachman Crags, Davies Dome). In the northern part of the island, a high number of lakes, mostly induced by glacial erosion and deposition were formed after ice sheet retreat during the Holocene (Nedbalová et al. 2013).

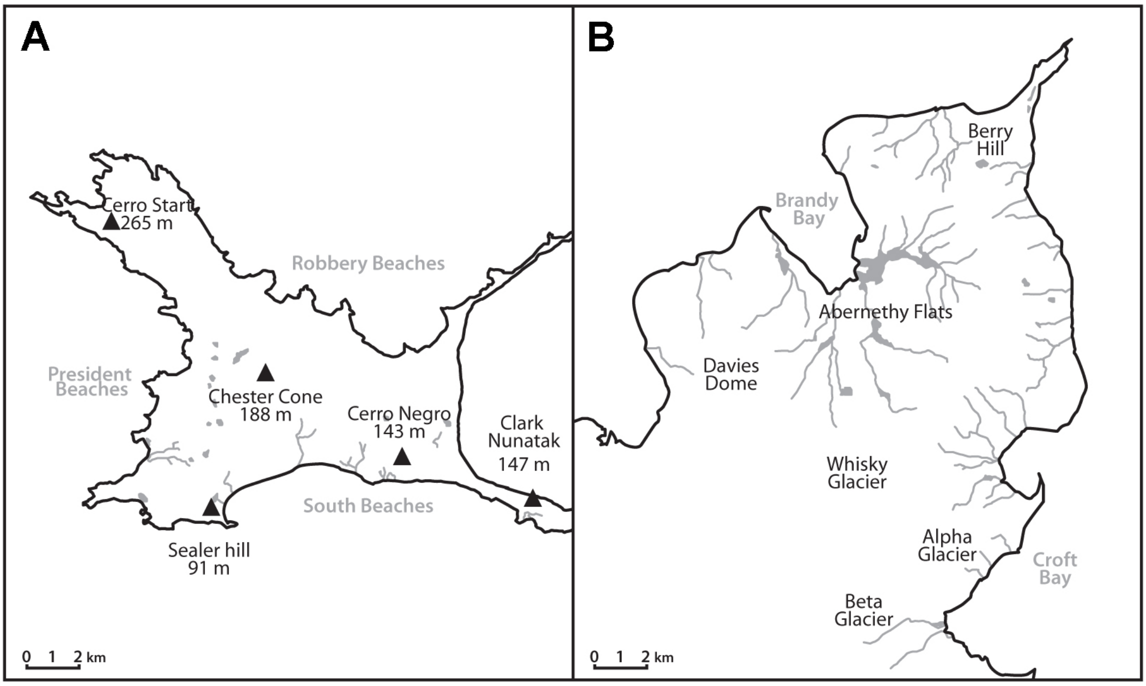


FIGURE 1.5 – Detailed map of the Byers Peninsula (**A**) and the Ulu Peninsula (**B)**

Climate

The climate of James Ross Island is typical for the transitional zone between the Continental and Maritime Antarctic. It is determined by cold, arid barrier winds from the south and by the presence of the precipitation shadow of the Antarctic Peninsula (Engel et al. 2012). In comparison with the South Shetlands Islands, the climate is more arid with a precipitation estimated to be less than 300 mm/yr. Owing to the dry air and often high wind speeds, the evaporation rate is high. The mean monthly air temperature exceeds 0 °C during the summer season, but only occasionally falling below –20 °C in winter. The annual mean air temperature at the Mendel Station was –7.2 °C in the period of 2006–2009 (Láska et al. 2010), so the island belongs to the zone of continuous permafrost (Washburn 1974, Fukuda et al. 1992). Further details on the climatic conditions can be found in Láska et al. (2011a) and Engel et al. (2012).

Fauna and flora

Physical conditions play a major role in determining the type of vegetation assemblages and biomass presence. The vegetation is composed solely of bryophytes and lichens and its distribution is usually limited due to the deficiency in liquid water (Robinson et al. 2003). They are located mainly in close neighbourhood of the lakes or streams. Lichens are one of the main vegetation components on the James Ross Island. Collections made by R.I. Lewis Smith in 1989 and 1999 reported 144 lichen species and 49 moss species from James Ross Island (based on METADATA database from British Antarctic Survey) (Láska et al. 2011b). *Usnea* species predominate in the vegetation of the ice-free areas on James Ross Island. On the other hand, the micro-flora, mostly composed of cyanobacteria, green algae and diatoms is well developed in freshwater ecosystems such as seepages, lakes and streams. Hawes et Brazier (1991) published one of first studies focussing on algal and cyanobacterial flora of streams from James Ross Island, but since that time, several more papers on freshwater algae and cyanobacteria have been published (e.g., Komárek et al. 2008, Komárek & Komárek 2010). Wetlands and streams are one of the most characteristic habitats of Maritime Antarctica (Elster 2002) usually supplied by melting water from retreating glaciers and snowfields (Engel et al. 2012).

The invertebrate fauna has been poorly studied. In lakes *Boeckella poppei* (Mrazek) and *Branchinecta gainii* (Daday) are present (Kopalová 2012, pers. observation). There are no penguin colonies on the shores of James Ross Island, only solitary individuals (mainly of *Pygoscelis adeliae* Hombron & Jacquinot) can be seen. Apart of penguins, several seabirds frequently visit the island. Marine mammals are represented by four seals.

The human presence is limited to the northern side of the island, where the Czech scientific base (Johann Gregor Mendel Station) was constructed in 2006, although summer campaigns have been regularly present for many decades within the ice-free area by several multi-disciplinary groups, mostly geologists and palaeontologists.

Sampling area: Ulu Peninsula

During the austral summers of 2004–2009, a total of 113 diatom samples was collected from different habitats of the Ulu Peninsula. Streams and seepages were sampled mostly in the surroundings of the Mendel research station located on the northern side of the island (Fig. 1.5B). A representative set of lakes were sampled and when possible, both epilithic and epipelic samples were collected in the littoral zone of the lakes, where periphytic communities are well developed. For the lake samples, more information on the physico-chemical characteristics is published in Nedbalová et al. (2013). Additionally, during the 2012 fieldwork, thirteen moss samples were taken for the analysis of moss inhabiting diatoms.

The Ulu Peninsula is the only large ice free area on James Ross Island, located close to the northern tip of the Antarctic Peninsula. Although the island is mostly covered by a permanent ice cap, the ice free area is characterized by the presence of a large number of lakes of glacial origin, seepages and streams (Nedbalová et al. 2013). Deglaciation of the area is dated before 12,5 ka (Nývlt, unpublished data). The streams are active during the entire summer season and sometimes reach a length of several kilometres. Microbial mats inhabit most of these streambeds where cyanobacteria and algae predominate (Komárek & Elster 2008). Seepages are usually less developed than on the western side of the Antarctic Peninsula and are much more isolated. The terrestrial vegetation is limited to bryophyte and lichen tundra. The deglaciated part is composed of Cretaceous back-arc basin sediments and mostly subglacial Neogene to Quaternary volcanic rocks (Smellie et al. 2008, Svojtka et al. 2009). The climate is characterized by short summers and the mean annual temperature at the Mendel station is –6,6 ˚C (Láska et al. 2010). Human presence is limited to the northern side of the island, where the Czech Johann Gregor Mendel Antarctic research station has been located since 2006.

DIATOM RESEARCH IN THE ANTARCTIC REGION

The first report on diatoms from the Antarctic Region dates from the middle of the 19th century when Ehrenberg in 1844 studied material collected during the expedition of James Clark Ross (1839–1843) to the Antarctic Continent. Since that time numerous expeditions to the Antarctic Continent and surrounding islands have been carried out and surveys have been performed at different localities throughout the region. The principal pioneer studies on the Antarctic diatom flora were made by Holmboe (1902), Van Heurck (1909), West & West (1911), Fritsch (1912, 1917), Carlson (1913) and Brown (1920). In 1979, Prescott listed all studies published on algal groups from the Antarctic and sub-Antarctic region. Jones (1996) reviewed the diatom composition from Maritime and Continental Antarctic inland waters and terrestrial environments followed by Van de Vijver & Beyens (1999a) reviewing all sub-Antarctic diatom literature. The most comprehensive list so far was published in 2002 by Kellogg & Kellogg summarizing all existing data from the Antarctic and sub-Antarctic regions and providing an almost complete list of reported diatom taxa with their Antarctic and/or sub-Antarctic distribution. This list is dominated by species known from the Northern Hemisphere, whereas the number of Antarctic or sub-Antarctic taxa is remarkably low.

Biogeographical diatom reports

The past few years, there is an increasing interest in diatom research in the Antarctic Region. Several authors (e.g., Sabbe et al. 2003, Van de Vijver et al. 2005) hypothesized that the number of the typical Antarctic species is clearly underestimated mainly due to the lack of adequate literature for diatom identification in the Antarctic regions resulting in force-fitting (Tyler 1996) and species drift. This led to an increased effort, based on recent changes in the concept of diatom taxonomy, in the revision of the diatom flora of the Antarctic and sub-Antarctic regions and subsequently, in new biogeographical and palaeoecological insights (e.g., Soininen 2007; Verleyen et al. 2009; Sterken et al. 2012). These findings confirmed the hypothesis that the level of endemism in Antarctic diatoms is much higher than earlier reported and showed that even a narrow-regional endemism exists in the boundaries of the different parts of the Antarctic and sub-Antarctic regions.

So far, several genera have been entirely revised and a large number of new taxa has been recognized and described. Spaulding & Stoermer (1997) and Spaulding et al. (1999) described several new species of *Muelleria* from Antarctica and sub-Antarctica. An additional ten new *Muelleria* species from the South Ocean and the Antarctic Continent were added (Esposito et al. 2008, Van de Vijver et al. 2010b). Within the genus *Stauroneis*, 25 species were reported of which 18 were described as new (Van de Vijver et al. 2004a, 2005, Zidarova et al. 2009) based on a detailed examination of more than 850 samples from mosses, soils and lake sediments from different parts in the Antarctic and sub-Antarctic regions. The obtained *Stauroneis* data enabled to separate clearly the diatom flora from the Arctic and Antarctic Regions based on a high degree of regional endemism, contradicting earlier data that pointed towards a bipolar distribution for most of the observed *Stauroneis* species (Van de Vijver et al. 2005). Recent investigations within the genus *Luticola* on several islands in the Maritime Antarctic Region showed that the diversity of *Luticola* taxa in Antarctica has been underestimated in the past as well (compare for instance the list of *Luticola* species in Kellogg & Kellogg (2002) with recently published papers), which is probably related to the erroneous identification of a number of species as infraspecific taxa of *Luticola mutica* (Kütz.) D.G.Mann, *L. muticopsis* (Van Heurck) D.G.Mann or *L. cohnii* (Hilse) D.G.Mann. Apart of these taxa, 13 new *Luticola* species were described from Antarctica (Van de Vijver et al. 2006, Esposito et al. 2008, Van de Vijver & Mataloni 2008, Kopalová et al. 2011). Similar trends were observed in the genus *Hantzschia*. Whereas in most cases the only reported taxon is the cosmopolitan *H. amphioxys* (Ehrenb.) Grunow or its varieties (see Kellogg & Kellogg 2002), several samples collected on Livingston Island, yielded eight different *Hantzschia* taxa, five of which appeared to be new to science (Zidarova et al. 2010). During the revision of the genus *Navicula* s.str in inland waters of Antarctica and sub-Antarctica, a considerably lower number of *Navicula* s.str. taxa was found compared to the number listed in Kellogg & Kellogg (2002). Of 14 confirmed taxa, ten seemed to be restricted to the Antarctic and/or Sub-Antarctic regions. As already found in the genera *Muelleria* and *Stauroneis*, a clear regional endemism was observed, separating the islands of the Antarctic Peninsula region from the other parts of the Antarctic Region (Van de Vijver et al. 2011a).

Diatom records from Livingston Island

On Livingston Island, all diatom research was carried out on the two largest ice-free areas of the island: Hurd and Byers Peninsula. Björck et al. (1991, 1993) analysed the changes in Holocene lake sediments from two lakes on Byers Peninsula: Midge and Åsa lakes. Hansson & Håkansson (1992) studied the response of diatom communities along a productivity gradient of lakes in the Antarctic Peninsula area, including Livingston and King George Islands. They found that species richness in diatom communities is influenced by both resources available and factors related to latitude.

On Hurd Peninsula, almost all diatom research was done by Bulgarian scientists, facilitated by the presence of the Bulgarian Antarctic base on this peninsula. Temniskova-Topalova et al. (1996) and Chipev & Temniskova-Topalova (1999) reported 125 diatom taxa and investigated their diversity and distribution pattern in different terrestrial and aquatic habitats on the island. Later on, all data obtained during a five-year survey period were summarized by Temniskova-Topalova & Chipev (2001), reporting 190 diatom taxa. They concluded that the diatom flora of the island consisted mainly of cosmopolitan taxa. In a study of the algal biodiversity on the island, Zidarova (2007) discussed the distribution of algae (incl. diatoms) in the aquatic and terrestrial habitats on Hurd Peninsula. She found 302 algal taxa, of which diatoms appeared the most diverse (171 taxa). A full list of the recorded algae on Livingston Island was published a year later (Zidarova 2008). However, all reported taxa in these studies were considered cosmopolitan or at least being present in the Northern Hemisphere.

Byers Peninsula received far less attention from diatom scientists. Only a few studies, amongst which one discussing lake benthic diatom communities (Jones et al. 1993) and a second one reporting stream algal mats (Davey 1993) were published. A general description of the freshwater ecosystems in Byers Peninsula was made by Ellis-Evans in 1996 followed in 2007 by Toro et al. who investigated almost all aspects of the aquatic biodiversity on the peninsula. Their analysis of the diatoms led them to the conclusion that cosmopolitan diatoms prevailed with a low degree of endemism. During the International Polar Year 2007-2008, a new expedition to this peninsula allowed the start of a more thorough analysis of the diatom flora.

Prior to this PhD research, several taxonomical revisions were carried out. Detailed morphological observations using LM and SEM and careful comparisons with the type material of the 'so-called' cosmopolitan taxa resulted in the recognition and description of a large number of new species mainly in the genera *Hantzschia*, *Navicula*, *Geissleria*, *Placoneis*,and *Stauroneis* (Zidarova et al. 2009, 2010). Further analysis concentrated on the genera *Neidium* and *Planothidium* (Hamilton et al. in press, Van de Vijver et al. 2013).

Diatom records from James Ross Island

Despite growing interest in characterising the diatom communities of the Antarctic Region, the diatom flora of James Ross Island has only been poorly studied. Until recently, only studies, containing mainly paleoecological reports and none of them presenting a detailed diatom iconography, were published. The validity of the diatom identification can therefore not be checked or compared with recent publications.

Hansson and Håkansson (1992) studied 21 Antarctic lakes with three of them located on James Ross Island (N. and S. Cape Lachman and Monolith lakes) with the aim to assess the importance of environmental variables determining the species composition and abundance of periphytic diatoms. Of a total of 66 identified diatom taxa, the distribution of 16 species was investigated in detail, although the results do not allow any conclusions about community composition. Later, sediment from holes and cracks from Cretaceous marine sediments, exposed on James Ross Island, was processed for diatoms by Burckle & Wasell (1995). The objective was to study, if diatoms were also present in the sediment and determine their origin. Håkansson et al. (1995) analysed the diatom content and chemical composition of a sediment core from a lake in the Brandy Bay area to verify the interaction of organisms, environment and climate. During the observation, 27 diatoms could be identified to species level, but these results are questioned compared to the modern taxonomical concept. Finally, sediment profiles from several lakes in the northern ice-free area of James Ross Island were subject of a multi-disciplinary paleo-environmental investigation performed by Björck et al. (1996). The results contained also diatom analyses in which 43 identified and 7 unidentified diatom taxa were present. The construction of the Czech research station on the Ulu Peninsula in 2006, initiated a renewed interest in the diatom analysis of this peninsula which led to the publication of several papers describing new diatom species from James Ross Island (Zidarova et al. 2009, Van de Vijver et al. 2010a).

AIM AND OUTLINE OF THIS THESIS

This thesis focuses on the taxonomical and ecological characterisation of aquatic, semi-aquatic and moss-inhabiting diatom communities from two Maritime Antarctic islands (James Ross Island and Livingston Island) located in the Antarctic Peninsula region. Although located close to each other, their geographical position on different sides of the Antarctic Peninsula makes them interesting localities to explore the impact of environmental conditions on their diatom communities. Using a combination of physico-chemical and environmental parameters and species distribution, the overall aim of this thesis is to improve our understanding of the ecological preferences of both diatom communities and individual species on the two studied islands. Since a thorough morphological and taxonomical revision of most diatom taxa on these two islands, and the entire region in general, has never been done prior to this PhD. A taxonomic study of some groups using both light and scanning electron microscopy was compulsory to allow for a better ecological and biogeographical characterisation of the diatom communities.

More particularly, the thesis focuses on four key subjects:

- Floristic and taxonomic analysis of the diatom flora of both islands. How cosmopolitan is the Maritime Antarctic diatom flora? Can all observed taxa be identified using the currently available literature? Do new species have to be described?

- Ecological analysis of the diatom communities on both islands and their relationship with their environment. Is it possible to identify particular assemblages of diatoms in specific habitats? Do these diatom communities reflect specific ecological conditions? Can these ecological responses be translated in applicable transfer functions for further paleo-ecological research?

- Comparative analysis of the diversity and composition of the diatom communities on the two geographically contrasting islands. Does the position of the island result in differences in the diatom flora? How large is the influence of the Antarctic Continent in shaping the diatom composition?

- Biogeographical analysis of the position of the two islands in the entire Antarctic Region. What are the similarities with the other parts of the Antarctic Region? How diverse is the flora compared to the sub-Antarctic islands? What is the degree of endemicity of the Maritime Antarctic Region?

After a short introduction (Chapter 1), the main part of the thesis is subdivided into a more taxonomical-ecological part (Chapters 2– 4) and a ecological-biogeographical part (Chapters 5– 7) concluded by a general discussion of the obtained results (Chapter 8). More scientific papers related to my thesis are added as Appendices 1–5. Appendix 6 shows my Curriculum Vitae, including complete list of all publications, presented posters and lectures.

INTRODUCTION

Chapter 1 gives a brief introduction on diatoms, the general characteristics of the Maritime Antarctic Region and more specifically the two studied islands, and a historical overview of the diatom research in this Region.

PART I. DIATOM TAXONOMY

In **Chapter 2**, five new *Luticola* species found in lakes on the Ulu Peninsula (James Ross Island) are described. In this chapter, the methodology of describing new species is applied to five unknown species, belonging to a widespread genus in the Antarctic Region. The chapter can therefore serve as an example how every genus needed to be precisely analysed and revised before reaching the final species list that could be used in further ecological work.

Chapter 3 shows not only the descriptions of several very small-celled naviculoid species but adds also two species that have been previously described and compared to the Antarctic populations. For this, historical material needed to be analysed.

Chapter 4 analyses the taxonomy, morphology and biogeography of the non-marine diatoms in seepage areas and streams from James Ross Island. That way, the chapter serves as a pioneer study for the larger ecological study of all aquatic habitats on James Ross Island.

PART II. DIATOM ECOLOGY & BIOGEOGRAPHY

In **Chapter 5**, the freshwater diatom communities of the Byers Peninsula are analysed. The diversity and species composition of the different samples was determined using light microscopy. The similarity between the observed diatom flora and the flora on other Antarctic localities has been determined using the Sørensen similarity index. Using multivariate techniques, it was possible to classify the samples based both on their chemical characteristics and their diatom composition.

Chapter 6 deals with a similar analysis of the aquatic diatom flora of the Ulu Peninsula on James Ross Island. The diatom composition and species richness of the different samples is explored using similarity analysis, diversity analysis and various multivariate techniques. In addition, a transfer function for the main determining parameter is constructed.

In **Chapter 7**, all moss samples from both islands studied in this thesis, are analysed together. The flora is compared with the aquatic flora and with other moss-inhabiting floras in the other parts of the Antarctic Region. Multivariate techniques are applied to determine the different diatom assemblages living in the moss vegetations and the factors influencing this composition are explored.

GENERAL DISCUSSION

Chapter 8 provides an overview of the observed diatom flora. The diversity and composition on the two studied islands is explored and compared to the other Antarctic localities. The diatom composition of the different habitats is compared on two levels: between habitats and between islands. Finally, the results are combined with the global Antarctic diatom database to investigate the biogeographical position of the diatom flora of the Maritime Antarctic Region, represented by James Ross Island and Livingston Island.

APPENDICES

Appendices 1–5 present taxonomic surveys of the non-marine diatoms from islands in the Antarctic Region. All chapters provide a description of new diatom species and discuss also the comparison with similar taxa.

Appendix 6 shows my Curriculum Vitae

PART I.

DIATOM TAXONOMY

CHAPTER 2

Description of five new species of the diatom genus *Luticola* (Bacillariophyta, Diadesmidaceae) found in lakes of James Ross Island (Maritime Antarctic Region)

<u>Published as:</u> *Kopalová K., Nedbalová L., de Haan M. & Van de Vijver B. (2011) Description of five new species of the diatom genus* Luticola *(Bacillariophyta, Diadesmidaceae) found in lakes of James Ross Island (Maritime Antarctic Region). Phytotaxa 27: 44–60.*

During a survey of the non-marine diatom flora from lakes on James Ross Island (Maritime Antarctic Region), five new Luticola *species have been recorded:* Luticola desmetii, L. doliiformis, L. evkae, L. permuticopsis *and* L. tomsui*. Detailed morphology descriptions of these taxa are given based on both light (LM) and scanning electron microscopy (SEM). The morphological features of each taxon have been compared with similar taxa and notes on the ecology of the species have been added.*

Key words: *Bacillariophyta, diatoms,* Luticola*, new species, morphology, ecology*

Introduction

The genus *Luticola* D.G.Mann in Round et al. (1990) is a common constituent of the terrestrial ecosystems in the Antarctic Region. In recent years, a large number of new *Luticola* taxa have been described from this region, making the genus one of the most species-rich in the area. At present, 26 different taxa are confirmed from the Antarctic Region, while six others have been reported; their presence needs to be verified (Esposito et al. 2008, Kopalová et al. 2009, Van de Vijver et al. 2002a, 2002b, 2006, 2011, Van de Vijver & Mataloni 2008). The genus is characterized by uniseriate striae composed of rounded to transapically elongate areolae covered internally by perforated hymenes, an isolated, usually distinct stigma in the central area, a longitudinal canal positioned within the valve wall and a simple, filiform raphe with variable raphe endings (Round et al. 1990).

In 2007 only 63 taxa were reported (Fourtanier & Kociolek 2007). This low number is most probably the result of lumping morphologically comparable taxa into catch-all species such as *Luticola muticopsis* (Van Heurck 1909: 12) D.G.Mann (Round et al. 1990: 671) or *L. mutica* (Kützing 1844: 93) D.G.Mann (Round et al. 1990: 671) by force-fitting and species drift. Some authors promote the use of a more narrow species concept based on morphological and morphometric differences, a practice that clarifies the diversity of the genus (Van de Vijver & Mataloni 2008, Pavlov et al. 2009, Van de Vijver et al. 2011).

Most *Luticola* taxa show a preference for terrestrial environments such as soils and damp moss habitats (Van de Vijver et al. 2002a, Lowe et al. 2007). The few studies focussed on terrestrial diatoms is another element that may have resulted in the underestimation of the species richness of the genus.

In 2006, a new Czech research station was constructed on the Ulu Peninsula located in the northern part of James Ross Island, which offered the opportunity for a more thorough taxonomic and ecological survey of the non-marine diatom flora of this Antarctic site. Recently, several studies describing the diatom communities from seepage areas and streams have been published confirming the presence of a partly endemic diatom flora of this island (Kopalová et al. 2009, Van de Vijver et al. 2011, Kopalová et al. 2012).

In the present paper, several species from the genus *Luticola* are discussed based on detailed light and scanning electron microscopy observations, resulting in the description of five new taxa.

Study Area

James Ross Island (JRI) (64°10’S, 57°45’W) is a rather large island (2450 km²) located in the northwestern part of the Weddell Sea, close to the northern tip of the Antarctic Peninsula (Fig. 2.1). The island is situated in the transitory zone between the Maritime Antarctic and Continental Antarctic regions (Øvstedal & Lewis-Smith 2001). Although more than 75% of the island is covered by a permanent icecap, the northern part of the island, Ulu Peninsula, is almost completely ice-free. Details on the geomorphology and climate of the island can be found in Komárek & Elster (2008) and Komárek et al. (2008). Ulu Peninsula is characterized by the presence of a large number of lakes of glacial origin. The vegetation is limited to non-vascular plants and composed of a predominantly bryophyte and lichen tundra. Vascular plants are absent.

Material & Methods

During the austral summers of 2008 and 2009, a total of 52 samples were collected from 29 different lakes and one terrestrial site on Ulu Peninsula. Diatom samples were fixed with 3% formaldehyde. Sampling locations are indicated on Fig. 2.1. An initial survey of the samples showed that only a few samples contained *Luticola* taxa. Therefore, only specimens from these samples have been the subject of detailed morphological analysis. Samples used in this study are:

JRI2008-D07: sampling date 27/1/2008, S63°51’32.8’/W57°49’19.0”, wet soil near Lachman Crags

JRI2009-D39: sampling date 19/1/2009, S63°57’36.3’/W57°54’22.7”, stable, shallow lake, pH 7.7, specific conductance 53 µS/cm, temperature 7.4 °C, sample taken from the epilithon

JRI2009-D44: sampling date 19/1/2009, S63°57’37.1”/W57°53’54.8”, stable, shallow lake, pH 7.4, specific conductance 60 µS/cm, temperature 6.8 °C, sample taken from the epilithon

JRI2009-D51: sampling date 27/1/2009, S63°54’54.2”/W57°57’24.6”, small, kettle lake, pH 7.8, specific conductance 91 µS/cm, temperature 5.5 °C, sample taken from the epilithon

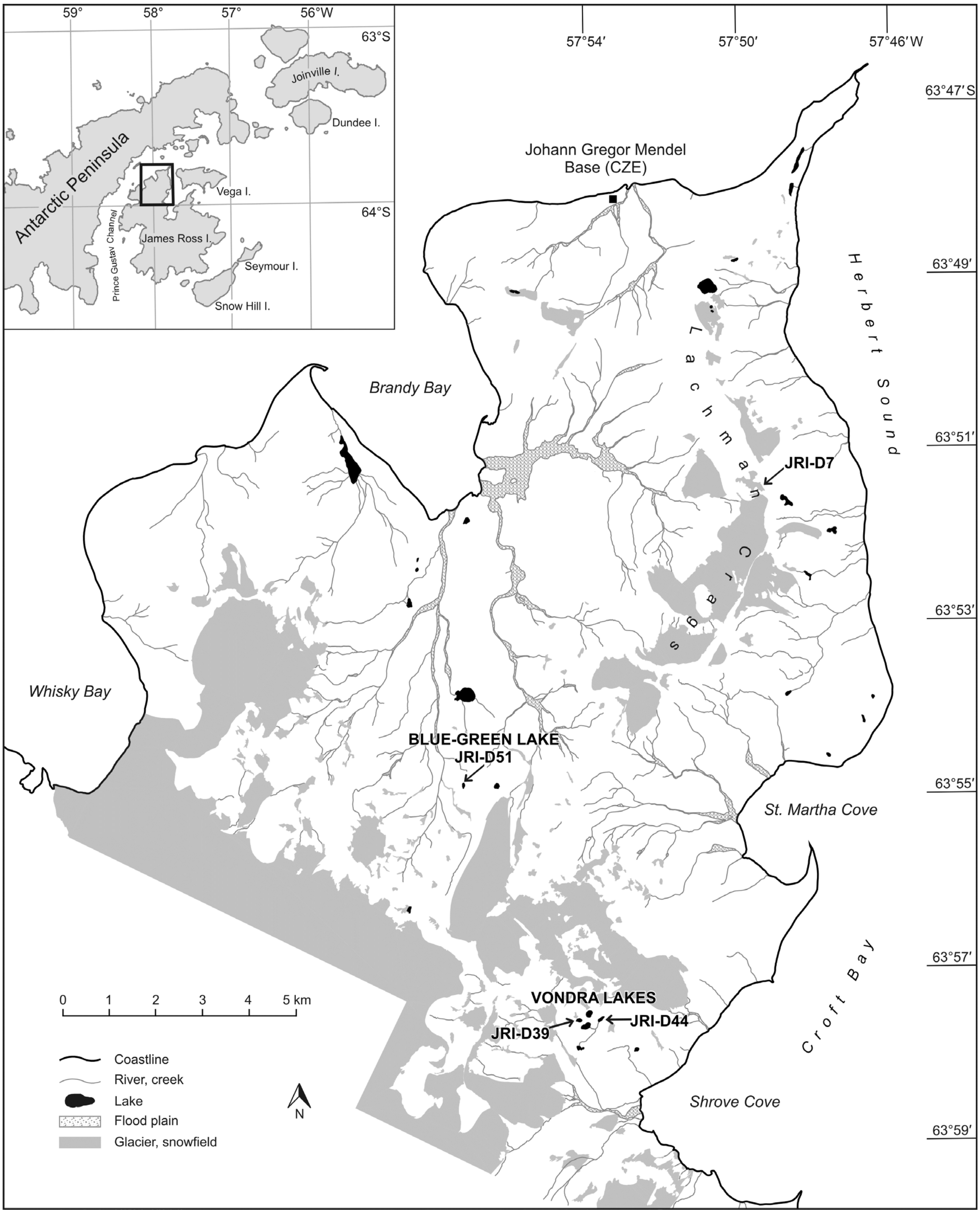


FIGURE 2.1 – Sketch map of northern part of James Ross Island (north-western part of the Weddell Sea, Antarctica) (Czech Geological Survey 2009) with position of study area and sampling locations indicated.

Diatom samples were cleaned by a modified method described in Van der Werff (1955). Subsamples were cleaned by adding 37% H_2O_2 and heating to 80 °C for about 1h. Oxidation of organic material was completed by addition of $KMnO_4$. Following digestion and centrifugation (10 minutes at 3700 x g), the resulting cleaned material was diluted with distilled water to avoid excessive concentrations of diatom valves on the slides, dried on microscope cover slips, and mounted in Naphrax®. Samples and slides are stored at the Department of Ecology, Charles University in Prague (Czech Republic) with duplicates at the National Botanic Garden of Belgium (Meise, Belgium).

Specimens were observed using an Olympus BX51 microscope equipped with Differential Interference Contrast (Nomarski) and Colorview I Soft Imaging System. For scanning electron microscopy (SEM), parts of the suspension were filtered using polycarbonate membrane filters with a pore diameter of 3 µm, pieces of which were fixed on aluminium stubs after air-drying. The stubs were sputter-coated with 50nm of Au and studied in a JEOL-5800LV at 25kV.

Morphological terminology follows Hendey (1964) and Round et al. (1990). The morphology of the new species has been compared with known European, Antarctic or South-American species using Hustedt (1966), Rumrich et al. (2000), Van de Vijver et al. (2002b, 2006, 2011), Esposito et al. (2008), Kopalová et al. (2009) and Van de Vijver & Mataloni 2008).

New taxon descriptions

During the Ulu Peninsula survey, 18 different *Luticola* taxa were found. The geographic distribution of the observed taxa indicates a highly specific *Luticola* flora on James Ross Island. Six *Luticola* taxa could not be identified using currently available literature. Although these six taxa were found to be the least numerous *Luticola* taxa in the samples, it was possible to undertake a detailed morphological analysis, with the exception of one taxon. Therefore, five taxa are described below as new species and compared with similar taxa from the Northern Hemisphere, the Antarctic Region and South America: *Luticola desmetii* Kopalová & Van de Vijver *sp. nov.*, *L. doliiformis* Kopalová & Van de Vijver *sp.*

nov., *L. evkae* Kopalová *sp. nov.*, *L. permuticopsis* Kopalová & Van de Vijver *sp. nov.* and *L. tomsui* Kopalová *sp. nov.*

Of the remaining 12 taxa, only two [*L. cohnii* (Hilse in Rabenhorst 1860: 962) D.G.Mann (in Round et al. 1990: 671) and *L. nivalis* (Ehrenberg 1853: 325) D.G.Mann (in Round et al. 1990: 671)] show a cosmopolitan distribution. Two taxa have a more widespread Antarctic distribution [*L. muticopsis* and its forma *reducta* (West & West 1911: 284) Spaulding (in Spaulding et al. 1997: 410)].

Six taxa [*L. australomutica* Van de Vijver (in Van de Vijver & Mataloni 2008: 458), *L. gigamuticopsis* Van de Vijver (in Van de Vijver & Mataloni 2008: 454), *L. higleri* Van de Vijver, Van Dam & Beyens (2006: 78), *L. vermeulenii* Van de Vijver (in Van de Vijver, Zidarova & de Haan 2011: 145), *L. truncata* Kopalová & Van de Vijver (in Kopalová et al. 2009: 118) and *L. adelae* Van de Vijver & Zidarova (in Van de Vijver, Zidarova & de Haan 2011: 148)] are at present only reported from the islands in the southern Atlantic Ocean (Van de Vijver et al. 2006, 2011, Van de Vijver & Mataloni 2008) or endemic to James Ross Island only (Van de Vijver et al. 2011). One taxon was already observed on the Antarctic Continent and the Maritime Antarctic Region: *L. austroatlantica* Van de Vijver et al. (in Esposito et al. 2008: 1383) whereas the last taxon, *L. gaussii* (Heiden in Heiden & Kolbe 1928: 623) D.G.Mann (in Round et al. 1990: 670) seemed to be previously only known from the Antarctic Continent (Esposito et al. 2008). Observation of *L. gaussii* on James Ross Island is the first record outside the Continent. This is not surprising considering the close vicinity of the Antarctic Continent and the fact that James Ross Island is considered part of the transitory zone between the Maritime Antarctic Region and the Antarctic Continent (Øvstedal & Lewis-Smith 2001). Nevertheless, the taxon has at present not been found on other localities in the Maritime Antarctic Region.

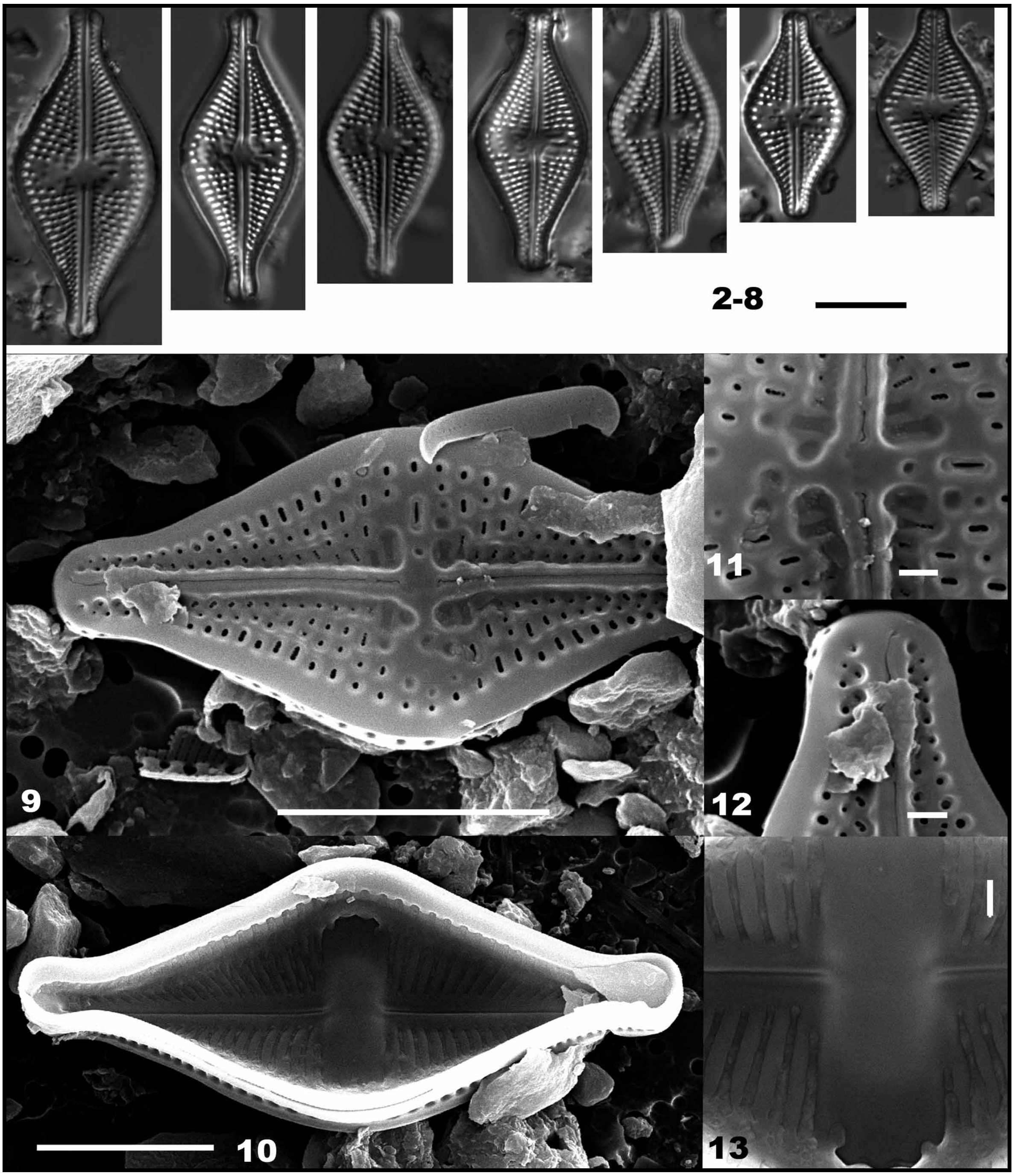
Luticola desmetii **Kopalová & Van de Vijver, sp. nov.** (Figs 2.2–2.13)

Valvae rhombicae at rhombicae-elliptica marginibus distincte convexis, apicibusque protractis, rostratis. Longitudo 22–42.5 µm, latitudo 11.3–16.8 µm. Area axialis angustissima, paene linearis ad linearis-lanceolata, leviter dilatata in aream centralem.

Sternum lineare adest marginatum depressionibus longitudinalibus. Area centralis irregularis, formans staurum rectangularem asymmetricum, marginatum serie una areolarum rotundatarum ad leviter transapicaliter elongatarum. Stigma solitaria magna rimiformis inter mediam partem valvae marginesque. Depressiones plures in area centrali, visibiles in microscopio photonico. Raphe filiformis, recta, terminationibus proximalibus indistinctis, fissurisque distalibus elongatis, deflexis. Striae transapicales radiatae in centro valvae, fortiter radiatae ad apices, 12–16 in 10 µm.

Valves rhombic to rhombic-elliptical with inflated, distinctly convex margins (Figs 2.2–2.8). Apices typically protracted, rostrate. Valve length 22–42.5 µm, valve width 11.3–16.8 µm (n=37). Axial area quite narrow, almost linear to linear-lanceolate, slightly widening towards the central area, formed by a raised, almost straight, linear sternum; bordered by longitudinal depressions (Fig. 2.9). Central area irregular, forming a rectangular, asymmetrical stauros, bordered by one series of rounded to very weakly transapically elongated areolae. One large, slit-like isolated stigma present, located halfway between valve margin and valve centre (Figs 2.9, 2.11). Multiple irregular, shallow depressions present in central area, visible in LM (Figs 2.9, 2.11). External raphe branches usually straight, with inconspicuous straight proximal raphe endings (Figs 2.9, 2.11). Distal raphe endings elongated, deflected towards stigma-bearing side (Figs 2.9, 2.12). Transapical striae radiate near valve centre, becoming strongly radiate towards poles, 12–16 in 10 µm. Pattern of areolae rather irregular. Striae usually composed of 2–3 small, rounded areolae and one slit-like areola close to valve margin (Fig. 2.9). Towards apices, striae composed of 1–2 strictly rounded areolae (Fig. 2.12). Internally, poroids of valve face occluded by hymenes (Figs 2.10, 2.13). Internal expression of stigma absent (Fig. 2.13). Distinct stauros visible (Fig. 2.13). Longitudinal canal covered by siliceous outgrowth (Figs 2.10, 2.13). Internal proximal raphe endings terminate on edge of stauros (Fig. 2.13). Distal raphe endings terminate on small helictoglossae (Fig. 2.10).

Type: ANTARCTICA. James Ross Island, Ulu Peninsula, Blue-Green Lake, sample D51, leg. *L. Nedbalová*, coll. date 27/01/2009, slide no. BR-4241 (holotype BR, Fig. 2.7 is the encircled holotype specimen), slide PLP-189 (isotype University of Antwerp, Belgium), BRM-ZU8/06 (isotype BRM).



FIGURES 2.2–2.13 – *Luticola desmetii* Kopalová & Van de Vijver sp. nov. Light (LM) and scanning electron micrographs (SEM). **Figs 2.2–2.8.** Light microscopy images of type specimens from James Ross Island showing variation in size (Fig. 2.7 is the holotype). **Fig. 2.9.** SEM of external view of entire valve, showing raphe structure, position of stigma and striae structure. **Fig. 2.10.** SEM of internal view of entire valve, showing typical structure for species in the genus *Luticola*. **Fig. 2.11.** SEM of external detail view of central area for specimen in fig 2.9. **Fig. 2.12.** SEM of external detail of polar endings, showing deflected raphe for specimen in fig 2.9. **Fig. 2.13.** SEM of internal detail of the central area. LM scale bar = 10 µm; SEM scale bar = 1 µm except for Figs 2.9 & 2.10, where scale bar = 10 µm.

Habitat, Ecology and Distribution: To date, *L. desmetii* has been found only in one small kettle lake (Blue-Green Lake) on James Ross Island close to the Whisky Glacier. The largest population was found in an epilithon sample. The lake had a pH of 7.8, a low specific conductance (91 µS/cm) and was relatively species rich with 32 species observed, dominated by *Nitzschia* taxa belonging to the complex around *Nitzschia perminuta* (Grunow in Van Heurck 1881: pl.68. Fig. 31) Peragallo (1903: 672) and *Psammothidium metakryophilum* (Lange-Bertalot & Schmidt in Schmidt et al. 1990: 64) Sabbe (in Sabbe et al. 2003: 242). A record from the South Shetland Islands (Håkansson & Jones 1994) has not be verified.

Etymology: *Luticola desmetii* is named after our dear friend and colleague Prof. Dr. Willem De Smet (University of Antwerp, Belgium) in honour of his Arctic and Antarctic limnological work.

Observations: At present, no *Luticola* taxa have a similar valve shape to *L. desmetii*. *Luticola higleri* and *L. katkae* Van de Vijver & Zidarova (in Van de Vijver, Zidarova & de Haan 2011: 143) have a similar irregular pattern of longitudinal depressions, raised sternum and shallow depressions in the axial and central area (Van de Vijver et al. 2006, 2011). However, both taxa have a different valve outline with clearly capitate apices (*L. katkae*) and broadly rounded valves (*L. katkae* and *L. higleri*). Moreover, *L. higleri* shows a distinct marginal rim on the valve face/mantle margin, which is absent in *L. desmetii*. Both have short distal raphe fissures in contrast to the elongated, deflected distal raphe endings in *L. desmetii*. At present, no taxon of *Luticola* has a similar valve outline. *Luticola heufleriana* (Grunow 1863: 155) D.G.Mann (in Round, Crawford & Mann 1990: 671) has weakly rhombic valves with clearly capitate apices, whereas *L. lagerheimii* (Cleve 1894: Taf. 7:11) D.G.Mann (in Round, Crawford & Mann 1990: 671) has a comparable outline but forms long chains, has deflected proximal raphe endings and short marginal spines. Björck et al. (1996) reported *L. heufleriana* from sediment cores taken in three lakes on Ulu Peninsula, close to Blue-Green Lake. Although this record could not be verified, due to the lack of samples and illustrations, it is highly likely that this taxon should be attributed to *L. desmetii*.

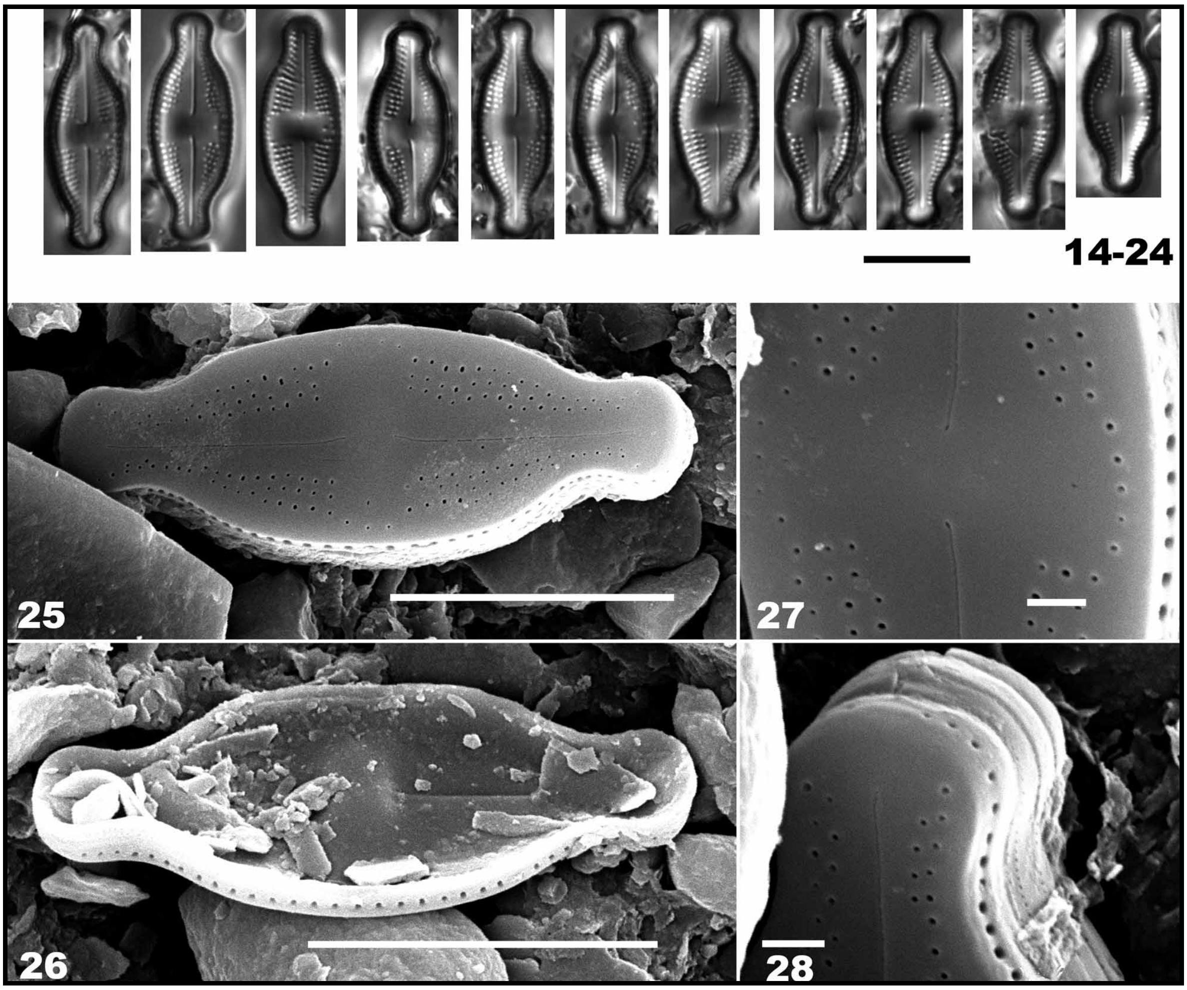
Luticola doliiformis **Kopalová & Van de Vijver, sp. nov.** (Figs 2.14–2.28)

Valvae lanceolatae marginibus convexis, apicibusque capitatis. Longitudo 17–22 µm, latitudo 7–8 µm. Area axialis lata, lanceolata, clare dilatata in aream centralem, leviterque dilatata in apices. Area centralis formans staurum rectangularem, marginatum serie una areolarum rotundatatrum. Stigma solitaria rotundata prope marginem valvae adest. Raphe filiformis, clare curvata, terminationibus proximalibus unilateraliter deflexis, fissurisque distalibuscurtis, rectis. Striae transapicales radiatae in centro valvae, convergentes ad apices, 18–20 in 10 µm. Areolae parvae, semper rotundae, 2–3 per striam.

Valves lanceolate with convex margins and capitate apices (Figs 2.14–2.24). Valve length 17–22 µm, valve width 7–8 µm (n=15). Axial area broad, lanceolate, clearly widening towards central area, only slightly widening towards apices (Fig. 2.25). Central area forming a broad, rectangular stauros, bordered by one series of small, rounded areolae (Fig. 2.27). One small, solitary, rounded stigma present, close to valve margin (Fig. 2.27). External raphe branches clearly curved, with weakly unilaterally deflected, simple proximal endings away from stigma (Fig. 2.27). Distal raphe fissures very short, straight (Fig. 2.28). Transapical striae radiate near valve centre becoming convergent towards apices, 18–20 in 10 µm (Fig. 2.25). Striae composed of 2–3 small, always rounded areolae (Fig. 2.25). Internal structure hardly visible since only one valve was found (Fig. 2.26). Clearly developed stauros present. Detail of internal stigma opening obscured by debris. Proximal raphe endings terminating on edge of stauros.

Type: ANTARCTICA. James Ross Island, Ulu Peninsula, Lachman Crags, sample D07, leg. *L. Nedbalová*, coll. date 27/01/2008, slide no. BR-4250 (holotype BR, Fig. 2.20 is the encircled holotype specimen), slide PLP-195 (isotype University of Antwerp, Belgium), BRM-ZU8/07 (isotype BRM).

Habitat, Ecology and Distribution: *Luticola doliiformis* was found in small cracks on wet soil on the table mountain Lachman Crags close to the glacier front. The sample was dominated by *Luticola cohnii*, *Hantzschia amphioxys* (Ehrenberg 1843: 413) Grunow (in Cleve & Grunow 1880: 103) and several unidentified species of *Diadesmis*.

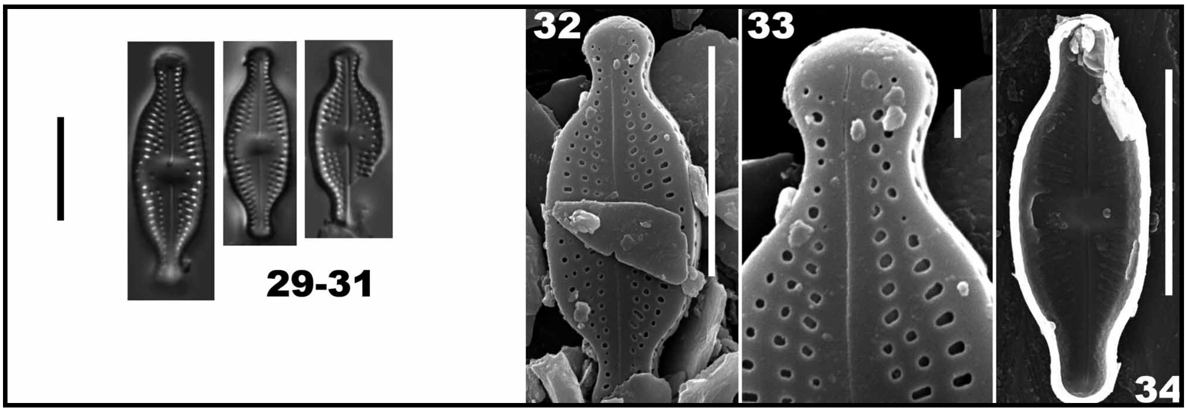


FIGURES 2.14–2.28 – *Luticola doliiformis* Kopalová & Van de Vijver sp. nov. Light (LM) and scanning electron micrographs (SEM). Specimens from James Ross Island. **Figs 2.14–2.24.** LM of size diminution series (Fig. 2.20 is the holotype). **Fig. 2.25.** SEM of external valve view. **Fig. 26.** SEM of Internal valve view. **Fig. 2.27.** SEM of external detail of central area **Fig. 2.28.** SEM of external detail of raphe endings. LM scale bar = 10 µm. SEM scale bars = 10 µm except for Figs 2.27 & 2.28, where scale bars = 1 µm

Etymology: This specific epithet *doliiformis* refers to its close resemblance to *L. dolia* (-*formis*: Latin for 'resembling').

Observations: The James Ross Island (JRI) specimen of *Luticola doliiformis* bears a strong resemblance to *L. dolia*, a taxon described from the McMurdo Dry Valleys on the Antarctic Continent (Esposito et al. 2008). The valve dimensions do not permit discrimination between the two taxa but there are other important differences. Unfortunately, in the original description of Esposito et al. (2008), the ultrastructure of the valves and girdle could not be examined as specimens were rare in the samples. Therefore, isotype material (INSTAAR Collection slide 532, isotype slide for *Luticola dolia*

Spaulding & Esposito, Esposito et al. 2008: 1385) was re-examined using SEM and two valves were found showing some of the morphological features enabling separation between *L. dolia* and *L. doliiformis* (Figs 2.29–2.34). Based on the description in Esposito et al. (2008) and our observations of the isotype material, several differences can be noted. The distal raphe fissures in the JRI population are very short contrary to *L. dolia* where slightly elongated fissures were noted (Fig. 2.33). The valve apices in *L. dolia* are usually much narrower than in *L. doliiformis* that have normally broadly rounded, enlarged apices (Figs 2.29–2.31). The shape and size of the areolae also differs with transapically elongated, larger areolae in *L. dolia*, whereas *L. doliiformis* has small, always rounded areolae (Figs 2.32, 2.33). Moreover, the number of striae in 10 µm is higher in the JRI population contrary to that stated in the original description (18–20 vs 14–18). Although the external stigma opening could not be observed in the isotype material, it is clear that, based on the LM and the internal SEM views of *L. dolia* (Fig. 2.34), the stigma opening is positioned more to the valve middle whereas in *L. doliiformis*, the stigma opening is closer to the valve margin (Fig. 2.25). Based on these differences, separation of these taxa can be made.



FIGURES 2.29–2.34 – *Luticola dolia* Eposito & Spaulding. Light (LM) and scanning electron micrographs (SEM). Specimens from isotype slide INSTAAR 532. **Figs 2.29–2.31.** LM images. **Fig. 2.32.** SEM of external valve view. **Fig. 2.33.** SEM of external detail of raphe endings. **Fig. 2.34.** SEM of Internal valve view. LM scale bar = 10 µm. SEM scale bars = 10 µm except for Figs 2.33, where scale bars = 1 µm.

Luticola evkae **Kopalová, sp. nov.** (Figs 2.35–2.50)

Valvae ellipticae-lanceolatae marginibus clare convexis apicibusque capitatis, late rotundatis. Valvae minores paene ellipticae. Longitudo 14–22 µm, latitudo 5.4–8.2 µm.

Area axialis latissima, lanceolata, leviter dilata in aream centralem. Ad apices, area axialis clare dilata. Area centralis formans staurum paene rectangularem, leviter dilatatum ad margines, marginatumque serie una areolarum minutissimarum. Stigma rotundata, punctiformis solitaria adest inter mediam partem valvae marginesque. Raphe filiformis, recta terminationibus proximalibus unilateraliter deflexis opposita stigma poris centralibus leviter expansis. Fissurae distales curtae, leviter deflexis. Striae transapicales radiatae in parte centrali valvae ad fortiter radiatae ad apices, 16–20 in 10 µm. Areolae rotundae 1–2 per striam terminans in areolam transapicaliter elongatam ad marginem.

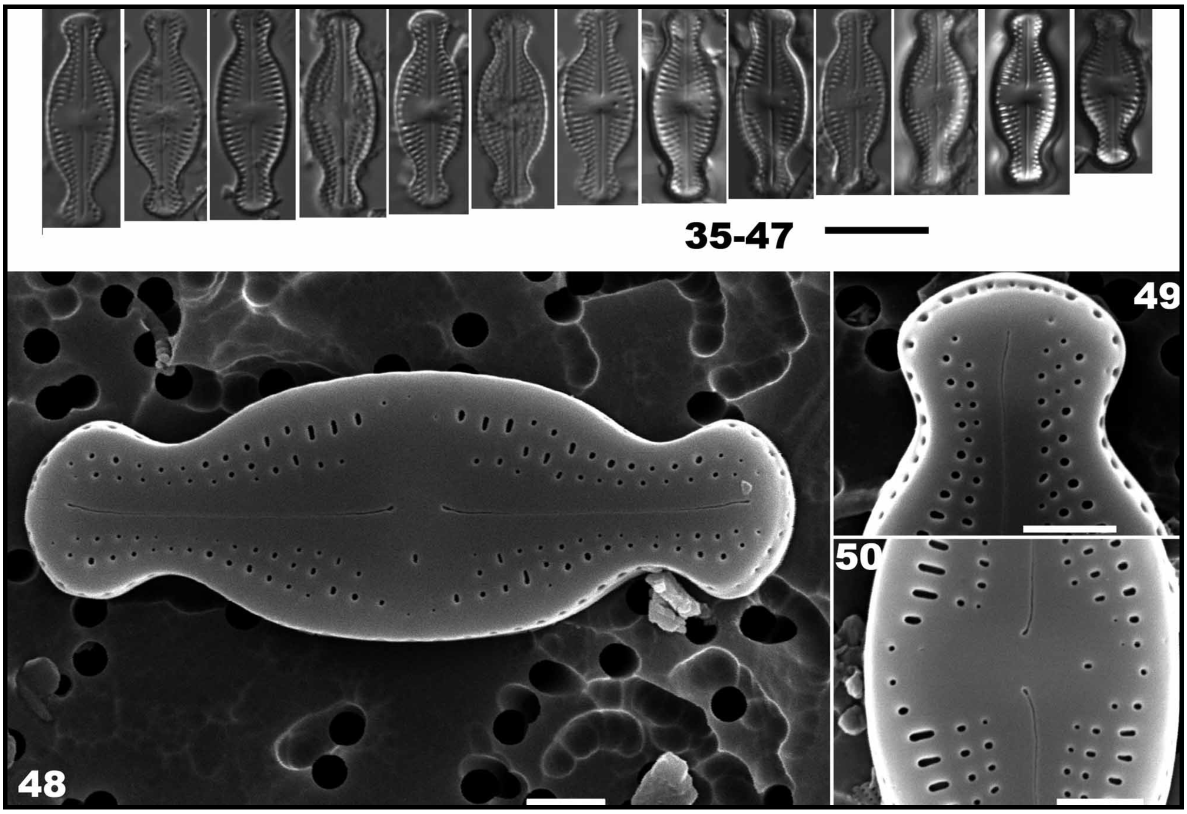
Valves elliptic-lanceolate with clearly convex margins and broadly rounded, capitate apices (Figs 2.35–2.46). Smaller valves almost elliptical (Fig. 2.47). Valve length 14–22 µm, valve width 5.4–8.2 µm (n=32). Axial area very broad, lanceolate, slightly widening towards central area (Fig. 2.48). Towards apices, axial area clearly widened (Fig. 2.49). Central area forming almost rectangular stauros, slightly widening towards margins, bordered by one series of very small rounded areolae (Fig. 2.50). One small, solitary, rounded stigma present, halfway between valve centre and margin (Figs 2.48, 2.50). Raphe branches filiform, straight with unilaterally deflected proximal endings away from stigma, terminating in weakly expanded central pores (Figs 2.48, 2.50). Distal fissures short, slightly deflected (Fig. 2.49). Transapical striae radiate near valve centre to strongly radiate towards poles, 16–20 in 10 µm, composed of two (occasionally 1) small rounded areolae terminating in one clearly transapically elongated areola in middle part of valve near margin (Fig. 2.50). Areolae always rounded near apices (Fig. 2.49). Internal structure not observed.

Type: ANTARCTICA. James Ross Island, Ulu Peninsula, Vondra II Lake, sample D39, leg. *L. Nedbalová*, coll. date 19/01/2009, slide no. BR-4242 (holotype BR, Fig. 2.46 is the encircled holotype specimen), slide PLP-190 (isotype University of Antwerp, Belgium), BRM-ZU8/08 (isotype BRM).

Habitat, Ecology and Distribution: *Luticola evkae* was described from the epilithon of a small, stable, shallow lake on Lagoons Mesa in the ice-free area close to Croft Bay. The lake had a pH of 7.7, a low specific conductance of 53 µS/cm and was dominated by several *Nitzschia* species such as *Nitzschia perminuta*, *Nitzschia paleacea* Grunow (in Van Heurck 1881: pl. 68, Figs 9–10) and *Nitzschia gracilis* Hantzsch (1860:40).

Etymology: Named after my dear friend, Eva (Evka) Volemanová (Prague, Czech Republic).

Observations: Based on valve dimensions and the shape of the axial and central area of the valves, *Luticola evkae* may at first appear similar to *Luticola dolia* and *L. doliiformis*. These three species can, however, be clearly distinguished based on their contrasting valve outlines.



FIGURES 2.35–2.50 – *Luticola evkae* Kopalová sp. nov. Light (LM) and scanning electron micrographs (SEM). Type specimens from James Ross Island. **Figs 2.35–2.47.** LM of specimens from the type population. **Fig. 2.48.** SEM of external valve view. **Fig. 2.49.** SEM of detail of the raphe endings. **Fig. 2.50.** SEM of detail of the central raphe endings. LM scale bar = 10 µm. SEM scale bars = 2 µm.

Luticola evkae has a typical elliptical central part of the valve whereas both *L. doliiformis* and *L. dolia* always have more elongated valves with, in most cases, almost parallel margins (Esposito et al. 2008). The apices in *L. evkae* are always broader and more capitate than in *L. dolia*, which has more rostrate to weakly capitate apices. This can be appreciated by the differences in valve width/apex ratio, which is 1.70±0.18 (n=13) in *L.*

evkae and 2.36±0.22 (n=13) in *L. dolia*; *L. doliiformis* has wider apices. Additionally, the shoulders just below the apices are more oblique in both *L. dolia* and *L. doliiformis*. In *L. evkae*, the outer row of areolae is always composed of transapically elongated areolae clearly visible in LM, whereas in *L. doliiformis* these areolae are always strictly rounded. *Luticola austroatlantica* is similar but distinguished by a different striation pattern with larger, usually elongated areolae. Moreover, *L. austroatlantica* lacks the broad axial area and has a more elongated valve outline. Smaller valves of *L. austroatlantica* with comparable valve dimensions as *L. evkae* always have rostrate apices contrary to the capitate apices in *L. evkae*. Other species that might be considered morphologically similar include *L. muticopsis* (and its smaller forms) and *L. palearctica* (Hustedt 1966: 613) D.G.Mann (in Round et al. 1990: 671). The former has a different valve outline, with one straight and one convex margin, clearly deflected proximal and distal raphe endings, rostrate apices and a narrower axial area (Van de Vijver & Mataloni 2008), whereas the latter is larger with more expanded apices and a higher areola density (Hustedt 1966). Finally, *L. truncata* has more areolae per stria (3–4 vs. 1–2 in *L. evkae*) with a more elliptical outline and truncated, non-capitate apices (Kopalová et al. 2009).

Luticola permuticopsis **Kopalová & Van de Vijver, sp. nov.** (Figs 2.51–2.72)

Valvae lineares-lanceolatae ad lineares-ellipticae marginibus distincte convexis apicibusque late rotundatis, stricte capitatis. Longitudo 18.5–26.0 µm, latitudo 7.3–9.2 µm. Area axialis moderate angusta, linearis, paene non dilatata in aream centralem apicesque. Area centralis formans staurum rectangularem ad cuneatum, marginatum serie una areolarum rotundatarum magnarum. Stigma paene rotundata adest in extremo striae curate vel isolata inter mediam partem valvae marginesque. Raphe filiformis, recta, terminationibus proximalibus unilateraliter clare deflexis, poris centralibus leviter expansis. Fissurae distales deflectis, clare expansae. Striae transapicales fortiter radiatae omnino, 18–22 in 10 µm. Areolae 3–6 per striam, moderate magnae.

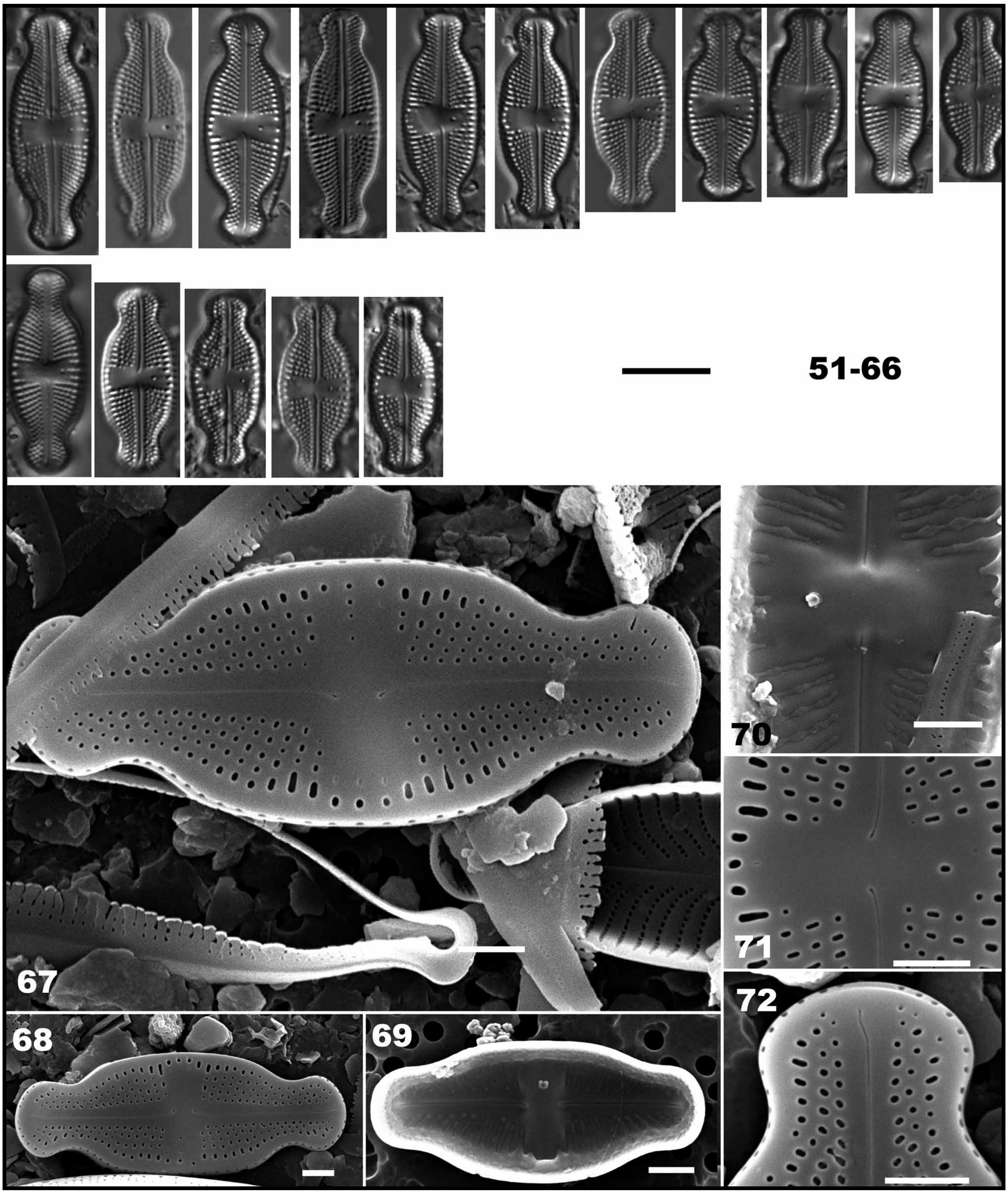
Valves linear-lanceolate to linear-elliptic with distinctly convex margins and broadly rounded, distinctly capitate apices (Figs 2.51–2.66). Valve length 18.5–26.0 µm, valve width 7.3–9.2 µm (n=15). Axial area moderately narrow, linear (Figs 2.67, 2.68), almost not widening towards apices (Fig. 2.72) and central area (Fig. 2.71). Central area forming a rectangular to wedge-shaped stauros, bordered by one series of large, rounded areolae. One solitary, almost rounded stigma present, usually at end of shortened stria, composed of 3 small, rounded areolae (Fig. 2.67) or isolated halfway between valve centre and margin (Fig. 2.71). External raphe branches straight with unilaterally clearly deflected, slightly expanded proximal raphe endings. Distal raphe fissures clearly elongated, deflected. Transapical striae rather strongly radiate throughout entire valve, composes of 3–6 moderately large, rounded areolae, 18–22 in 10 µm. Near central area, areolae close to margin, clearly enlarged (Figs 2.67, 2.71) Internally, poroids of valve face occluded by hymens forming continuous strip on each stria (Fig. 2.69). Internal stigma opening consisting of almost rounded lipped slit (Fig. 2.70). Stauros clearly developed (Fig. 2.70). Internal proximal raphe endings straight, terminating on edge of stauros. Distal raphe endings terminating on small helictoglossae (Fig. 2.69).

Type: ANTARCTICA. James Ross Island, Ulu Peninsula, Vondra IV Lake, sample D44, leg. *L. Nedbalová*, coll. date 19/01/2009, slide no. BR-4243 (holotype BR, Fig. 2.55 is the encircled holotype specimen), slide PLP-191 (isotype University of Antwerp, Belgium), BRM-ZU8/09 (isotype BRM).

Habitat, Ecology and Distribution: *Luticola permuticopsis* has been found in a few lakes on James Ross Island on the Lagoons Mesa plateau near the ice-free area close to Croft Bay. The largest population was found in the epilithon of a perennial shallow lake with a pH of 7.4, a specific conductance value of 60 µS/cm and a temperature 6.8 °C. Dominant species in the sample include *Nitzschia gracilis*, *N. paleacea* and *N. perminuta*.

Etymology: *permuticopsis* refers to the close resemblance to *L. muticopsis* (*per-*: Latin for 'quite equally').

Observations: The past few years, a large number of capitate species of *Luticola* have been separated from *Luticola muticopsis* s.l. Table 2.1 includes the main morphological characters of these species, in comparison to *L. permuticopsis*. *Luticola permuticopsis* can be separated from *L. muticopsis* by its typical valve outline: *L. muticopsis* has one straight and one convex margin, *L. permuticopsis* always has two convex margins; the apices in *L. muticopsis* are always more rostrate than capitate, contrary to *L. permuticopsis,* which has capitate, broadly rounded apices. Another important difference is formed by the areola pattern: in *L. permuticopsis* the striae are composed of 3–6 moderately large, densely packed areolae, whereas in *L. muticopsis*, there are only 3–4, more spaced areolae present, a feature easily discernible in LM (Van de Vijver & Mataloni 2008: p. 463, Fig. 77). Finally, the proximal raphe endings in *L. permuticopsis* are deflected, whereas in *L. muticopsis*, they are clearly bent. These differences separate the two species. Carlson (1913) described *Navicula muticopsis* f. *capitata* while Peragallo (1921) described *Navicula muticopsis* var. *capitata*—both separated by their asymmetrical valve outline, with one straight and one convex margin. Both taxa have a strong affinity with *L. muticopsis* but type material of neither can be investigated due to lack of material. Other similar species are *L. austroatlantica*, *L. palearctica*, *L. dolia* and *L. murrayi* (West West 1911: 285) D.G.Mann (in Round et al. 1990: 671) *sensu* Hustedt (1966). *Luticola austroatlantica* can be separated by its more slender, elongated valve outline and a lower number of areolae per stria [2–3(4) vs. 3–6 in *L. permuticopsis*] (Esposito et al. 2008). *Luticola permuticopsis* has a more compact, robust outline. Moreover, near the apices, the areolae in *L. permuticopsis* continue almost entirely to the end, whereas in *L. austroatlantica* there is a hyaline zone surrounding the apices. Finally, the distal raphe fissures in *L. austroatlantica* are shorter than in *L. permuticopsis*. *Luticola palearctica* has similar valve dimensions to *L. permuticopsis* (Hustedt 1966) but a more clearly elliptical valve outline and broadly rounded, large capitate apices, showing little difference between the width of the apices and the width near the central area. In *L. permuticopsis* the apices are always clearly more narrower than the valve centre. Its discrimination from *Luticola murrayi sensu* Hustedt (1966) is based on valve outline, with *L. murrayi sensu* Hustedt (1966) having broadly rounded margins and apices. The latter is currently under revision and will be described as a new species separate from *L. murrayi s.s.* (Van de Vijver et al. , unpubl.). Finally, *L. dolia* has straighter valve margins and a large axial area with only 1–3 areolae per stria (Esposito et al. 2008 and this paper). It can be separated from two other species present on James Ross Island: *Luticola gigamuticopsis* is much larger (length 38–46 µm, width 14–17 µm vs. 8.5–23.0 µm and 6.5–8.1 µm in *L. permuticopsis*) (Van de Vijver & Mataloni 2008); *Luticola gaussii* has an almost elliptical valve outline with constricted broadly rounded, large apices.



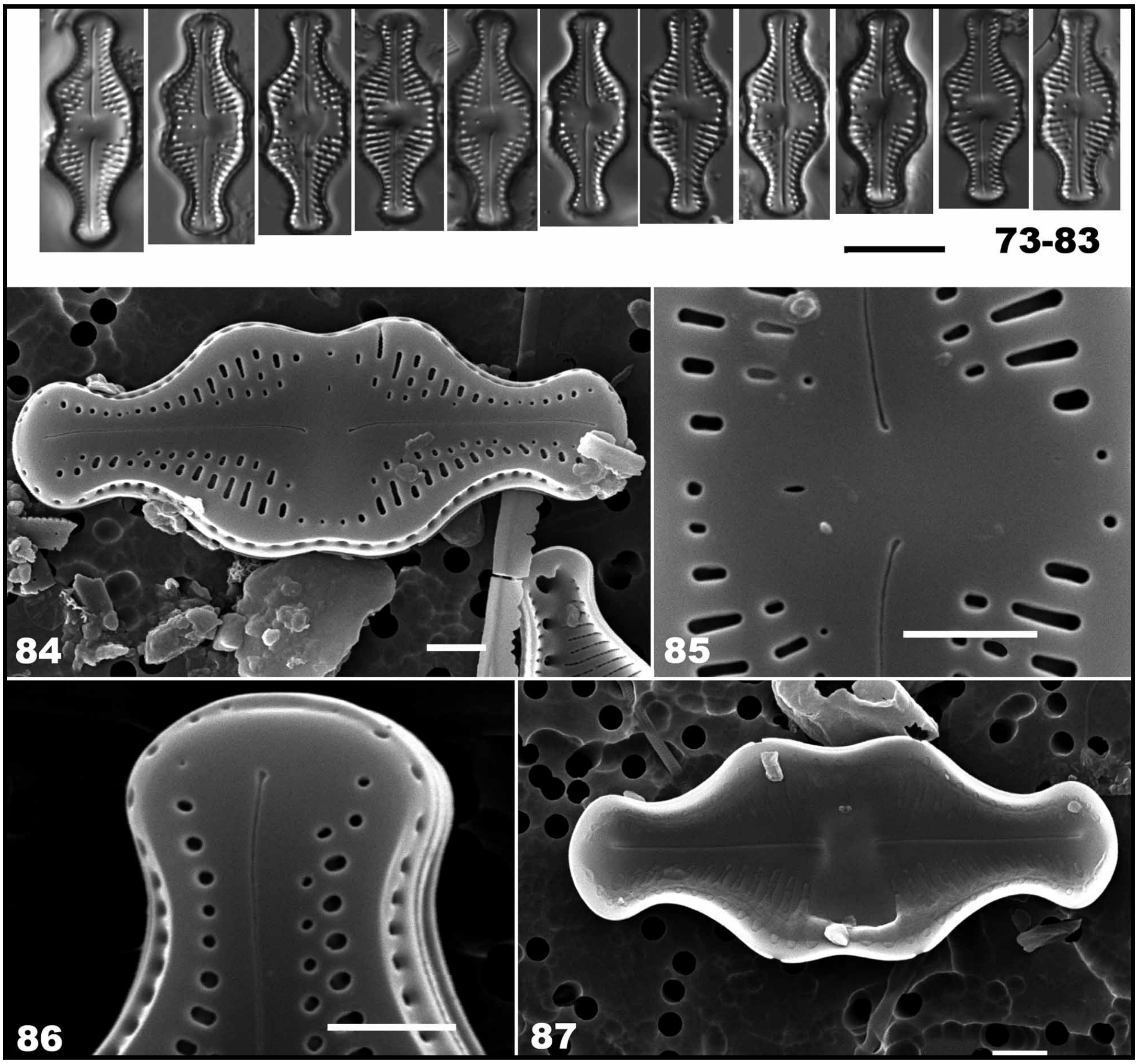
FIGURES 2.51–2.72 – *Luticola permuticopsis* Kopalová & Van de Vijver sp. nov. Light (LM) and scanning electron micrographs (SEM). **Figs 2.51–2.66.** LM of type population from Vondra IV lake on James Ross Island to illustrate variation in valve size. **Figs 2.67–2.68.** SEM of external view showing composition of striae and typical raphe structure. **Fig. 2.69.** SEM of internal view. **Fig. 2.70.** SEM of internal view showing typical central area with distinct siliceous covering around stigma. **Fig. 2.71.** SEM of external view of central area. **Fig. 2.72.** SEM of detail of deflected raphe endings. LM scale bar = 10 µm. SEM scale bars = 2 µm

Luticola tomsui **Kopalová, sp. nov.** (Figs 2.73–2.87)

Valvae lineares ad lineares-ellipticae apicibus late rotundatis. Margines clare sed asymmetrice constrictae in media parte valvae. Longitudo 18.5–23 µm, latitudo 6.5–8.1 µm. Area axialis lata, lanceolata, clare dilatata ad apices areamque centralem. Area centralis formans staurum rectangularem ad paene ellipticum, marginatum serie una areolarum parvarum rotundatarum ad leviter transapicaliter elongatarum. Stigma rimiformis solitaria adest, inter mediam partem valvae marginesque. Raphe filiformis, terminationibus proximalibus recta unilateraliter deflexis opposite stigma poris centralibus indistinctis. Fissurae distales curtae, leviter deflexae. Striae transapicales radiatae omnino, positae prope margines valvae, 16–18 in 10 µm. Areolae 1–2 rimiformes. Ad margines, areola expansa adest.

Valves linear to linear-elliptic with broadly rounded, capitate apices (Figs 2.73–2.83). Stigma-bearing side almost straight with opposite side more convex. Valve margins clearly convex but asymmetrically constricted near valve middle. Valve length 18.5–23 µm, valve width 6.5–8.1 µm (n=15). Axial area broad, lanceolate, widening towards apices and central area, (Fig. 2.84). Central area forming rectangular to almost elliptical stauros, bordered by one series of small rounded to very weakly transapically elongated areolae (Figs 2.84, 2.85). One small slit-like solitary stigma present, halfway between valve centre and margin (Fig. 2.85). External raphe branches straight to weakly curved with unilaterally deflected proximal raphe endings, away from the stigma, terminating in almost unexpanded central pores (Fig. 2.85). Distal raphe fissures short, weakly deflected (Fig. 2.86). Transapical striae radiate throughout entire valve, positioned close to valve margin, 16–18 in 10 µm (Fig. 2.84). Striae composed of 1–2 small, slitlike areolae and one enlarged areola close to valve margin (Fig. 2.84). Towards apices, striae composed only one areola. Internally, poroids of valve face occluded by hymens, forming continuous strip on each stria. Internal stigma opening consisting of small, rounded lipped slit. Stauros clearly developed (Fig. 2.87). Internal proximal raphe endings straight, terminating on stauros edge. Distal raphe endings terminating on small helictoglossae (Fig. 2.87).

Type: ANTARCTICA. James Ross Island, Ulu Peninsula, Vondra II Lake, sample D39, leg. *L. Nedbalová*, coll. date 19/01/2009, slide no. BR-4244 (holotype BR, Fig. 2.78 is the encircled holotype specimen), slide PLP-192 (isotype University of Antwerp, Belgium), BRM-ZU8/10 (isotype BRM).



FIGURES 2.73–2.87 – *Luticola tomsui* Kopalová sp. nov. Light (LM) and scanning electron micrographs (SEM). Specimens from the type population from Vondra II lake on James Ross Island. **Figs 2.73–2.83.** LM showing variation in valve margin shape and its distortion. **Fig. 2.84.** SEM of external valve view, showing typical striation, margin shape and raphe structure. **Fig. 2.85.** SEM of external view of central area and deflected central raphe endings. **Fig. 2.86.** SEM of external detail of the deflected distal raphe endings. **Fig. 2.87.** SEM of internal valve view. LM scale bar = 10 µm. SEM scale bars = 2 µm.

Habitat, Ecology and Distribution: *Luticola tomsui* has been found in only two samples from one lake on James Ross Island. The largest population was found in the epilithon of the shallow Vondra II Lake located on the Lagoons Mesa plateau near the ice-free area close to Croft Bay. The lake had a pH of 7.7, a low specific conductance value (53µS/cm) and was dominated by *Nitzschia* species including *Nitzschia perminuta*, *N. paleacea* and *Nitzschia gracilis*.

Etymology: *Luticola tomsui* is named after my dear friend Jan Tomšů (Prague, Czech Republic).

Observations: The number of *Luticola* taxa with constricted valves is low thus confusion with *L. tomsui* is unlikely. Recently, *L. adelae* was described from White Lake on James Ross Island (Van de Vijver et al. 2011) and *L. binodis* (Hustedt 1922: 239) Edlund (in Edlund et al. 2001: 85) was reported from the nearby Livingston Island (South Shetland Islands) (Van de Vijver et al. 2011). Both are species with constricted valves. The valve size ranges of *L. tomsui* (L 18–23 µm, W 6,5–8.0 µm) is in between those of *L. adelae* and *L. binodis*: *L. adelae* is smaller (L 16–20 µm, W 5–6 µm), *L. binodis* is larger (L ±24 µm, W ± 7,5 µm). *L. adelae* and *L. binodis* both differ from *L. tomsui* in having a more slender valve outline and less inflated valve centre. Additionally, the number of areolae per stria in *L. binodis* is higher than *L. tomsui* and the axial area is smaller compared to the rather broad axial area in *L. tomsui*. Other species with constricted valves, such as *L. mollis* Lange-Bertalot & Rumrich (in Rumrich et al. 2000: 149) and *L. incoacta* (Hustedt 1966: 619) D.G.Mann (in Round et al. 1990: 670), have a higher number of areolae per stria, a narrower axial area and deeper constrictions. Finally, when *L. tomsui* is compared to *L. nivalis*, the latter has a valve outline with more undulations.

Acknowledgments

This study has been supported by the projects GA UK 394211 (Charles University Grant Agency) and MSMT KONTAKT ME 945. Part of this research was funded by the projects: MSMT 0021620828 and AV0Z60050516. Additional funding was provided by the FWO project G.0533.07 and an Erasmus travel grant to the University of Antwerp, Belgium. The authors also like to thank members of the expeditions to the Czech Antarctic Station 'J.G. Mendel', especially Dr J. Elster, for their help during sampling. Dr Sarah Spaulding is acknowledged for sending the isotype material of *L. dolia*. Dr Paul Hamilton and an anonymous reviewer are thanked for their valuable comments and discussions that helped to improve the manuscript.

TABLE 2.1. – Comparison table of capitate *Luticola*-taxa, mainly from the Antarctic Region

	muticopsis	*austroatlantica*	*gigamuticopsis*	*pseudomurrayi*	*muticopsis f. capitata**	*muticopsis var. capitata**	*palearctica*	*permuticopsis*
length (µm)	10–22	11–31	38–46	15,5–50,0	29	28	22–38	18,5–26,0
width (µm)	7,8–9,7	6,4–8,7	14–17	7,5–12,0	10	13	7,5–11	7,3–9,2
valve outline	asymmetrical, rectangular to broadly elliptic	symmetrical, linear-lanceolate to elliptic-lanceolate, slender	asymmetrical, broadly elliptical	symmetrical, broadly lanceolate to broadly elliptic	asymmetrical, linear-lanceolate to lanceolate	asymmetrical, elliptic-lanceolate	symmetrical, elliptic to linear-elliptic, compact	symmetrical, linear-lanceolate to linear-elliptic, compact
margins	one clearly convex, on straight	both convex	almost parallel, one convex, one straight	both convex to rounded	one slightly convex, the other straight	one almost straight, one convex	both convex	both convex
apices	rostrate to rostrate-capitate	protracted, capitate	distinctly capitate, broadly rounded	broadly rostrate to capitate	protracted, distinctly capitate	protracted, distinctly capitate	protracted, capitate	broadly rounded, capitate
raphe	straight with bent central and terminal endings	straight to weakly curved, clearly deflected central endings, terminal fissures short	straight to very weakly curved, central endings distinctly hooked, terminal fissures short, slightly curved	straight with weakly deflected central endings and short, weakly deflected terminal fissures	straight	straight	straight, weakly deflected central endings	straight, clearly deflected central endings, terminal fissures elongated, deflected
striae (in 10 µm)	15–18	15–17	14–15	17–20 (22)	14	14	15	18–22
areolae (per stria)	3–4	2–3 (4)	2–5	4–5	4–5	4–5	4–5	3–6

*measurements based on line drawing in original publication

CHAPTER 3

New and interesting small-celled naviculoid taxa from the Maritime Antarctic Region

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Four new small-celled naviculoid diatom species belonging to the genera Adlafia*,* Chamaepinnularia*,* Mayamaea*, and* Microcostatus *were observed during a survey of the non-marine diatom flora of the South Shetland Islands and James Ross Island (Maritime Antarctic Region). Following both light and scanning electron microscopy observations, the following species were described as new:* Adlafia submuscora *sp. nov.,* Mayamaea josefelsteri *Kopalová, Nedbalová & Van de Vijver sp. nov.,* Microcostatus australoshetlandicus *sp. nov. and* Chamaepinnularia antarctica *sp. nov. The new species are compared to other morphologically similar species from Europe, South America and the (sub-)Antarctic region. Data on their ecology and biogeography are added. In addition, the morphology; biogeography and taxonomic position two other small-celled naviculoid diatom species,* Craticula glaberrima *(W. & G.S. West) nov. comb. and* Sellaphora nana *(Hustedt) Lange-Bertalot et al. have been discussed.*

***Key words**: Bacillariophyceae, Diatoms, Maritime Antarctic Region, new species, morphology, taxonomy*

Introduction

Diatoms are one of the most abundant algal groups in the Antarctic Region, both in number of species as in number of individuals (Jones 1996, Van de Vijver & Beyens 1999a). For a long time, this diatom flora was considered to be composed mainly of cosmopolitan taxa (Sabbe et al. 2003), although intensive taxonomic research during the past few years has shown that due to force-fitting (Tyler 1996) and taxonomic drift, the actual diatom diversity in this region has been severely underestimated. The ongoing revision of the non-marine diatom flora of the Maritime Antarctic Region resulted already in the description of a large number of new taxa, mainly belonging to the genera *Pinnularia* (Van de Vijver & Zidarova 2011, Zidarova et al. 2012), *Stauroneis* (Van de Vijver et al. 2004a), *Hantzschia* (Zidarova et al. 2010), *Muelleria* (Van de Vijver et al. 2010b), *Luticola* (Van de Vijver & Mataloni 2008, Van de Vijver et al. 2011c, Kopalová et al. 2011) and *Navicula* (Van de Vijver et al. 2011b). Most of these taxa have a restricted and sometimes even endemic distribution (Van de Vijver et al. 2005), indicating that it is highly likely that more new taxa are awaiting a formal description belonging to at present unstudied genera.

During the Antarctic diatom survey, several unknown small-celled (valve length < 20 µm) taxa were observed belonging to several genera, formerly grouped under the catch-all genus *Navicula* s.l., that could not be identified using the currently available literature. Following detailed scanning electron microscopy, four of them are described as new species and compared with similar taxa: *Adlafia submuscora* sp. nov., *Mayamaea josefelsteri* Kopalová, Nedbalová & Van de Vijver sp. nov., *Microcostatus australoshetlandicus* sp. nov. and *Chamaepinnularia antarctica* sp. nov. A fifth presumably new taxon belonging to the genus *Craticula* was finally identified as *C. glaberrima* (W. & G.S. West) nov. comb., so far only known from the type locality on the Antarctic Continent (West & West 1911, Van de Vijver et al. 2012) and is morphologically characterized. A sixth taxon, *Sellaphora nana* (Hustedt) Lange-Bertalot et al. shows some morphological variability when populations between islands are compared.

Material & Methods

Sediment samples were collected from various freshwater habitats on Livingston Island, Deception Island (South Shetland Islands) and James Ross Island. The South Shetland Islands

(63°00'S/60°00'W), situated just north of the Antarctic Peninsula consist of 11 larger and many smaller islands and islets with King George Island (1150 km²) and Livingston Island (972 km²) being the largest of them all. The islands have a typical maritime oceanic climate with mean annual temperatures around –5 °C, high precipitation rates and strong westerly winds. Most of islands are covered by permanent ice and snow cover leaving only small parts ice-free. The vegetation on the islands is limited to lichens and mosses with only two flowering plants [*Colobanthus quitensis* (Kunth) Bartl. and *Deschampsia antarctica* Desv.]. James Ross Island (64°10'S, 57°45'W), is located more to the south, in the north-western part of the Weddell Sea, close to the northern tip of the Antarctic Peninsula. This fairly large island (2450 km²) is situated in a transitory zone between the Maritime Antarctica and Continental Antarctica regions (Øvstedal & Lewis-Smith, 2001). Only the northern part of the island, Ulu Peninsula, is ice-free. The temperature is comparable to the South Shetland Islands but precipitation is limited to only 150 mm/y in the northern part (Aristarain et al. 1987) with high evaporation rates reducing the formation of large open waterbodies. The terrestrial vegetation is limited to only non-vascular plants forming at some places a bryophyte and lichen tundra.

Sampling methods are described in Kopalová et al. (2012) and Kopalová & Van de Vijver (2013). Diatom samples were prepared following the method of Van der Werff (1955). Small parts of the samples were cleaned by adding 37% H_2O_2 and heating to 80 °C for about one hour, followed by addition of $KMnO_4$. After digestion and centrifugation (3 times 10 minutes at 3700 x g), the material was diluted with distilled water to avoid excessive concentrations of diatom valves that may hinder reliable observations. Cleaned diatom valves were mounted in Naphrax®. All samples and slides are stored at the National Botanic Garden of Belgium (BR), Department of Bryophyta and Thallophyta. The slides were analyzed using an Olympus BX51 microscope, equipped with Differential Interference Contrast (Nomarski®) and the Colorview I Soft Imaging System. For Scanning Electron Microscopy (SEM), part of the suspension was filtered through polycarbonate membrane filters with a pore diameter of 1 µm, pieces of which were fixed on aluminium stubs after air-drying. The stubs were sputter-coated with 20 nm of Au–Pd and studied in a Zeiss ultra microscope at 3 kV. Terminology of valve morphology is based on Hendey (1964), Ross et al. (1979) and Round et al. (1990). The new species were compared with similar taxa from the Antarctic Region (Van de Vijver et al. 2002a), Europe and South America (Lange-Bertalot 2001, Lange-Bertalot & Genkal 1999, Metzeltin & Lange-Bertalot 2007, Lange-Bertalot et al. 2003).

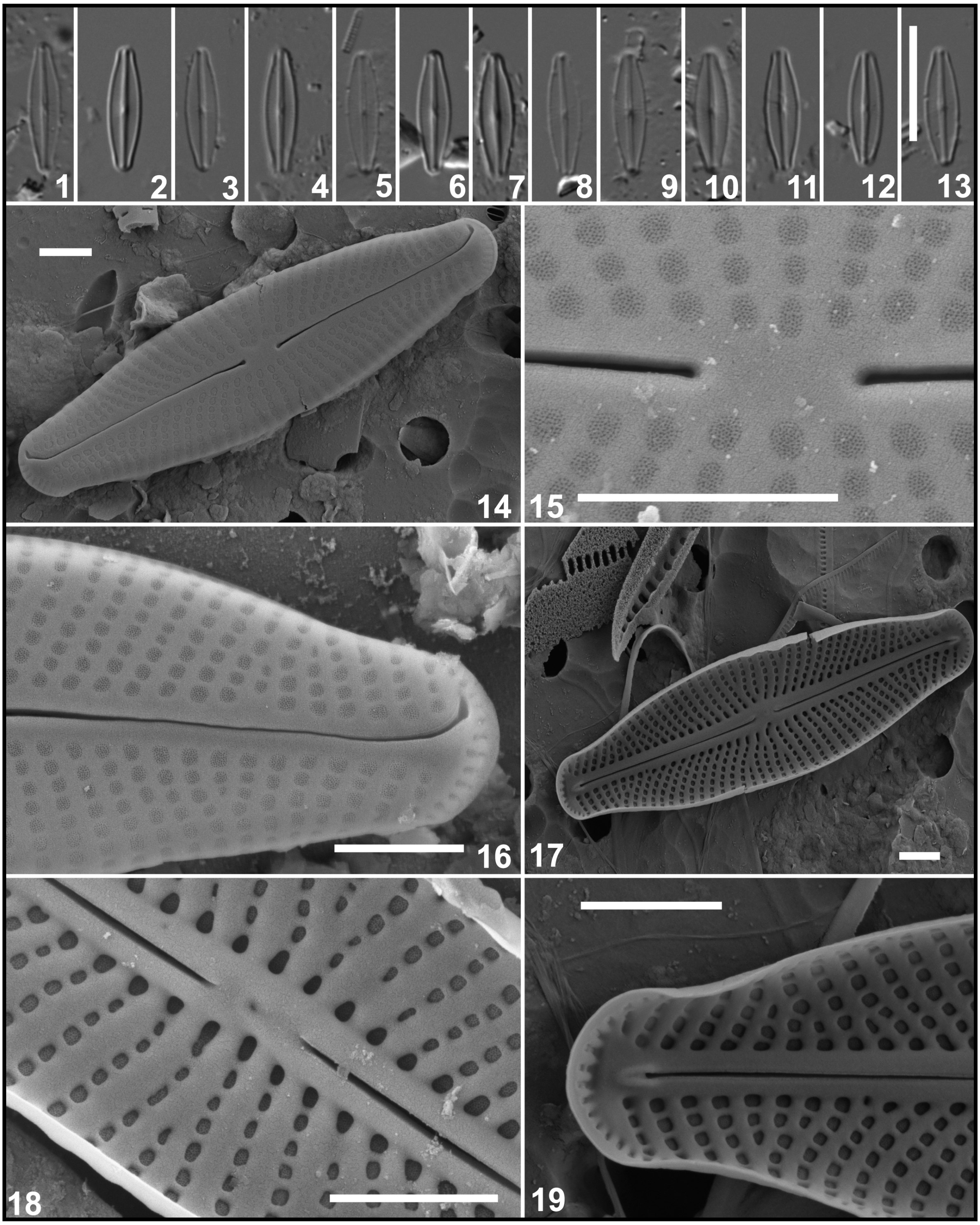
New taxon descriptions

Adlafia submuscora **sp. nov.** (Figs 3.1–3.19)

Valvae lanceolatae at anguste lanceolatae marginibus claro convexis apicibusque protractis, subrostratis. Longitudo 10–12 µm, latitude 2.5–3.1 µm. Area axialis angustissima, linearis omnino. Area centralis paene absens. Rami raphis externi leviter undulati, terminationibus proximalibus rectis, non expansis. Fissurae distales longae, non extensae in limbo, unilateraliter curvatae, expansae. Striae transapicales uniseriatae, claro radiatae, convergentes in apices, paene discernendae in microscopic photonico, 40–45 in 10 µm. Striae in area centrali leviter magis distantes.

Valves lanceolate to narrowly lanceolate, with clearly convex margins and protracted subrostrate apices. Valve dimensions (n=15): length 10–12 µm, width 2.5–3.1 µm. Axial area very narrow, less than 1/6 of the total valve width, linear throughout its entire length. Central area almost non-existing formed by a slight widening of the axial area. External raphe branches slightly undulating with proximal raphe endings almost straight and simple. External distal raphe fissures long, not extending onto the valve mantle, unilaterally bent, terminating in an enlarged groove. Internally, raphe branches straight located on a raised sternum, with simple, straight proximal endings and distal endings terminating on small helictoglossae. Striae clearly radiate, becoming abruptly convergent near the apices, almost not discernible in LM, 40–45 in 10 µm, slightly more spaced near the central area. Occasionally, one shortened stria can be inserted in the central area. Striae uniseriate, composed of large, rounded areolae covered on the outside by a porous hymen.

Type: ANTARCTICA. James Ross Island, Clearwater Mesa, Lake 3, sample CLW60 (Coll. L. Nedbalová & J. Elster, 09/02/2009). Holotype BR–4271 (National Botanic Garden, Meise, Belgium), Isotypes PLP–215 (UA, University of Antwerp, Belgium), BRM–ZU8/51 (Hustedt Collection, Bremerhaven, Germany)



FIGURES 3.1–3.19 – *Adlafia submuscora*. Specimens from the type population on the Clearwater Mesa, James Ross Island. **Figs 3.1–3.13.** Light microscopy showing the variation in size and outline. **Fig. 3.14.** SEM external valve view of an entire valve showing the ultrastructure of the raphe and the areolae. **Fig. 3.15.** SEM external valve view of the areolae with the typical external coverings. **Fig. 3.16.** SEM external valve view of the apex with the distal raphe fissures. **Fig. 3.17.** SEM internal valve view of an entire valve**. Fig. 3.18.** SEM internal valve view of the central area with the straight proximal raphe endings and the open areolae. **Fig. 3.19.** SEM

internal valve view of the apex with the helictoglossa. Scale bar represents 10 µm except for Figs 3.15, 3.16, 3.18, 3.19 where scale bar = 1 µm.

Ecology: The type population was found on the Clearwater Mesa, a table mountain in the northern part of James Ross Island. The sample was taken from a stable, shallow lake with a rather alkaline pH (8.2), a moderately high specific conductance value (479 µS/cm) and very low nutrient levels. The sample was dominated by *Nitzschia perminuta* (Grunow) Peragallo, *Amphora* cf. *veneta* Kützing, *Pinnularia australomicrostauron* Zidarova et al. and *Achnanthidium lailae* Van de Vijver. Other important populations were present in several larger lakes on the central plateau of Byers Peninsula with slightly alkaline pH (7.3–7.6), low specific conductance values (60–130 µs/cm) and low nutrient values.

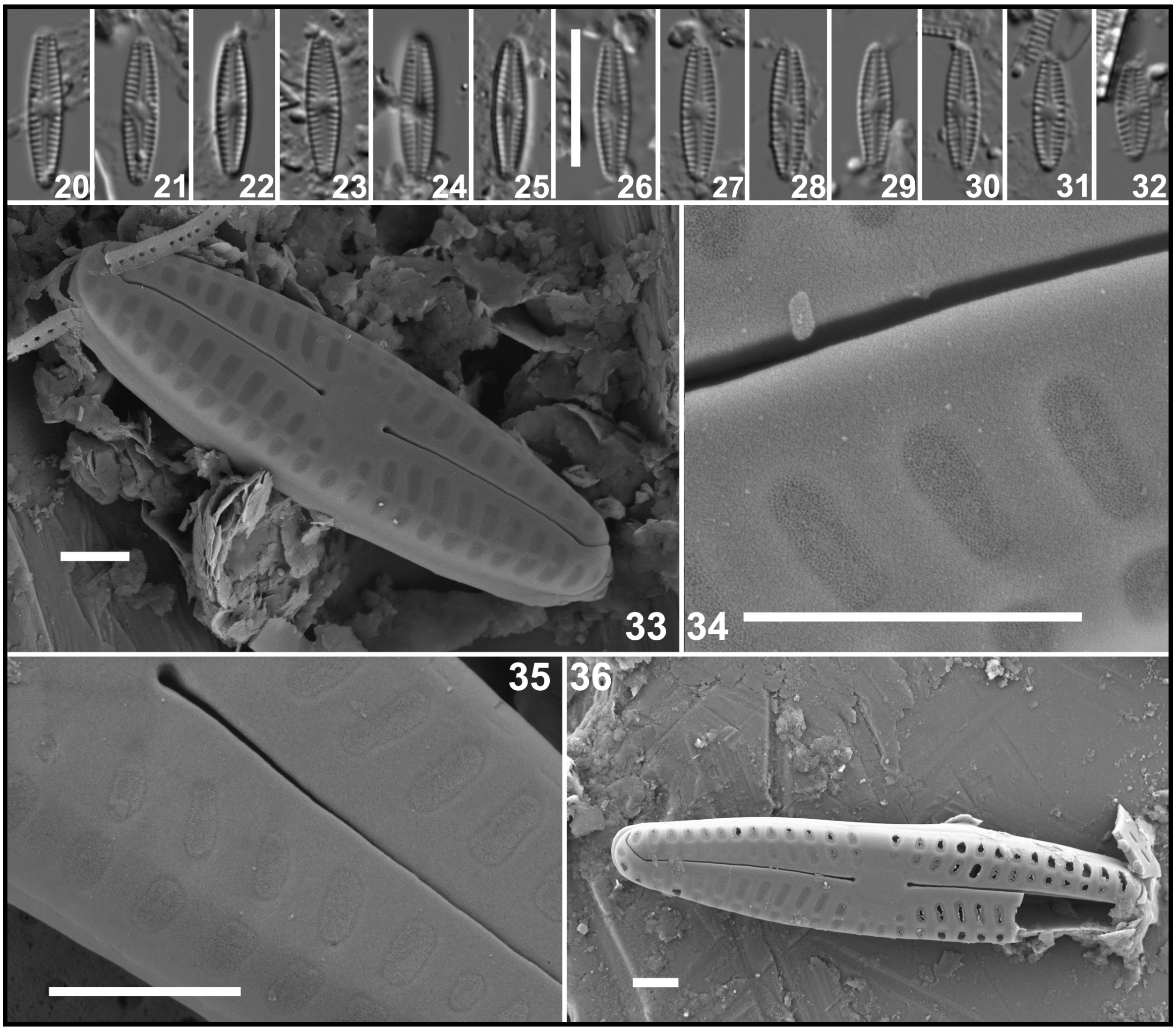
Etymology: The specific epithet refers to the close resemblance to *Adlafia muscora* (Kociolek & Reviers) Lange-Bertalot in Moser et al. but the valves are always much smaller (Latin: *sub-*: under, lower)

Confirmed Distribution: *Adlafia submuscora* has so far been found on several islands in the Maritime Antarctic Region including Livingston Island and James Ross Island. It is possible that this taxon has been confused with the much larger *Adlafia bryophila* (Petersen) Lange-Bertalot in Moser et al. that has been found several times in the Maritime Antarctic Region (Kellogg & Kellogg 2002). Unfortunately, as long as these records could not be verified, its distribution in this region remains unclear. On the sub-Antarctic islands in the southern Indian Ocean, the species has so far not been found (Van de Vijver et al. 2002a).

***Chamaepinnularia antarctica* sp. nov.** (Figs 3.20–3.36)

Valvae anguste lanceolate marginibus leviter convexis, paene parallelis. Apîces leviter protractae, aliquando subrostratae. Longitudo 7.5–12.0 µm, latitudo 2.4–2.8 µm. Area axialis angusta, linearis, dilatans in aream centralem. Area centralis rectangularis, cum 1–3 striis abbreviates. Fascia numquam praesens. Rami raphis claro curvati terminationibus proximalibus rectis, guttiformibus, fissuris distalibus flexis. Striae radiatae, paene parallelae in apices, 21–23 in 10 µm.

Valves (very) narrowly lanceolate with weakly convex, almost parallel margins gradually tapering towards the weakly protracted, sometimes weakly subrostrate apices. Valve dimensions (n=15): length 7.5–12.0 µm, width 2.4–2.8 µm. Axial area narrow, less than ¼ of the total valve width, linear, widening towards the central area. Central area rectangular due to the presence of 1–3 irregularly shortened striae. Fascia never present. External raphe branches clearly curved with almost straight, drop-like expanded proximal endings and bent distal fissures, continuing onto the valve mantle. Transapical striae radiate, becoming almost parallel near the apices, 21–23 in 10 µm. Striae composed of one large areola, interrupted by a hyaline line near the valve face/mantle junction. Areolae covered externally by a porous hymen. When eroded, large open areola foramina visible. Striae continuing around the apices. Internal structures could not be observed.



FIGURES 3.20–3.36 – *Chamaepinnularia antarctica*. Specimens from the type population on Byers Peninsula, Livingston Island. **Figs 3.20–3.32.** Light microscopy showing the variation in size, striation and outline. **Fig. 3.33.** SEM external valve view of an entire valve showing the ultrastructure of the raphe and the striae with the interruption near the valve face/mantle junction. **Fig. 3.34.** SEM external valve view of the areolae with the typical external coverings. **Fig. 3.35.** SEM external valve view of the striae. **Fig. 3.36.** SEM

external valve view of a broken valve with eroded striae showing the large areolae. Scale bar represents 10 µm except for Figs 3.34, 3.35 where scale bar = 1 µm.

Type locality: ANTARCTICA, South Shetland Islands, Livingston Island, Byers Peninsula, sample BY049 (Coll. B. Van de Vijver, Coll. date 14/01/2009). Holotype BR–4272 (National Botanic Garden, Meise, Belgium), Isotypes PLP–216 (UA, University of Antwerp, Belgium), BRM–ZU8/52 (Hustedt Collection, Bremerhaven, Germany)

Ecology: The type population of *Chamaepinnularia antarctica* was sampled in a lake on the central plateau of Byers Peninsula. This relatively large lake is situated on the main central plateau next to Limnopolar Lake at an altitude of 75 m. The lake has a pH of 7.6 with a specific conductance value of 60 µS/cm. Both nutrient and mineral levels are quite low (Kopalová & Van de Vijver, in press). The sample is dominated by *Staurosirella pinnata* (Ehrenberg) D.M.Williams & F.E.Round, *Fragilaria capucina* s.l. Desmazières, *Planothidium frequentissimum* (Lange-Bertalot) Round & Bukhtiyarova and *Psammothidium papilio* (Lange-Bertalot & Rol.Schmidt) Van de Vijver & Kopalová. The species was found in several other lakes and streams on Byers Peninsula, but always in low abundances. Almost all samples were taken in or near flowing water or places where flowing water entered the lake. The species has so far not been observed on Hurd Peninsula where only several populations of *C. australomediocris* are found. On James Ross Island, only very small populations of the species were observed.

Confirmed Distribution: Due to confusion with *C. australomediocris*, the current distribution of *C. antarctica* is not well known. The species was found with certainty on Livingston Island (Kopalová & Van de Vijver, in press) and James Ross Island (Kopalová et al. unpubl. data). Most probably it will be present on other localities in the Maritime Antarctic Region but these needs to be confirmed after revision of the observed *C. australomediocris* populations.

Mayamaea josefelsteri **Kopalová, Nedbalová & Van de Vijver sp. nov.** (Figs 3.37–3.51)

Valvae elongatae, ellipticae at ellipticae-lanceolatae marginibus convexis, apicibusque obtuse rotundatis, non protractis. Longitudo 10.5–11.5 µm, latitudo 2.9–3.4 µm. Area axialis potius angusta, linearis. Area centralis rectangularis ad paene rotunda, marginata a 2–5 striis abbreviatis. Rami raphis externi claro curvati terminationibus proximalibus deflexis *fissurisque distalibus flexis, non extensis in limbo. Striae transapicales radiatae, curvatae prope aream centralem, parallae in apices, 25–27 in 10 µm.*

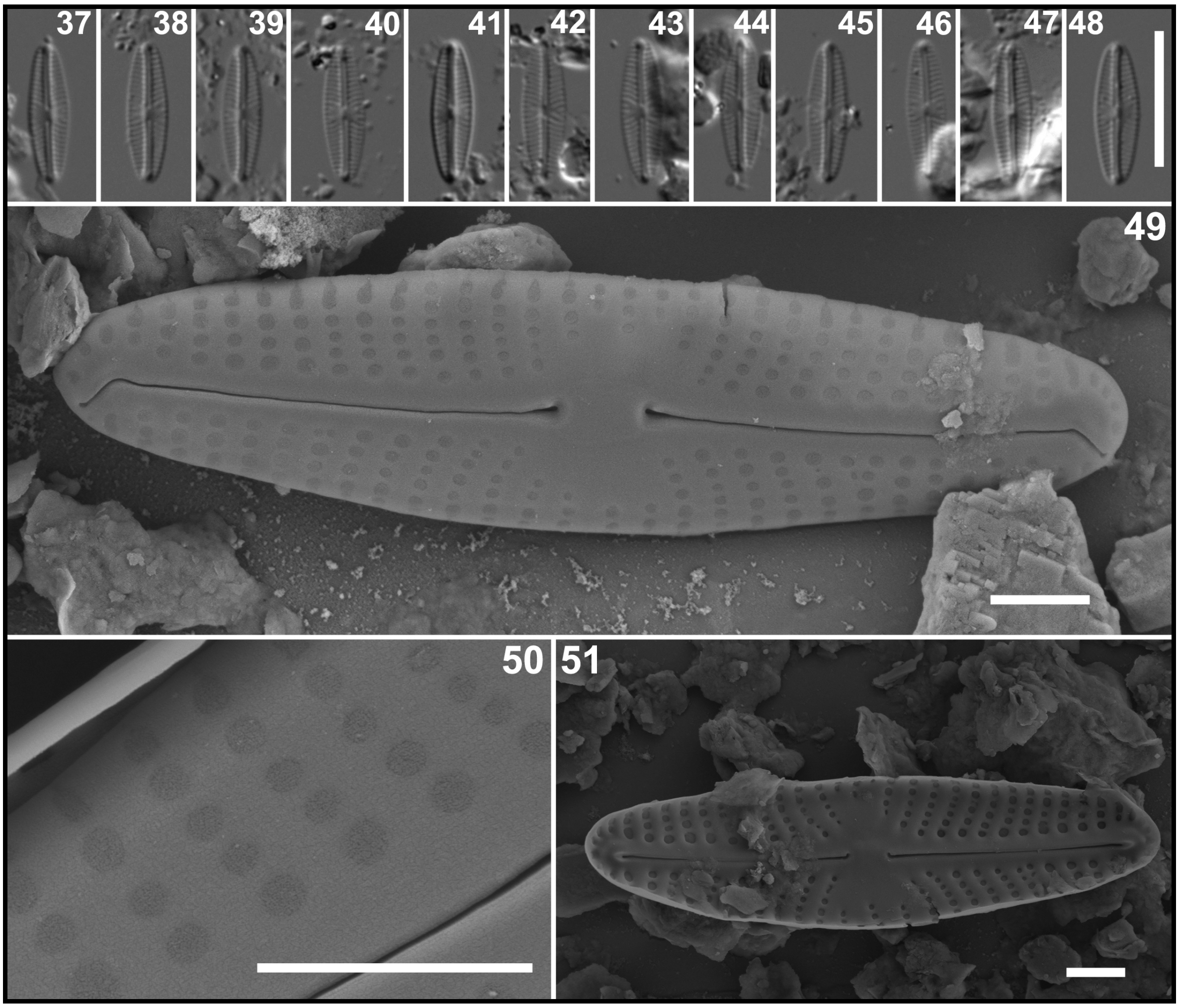
Valves elongated elliptical to elliptic-lanceolate with convex margins and bluntly rounded, non-protracted apices. Valve dimensions (n=15): length 10.5–11.5 µm, width 2.9–3.4 µm. Axial area rather narrow, linear. Central area rectangular to almost rounded, bordered by several (2–5) shortened striae. External raphe branches clearly curved with deflected, expanded proximal raphe endings and elongated, bent distal raphe fissures, not continuing onto the valve mantle. Internally, raphe branches straight with short, simple, deflected proximal raphe endings. Central nodule weakly developed. Internal distal raphe endings terminating on small helictoglossae. Transapical striae radiate, curved near the central area, becoming more parallel near the apices, 25–27 in 10 µm. Striae continuing around the valve apices. Striae uniseriate, composed of several large, rounded areolae. Areolae covered externally by porous hymenes.

Type: ANTARCTICA. James Ross Island, Ulu Peninsula, Láska Lake, sample JRI–D22 (Coll. L. Nedbalová, coll. date 17/02/2008). Holotype BR–4273 (National Botanic Garden, Meise, Belgium), Isotypes PLP–217 (UA, University of Antwerp, Belgium), BRM–ZU8/53 (Hustedt Collection, Bremerhaven, Germany)

Ecology: *Mayamaea josefelsteri* has been found in several larger lakes on Ulu Peninsula in the northern part of James Ross Island. The type population was sampled in a kettle lake with an almost circumneutral pH (6.9), a very low specific conductance valve (26 µS/cm) and low nutrient levels (Nedbalová et al. unpubl. data). All other populations were sampled in coastal lakes with comparable pH values (7–7.5) although in one lake, the specific conductance value was much higher (up to 1038 µS/cm). Dominating species in the diatom flora include *Nitzschia homburgensis* Lange-Bertalot, *Microcostatus naumanii* (Hustedt) Lange-Bertalot, *Mayamaea atomus* (Kützing) Lange-Bertalot and *Psammothidium papilio.*

Etymology: The species is named after our colleague Dr. Josef Elster (University of South Bohemia, Czech Republic) in honor of his impressive contribution to Arctic and Antarctic (algal) science.

Confirmed Distribution: So far, *M. josefelsteri* has only been found on James Ross Island. Its presence on other localities of the Maritime Antarctic Region needs to be confirmed after revision of the *Mayamaea* populations that were previously reported.



FIGURES 3.37–3.51 – *Mayamaea josefelsteri*. Specimens from the type population on Ulu Peninsula, James Ross Island. **Figs 3.37–3.48.** Light microscopy showing the variation in size, striation and outline. **Fig. 3.49.** SEM external valve view of an entire valve showing the ultrastructure of the raphe and the areolae. **Fig. 3.50.** SEM external valve view of the areolae with the typical external coverings. **Fig. 3.51.** SEM internal valve view of an entire valve. Scale bar represents 10 µm except for Fig. 3.50. where scale bar = 1 µm.

Microcostatus australoshetlandicus **sp. nov.** (Figs 3.52–3.69)

Valvae lanceolatae ad ellipticae-lanceolatae in speciminibus minoribus, marginibus convexis, apicibusque paene non protractis, cuneatim rotundatis. Longitudo 6.5–9.0 µm, latitudo 2.9–3.2 µm. Area axialis moderate lata, formans sternum elevatum cum conopeo tegenti partes striarum, marginatum a fissuribus longitudinalibus.Area centralis rotunda, marginata a striis abbreviatis. Raphe filiformis, terminationibus proximalibus rectis, leviter expansis, fissurisque distalibus claro flexis. Microcostae absunt. Striae transapicales claro radiatae, geniculatae, parallelae ad apices, 24–28 in 10 µm. Solum una areola transapicaliter elangata pro stria.

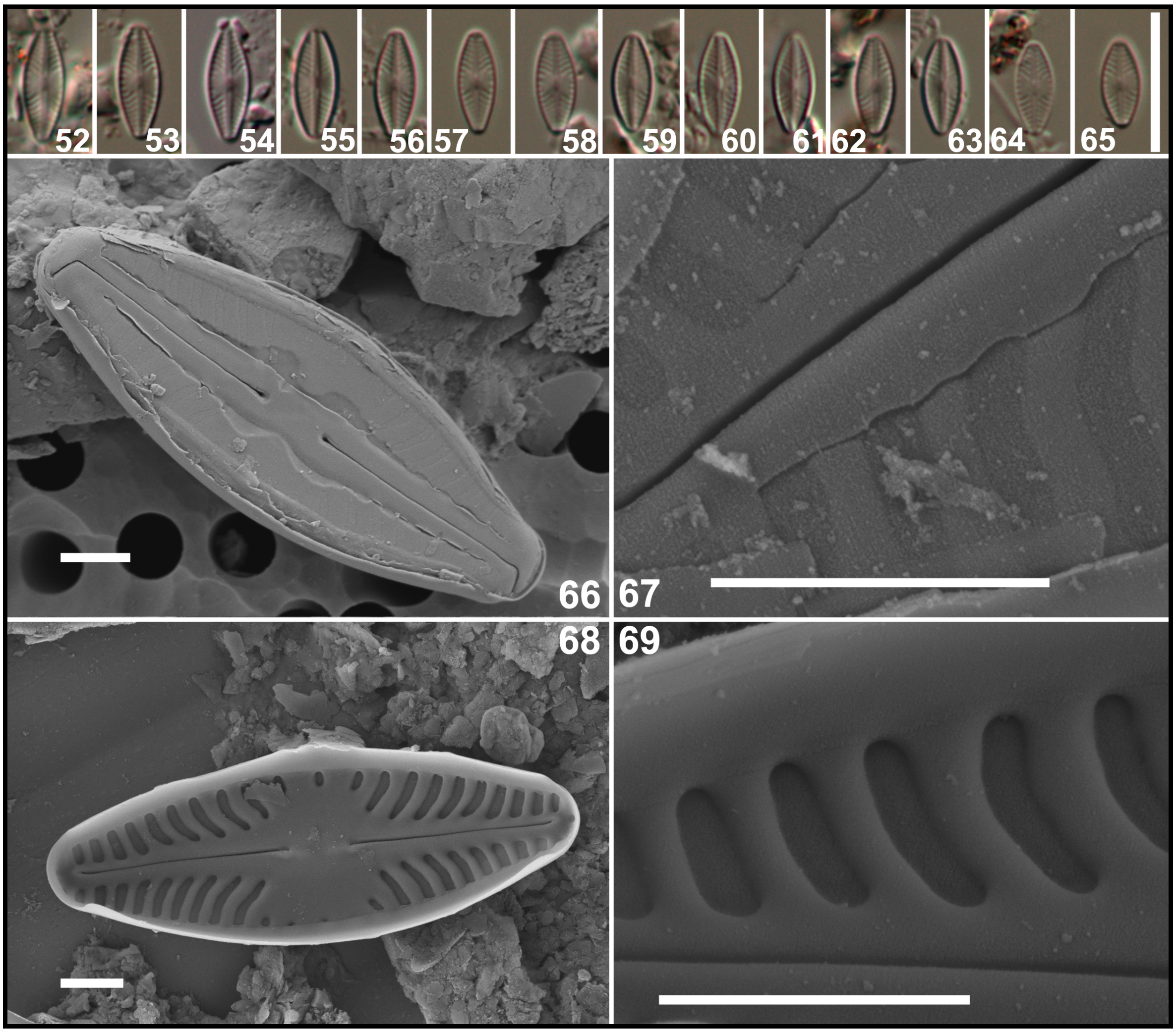
Valves lanceolate to elliptic-lanceolate in smaller specimens with convex margins and almost non-protracted, cuneately rounded apices. Valve dimensions (n=15): length 6.5–9.0 µm, width 2.9–3.2 µm. Axial area moderately broad, almost 1/3 to ¼ of the total valve width, formed by a raised sternum with a conopeum covering part of the striae, bordered by two longitudinal grooves. Central area rounded, bordered by several shortened striae. Raphe filiform with straight external weakly expanded proximal raphe endings and clearly bent external distal raphe fissures. Internally, proximal raphe endings not or very faintly unilaterally deflected. Internal distal raphe endings terminating on poorly developed helictoglossae. Transapical striae clearly radiate, geniculate becoming parallel towards the apices, 24–28 in 10 µm. Striae composed of one transapically elongated areola reaching the valve margin, covered on the outside by a porous hymen. Striae continuing in the longitudinal grooves, bordering the sternum. Microcostae not discernible.

Type: ANTARCTICA. Deception Island, South Shetland Islands, sample IR, near Irizar Lake (coll. G. Mataloni, coll. date February 2002). Holotype BR–4274 (National Botanic Garden, Meise, Belgium), Isotypes PLP–218 (UA, University of Antwerp, Belgium), BRM–ZU8/54(Hustedt Collection, Bremerhaven, Germany)

Ecology: The type population was collected in a circumneutral soil sample (pH = 6.95) near Irizar Lake on the southwestern side of the island. The sample has a low mineral and organic content with very low nutrient concentrations (Fermani et al. 2007) and is dominated by several *Muelleria* species including *M. aequistriata*, *M. sabbei* and *M. australoatlantica*, occurring together with *Pinnularia borealis* s.l. and *Psammothidium germainii*. Smaller populations on Deception Island were found in other samples in the same area, all taken from very stable soils with a low degree of historical disturbance by volcanic and/or human activity (Fermani et al. 2007). On Livingston Island, only very small populations were found in algal mat samples taken from small pools on Byers Peninsula and among almost dry mosses on Hurd Peninsula

Confirmed Distribution: So far, *M. australoshetlandicus* was found on Livingston Island and Deception Island, two islands of the South Shetland Islands. At present, it has not been observed on James Ross Island (Kopalová et al. 2012, unpublished results). Due to its inconspicuous size, it is possible that the taxon is present on more Antarctic localities but has always been overlooked.

Etymology: The specific epithet refers to the South (Latin *australis*) Shetland (Latin *shetlandicus*) Islands since the species was found on several islands of this archipelago.



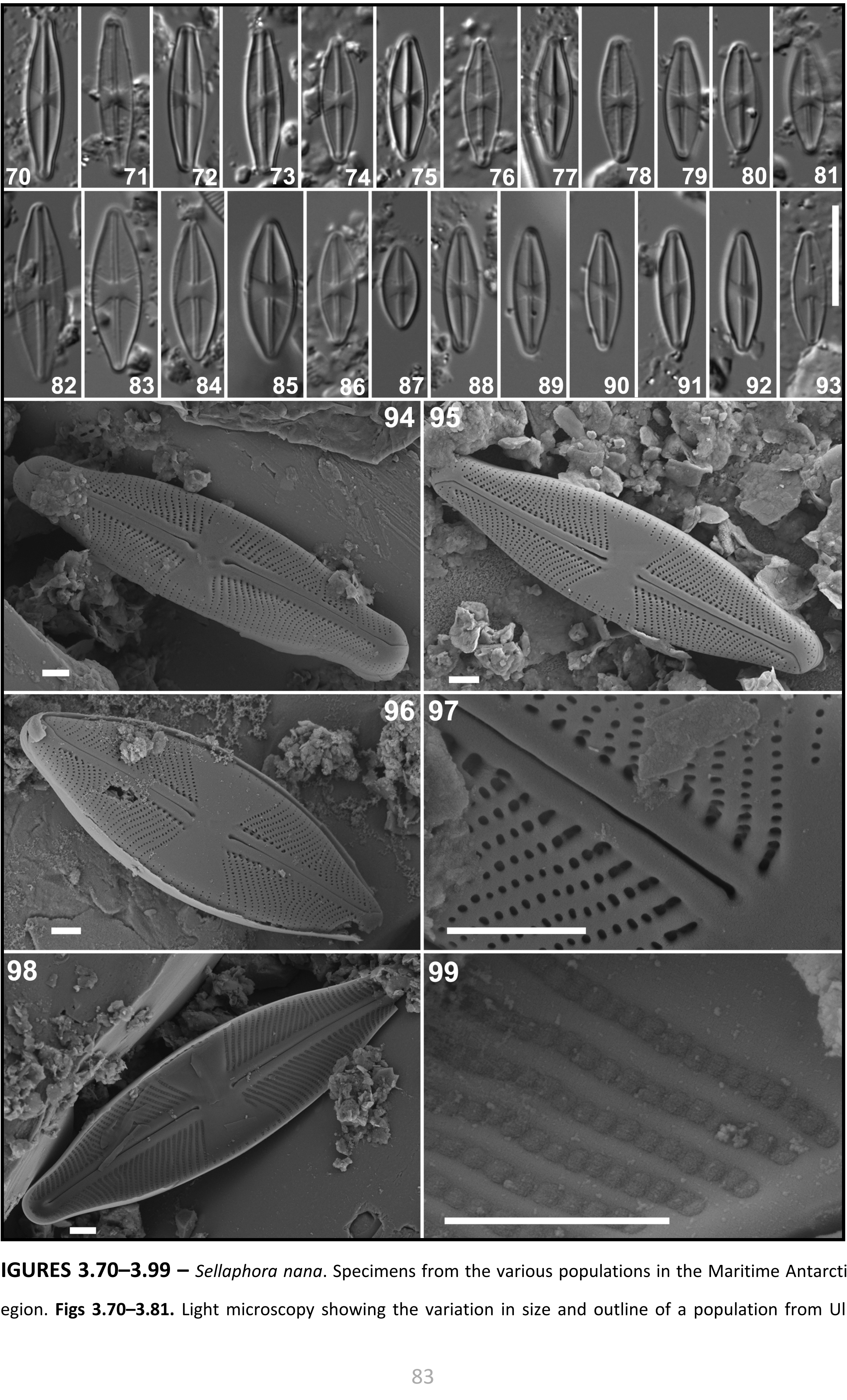
FIGURES 3.52–3.69 – *Microcostatus australoshetlandicus*. Specimens from the type population near Irizar Lake, Deception Island. **Figs 3.52–3.65.** Light microscopy showing the variation in size, striation and outline. **Fig. 3.66.** SEM external valve view of an entire valve showing the ultrastructure of the sternum, conopeum and the areolae. **Fig. 3.67**. SEM external valve view of the areolae with the typical external coverings and the conopeum covering the striae. **Fig. 3.68.** SEM internal valve view of an entire valve. **Fig. 3.69.** SEM internal valve view of the open areolae. Scale bar represents 10 µm except for Figs 3.67, 3.69 where scale bar = 1 µm.

Sellaphora nana **(Hustedt) Lange-Bertalot et al.** (Figs 3.70–3.99)

Valves narrowly lanceolate to elliptic-lanceolate in some populations with clearly to moderately convex margins and protracted, rostrate to subrostrate apices. Valve dimensions (n=25): length 8.5–19 µm, width 3.5–5.3 µm. Axial area narrow, formed by a weakly raised sternum widening towards the central area, bordered by shallow grooves. Central area typically wedge-shaped, bordered by several (5–12) shortened striae composed of only a few (< 10) areolae. Raphe filiform with deflected, expanded and slightly undulating external proximal raphe endings and clearly deflected external distal raphe fissures, shortly continuing onto the valve mantle. Internally, proximal raphe endings expanded, short but clearly unilaterally deflected. Internal distal raphe endings terminating on helictoglossae. Transapical striae clearly radiate, geniculate near the valve center, abruptly becoming convergent at 1/3 before the valve apices, 40–50 in 10 µm. Striae composed of long series of very small, rounded areolae (ca. 90 in 10 µm) continuing onto the valve margin. Near the sternum, areolae sometimes fused, continuing into the shallow grooves. Internally areolae individually covered by a porous hymen.

Ecology: Several populations of *Sellaphora nana* were found in the Maritime Antarctic Region, mostly on the South Shetland Islands. On Hurd Peninsula (Livingston Island), very small populations were found living epiphytically on mosses bordering small puddles and streams (F=VI–VII) and in soil samples collected under moss vegetations. On the other large icefree peninsula of the island, Byers Peninsula, the largest population was observed in Asa Lake, a large lake on the central plateau. This slightly alkaline lake (pH = 7.5) has a low specific conductance value (114 µS/cm) and was located in a stony area surrounded by seepage areas. The dominant taxa in the sample included *Nitzschia paleacea* Grunow, *Fragilaria capucina* s.l. and *Sellaphora* cf. *seminulum* (Grunow) D.G.Mann. On James Ross Island, small populations were found in both coastal lakes and stable shallow lakes on higher altitudes (Vondra Lakes). All lakes were characterized in having a more alkaline pH (7.5–8.0) and a broad range of specific conductance values (<50 to >1000 µS/cm).

Confirmed Distribution: *Sellaphora nana* is presumably a cosmopolitan species with records from a.o. Sardinia (Lange-Bertalot et al. 2003), Finland (Lange-Bertalot & Metzeltin 1996), Germany (Hustedt 1957), Argentina (Romero 1995), South Africa (Schoeman 1970) and Maritime Antarctica where species was found on the South Shetland Islands, James Ross Island and Signy Island (Sterken, pers. comm.). So far, no records exist from the sub-Antarctic islands nor the Antarctic Continent. The record of *Stauroneis nana* on the Crozet archipelago (Van de Vijver & Beyens 1998) was corrected in 2002 as *Frustulia cirisiae* Van de Vijver.



FIGURES 3.70–3.99 – *Sellaphora nana*. Specimens from the various populations in the Maritime Antarctic Region. **Figs 3.70–3.81.** Light microscopy showing the variation in size and outline of a population from Ulu

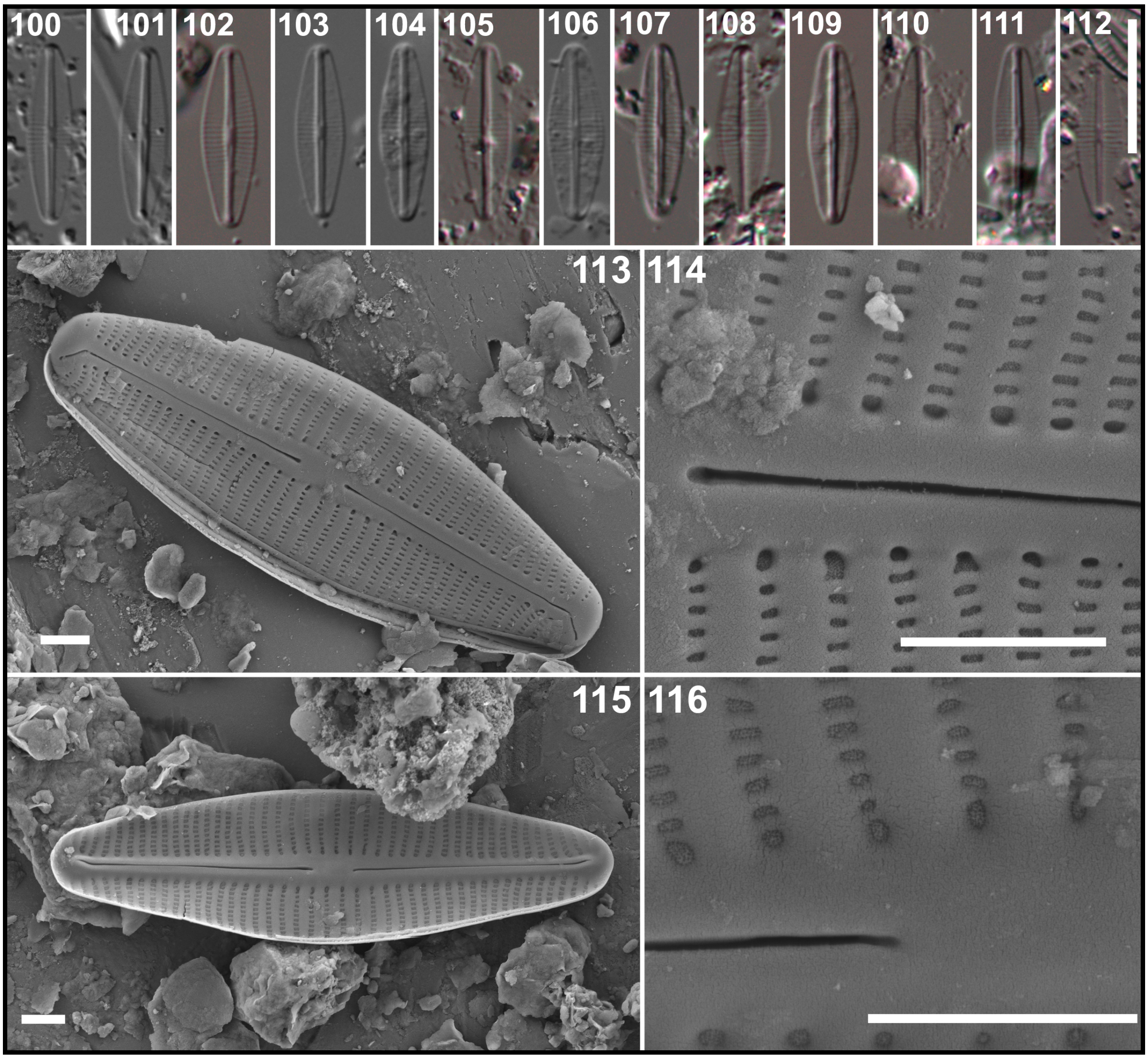
Peninsula, James Ross Island. **Figs 3.82–3.87.** Light microscopy showing the variation in size and outline of a population from Deception Island. **Figs 3.88–3.93.** Light microscopy showing the variation in size and outline of a population from Byers Peninsula, Livingston Island. **Fig. 3.94**. SEM external valve view of an entire valve (Livingston Island) showing the ultrastructure of the raphe and the striae. **Fig. 3.95.** SEM external valve view of an entire valve (James Ross Island). **Fig. 3.96.** SEM external valve view an entire valve (Deception Island). **Fig. 3.97.** SEM external detail view of the areolae and the proximal raphe endings (James Ross Island). **Fig. 3.98** SEM internal valve view of an entire valve (Deception Island). **Fig. 3.99.** SEM internal valve view of the areolae with the typical individual coverings (Deception Island). Scale bar represents 10 µm except for Figs 3.97, 3.99 where scale bar = 1 µm.

Craticula glaberrima **(W.&G.S.West) nov. comb.** (Figs 3.100–3.116)

Basionym: *Navicula glaberrima* W. & G.S. West Freshwater algae. *British Antarctic Expedition (1907–1909) Science Report, Biology* 1(7): 282, Plate XXVI, Fig. 125.

Valves lanceolate to rhombic-lanceolate with convex (never parallel) margins and sub-rostrate to rostrate apices. Valve dimensions (n=20): length 13–15 µm, width 3.4–4.5 µm. Axial area very narrow, formed by a weakly raised linear sternum. Central area absent. Raphe filiform with straight, non-expanded proximal external raphe endings. External distal raphe fissures clearly deflected, short, terminating on the valve face. Transapical striae parallel to weakly radiate throughout the entire valve, becoming slightly convergent near the apices. Central striae more spaced, 28–30 in 10 µm, compared to striae near the apices (34–40 in 10 µm) making them discernible in LM. Apices hyaline, lacking any striae apart from one short stria composed of very small rounded areolae. Striae uniseriate, composed of small apically elongated, slitlike areolae, ca. 90 in 10 µm. Areolae close to the axial area slightly enlarged. Internally, proximal raphe endings very weakly deflected. Distal endings short, terminating on well developed helictoglossae. Areolae internally bearing porous hymens.

Ecology: *Craticula glaberrima* is a rare species with its largest population (<1% of all counted valves) found in the kettle Láska Lake, located on the ice-free area of Ulu Peninsula. Láska lake has an almost circumneutral pH with a very low specific conductance value (26 µS/cm) and low nutrient levels. Dominant taxa in the sample include *Nitzschia homburgiensis Sellaphora nana* and *Microcostatus naumanii*.



FIGURES 3.100–3.116 – *Craticula glaberrima*. Specimens from the largest population on the Clearwater Mesa, James Ross Island. **Figs 3.100–3.112.** Light microscopy showing the variation in size, striation and outline. **Fig. 3.113.** SEM external valve view of an entire valve showing the ultrastructure of the raphe and the areolae. **Fig. 3.114.** SEM external valve view of the central area showing in detail the areolae and a proximal raphe ending. **Fig. 3.115.** SEM internal valve view of an entire valve. **Fig. 3.116.** SEM internal valve view of the areolae with the typical hymen structure. Scale bar represents 10 µm except for Figs 3.114, 3.116 where scale bar = 1 µm.

Confirmed Distribution: *Craticula glaberrima* was so far only found on the Antarctic Continent (West & West 1911), probably due to confusion with similar taxa such as *C. molestiformis* (Hustedt) Lange-Bertalot or *C. submolesta* (Hustedt) Lange-Bertalot. The species is with certainty present on James Ross Island were several small populations were observed (Kopalová et al. unpublished results). On the South Shetland Islands, the species was so far only found once. A very small population was recorded on Byers Peninsula (Livingston Island).

Discussion

The four new taxa present each a unique combination of morphological characters that separates them from similar taxa worldwide. The application of a more fine-grained taxonomy based on a narrower species concept, resulted in the separation of these taxa from their European or American relatives. It is highly likely that these taxa were lumped together in the past making the (paleo-)ecological or biogeographical interpretations based on literature data quite difficult and even incorrect. Nevertheless, the four new naviculoid taxa can be easily distinguished.

Adlafia submuscora clearly belongs to the genus *Adlafia* based on the structure of the raphe and the areolae covered by porous external hymens. Several *Adlafia* species show some resemblance to the new taxon, such as *A. muscora*, *A. minuscula* (Grunow) Lange-Bertalot and even *A. suchlandtii* (Hustedt) Lange-Bertalot. Larger taxa such as *A. bryophila* and *A. parabryophila* Lange-Bertalot differ sufficiently in shape and size, being much larger with clearly capitate to subcapitate apices, to be confused with *A. submuscora*. *Adlafia suchlandtii* is narrower (valve width 2.5–3 µm) with straight, parallel margins. *Adlafia minuscula* has more elliptic-lanceolate valves lacking subrostrate apices with different (shorter) external distal raphe endings. Finally, *A. muscora* is the most similar taxon but can be differentiated in having larger valve dimensions (length around 20 µm vs. 10–12 µm), more rostrate apices, deflected expanded central raphe endings (contrary to the straight simple endings in *A. submuscora*) and a lower number of striae (23–26 in 10 µm vs. 40–45 in 10 µm in *A. submuscora*) (Kociolek & de Reviers 1996).

Chamaepinnularia antarctica is a typical member of the genus *Chamaepinnularia*, based on the stria structure composed of one large areola interrupted near the valve face/mantle junction, the raphe structure with the bent distal fissures and the external porous hymenes (Lange-Bertalot & Metzeltin 1996). *Chamaepinnularia* species are almost always quite small, consistent with the dimensions of *C. antarctica*. The new taxon has been confused with *C. australomediocris*, another typical constituent of the Antarctic diatom flora (Schmidt et al.

1990, Van de Vijver et al. 2002a). The latter can be separated based on its more broadly lanceolate valve outline, the clearly protracted, subrostrate apices, the presence of a large fascia (never observed in *C. antarctica*), its often larger valve dimensions (width 3–4 µm vs. 2.4–2.8 µm in *C. antarctica*) and a higher number of striae (above 23 vs. 21–23 in *C. antarctica*). Where both species co-occur, the presence of the fascia is a good criterion to separate *C. australomediocris* from *C. antarctica*. *Chamaepinnularia submuscicola* (Krasske) Lange-Bertalot and *C. soehrensis* (Krasske) Lange-Bertalot & Krammer both have more protracted, almost capitate apices whereas in *C. antarctica*, only weakly subrostrate apices have been observed (Lange-Bertalot & Metzeltin 1996, Werum & Lange-Bertalot 2004). *C. reinventa* Wydrzycka & Lange-Bertalot has a more linear valve outline but less radiate striae and usually a narrow rectangular fascia (Wydrzycka & Lange-Bertalot 2001).

The species of the genus *Mayamaea* are characterized in having small valve dimensions, an elliptical to lanceolate-elliptical valve outline, a simple raphe structure with bent distal fissures and rounded areolae with external porous hymenes (Lange-Bertalot 1997). The latter feature discriminates the genus from the genus *Eolimna* whose species have areolae coverings that are positioned halfway the areolar canal (Schiller & Lange-Bertalot 1997). *Mayamaea josefelsteri* clearly belongs to *Mayamaea*. At present, several *Mayamaea* species belonging to the complex around *M. atomus* have been found in the Antarctic Region (Kellogg & Kellogg 2002). They all have more rounded, elliptical valves contrary to the more elongated, elliptical valves of *M. josefelsteri*. The only species that can be confused with *M. josefelsteri*, is *M. agrestis* (Hustedt) Lange-Bertalot, but the latter has more acutely rounded valve apices and straight radiate striae whereas *M. josefelsteri* has clearly curved striae near the central area. The central area in *M. agrestis* is less developed due to the longer central striae (Lange-Bertalot et al. 2003). Other *Mayamaea* taxa such as *M. aliena* (Krasske) Lange-Bertalot differ by the shape of the central area and the striation pattern (Lange-Bertalot 2001).

It is not entirely clear whether *Microcostatus australoshetlandicus* belongs to the genus *Microcostatus*. Based on valve outline, the presence of the raphe enclosed by an asymmetrically constricted sternum and the raphe structure are features that can be found in *Microcostatus*. On the other hand, there are several features that do not match the original genus description (Johansen & Sray 1998). The striae in most *Microcostatus* species are composed of series of small linear-elongate areolae whereas in *M. australoshetlandicus* the striae are composed of one single areola. Internally, the striae show more affinities with the genus *Chamaepinnularia* although there is no interruption near the valve face/mantle junction as is commonly seen in the latter genus. In *Microcostatus*, these chamber-like striae have never been observed. Only in *M. monsviridis* Metzeltin & Lange-Bertalot, described from Costa Rica, striae composed of one areola have been observed. Metzeltin & Lange-Bertalot (2007) commented the differences with the genus description of *Microcostatus* but were not in favor of describing a new genus based on these differences. According to the genus description, *Microcostatus* lacks a conopeum. Following the definition by Ross et al. (1979), a conopeum is a 'flap of silica attached to or near to, the axial area and extending over the valve towards the margin'. In *M. australoshetlandicus*, the presence of a conopeum can be clearly demonstrated covering the longitudinal groove. Taylor et al. (2010) already reported the presence of a conopeum and a pseudoconopeum in several new *Microcostatus* species from South Africa, contradicting the original genus description. The so-called microcostae, the key feature of this genus could not be observed but this is probably due to the presence of the conopeum covering most of the axial area and extending onto the striae. Other genera with striae composed of only an elongated areola, such as *Diadesmis*, *Microfissurata*, *Gomphosphenia* or the complex of species around *Navicula schmassmannii* Hustedt all present too many morphological differences to be excluded as host genus for this new species, making a combination in *Microcostatus* at the moment the most likely solution.

Sellaphora nana was originally in 1957 as *Stauroneis nana* Hustedt described based on a single valve found in the plankton of the river Weser in Germany. Lange-Bertalot et al. (2003) transferred the species to the genus *Sellaphora* although he raises some doubt about the correct taxonomic position. The populations observed in the Maritime Antarctic Region show some a rather broad morphological plasticity. The shape of the valves varies from clearly elliptic-lanceolate with convex margins to narrowly lanceolate with almost parallel margins and seems to be determined by the geographic locality where the populations are found. On Livingston Island and Deception Island, valves tend to become broader whereas on James Ross Island and Signy Island, narrower valves are found. Apart from the variability in shape, no other differences could be found making it unlikely to give these populations a different taxonomic identity, despite the fact that some of them do not correspond to the single valve Hustedt used to describe the species. In Lange-Bertalot et al. (2003) the shape plasticity is likewise quite large and corresponds to some of the shapes that are found in the Maritime Antarctic Region. Several other species show some similarity with *S. nana* such as *Sellaphora nanoides* Lange-Bertalot et al. and *S. stauroneioides* (Lange-Bertalot) J.Vesela & J.R.Johansen. *Sellaphora nanoides* can be separated in having a more coarse striation pattern (30–33 striae in 10 µm vs. 37–40 in *S. nana*) and larger valves (width 4.5–7.0 vs. 3–4.5 µm). *Sellaphora stauroneioides* has more parallel valve margins with always clearly rostrate to even capitate apices. Valve width in the latter is usually also much higher (5.5–6.5 vs. 3–4.5 µm). The valves shown in Rumrich et al. (2000, Plate 79, Figs 1–4 and Plate 87, Figs 21–23) resp. under the name *Adlafia* sp. and *Naviculadicta* (?nov.) spec. most probably also belong to *S. nana*.

Finally, *Navicula glaberrima* was originally described by W. & G.S West from the Antarctic Continent (1911). A re-analysis of the type material yielded only two valves observed in light microscope with no observations in SEM (Van de Vijver et al. 2012). It is most likely that the valves observed on James Ross Island represent *Craticula* (*Navicula*) *glaberrima* although they seem to be less capitate as was observed in the West & West material. The original drawing shows however no capitate apices making conspecificity with the James Ross population most likely. *C. glaberrima* shows some similarities with *C. submolesta* (Hustedt) Lange-Bertalot based on valve outline, dimensions and stria density. *C. submolesta* has never been observed on the Antarctic Continent (Kellogg & Kellogg 2002) although it was reported from localities closeby such as the South Shetland Islands (Håkansson & Jones 1994) and Horseshoe Island (Wasell & Håkansson 1992, Wasell 1993). Based on the morphological analysis of the James Ross Island populations, several important differences can be noted. *Craticula glaberrima* has a higher stria density (>30 vs. 19–24 in 10 µm in *C. submolesta*). Valves in *C. submolesta* tend to be more linear with more parallel margins and clearly developed (sub-rostrate) apices, never observed in *C. glaberrima*. Another smaller *Craticula* species is *C. molestiformis* (Hustedt) Lange-Bertalot but the stria density in the latter is likewise much lower (23–26 in 10 µm) with striae visible in LM almost up to the apices. A second *Craticula* species has been regularly found in larger populations than *C. glaberrima* on the Antarctic Continent and the Maritime Antarctic region. This species has been for a long time identified as *Craticula* (*Navicula*) *molesta* (Krasske) Lange-Bertalot & Willmann, a species described in 1938 from Spitsbergen by G. Krasske (or as *Navicula zizix* Van Landingham as it was called later) but recently, it was described as *Craticula antarctica* Van de Vijver & Sabbe (Van de Vijver et al. 2010a). Possible conspecificity between *C. glaberrima* and *C. antarctica* has to be excluded based on differences in valve outline and dimensions.

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CHAPTER 4

Benthic diatoms (Bacillariophyta) from seepages and streams on James Ross Island (NW Weddell Sea, Antarctica)

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The non-marine diatom communities in the Antarctic Region are characterized by a typical species composition, in close relationship with their environment. Despite the growing interest, the diatom flora of James Ross Island is only poorly known. The present paper discusses the diversity of limnoterrestrial diatoms on this island: seepages and streams. The diatom flora of 53 samples taken on the eastern side of the Ulu Peninsula on James Ross Island has been studied using light and scanning electron microscopy. A total of 69 diatom taxa belonging to 26 genera have been observed. The genera Luticola, Diadesmis, Muelleria *and* Pinnularia *dominated the species composition. The flora shows an interesting mixture of cosmopolitan and Antarctic species containing several species reaching on James Ross Island their most northern distribution in the Antarctic Region. The taxonomical position of one widespread Antarctic species,* Psammothidium papilio *(Kellogg et al.) Kopalová & Van de Vijver comb. nov., is corrected. The limnoterrestrial diatom flora of James Ross Island has a rather low number of species, of which a large proportion shows a restricted Antarctic distribution.*

Key words: *Antarctic Peninsula, Bacillariophyceae, diatoms, biogeography, James Ross Island, seepages, streams.*

Introduction

Limno–terrestrial diatoms (Bacillariophyceae) are one of the most abundant and successful microbial groups in terrestrial and freshwater ecosystems in the Antarctic and sub-Antarctic Regions (Jones 1996, Van de Vijver & Beyens 1999a, Vanormelingen et al. 2008, Vyverman et al. 2010) both in number of species and number of individuals. Their characteristic silica outer shell (= valve) and the significant responses on changes in their physical and chemical environment, make them excellent bio-indicators used in both applied environmental, biogeographical and palaeoecological studies (e.g., Soininen 2007, Verleyen et al. 2009).

The use of a narrower species concept, based on the sometimes only subtle variability of the siliceous cell wall morphology, has revealed that older data do not always reflect real diatom diversity (see review on species concepts by Mann 1999). 'Force-fitting', as a result of the use of European- or North-American identification guides in other continents (Tyler 1996), and too broad interpretations of the original species description, led to the idea that the number of species with a restricted Antarctic distribution remained low in diatom reports from Antarctic localities (Van de Vijver & Beyens 1999a, Kellogg & Kellogg 2002, Van de Vijver et al. 2005). In contrast to previous (recent) studies stressing upon the cosmopolitan nature of the Antarctic flora (Toro et al. 2007, Vinocur & Maidana 2010), a high degree of endemism has been demonstrated in the diatom flora on the different islands in the southern part of the Atlantic Ocean (e.g., Sabbe et al. 2003, Van de Vijver et al. 2005, Van de Vijver 2008, Van de Vijver & Mataloni 2008, Kopalová et al. 2009, Van de Vijver et al. 2010a, 2011a, 2011b). The application of this more fine-grained taxonomy also resulted in a reconsideration of the diatom biogeography showing that the Antarctic diatom flora should be considered to be much more unique than previously accepted (Vyverman et al. 2007, 2010).

Despite this growing effort in characterising better the diatom flora of the Antarctic Region, the limnoterrestrial diatom flora of James Ross Island is only poorly known. Until recently, reports on the James Ross Island diatom flora comprised only four papers, focusing mainly on (subfossil) diatoms in sediment cores (Hansson & Håkansson 1992, Burckle & Wasell 1995, Håkansson et al. 1995, Björck et al. 1996). The construction of the Czech research station in 2006 on the northern tip of James Ross Island, was the start of a renewed interest in the microbial biodiversity of this island (Komárek & Elster 2008, Komárek et al. 2008) including new primary research on the diatom flora in the northern part of the island. The results obtained so far contradict the previous statements on the cosmopolitan character of the composing diatom flora as a fairly large number of new taxa was recently described (Esposito et al. 2008, Kopalová et al. 2009, Zidarova et al. 2009, Van de Vijver et al. 2010a, 2011a, 2011b). Moreover, a recent analysis of the seepage and stream diatom flora from James Ross Island indicated that the previously published literature on the James Ross Island diatoms contained a large number of misidentifications and inconsistencies, making a thorough and detailed taxonomic analysis of the limno–terrestrial diatoms necessary.

The present study is the first in a series of papers discussing the actual living diatom communities on James Ross Island. This first paper describes the limno–terrestrial diatoms found in seepage areas and streams. Information on the geographic distribution and autoecology of the observed taxa is provided. Later papers will focus on diatoms in lake ecosystems and moss vegetations.

Material and methods

Site Description

James Ross Island (64°10'S, 57°45'W) is situated in the northwestern part of the Weddell Sea, close to the northern tip of the Antarctic Peninsula. The island, with a total surface area of 2450 km², belongs to the transitory zone between the Maritime Antarctic and Continental Antarctic regions (Øvstedal & Lewis-Smith, 2001). More than 75% of the island is permanently covered with ice, leaving only Ulu Peninsula, the northernmost part of the island (covering approximately 100 km^2), ice-free. The mean annual air temperature rarely exceeds –5 °C at sea level with the mean summer temperature slightly below 0 °C (Schwerdtfeger 1984). Precipitation is limited [150 mm/y in the northern part (Aristarain et al. 1987)] with high evaporation rates reducing the formation of large open water bodies. Compared to the South Shetland Islands on the northern side of the Antarctic Peninsula, James Ross Island is more arid (Komárek & Elster 2008). The terrestrial vegetation on the island is limited to non-vascular plants and composed of a predominantly bryophyte and lichen tundra. The human presence is limited to the northern side of the island where the Czech Johann Gregor Mendel Antarctic Research Station has been located since 2006. More information on the geology and climate of Ulu Peninsula can be found in Komárek & Elster (2008).

During the study, two different habitat types were sampled: seepage areas and small streams. The morphological and ecological differences between seepages and streams are discussed in Komárek & Elster (2008). Briefly, streams on James Ross Island are the result of melting of glaciers, snowfields and ice corns in moraine deposits and therefore never present apermanent flowing regime. Their pH ranged from 7 to 8.6 (Komárek & Elster 2008) while the specific conductance depends largely on the distance from the melting zone. Their microflora is composed mainly of diatoms, filamentous cyanobacteria and green algae (*Klebsormidium*) (Komárek & Elster 2008). The character of streams is different due to the distinct geological bedrock. Algal and Bohemian stream are flowing through unstable Cretaceous sediments, whereas Tern and Elster creek are located in the volcanic part of the Ulu Peninsula (Fig. 4.1). Seepage areas are shallow wetland ecosystems, usually on permafrost soil, that are supplied by melting water (Komárek & Elster 2008). They prevail in the entire Antarctic Region and form one of the most characteristic habitats for micro-organisms (Wharton et al. 1983). The physico-chemical features of seepage areas show a large variability with the amount and availability of moisture being one of the determining factors of the biodiversity in these areas.

Sampling

A total of 53 samples from streams (34 samples taken from 4 streams) and seepage areas (19 samples from 6 different seepage areas) were collected from James Ross Island (64°10'S, 57°45'W) during the austral summers of 2004, 2006, 2007 and 2009. Sampling areas are indicated on Fig. 4.1 (Czech Geological Survey 2009) with a detailed overview of the collected samples given in Table 4.1. Due to the restricted logistic possibilities of working in these extreme conditions, it was almost impossible to collect data on environmental parameters for every sample. Basic ecological parameters (pH, conductivity) were measured using WTW multi 340i (WTW®, Weilheim, Germany) in 2004 and 2006 to characterise the seepage habitat below Berry Hill (samples SP2, SP3), Algal, Bohemian stream and Tern Creek.

Slide preparation

Diatom samples collected in 2004 were kept frozen until analysis, whereas those from 2006, 2007 and 2009 were fixed with formaldehyde (3% final concentration). Subsamples were cleaned by a modified method described in Van der Werff (1955): 37% H_2O_2 was added to samples that were heated to 80 °C for 1h. Oxidation of organic material was completed by addition of $KMnO_4$. Following digestion and oxidation, samples were rinsed 3 times with deionised H_2O alternated with centrifugation (10 minutes at 3700 x g). The resulted cleaned material was diluted with distilled water, dried on microscope cover slips, and mounted in Naphrax®. Samples and slides are stored at the Department of Ecology, Charles University in Prague (Czech Republic) with duplicates at the National Botanic Garden of Belgium (Meise, Belgium).

Sample analysis

In each sample, at least 300 valves were enumerated on random transects at 1000x magnification under oil immersion using a Nikon ECLIPSE E400 microscope equipped with Differential Interference Contrast (Nomarski) optics. For scanning electron microscopy (SEM), parts of the oxidized suspensions were filtered through polycarbonate membrane filters with a pore diameter of 1 µm, pieces of which were fixed on aluminum stubs after air-drying. The stubs were sputter-coated with 50 nm of Au and studied in a JEOL-5800LV at 25 kV. Valve dimensions [length (L), width (W) and stria densities (S)] were determined on 'n' valves. For each dimension, the minimum and maximum values are given. Striae densities were measured according to Schoeman & Archibald (1976–1980), i.e. along the raphe branches between the central and terminal raphe endings. Biogeographic and autoecological notes are based on literature data provided with unambiguous illustrations and/or descriptions and based on Kellogg & Kellogg (2002), Van de Vijver et al. (2002a, 2004, 2010a, 2010b, 2011a, 2011b), Sabbe et al. (2003), Esposito et al. (2008), Van de Vijver (2008), Van de Vijver & Mataloni (2008), Kopalová et al. (2009, 2011) and Zidarova et al. (2009, 2010). When the identity of a taxon could not be determined with 100% certainty, this was shown using 'cf' or 'sp' and its distribution is listed as unknown. For Antarctic species, the geographic distribution was further subdivided in sub-Antarctic (SA), Maritime Antarctic (MA) and Continental Antarctic (CA) Region based on Chown & Convey (2007).

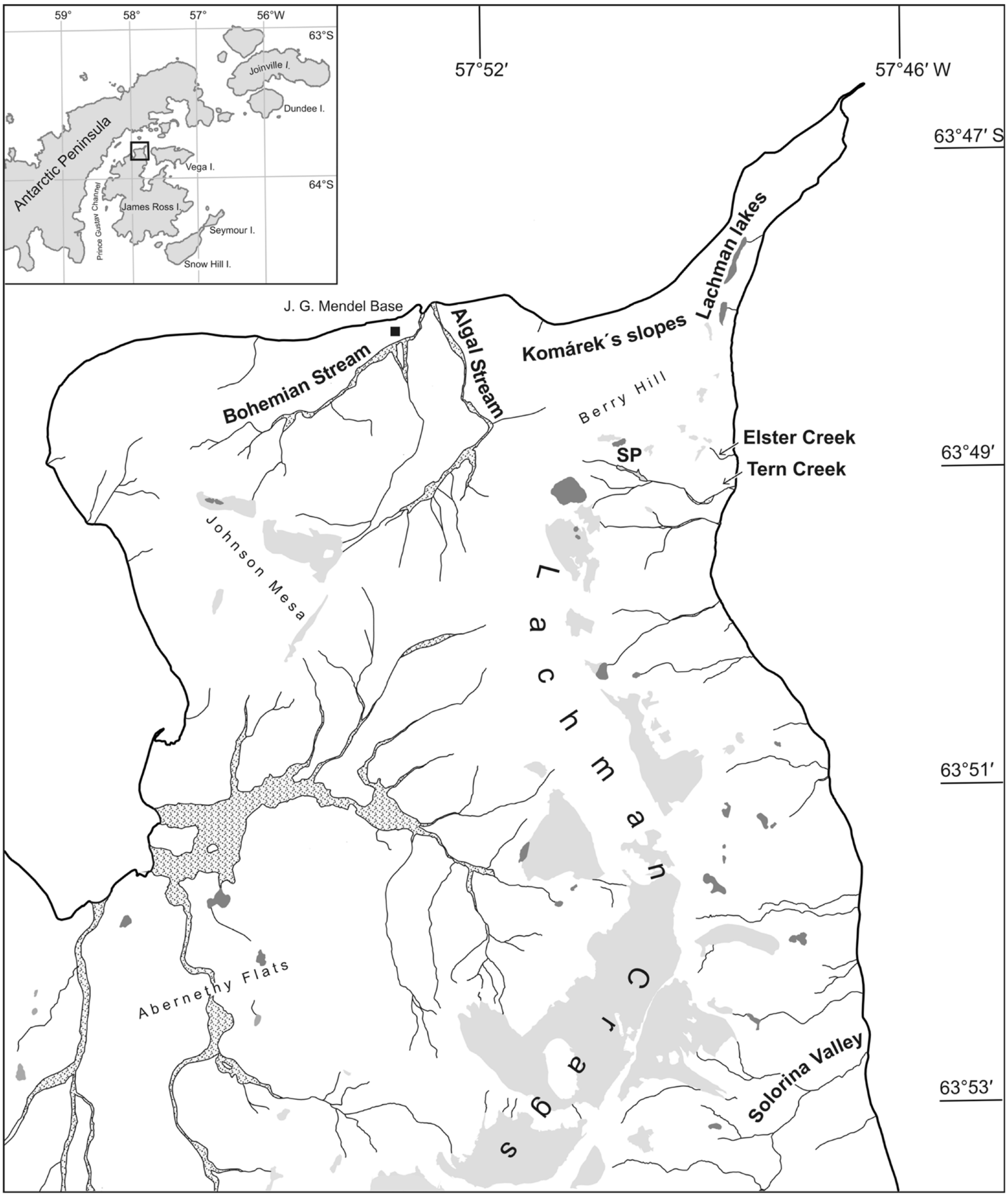

FIGURE 4.1 – Detailed map of Ulu Peninsula in the north of James Ross Island with the main sampled areas indicated. More than one sample was taken at a particular locality. The inset map shows the Antarctic Peninsula with the position of James Ross Island and Ulu Peninsula.

To determine the extent to which our sampling effort represented the diatom flora of the James Ross Island seepages and streams, we calculated the incidence-based species richness estimator (ICE, Chao et al. 2000) and the mean Chao2 richness estimator (Chao 1984), both using the EstimateS program version 8.2 (Coldwell 2009). The species accumulation curve was prepared using Primer-E 6.0 after 999 permutations.

Results

Species composition and diversity

A total of 69 diatom taxa (including species, varieties and forms) belonging to 26 genera was identified in the sample set. Table 4.2 provides a full list of all taxa together with their biogeographic distribution.

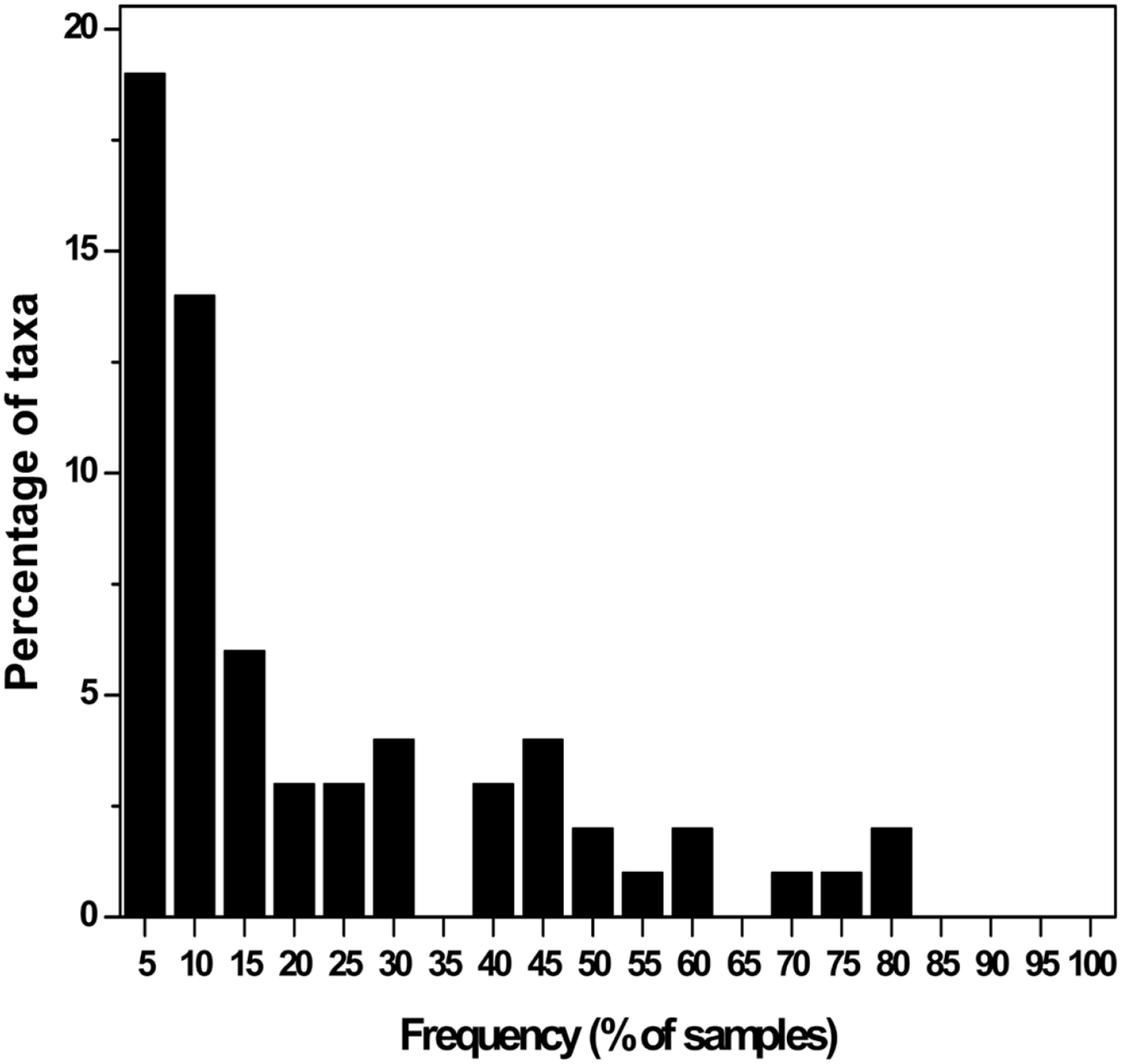

FIGURE 4.2 – Frequency classes of taxa occurences in the samples analysed (e.g. 5 indicates 1-5% of all samples).

TABLE 4.1 – List of samples and geographic characteristics used in this paper. Asterisk (*): when determined.

Sample code	Sampling location	Sampling date	Altitude (m)*	Coordinates (GPS)*
Seepages				
S2	Komarek’s slopes below Berry Hill	20/02/2004	56	63°48.200’S 57°50.772’ W
S3	Komarek’s slopes below Berry Hill	20/02/2004	52	63°48.173’S 57°50.592’W
ST	Tern creek, upper part, seepages	21/02/2004	194	63°48.962’S 57°50.237’W
S1A-J	Komarek’s slopes below Berry Hill	22/02/2007	~50	63°48.183’S 57°50.980’W
SL1	seepages near Lachmann lake	2/01/2009		
SL2	seepages near Lachmann lake	2/01/2009		
SB	seepages, Bohemian stream	4/01/2009		
SS	seepages in Solorina Valley	5/01/2009		
SP2	seepages, Halozetes Valley	15/01/2009		
SP3	seepages, Halozetes Valley	1/02/2009		
Streams				
T0	Tern creek	22/02/2007	14	63°49.128’S 57°48 512’W
T1	Tern creek	10/02/2006		
T2	Tern creek	10/02/2006	~20	63°49.134’S 57°48.567’W
T3	Tern creek	10/02/2006		
T4	Tern creek	10/02/2006	27	63°49.225’S 57°48.981’W
T6	Tern creek	10/02/2006	114	63°49.075’S 57°49.716’W
T7	Tern creek	10/02/2006	184	63°48.984’S 57°50.149’W
T8	Tern creek	10/02/2006		
B	Bohemian stream	22/02/2007	16	63°48.086’S 57°52.600’W
B1	Bohemian stream	1/02/2006	13	63°48.076’S 57°52.894’W
B2	Bohemian stream	1/02/2006	17	63°48.204’S 57°53.220’W
B3	Bohemian stream	1/02/2006	28	63°48.378’S 57°53.881’W
B4	Bohemian stream	1/02/2006	39	63°48.582’S 57°54.551’W
B5	Bohemian stream	1/02/2006	45	63°48.625’S 57°54.654’W
B6	Bohemian stream	1/02/2006	64	63°48.745’S 57°55.183’W
B7	Bohemian stream	1/02/2006	94	63°48.805’S 57°55.788’W
A1	Algal stream	28/01/2006	16	63°48.086’S 57°52.600’W
A2	Algal stream	28/01/2006		
A3	Algal stream	28/01/2006		
A4	Algal stream	28/01/2006		
A5	Algal stream	2/02/2006	74	63°48.523’S 57°52.292’W
A6	Algal stream	2/02/2006		
A7	Algal stream	2/02/2006	75	63°48.610’S 57°52.194’W
A8	Algal stream	2/02/2006	75	63°48.610’S 57°52.194’W
A9	Algal stream	2/02/2006	94	63°48.761’S 57°51.859’W
A10	Algal stream	2/02/2006		
A11	Algal stream	2/02/2006	96	63°49.036’S 57°51.718’W
A12	Algal stream	2/02/2006		
A13	Algal stream	2/02/2006	125	63°49.410’S 57°52.571’W
A14	Algal stream	2/02/2006		
A15	Algal stream	2/02/2006		
E1	Elster creek	19/01/2009		
E2	Elster creek	19/01/2009		
E3	Elster creek	19/01/2009		

TABLE 4.2 – List of all observed species in the investigated streams and seepage areas of James Ross Island. The relative abundance of the species in streams or seepage areas is given. Distribution: CA, Antarctic Continent; MA, Maritime Antarctic Region; SA, sub-Antarctic Region; C, Cosmopolitan; U, Unknown

Taxon name	Seepages	Streams	Distribution
Achnanthes coarctata (Bréb.) Grunow	1.7	0.1	C
Achnanthes muelleri G.W.F.Carlson	0.8	0.1	MA/SA
Achnanthes taylorensis D.E.Kellogg, Stuiver, T.B.Kellogg & G.H.D.Denton	0.2	< 0.1	MA/CA
Achnanthidium minutissimum (Hust.) Czarn. s. lat.		< 0.1	C
Amphora sp.	0.1	< 0.1	U
Brachysira minor (Krasske) Lange-Bert.	0.4	0.1	MA
Chamaepinnularia gerlachei Van de Vijver & Sterken	0.1	0.1	MA
Chamaepinnularia krookiiformis (Krammer) Lange-Bert. & Krammer		0.1	C
Craticula antarctica Van de Vijver & Sabbe		0.4	MA/CA
Diadesmis arcuata (Heiden) Lange-Bert.	3.1	1.4	MA/SA
Diadesmis comperei Le Cohu & Van de Vijver	1.6	0.2	MA/SA
Diadesmis inconspicua Kopalová & Van de Vijver	0.4	2.1	MA
Diadesmis ingeae Van de Vijver	0.7	0.4	MA/SA
Diadesmis sp.	0.1		U
Eolimna jamesrossensis Kopalová & Van de Vijver	**14.3**	**16.2**	MA
Eolimna minima (Grunow) Lange-Bert.		0.2	C
Fistulifera saprophila (Lange-Bert. & Bonik) Lange-Bert.		**17.1**	C
Fragilaria capucina s. lat. Desm.	0.4	**18.1**	C
Geissleria gabrielae Van de Vijver & Zidarova	< 0.1		MA
Gomphonema sp.	1.5	< 0.1	U
Hantzschia abundans Lange-Bert.	2.3	0.6	C
Hantzschia amphioxys (Ehrenb.) Grunow	4.9	1.3	C
Hantzschia hyperaustralis Van de Vijver & Zidarova	0.3	0.6	MA/CA
Karayevia oblongella (Østrup) Aboal		< 0.1	C
Luticola australomutica Van de Vijver	1.3	0.4	MA
Luticola austroatlantica Van de Vijver, Kopalová, S.A.Spaulding & Esposito	0.3	3.8	MA/CA
Luticola cohnii (Hilse) D.G.Mann	0.5	0.1	C
Luticola doliiformis Kopalová & Van de Vijver		< 0.1	MA
Luticola gigamuticopsis Van de Vijver	0.5	0.1	MA
Luticola katkae Van de Vijver & Zidarova	< 0.1		MA
Luticola muticopsis (Van Heurck) D.G.Mann	7.0	0.8	MA/CA/SA
Luticola sp. 1	1.2	< 0.1	U
Luticola sp. 2		< 0.1	U
Luticola sp. 3	0.9	< 0.1	U
Luticola sp. 4		< 0.1	U
Luticola truncata Kopalová & Van de Vijver	0.8	< 0.1	MA
Luticola vermeulenii Van de Vijver		0.1	MA
Mayamaea atomus (Kütz.) Lange-Bert.	0.1	1.5	C
Mayamaea permitis (Hust.) Bruder & Medlin	0.9	9.2	C
Microcostatus naumannii (Hust.) Lange-Bert.		< 0.1	C
Muelleria aequistriata Van de Vijver & S.A.Spaulding	< 0.1		MA
Muelleria australoatlantica Van de Vijver & S.A.Spaulding	< 0.1		MA
Muelleria luculenta S.A.Spaulding & Stoermer	0.3	0.1	MA/SA
Muelleria regigeorgiensis Van de Vijver & S.A.Spaulding	< 0.1		MA
Muelleria sp.		< 0.1	U
Navicula seibigeana (Ehrenb.) Ralfs	0.1	0.7	C
Navicula sp.		< 0.1	U

TABLE 4.2 – (continued)

Taxon name	Seepages	Streams	Distribution
Nitzchia gracilis Hantzsch	**30.8**	**12.6**	C
Nitzschia homburgiensis Lange-Bert.	4.0	4.8	C
Nitzschia paleacea (Grunow) Grunow	< 0.1		C
Nitzschia perminuta (Grunow) Perag.	**14.9**	4.0	C
Nitzschia sp. 1		< 0.1	U
Nitzschia sp. 2		< 0.1	U
Orthoseira roeseana (Rabenh.) O'Meara	< 0.1	0.8	C
Pinnularia australorabenhorstii Van de Vijver	< 0.1		MA
Pinnularia borealis var. *islandica* Krammer	0.1	0.1	C
Pinnularia borealis var. *pseudolanceolata* Van de Vijver & Zidarova	0.2	< 0.1	MA
Pinnularia borealis var. *scalaris* (Ehrenb.) Rabenh.	0.2	< 0.1	C
Pinnularia divergens var. *media* Krammer		< 0.1	C
Pinnularia intermedia (Lagerst.) Cleve		< 0.1	C
Pinnularia subaltiplanensis Zidarova, Kopalová & Van de Vijver	0.2	0.1	C
Planothidium cf. *delicatulum* (Kütz.) Round & Bukht.		< 0.1	C
Planothidium lanceolatum (Bréb.) Round & Bukht.		< 0.1	C
Psammothidium papilio (D.E.Kellogg) Van de Vijver & Kopalová	0.7	< 0.1	MA/CA
Sellaphora nana (Hust.) Lange-Bert., Cavacini, Tagliaventi & Alfinito	< 0.1	0.1	C
Stauroneis jarensis Lange-Bert., Cavacini, Tagliaventi & Alfinito	0.6	0.1	C
Stauroneis latistauros Van de Vijver & Lange-Bert.	1.1	0.8	MA/CA
Stauroneis pseudomuriella Van de Vijver & Lange-Bert.	0.2		MA/SA
Stauroneis pseudoschimanskii Van de Vijver & Lange-Bert.	0.3	0.1	MA

In general, the genera *Nitzschia* (30.5%), *Eolimna* (15.7%), *Fragilaria* (12.4%) and *Fistulifera* (11.6%) dominated the counts when considering the frequencies of counted valves. However, most taxa belonged to *Luticola* (13 taxa), followed by *Pinnularia* (7 taxa), *Nitzschia* (6 taxa) and *Diadesmis* (5 taxa). Species richness per sample ranged from 4 to 28 with a median value of 12. The highest species richness was recorded in samples A10 (28 taxa), S2 (27 taxa) and A14 (26 taxa). Fifty-three taxa were found with a relative abundance lower than 1% whereas the 10 most important taxa accounted for almost 85% of all counted valves (Table 4.3). The most abundant taxa were *Nitzschia gracilis* Hantzsch (18.5% of all counted valves), *Eolimna jamesrossensis* Kopalová & Van de Vijver (15.6%), *Fragilaria capucina* Desmazières (12.4%) and *Fistulifera saprophila* (Lange-Bert. & Bonik) Lange-Bert. (11.6%). As can be seen in Fig. 4.2, a large number of taxa is restricted to only a few samples and only a very few taxa occur in 50% or more of all samples.

Species richness in the samples varied between 4 and 27 (median=13) for the seepage area samples and 7–28 (median=13) for the stream samples. No difference in the distribution of species numbers per sample was found between both habitats. Some species seemed to show a preference for seepage areas such as *Achnanthes coarctata* (Bréb.) Grunow or *Luticola muticopsis* (Van Heurck) D.G.Mann whereas others apparently such as *Fistulifera saprophila* (Lange-Bert. & Bonik) Lange-Bert. and *Fragilaria capucina* s.l. Desmaz. are more frequent in stream samples.

The flattening (towards the end) of the species accumulation curve (Fig. 4.3) indicates that a large part of the diatom flora was collected. Using species richness estimators, it is possible to evaluate how well the sampling effort reflected the true diatom richness. The expected total number of taxa in all samples is 79 (ICE) or 107 (Chao2) for the James Ross Island seepage and stream samples, suggesting that our counting scored between 65 and 87% of the (theoretical) total number of taxa present in the samples overall.

TABLE 4.3 – Relative abundance of the commonly encountered species in the samples.

Taxon name	Relative abundance (%)
Nitzschia gracilis	18.5
Eolimna jamesrossensis	15.6
Fragilaria capucina	12.4
Fistulifera saprophila	11.6
Nitzschia perminuta	7.5
Mayamaea permitis	6.6
Nitzschia homburgiensis	4.5
Luticola muticopsis	2.8
Luticola austroatlantica	2.7
Hantzschia amphioxys	2.4
Total	84.6

Twenty-eight taxa showed a cosmopolitan distribution (Figs 4.4A–AP), thirty were restricted to the Antarctic Region (Figs 4.5A–AY) and for eleven others, it was impossible to establish their correct taxonomical identity (Figs 4.4AQ–AT) and are left unidentified. Four species were previously described from the seepage areas: *Diadesmis inconspicua* Kopalová & Van de Vijver, *Eolimna jamesrossensis* Kopalová & Van de Vijver, *Luticola truncata* Kopalová & Van de Vijver and *L. austroatlantica* Van de Vijver et al. (Esposito et al. 2008, Kopalová et al. 2009) and one species, *Luticola doliiformis* Kopalová & Van de Vijver was recently described from a soil sample near the Lachman Crags (Kopalová et al. 2011). Of the thirty species with a typical distribution in the Maritime Antarctic Region, seventeen were confined only to this Region, six are also found in the sub-Antarctic Region, six also on the Antarctic Continent and only one in all three regions (i.e. *L. muticopsis*). The morphology, biogeographic distribution and ecology of the Antarctic species are briefly discussed below.

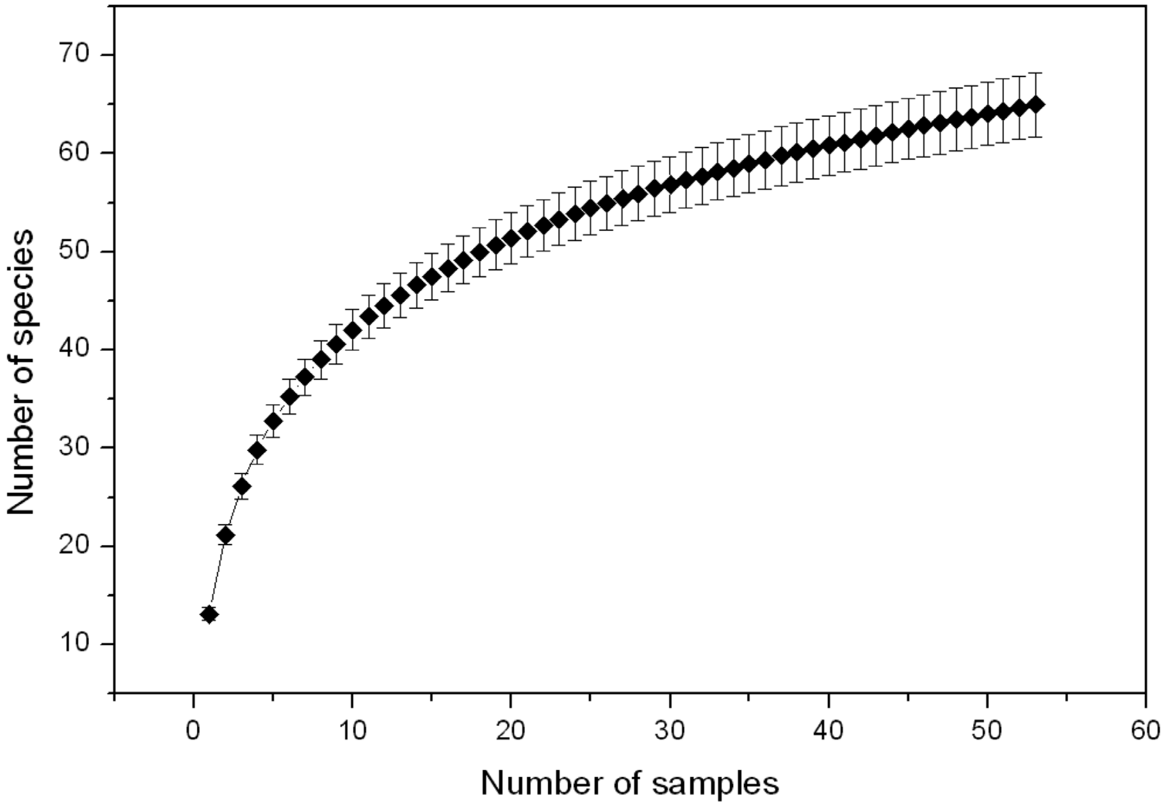

FIGURE 4.3 – Expected species accumulation curve for the total sample set.

Achnanthes muelleri Carlson (Figs 4.5A–B)

Dimensions: L: 24.6–42.6 μm; W: 10.0–14.0 μm; S: 11–13 in 10 μm (n = 25)

Remarks: The James Ross Island specimens are similar in outline to the valves shown in Carlson (1913) and comparable to the observations in Van de Vijver et al. (2002a) although they seem smaller. Carlson (1913) mentions a valve width of 16–21 μm. Based on the drawings published in Carlson (1913), an orbiculus should be lacking near the valve ends of the rapheless valve, an observation not shared by Van de Vijver et al. (2002a). Peragallo (1921) described a similar species (*A. muscorum* A.Perag.) that, based on the description and illustrations herein, is most likely conspecific to *A. muelleri*.

Distribution: *Achnanthes muelleri* was already found on several Antarctic locations ranging from the sub-Antarctic islands in the southern Indian Ocean (Van de Vijver et al. 2002a, 2004, 2008) to South Georgia (Van de Vijver & Beyens 1996) in the southern Atlantic Ocean. The observation on James Ross Island is at present the most southern record as the species was never reported from the Antarctic Continent (Kellogg & Kellogg 2002, Sabbe et al. 2003, Ohtsuka et al. 2006). Peragallo (1921) reported the species (as *A. muscorum*) from several islands in the Antarctic Peninsula region (Booth-Wandel Is., Peterman Is., Jenny Is.).

Autecology: on James Ross Island, the species was found mostly in low frequencies in seepage samples near Lachman Lake and Halozetes Valley. Only a few valves were observed in stream samples. Peragallo (1921) found it to be dominant in moss samples and Van de Vijver et al. (2002a) reported the species from lakes and pools with higher specific conductance values.

Achnanthes taylorensis **D.E.Kellogg et al.** (Figs 4.5C–D)

Dimensions: L: 23.0–27.5 μm; W: 6.0–7.3 μm; S: 14–16 in 10 μm (n = 12)

Remarks: The species was originally identified in the Antarctic literature as *A. brevipes* var. *intermedia* (Kütz.) Cleve but has a higher number of striae (14–16 vs. 10 in 10 μm) and a more slender valve outline. It can be easily separated from *A. muelleri* by its lower valve width and more linear-lanceolate valve outline whereas *A. muelleri* has a more rhombic-lanceolate outline.

Distribution: *Achnanthes taylorensis* is a typical Antarctic endemic that up to now was only found on the Antarctic Continent (often under the name of *A. brevipes* var. *intermedia*). It was reported a.o. from the Larsemann Hills (Sabbe et al. 2003), Vestfold Hills (Kellogg et al. 1980). The observation by Le Cohu & Maillard (1983) from the sub-Antarctic Kerguelen Islands (as *A. coarctata* var. *elliptica* Krasske) is probably a misidentification and should be attributed to *A. muelleri*. Older records of *A. brevipes* var. *intermedia* need to be verified to establish the exact geographic distribution of this species as confusion with *A. muelleri* is likely.

Autecology: on James Ross Island, the species is a very rare species, only observed in three seepage samples with an abundance <2%. No valves were observed in stream samples. Due to the confusion with similar *Achnanthes* species, its exact ecological preferences are not well known.

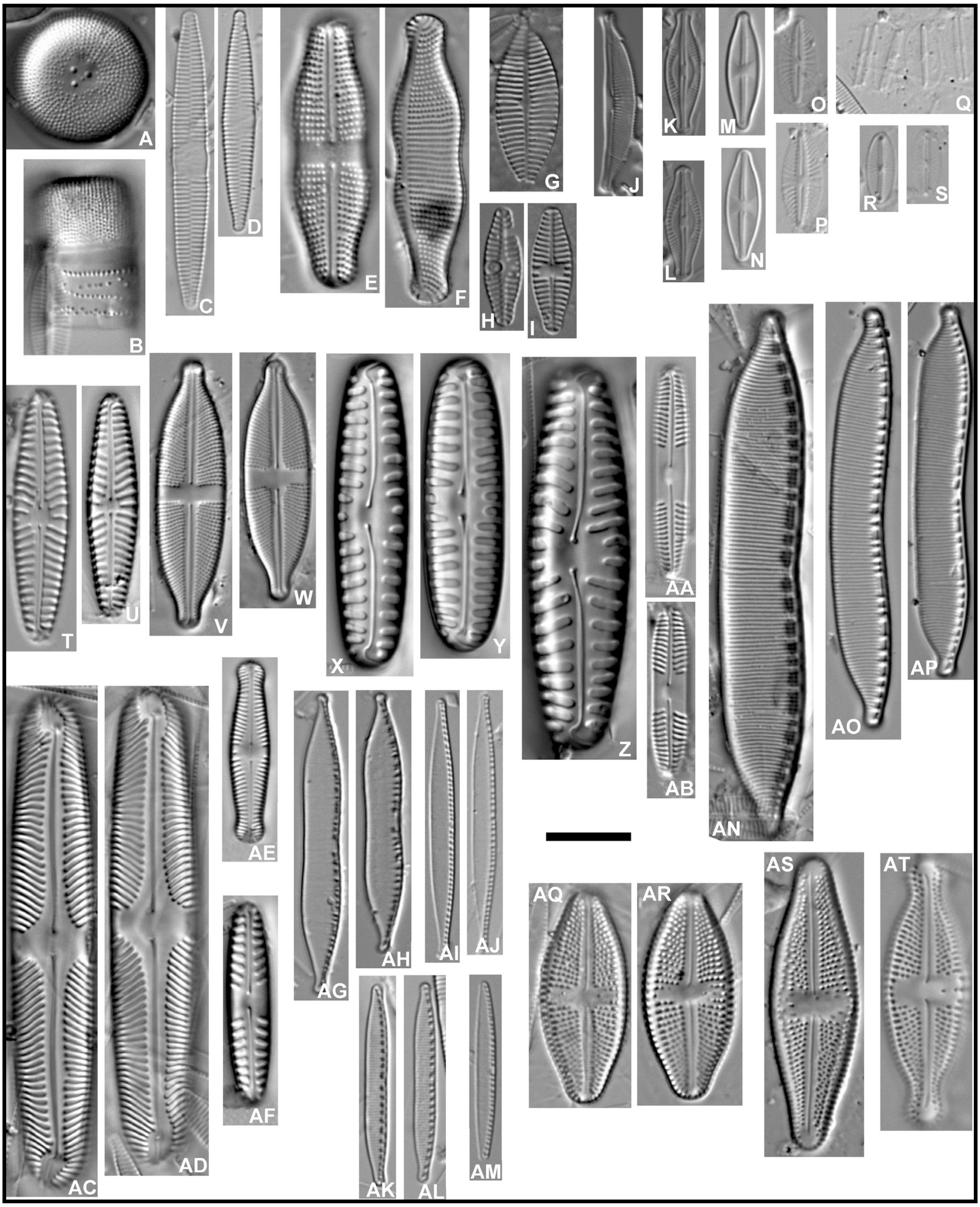

FIGURE 4.4 – LM micrographs of the taxa with a cosmopolitan or unknown biogeographic distribution found in the seepage and stream samples of James Ross Island: **A**, *Orthoseira roeseana*; **B**, *O. roeseana*; **C**, *Fragilaria capucina* s.l.; **D**, *F. capucina* s.l.; **E**, *A. coarctata*, raphe valve; **F**, *A. coarctata*, rapheless valve; **G**, *Planothidium delicatulum*, rapheless valve; **H**, *P. frequentissimum* rapheless valve; **I**, *P. frequentissimum* raphe valve; **J**, *Amphora* sp.; **K**, *Microcostatus naumanii*; **L**, *M. naumanii*; **M**, *Sellaphora nana*; **N**, *S. nana*; **O**, *Mayamaea atomus*; **P**, *M. atomus*; **Q**, *Fistulifera saprophila*; **R**, *Mayamaea permitis*; **S**, *M. permitis*; **T**, *Navicula seibigeana*; **U**, *N. seibigeana*; **V**, *Stauroneis jarensis*; **W**, *S. jarensis*; **X**, *Pinnularia borealis* var. *scalaris*; **Y**, *P. borealis* var. *scalaris*; **Z**, *P. borealis* var. *islandica*; **AA**, *P*. cf. *schoenfelderi*; **AB**, *P*. cf. *schoenfelderi*; **AC**, *P. microstauron*; **AD**, *P.*

microstauron; **AE**, *Chamaepinnularia krookiiformis*; **AF**, *P. intermedia*; **AG**, *Nitzschia homburgiensis*; **AH**, *N. homburgiensis*; **AI**, *N. gracilis*; **AJ**, *N. gracilis*; **AK**, *N. perminuta*; **AL**, *N. perminuta*; **AM**, *N. paleaecea*; **AN**, *Hantzschia abundans*; **AO**, *H. amphioxys*; **AP**, *H. amphioxys*; **AQ**, *Luticola* sp1; **AR**, *Luticola* sp1; **AS**, *Luticola* sp2; **AT**, *Luticola* sp3. Scale bar represents 10 µm.

Brachysira minor **(Krasske) Lange-Bertalot** (Figs 4.5O–P)

Dimensions: L: 11.0–15.5 µm; W: 2.5–3.3 µm; S: 35–40 in 10 µm (n = 15)

Remarks: The specimens from James Ross Island belong to the lower of the length range. Lange-Bertalot & Moser (1994) mention 12–28 µm as valve length range for this species. On South Georgia, longer specimens were found (up to 30 µm) (Van de Vijver, National Botanic Garden of Belgium, pers. obs.).

Distribution: *Brachysira minor* has its main distribution in the Maritime Antarctic Region. Originally described from southern Chile (Krasske 1939) as *Anomoeoneis minor* Krasske, the species was reported from South Georgia (Van de Vijver & Beyens 1996) and several Maritime Antarctic localities such as the South Shetland Islands (Schmidt et al. 1990, Kellogg & Kellogg 2002, Zidarova 2008) and the South Orkney Islands (Håkansson & Jones 1994). The species was previously reported from James Ross Island by Björck et al. (1996). Records from the southern Indian Ocean (Van de Vijver & Beyens 1998, 1999) are based on misidentifications, based on confusion with species from the genus *Diadesmis*. The species has never been found on the Antarctic Continent (Kellogg & Kellogg 2002).

Autecology: The species is rather rare in the seepage and stream samples from James Ross Island, with relative abundances never exceeding 2%. On South Georgia, the species was co-dominant in a small, almost circumneutral (pH = 7.7) stream near Husvik Harbour. Zidarova (2008) found the species in almost every investigated habitat ranging from streams to lakes and terrestrial habitats.

Chamaepinnularia gerlachei **Van de Vijver & Sterken** (Figs 4.5AX–AY)

Dimensions: L: 12.0–30.0 µm; W: 3.3–4.9 µm; S: 17–20 in 10 µm (n = 25)

Remarks: The species was recently described (Van de Vijver et al. 2010a) from James Ross Island to separate the species from the northern hemisphere species *C. gandrupii* (J.B.Petersen) Lange-Bert. & Krammer.

Distribution: Due to confusion with other small-celled *Chamaepinnularia* taxa, its exact distribution is most likely not entirely known. *Chamaepinnularia gerlachei* has been reported with certainty from several localities in the Maritime Antarctic Region and South Georgia (Van de Vijver et al. 2010a). Up to know, no observations were made on the Antarctic Continent nor on the sub-Antarctic islands of the Southern Indian Ocean.

Autecology: The species is rather rare in the seepage and stream samples from James Ross Island. The largest population was observed in Tern Creek, a sample dominated by *Nitzschia gracilis*.

Craticula antarctica **Van de Vijver & Sabbe** (Fig. 4.5E)

Dimensions: L: 23.0–36.0 μm; W: 6.5–8.0 μm; S: 17–20 in 10 μm (n = 20)

Remarks: The species was recently described (Van de Vijver et al. 2010a) from James Ross Island but is known for a long time to be present in the Antarctic Region, but under different names (Van de Vijver et al. 2010a). It is a typical example of force-fitting as only European names were used for this species such as *Navicula molesta* Krasske (Tyler 1996). Detailed morphological research of the type indicated however that both taxa should be separated (Van de Vijver et al. 2010a).

Distribution: So far, *C. antarctica* was only found on the Antarctic Continent (Sabbe et al. 2003, Gibson et al. 2006, Ohtsuka et al. 2006,) and on James Ross Island (Van de Vijver et al. 2010a). Records from the South Orkney Islands (Sterken, University of Ghent, unpubl. res.) need to be verified and may represent a different species. On the sub-Antarctic islands, another *Craticula* species is present that shows some similarity with *C. antarctica* but can be separated based on valve dimensions and valve outline (Van de Vijver et al. 2002a).

Autecology: The species is absent in the seepage area samples but present in almost every stream sample, though never in large abundances. Its largest abundance was reached in Algal Stream. In lakes, the species seems to be more abundant in lakes (Kopalová & Van de Vijver, unpubl. results). The type population was described from an alkaline lake with high specific conductance and moderate total phosphorus levels (Van de Vijver et al. 2010a).

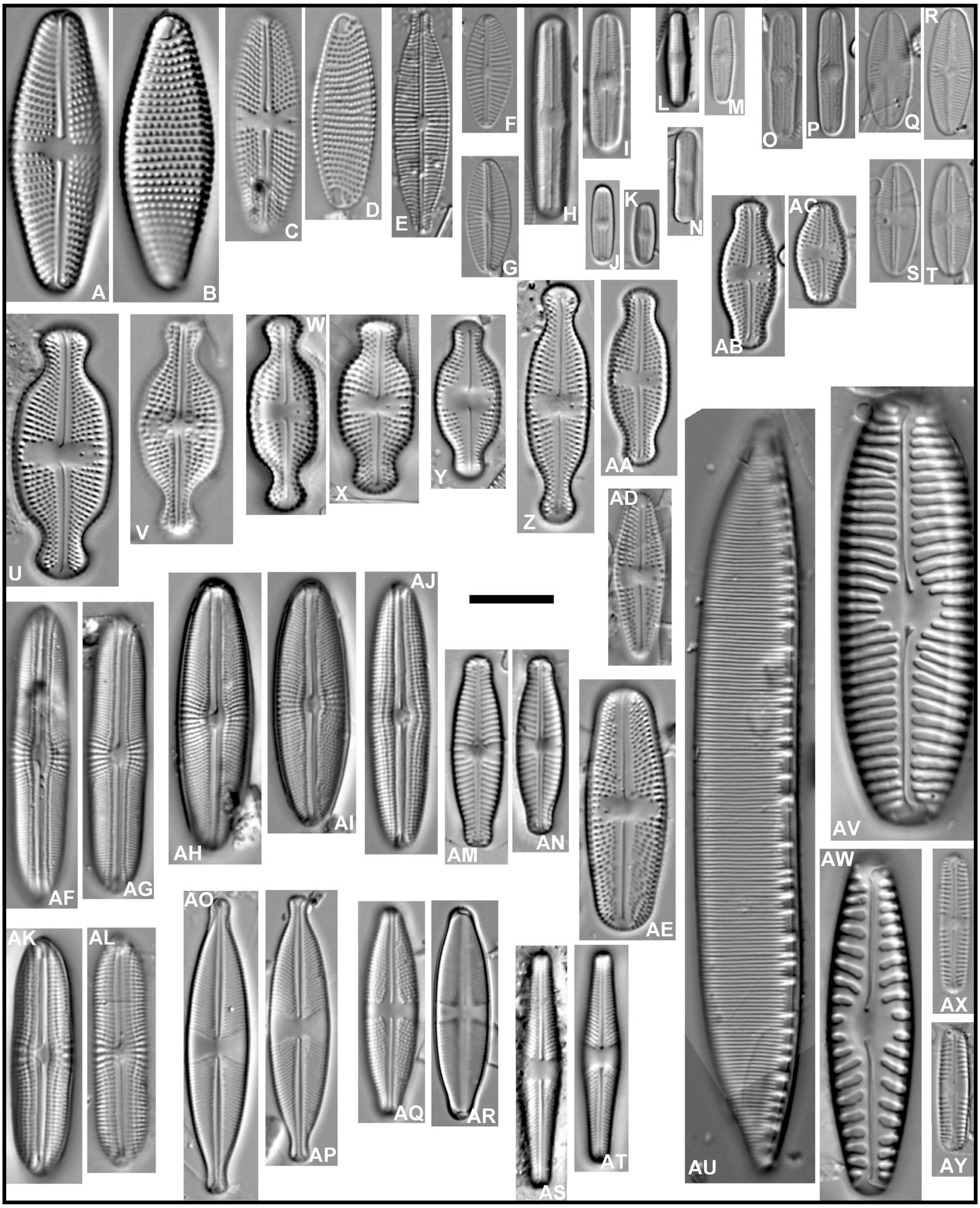

FIGURE 4.5 – LM micrographs of the taxa with a Antarctic biogeographic distribution found in the seepage and stream samples of James Ross Island: **A**, *Achnanthes muelleri*, raphe valve; **B**, *A. muelleri*, rapheless valve; **C**, *A. taylorensis*, raphe valve; **D**, *A. taylorensis*, rapheless valve; **E**, *Craticula antarctica*; **F**, *Eolimna jamesrossensis*; **G**, *Eolimna jamesrossensis*; **H**, *Diadesmis arcuata*; **I**, *Diadesmis arcuata*; **J**, *D. inconspicua*; **K**, *D. inconspicua*; **L**, *D. comperei*; **M**, *D. comperei*; **N**, *D. ingeae*; **O**, *Brachysira minor*; **P**, *B. minor*; **Q**, *Psammothidium papilio*, rapheless valve; **R**, *P. papilio*, rapheless valve; **S**, *P. papilio*, raphe valve; **T**, *P. papilio*, raphe valve; **U**, *Luticola gigamuticopsis*; **V**, *L. katkae*; **W**, *L. muticopsis*; **X**, *L. muticopsis*; **Y**, *L. doliaeformis*; **Z**, *L. austroatlantica*; **AA**, *L. austroatlantica*; **AB**, *L. truncata*; **AC**, *L. truncata*; **AD**, *L. australomutica*; **AE**, *L. vermeulenii*; **AF**, *Muelleria*

luculenta; **AG**, *M. luculenta*; **AH**, *M. regigeorgiensis*; **AI**, *M. regigeorgiensis*; **AJ**, *M. aequistriata*; **AK**, *M. regigeorgiensis*; **AL**, *M.regigeorgiensis*; **AM**, *Geissleria gabrielae*; **AN**, *Geissleria gabrielae*; **AO**, *Stauroneis latistauros*; **AP**, *S. latistauros*; **AQ**, *S. pseudoschimanskii*; **AR**, *S. pseudoschimanskii*; **AS**, *S. pseudomuriella*; **AT**, *S. pseudomuriella*; **AU**, *Hantzschia hyperaustralis*; **AV**, *Pinnularia australorabenhorstii*; **AW**, *P.* cf. *borealis* var. *lanceolata*; **AX**, *Chamaepinnularia gerlachei*; **AY**, *C. gerlachei*. Scale bar represents 10 µm.

Diadesmis arcuata **(Heiden) Lange-Bertalot** (Figs 4.5H –I)

Dimensions: L: 8–27 µm; W: 3.3–4.6 µm; S: 28–35 in 10 µm (n = 25)

Remarks: The specimens from James Ross Island are slightly narrower (3.3–4.6 µm vs 4.0–5.5 µm) than the valves observed on the sub-Antarctic islands (Van de Vijver et al. 2002a). Since this is the only difference, conspecificity is more than likely. There are hardly any other larger *Diadesmis* species that have a similar morphology. Only *D. costei* Le Cohu & Van de Vijver shows a similar morphology and comparable dimensions but can be separated based on its striation pattern that is convergent near the poles in *D. arcuata* but divergent in *D. costei*.

Distribution: *Diadesmis arcuata* is present throughout the entire Maritime Antarctic (Schmidt et al. 1990, Zidarova 2008) and sub-Antarctic (Van de Vijver et al. 2002a) Region but absent from the Antarctic Continent (Kellogg & Kellogg 2002).

Autecology: The species was found in almost every stream and seepage area sample forming sometimes large populations. The largest populations were found in seepage areas below Berry Hill (10–20%) and Algal Stream (33%).

Diadesmis comperei **Le Cohu & Van de Vijver** (Figs 4.5L–M)

Dimensions: L: 10–13 µm; W: 2.5–3.5 µm; S: 30–34 in 10 µm (n = 10)

Remarks: The specimens from James Ross Island show a slightly different morphology in comparison with the type population from the Kerguelen Islands (Le Cohu & Van de Vijver 2002) in having a more lanceolate valve outline (compared to the linear outline on the Kerguelen Islands). But striation pattern, valve dimensions and raphe structure are similar making conspecificity highly likely.

Distribution: *Diadesmis comperei* is present in the sub-Antarctic (Van de Vijver et al. 2002a, Le Cohu & Van de Vijver 2002) region but absent from the Antarctic Continent (Kellogg &

Kellogg 2002). Records from the Maritime Antarctic Region are lacking at the moment, most probably because of confusion with similar *Diadesmis* taxa.

Autecology: The species was mostly observed in seepage area samples, with a relative abundance up to almost 20% in some seepages below Berry Hill. In stream samples, *D. comperei* was only sporadically observed.

Diadesmis inconspicua **Kopalová & Van de Vijver** (Figs 4.5J–K)

Dimensions: L: 6–11 μm; W: 2–3 μm; S: 45–60 in 10 μm (n = 10)

Remarks: The species was recently described from James Ross Island (Kopalová et al. 2009) and is probably one of the smallest diatoms that can be found in the Antarctic Region. It can hardly be confused with other taxa due to its high number of striae and its small valve dimensions.

Distribution: Due to its small size, *Diadesmis inconspicua* is probably often overlooked or misidentified making its geographic distribution hard to determine. So far, it was not reported from the Antarctic Continent. In the Maritime Antarctic Region, the species was recently observed in lake samples from Livingston Island (South Shetland Islands) (Van de Vijver, National Botanic Garden of Belgium, unpubl. res.).

Autecology: *Diadesmis inconspicua* was present in a large number of samples from James Ross Island, but usually in small populations (<5% of the total diatom composition). The largest population was found in a stream sample from Algal Stream, taken from mosses growing in a small brook which was rather alkaline pH (7.30) with a very low specific conductance (28.5 μS/cm) and nutrient values.

Diadesmis ingeae **Van de Vijver** (Fig. 4.5N)

Dimensions: L: 9–11 μm; W: 2–3.5 μm; S: 34–36 in 10 μm (n = 8)

Remarks: Compared to the type population on the Crozet archipelago, the specimens from James Ross Island seem to be conspecific. Small differences can be noted in valve outline with a less inflated middle part of the valve and small apices. Detailed investigation of the largest population will be necessary to reveal its exact taxonomic position.

Distribution: *Diadesmis ingeae* seems to be a widespread (sub-)Antarctic species (Van de Vijver et al. 2002a, 2002b) with records from almost every sub-Antarctic island. However, the species seems absent from the Antarctic Continent. Records from the Maritime Antarctic Region are scarce, due to confusion with similar *Diadesmis* taxa. The species was observed on the South Shetland Islands (Van de Vijver, National Botanic Garden of Belgium, unpubl. results).

Autecology: The species was present in a large number of samples from both streams and seepage areas, though never with high relative abundances. On the sub-Antarctic islands, the species was very common in soils and drier mosses making it one of the most common limnoterrestrial diatoms in the sub-Antarctic Region (Van de Vijver et al. 2002a, 2002b).

Eolimna jamesrossensis **Kopalová & Van de Vijver** (Figs 4.5F–G)

Dimensions: L: 12–14 μm; W: 5.0–5.5 μm; S: 20–22 in 10 μm (n = 20)

Remarks: The species was recently described from the seepage areas of James Ross Island (Kopalová et al. 2009) and is probably one of the most important species in the seepage areas of the island. It can hardly be confused with any other species.

Distribution: *Eolimna jamesrossensis* was recently found on Livingston Island (South Shetland Islands) (Van de Vijver, National Botanic Garden of Belgium, unpubl. results). No observations exist from the sub-Antarctic Region or the Antarctic Continent.

Autecology: The species was present in a large number of seepage area samples from James Ross Island with sometimes very high relative abundances. Nevertheless, in stream samples, the species seems less frequent.

Geissleria gabrielae **Van de Vijver & Zidarova** (Figs 4.5AM–AN)

Dimensions: L: 19–21 μm; W: 5.5–6.1 μm; S: 15 in 10 μm (n = 8)

Remarks: *Geissleria gabrielae*, recently described from Deception Island (Zidarova et al. 2009) can be separated from the European *G. dolomitica* (W.Bock) Lange-Bert. & Metzeltin based on differences in valve outline, a lower stria density and a different central area. More differences with other taxa can be found in Zidarova et al. (2009).

Distribution: *Geissleria gabrielae* is a widespread species in the Antarctic Maritime Region with confirmed records from the South Shetland Islands and James Ross Island. The species was also found on South Georgia (Zidarova et al. 2009). So far, there are no records from the islands in the southern Indian Ocean (Van de Vijver et al. 2002a) nor from the Antarctic Continent (Sabbe et al. 2003, Gibson et al. 2006).

Autecology: One very small population of this species was found in a stream sample on James Ross Island. The type population was described from slightly acid volcanic soil on Deception Island (South Shetland Islands). Usually, populations tend to be quite small (Van de Vijver, pers. obs.).

Hantzschia hyperaustralis **Van de Vijver & Zidarova** (Fig. 4.5AU)

Dimensions: L: 63–115 µm; W: 11–14 µm; S: 20–24 in 10 µm (n = 15)

Remarks: The species was recently separated from *H. hyperborea* (Grunow) Lange-Bert., a dominant species in arctic and boreal habitats based on differences in the ultrastructure of the raphe system and the valve outline (Zidarova et al. 2010).

Distribution: *Hantzschia hyperaustralis* is a widespread species in the Maritime Antarctic Region, present on the South Shetland Islands (Zidarova et al. 2010), however often under a different name. Most records of *H. amphioxys* var. *major* Grunow apparently belong to this species (Kellogg & Kellogg 2002). The species is also present on the Antarctic Continent but seems absent from the sub-Antarctic Region (Van de Vijver et al. 2002a).

Autecology: The species was present in a small number of stream and seepage area samples, but never in high abundances. The largest population (< 6 %) was found in Algal Stream. On Livingston Island (South Shetland Islands), *H. hyperaustralis* is a typical limnoterrestrial species, found among mosses near small ponds and streams.

Luticola australomutica **Van de Vijver** (Fig. 4.5AD)

Dimensions: L: 14–30 µm; W: 5.5–7.5 µm; S: 17–18 in 10 µm (n = 15)

Remarks: In the past, this species was confused with *Luticola mutica* (Kütz.) D.G.Mann, a species considered to be widespread worldwide. However, detailed morphological research indicated that the Antarctic populations needed to be separated (Van de Vijver & Mataloni 2008). The James Ross Island specimens show no morphological differences with the type population of Deception Island (South Shetland Islands).

Distribution: *Luticola australomutica* is a typical species of the Maritime Antarctic Region (Van de Vijver & Mataloni 2008). Due to confusion with *L. mutica* that was reported from almost all investigated Antarctic localities (Kellogg & Kellogg 2002), its exact distribution is at present not entirely known. The species was found on the South Shetland Islands (Van de Vijver & Mataloni 2008, Zidarova, University of Sofia, Bulgaria, pers. comm.) but seems absent from the Antarctic Continent. So far, the species was also not observed on the sub-Antarctic islands (Van de Vijver et al. 2002a).

Autecology: The species seems to prefer seepage areas over streams as most of the larger (up to 15 %) populations are found in seepage samples. Van de Vijver & Mataloni (2008) indicated that the species is a common constituent of Antarctic soil floras. On Deception Island *L. australomutica* seemed to prefer slightly acid soils with high specific conductance values.

Luticola austroatlantica **Van de Vijver et al.** (Figs 4.5Z–AA)

Dimensions: L: 11–31 μm; W: 6.4–8.7 μm; S: 15–17 in 10 μm (n = 15)

Remarks: In the past, this species was confused with *Luticola muticopsis* (Van Heurck) D.G.Mann based on the presence of the capitate apices. However, the species has a symmetric, lanceolate valve outline with smoothly rounded convex margins and a different raphe structure with deflected instead of hooked proximal raphe endings (Esposito et al. 2008, Van de Vijver & Mataloni 2008).

Distribution: *Luticola austroatlantica* is a widespread species in the Maritime Antarctic Region and the Antarctic Continent (Esposito et al. 2008) but due to confusion with *L. muticopsis*, its exact distribution area is not well known. With certainty, the species was reported from the South Shetland Islands (Van de Vijver & Mataloni 2008 as *Luticola* aff. *muticopsis* 1), James Ross Island (type locality) and the McMurdo Dry Valleys (Antarctic Continent) (Esposito et al. 2008). No records exist for the sub-Antarctic islands (Van de Vijver et al. 2002a).

Autecology: *Luticola austroatlantica* is a common constituent of the diatom flora of streams on James Ross Island with populations often reaching almost 20%. Especially in Algal Stream, the species was co-dominant. In seepage areas, the species is less represented and in most places even absent. On the South Shetland Islands, the species was found in wet soils and near lakes (Van de Vijver & Mataloni 2008). On the Antarctic Continent, all records originate from streams (Esposito et al. 2008).

Luticola doliiformis **Kopalová & Van de Vijver** (Fig. 4.5Y)

Dimensions: L: 17–22 μm; W: 7–8 μm; S: 18–20 in 10 μm (n = 10)

Remarks: The ultrastructure of this species was recently studied from a soil near Lachman Crags on James Ross Island (Kopalová et al. 2011). The species can be easily separated from all other *Luticola* species by its large (hyaline) central and axial area and the short striae composed of only 3 areolae. Only *Luticola dolia* Spaulding & Esposito shows some resemblance but the shape of the areolae and the general outline of the valves show sufficient differences to separate both species (Esposito et al. 2008, Kopalová et al. 2011).

Distribution: *Luticola doliiformis* was only found in a soil sample near Lachman Crags (Kopalová et al. 2011).

Autecology: The species is very rare on James Ross Island and only a few valves were found in seepage area samples. In the soil sample from where the species was described, the species is likewise rather rare.

Luticola gigamuticopsis **Van de Vijver** (Fig. 4.5U)

Dimensions: L: 36–38 μm; W: 14–15 μm; S: 14–16 in 10 μm (n = 5)

Remarks: Compared to most other Antarctic *Luticola* species*, L. gigamuticopsis* is a rather large species that can hardly be confused with other taxa. The valves observed on James Ross Island belong to the lower end of the size range but the combination of the high number of areolae per stria, the rounded, capitate apices, the convex margins and the valve dimensions make every confusion very unlikely (Van de Vijver & Mataloni 2008).

Distribution: Apart from the type locality on Deception Island, and some valves observed on the nearby Livingston Island (Van de Vijver, National Botanic Garden of Belgium, pers. obs.), the species was not found elsewhere. The James Ross Island record is the first outside the South Shetland Islands. At present, no records exist from the sub-Antarctic region, nor from the Antarctic Continent.

Autecology: The species is rather rare on James Ross Island and mostly found in seepage area samples (apart from a few valves in Elster Creek). The type population was found in a dark, slightly acid soil sample close to Crater Lake, Deception Island (Van de Vijver & Mataloni 2008).

Luticola katkae **Van de Vijver & Zidarova** (Fig. 4.5V)

Dimensions: L: 22–28 μm; W: 10–12 μm; S: 15–18 in 10 μm (n = 5)

Remarks: *Luticola katkae* is recently described from King George Island (South Shetland Islands) and can be separated from *L. muticopsis* s.s. by differences in valve outline (two convex margins compared to only one in *L. muticopsis*), a different raphe system and a larger valve width. Moreover, *L. katkae* has a typically raised sternum, absent in *L. muticopsis* (Van de Vijver et al. 2011c).

Distribution: Due to confusion with *L. muticopsis*, the geographic distribution of this taxon is probably underestimated. Apart from the type locality on King George Island, and some valves observed on the nearby Livingston Island (Van de Vijver, National Botanic Garden of Belgium, pers. obs.), the species was not found elsewhere. The James Ross Island record is the first outside the South Shetland Islands.

Autecology: The species is very rare on James Ross Island and only found in samples from Tern Creek. On King George Island, the species was described from an alkaline (pH = 8.8) pool with a moderate specific conductance (250 μS/cm).

Luticola muticopsis **(Van Heurck) D.G.Mann (**Figs 4.5W–X)

Dimensions: L: 19–28 μm; W: 8–9 μm; S: 15–17 in 10 μm (n = 30)

Remarks: *Luticola muticopsis* is probably one of the most reported species from the Antarctic Region. A recent revision of the type of the species (Van de Vijver & Mataloni 2008) delimited the morphological features of the species, reducing its apparent morphological variability. The species is characterized in having asymmetrical valves with one straight and one convex margin, typically bent proximal and distal raphe endings and capitate apices. Based on this combination, a large number of species has been separated and described as independent species such as *L. gigamuticopsis* and *L. austroatlantica* and it is likely that more species will be distinguished after thorough morphological analysis.

Distribution: Due to confusion with a large number of species that were previously lumped together in *L. muticopsis* s.l., the exact distribution of *L. muticopsis* s.s. is still unclear. Confirmed records include the South Shetland islands (Van de Vijver & Mataloni 2008), the Antarctic Continent (Sabbe et al. 2003, Ohtsuka et al. 2006, Gibson et al. 2006) and the sub-

Antarctic Region (Van de Vijver et al. 2002a), making this species the only one with a distribution in all three biogeographical provinces.

Autecology: On James Ross Island, the species is most typical for seepage areas where it can form large populations. On the hand, in stream samples, the species is less present. The species is a common constituent of wet to semi-wet soils (Van de Vijver & Mataloni 2008, Zidarova 2008).

Luticola truncata **Kopalová & Van de Vijver** (Figs 4.5AB–AC)

Dimensions: L: 16–26 µm; W: 7.0–9.5 µm; S: 16–17 in 10 µm (n = 20)

Remarks: *Luticola truncata* is described from the seepage areas on James Ross Island (Kopalová et al. 2009) and can easily be separated from similar species such as *L. muticopsis* s.s. and *L. austroatlantica* by the typical truncated apices, the symmetrical valve outline and the differences in raphe structure. Both mentioned species have capitate, broadly rounded apices.

Distribution: Due to confusion with *L. muticopsis*, the geographic distribution of this taxon is probably underestimated. So far, it is only reported with certainty from James Ross Island. No published records exist from the rest of the Maritime Antarctic Region, the sub-Antarctic islands and the Antarctic Continent.

Autecology: The largest populations of *Luticola truncata* were all found in seepage area samples whereas in streams only a few valves were found. The type population was described from moss tundra seepage at a rather high altitude.

Luticola vermeulenii **Van de Vijver** (Fig. 4.5AE)

Dimensions: L: 20–30 µm; W: 10–13 µm; S: 14–16 in 10 µm (n = 15)

Remarks: The dimensions of *Luticola vermeulenii* in the seepage area and stream samples on James Ross Island are somewhat lower than the type population on King George Island (length 24–50 µm) (Van de Vijver et al. 2011c). Nevertheless, all morphological features are similar making conspecificity between this populations and *L. vermeulenii* most likely. The species has been confused for a long time with the cosmopolitan species *L. cohnii* (Hilse) D.G.Mann but based on a recent study of the type material of the latter (Van de Vijver et al.

2011c), both can be separated using differences in raphe structure, valve dimensions and general valve outline.

Distribution: Due to confusion with *L. cohnii* and *L. mutica*, the geographic distribution of this taxon is probably underestimated. Its presence is confirmed in almost the entire Maritime Antarctic Region including the South Shetland Islands, the South Orkney Islands and James Ross Island (Van de Vijver et al. 2011c). No records exist at present from the sub-Antarctic islands and the Antarctic Continent.

Autecology: *Luticola vermeulenii* is rare in stream samples, with only one population in Algal Stream, and absent in seepage area samples. In the James Ross Island lakes, the species is more common and seems to prefer circumneutral (pH = 7.6) shallow lakes with higher specific conductance values (up to 1000 µS/cm) (Kopalová, Charles University in Prague, Czech Republic, unpubl. res.).

Muelleria aequistriata **Van de Vijver & S.A.Spaulding** (Fig. 4.5AJ)

Dimensions: L: 28–40 µm; W: 6.0–7.5 µm; S: 18–19 in 10 µm (n = 5)

Remarks: This species was recently described from King George Island (Van de Vijver et al. 2010b) and belongs to a rather small group of *Muelleria* species lacking a different stria density in the central part of the valves. *Muelleria peraustralis* (W.& G.S. West) S.A.Spaulding & Stoermer is the only similar species in the region but shows a different valve outline with capitate ends and less parallel valve margins.

Distribution: The presence of this species is confirmed from the South Shetland Islands and James Ross Island but it is absent on the Antarctic Continent and the sub-Antarctic islands (Van de Vijver et al. 2010b).

Autecology: As most of the *Muelleria* species, *M. aequistriata*, is typical for soil samples. On James Ross Island, it was found in seepage area samples but absent in streams. The type population on King George Island was sampled in a small mud pool but it was also found in soil samples moistened by wet snow (Zidarova 2008).

Muelleria australoatlantica **Van de Vijver & S.A.Spaulding** (Figs 4.5AK–AL)

Dimensions: L: 30–40 µm; W: 6–7 µm; S: 19–20 in 10 µm, (14–16 in the center) (n = 5)

Remarks: This species was recently described from Deception Island (Van de Vijver et al. 2010b). It shares features with *M. meridionalis* S.A.Spaulding & Stoermer, a species with a restricted distribution on the Antarctic Continent but can be separated by its different valve outline with more undulating margins and a different areola structure (Van de Vijver et al. 2010b).

Distribution: The presence of this species is confirmed from the South Shetland Islands and James Ross Island but it is absent on the Antarctic Continent and the sub-Antarctic islands (Van de Vijver et al. 2010b).

Autecology: *Muelleria australoatlantica* is found in several seepage area samples but absent in stream samples. Its type population on Deception Island (South Shetland Islands) originated from a rather acid, volcanic coastal soil sample while on King George Island, the species was observed growing epiphytically on mosses (Van de Vijver et al. 2010b).

Muelleria luculenta **S.A.Spaulding & Stoermer** (Figs 4.5AF–AG)

Dimensions: L: 34–45 µm; W: 8–10 µm; S: 20–24 in 10 µm, (14–16 in the center) (n = 10)

Remarks: This species was described from the sub-Antarctic Region (Spaulding et al. 1999) and belongs to the complex of species around *M. linearis* (O.Müller) Frenguelli. It can be separated from the closely related *M. algida* S.A.Spaulding & Kociolek by its higher number of areolae per 10 µm and the more distinctly radiate striae.

Distribution: *Muelleria luculenta* is known from the sub-Antarctic Region (Spaulding et al. 1999, Van de Vijver et al. 2002a) and from the Maritime Antarctic Region (Spaulding et al. 1999) where it is reported on the South Shetland Islands and James Ross Island (this study). No records so far exist from the Antarctic Continent.

Autecology: The species is rather rare on James Ross Island and almost exclusively found in seepage area samples. In the sub-Antarctic Region, the species was found in lakes and wet soils (Van de Vijver et al. 2002a).

Muelleria regigeorgiensis **Van de Vijver & S.A.Spaulding** (Figs 4.5AH–AI)

Dimensions: L: 30–40 µm; W: 6–8 µm; S: 24–26 in 10 µm, (16–18 in the center) (n = 15)

Remarks: This species was recently described from Deception Island (Van de Vijver et al. 2010b). It shares features with *M. meridionalis* S.A.Spaulding & Stoermer, a species with a restricted distribution on the Antarctic Continent but can be separated by its different valve outline with more undulating margins and a different areola structure (Van de Vijver et al. 2010b).

Distribution: The presence of this species is confirmed from the South Shetland Islands and James Ross Island but it is absent on the Antarctic Continent and the sub-Antarctic islands (Van de Vijver et al. 2010b).

Autecology: *Muelleria regigeorgiensis* is one of the most common *Muelleria* species on James Ross Island although its populations are never large. Most valves were found in seepage area samples (Van de Vijver et al. 2010b).

Pinnularia australorabenhorstii **Van de Vijver** (Fig. 4.5AV)

Dimensions: L: 48–55 μm; W: 15.5–17 μm; S: 6–7 in 10 μm (n = 5)

Remarks: *Pinnularia australorabenhorstii* can hardly be confused with any other *Pinnularia* species of the section Distantes based on its rather wide valves and the high stria density, uncommon in this section (Van de Vijver 2008). It is one of the largest *Pinnularia* species in the region.

Distribution: This recently described species is quite common in the Maritime Antarctic Region with records from the South Shetland Islands (Van de Vijver 2008, Van de Vijver & Zidarova 2011) and James Ross Island (this study), but seems absent from the sub-Antarctic Region (Van de Vijver et al. 2002a) and the Antarctic Continent (Sabbe et al. 2003, Gibson et al. 2006).

Autecology: *Pinnularia australorabenhorstii* is rather uncommon on James Ross Island and so far only found in some stream samples. The species is present in circumneutral to alkaline lakes with low to moderate specific conductance values on Livingston Island (Van de Vijver, unpubl. results). On King George Island, the species was found in both wet terrestrial and freshwater habitats with the largest population in a rather alkaline shallow mud pool (Van de Vijver 2008).

Pinnularia borealis **var.** ***pseudolanceolata*** **Van de Vijver & Zidarova** (Fig. 4.5AW)

Dimensions: L: 24–40 μm; W: 8–9 μm; S: 6–8 in 10 μm (n = 15)

Remarks: This recently described species was for a long time misidentified as *P. borealis* var. *lanceolata* Hust., an European *borealis*-variety from Switzerland. However, both varieties can be separated based on a higher number of striae (in var. *pseudolanceolata*) and a lower valve width (Van de Vijver & Zidarova 2011).

Distribution: Kellogg & Kellogg (2002) listed all occurrences of *Pinnularia borealis* Ehrenb. Unfortunately, almost all listed records never mentioned which variety was dealt with in the published papers making it highly likely that the var. *pseudolanceolata* is more widespread than currently known. Confirmed records include at the moment only James Ross Island (this study) and the South Shetland Islands (Van de Vijver & Zidarova 2011). The variety is so far not reported from the sub-Antarctic islands nor the Antarctic Continent.

Autecology: *Pinnularia borealis* var. *pseudolanceolata* is a rare constituent from seepage areas but almost completely absent in streams. On Livingston Island, the species was observed in a small, almost circumneutral pool surrounded by fellfield areas, but likewise also in soil and moss samples (Van de Vijver & Zidarova 2011).

Psammothidium papilio (D.E.Kellogg et al.) Van de Vijver & Kopalová nov. comb.

(Figs 4.5Q–T)

Basionym: *Navicula papilio* D.E.Kellogg, Stuiver, T.B.Kellogg & Denton, Non-marine diatoms from Late Wisconsin perched deltas in Taylor Valley, Antarctica. Palaeogeography, Palaeoclimatology & Palaeoecology 30, p. 183, plate I,15 & II, 3 (Kellogg, et al. 1980).

Synonyms: *Achnanthes metakryophila* Rol.Schmidt & Lange-Bert., *Psammothidium metakryophilum* (Rol.Schmidt & Lange-Bert.) Sabbe.

Dimensions: L: 10.5–14.5 µm; W: 4–5 µm; S: 25–30 in 10 µm (n = 25)

Remarks: Sabbe et al. (2003) already pointed out that *Psammothidium metakryophilum* might be a younger synonym of *Navicula papilio* based on a comparison of the two illustrations in Kellogg et al. (1980). The species was originally described as a *Navicula* belonging to the subgenus *Minuscula* since only a raphe-bearing valve was observed. We were unable to locate the holotype (Philadelphia Academy of Sciences, M. Potapova, pers. comm.) nor isotype material (Copenhagen University, Botanical Institute, R. Nielsen, pers. comm.) as it was probably never sent (T.E. Kellogg; pers. comm.). However, analysis of core material (not the type material) used in Kellogg et al. (1980), revealed that both rapheless and raphe-bearing valves of *N. papilio* are present, identical to the description of *P. metakryophilum*. However, since *N. papilio* was published in 1980 and *Psammothidium metakryophilum* (as *Achnanthes metakryophila*) was only published 10 years later (Schmidt et al. 1990), the former has priority according to the International Code for Botanical Nomenclature. Therefore, the new combination *Psammothidium papilio* is proposed. Spaulding et al. (1997) and Esposito et al. (2008) identified this species as *Psammothidium chlidanos* (Hohn & Hellerman) Lange-Bert., a typical European species with different valve dimensions and a different axial and central area. It is thus highly possible that this should be considered as a misidentification. Sabbe et al. (2003) discussed its separation from other *Psammothidium* species including *P. chlidanos*.

Distribution: According to Kellogg & Kellogg (2002), *Navicula papilio* was only found in the core material of Taylor Valley and in Lake Chad (Kellogg et al. 1980) on the Antarctic Continent. Contrary, *Psammothidium metakryophilum* was found in numerous places in the Maritime Antarctic Region (Schmidt et al. 1990, Zidarova 2008, this study) and the Antarctic Continent (Sabbe et al. 2003, Gibson et al. 2006, Ohtsuka et al. 2006) and is probably one of the more common freshwater diatoms in this region. It is likely that, due to confusion with other taxa, the species has a larger geographic distribution.

Autecology: *Psammothidium papilio* was present in only one seepage area sample with an abundance of 12%. According to Sabbe et al. (2003), the species prefers freshwater lakes. Indeed, the species seemed more abundant in lake samples from James Ross Island (Kopalová, Charles University in Prague, Czech Republic, unpubl. res.). In stream samples, only a few valves were found.

Stauroneis latistauros **Van de Vijver & Lange-Bert.** (Figs 4.5AO–AP)

Dimensions: L: 24–50 µm; W: 6.5–8.0 µm; S: 20–21 in 10 µm (n = 25)

Remarks: The species was separated in 2004 from the catch-all species *Stauroneis anceps* Ehrenb. that has broader valves and a different shape of the stauros (Van de Vijver et al. 2002a). According to Kellogg & Kellogg (2002), *S. anceps* is one of the most widespread species in the Antarctic Region. However, a detailed analysis of the type material of *S. anceps* and a large number of populations from all over the world resulted in a better delimitation of this species and the description of a large number of new species, including *S. latistauros* (Reichardt 1995, Lange-Bertalot et al. 2003, Van de Vijver et al. 2004a).

Distribution: Due to confusion with *S. anceps*, the exact distribution is not well known. The species has been reported with certainly from the Antarctic Continent [Sabbe et al. 2003 (as *S. anceps*), Gibson et al. 2006, Ohtsuka et al. 2006 and references therein] and the Maritime Antarctic Island (Van de Vijver et al. 2004a, 2005). On the sub-Antarctic islands, the species has so far not been found (Van de Vijver et al. 2002a).

Autecology: *Stauroneis latistauros* is rather common species on James Ross Island, present in both seepage areas as stream samples, although its populations rarely exceed 10% of the total valve counts. On the South Shetland Islands, the species is present in alkaline (pH 7.4–8.8), small pools and lakes with low specific conductance values (Van de Vijver et al. 2004a). Zidarova (2008) recorded the species in several aquatic and wet terrestrial habitats.

Stauroneis pseudomuriella **Van de Vijver & Lange-Bert.** (Figs 4.5AS–AT)

Dimensions: L: 24–29 µm; W: 4.0–5.5 µm; S: 21–23 in 10 µm (n = 10)

Remarks: The specimens from James Ross Island are narrower than the type population on Heard Island in the southern Indian Ocean. Nevertheless, all morphological features match entirely with the species description making conspecificity likely. *Stauroneis muriella* Lund is somewhat similar but can be separated by its lower valve dimensions and the denser striation (Van de Vijver et al. 2004a).

Distribution: *Stauroneis pseudomuriella* is one of the few *Stauroneis* species that is present on localities in both the southern Atlantic and Indian Ocean. The species was originally described from Heard Island (Van de Vijver et al. 2004a). Zidarova (2008) found the species on Livingston Island (South Shetland Islands) and now its presence is also confirmed on James Ross Island. On the Antarctic Continent, the species has not been found so far as it is not reported in more recent studies (Sabbe et al. 2003, Gibson et al. 2006, Esposito et al. (2008).

Autecology: On James Ross Island, the species is very rare in seepage area samples and entirely absent in stream samples. The type population was described from semi-wet soils on cliffs bordering the ocean. The species was also found in terrestrial wet mosses growing in sheltered, shaded places (Van de Vijver et al. 2004a). On Livingston Island, Zidarova (2008) recorded the species in rivers, pools, wet mosses, soils and growing on wet rocks.

Stauroneis pseudoschimanskii **Van de Vijver & Lange-Bert.** (Figs 4.5AQ–AR)

Dimensions: L: 23–29 µm; W: 5.5–6.5 µm; S: 23–25 in 10 µm (n = 10)

Remarks: The species was described from South Georgia separating it from the European *S. schimanskii* Krammer in Krammer & Lange-Bert based on differences in valve outline and the presence of pseudosepta in *S. pseudoschimanskii*. Other taxa with a similar combination of morphological characters have so far not been found (Van de Vijver et al. 2004a).

Distribution: *Stauroneis pseudoschimanskii* was originally described from the sub-Antarctic island of South Georgia in the southern Atlantic Ocean (Van de Vijver et al. 2004a) and is known at present from the South Shetland Islands (Zidarova 2008) and James Ross Island (this study).

Autecology: On James Ross Island, the species is very rare in seepage area samples and entirely absent in stream samples. The type locality on South Georgia was a semi-dry moss vegetation (Van de Vijver et al. 2004a). Zidarova (2008) found the species in almost every investigated habitat ranging from rivers to pools, moss vegetations and wet rocks. Only in lakes, the species was ever observed.

Discussion

The rather low number of taxa recorded during this survey (i.e. 69) roughly corresponds to the diatom richness that can be expected on James Ross Island following the general hypothesis of decreasing diatom diversity when moving southwards (Jones 1996). Theoretically, based on the species richness estimators only a maximum of 107 taxa could be expected. Although it is always dangerous to compare diatom floristic lists with other geographic localities differences in sample size, sample type and the used taxonomic level may influence largely the conclusions, a certain trend can be noted. On Livingston Island, the second largest island of the South Shetland Islands, almost 135 taxa were found in streams and seepage areas (Zidarova 2008). On Deception Island, another island of the same archipelago, Fermani et al. (2007) reported 77 taxa from 18 samples collected in 14 different soil sites. Older studies mention lower numbers such as Kawecka & Olech (1993) with only

74 in 7 samples from creeks on King George Island but these numbers should be treated with care as they were published before the start of the taxonomic revision of the non-marine Antarctic diatom flora that started after 2000 (for references see Material & Methods). On the sub-Antarctic islands of the southern Indian Ocean, more than 250 taxa can be found (Van de Vijver et al. 2001, 2002a, 2008). Moving southwards from James Ross Island, the number of taxa decreases sharply. In East-Antarctica, less than 25 taxa (in 13 lakes) were found by Ohtsuka et al. (2006) and only 31 (in 56 lakes) by Sabbe et al. (2003). In the McMurdo Dry Valley streams, Alger et al. (1997) observed only 38 diatom taxa, of which 60% were considered to be endemic. Gibson et al. (2006) only found 29 taxa in lakes in the Bunger Hills. It should be noted that the latter studies focused on aquatic diatoms in lakes and did not take into account limnoterrestrial species. More research comparing the different floras using rarefaction analyses will be necessary to confirm statistically this trend but the discussed numbers seem to confirm the hypothesis of the decreasing species richness. The high number of unidentified taxa is not surprising and is the result of the more fine-grained taxonomy that is used nowadays when characterizing the Antarctic diatom flora. In the past, these unidentified species were most probably given European or north American names as a result of a too broad interpretation of the original species descriptions. Further research will be necessary to identify their correct taxonomic status. Based on Table 4.2, it is clear that less than 50% of the taxa identified up to the species level have a cosmopolitan nature. These results will contribute to the ongoing debate about the possible cosmopolitan nature of the diatoms. According to Finlay & Clarke (1999), microorganisms are supposed to present a cosmopolitan distribution due to their small size, large population sizes and excellent dispersion possibilities. However, Vyverman et al. (2007) demonstrated that based on genus level, diatoms present a restricted distribution with a high level of regional endemism. Even within the species restricted to the Antarctic Region, the latter statement is confirmed. The geographic distribution of the Antarctic species clearly indicates the presence of a unique diatom flora on James Ross Island composed of a mixture of Maritime Antarctic diatom species that are absent on the Antarctic Continent such as *Luticola gigamuticopsis* (Van de Vijver & Mataloni 2008), several species that reach their most northern distribution limit on James Ross Island such as *Craticula antarctica* and *Achnanthes taylorensis.* However, only seven out of 69 taxa are shared by James Ross Island and the Antarctic Continent (Sabbe et al. 2003, Van de Vijver et al. 2005, Esposito et al. 2008,

Van de Vijver et al. 2010b). On the contrary, several taxa described from the Antarctic Continent and widespread on the investigated continental localities (Sabbe et al. 2003, Gibson et al. 2006, Ohtsuka et al. 2006), such as *Muelleria peraustralis* or *Chamaepinnularia cymatopleura* (W.&G.S.West) Cavacini have never been found outside the Antarctic Continent (Cavacini et al. 2006). These results confirm the highly specific character of the diatom flora on the Continent and on the Peninsula region showing a high degree of endemism, which was already suggested in previous studies (Sabbe et al. 2003, Esposito et al. 2008, Van de Vijver & Mataloni 2008) and which led to the proposition of the so-called Gressitt Line, made by Chown & Convey (2007) separating the Antarctic Peninsula communities from the continental terrestrial communities. The results are also in line with previously observed differences in diatom composition between the communities on the islands in the southern Atlantic Ocean, compared to the southern Indian Ocean (Van de Vijver et al. 2002a, 2005, 2011b). Most of the species reported from the southern Indian Ocean, are absent on James Ross Island while the dominant James Ross Island species such as *Eolimna jamesrossensis* have never been reported on the southern Indian Ocean islands (Kopalová et al. 2009, Van de Vijver et al. 2010a). In a recent global analysis of a dataset comprising the entire Antarctic Region, it was shown that Antarctic and sub-Antarctic floras exhibit high levels of endemism (up to at least 51%), which is strikingly congruent with patterns found in multicellular organisms (Convey et al. 2008) as was also the case for the geographical structuring of diatom metacommunities (Verleyen, University of Ghent, Belgium, unpubl. res.). The results of this taxonomic study showed that the diatom flora of these habitats is diverse and composed of a large number of Antarctic taxa, in contrast with the general idea that cosmopolitanism is the rule in these areas.

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PART II.

DIATOM ECOLOGY & BIOGEOGRAPHY

CHAPTER 5

Structure and ecology of freshwater benthic diatom communities from Byers Peninsula (Livingston Island, South Shetland Islands)

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Diatom and water chemistry samples were collected from 49 lakes, pools and rivers on Byers Peninsula (Livingston Island, South Shetland Islands) during the austral summer of 2009. A diverse diatom flora of 143 taxa was found. Fragilaria capucina *s.l.,* Psammothidium papilio*,* Navicula dobrinatemniskovae *and several* Nitzschia *taxa dominated the flora. The biogeographical analysis showed that more than 55% of all observed taxa presented a restricted Antarctic biogeographic distribution and only 30% had a cosmopolitan distribution, contrary to previously published data. Cluster analysis and Principal Component Analysis were used to classify the samples based on their chemical characteristics, revealing that nutrients and specific conductance were the main factors dividing the samples into four groups: young lakes, coastal lakes, larger lakes on the central plateau and smaller, temporary pools. Diatom communities corresponded well to this division and were strongly influenced by salinity and nutrients.*

Key words: *Bacillariophyta, lakes, streams, Maritime Antarctic Region*

Introduction

Significant progress has been made during the past decade with respect to our knowledge of the diversity and taxonomy of the aquatic and limno-terrestrial diatom flora of the Antarctic Region. Diatoms (Bacillariophyta) are one of the most abundant and productive algal groups in Antarctic and sub-Antarctic inland waters and terrestrial environments (Jones 1996, Van de Vijver & Beyens 1999a). However, while the diatom flora in the southern Indian Ocean has been the subject of intensive taxonomic and morphological analyses (Van de Vijver et al. 2002a), the diatom flora in the Maritime Antarctic Region is less studied. Previously published studies from this region report that the diatom floras in the Antarctic ecosystems are composed of only a limited number of taxa (Jones 1996, Van de Vijver & Beyens 1999a, Sabbe et al. 2003). In the past, discrete forms have been lumped together as one single, morphologically variable species while many taxa were force-fitted into European or North American species (Tyler 1996, Sabbe et al. 2003, Van de Vijver et al. 2005), indicating that older literature data not always reflect true diatom diversity. This has lead to incorrect and incomplete interpretations of the biogeography and ecology of the Antarctic diatoms (Sabbe et al. 2003, Van de Vijver et al. 2005).

So far, published information on Byers Peninsula is rather limited. Björck et al. (1991, 1993) studied Holocene lake sediments from two lakes on Byers Peninsula, Midge and Åsa lakes tracking changes in diatoms, spores, tephra and moss remains. Hansson & Håkansson (1992) studied diatom communities of lakes in the Antarctic Peninsula area, including Livingston Isl. and King George Isl. and concluded that the diatom species richness was mainly influenced by both available nutrient availability and latitude. Jones et al. (1993) published a detailed ecological study of the diatom flora in the lakes of Byers Peninsula, Livingston Island, and concluded that the diatom species abundance was mostly related to salinity and nutrient gradients. On Hurd Peninsula, another ice-free area on the island, Temniskova-Topalova & Chipev (2001) reported 190 diatom taxa and concluded that the diatom flora of the island consists of mainly cosmopolitan taxa. This research was continued by Zidarova (2008) who described the distribution of algae in the aquatic and terrestrial habitats on Hurd Peninsula. In 2007, Toro et al. (2007) published a complete overview of the limnological characteristics of the freshwater ecosystems on Byers Peninsula and concluded that a major number of cosmopolitan diatom taxa rather than typical Antarctic taxa, were present.

Recently, a new survey was started to provide a taxonomic and ecological revision of all non-marine diatoms on Livingston Island, based on a more fine-grained taxonomy. This effort so far resulted in the description of a large number of new species, mainly in the genera *Pinnularia*, *Navicula* and *Hantzschia* (Van de Vijver et al. 2011a, Zidarova et al. 2010, 2012), showing that the conclusions about the cosmopolitanism of the Livingston Island diatom flora in previous reports are not correct.

The objective of the present paper was therefore to identify the ecological factors that determine the composition and distribution of diatom communities in freshwater habitats on Byers Peninsula using revised taxonomical data.

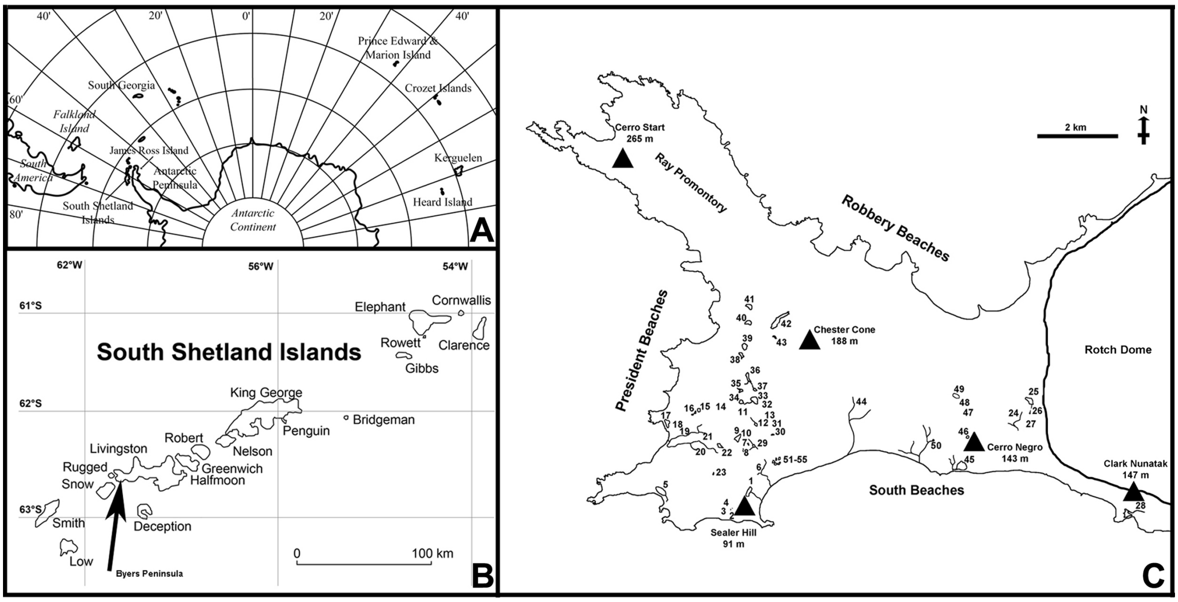

FIGURE 5.1 – Location of the South Shetland Islands in the southern hemisphere close to the Antarctic Peninsula (A), Livingston Island within the South Shetland Islands (B) and Byers Peninsula with the location of all sampling sites (C). Numbers refer to sampling sites listed in Table 5.1.

Methods

Study site

Livingston Island (62° 36′ S, 60° 30′ W) is the second largest island of the South Shetland Islands with a total surface area of 974 km², situated in the southern Atlantic Ocean at *ca*. 150 km west-northwest of the northernmost tip of the Antarctic Peninsula (Fig. 5.1). The entire archipelago is part of the Maritime Antarctic Region (Chown & Convey 2007), characterized by a less extreme climate than the Antarctic Continent with higher temperatures and precipitation levels. Most of Livingston Island is covered by glaciers, apart from several ice-free areas of which Byers Peninsula, (62°39'S, 61°06'W) forming the western tip of Livingston Island, is the largest (61 km²). The entire peninsula has been designated as an Antarctic Specially Protected Area (ASPA 126). The central part is dominated by a 50–100 m high plateau composed of sedimentary, volcanic and volcaniclastic rocks, bordered on its eastern side by the edge of the Rotch Ice Dome. Cerro Start, in the north-western part of the peninsula, is the highest point (265 m a.s.l.). Permafrost starts at 30 cm and is covered by an active lithosol layer. Björck et al. (1993) discussed the geological history of the peninsula and concluded that some of the lakes underwent deglaciation ca. 5000 years BP. Scattered over the entire peninsula, more than 110 lakes and ponds of variable sizes covering a total surface of 1.5 % of the total surface of the ice-free area (Toro et al. 2007) can be found. Streams are usually quite shallow, organised in three hydrographic systems with flow regimes determined by precipitation patterns (Toro et al. 2007).

The climate is typically maritime with mean summer temperatures ranging from 1 to 3 °C, daily maxima up to 10 °C and minima not lower than –10 °C. Precipitation is much higher than in Continental Antarctica with mean annual values of 700–1000 mm (Toro et al. 2007).

The terrestrial vegetation on Byers Peninsula is rather sparse, mainly composed of lichen and moss species and two higher vascular plants [*Deschampsia antarctica* Desv. and *Colobanthus quitensis* (Kunt) Bartl.], which form small carpets in the coastal areas. The inland part of Byers Pensinsula is almost unvegetated apart from moss and lichen carpets on wet valley floors and seepage areas. The fauna is restricted to marine birds (penguins, petrels) and mammals [mainly elephant seals (*Mirounga leonina*)] often forming large colonies on the beaches and lowlands. More details on the geology, climate, hydrology and vegetation of Byers Peninsula can be found in Björck et al. (1993) and Toro et al. (2007).

Sampling

Fieldwork was carried out during the austral summer of 2009 in the framework of the Limnopolar Project POL2006-06635. A total of 71 diatom surface samples were collected in January 2009 from 29 lakes, 18 pools (surface area <100 m²) and 8 streams (Table 5.1, Fig. 5.1). Geographical coordinates of each sampling location were recorded using a Garmin®

Map60CSx GPS. For every sample, bottom sediment in the littoral zone was collected in small PVC bottles and fixed with 3% formalin. At 49 sampling sites, water has been collected 20 cm below the surface, filtered in situ and kept frozen until laboratory analysis. PH and specific conductance were measured in the field using a YSI 556 MPS handheld Multiparameter instrument (YSI Ltd, Hampshire, UK).

TABLE 5.1 – List of studied waterbodies and diatom samples.

Site code	Sample code	Water body	Longitude W	Latitude S	Elevation (m a.s.l.)
1	BY001, BY002	lake	62°40'11.4"	61°06'02.0"	6
2	BY003, BY004	lake	62°40'27.5"	61°06'56.0"	10
3	BY005	lake	62°40'23.1"	61°07'28.4"	5
4	BY006, BY007	stream	62°40'21.3"	61°07'25.9"	5
5	BY008	lake	62°40'11.3"	61°08'45.3"	5
6	BY009, BY010	stream	62°39'45.3"	61°05'58.5"	11
7	BY011	pool	62°39'35.7"	61°06'24.3"	61
8	BY012, BY013	pool	62°39'31.7"	61°06'48.0"	66
9	BY014, BY015	lake	62°39'24.1"	61°06'48.9"	60
10	BY016	lake	62°39'24.3"	61°06'46.1"	61
11	BY017, BY018	stream	62°39'16.1"	61°06'44.4"	60
12	BY019	lake	62°39'11.4"	61°06'19.4"	62
13	BY020	lake	62°39'13.5"	61°06'04.5"	68
14	BY021	pool	62°38'59.4"	61°07'07.9"	64
15	BY022, BY023	lake	62°39'04.1"	61°07'51.8"	38
16	BY024, BY025	lake	62°39'06.3"	61°08'03.9"	34
17	BY026	lake	62°39'11.5"	61°08'52.4"	11
18	BY027, BY028	stream	62°39'18.0"	61°08'23.7"	8
19	BY029, BY030	stream	62°39'22.1"	61°08'08.6"	20
20	BY031	pool	62°39'23.2"	61°07'47.6"	29
21	BY032	pool	62°39'24.7"	61°07'46.0"	29
22	BY033, BY034	lake	62°39'24.8"	61°07'26.1"	35
23	BY035	lake	62°39'42.8"	61°07'12.4"	33
24	BY036	pool	62°38'56.2"	60°58'45.9"	51
25	BY037	lake	62°38'50.1"	60°58'24.6"	50
26	BY038	pool	62°38'56.6"	60°58'27.0"	61
27	BY039	lake	62°39'00.0"	60°58'29.1"	67
28	BY040, BY041	stream	62°40'11.0"	60°55'35.6"	5
29	BY042	lake	62°39'32.8"	61°06'21.3"	57
30	BY043	lake	62°39'24.5"	61°06'05.5"	66
31	BY044	pool	62°39'17.2"	61°06'02.9"	76
32	BY045	pool	62°38'58.9"	61°05'53.3"	72
33	BY046	lake	62°38'56.5"	61°06'16.9"	60
34	BY047	lake	62°38'54.9"	61°06'39.6"	63
35	BY048	pool	62°38'45.6"	61°06'45.0"	63
36	BY049, BY050	pool	62°38'43.1"	61°06'22.9"	75
37	BY051	lake	62°38'45.9"	61°06'15.9"	60
38	BY052	lake	62°38'20.1"	61°06'44.2"	66
39	BY053	lake	62°38'14.3"	61°06'39.3"	72
40	BY054	lake	62°37'52.4"	61°06'30.0"	38
41	BY055	lake	62°37'41.7"	61°06'30.4"	40
42	BY056	lake	62°37'55.5"	61°05'55.3"	77
43	BY057	lake	62°38'01.4"	61°05'49.7"	78
44	BY058	stream	62°39'14.8"	61°04'21.5"	20
45	BY059	lake	62°39'41.4"	61°00'26.4"	4
46	BY060	lake	62°39'21.7"	61°00'10.4"	93
47	BY061	pool	62°38'45.7"	61°00'25.6"	74
48	BY062	pool	62°38'34.5"	61°00'39.5"	80
49	BY063	lake	62°38'27.6"	61°00'44.6"	40
50	BY064, BY065	stream	62°39'28.2"	61°01'27.9"	5
51	BY066	pool	62°39'44.0"	61°05'53.8"	11
52	BY067	pool	62°39'45.5"	61°05'51.2"	12
53	BY068	pool	62°39'45.3"	61°05'48.2"	11
54	BY069	pool	62°39'44.2"	61°05'49.3"	12
55	BY070, BY071	pool	62°39'42.4"	61°05'50.4"	13

Frozen water samples were analyzed for NO_2^-+NO_3^--N, NH_4^+-N, PO_4^{3-}-P, SO_4^{2-}, Cl^-, Na^+, K^+, Mg^{2+}, Ca^{2+}, Fe^{3+} at the Laboratory for Ecosystem Management (University of Antwerp, Belgium). NH_4^+-N concentration was always below the detection limit (<0.08 mg/l) and therefore was not used in the analyses. Table 5.2 lists all samples together with their chemical characteristic. To obtain a more complete picture of the diatom diversity of Byers Peninsula, 22 additional samples were taken from the same localities for diatom analysis only, often from different substrates such as floating filamentous algae, stones or microbial mats.

Slide preparation and diatom identification

Diatom samples were cleaned using a modified method described in Van der Werff (1955). Subsamples were cleaned by adding 37% H_2O_2 and heating to 80 °C for about 1h. Oxidation of organic material was completed by addition of $KMnO_4$. Following digestion and centrifugation (10 minutes at 3700 x g), the resulting cleaned material was diluted with distilled water to avoid excessive concentrations of diatom valves on the slides, dried on microscope cover slips, and mounted in Naphrax®. Samples and slides are stored at the National Botanic Garden of Belgium (Meise, Belgium). In each sample, 400 diatom valves were identified and enumerated on random transects at x1000 magnification under oil immersion using an Olympus BX51 microscope equipped with Differential Interference Contrast (Nomarski®) optics. After the count, the rest of the slide was scanned for rare species that were not observed during the counting.

Diatom identification was based on the latest taxonomic publications (e.g., Kopalová et al. 2012, Van de Vijver et al. 2002a, 2010b, 2011a, Zidarova et al. 2010, 2012; and references therein). For several species, identification up to species level was not possible due to their unclear taxonomic status. All valves belonging to the genus *Gomphonema* were grouped under *Gomphonema* spp. whereas the valves belonging to the *Nitzschia perminuta*-complex were split into *N. perminuta*-capitate forms and *N. perminuta*-non-capitate forms based on the shape of their apices. Further morphological and taxonomic research will be necessary to establish their correct identity.

TABLE 5.2 – Water chemistry characteristics of sampling locations.

	pH	Spec. Cond. (μS cm^{-1})	(NO_2^-+NO_3^-) N (mg l^{-1})	PO_4^{3-}-P (mg l^{-1})	SO_4^{2-} (mg l^{-1})	Cl^- (mg l^{-1})	Na (mg l^{-1})	K (mg l^{-1})	Ca (mg l^{-1})	Mg (mg l^{-1})	Fe (mg l^{-1})
BY001	7.27	247	3.9	0.16	35	22	21.4	1.4	4.2	1.31	0.25
BY003	7.69	101	0.94	0.12	12	21	27.1	1.8	0.7	1.09	0.11
BY005	7.43	266	69.2	0.01	120	16	20.9	0.4	15.5	2.63	0.02
BY006	7.48	262	0.26	0.01	131	13	13.9	0.3	9.9	1.49	0.01
BY008	7.46	158	24.3	0.01	36	29	34.3	2.2	5.6	3.33	0.05
BY009	7.03	54	0.09	3.13	6	9	9.4	1.6	1.5	0.64	0.02
BY011	8.58	84	0.25	0.06	2	23	13.7	0.4	3.4	2.61	0.04
BY012	8.18	108	0.05	0.03	8	29	7.8	0.15	4.2	1.83	0.02
BY014	7.98	94	0.025	0.02	4	25	16.2	0.2	7.8	3.61	0.03
BY016	7.85	102	0.025	0.01	10	21	14.4	0.15	9.4	3.61	0.02
BY017	7.83	58	0.025	0.01	6	11	5.4	0.15	2.9	1.26	0.01
BY019	7.69	58	0.025	0.01	9	8	6.8	0.15	4.7	1.41	0.02
BY020	7.59	47	0.025	0.01	4	10	5.3	0.15	4.1	1.10	0.01
BY021	7.44	177	0.025	2.27	23	32	19.3	2.2	11.6	3.98	0.23
BY022	7.64	85	0.05	0.08	6	17	6.1	0.15	3.1	1.23	0.02
BY024	8.4	153	0.45	0.02	15	33	6.2	0.15	4.6	1.67	0.005
BY026	7.74	236	2.7	0.13	39	39	17.6	1.3	2.1	2.1	3.34
BY027	7.81	163	0.19	0.03	44	15	10.9	0.4	13.9	2.9	0.10
BY029	7.84	86	0.09	0.01	17	11	7.5	0.15	5.7	1.19	0.005
BY031	9.44	197	0.08	0.02	42	30	8.7	0.2	10.1	2.10	0.01
BY032	8.83	220	0.9	0.01	45	32	17.8	0.6	17.9	4.80	0.02
BY033	8.42	52	0.025	0.01	4	9	7.1	0.15	3.9	1.64	0.08
BY035	7.94	153	0.16	0.01	73	11	6.9	0.2	13.5	2.88	0.17
BY036	6.88	34	0.025	3.28	2	5	4.9	1.0	1.0	0.36	0.03
BY037	6.82	25	0.09	0.08	2	6	3.0	0.15	0.8	0.28	0.02
BY038	7.56	49	0.025	0.03	2	12	7.3	0.15	1.4	1.08	0.02
BY039	7.06	18	0.025	0.02	2	3	4.3	0.15	0.6	0.48	0.005
BY040	6.7	8	0.025	0.01	2	1.5	0.3	0.2	0.2	0.06	0.005
BY042	6.72	49	0.19	2.94	4	7	4.9	0.9	2.2	0.62	0.03
BY043	6.76	52	0.025	0.08	5	13	6.3	0.2	2.6	0.97	0.01
BY044	7.86	113	0.025	0.03	11	18	7.9	0.3	11.6	1.99	0.06
BY045	7.96	140	0.025	0.01	8	22	10.1	0.2	14.9	2.47	0.01
BY046	7.5	79	0.025	0.05	12	13	8.9	0.15	7.1	2.04	0.06
BY047	7.42	108	0.025	0.02	7	25	7.9	0.2	2.8	1.62	0.01
BY048	7.98	99	0.025	0.02	6	19	8.8	0.15	3.4	1.28	0.01
BY049	7.59	58	0.35	0.01	7	8	6.1	0.15	4.5	1.16	0.02
BY051	7.25	58	0.025	0.01	8	8	4.5	0.15	3.0	0.87	0.03
BY052	7.35	97	0.13	5.2	8	15	11.4	2.6	3.0	1.35	0.03
BY053	7.42	75	0.08	0.07	6	14	10.2	0.15	2.9	1.62	0.01
BY054	7.51	114	0.07	0.03	16	21	21.6	0.6	6.1	3.11	0.02
BY055	7.48	130	0.025	0.01	26	18	20.0	0.6	12.1	3.37	0.01
BY056	7.48	70	0.025	0.02	8	16	12.6	0.2	3.9	1.73	0.01
BY057	7.45	48	0.025	0.01	2	11	8.2	0.15	2.2	1.34	0.01
BY058	7.32	76	0.025	0.01	22	8	3.8	0.2	2.6	0.58	0.005
BY059	7.58	148	3.3	2.33	13	32	48.5	3.1	0.4	0.41	0.14
BY060	7.41	48	0.29	0.1	2	12	11.5	0.2	0.9	1.06	0.02
BY061	7.26	53	0.7	0.02	2	11	13.0	0.2	2.5	2.31	0.005
BY062	7.41	48	0.24	0.01	2	11	13.0	0.15	1.3	1.40	0.005
BY064	7.47	44	0.73	0.05	2	7	14.1	0.15	1.2	0.54	0.005

Data analysis

For a pairwise comparison of the diatom flora of Byers Peninsula with other Antarctic localities (Antarctic Continent, James Ross Island, Crozet Archipelago), the similarity coefficient of Sørensen (1948) was used. To compare the studied flora with the species composition of the Antarctic Continent, a species list was compiled based on Sabbe et al. (2003), Ohtsuka et al. (2006), Gibson et al. (2006) and Esposito et al. (2008). For James Ross Island, the comparison is based on a partly unpublished species list (Kopalová et al. 2012, unpubl. data). The species list from the Crozet Archipelago in Van de Vijver et al. (2002a) was used as a proxy for the entire sub-Antarctic Region in the southern Indian Ocean as almost 90% of the diatom flora is shared by all 4 islands in this subregion (Van de Vijver et al. 2008).

The geographic distribution of the taxa was based on literature data provided with unambiguous illustrations and/or descriptions (Appendix 5.1). When the identity of a taxon could not be determined with 100% certainty, this was shown using 'cf.' or 'sp.' and, its distribution was usually listed as unknown (U). Several unidentified species (mainly in the genus *Diadesmis*, *Eunotia*, *Surirella*) are currently under revision and their description as new (Antarctic) species is pending (Kopalová et al., unpubl. data, Van de Vijver et al. unpubl. data). Their distribution is listed as Maritime Antarctica (MA). For Antarctic species, the geographic distribution was further refined in MA when the species only occurred in the Maritime Antarctic Region. Antarctic taxa with a wider distribution in the entire Antarctic Region are listed as 'A'.

To determine the extent to which our sampling effort represented the diatom flora in the lakes of Byers Peninsula, we calculated the incidence-based species richness estimator (ICE, Chao et al. 2000) and the mean Chao2 richness estimator (Chao 1984), using the EstimateS program version 8.2 (Coldwell 2009). Shannon-Wiener diversity index ($\log_{10}$-based) and Hill's evenness index were calculated using the statistical package MVSP. All environmental variables except pH were log-transformed since they had skewed distributions.

A hierarchic-agglomerative clustering, based on minimum variance strategy with Squared Euclidean Distance as dissimilarity measure, was used to classify the samples based on the water chemistry data. Principal Components Analysis (PCA), based on a standardized correlation matrix, was used to determine the main directions of variation in the water chemistry data set. Constrained ordination techniques were used to elucidate patterns in diatom species composition in relation to measured water chemistry characteristics. All statistical analysis was performed using CANOCO version 4.5 (ter Braak & Smilauer 1998). Square-root transformed abundance data were used in the ordinations. Rare taxa (i.e. a taxon not present in at least one sample with a minimum relative abundance of 1%) were removed from the analyses. As an initial detrended correspondence analysis (DCA) revealed a gradient length in standard deviation (SD) units smaller than 2 SD, linear species reponse curves could be expected (ter Braak & Prentice 1988). We therefore used a linear ordination technique, redundancy analysis (RDA). As environmental variables are often correlated, Redundancy Analysis (RDA) with forward selection and unrestricted Monte Carlo permutation tests (999 permutations, $P < 0.05$) was used to select a minimal subset of environmental variables that independently and significantly explain the variation in the species data. Groups of significantly correlated ($P < 0.05$) environmental variables were first identified using a Pearson correlation matrix with Bonferroni-adjusted probabilities.

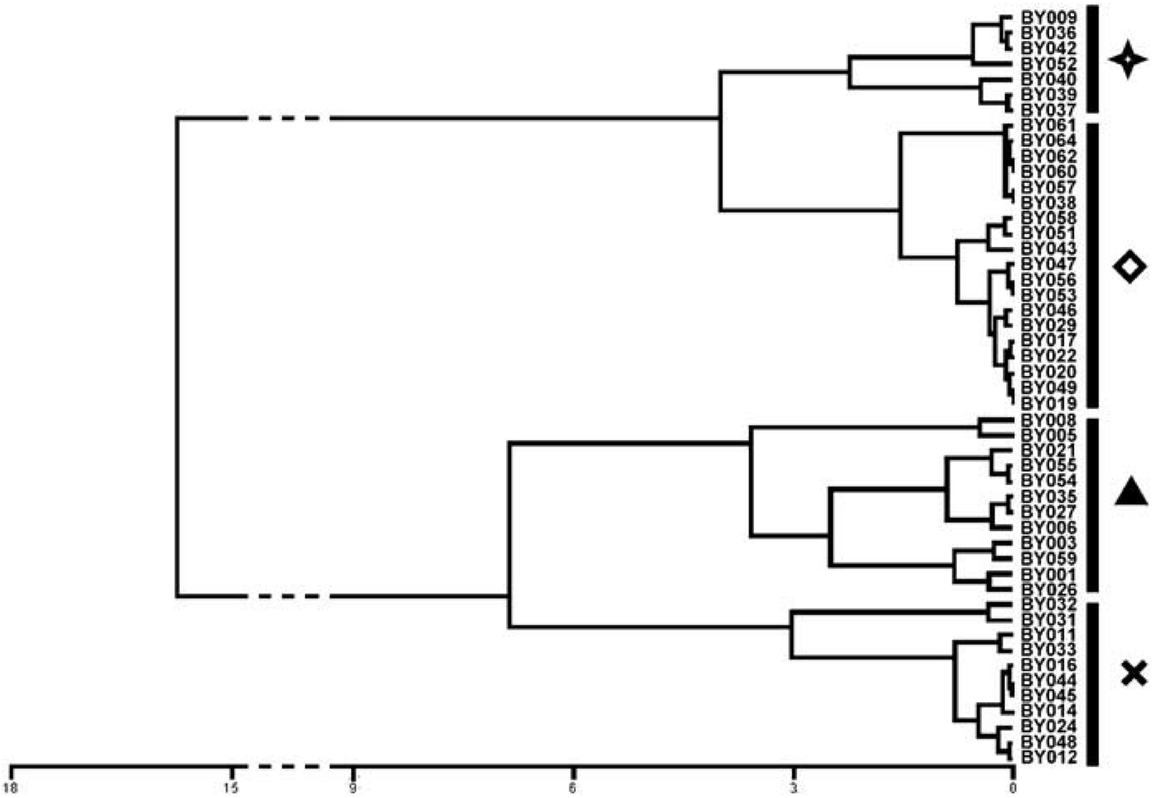

FIGURE 5.2 – Dendrogram showing the results of the cluster analysis of 49 sites based on water chemistry data. Symbols correspond to groups shown in Fig. 5.3.

In each group, forward selection was then used to select the minimal number of significant parameters that could explain the largest amount of variation in the species data. The selected variables of each group were then combined together and analysed again by forward selection to obtain a final set of environmental parameters to be used in RDA. Monte Carlo unrestricted permutation tests (999 permutations) were used to test significance of the constrained ordination axes (ter Braak & Šmilauer 1998).

Results

Water chemistry

To summarize the major patterns of variation within the chemistry data, cluster analysis (Fig. 5.2) and PCA (Fig. 5.3) were used. Cluster analysis (Fig. 5.2) was used to divide the samples into four groups. These groups could be identified on the PCA diagram (Fig. 5.3) marking the samples with four different symbols. PCA axis 1 accounts for 51.7% of the total variance ($\lambda_1 = 0.517$) in the dataset. The axis represents a gradient related to salinity (Specific Conductance, Cl^-, Ca^{2+}, Mg^{2+}, SO_4^{2-}, Na^+) whereas the second axis accounts for 22.2 % of the total variance ($\lambda_2 = 0.222$) and appears to represent a nutrient gradient. Table 5.3 shows the mean parameter values for each group. The first group contains relatively young, recently deglaciated lakes situated close to the Rotch Ice Dome. They are characterized by low specific conductance values (40 ± 30 µS/cm), an almost circumneutral pH (6.9 ± 0.2), and low nutrient and major ions levels. The higher amount of PO_4^{3-} is the result of the inclusion of some lakes from the general plateau that have a higher phosphate level (up to 5.2 mg/l). A second group, related to the first one, contains all larger lakes located on the central plateau (alt. >50m). They usually have a higher pH (7.46 ± 0.23), rather low specific conductance values (63 ± 17 µS/cm) and slightly higher nutrient and cation levels (except PO_4^{3-}) than the previous group. The third and fourth group have a completely different chemistry. The third group contains coastal lakes with high nutrient (except PO_4^{3-}), sulphate (47 ± 40) and specific conductance values (179 ± 58 µS/cm) but with an equal pH compared to group II (7.57 ± 0.19). The fourth group is composed of several smaller, shallow temporary pools. They are characterized by higher pH (8.3 ± 0.5), a moderate specific conductance and higher nutrient and cation values. The different streams in the study do not seem to be restricted to one group but can be found in groups I, II and III with a majority in group II. Four of them are meltwater streams (e.g., BY027, BY029), flowing out of snowfields and feeding the lakes on the higher plateau. Two flow in the coastal region and two are situated close to the Rotch Dome.

Species composition and biogeography

A total of 143 diatom taxa (including species, varieties and forms) belonging to 38 genera were found (Appendix 5.1). Species richness per sample ranged from 5 to 48 (median value 30, average number 28 ± 9). The highest species richness was recorded in samples BY029 (48 taxa), BY009 and BY014 (45 taxa) and BY067 (44 taxa) whereas lowest species richness was found in sample BY050 (5 taxa). Diversity analysis revealed a mean Shannon-Wiener diversity index of 1.02 with an SD of 0.25 and a mean evenness measure of 0.68 ± 0.14. Species relative abundance varied considerably. Fifteen taxa were only found after scanning the slides after counting and seven taxa were found with only one single valve in all counts together (28400 valves). Sixty-three taxa (almost half of all taxa) together accounted for 1 % of all diatoms counted. A large number of species is restricted to only a few samples and very few taxa occur in 50 % or more of all samples (Fig. 5.4).

TABLE 5.3 – Water chemistry characteristics and elevation in sample groups identified by cluster analysis (mean and standard deviation).

	Group I	Group II	Group III	Group IV
pH	6.94 ± 0.23	7.47 ± 0.24	7.57 ± 0.19	8.3 ± 0.5
Spec. cond. (µS cm^{-1})	41 ± 30	63 ± 17	180 ± 58	124 ± 50
$(NO_2+NO_3)N$	0.08 ± 0.06	0.15 ± 0.22	9 ± 20	0.17 ± 0.27
PO_4 (mg l^{-1})	2.1 ± 2.1	0.032 ± 0.030	0.4 ± 0.9	0.021 ± 0.015
SO_4 (mg l^{-1})	3.7 ± 2.4	7 ± 5	47 ± 40	14 ± 15
Cl (mg l^{-1})	6.6 ± 4.4	12 ± 4	22 ± 9	24 ± 7
Na (mg l^{-1})	5 ± 4	8 ± 3	22 ± 11	11 ± 4
K (mg l^{-1})	0.9 ± 0.9	0.15 ± 0.00	1.2 ± 0.9	0.23 ± 0.15
Ca (mg l^{-1})	1.3 ± 1.0	3.1 ± 1.6	8 ± 5	8 ± 5
Mg (mg l^{-1})	0.5 ± 0.4	1.3 ± 0.4	2.4 ± 1.1	2.5 ± 1.1
Fe (mg l^{-1})	0.020 ± 0.011	0.015 ± 0.013	0.4 ± 0.9	0.027 ± 0.024
number of pools	1	4	1	7
number of lakes	4	11	8	2
number of streams	2	4	2	0
mean elevation	44 ± 25	60 ± 23	19 ± 19	53 ± 18

Based on the species richness estimators, it is possible to evaluate how well the sampling effort reflected true diatom species richness. The expected total number of taxa in all samples is 139 (ICE) or 138 (Chao2) for the Byers Peninsula lakes, suggesting that the counting protocol scored about 93% of the total taxa present in the samples overall.

The genera *Nitzschia* (31.7 % of all counted valves), *Fragilaria* (11.6 %) and *Psammothidium* (10.8 %) dominated the counts when considering the frequencies of counted valves. The most species-rich genus was *Pinnularia* (22 taxa), followed by *Luticola* (14 taxa), *Diadesmis* (10 taxa) and *Muelleria* (10 taxa). The most abundant taxa were *Fragilaria capucina* (11.5 %), *Nitzschia perminuta*-capitate form (9.7%) *N. homburgiensis* (7.7 %), *Psammothidium papilio* (6.3%) and *Gomphonema* spp. (5.2 %). The ten most abundant taxa accounted for 60.3% of all counted valves; these are indicated in bold in Appendix 5.1.

A large number of unknown taxa, mainly belonging to the genus *Pinnularia* were found. A taxonomic revision of the latter genus resulted in seventeen published new taxa (Van de Vijver & Zidarova 2011, Zidarova et al. 2012). Several other taxa were only recently described from Livingston Island: *Placoneis australis* (Zidarova et al. 2009), *Hantzschia hyperaustralis*, *H. acuticapitata*, *H. confusa*, *H. incognita* (Zidarova et al. 2010) and *Navicula dobrinatemniskovae* (Van de Vijver et al. 2011a).

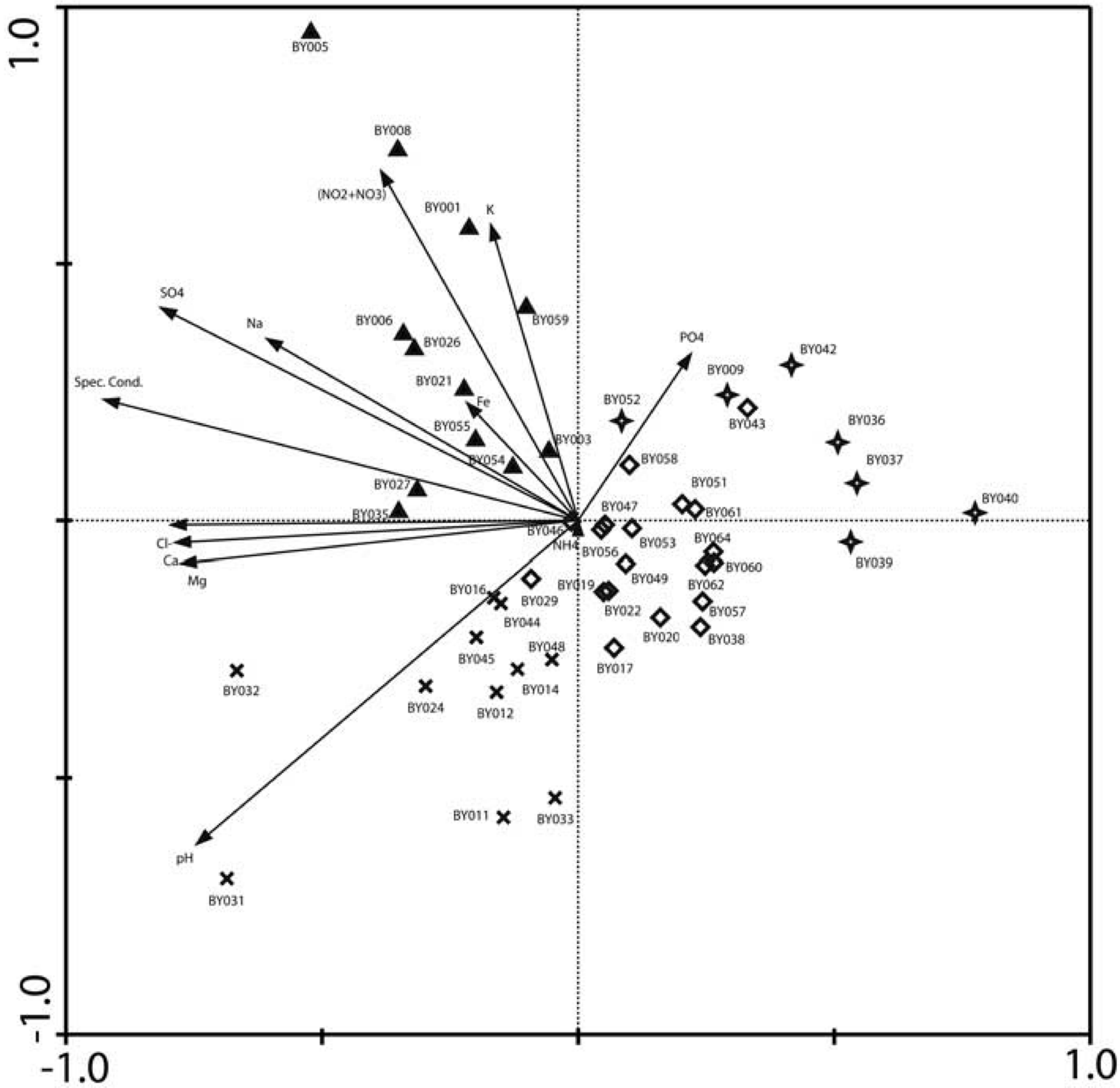

FIGURE 5.3 – A correlation biplot of samples and environmental variables resulting from the Principal Components Analysis of the water chemistry data set. Symbols indicate sample membership in the groups, identified by the cluster analysis, (stars = young lakes close to the Rotch Ice Dome, diamonds = larger lakes on the plateau, crosses = coastal lakes with high nutrients, pyramids = temporary shallow pools).

Almost 56 % of all observed species have a restricted Antarctic distribution with a majority of these (78%) only confined to the Maritime Antarctic Region. Only 44 taxa (31%) have a cosmopolitan distribution, such as *Navicula gregaria* Donkin, *Pinnularia borealis* or *Mayamaea permitis*. A very small proportion of all counted valves (7 taxa) belonged to marine species, probably blown in by wind or sea-spray.

TABLE 5.4 – List of diatom species with a cumulative fit of > 25% in RDA and their mean relative abundances in the four groups of samples identified by the cluster analyses of water chemistry data (X > 10%, O 5–10 %, ° 2–5 %, + < 2 %). I to IV represent the different sample groups.

Taxon name	Code	I	II	III	IV
Diadesmis arcuata	Diaarc	X	+	+	+
Brachysira minor	Bramin	X	+	°	+
Psammothidium papilio	Psamet	X	°	O	O
Nitzschia homburgensis	Nithom	X	°	°	X
Fragilaria capucina s.l.	Fracap	O	°	O	O
Stauroforma exiguiformis	Stfexi	°	+	+	+
Diadesmis inconspicua	Diainc	°	+	+	+
Psammothidium germainii	Psager	°	+	+	°
Nitzschia inconspicua	Nitinc	°	+	°	+
Planothidium lanceolatum	Plalan	°	+	°	+
Nitzschia perminuta - capitate form	Nitpcap	°	X	X	°
Navicula dobrinatemniskovae	Navdob	+	X	+	O
Gomphonema spp.	Gomspp	°	O	O	°
Nitzschia perminuta - non-capitate form	Nitpnca	+	O	O	+
Staurosira alpestris	Stralp		°	+	+
Navicula austroshetlandica	Navash	+	°	+	+
Diadesmis australis	Diaaus	+	°	+	+
Pinnularia australomicrostauron	PinspA	+	°	+	+
Nitzschia paleacea	Nitpal	+	°	°	+
Nitzschia gracilis	Nitgra	°	°	O	°
Navicula cremeri	Navcre	+	+	°	+
Staurosira pinnata	Strpin	+	+	°	+
Sellaphora seminulum	Selsem	+	+	°	+
Psammothidium abundans	Psaabu			°	
Psammothidium subatomoides	Psasub	+		°	+
Planothidium delicatulum	Pladel	+	+	°	O
Chamaepinnularia krookiiformis	Chakrf	°	+	+	O
Navicula gregaria	Navgre	+	+	+	O
Hippodonta hungarica	Hiphun	+	+	+	°
Mayamaea permitis	Mayper	+		+	°
Stauroneis pseudoschimanskii	Stapsch	+	+	+	
Pinnularia subantarctica var. *elongata*	Pinsub	+	+	+	+
Psammothidium incognitum	Psainc	+	+	+	+
Chamaepinnularia gerlachei	Chager	+	+	+	+
Diadesmis spB	Diaing	+	+	+	+
Diadesmis spA	Diasp	+	+	+	+
Amphora veneta	Ampven		+	+	+
Fistulifera saprophila/pelliculosa	Fissap	+		+	+

Similarity was fairly high between the diatom floras of the Byers Peninsula and James Ross Island (Sørensen's Index = 0.63) but low between the studied flora and the flora of the sub-Antarctic islands (as represented by the Crozet Archipelago) and the Antarctic Continent (respectively 0.28 and 0.19).

Diatom community analysis

In the ordinations, a data set of 49 samples and 81 diatom taxa was used. All environmental variables related to salinity (specific conductance, SO_4^{2-}, Na^+, Mg^{2+}, Cl^-, K^+ and Ca^{2+}) were highly correlated. Forward selection in RDA that used only these parameters as constraints, identified specific conductance, SO_4^{2-}, Ca^{2+} and Cl^- as environmental variables that together significantly explained variation in the diatom data ($p<0.05$). In the second RDA, these four parameters and nitrogen ($=NO_3^-+NO_2^-$), PO_4^{3-}, pH and Fe^{3+} were used as constraints The forward selection in this second RDA selected pH, SO_4^{2-}, Ca^{2+}, Cl^-, nitrogen and specific conductance as a minimal set of variables that together significantly explained variation in species data.

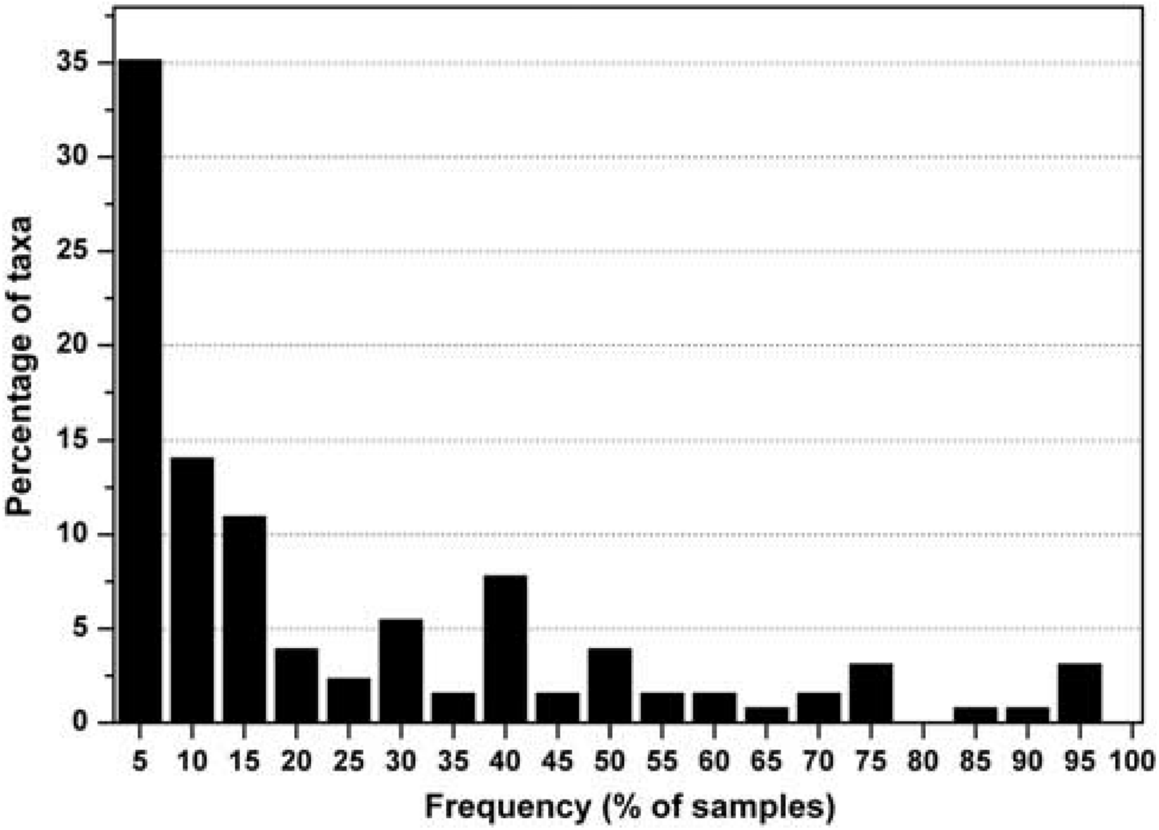

FIGURE 5.4 – Frequency distribution of diatom taxa in studied samples (e.g., 5 indicates 1-5% of all samples).

The second RDA constrained to the six selected environmental variables (Fig. 5.5) explained only a small proportion of the species variance in the samples. The first two axes ($\lambda_1 = 0.112$, $\lambda_2 = 0.054$) were highly significant ($p=0.001$) but accounted for only 16.6 of the cumulative variance in the diatom data. This is low but typical for noisy datasets with many blank values (Stevenson et al. 1991). RDA axis 1 is relatively strongly correlated with pH (inter-set correlation = -0.68) and to a lesser extent with Cl^- (0.48), separating the lakes sampled close to the Rotch Ice Dome on the right side of the diagram (group I) from the smaller temporary pools on the left side of the diagram (group II). All larger lakes have an intermediate position between these two groups (group III). The second axis is related to SO_4^{2-} (inter-set correlation 0.50), separating a group of coastal lakes, characterized by higher nitrogen and SO_4^{2-}-levels (group IV). There are marked differences in diatom speceis composition between the different groups (Table 5.4, Fig. 5.5).

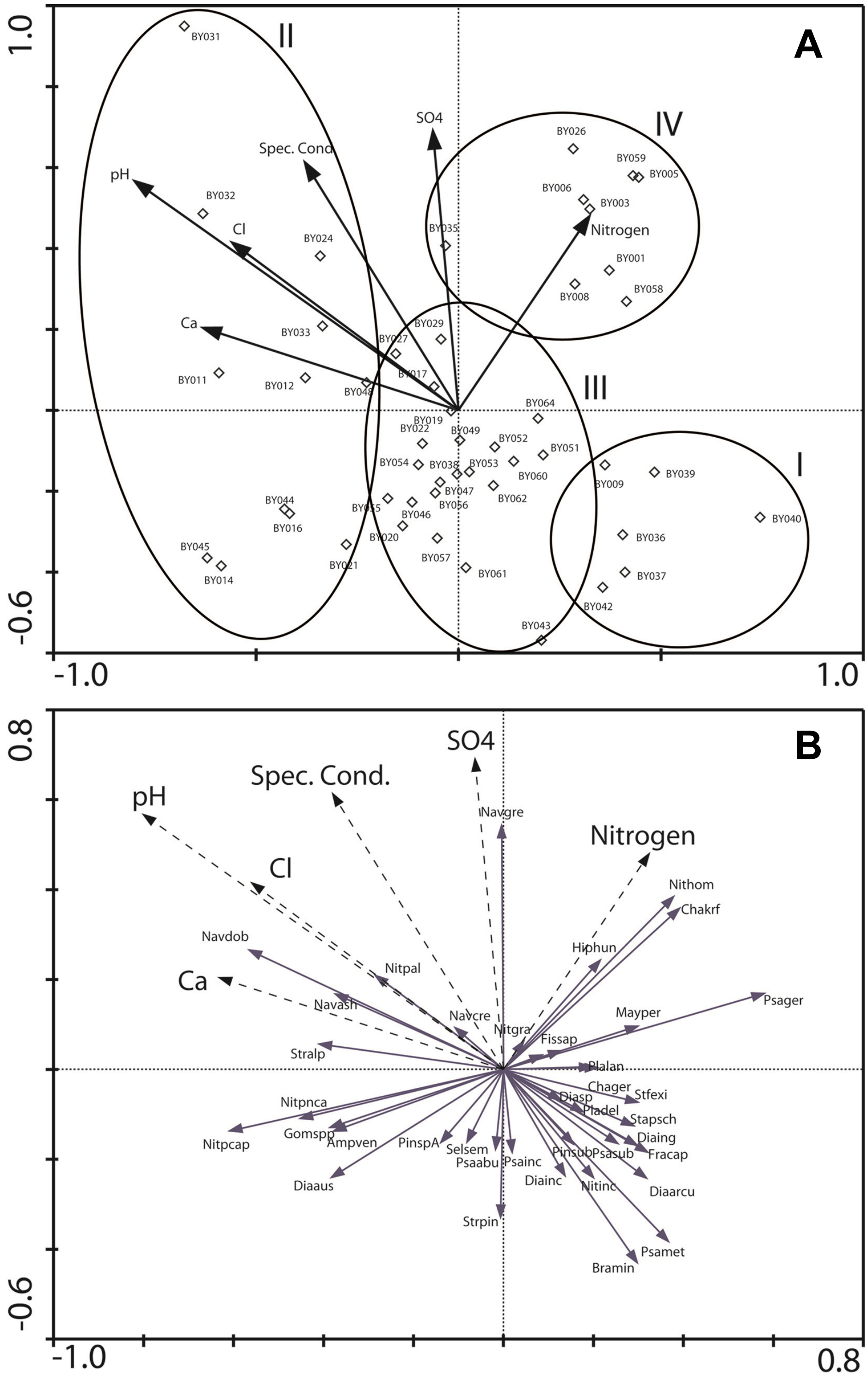

FIGURE 5.5 – Redundancy Analysis (RDA) correlation biplots. A. Sample and environmental variables biplot. B. Species and environmental variables biplot. The codes of species names are given in Table 5.4.

Only species with a cumulative fit of > 25% in an RDA diagram have been shown in Table 5.4 and Fig. 5.5. Although some taxa seem to occur in high abundances in almost every group (such as *Psammothidium papilio*, *Fragilaria capucina* s.l. or *Nitzschia perminuta* – capitate form) it is clear that a number of taxa showed a distinct preference for a particular group. Group I is characterized by high frequencies of *Brachysira minor*, *Diadesmis arcuata*, *Stauroforma exiguiformis*, *Diadesmis inconspicua* and *Nitzschia homburgensis*, although the latter is shared with group IV. The temporary pools (group II) contain higher numbers of several *Navicula* taxa, *Staurosira alpestris*, *Nitzschia perminuta* –non-capitate form and several other *Nitzschia* species such as *N. gracilis* and *N. paleacea*. Larger lakes (group III) do not seem to have a specific diatom flora since most dominant taxa are also present in high numbers in other groups, although taxa such as *Sellaphora seminulum*, *Psammothidium abundans*, and *Staurosira pinnata* show their highest abundances in this environment. Finally, coastal pools are dominated by *Navicula gregaria*, *Planothidium delicatulum*, *Chamaepinnularia krookiiformis*, *Mayamaea permitis* and *Hippodonta hungarica*.

Discussion

Species composition and biogeography

In the first diatom study on diatoms from Byers Peninsula (Jones et al. 1993) only 52 taxa were listed, of which 14 could not be identified to the species level despite the fact that a comparable amount of lakes and habitat types were sampled. In the present study, a total of 143 taxa was observed. Although part of the observed flora is the same (some nomenclatural changes notwithstanding), several taxa formerly identified as cosmopolitan have now been described as separate species, most of which are endemic to the Antarctic. Examples include *Navicula cryptocephala* var. *veneta* (Kütz.) Rabenh. [now split in three new Antarctic species, viz. *N. austroshetlandica*, *N. dobrinatemniskovae* and *N. cremeri* (Van de Vijver et al. 2011a)], *N. bicephala* Hust. [now *N. bicephaloides* (Van de Vijver et al. 2011a)], and *Navicula elginensis* (Greg.) Ralfs in Pritch. recently described as *Placoneis australis* (Zidarova et al. 2009). Apart from taxonomic changes, more differences between the two studies can be noted. Several genera are completely missing from Jones et al. (1993), such as *Hantzschia*, *Diadesmis*, *Muelleria* and *Luticola* (the latter three were formerly included in *Navicula* s.l.), although it is possible that some of these species are included in the species list as unidentified taxa. On the other hand, some taxa are listed that could not be found in the present study such as *Achnanthes pinnata* Hust. or *A. mollis* Krasske (although the latter might be the consequence of a misidentification due to its similarity with *Psammothidium abundans*). These differences in species composition may also be due to differences in the sampling strategy since samples in Jones et al. (1993) were taken from the deepest parts of the lakes using a gravity corer whereas in the present study, surface samples were taken from the littoral zone. In Jones et al. (1993), no lakes close to the Rotch Dome were sampled. In the present study however, a lot of species have been found in those young lakes which may also partly explain the higher number of taxa found in our study.

Based on these observations, it is not surprising that several diatom studies, even quite recent ones, concluded that the freshwater diatom flora in this part of the world is merely composed of cosmopolitan taxa (Jones 1996, Van de Vijver & Beyens 1999a, Toro et al. 2007, Vinocur & Maidana 2010) or that no differences could be noted between the different parts of the Antarctic Region (Jones et al. 1993). However, with almost 56% of the observed taxa being restricted to the Antarctic Region, it is clear that these statements can no longer be accepted. Similarities with the other part sof the Antarctic such as the Antarctic Continent, are quite low, contradicting the presumed cosmopolitanism of the Antarctic diatom flora. The low similarity between the biotas of the Antarctic Peninsula and the Antarctic Continent has been demonstrated earlier for other taxonomic groups such as nematodes (Andrássy 1998) and free-living mites (Pugh 1993). This led to the establishment of the so-called Gressit-line, separating the biota of the Antarctic Peninsula from those from the Antarctic Continent (Chown & Convey 2007). The diatom flora of James Ross Island is most similar although there is still almost 37 % of difference between the two island floras, probably due to the location of James Ross Island in the transition zone between the Maritime Antarctic Region and the Antarctic Continent. Several typical Antarctic Continent taxa such as *Luticola gaussii* (Heiden) D.G.Mann and *Achnanthes taylorensis* Kellogg & Kellogg are absent on Byers Peninsula, but present on James Ross Island (Kopalová et al. 2012). Lack of taxonomic consistency (following considerable taxonomic revisions in several genera) in previously published studies from other Maritime Antarctic localities make a floristic comparison, however, impossible. Key taxa such as *Navicula muticopsis* Van Heurck, *Hantzschia amphioxys* (Ehrenb.) Grunow and *Stauroneis anceps* Ehrenb. were split up in a large number of Antarctic taxa. It is clear that further taxonomic research, revising not only on the diatom flora of these other localities, but also of genera that lack a proper revision such as *Gomphonema* or *Nitzschia*, will influence and enhance greatly the biogeographic insights of the Maritime Antarctic diatom flora. Additionally, a recent study has indicated that even in so-called cosmopolitan taxa such as *Pinnularia borealis*, cryptic diversity may be hidden making that the currently observed degree of endemicity is probably a conservative estimate (Souffreau et al. 2012).

Ecology of the diatom communities

It is clear that the composition of the benthic diatom communities on Byers Pensinsula is largely influenced by two environmental gradients: salinity and nutrients. The pH-gradient is not very strong, probably because of the dominance of alkaline soils similarly to several other Maritime Antarctic locations (Vinocur & Unrein 2000). Jones et al. (1993) also identified the first two gradients to be of prime importance for the classification of the diatom communities. Salinity and nutrient gradients seem to be also the crucial factors in almost all Maritime Antarctic lakes. On nearby King George Island, nutrients and, to a lesser extent, pH and conductivity determined the composition of the algal communities in lakes and ponds on the Potter Peninsula (Vinocur & Unrein 2000). They found a clear gradient in the algal (not exclusively diatom) species composition from oligotrophic to hypereutrophic sites, indicating that the influence of marine animals in the nutrient balance of lakes was of prime importance. Hansson & Håkansson (1994) identified the nutrient status of the lakes as the principal factor separating the diatom communities on several Antarctic localities such as Byers Peninsula, James Ross Island and King George Island. Similar observations were also made by Oppenheim (1990) on Signy Island (South Orkney Islands) and by Ohtsuka et al. (2006) and Gibson et al. (2006) for the Antarctic Continent lakes.

At least four groups of habitats and corresponding diatom communities could be identified in the present study. The most recently formed lakes, situated close to the Rotch Ice Dome, showed the highest species richness with a higher evenness than in the other habitats. *Brachysira minor*, *Diadesmis arcuata*, *Psammothidium papilio* and *Nitzschia homburgensis* dominated the flora with the first two species almost absent in the other habitats. The low levels of almost all major ions, the lower pH and the low specific conductance values are typical for these recently formed lakes that are almost entirely fed by glacial meltwater, coming from the Rotch Ice Dome. It is therefore possible that the actual diatom composition of these lakes and pools may reflect a pioneer state in the diatom succession on Byers Peninsula. The higher number of aerophilic taxa from the genera *Diadesmis*, *Psammothidium*, *Luticola* and *Pinnularia* in these lakes may be linked on one hand to the oligotrophic nature of the lakes and on the other hand to the large number of small, shallow, temporary meltwater streams that feed these lakes.

The central plateau on the other hand has been ice-free for several thousands of years (Björck et al. 1993) and diatom communities had the time to develop into their present-day species composition. Both larger lakes and smaller usually temporary pools can be found on this plateau. Both habitats show some similarities in species composition with a dominance of *Nitzschia perminuta* (both capitate and non-capitate forms) and *Gomphonema* spp. Further taxonomic research will be necessary to clarify whether these taxon complexes are composed of one or several taxa with a preference for both or only one of the two habitats. Nevertheless, differences in species composition can be noted between the two habitats. Temporary pools seem to have high frequencies of *Navicula dobrinatemniskovae* whereas larger lakes are co-dominated by *Psammothidium papilio*, *Nitzschia gracilis* and *Fragilaria capucina* s.l. As can be seen in Table 5.4, the sub-dominant species composition is also rather different and reflects the typical habitat preferences of most lake species. Smaller pools have a higher pH, higher specific conductance values and higher ion concentrations, most likely confirming their temporary nature. Drying out of the pools during warmer days may increase the values of the different environmental parameters in these pools. Ohtsuka et al. (2006) concluded that *P. papilio* is most probably a halophobe species, an observation shared by Sabbe et al. (2003) and Gibson et al. (2006).

Finally, the coastal lakes are largely influenced by two factors: salinity input by sea spray and the presence of marine mammals and birds, especially elephant seals and penguins, which increases the nutrient levels in the lakes. Most of these coastal lakes showed, therefore, the highest nutrient and specific conductance values, which was reflected in the diatom community. Taxa such as *Navicula gregaria*, *Hippondonta hungarica* and *Mayamaea permitis*, that dominate the flora in these lakes, are well known to prefer higher specific conductance and nutrient levels (Lange-Bertalot 2001). In more nutrient-enriched sites, taxa with a restricted Antarctic distribution seem to be less dominant contrary to the more oligotrophic lakes on the central plateau where they often reach high abundances. Most probably, nutrient-tolerant taxa are more likely to survive in a larger variety of habitats whereas the taxa with limited preferences have more difficulties in establishing larger populations in less-favorable conditions. Jones et al. (1993) reported the same species composition from these lakes, indicating the constant nature of these communities.

Streams form an important habitat in the Antarctic Region (e.g. Kawecka & Olech 1993) but seem to be less determining in the present study in separating typical diatom communities. A similar result could be derived from Toro et al. (2007) who also included streams in their study but did not seem to find important differences with the lake environment.

As Jones et al. (1993) already suggested, the obtained results will be useful in reconstructing past environmental changes in Antarctic lakes. Using a more fine-grained taxonomy will most likely help in fine-tuning species' responses to environmental and climatologic changes that might have been lost since based on insufficiently correct baseline data. A similar approach was used several years ago when determining the environmental history of the Larsemann Hills on the Antarctic Continent (Hodgson et al. 2005).

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APPENDIX 5.1 – List of all observed species in the investigated samples of Livingslon Island. (A=entire Antarctic Region, MA= Maritime Antarctic Region, C=Cosmopolitan, U=Unknown). Marine species are marked with an *. The ten most dominant species are put in bold.

Achnanthes coarctata (Brébisson) Grunow	C
Achnanthes muelleri Carlson	A
**Achnanthes* sp.	U
Achnanthidium cf. *minutissimum* (Hustedt) Czarnecki s.l.	U
Achnanthidium exiguum (Grunow) D. B. Czarnecki	C
Adlafia sp.	U
Amphora cf. *veneta* Kützing	U
Brachysira minor (Krasske) Lange-Bertalot	MA
Caloneis bacillum (Grunow) Cleve	C
Chamaepinnularia aff. *evanida* (Hustedt) Lange-Bertalot	A
Chamaepinnularia australomediocris (Lange-Bertalot & Schmidt) Van de Vijver	A
Chamaepinnularia gerlachei Van de Vijver & Sterken	MA
Chamaepinnularia krookii (Grunow) Lange-Bertalot & Krammer	C
Chamaepinnularia krookiiformis (Krammer) Lange-Bertalot & Krammer	C
**Cocconeis* sp.	U
Craticula antarctica Van de Vijver & Sabbe	A
Craticula subpampeana Van de Vijver & Sterken	MA
**Denticula* sp.	U
Diadesmis arcuata (Heiden) Lange-Bertalot	A
Diadesmis australis Van de Vijver & Sabbe	MA
Diadesmis contenta (Grunow ex Van Heurck) Mann ex Round et al.	C
Diadesmis inconspicua Kopalova & Van de Vijver	MA
Diadesmis langebertalotii Le Cohu & Van de Vijver	A
Diadesmis spA	MA
Diadesmis spB	MA
Diadesmis spC	MA
Diadesmis spD	MA
Diadesmis tabellariaeformis (Krasske) Lange-Bertalot & Wojtal	MA
Eolimna jamesrossensis Kopalova & Van de Vijver	MA
Eolimna minima (Grunow) Lange-Bertalot	C
Eucocconeis aretasii (Manguin) Lange-Bertalot	A
Eunotia paludosa Grunow	C
Eunotia sp.	MA

APPENDIX 5.1 – (continued)

Fistulifera saprophila (Lange-Bertalot & Bonik) Lange-Bertalot	C
***Fragilaria capucina* s.l. Desmazières**	C
Geissleria gabrielae Van de Vijver & Zidarova	MA
***Gomphonema* spp**	U
**Gomphonemopsis* sp.	U
Hantzschia abundans Lange-Bertalot	C
Hantzschia acuticapitata Zidarova & Van de Vijver	MA
Hantzschia amphioxys (Ehrenberg) Grunow	C
Hantzschia confusa Van de Vijver & Zidarova	MA
Hantzschia hyperaustralis Van de Vijver & Zidarova	MA
Hantzschia incognita Zidarova & Van de Vijver	MA
Hippodonta hungarica (Grunow) Lange-Bertalot, Metzeltin & Witkowski	C
Luticola austroatlantica Van de Vijver, Kopalová, Spaulding & Esposito	MA
Luticola australomutica Van de Vijver	MA
Luticola caubergsii Van de Vijver	MA
Luticola cohnii (Hilse) Mann	C
Luticola gigamuticopsis Van de Vijver	MA
Luticola higleri Van de Vijver, Dam & Beyens	MA
Luticola katkae Van de Vijver & Zidarova	MA
Luticola muticopsis (Van Heurck) Mann	A
Luticola muticopsis f. *reducta* West & West	A
Luticola permuticopsis Kopalová & Van de Vijver	MA
Luticola quadriscrobiculata Van de Vijver	MA
Luticola sp.	U
Luticola truncata Kopalová & Van de Vijver	MA
Luticola vermeulenii Van de Vijver	MA
Mayamaea atomus (Kützing) Lange-Bertalot	C
Mayamaea permitis (Hustedt) Bruder & Medlin	C
Mayamaea sp.	U
Microcostatus naumannii (Hustedt) Lange-Bertalot	C
Muelleria aequistriata Van de Vijver & Spaulding	MA
Muelleria algida Spaulding & Kociolek	MA
Muelleria austroatlantica Van de Vijver & Spaulding	MA
Muelleria kristinae Van de Vijver	MA
Muelleria luculenta Spaulding & Stoermer	A

APPENDIX 5.1 – (continued)

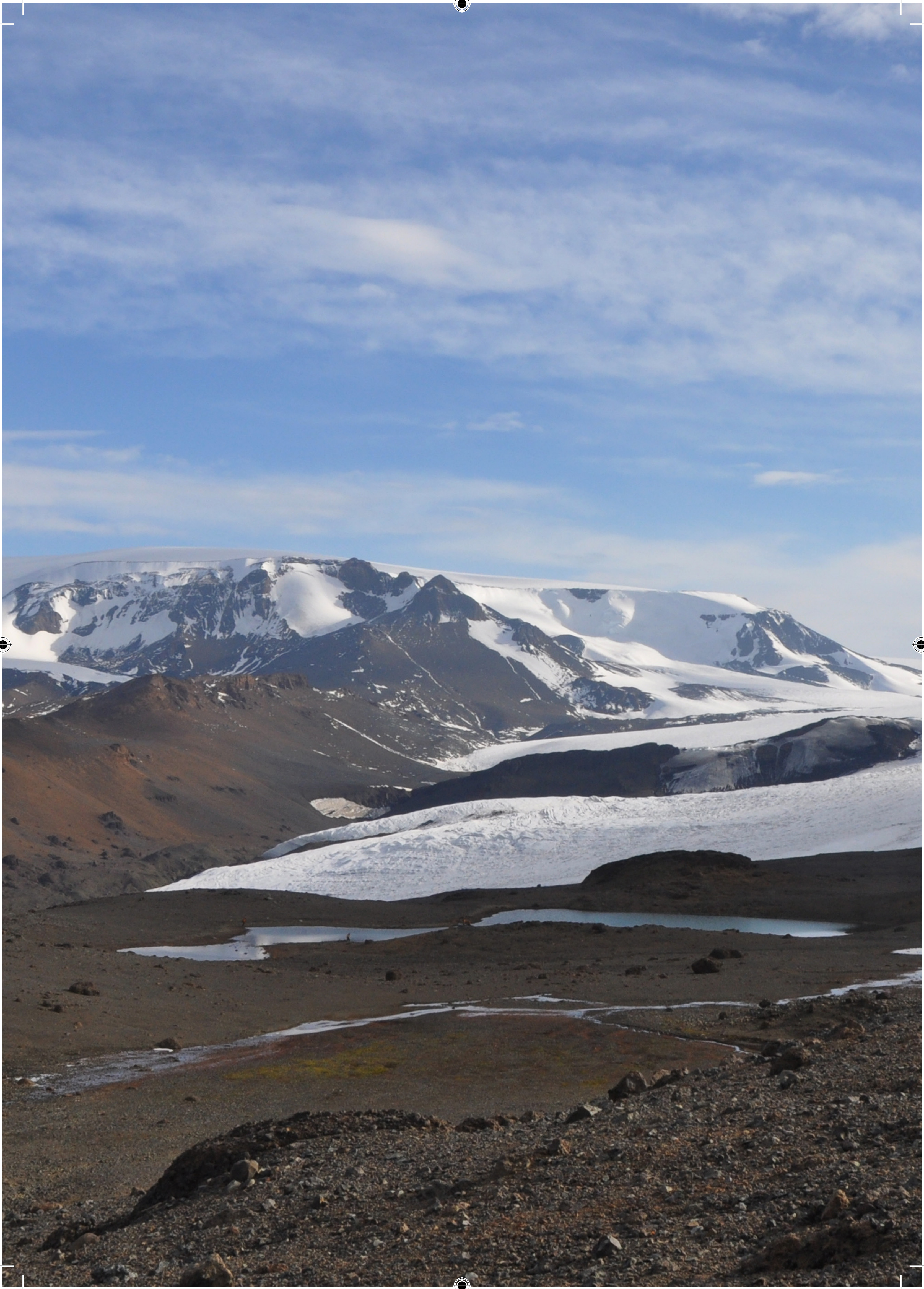
Muelleria regigeorgiensis Van de Vijver & Spaulding	MA
Muelleria rostrata Van de Vijver & Spaulding	MA
Muelleria sabbei Van de Vijver & Spaulding	MA
Muelleria tumida Van de Vijver & Spaulding	MA
Muelleria variolata Spaulding & Kociolek	MA
Navicula australoshetlandica Van de Vijver	MA
Navicula bicephaloides Van de Vijver & Zidarova	MA
Navicula cf perminuta Grunow	C
Navicula cremeri Van de Vijver & Zidarova	MA
***Navicula dobrinatemniskovae* Zidarova & Van de Vijver**	MA
***Navicula gregaria* Donkin**	C
**Navicula* sp.	U
Navicula seibigeana (Ehrenberg) Ralfs	C
Naviculadicta sp.	U
Nitzschia debilis (Arnott) Grunow	C
***Nitzchia gracilis* Hantzsch**	C
***Nitzschia homburgensis* Lange-Bertalot**	C
Nitzschia inconspicua Grunow	C
***Nitzschia paleacea* Grunow**	C
***Nitzschia perminuta* (Grunow) Peragallo- capitate form**	U
***Nitzschia perminuta* (Grunow) Peragallo-non-capitate form**	U
Nitzschia cf. *pusilla* Grunow	C
Orthoseira roeseana (Rabenhorst) O'Meara	C
Pinnularia australodivergens Zidarova et al.	MA
Pinnularia australoglobiceps Zidarova et al.	MA
*Pinnularia australomicrostauron*Zidarova et al.	MA
Pinnularia australorabenhorstii Van de Vijver	MA
Pinnularia australoschoenfelderi Zidarova et al.	MA
Pinnularia austroshetlandica Carlson	A
Pinnularia borealis Ehrenberg	C
Pinnularia borealis var. *pseudolanceolata* Van de Vijver & Zidarova	MA
Pinnularia gemella Van de Vijver	MA
Pinnularia hamiltonii Zidarova et al.	MA
Pinnularia magnifica Zidarova et al.	MA
Pinnularia microstauroides Zidarova et al.	MA

APPENDIX 5.1 – (continued)

Pinnularia obaesa Van de Vijver	MA
Pinnularia perlanceolata Van de Vijver & Zidarova	MA
Pinnularia pseudolaucensis Zidarova et al.	MA
Pinnularia quesadae Van de Vijver & Zidarova	MA
Pinnularia rabenhorstii Hilse	C
Pinnularia sergiplaiana Zidarova et al.	MA
Pinnularia sp.	U
Pinnularia strictissima Manguin	C
Pinnularia subaltiplanensis Zidarova et al.	MA
Pinnularia subantarctica var. *elongata* (Manguin) Van de Vijver & Le Cohu	A
Placoneis australis Van de Vijver & Zidarova	MA
***Planothidium delicatulum* (Kützing) Round & Bukhtiyarova**	C
Planothidium frequentissimum (Lange-Bertalot) Round & Bukhtiyarova	C
Planothidium haynaldii (Schaarschmidt em. Cleve) Haw & Kelly	C
Planothidium lanceolatum (Brébisson) Round & Bukhtiyarova	C
Planothidium renei (Lange-Bertalot & Schmidt) Van de Vijver	A
Psammothidium abundans (Manguin, Bourelly & Manguin) Bukhtiyarova	A
Psammothidium germainii (Manguin) Sabbe	A
Psammothidium incognitum (Krasske) Van de Vijver	A
Psammothidium manguinii (Hustedt) Van de Vijver	A
Psammothidium papilio (Kellogg et al.) Kopalová & Van de Vijver	MA
Psammothidium subatomoides (Hustedt) Bukhtiyarova & Round	C
**Pseudostaurosira* sp.	U
**Rhabdonema* sp.	U
Sellaphora nana (Hustedt) Lange-Bertalot et al.	C
Sellaphora seminulum (Grunow) Mann	C
Stauroforma exiguiformis (Lange-Bertalot) Flower	C
Stauroneis acidoclinata Lange-Bertalot & Werum	C
Stauroneis huskvikensis Van de Vijver & Lange-Bertalot	MA
Stauroneis jarensis Lange-Bertalot et al.	C
Stauroneis latistauros Van de Vijver & Lange-Bertalot	A
Stauroneis obtusa Lagerstedt	C
Stauroneis pseudomuriella Van de Vijver & Lange-Bertalot	A
Stauroneis pseudoschimanskii Van de Vijver & Lange-Bertalot	MA
Stauroneis subgracilior Lange-Bertalot et al.	C

APPENDIX 5.1 – (continued)

Staurosira alpestris (Krasske ex Hustedt) Van de Vijver	C
Staurosira pinnata Ehrenberg	C
Staurosira cf. *venter* (Ehrenberg) Cleve & Moller	U
Surirella sp.	MA
**Thalassiosira* sp.	U



CHAPTER 6

Diversity, ecology and biogeography of the freshwater diatom communities from Ulu Peninsula (James Ross Island, NE Antarctic Peninsula)

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The diversity, ecology and biogeography of diatoms in lakes, seepage areas and streams on the Ulu Peninsula were studied. A diverse diatom flora of 123 taxa was observed, dominated by several Nitzschia *taxa,* Psammothidium papilio*,* Eolimna jamesrossensis*,* Fragilaria capucina *and* Fistulifera saprophila*. The results from the similarity and diversity analysis suggest James Ross Island to be biogeographically positioned within the Maritime Antarctic region, yet with some affinities with the flora of Continental Antarctica. Based on our data, James Ross Island can thus be located close to the boundary of the two main Antarctic biogeographical regions. Diatom communities present in streams and seepage areas could be clearly distinguished from those in lakes, the latter being much more species rich. Based on the multivariate analysis, conductivity and nutrients were selected as the two main environmental factors determining the diatom composition in the Ulu Peninsula lakes. The revised taxonomy of the Antarctic diatom flora induced the construction of a transfer function for water conductivity in the studied lakes that can be applied in further palaeoecological studies.*

Key words: *Diatoms, lakes, seepages, streams, Ulu Peninsula, James Ross Island, community analysis, Antarctic Peninsula*

Introduction

The Antarctic Peninsula together with the neighbouring islands and archipelagos is a very dynamic region recently undergoing severe environmental changes, as opposed to the Antarctic Continent (Vaughan et al. 2003). These changes are most likely related to climate change affecting the ecosystems and their biodiversity (Laybourn-Parry and Pearce 1997, Quayle et al. 2002). The analysis and interpretation of the terrestrial and freshwater biodiversity in the Antarctic and sub-Antarctic regions and the environmental factors influencing this diversity are some of the key research topics of the past two decades as demonstrated in the growing number of papers dealing with this subject (e.g., Convey 2001, Chown & Convey 2007 and references therein).

Diatoms (Bacillariophyta) are one of the most abundant algal groups in terrestrial and freshwater ecosystems in the Antarctic and sub-Antarctic regions (Jones 1996, Van de Vijver & Beyens 1999a, Vyverman et al. 2010). Diatom assemblages often serve as valuable bio-indicators, due to the narrow tolerances of most species to site-specific characteristics. Their frustules are composed of long term resistant silica and are therefore well preserved in sediments. Since the 1990s, diatoms have been widely used in ecological, biogeographical and palaeoecological studies across the entire Antarctic Region (e.g. Oppenheim & Greenwood 1990, Jones et al. 1993, Kawecka & Olech 1993, Roberts & McMinn 1996, Van de Vijver & Beyens 1996, Gremmen et al. 2007, Verleyen et al. 2009, Sterken et al. 2012). In contrast to several previously published studies stressing upon the cosmopolitan nature of the Antarctic flora (Toro et al. 2007, Vinocur & Maidana 2010), a highly specific diatom flora has been observed on various islands in the northern Antarctic Peninsula region (e.g., Sabbe et al. 2003, Van de Vijver et al. 2010a, 2011c, 2012, Zidarova et al. 2010, Kopalová et al. 2011).

The construction of the Czech J. G. Mendel research station on the Ulu Peninsula (James Ross Island, NE Antarctic Peninsula) enabled the study of the freshwater habitats and their diatom flora in this area. Until now, only a few non-taxonomic studies focusing on the diatom flora of this island had been published, mostly dealing with palaeoecological issues (Hansson & Håkansson 1992, Burckle & Wasell 1995, Håkansson et al. 1995, Björck et al. 1996). Recently, the diatom diversity of seepage areas and streams has been analysed based on a refined taxonomy (Kopalová et al. 2012). Although a high number of new taxa has recently been described from James Ross Island (Esposito et al. 2008, Kopalová et al. 2009, 2011), the factors influencing the diatom flora in the freshwater habitats of James Ross Island are only poorly known.

The present study is the first focusing on the ecology of diatom communities in freshwater ecosystems on James Ross Island, revealing relationships between site-specific environmental parameters and diatom diversity. As the island is located on the boundary between Maritime and Continental Antarctica (Øvstedal & Lewis-Smith 2001), studying its diatom flora can add valuable information on the biogeographical boundaries of several typical Antarctic taxa.

Study area

The present study has been carried out on the Ulu Peninsula, northern James Ross Island (64°10'S, 57°45'W), a 2600 km² large island, situated in the north-western part of the Weddell Sea, close to the northern tip of the Antarctic Peninsula (Fig. 6.1).

Eighty percent of the island is permanently covered by ice. Only Ulu Peninsula in the northern part of the island deglaciated during the last 12.5 ka (Nývlt et al., pers. observation) forming nowadays a large ice-free area (Davies et al. , 2013). Its location in the precipitation shadow of the Antarctic Peninsula, which forms an effective barrier to prevailing westerly winds (Engel et al. 2012), gives the island a more arid outlook compared to islands in the Maritime Antarctic Region. Climatic conditions are described in Láska et al. (2011) and in Engel et al. (2012). The terrestrial vegetation of Ulu Peninsula is composed of bryophytes and lichens only (Láska et al. 2011). In the northern part of the island, a higher number of large open water bodies and fresh water ecosystems can be found, mostly induced by glacial erosion and deposition and formed after ice cap retreat during the Holocene (Nedbalová et al. 2013). More details on the geology of the Ulu Peninsula can be found e.g., in Košler et al. (2009), Svojtka et al. (2009) and Nývlt et al. (2011). Recently, a study of the origin, geomorphological position, hydrological stability, bedrock geology and physical and chemical conditions of the lakes of Ulu Peninsula has been conducted (Nedbalová et al. 2013) defining six different lake types: stable shallow lakes in higher altitudes, semi-stable shallow coastal lakes, stable lakes in old moraines, small unstable lakes in young moraines, less-stable deep cirque lakes and very unstable kettle lakes. Stable lakes are permanent, old lakes and probably already present in the area for several hundreds to thousands of years. Seepages and streams are well developed. Seepage areas are shallow wetlands, representing one of the most characteristic habitats of Maritime Antarctica (Elster 2002). Together with streams, they are fed by melting water from retreating glaciers and snowfields (Engel et al. 2012). Their microflora is mostly composed of cyanobacteria, green algae and diatoms (Komárek & Elster 2008).

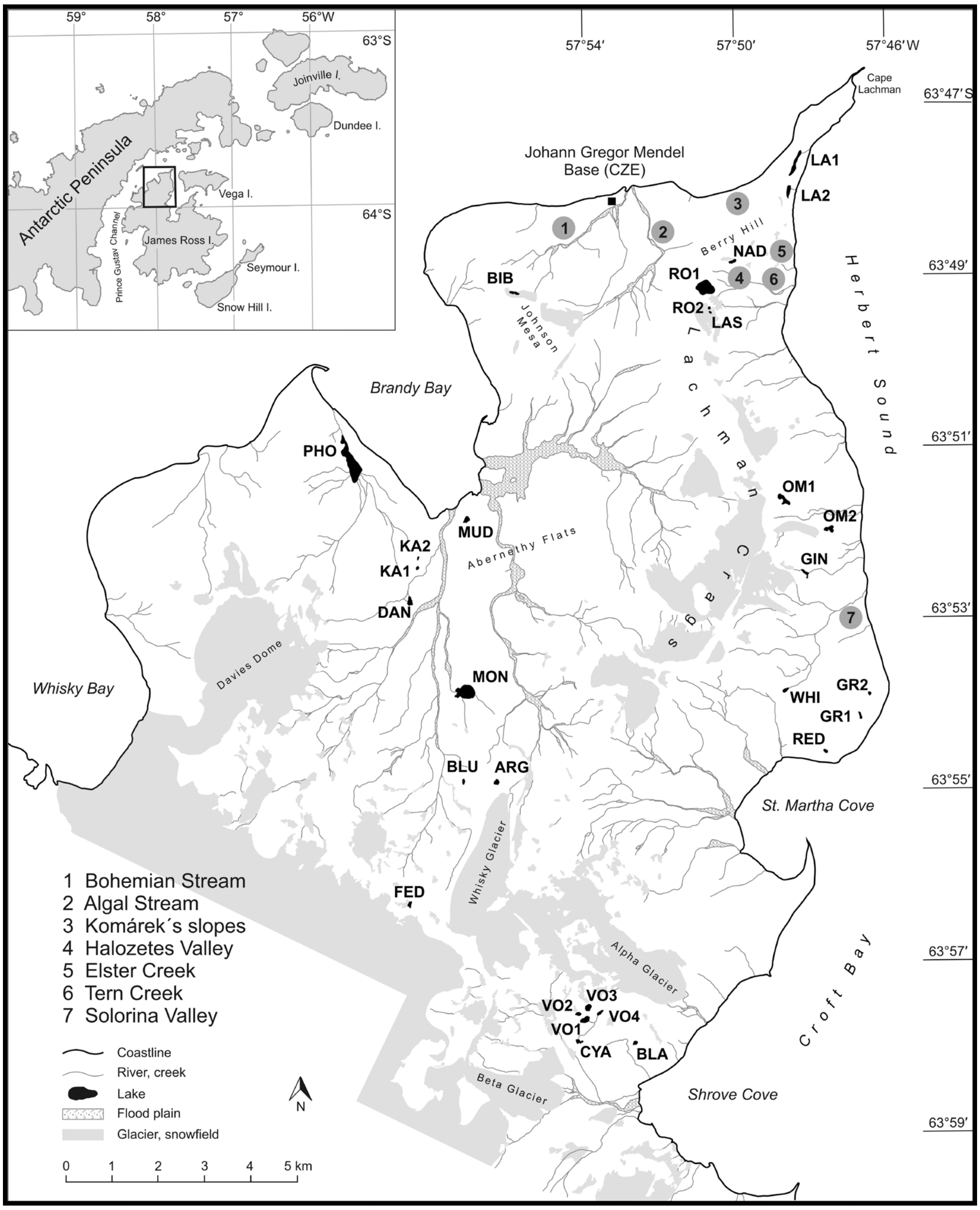


FIGURE 6.1 – Location of the sampled streams, seepage areas and lakes on the Ulu Peninsula. The inset map shows the position of James Ross Island in the Weddell Sea with the location of the Ulu Peninsula. Topography based on the map by Czech Geological Survey (2009).

Material and Methods

Sampling

A total of 103 samples from streams, seepage areas and lakes was collected from James Ross Island (64°10’S, 57°45’W) during the austral summers of 2004 and 2006–2009 (Fig. 6.1, Table 6.1). Due to logistic constraints, no physico-chemical data were collected for stream and seepage area samples. Appendix 6.1 summarizes the main physico-chemical parameters of the lake samples. When possible, both epilithic and epipelic samples were taken in the littoral zone of the lakes.

Slide preparation

Diatom samples collected in 2004 were kept frozen until analysed, whereas those from 2006–2009 were fixed with formaldehyde (3% final concentration). Subsamples were cleaned by a modified method described in Van der Werff (1955): small parts of the samples were cleaned by adding 37% H_2O_2 and heating to 80 °C for about one hour, followed by addition of $KMnO_4$. After digestion and centrifugation (3 times 10 minutes at 3700 x g), the material was diluted with distilled water to avoid excessive concentrations of diatom valves. Cleaned diatom valves were mounted in Naphrax®. Samples and slides are stored at the Department of Ecology, Charles University in Prague (Czech Republic) with duplicates at the National Botanic Garden of Belgium (Meise, Belgium).

Sample analysis

In each sample 400 (lake samples) or 300 (seepage and stream samples) valves were enumerated on random transects at 1000x magnification under oil immersion using a Olympus BX51 microscope equipped with Differential Interference Contrast optics. Identifications of Antarctic species are based on Van de Vijver et al. (2002a, b, 2004, 2010a, b, 2011c, b), Sabbe et al. (2003), Ohtsuka et al. (2006), Esposito et al. (2008), Van de Vijver and Mataloni (2008), Kopalová et al. (2009, 2011), Zidarova et al. (2009, 2010, 2012) and Van de Vijver and Zidarova (2011). For several species, identification up to species level was not possible due to their unclear taxonomic situation. Valves belonging to the *Nitzschia perminuta* (Grunow) M. Peragal.-complex were split into *N. perminuta*-capitate specimens and *N. perminuta*-non-capitate specimens based on the shape of the valve apices.

Further morphological, taxonomic and ecological research will be necessary to establish the correct identity of this species complex in the entire Maritime Antarctic Region.

Data analysis

Diversity analysis [Shannon-Wiener diversity index ($\log_{10}$-based) and evenness index] was performed using the multivariate statistical package MVSP (Shannon and Weaver 1949). To determine the extent to which our sampling efforts represented the freshwater diatom flora of the Ulu Peninsula, the incidence-based species richness estimator (ICE, Chao et al. 2000) and the mean Chao2 richness estimator (Chao 1984), both using the EstimateS program version 8.2 (Coldwell 2009), were calculated.

For a pair wise comparison of the diatom flora of James Ross Island with other Antarctic localities such as the Continental Antarctica, South Shetland Islands, Signy Island and the sub-Antarctic Region, the community coefficient of Sørensen (1948) was used. This index has the following formula: $2c/(a+b+2c)$ where ‘a’ and ‘b’ are the numbers of species exclusively observed in each of the two sites and ‘c’ is the number of species shared by these sites. To enable the comparison with the species composition of the Continental Antarctica, a species list was compiled based on Sabbe et al. (2003), Gibson et al. (2006), Ohtsuka et al. (2006) and Esposito et al. (2008). For the South Shetland Islands, the comparison is based on the species list of Livingston Island (Kopalová & Van de Vijver 2013) and on the revised list in Zidarova (2008). For Signy Island (South Orkney Islands), unpublished data from Sterken et al. have been used. The species list of Île de la Possession (Crozet Archipelago) in Van de Vijver et al. (2002a), completed with additional data from Kerguelen, Heard Island and the Prince Edward Islands (Van de Vijver et al. 2001, 2004, 2008) was used as a proxy for the sub-Antarctic Region.

Diatom species were expressed as relative abundances (% of total diatom valves per sample). Only those species present at >1% in any single sample or with more than two occurrences were included in the analysis. All environmental variables except pH were log-transformed [$\log_{10}(x+1)$] prior to all statistical analyses since they had skewed distributions. All ordinations were performed using CANOCO version 4.5 (ter Braak & Šmilauer 2002) with rare species downweighted in all cases. Acronyms of diatom taxa were generated *ad hoc* and listed in Appendix 6.2.

TABLE 6.1 – List of all samples and sample codes used in this paper.

	Sampling location (lake code)	Sample nature
Lake sample		
D1	Lachman 2 (LA2)	Epipelon
D2	Lachman 2 (LA2)	Epilithon
D3	Lachman 1 (LA1)	Epipelon
D4	Lachman 1 (LA1)	Epilithon
D5	Bibby (BIB)	Epipelon
D6	Bibby (BIB)	Epilithon
D8	Phormidium (PHO)	Epipelon
D9	Phormidium (PHO)	Epilithon
D10	Monolith (MON)	Epipelon
D11	Monolith (MON)	Epilithon
D12	Katia 1 (KA1)	Epipelon
D13	Katia 1 (KA1)	Epilithon
D14	Katia 2 (KA2)	Epipelon
D15	Katia 2 (KA2)	Epilithon
D16	Muddy (MUD)	Epipelon
D17	Muddy (MUD)	Epilithon
D19	Dan (DAN)	Epipelon
D20	Dan (DAN)	Epilithon
D21	Rozmberk 1 (RO1)	Epilithon
D22	Laska (LAS)	Epipelon
D23	Laska (LAS)	Epilithon
D24	Nadeje (NAD)	Epilithon
D25	Nadeje (NAD)	Sediment, 6 m depth
D26	Green 1 (GR1)	Epilithon
D27	Red (RED)	Epipelon
D28	Red (RED)	Epilithon
D29	White (WHI)	Epipelon
D30	White (WHI)	Epilithon
D31	Green 2 (GR2)	Epilithon
D32	Green 2 (GR2)	Epipelon
D33	Omega 2 (OM2)	Epilithon
D34	Omega 1 (OM1)	Epilithon
D35	Ginger (GIN)	Epilithon
D36	Ginger (GIN)	Epipelon
D37	Vondra 1 (VO1)	Epilithon
D38	Vondra 1 (VO1)	Epipelon
D39	Vondra 2 (VO2)	Epilithon
D40	Vondra 2 (VO2)	Epipelon
D41	Vondra 3 (VO3)	Epilithon
D42	Vondra 3 (VO3)	Epipelon
D43	Vondra 4 (VO4)	Epilithon
D44	Vondra 4 (VO4)	Epipelon
D45	Cyanobacterial (CYA)	Epilithon
D46	Cyanobacterial (CYA)	Epipelon
D47	Black (BLA)	Epilithon
D48	Black (BLA)	Epipelon
D49	Federico (FED)	Epilithon
D50	Argentino (ARG)	Epilithon
D51	Blue-green (BLU)	Epilithon
D52	Blue-green (BLU)	Epipelon
Stream and seepage sample		
S2	Komarek's slopes below Berry Hill	Seepage
S3	Komarek's slopes below Berry Hill	Seepage
ST	Tern creek, upper part, seepages	Seepage
S1A-J	Komarek's slopes below Berry Hill	Seepage
SL1	Seepages near Lachman Lakes	Seepage
SL2	Seepages near Lachman Lakes	Seepage
SB	Seepages, Bohemian stream	Seepage
SS	Seepages in Solorina Valley	Seepage
SP2	Seepages, Halozetes Valley	Seepage
SP3	Seepages, Halozetes Valley	Seepage
T0	Tern Creek	Stream
T1	Tern Creek	Stream
T2	Tern Creek	Stream
T3	Tern Creek	Stream
T4	Tern Creek	Stream
T6	Tern Creek	Stream
T7	Tern Creek	Stream
T8	Tern Creek	Stream
B	Bohemian Stream	Stream
B1	Bohemian Stream	Stream
B2	Bohemian Stream	Stream
B3	Bohemian Stream	Stream
B4	Bohemian Stream	Stream
B5	Bohemian Stream	Stream
B6	Bohemian Stream	Stream
B7	Bohemian Stream	Stream
A1	Algal Stream	Stream
A2	Algal Stream	Stream
A3	Algal Stream	Stream
A4	Algal Stream	Stream
A5	Algal Stream	Stream
A6	Algal Stream	Stream
A7	Algal Stream	Stream
A8	Algal Stream	Stream
A9	Algal Stream	Stream
A10	Algal Stream	Stream
A11	Algal Stream	Stream
A12	Algal Stream	Stream
A13	Algal Stream	Stream
A14	Algal Stream	Stream
A15	Algal Stream	Stream
E1	Elster Creek	Stream
E2	Elster Creek	Stream
E3	Elster Creek	Stream

The statistical techniques used in this study are described in full detail in Jongman et al. (1995). Ordination techniques were used to elucidate patterns in species composition. An initial correspondence analysis (CA) was carried out to estimate gradient length, indicating that an unimodal relationship should be used in all further analysis (ter Braak & Prentice 1988).

To discover the principal patterns in the distribution of diatoms and their communities within all freshwater samples from James Ross Island, unconstrained ordination (DCA) was used on the entire dataset.

Complete physico-chemical data were only available for the lake samples and direct multivariate analyses were restricted to epilithic samples reducing the initial set to only 27 samples. The sample D21 did not contain not sufficient amount of diatoms and it was removed from further analysis. As not all of the 24 environmental variables influence the diatom distributions independently, Canonical Correspondence Analysis (CCA) with forward selection and unrestricted Monte Carlo permutation tests (999 permutations, $P < 0.05$) was applied. Following Hall & Smol (1992), groups of significantly correlated ($P < 0.05$) environmental variables were identified first by making a Pearson correlation matrix with Bonferroni-adjusted probabilities (Wilkinson 1988) (Appendix 6.3). In each group, forward selection was used to select the minimum number of parameters that could explain the largest amount of variation in the species data. The selected variables of each group were then combined together and analysed again by forward selection to obtain a final set of environmental parameters to be used in further analysis.

The significance of each selected variable was assessed using an unrestricted Monte Carlo permutation test (999 permutations). A CCA was performed with the environmental variable of interest as the only explanatory variable. The ratio of the eigenvalue of the first (constrained) axis to the eigenvalue of the second (unconstrained) CCA axis (λ_1/λ_2) gives a good indication of the explanatory strength of the individual variable. Ratios higher than 0.50 suggest a strong diatom signal for that variable. Values less than 0.50 are less robust and would be of less use in inference models (Dixit et al. 1991, Roberts & McMinn 1996).

To test whether an environmental parameter is of prime importance in determining the diatom composition, the species turnover along the parameter gradient was calculated. The turnover in species composition along a conductivity gradient was determined using Cody's β-diversity (β_c) (Cody 1975): β_c=(G+L)/2 with G being the number of species gained and L the number of species lost along the conductivity gradient in comparison with the next group of lakes. Low values of β_c indicate low species turnover. Following Verleyen et al. (2003), the conductivity gradient was divided into intervals with the upper limits (UL) determined using the following equation: $UL_x= UL_{x-1} * 2$.

Weighted averaging (WA) and weighted averaging with tolerance downweighting (WA(tol)) were applied to the 27 epilithon lake samples and the 75 selected diatom taxa in the training set for conductivity reconstruction after removing the outliers. A sample was considered to be an outlier if its WA residual was higher than the standard deviation of the $\log_{10}$-transformed conductivity (Jones & Juggins 1995). Weighted averaging partial-least-square (WA-PLS) was likewise applied after removing the outliers. Verleyen et al. (2003) discuss the rationale for testing both WA and WA-PLS. WA-PLS often produces calibration models with lower root-mean-squared errors of prediction (RMSEP) than WA (Birks 1998). Since none of the WA-PLS components showed a decrease in RMSEP, only simple WA was used for modelling. In WA reconstructions, averages are taken in both the WA regression and the WA calibration. Therefore, the resulting shrinkage of the inferred environmental parameter is corrected using inverse or classical deshrinking regression (Birks et al. 1990). WA, WA(tol) and WA-PLS were performed using C2 (Juggins 2007).

Results

Species composition and similarity analysis

A total of 123 taxa including species, varieties and forms, belonging to 37 genera has been found in the analysed samples (Appendix 6.2). Samples D8, D21 and D42 contained (almost) no diatoms, even after counting an entire slide. Subsequently, these samples have been removed from the total sample set. Eleven taxa were found outside the counts, when scanning the slides for additional species. Several, mainly small-celled naviculoid taxa, could not be identified up to the species level and further morphological investigations were necessary to clarify their taxonomic position. Five of them belonged to the genus *Luticola* and following detailed light and scanning electron microscopy, they were described as new species such as *Luticola desmetii* Kopalová & Van de Vijver and *L. tomsui* Kopalová (Kopalová et al. 2011). Eleven other taxa were recently described from James Ross Island, such as

Eolimna jamesrossensis Kopalová and Van de Vijver and *Luticola austroatlantica* Van de Vijver et al. , or from the South Shetland Islands such as *Pinnularia australorabenhorstii* Van de Vijver (Esposito et al. 2008, Kopalová et al. 2009, Van de Vijver et al. 2011c, b). A few taxa are reported here with certainty for the first time outside Continental Antarctica such as *Luticola gaussii* (Heiden) D.G.Mann and *Achnanthes taylorensis* Kellogg et al. whereas *Pinnularia splendida* Hust. is only reported for the second time in the Antarctic Region, apart from the type locality on South Georgia (Hustedt in Schmidt et al. 1934).

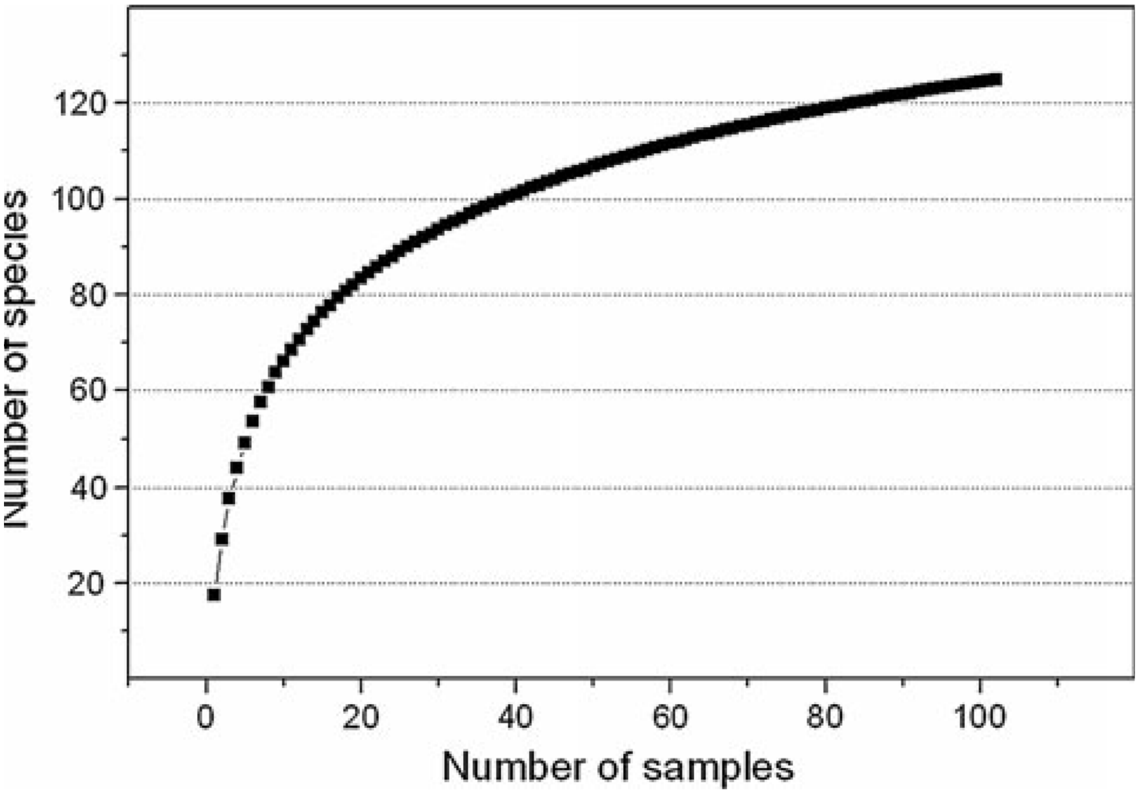


FIGURE 6.2 – Species accumulation curve for the Ulu Peninsula sample set.

The flattening towards the end of the species accumulation curve (Fig. 6.2) indicates that a large part of the freshwater diatom flora was collected. Using species richness estimators, it is possible to evaluate how well the sampling effort reflected the true diatom richness of the area. The expected total number of taxa in all samples is 147 (ICE) or 148 (Chao2) for the James Ross Island freshwater samples, suggesting that our counting scored around 85% of the (theoretical) total number of taxa present in the samples overall, comparable to the number found in other Antarctic localities where the same taxonomical concepts and sampling strategies have been followed (Van de Vijver et al. 2008, Kopalová & Van de Vijver 2013).

The similarity analysis between the James Ross Island diatom flora and the (revised) floras from several other Antarctic localities revealed a high similarity between James Ross Island and Livingston Island (Sørensen's Index = 0.63) and to a lesser extent Signy Island (0.46). A low affinity was found between James Ross Island and Continental Antarctica (0.25). The lowest similarity was found with the sub-Antarctic islands (=0.15).

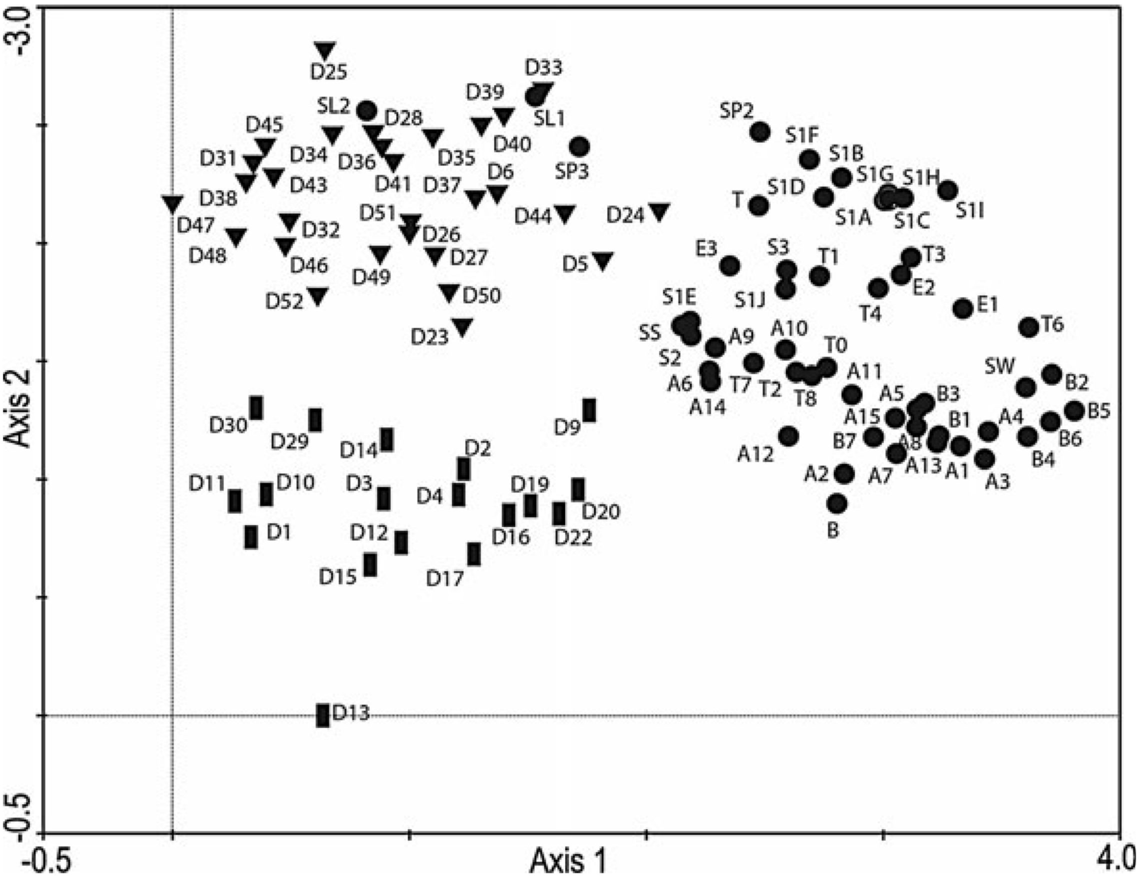


FIGURE 6.3 – Detrended Correspondence Analysis (DCA) of the entire sample set [lakes subdivided in 2 subgroups (▮ and ▼), streams and seepage areas (●)]; the first two axes are shown.

Community analysis

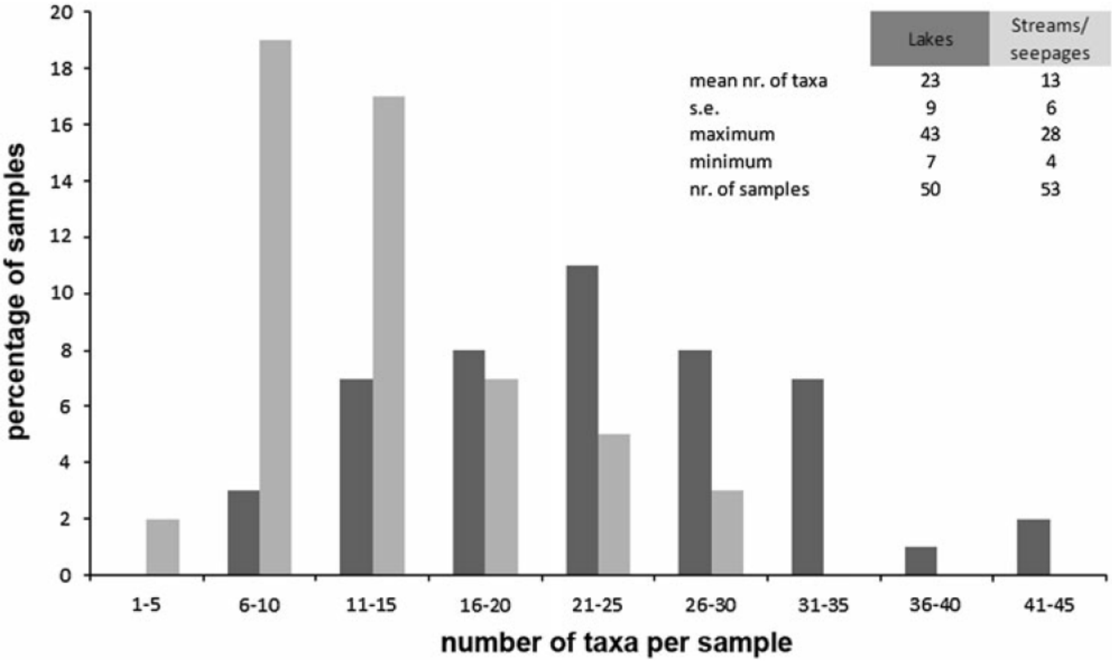
Using DCA analysis (Fig. 6.3), it was possible to group the samples into two large groups. The first two DCA axes explained 16.4% of variation in diatom composition. This is low, but not unusual for noisy datasets, i.e. datasets containing many blank values (Stevenson et al. 1991). On the right side of the diagram, almost all samples from streams and seepage areas (●) are grouped together, whereas all lake samples (▮ and ▼) and a few seepage area samples (SL1, SL2 and SP3) are positioned at the left side of the diagram. Although not entirely separated, it is clear that stream samples from Algal (Ax) and Bohemian Stream (Bx) are positioned in the lower half of the streams and seepage area group, whereas seepage areas are more in the upper part. Within the lake samples, two subgroups can be distinguished. In the lower half of the diagram, 10 lakes compose the first subgroup (■) grouping White Lake, Dan Lake, Monolith Lake, Lachman lakes 1 and 2, Katia lakes 1 and 2, Phormidium Lake, Muddy Lake and the epipelic sample from Laska Lake. All other lakes and the three seepage area samples form the second (▼) subgroup.

TABLE 6.2 – Relative abundances of the most commonly encountered species in all samples (overall), lake samples (lakes) and seepage area and stream samples (streams/seepages). The principal species are highlighted.

	Overall	Lakes	Streams/ seepages
Nitzschia perminuta capitate forms	16.8	**24.8**	7.5
N. gracilis	10.3	3.4	**18.5**
N. homburgiensis	8.5	**11.8**	4.5
Eolimna jamesrossensis	7.2	0.1	**15.6**
Fragilaria capucina-complex	6.4	1.3	**12.4**
N. perminuta non-capitate forms	6.2	**11.4**	0.0
N. paleacea	5.8	**10.8**	0.0
Fistulifera saprophila	5.5	0.4	**11.6**
Mayamaea atomus permitis	5.0	3.7	6.5
Diadesmis australis	2.3	4.2	0.0
Psammothidium papilio	2.1	3.6	0.2
N. inconspicua	1.5	2.7	0.0
Luticola muticopsis	1.4	0.2	2.8
Hantzschia amphioxys	1.3	0.4	2.5
L. austroatlantica	1.3	0.1	2.7
Achnanthidium lailae	1.2	2.3	0.0

The distinction between the two groups is clearly reflected in the species composition. Fifty taxa (40%) were found in both lake samples and streams and seepage area samples, whereas 58 (46%) and 17 (14%) have been recorded exclusively in the lake samples and stream plus seepage area samples respectively. Species richness in the samples varied between 7 and 43 taxa for lake samples and between 4 and 28 taxa for stream and seepage area samples with an average ± SD of 18 ± 8 (Fig. 6.4). Table 6.2 shows the most common species in the overall dataset and in the two groups. Most taxa however belong to the genus

Luticola (17 taxa) followed by *Nitzschia* (9 taxa), *Diadesmis* (7 taxa) and *Pinnularia* (7 taxa). The most abundant taxa in the lake samples are *Nitzschia perminuta* capitate form (24.8% of all counted lake valves), *N. homburgiensis* Lange-Bertalot (11.8%), *N. perminuta* non-capitate form (11.2%) and *N. paleacea* Grunow (10.8%) (Table 6.2). Stream and seepage area samples are dominated by *Nitzschia gracilis* Hantzsch (18.5% of all counted stream valves), *Eolimna jamesrossensis* Kopalová & Van de Vijver (15.6%) and *Fragilaria capucina* Desmazières (12.4%).



	Lakes	Streams/ seepages
mean nr. of taxa	23	13
s.e.	9	6
maximum	43	28
minimum	7	4
nr. of samples	50	53

FIGURE 6.4 – Distribution of species richness per sample for the two sample categories: Streams/seepage areas and lakes.

The original set of 24 environmental variables was reduced to 4 following the different selection procedures. Based on a Pearson product-moment correlation matrix, several groups of parameters could be formed. A first group included all parameters related to conductivity (Cond, Ca^{2+}, Na^{+}, F^{-}, K^{+}, Cl^{-}, SO_4^{2-}). A second group is composed of total phosphorus (TP), total carbon (TC), total nitrogen (TN), dissolved nitrogen (DN), dissolved carbon (DC), chlorophyll a (Chla) and dissolved organic carbon (DOC). Forward selection using only each of these groups of variables identified conductivity, TP and DOC as environmental variables explaining significant variation in the diatom data ($p \leq 0.05$). The two variables related to phosphorus [Soluble Reactive Phosphorus (SRP) and Total Dissolved Phosphorus (TDP)] showed a correlation of more than 99% and SRP was selected. The same procedure was followed for O_2 and sat. O_2 (87% correlation) selecting O_2 to be included. Finally, the selected variables were combined with pH, alkalinity, R-Si, NO_3-N, NO_2-N and NH_4-N. A second forward selection with only these eleven variables resulted in the selection of pH, conductivity, TP and SRP as explaining variables. The other variables were excluded since they did not significantly contribute in explaining the variation in the diatom data.

TABLE 6.3 – Intra-set correlations of selected environmental variables for axes 1 and 2 of the CCA-analysis.

Variable	Intra-set correlation axis 1	Intra-set correlation axis 2
Conductivity	-0.71	-0.02
SRP	0.65	0.48
TP	0.03	0.74
pH	0.47	-0.24

A CCA of the 27 samples in the dataset constrained to the four selected environmental variables (Fig. 6.5) explained only a small proportion of the species variance in the samples. The first two axes (λ_1 = 0.294, λ_2 = 0.142) account for only 17.4% (11.5% and 5.9% respectively) of the cumulative variance in the diatom data, which is not surprising for noisy datasets (Stevenson et al. 1991). Forward selection identified four significant ($p<0.05$) environmental variables (Cond, SRP, TP and pH) explaining 52% of the total diatom variance that can be explained by the 24 environmental variables initially taken into account in this study. Conductivity ($p>0.001$) accounted for 17% of the variance explained, followed by SRP (14%), pH (11%) and TP (10.5%). Monte Carlo unrestricted permutation test (999 permutations) of axes 1 and 2 indicated that both axes were highly significant ($p=0.001$) (ter Braak and Šmilauer 2002). Axis 1 is relatively strongly correlated with conductivity (inter-set correlation = 0.71) and to a lesser extent to SRP (0.65). The second axis is related to TP (0.74). Consequently, the first gradient, from right to left on axis 1 corresponds to a gradient in conductivity. Coastal lakes such as Phormidium Lake (D9), both Lachman lakes (D2, D4) and Muddy Lake (D17) are separated from the lakes located more southerly on the peninsula (D23–D35). Coastal lakes are dominated by *Nitzschia homburgiensis*, *Sellaphora seminulum* (Grunow) D.G.Mann, *Stauroneis latistauros* Van de Vijver and Lange-Bert. and *Fistulifera saprophila* (Lange-Bert. and Bonik) Lange-Bert. Typical taxa in the more southern lakes include *Brachysira minor* (Krasske) Lange-Bert., *Psammothidium papilio* (Kellogg et al.) Kopalová and Van de Vijver, *Nitzschia perminuta* capitate-forms and several *Diadesmis* taxa. The second gradient from bottom to top along axis 2 corresponds with TP concentrations. Most lakes in the southern part of the study area (Lagoons Mesa, D37–D47) with low TP concentrations are separated from the coastal lakes and the more southerly located lakes showing moderate to higher TP values. The Lagoons Mesa lakes are dominated by *Nitzschia perminuta* non-capitate form, *Navicula cremeri* Van de Vijver and Zidarova, *Amphora* sp1, *Fragilaria capucina* s.l. and several *Gomphonema* species. On the other hand, *Fistulifera saprophila*, *Navicula gregaria* Donkin, several *Mayamaea* species and *Sellaphora seminulum* show a high TP preference.

TABLE 6.4 – Species turnover along the conductivity gradient.

Conductivity range (µS.cm^{-1})	Number of lakes	Number of species	Species gained	Species lost	Cody diversity
0–25	1	19			
			22	6	24
26–50	3	33			
			40	8	24
51–100	11	65			
			19	19	19
101–200	7	65			
			2	47	24.5
201–400	1	20			
			28	10	19
401–800	3	38			
			13	15	14
801–1600	1	36			

Transfer function for lake water conductivity

Constrained CCAs using conductivity, SRP, TP and pH individually indicated that conductivity (λ_1/λ_2= 0.76) and SRP (λ_1/λ_2= 0.71) had ratios higher than 0.50, suggesting that both may yield significant inference models (Dixit et al. 2002). The degree of species turnover along the conductivity gradient is rather uniform showing similar turnover values in the lower and the upper parts of the gradient (Table 6.3). Since this is not the case for SRP, making an inference model for conductivity for the reconstruction of the ion balance in the Ulu Peninsula lakes more appropriate. Because of the low λ_1/λ_2-ratios, it is not realistic to develop inference models for pH (0.47) and TP (0.39).

TABLE 6.5 – Summary of the performance of WA and WA_{tol} transfer functions for conductivity using inverse and classical deshrinking.

Calibration	Deshrinking	R^2	R^2_{jack}	RMSE	RMSEP
WA	classical	0.78	0.49	0.18	0.275
WA	inverse	0.78	0.46	0.16	0.272
WA_{tol}	classical	0.84	0.59	0.15	0.269
WA_{tol}	inverse	0.84	0.57	0.13	0.274

Lachman 1 Lake (D4), Katia 1 Lake (D13) and Nadeje Lake (D24) were removed from the model construction since their WA residuals exceeded the standard deviation of $\log_{10}$-transformed conductivity (0.42).

The WA model shows a strong predicted relationship between observed and diatom-inferred $\log_{10}$-transformed conductivity values (r^2=0.78). The predictive abilities for simple and tolerance downweighted WA are almost identical (Table 6.4). WA(tol) was chosen as it produces a slightly higher predicted correlation between measured and diatom-inferred conductivity (0.84 vs. 0.78) with almost no difference in RMSEP (0.269 and 0.274 vs. 0.275 and 0.272). Both deshrinking techniques produced equal RMSEP values (Table 6.5).

Classical deshrinking showed a slightly higher r^2_{boot} (0.59 vs. 0.57) and had no residual trend compared to inverse deshrinking indicating that classical deshrinking will provide a more reliable estimate of the conductivity, especially at the extremes of the gradient (Jones & Juggins 1995, Roberts & McMinn 1998). Figure 6.6 shows the plots of observed versus diatom inferred $\log_{10}$-transformed conductivity and the observed versus residual $\log_{10}$-transformed conductivity. Conductivity inferences were calculated from the optima and tolerance for the principal diatom taxa in the Ulu Peninsula lake samples. Conductivity optima ranged from 28 to 570 µS.cm^{-1}. Appendix 6.2 lists the calculated conductivity optima and tolerance for all taxa with an occurrence in at least 2 samples. Both taxa with narrow and broad tolerances can be identified along the conductivity gradient.

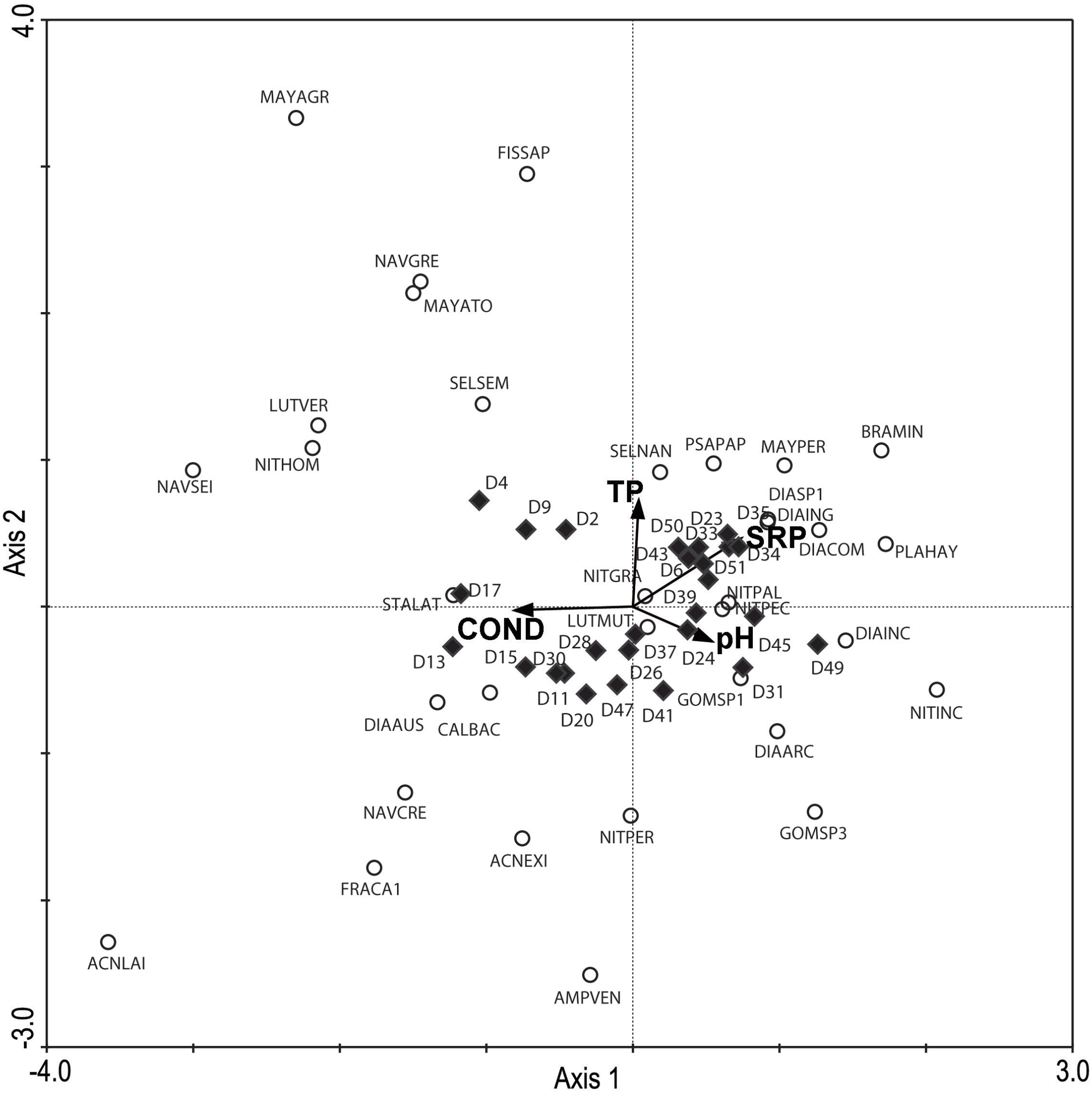


FIGURE 6.5 – Canonical Correspondence Analysis (CCA) ordination biplot (the first two axes) showing epilithon lake samples (black diamonds) and species. For sample numbers see Table 6.1, for species labels see Appendix 6.1.

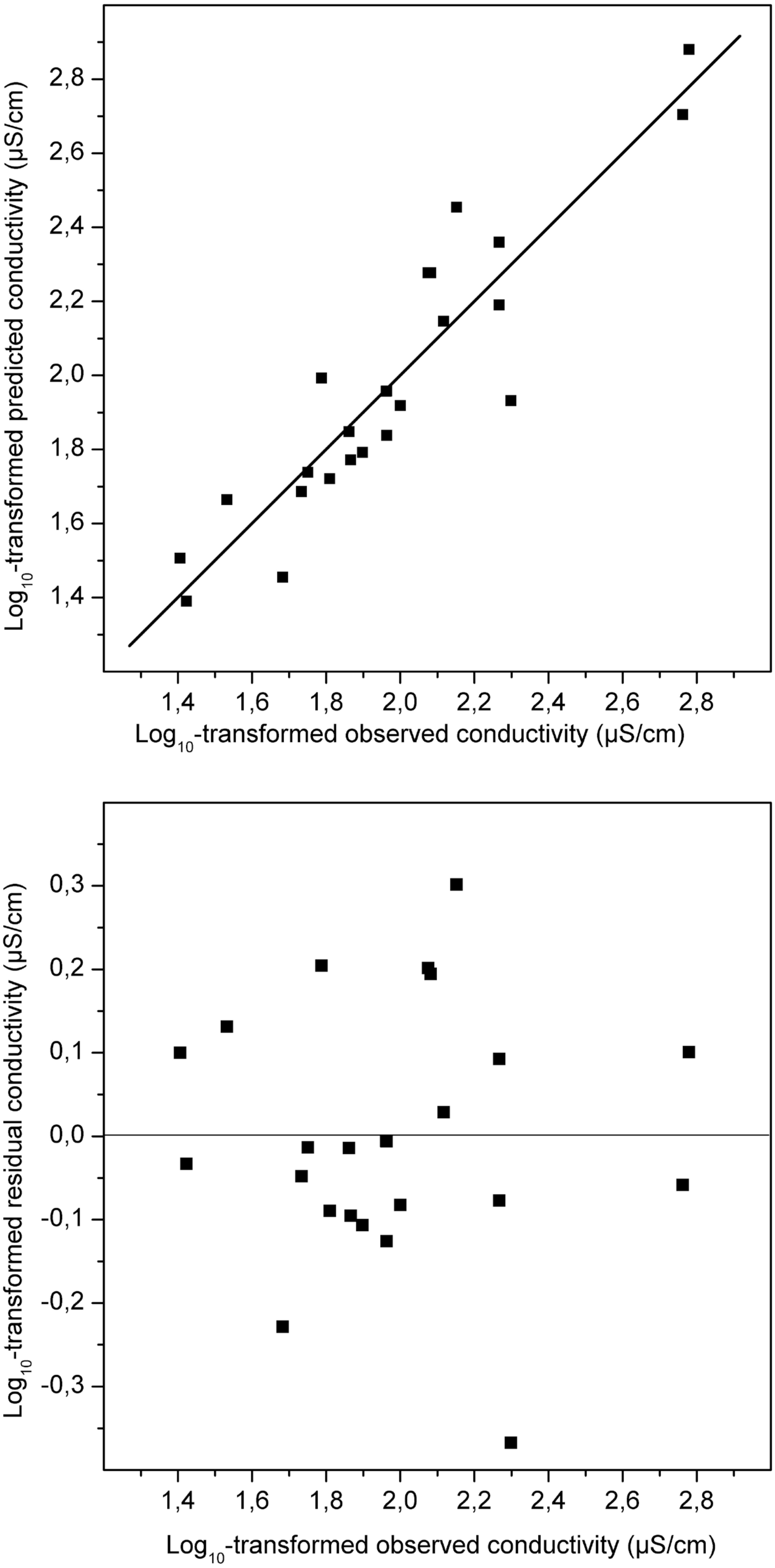


FIGURE 6.6 – Plots of observed versus diatom-inferred conductivity for the Ulu Peninsula lake dataset and observed vs. residual conductivity (observed minus diatom-inferred conductivity) based on weighted averaging regression and calibration model. The dark squares represent the different samples.

Discussion

Species composition and biogeography

According to the Ubiquity theory proposed by Finlay & Clarke (1999), the level of endemism in the entire Antarctic Region is supposed to be low. However, the application of a better defined, narrower species-concept (Mann 1999) in combination with more advanced taxonomic-analytical methods reduced the force-fitting of many taxa into similar European or North American relatives (Tyler 1996). Subsequently, a much higher degree of endemism has been demonstrated in the diatom flora on the different islands of the Maritime Antarctic Region than previously accepted (Jones 1996, Toro et al. 2007), following major taxonomic revisions and the description of a large number of new taxa (Van de Vijver et al. 2005, 2010a, 2011c, Van de Vijver & Mataloni 2008, Zidarova et al. 2010, Kopalová et al. 2011).

Based on macro-organism species level, three biogeographical regions were defined in the Antarctic Region: sub-Antarctica, Maritime Antarctica and Continental Antarctica, with the latter two separated by the so-called "Gressitt Line" based on faunal differences between these regions (Chown & Convey 2007). The similarity analysis based on the diatom composition justified the biogeographical position of James Ross Island within the Maritime Antarctic Region. A much lower similarity with Continental Antarctica and the sub-Antarctic Islands could be found. The hypothesis of a decreasing trend in diatom diversity with increasing latitude (Jones 1996, Van de Vijver & Beyens 1999) is confirmed with the data from James Ross Island. The number of observed species decreases rapidly southwards starting at the sub-Antarctic islands where 200–250 different taxa have been observed (Van de Vijver et al. 2001, 2002a, 2004, 2008) and terminating in Continental Antarctica where only 30–50 taxa could be enumerated (Gibson et al. 2006; Ohtsuka et al. 2006). The Maritime Antarctic Region shows an intermediate position but even within this region, the longitudinal decreasing diversity trend is visible with 125–175 taxa on the South Shetland Islands (Fermani et al. 2007, Zidarova 2008) but only 123 on James Ross Island. Possible causes for this diversity change are multiple and include besides climatic factors, also the availability of microhabitats, oceanic influence and length of time since ice retreat (Jones 1996). This is however in clear contrast with biodiversity results in other taxonomic groups such as nematodes for which diversity hotspots were found (Nielsen et al. 2011) in the Maritime Antarctic Region, obscuring a clear decreasing diversity trend for this taxonomic group when moving southwards.

The transitional position of James Ross Island resulted in a higher similarity with Continental Antarctica than observed between the South Shetland Islands and Continental Antarctica (which was set at 0.19 by Kopalová & Van de Vijver 2013). Several typical continental taxa such as *Luticola gaussii* (Heiden) D.G.Mann and *Achnanthes taylorensis* Kellogg and Kellogg are present on James Ross Island, but absent from all other Maritime Antarctic localities (Kopalová et al. 2012, Kopalová & Van de Vijver 2013).

The presence of these typical continental diatom taxa might be explained by long-range transport connected to the general sea and air circulation in the Weddell Sea. Algae are known to be dispersed by air (Marshall & Chalmers 1997), making the airborne dispersal of the continental diatoms towards James Ross Island highly likely. Although no verified diatom records exist for the Weddell Sea sector of the Antarctic Continent (Kellogg & Kellogg 2002), all observed continental diatom species on James Ross Island are widely distributed in Continental Antarctica (Kellogg & Kellogg 2002). Persistent low-level counter clockwise katabatic air circulation (Parish & Bromwich 1987) in the Coats and Dronning Maud Lands brings Antarctic continental material towards the western coast of the Weddell Sea. This is predominantly deposited in sea water, but also on snow, sea ice or ice shelves. Ocean circulation in the Weddell Sea area is controlled by the Weddell Gyre (e.g., Diekmann and Kuhn 1999). Surface waters in the Weddell Sea flow as Antarctic coastal current (Gill 1973) clockwise along the coast of Coats Land towards the southern Weddell Sea, where it merges with dense and cold ice shelf waters (Foldvik et al. 1985) in front of the Filchner-Ronne Ice Shelf. From the southern Weddell Sea they follow, similarly to the deep Weddell waters, the Antarctic Peninsula continental shelf towards the north (Hollister & Elder 1969). A similar pattern was found for air circulation on the Weddell Sea. Already in 1970s Schwerdtfeger brought evidences of strong, cold barrier winds (or low level jets; Stensrud 1996) flowing from the south or southwest along the eastern coast of the Antarctic Peninsula (Schwerdtfeger 1975). They mostly occur when stable air masses in the central Weddell Sea moves westward and are blocked by the ridge of the Antarctic Peninsula. This leads to an increase of pressure and winds turn north and continue along the Antarctic Peninsula coast to the James Ross Island area. It was shown by different studies (e.g., Swithinbank et al. 1980, Diekmann & Kuhn 1999), that the strong barrier winds along the Antarctic Peninsula eastern coast, together with the Weddell Gyre surface currents are responsible for the transport of a significant proportion of pack ice into the north-western part of the Weddell Sea. Thus diatoms may be transported either directly by wind or frozen in packed sea ice or in icebergs from the Coats Land and Dronning Maud Land coast to the James Ross Island archipelago similarly to abiotic material (e.g., Diekmann & Kuhn 1999).Furthermore, the survival of continental Antarctic taxa on the island can be supported by much more arid and also colder climatic conditions on James Ross Island in comparison with the rest of the Maritime Antarctic Region resulting in favourable environmental conditions for continental Antarctic taxa on James Ross Island.

Habitat comparison of diatom communities

Seepage areas, streams and lakes consititute important habitats in Antarctica and the results of our study show marked differences in diatom communities between these habitats (Fig. 6.3). Not only the relative abundance of the composing taxa differed between habitats, but Fig. 6.4 also clearly showed that lakes were far more diverse than seepage areas and streams. The cyanobacterial composition of the different habitats on James Ross Island likewise separates lakes from streams and seepage areas (Komárek et al. 2008). In contrast to diatoms, cyanobacterial communities in lakes seem to have a lower species richness than in seepage areas and streams.

Streams form a typical habitat of the coastal Polar Regions as a result of the melting of glaciers and snowfields during summer seasons. Although only poorly studied in the past (Jones 1996), stream diatom communities seem to be directly influenced by their habitat features. The relatively low species diversity dominated by only a few taxa is most probably a consequence of the ephemeral nature of these streams. Hawes & Brazier (1991) already pointed out that turbidity was apparently one of the main factors in glacial streams on James Ross Island affecting the abundance and distribution of the microflora. Our results seem to confirm this assumption as a distinct species composition was found in highly turbid streams with high shares of suspended load originating from Cretaceous bedrock. Vincent & James (1996) stated that streams were highly unstable systems, subject to large variations in their chemical and physical properties with sometimes even daily fluctuations. At the beginning and towards the end of the summer, water in streams can freeze (Komárek & Elster 2008) presenting stressful factors for the biota, such as desiccation-rehydration and freeze-thaw cycles. Up to now, diatom strains were not included in laboratory studies testing the tolerance of cyanobacteria and algae to freezing (Elster 2002, Šabacká & Elster 2006). It is clear that the adaptation mechanisms in Antarctic diatoms to these conditions are still poorly. Future studies should therefore focusmore on seasonal colonisation strategies and dynamics of algal vegetation in these environments. It is however clear that only diatom taxa tolerating the combination of these unstable conditions and sometimes high stream velocities are able to survive in this habitat. The genus *Fragilaria*, dominating the stream diatom flora on James Ross Island, is often considered to be a pioneer species linked to rapid changes in water chemistry, mainly trophic status fluctuations (Stabell 1985, Denys 1990), benefiting from short but important nutrient releases after ice and snow melting. The high nutrient status of the James Ross Island streams is strongly suggested by the co-dominance of *Fistulifera saprophila* and *Mayamaea permitis*, both regarded as typically eutrophic species (Lange-Bertalot 2001). Similar results were reported from the sub-Antarctic islands (Van de Vijver & Beyens 1999b, Van de Vijver et al. 2001, 2004b, 2008), Signy Island (Hawes 1989) and Livingston Island (Van de Vijver, pers. observation). Only on King George Island *Fragilaria* taxa seem to play only a minor role in the stream diatom composition (Kawecka & Olech 1993).

On the other hand, seepage areas are much more diverse than streams. Contradictory, the main reason is most likely the unstable moisture regime in these areas suggested by the high abundance both in number of taxa as in number of counted valves of typical aerophilic genera such as *Luticola, Diadesmis, Hantzschia* and *Orthoseira* (Van de Vijver et al. 2002b, 2011b, Kopalová et al. 2009, Zidarova et al. 2010). These genera are among the most species-rich in the Antarctic Region (Zidarova et al. 2010, Kopalová et al. 2011) and are well known to survive extreme environmental conditions (Souffreau et al. 2010) but seem less competitive in aquatic habitats, hence their lower abundance in streams. The high diatom diversity of seepage areas is not unique and is shared by a high cyanobacterial diversity (Komárek & Elster 2008). Unfortunately, it is almost impossible to judge the high diversity of seepage areas in Polar Regions as comparable studies are almost entirely lacking in both Arctic and Antarctic conditions. On Deception Island, the soil algal (including diatoms) communities were studied, but only one sample was taken from a seepage area (Fermani et al. 2007). Our results show however clearly that seepage areas probably host some of the most diverse terrestrial diatom communities in the entire Antarctic Region and that further studies on similar habitats across the Antarctic Region need to be undertaken.

Nedbalová et al. (2013) distinguished six lake types on the Ulu Peninsula based on their geomorphological position, stability and physic-chemical characteristics and it might be expected that the differences in lake characteristics would also influence the diatom communities. Our results show that only two subgroups could be distinguished within the lake diatom communities. However, each of these subgroups contains specific lake types. Two major environmental gradients seem to play the important role in controlling the composition of the James Ross Island lake diatom communities: conductivity and nutrients, regardless of the origin or hydrological stability of the lakes. The same environmental gradients are driving the limnological diversity of the lakes (Nedbalová et al. 2013).

The first subgroup represent lakes found mostly at lower altitudes (shallow coastal lakes and stable lakes in old moraines), situated on calcareous substrates originated from underlying Cretaceous marine sediments and old glacial sediments. A strong marine influence together with enrichment from the bedrock resulted in a higher conductivity of these lakes. All lakes positioned at higher altitudes and on volcanic substrate were combined in the second subgroup that was characterised by lower conductivity resulting mainly from weaker marine influence. This subgroup include stable shallow lakes on higher-lying levelled surfaces, small lakes in young moraines, cirque and kettle lakes (Nedbalová et al. 2013). Similar results were obtained on other Maritime Antarctic localities such as the South Shetland Islands (Jones 1996, Kopalová & Van de Vijver 2013), the South Orkney Islands (Oppenheim 1990) and on the Antarctic Continent (Sabbe et al. 2003, Cremer et al. 2004, Ohtsuka et al. 2006). Although more diverse, lakes on Livingston Island (South Shetland Islands) apparently present the same dominant species as on James Ross Island with *Nitzschia perminuta*, *Psammothidium papilio* and *Nitzschia homburgiensis* as dominant taxa (Kopalová & Van de Vijver 2013). This is in clear contrast with the sub-Antarctic islands where *Nitzschia* species are less dominant in lake ecosystems (Van de Vijver et al. 2008). On the ice-free areas of East Antarctica such as Skarvsnes Foreland or Amery Oasis, on the other hand, only part of the dominant flora is similar, but this is most likely the result of the unique nature of the continental diatom flora. *Stauroneis latistauros* and *Psammothidium papilio* are markedly present in most lakes, but seem to be replaced as dominant species in lakes with higher conductivity by *Amphora* sp. (Ohtsuka et al. 2006), a species absent in the Maritme Antarctic Region. As a conclusion, Antarctic diatom communities seem to be more suitable as bio-indicators for chemical rather than physical changes in their environment.

The construction of transfer functions will greatly improve the use of diatoms in reconstructing these chemical changes. Verleyen et al. (2003) discusses the value of these transfer functions in reconstructing past environmental and climate changes in the entire Antarctic Region. The past 15 years, several transfer functions were developed in the entire Antarctic Region (Jones & Juggins 1995, Roberts & McMinn 1998, Verleyen et al. 2003), but the combination of a revised (more fine-grained) taxonomy of the Antarctic diatom flora and the unique geographical position of James Ross Island urged the need for a new transfer function for this island in the light of further palaeoecological studies.

The new data greatly improve our knowledge of the environmental preferences of the Antarctic taxa as up to now, usually European data were used. As the species turnover is rather uniform along the entire gradient, the response of the species to conductivity changes for different lake types (oligo- to mesosaline) can be used to reconstruct past conductivity.

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APPENDIX 6.1 – Physico-chemical results of Lakes from James Ross Island (after Nedbalová et al. 2013).

Lake/Parameters	Cond. µS.cm^{-1}	O$_2$ mg.L^{-1}	sat. O$_2$ %	pH	Alkal. mmol.L^{-1}	Na$^+$ mg.L^{-1}	K$^+$ mg.L^{-1}	Ca^{2+} mg.L^{-1}
Lachman 2	118	10,7	97,0	7,28	288	10,8	1,1	3,1
Lachman 1	1094	11,6	102,0	7,67	631	83,0	5,1	40,2
Bibby	25	10,6	100,7	6,80	65	6,4	0,3	0,7
Phormidium	184	10,6	100,7	7,49	408	16,1	0,3	11,0
Monolith	120	13,2	114,0	7,24	228	6,8	0,4	8,2
Katia	663	12,4	114,0	7,05	233	17,5	0,6	63,5
Katia II	578	11,5	106,1	7,31	296	21,3	0,7	57,7
Muddy	601	11,4	100,2	6,85	119	44,3	2,1	46,4
Dan	141	13,4	118,1	7,55	412	11,4	0,2	15,4
Rožmberk	92	13	90,4	7,63	491	15,9	0,5	1,5
Láska	26	13	99,8	6,91	120	5,3	0,2	0,7
Nadeje	238	13,3	100,1	8,38	710	28,3	0,9	6,0
Green	55	11,6	102,0	7,23	236	4,7	0,2	2,1
Red	198	14,0	98,6	7,8	397	16,6	0,5	5,5
White	184	10,7	97,0	7,57	407	12,2	0,7	10,6
Green 2	91	13,7	128	8,99	455	11,2	0,6	2,3
Omega 2	47	11,6	103,1	7,50	335	8,4	0,1	0,4
Omega 1	73	11,3	100,9	7,73	399	12,1	0,2	0,8
Ginger	33	11,5	104,8	7,18	180	5,1	0,2	0,6
Vondra 1	64	12,5	105,2	7,65	496	6,0	0,4	4,9
Vondra 2	53	12,9	107,6	7,71	368	6,0	0,3	2,8
Vondra 3	72	12,5	104,9	7,98	570	7,6	0,5	3,8
Vondra 4	60	12,5	102,4	7,43	346	5,7	0,3	3,6
Cyanobacterial	99	13,2	108,9	8,72	884	15,6	0,5	4,9
Black	130	12,0	101,7	7,89	751	10,6	0,7	6,1
Federico	78	23,0	179,5	9,53	382	12,3	0,2	0,9
Argentino	91	16,9	118,8	7,62	562	13,4	0,4	3,0
Blue-green	91	16,4	130	7,81	698	10,3	0,4	5,2

APPENDIX 6.1 – (continued)

Lake/Parameters	SO_4^{2-} mg.L^{-1}	Cl^- mg.L^{-1}	F^- mg.L^{-1}	R-Si mg.L^{-1}	NO_3-N µg.l^{-1}	NO_2-N µg.l^{-1}	NH_4-N µg.l^{-1}	DN mg.L^{-1}
Lachman 2	20,6	8,5	0,08	1,2	<5	0,4	<5	0,2
Lachman 1	162,4	185,1	0,12	0,4	<5	0,9	<5	0,6
Bibby	1,9	7,8	0,01	0,2	<5	0,8	<5	0,1
Phormidium	48,9	5,7	0,08	1,5	10	0,8	<5	0,1
Monolith	14,8	14,1	0,02	1,2	<5	0,8	<5	0,1
Katia	57,3	127,1	0,04	0,3	<5	0,8	39	0,2
Katia II	66,1	106,1	0,05	1,6	<5	0,6	<5	0,3
Muddy	152,4	66,3	0,12	0,2	<5	0,2	<5	0,2
Dan	44,8	4,9	0,08	1,1	<5	1,1	<5	0,1
Rožmberk	5,6	6,7	0,07	2,4	225	0,9	5	0,3
Láska	3,0	3,5	0,02	0,2	<5	1,3	<5	0,2
Nadeje	8,4	32,7	0,03	1,9	13	0,2	<5	0,2
Green	1,7	5,3	0,02	1,5	<5	0,6	6	0,2
Red	3,6	31,4	0,03	1,6	11	0,1	30	0,3
White	30,6	18,0	0,04	0,6	<5	0,8	9	0,2
Green 2	2,6	10,6	0,0	2,9	<5	0,1	<5	0,4
Omega 2	2,0	2,6	0,0	0,1	22	0,1	<5	0,1
Omega 1	2,1	7,5	0,0	1,2	95	0,1	<5	0,2
Ginger	1,1	3,3	0,0	0,2	60	0,1	7	0,1
Vondra 1	1,4	3,6	0,0	0,2	<5	0,2	<5	0,2
Vondra 2	1,7	4,2	0,0	0,9	<5	0,3	<5	0,2
Vondra 3	1,5	4,1	0,0	0,4	<5	0,1	<5	0,2
Vondra 4	5,3	3,4	0,0	0,3	18	0,2	<5	0,1
Cyanobacterial	2,5	3,5	0,0	3,0	10	0,5	<5	0,2
Black	2,5	14,8	0,0	2,2	6	0,2	107	0,4
Federico	3,2	7,0	0,0	1,9	13	1,5	<5	0,3
Argentino	10,1	3,3	0,0	1,0	37	0,8	<5	0,1
Blue-green	2,6	4,1	0,0	1,3	18	0,4	<5	0,1

APPENDIX 6.1 – (continued)

Lake/Parameters	TN mg.L^{-1}	DC mg.L^{-1}	DOC mg.L^{-1}	TC mg.L^{-1}	SRP µg.L^{-1}	TDP µg.L^{-1}	TP µg.L^{-1}	chl a µg.L^{-1}
Lachman 2	0,6	35,4	7,3	37,4	8,5	12,6	157,2	3,4
Lachman 1	1,9	18,8	6,8	24,9	19,4	32,6	592,0	9,8
Bibby	0,1	1,4	0,4	1,4	27,5	27,9	35,6	0,3
Phormidium	0,1	5,6	1,7	7,3	4,9	7,6	213,1	2,5
Monolith	0,2	3,9	1,7	4,5	1,6	5,0	9,7	1,0
Katia	0,3	4,7	2,6	5,1	1,8	4,7	20,9	1,2
Katia II	0,3	6,3	3,5	7,3	6,3	10,5	15,9	7,2
Muddy	0,4	5,0	4,5	5,9	4,6	11,8	46,5	4,7
Dan	0,1	6,2	1,5	6,5	2,2	4,6	8,6	0,2
Rožmberk	0,3	7,0	0,7	7,3	99,6	97,7	130,7	2,7
Láska	0,2	2,6	1,6	2,6	27,7	27,8	54,0	0,8
Nadeje	0,2	9,8	1,1	10,7	43,9	44,5	61,1	4,0
Green	0,2	4,2	1,3	4,3	4,0	7,8	12,4	0,9
Red	0,4	6,4	2,1	8,7	6,1	8,8	26,6	0,3
White	0,2	6,1	1,0	6,9	1,8	4,8	14,5	1,1
Green 2	0,4	10,6	2,2	11,9	19,3	30,4	42,1	6,0
Omega 2	0,2	6,5	0,5	7,0	67,6	68,7	97,7	2,6
Omega 1	0,3	7,8	0,7	8,7	113,4	114,9	125,7	4,1
Ginger	0,2	4,6	0,7	8,0	63,0	64,3	88,1	0,5
Vondra 1	0,4	10,1	2,8	10,5	4,6	10,9	25,5	6,6
Vondra 2	0,2	6,5	1,3	7,0	17,6	24,6	36,1	7,1
Vondra 3	0,2	8,9	1,3	9,7	4,3	7,0	11,3	1,9
Vondra 4	0,2	6,1	0,9	6,4	36,4	45,5	80,7	2,5
Cyanobacterial	0,3	12,9	1,3	13,9	54,9	64,9	85,8	5,9
Black	0,6	15,2	5,1	17,8	3,6	7,6	13,6	1,5
Federico	0,3	7,5	1,7	8,3	64,2	71,0	94,6	6,7
Argentino	0,2	8,8	0,5	9,2	45,4	48,5	126,9	1,5
Blue-green	0,2	9,4	0,8	11,3	54,5	63,2	78,9	2,6

APPENDIX 6.2 – List of all observed species on Ulu Peninsula, Livingston Island with their CCA acronyms, WA conductivity optima and tolerances.

Diatom taxon	CCA Acronym	WA conductivity optimum (µS/cm)	WA conductivity tolerance (µS/cm)	Number of samples in which the species occurred (max = 27)
Achnanthes coarctata (Brébisson) Grunow		524	89	3
Achnanthes muelleri Carlsson				
Achnanthes sp1				
Achnanthes sp2				
Achnanthes taylorensis Kellogg & Kellogg				
Achnanthidium exiguum (Grunow) Czarnecki	ACNEXI	105	10	9
Achnanthidium lailae Van de Vijver	ACNLAI	570	72	2
Adlafia sp1		202	41	3
Amphora sp1	AMPVEN	113	21	13
Brachysira minor (Krasske) Lange-Bertalot	BRAMIN	61	5	11
Caloneis bacillum (Grunow) Cleve	CALBAC	108	33	10
Cavinula pseudoscutiformis (Hustedt) Mann and Stickle		129	12	3
Chamaepinnularia australomediocris (Lange-Bertalot and Schmidt) Van de Vijver		117	16	2
Chamaepinnularia gerlachei Van de Vijver & Sterken		222	**53**	3
Chamaepinnularia krookiiformis (Krammer) Lange-Bertalot & Krammer		119	26	3
Chamaepinnularia sp1				
Chamaepinnularia sp2				
Cocconeis costata Gregory				
Coscinodiscus sp.				
Craticula antarctica Van de Vijver & Sabbe		72	9	2
Craticula sp1				
Craticula subpampeana Van de Vijver & Sterken		264	52	2
Denticula rainierensis Sovereign				
Diadesmis arcuata (Heiden) Lange-Bertalot	DIAARC	68	4	5
Diadesmis australis Van de Vijver & Sabbe	DIAAUS	154	28	14
Diadesmis contenta (Grunow ex Van Heurck) D.G. Mann		39	6	10
Diadesmis inconspicua Kopalova & Van de Vijver	DIAINC	76	5	2
Diadesmis sp1	DIASP1	37	8	11
Diadesmis sp2	DIAING	78	10	14
Diadesmis sp3	DIACOM	78	13	4
Eolimna jamesrossensis Kopalova & Van de Vijver		149	9	4
Eolimna minima (Grunow) Lange-Bertalot				
Fistulifera saprophila (Lange-Bertalot & Bonik) Lange-Bertalot	FISSAP	99	14	5
Fragilaria capucina Desmazières	FRACA1	139	10	9
Fragilariopsis sp				
Geissleria gabrielae Van de Vijver & Zidarova				
Gomphonema sp1	GOMSP1	67	7	14

APPENDIX 6.2 – (continued)

Gomphonema sp2		102	22	2
Gomphonema sp3	GOMSP3	80	3	4
Gomphonema sp4		436	85	3
Hantzschia abundans Lange-Bertalot		85	12	10
Hantzschia amphioxys (Ehrenberg) Grunow		104	27	11
Hantzschia hyperaustralis Van de Vijver & Zidarova		136	26	7
Luticola australomutica Van de Vijver		114	7	2
Luticola austroatlantica Van de Vijver, Kopalová, Spaulding & Esposito		82	20	8
Luticola caubergsii Van de Vijver				
Luticola cohnii (Hilse) Mann		235	51	7
Luticola desmetii Kopalová & Van de Vijver		92	1	2
Luticola doliiformis Kopalová & Van de Vijver				
Luticola evkae Kopalová		54	3	2
Luticola gaussii (Heiden) Mann		73	4	2
Luticola gigamuticopsis Van de Vijver				
Luticola higleri Van de Vijver, van Dam & Beyens		166	33	5
Luticola katkae Van de Vijver & Zidarova				
Luticola muticopsis (Van Heurck) Mann	LUTMUT	69	17	12
Luticola muticopsis f. *reducta* (West & West) Spaulding				
Luticola nivalis (Ehrenberg) Mann				
Luticola permuticopsis Kopalová & Van de Vijver				
Luticola sp1				
Luticola sp2				
Luticola sp3				
Luticola sp4				
Luticola tomsuii Kopalová				
Luticola truncata Kopalová & Van de Vijver		68	6	4
Luticola vermeulenii Van de Vijver	LUTVER	238	40	8
Mayamaea atomus (Kützing) Lange-Bertalot	MAYATO	115	21	5
Mayamaea exelsa (Krasske) Lange-Bertalot				
Mayamaea permitis (Hustedt) Bruder & Medlin	MAYPER	47	8	12
Mayamaea sp1	MAYAGR	119	23	5
Microcostatus naumannii (Hustedt) Lange-Bertalot		175	53	4
Muelleria luculenta Spaulding & Stoermer				
Muelleria regigeorgiensis Van de Vijver & Spaulding		143	7	2
Muelleria sabbei Van de Vijver & Spaulding				
Muelleria sp1				
Muelleria variolata Spaulding & Kociolek				
Navicula cremeri Van de Vijver & Zidarova		130	12	6
Navicula gregaria Donkin	NAVGRE	112	13	7
Navicula seibigeana (Ehrenberg) Ralfs	NAVSEI	373	55	7

APPENDIX 6.2 – (continued)

Nitzschia commutata Grunow		168	8	2
Nitzschia debilis (Arnott) Grunow				
Nitzschia gracilis Hantzsch	NITGRA	67	8	19
Nitzschia homburgiensis Lange-Bertalot	NITHOM	242	39	11
Nitzschia inconspicua Grunow	NITINC	82	4	12
Nitzschia paleacea Grunow	NITPAL	74	11	19
Nitzschia perminuta (Grunow) Peragallo - capitate form	NITPEC	79	12	13
Nitzschia perminuta (Grunow) Peragallo - non-capitate form	NITPER	117	11	23
Nitzschia sp1				
Nitzschia sp2				
Orthoseira roeseana (Rabenhorst) O'Meara		58	13	2
Pinnularia australoborealis Van de Vijver & Zidarova				
Pinnularia australodivergens Zidarova, Van de Vijver & Kopalová				
Pinnularia australomicrostauron Zidarova, Van de Vijver & Kopalová		155	29	11
Pinnularia australorabenhorstii Van de Vijver				
Pinnularia australoschoenfelderi Zidarova, Van de Vijver & Kopalová				
Pinnularia borealis Ehrenberg		148	24	7
Pinnularia borealis var. *pseudolanceolata* Van de Vijver & Zidarova				
Pinnularia intermedia (Lagerstedt) Cleve				
Pinnularia laterotundata Van de Vijver & Zidarova				
Pinnularia splendida Hustedt		110	5	2
Placoneis australis Van de Vijver & Zidarova		70	4	3
Planothidium delicatulum (Kützing) Round & Bukhtiyarova				
Planothidium frequentissimum (Lange-Bertalot) Round & Bukhtiyarova		75	4	4
Planothidium haynaldii (Schaarschmidt em. Cleve) Haw & Kelly	PLAHAY	83	6	8
Planothidium lanceolatum (Brébisson) Round & Bukhtiyarova		120	1	2
Planothidium quadripunctatum (Oppenheim) Sabbe				
Planothidium renei (Lange-Bertalot & Schmidt) Van de Vijver				
Psammothidium germainii (Manguin) Sabbe		28	1	3
Psammothidium papilio (Kellogg et al.) Van de Vijver & Kopalová	PSAPAP	43	11	20
Sellaphora nana (Hustedt) Lange-Bertalot et al.	SELNAN	73	7	6
Sellaphora seminulum (Grunow) Mann	SELSEM	105	5	6
Stauroneis cf. *subgracilior* Lange-Bertalot et al.				
Stauroneis huskvikensis Van de Vijver & Lange-Bertalot				
Stauroneis jarensis Lange-Bertalot et al.		72	5	6
Stauroneis latistauros Van de Vijver & Lange-Bertalot	STALAT	171	31	18
Stauroneis pseudomuriella Van de Vijver & Lange-Bertalot				
Stauroneis pseudoschimanskii Van de Vijver & Lange-Bertalot				
Stauroneis sp.				
Staurosira cf. venter (Ehrenberg) Cleve & Moller				
Staurosira pinnata Ehrenberg				
Thalassiosira sp.				

APPENDIX 6.3 – Matrix of all pearson product-moment corerlations between environmental variables. Significant results, based on Bonferroni-adjusted probabilities are marked with an asterisk.

	O2	sat. O2	pH	Alkal.	Cond.	R-Si	TP	TDP	SRP	Cl-	NO3-N	NO2-N	SO42-	F-	Na+	NH4-N	K+	Ca2+	DOC	TN	DN	TC	DC	chl a
O2	1,00																							
sat. O2	0,88*	1,00																						
pH	0,64*	0,65*	1,00																					
Alkal.	0,23	0,11	0,63*	1,00																				
Cond.	-0,18	-0,09	-0,16	0,04	1,00																			
R-Si	0,31	0,26	0,68*	0,55*	-0,15	1,00																		
TP	-0,06	-0,07	0,05	0,23	0,57*	-0,07	1,00																	
TDP	0,29	0,14	0,28	0,17	-0,26	0,18	0,23	1,00																
SRP	0,27	0,10	0,23	0,12	-0,30	0,16	0,18	0,99*	1,00															
Cl-	-0,17	-0,08	-0,16	0,00	0,98*	-0,17	0,53*	-0,24	-0,27	1,00														
NO3-N	0,13	-0,12	0,15	0,34	-0,22	0,30	0,02	0,41*	0,43*	-0,23	1,00													
NO2-N	0,40*	0,36	-0,03	-0,20	0,12	0,01	0,19	-0,01	0,00	0,12	-0,03	1,00												
SO42-	-0,24	-0,12	-0,27	-0,10	0,90*	-0,24	0,55*	-0,29	-0,33	0,80*	-0,25	0,16	1,00											
F-	-0,28	-0,25	-0,23	0,00	0,68*	-0,01	0,57*	-0,15	-0,17	0,55*	-0,02	0,20	0,85*	1,00										
Na+	-0,10	-0,10	0,01	0,21	0,88*	-0,05	0,77*	-0,04	-0,09	0,82*	-0,11	0,10	0,87*	0,75*	1,00									
NH4-N	-0,07	-0,10	0,02	0,26	0,06	0,23	-0,19	-0,23	-0,22	0,09	0,18	-0,16	-0,09	-0,07	-0,07	1,00								
K+	-0,17	-0,14	-0,04	0,19	0,84*	-0,13	0,79*	-0,14	-0,19	0,78*	-0,13	0,05	0,83*	0,70*	0,95*	-0,02	1,00							
Ca2+	-0,20	-0,05	-0,29	-0,15	0,87*	-0,18	0,16	-0,38*	-0,40*	0,86*	-0,25	0,11	0,78*	0,54*	0,57*	0,10	0,49*	1,00						
DOC	-0,22	-0,12	-0,08	0,08	0,61*	0,02	0,44*	-0,42*	-0,45*	0,57*	-0,20	-0,03	0,60*	0,62*	0,58*	0,29	0,69*	0,46*	1,00					
TN	-0,09	-0,06	0,09	0,27	0,72*	-0,02	0,82*	-0,08	-0,14	0,71*	-0,08	0,05	0,62*	0,55*	0,82*	0,11	0,92*	0,34	0,75*	1,00				
DN	0,07	0,07	0,32	0,35	0,55*	0,27	0,49*	-0,02	-0,07	0,57*	0,12	-0,06	0,39*	0,33	0,61*	0,40*	0,67*	0,28	0,63*	0,82*	1,00			
TC	-0,09	-0,06	0,21	0,41*	0,25	0,22	0,51*	-0,07	-0,11	0,22	0,00	-0,17	0,20	0,40*	0,36	0,14	0,50*	0,01	0,77*	0,65*	0,47*	1,00		
DC	-0,08	-0,05	0,21	0,39*	0,17	0,24	0,42*	-0,07	-0,10	0,14	0,01	-0,16	0,13	0,35	0,27	0,12	0,41*	-0,03	0,74*	0,56*	0,39*	0,99*	1,00	
chl a	0,16	0,24	0,45*	0,32	0,45*	0,22	0,48*	0,17	0,09	0,43*	-0,06	-0,05	0,40*	0,27	0,54*	-0,26	0,53*	0,28	0,41*	0,56*	0,53*	0,37*	0,34	1,00

CHAPTER 7

Moss-inhabiting diatoms from two islands in the Maritime Antarctic Region

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The Maritime Antarctic vegetation is a poorly developed tundra dominated by lichens and mosses, mostly present on moist habitats, providing a favourable habitat for microorganisms. Although, diatoms represent one of the most common algal groups in the Antarctic region, bryophytic diatoms are rarely studied. All of these moss-inhabiting diatom species are of particular interest as little is known about their species composition, ecological preferences and habitats. The present paper discusses the diversity of moss inhabiting diatoms from Byers Peninsula (Livingston Island) and Ulu Peninsula (James Ross Island), Maritime Antarctic Region. A total of 85 moss samples collected from Byers Peninusla, Livingston Island and the area of Lagoons Mesa, James Ross Island has been studied using light and scanning electron microscopy. A total of 134 taxa, belonging to 39 genera has been recorded. Cluster analysis using the entire sample set clearly separates James Ross Island from Livingston Island showing mostly the dominance of the terrestrial flora. A second cluster analysis with only the Livingston Island samples in combination with a PCA analysis created three groups based on their diatom species composition. Although some taxa seem to occur in high abundances in several assemblages, it is clear that a number of taxa showed a distinct preference for a particular assemblage.

Key words: *Diatoms, mosses, Livingston Island, James Ross Island, Community analysis, Antarctic Peninsula, Maritime Antarctic Region*

Introduction

The Maritime Antarctic vegetation is strongly affected by its geographical isolation as well as the climatic and environmental conditions prevailing in this Region. A classical description made by Holdgate et al. (1970) defined the Maritime Antarctic Region as the zone concluded between the southern limit of the extensive, closed phanerogamic vegetation to the southern limit of the extensive cryptogamic (mainly bryophyte) communities, roughly comprising all landmasses between 70°S northwards to 55°S, including several islands and archipelagos (South Sandwich, South Orkney, South Shetland Islands, Palmer Archipelago), as well as the west coast of the Antarctic Peninsula south to Marguerite Bay. The presence of vascular plants is limited to only two native species reaching their southern limits on north-west Alexander Island in the Maritime Antarctic region: *Deschampsia antarctica* Desv. and *Colobanthus quitensis* (Kunth) Bartl. (Ochyra et al. 2008). The Maritime Antarctic vegetation is therefore restricted to a poorly developed tundra, of which lichens and mosses form the dominant component, mostly present on moist, low altitudinal, sheltered coastal habitats with a northerly aspect (Ochyra et al. 2008). Habitat seems to play an important role in shaping the diversity of the moss communities that can be dominated by either one or rarely several moss species. Recently Ochyra et al. (2008) reported the presence of a total of 111 moss species and two varieties belonging to 55 genera in the entire Antarctic Region (excluding the sub-Antarctic islands). The most diverse moss flora has been reported from the South Shetland Islands, where 87 species and one variety are present (Li at al. 2009).

Although their occurrence is strongly influenced by their local environment, moss vegetations can sometimes cover up to several hectares in the Maritime Antarctic Region providing unique microhabitats for a wide range of microbial epiphytes, such as cyanobacteria, chlorophytes and pennate diatoms. Within Antarctica the more northerly-situated bryophyte communities in the maritime zone contain a richer algal flora (Broady 1986) than the rest of the Region. Habitats with relatively stable conditions tend to have a low moss species diversity compared to more complex habitats, where species diversity significantly increases (Ochyra et al. 2008). Species diversity decreases wherever conditions become colder and drier, for instance in the coastal zones of Continental Antarctica, whereas only a few species are able to survive the extreme conditions of continental inland sites.

Temperature and extreme aridity are the most important features affecting the suitability of a microbial habitat. Since diatoms tolerate a wide range of environmental conditions, making them excellent bio-indicators (Rimet 2012), they represent one of the most common algal groups in terms of both species richness and number of individuals in the Antarctic Region (Jones 1996, Van de Vijver & Beyens 1999a, Sabbe et al. 2003). They are present in almost all aquatic and terrestrial habitats, either epiphytically on aquatic and terrestrial moss communities or as epilithon, epipsammon and epipelon biofilms in both lentic and lotic water-bodies (Round et al. 1990). Diatoms are also able to survive in non-submerged or even dry habitats such as terrestrial mosses (Van de Vijver & Beyens 1998). All of these moss-inhabiting diatom species are of particular interest as little is known about their species composition, ecological and habitat preferences.

The past decades, there is a growing interest in the use of the Antarctic diatom flora to solve questions about biogeography, paleoecology and processes related to environmental changes. Despite this increased diatom research, only a few papers reporting the Antarctic moss-inhabiting diatom flora have been published. Most publications deal with moss-epiphytic diatom communities from the sub-Antarctic region (a.o., Hickmann & Vitt 1974, Van de Vijver & Beyens 1998, 1999a, Van de Vijver et al. 2001, 2004b, 2008 and Gremmen et al. 2007). In Van de Vijver & Beyens (1997a), one moss sample from King George Island (South Shetland Islands) was analysed together with 11 aquatic and one soil sample. Toro et al. (2007) reported on moss communities from Livingston Island, but they only discussed them in relation to the invertebrates living near them and did not mention any diatom communities associated with these mosses. Van de Vijver et al. (2011a) described *Luticola adelae* from a moss sample taken near White Lake on James Ross Island but apart from the formal description, no further analyses were carried out on the sample. Actually, only one recent paper discusses the Maritime Antarctic moss-inhabiting diatom flora: Vinocur & Maidana (2009) provided the first analysis of the spatial and temporal variations in the diatoms associated with mosses on the South Shetland Islands. Unfortunately, their species list is apparently composed of a large number of cosmopolitan taxa that so far were never found in the Maritime Antarctic Region but quite common on more temperate localities (and hence suggesting a severe contamination during the analysis) reducing the value of the entire analysis.

Recently, a thorough taxonomical and ecological revision of the Livingston and James Ross Island diatom flora started which not only resulted in the description of a large number of new taxa (Kopalová et al. 2011, 2012, Van de Vijver et al. 2010a, 2010b, 2013, Van de Vijver & Zidarova 2011, Zidarova et al. 2009, 2012) but also led to a better ecological characterisation of the aquatic diatom assemblages present on both islands (Kopalová & Van de Vijver 2013, Kopalová et al. 2013).

The present paper completes the ecological analysis of the Livingston and James Ross Island diatom assemblages discussing the eu-terrestrial diatom communities associated with different moss species on both islands. The objective of this study was to investigate the diatom flora of these two islands, the similarities and differences between them, their biogeographical position within the Maritime Antarctic Region, and the different communities on the islands in relation to several habitat characteristics.

Material and Methods

Field sampling

During the austral summer of 2009–2010, (Limnopolar Project POL 2006-06635), a total of 68 water-saturated and dry moss samples for diatom analysis were collected from Byers Peninsula (Livingston Island, South Shetland Islands). An additional set of 16 water-saturated and dry moss samples from the Lagoons Mesa from Ulu Peninsula (James Ross Island) was collected during the 2012 summer expedition. All moss samples were fixed with alcoholand stored in plastic vials. Sampling locations together with GPS co-ordinates are presented in Appendix 7.1.

Due to the restricted logistic possibilities of working in these extreme conditions, only a limited number of environmental parameters were measured. For all samples we noted: elevation (m a.s.l.), biotic influence (0 = none, 1 = heavy manuring and trampling by marine mammals or birds), habitat type (1 = lake, 2 = pond, 3 = stream, 4 = terrestrial) and dominant moss species present. Appendix 7.1 lists all samples. Moss species in the samples were identified using Ochyra et al. (2008). Sixteen different moss species, belonging to 13 genera, were found in whole sample set. On James Ross Island, only 6 species were identified, compared to Livingston Island where 12 different species were found. Only two of all moss species were in common between both islands. In order to determine the differences in diatom composition due to moisture content, the F-value, referring to the F-classification of Jung (1936) was selected as representative for moisture as used for each sample of Livingston Island. F-value was not determinate for James Ross samples. It is a humidity scale based on water content as follow: FI = submerged mosses, FII = free floating mosses, FIII = very wet (water drips from the samples without pressure), FIV = wet (water drips with a slight pressure), FV = quasi-wet (water drips after moderate pressure), FVI = moist (little water produced after high pressure), FVII = quasi-dry (only a few drops of water can be squeezed out), FVIII = dry (contains no water).

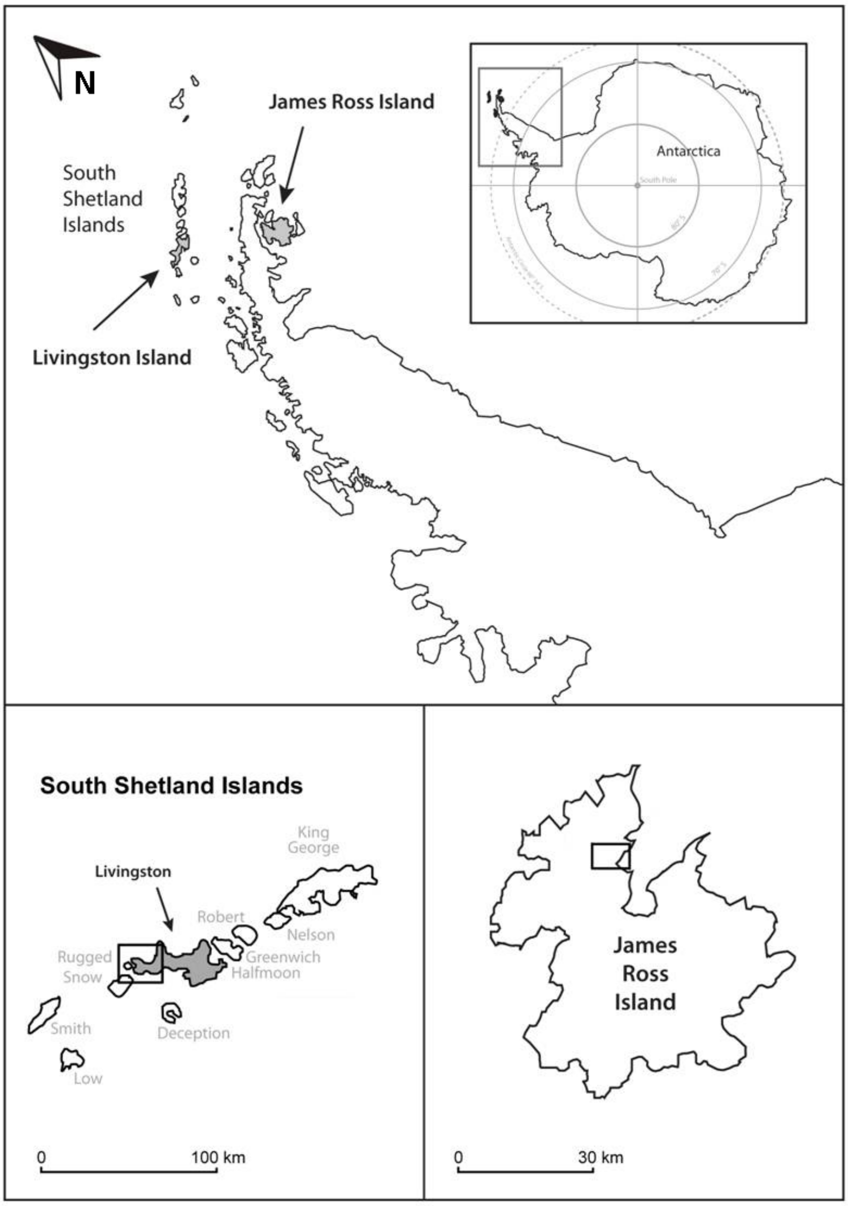

FIGURE 7.1 – Detailed map of Antarctic Peninsula region showing position of James Ross Island and Livingston Island with the main sampled areas indicated.

Study area – Livingston Island

Livingston Island is the second largest island of the South Shetland Islands, with a total area of about 950 km^2. Based on its ecological and climatological characteristics, this archipelago belongs to the Maritime Antarctic Region (Chown & Convey 2007). The island (62°36′ S, 60°30′ W), located 150 km north-west of the Antarctic Peninsula (Fig. 7.1), is almost entirely covered by permanent glaciers and icecaps leaving only 10% of the island ice-free. Byers Peninsula, the largest ice-free area (almost 61 km^2) forming the western tip of the island, is the most important biodiversity area on Livingston Island and is currently included within the list of the Antarctic Specially Protected Areas (ASPA No 126). More information on the climate, geology, hydrology and geomorphology of this area can be found in Chipev & Veltchev (1996) and Toro et al. (2007). Vegetation cover on Livingston Island, as typical for the Antarctic region, is scarce an has a mosaic structure. It is mainly formed by cryptogams, with lichens and mosses as dominant lifeforms with only the two above mentioned vascular plants forming small cushions (Toro et al. 2007). Several of the lakes have well developed monospecific stands of the benthic moss *Drepanocladus longifolius* (Mitt.) Broth. ex Paris, which might dominate overall lake productivity because of its large standing stocks (Li et al. 2009).

Study area – James Ross Island

James Ross Island is a large island with a total area of ~2600 km^2, in the north-western part of the Weddell Sea, close to the northern tip of the Antarctic Peninsula. It belongs to the transitory zone between the Maritime Antarctic and Continental Antarctic Region (Øvstedal & Levis-Smith 2001). More than 80% of the island is covered by an ice cap leaving only the northern part of the island, Ulu Peninsula, ice free (100 km^2). Olivero et al. (2008), Smellie et al. (2008) and Svojtka et al. (2009) discussed the geological history of the island. Ulu Peninsula is characterized by the presence of a large number of streams, seepages and lakes of glacial origin (Nedbalová et al. 2013). The human presence is limited to the Czech scientific base (Johann Gregor Mendel Station) that was constructed on Ulu Peninsula in 2006. The climate of James Ross Island is determined by cold, arid barrier winds from the south and by the location in the precipitation shadow of the Antarctic Peninsula (Engel et al. 2012). In comparison to the South Shetlands Islands, the climate is more arid with a low precipitation, estimated to be less than 300 mm/yr. Owing to the dry air and often high wind speeds, evaporation rate is high. Further details on the climatic conditions can be found in Láska et al. (2010, 2011a,b) and in Engel et al. (2012). Inland vegetation, lacking any vascular plants, is restricted to bryophytes and lichens. Their distribution is usually limited due to the deficiency of liquid water (Robinson et al. 2003). Although moss communities are not very frequent on James Ross Island, there are several patches of live or moribund moss (Láska et al. 2011b). On the other hand, the microflora, mostly composed of cyanobacteria, green algae and diatoms, is well developed in freshwater ecosystems such as seepages, lakes and streams (Komárek & Elster 2008, Kopalová et al. 2012, 2013).

Sample treatment and counting

Diatom samples were prepared using the method described in Van der Werff (1955). Subsamples were cleaned by adding 37% H_2O_2 and heating to 80 °C for about 1h. Oxidation of organic material was completed by addition of $KMnO_4$. Following digestion and centrifugation (10 min at 3700 x g), the resulting cleaned material was diluted with distilled water to avoid excessive concentrations of diatom valves on the slides, dried on microscope cover slips, and mounted in Naphrax®. Samples and slides are stored at the National Botanic Garden of Belgium (Meise, Belgium). In each sample, 400 diatom valves were identified and enumerated on random transects at x1000 magnification under oil immersion using an Olympus BX51 microscope equipped with Differential Interference Contrast (Nomarski®) optics. Identifications of Antarctic species are based on Van de Vijver et al. (2002a, b, 2004a, 2010a, b, 2011a, b), Sabbe et al. (2003), Ohtsuka et al. (2006), Esposito et al. (2008), Van de Vijver & Mataloni (2008), Kopalová et al. (2009, 2011, 2012), Zidarova et al. (2009, 2010, 2012), Van de Vijver & Zidarova (2011) and references therein. For several species, identification up to species level was not possible due to their unclear taxonomic situation. All valves belonging to the genus *Gomphonema* were grouped as *Gomphonema* spp. The different taxa with affinity to *Nitzschia perminuta* (Grunow) Perag. were combined as *N. perminuta*-complex. Further morphological and taxonomic research (ongoing) will be necessary to establish their correct identity.

Data analysis

For a pairwise comparison of the moss-inhabiting diatom flora of Livingston Island and James Ross Island with similar bryophytic communities in the sub-Antarctic Region, the community coefficient of Sørensen (1948) was used. This index has the following formula: 2c/(a+b+2c) where ‘a’ and ‘b’ are the numbers of species exclusively observed in each of the two sites and ‘c’ is the number of species shared by these sites. The comparison is based on the revised species lists of South Georgia (Van de Vijver & Beyens 1997b), Heard Island (Van de Vijver et al. 2004) and the Prince Edward Islands (Van de Vijver et al. 2008). For the Antarctic Continent, unfortunately, no recent data on moss-inhabiting diatoms are available.

The geographic distribution of the taxa was based on literature data provided with illustrations or descriptions (Appendix 7.2). When the identity of a taxon could not be determined this was shown using ´cf.´ or ´spp.´ and its distribution was listed usually as unknown (U). For Antarctic species, the geographic distribution was further split in ‘MA’ when the species occurred only in the Maritime Antarctic Region. Taxa present in the entire Antarctic Region are listed as ´A´. Cosmopolitan taxa present as ´C´.

To determine the extent to which our sampling effort represented the total diatom flora of the two islands, the incidence/based species richness estimator (ICE, Chao et al. 2000) and the mean Chao2 richness estimator (Chao 1984), both using the EstimateS program version 9.0 (Coldwell 2013). Shannon-Wiener diversity index ($\log_{10}$-based) and Hill’s evenness index were calculated using the statistical package MVSP 3.2 (Kovach Computing Services 1993).
Ordination was used to elucidate the principal patterns in species composition in the moss samples of Livingston Island. Squareroot-transformed abundance data with downweighting of rare taxa were used in the ordinations. The statistical and numerical techniques used in this study are described in full detail in Jongman et al. (1995). Detrended correspondence analysis (DCA) was carried out to estimate gradient length. The results showed that 2 samples were clear outliers. Sample BYM-02 contained exclusively a very large population of *Eunotia paludosa* Grunowwhereas sample BYM-59 was entirely dominated by *Psammothidium germainii* (Manguin) Sabbe. A DCA with the two outliers omitted showed gradient lengths for the first four axes of 2.655, 2.521, 2.228 and 1.948, suggesting that methods based on linear models (Principal Component Analysis) would be appropriate for a subsequent ordination (ter Braak & Prentice 1988). All ordination analyses were performed using the computer program CANOCO version 4.5 (ter Braak & Šmilauer 1998).

A hierarchic-agglomerative clustering, based on minimum variance strategy with the Squared Euclidean Distance as dissimilarity measure, was used to classify the samples based on their diatom composition (performed by MVSP).

Results

Species composition and diversity

The microscopic analysis of 85 samples revealed a total of 128 diatom taxa (including species, varieties and forms) belonging to 39 genera. Six samples (V3M3, M1 and M21 from James Ross Island and BYM-9, BYM-10 and BYM-40 from Livingston Island) contained (almost) no diatoms, even after counting an entire slide. Subsequently, these samples have been removed from further analysis. On Livingston Island (69 samples), 123 diatom taxa belonging to 39 genera were found, whereas from James Ross Island (16 samples), only 57 taxa from 23 genera were identified. Appendix 7.2 provides an alphabetical list of all observed species together with their biogeographical distribution.

Almost 53% of all observed species have a restricted Antarctic distribution with a majority of these (79%) confined to the Maritime Antarctic Region whereas only 43 taxa (32%) have a typical cosmopolitan distribution, such as *Fragilaria capucina* Desm., *Navicula gregaria* Donkin and *Nitzschia gracilis* Hantzsch.

The similarity analysis indicates that the moss diatom flora of Livingston Island and James Ross Island shows a clear difference to the moss-inhabiting diatom flora from South Georgia (Sørensen index = 0.191), Heard Island (0.265) and the Prince Edward Islands (0.235). Species richness per sample ranged from 9 to 46 for Livingston Island and 7 to 24 for James Ross Island. The distribution of species number per sample clearly differs between both islands. The average number of taxa per sample was 25 ± 8 for Livingston Island and 16 ± 6 for James Ross Island (Fig. 7.2). The highest species richness was recorded in several Livingston Island moss samples: BYM-11 (46 taxa), BYM-53 (45 taxa) and BYM-27 (40 taxa) whereas on James Ross Island, the maximum number of counted species was only 24 (sample M22) following by samples M23 and V3M1 with 23 counted species. The flattening (towards the end) of the species accumulation curve for Livingston Island indicates that this sample set contains a large part of the total diatom flora contrary to the James Ross Island sample set for which still a considerable number of samples will be needed to have a representative dataset. Using species richness estimators, it is possible to evaluate how well the sampling effort reflected the true diatom richness. The expected total number of taxa in all samples is 138 (Chao2) or 142 (ICE) for Livingston, suggesting that our counting scored between 87 and 89 % of the (theoretical) total number of taxa present in the samples overall. Based on these differences in species richness, the limited amount of samples from James Ross Island and the species accumulation curve, both datasets are treated separately in the following diversity and community analyses.

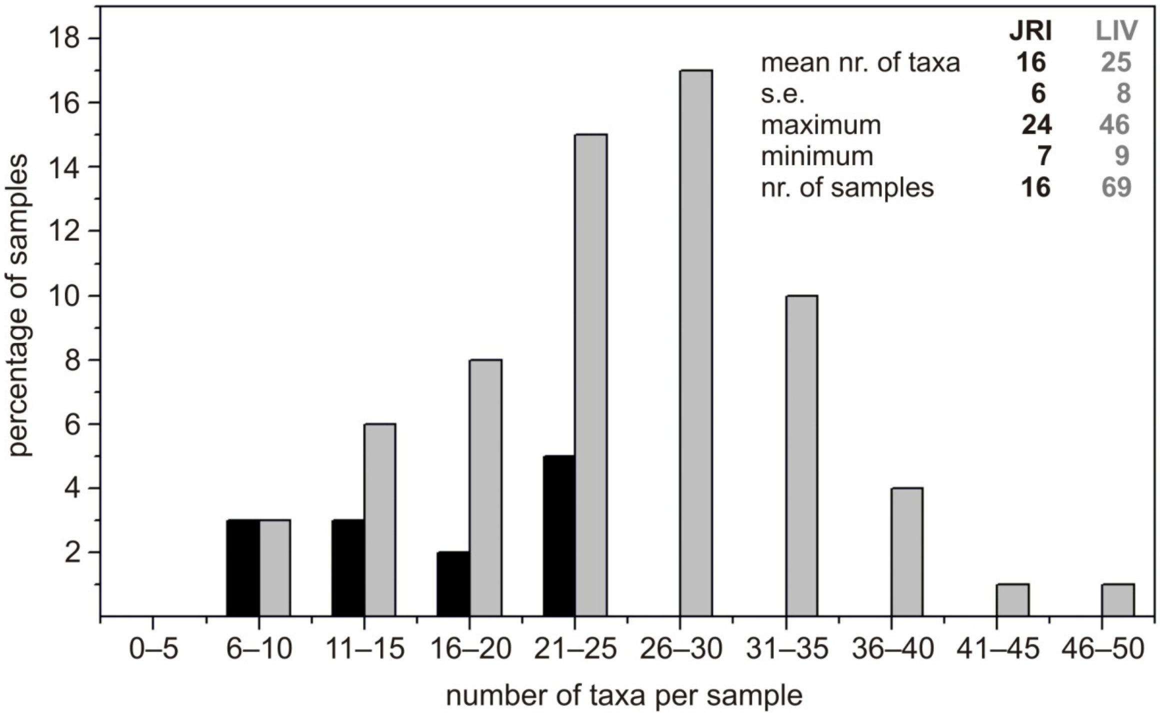

FIGURE 7.2 – Distribution of samples for the two sample sets based on species richness. JRI – James Ross Island (black), LIV – Livingston Island (grey).

On Livingston Island, the 51 least abundant species (=38% of all observed species) together made up only 1% of the total number of valves counted whereas the 7 most dominant species accounted for 50% of all counted valves. As can be seen in Fig. 7.2, a large number of species is restricted to only a few samples and only a few species occur in 50% or more of all samples. The genera *Pinnularia* (16 taxa) and *Luticola* (13 taxa) and *Psammothidium* (9 taxa) were the most species rich genera. Other important genera include *Diadesmis*, *Muelleria*, *Navicula* and *Nitzschia* (7 taxa). The dominant species is *Nitzschia perminuta* (Grunow) Perag. with more than 15% of all counted valves followed by *Fragilaria capucina* Desm.

(9.0%), *Psammothidium incognitum* (Krasske) Van de Vijver (6.6%) and *Gomphonema* spp (6.3%). It should be noted however that both *N. perminuta* and *Gomphonema* spp most likely represent complexes of several taxa that need to be split into several independent, most probably new taxa. The situation is completely different on James Ross Island where the dominant genera include *Luticola* (11 taxa), *Diadesmis* (6 taxa) and *Pinnularia* (5 taxa). The flora on this island was dominated by *Pinnularia borealis* Ehrenb. (24.6%), *Hantzschia amphioxys* (Ehrenb.) Grunow (10.7%) and *Nitzschia perminuta* (8.9%).

A considerable number of taxa appeared to be new for science (e.g., *Planothidium rostrolanceolatum* Van de Vijver, Kopalová & Zidarova). Several of them have been recently published (Van de Vijver et al. 2013) whereas others (such as *Psammothidium* sp. (manuscriptname), *Halamphora* sp. or *Diadesmis* sp1 and sp2) await a formal description.

A very small proportion (<0.1%) of all counted valves belonged to marine species (indicated as '*' in appendix 7.2) probably blown in by seaspray or wind or transported on the skin of marine mammals or birds such as elephant seals (*Mirounga leonina* (L.)), gentoo penguins (*Pygoscelis papua* Forster) or southern giant petrels (*Macronectes giganteus* Gmelin).

Community analysis

An initial cluster analysis using the entire sample set clearly separates all 16 samples collected on James Ross Island from the samples from Livingston Island. All JRI samples are dominated by *Pinnularia borealis*, *Hantzschia amphioxys* and *H. abundans*, typical terrestrial species that only play a minor role on Livingston Island.

A second cluster analysis (Fig. 7.3) with only the Livingston Island samples, combined with a PCA analysis divides these samples intro three groups (Fig. 7.4). The distinction between these groups is clearly reflected in the species composition. The first two PCA axes (λ_1 = 0.168, λ_2 = 0.104) were highly significant (p=0.001) and explained 27.3 % of the variation in the diatom composition with an additional 15.7% explained on the next 2 axes. Table 7.3 shows the principal characteristics of the different groups including the dominant species.

The samples on the right side of the diagram (**X**) form assemblage A. They can be subdivided into two sample groups: assemblage A1 groups coastal localities where the influence of marine mammals and/or birds is very high whereas assemblage A2 contains sites close to the Rotch Dome ice cap, formed after recent glacier retreats. On the left side, two assemblages can be formed within the samples. In the upper half of the diagram, assemblage B (▼) comprises mainly samples from more terrestrial sites at higher elevations, whereas the lower half (assemblage C, ■) is characterized by samples from aquatic habitats (pools and lakes) located at lower altitudes. There are clear differences in diatom species composition between the different assemblages (Table 7.3). Only species with a cumulative fit of > 25% in the PCA diagram are shown (species acronyms are added to Appendix 7.2). Although some taxa seem to occur in high abundances in several assemblages (such as *Nitzschia perminuta*, *Chamaepinnularia krookiiformis* (Krammer) Lange-Bert. & Krammer or *Fragilaria capucina*) it is clear that a number of taxa showed a distinct preference for a particular assemblage. Assemblage A1 is characterized by high frequencies of *Chamaepinnularia krookiiformis*, several *Psammothidium* species (*P. germainii,P.* sp., *P. papilio* (Kellogg et al.)Kopalová & Van de Vijver)*, Nitzschia homburgiensis* Lange-Bert. and *P. subantarctica* var. *elongata* (Manguin) Van de Vijver & Le Cohu. Assemblage A2 is characterized by several *Diadesmis* species (mostly *D. arcuata*), *Pinnularia borealis* and *Psammothidium* sp.

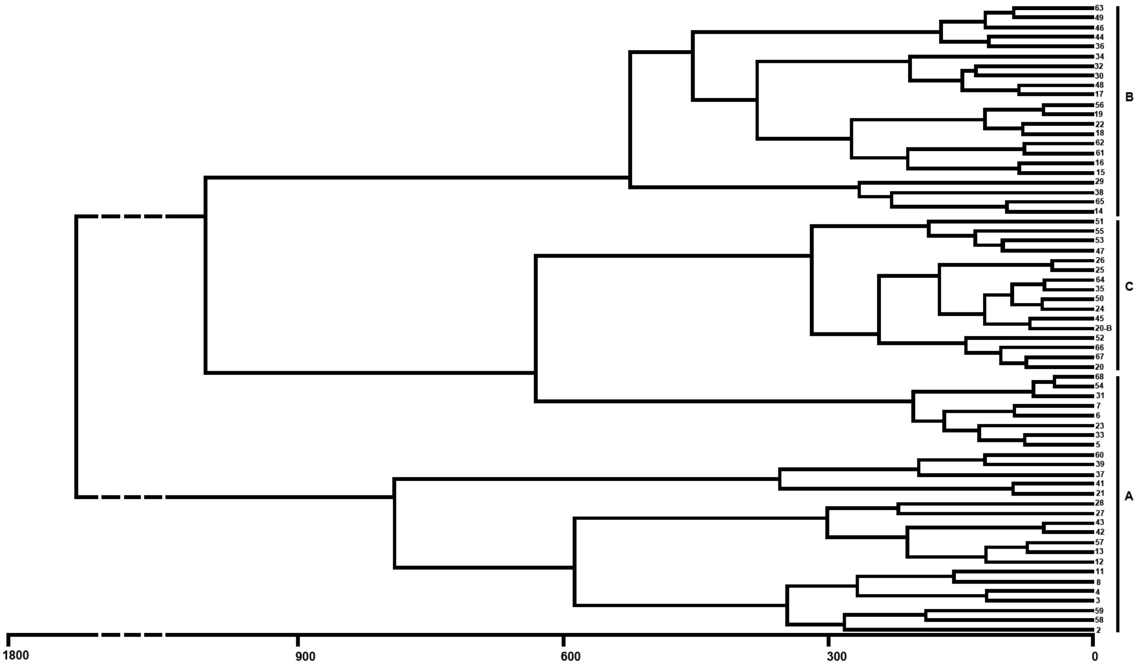

FIGURE 7.3–A hierarchic-agglomerative cluster analysis of the Livingston Island sample set. Division into the three groups corresponds with the groups shown in Fig.7.4.

The second assemblage (B) is dominated by *Nitzschia perminuta*, *Psammothidium incognitum*, *Brachysira minor* (Krasske) Lange-Bert., *Diadesmis inconspicua* Kopalová & Van de Vijver, *D. tabellariaeformis* (Krasske) Lange-Bert. & A.Wojtal, *Planothidium rostrolanceolatum* Van de Vijver, Kopalová & Zidarova and *Gomphonema* spp. Finally, the flora in assemblage C is mostly composed of several *Nitzschia* species (*N. paleacea* Pantoczek, *N. gracilis*, *N. perminuta*), *Navicula australoshetlandica* Van de Vijver, *N. dobrinatemniskovae* Zidarova & Van de Vijver and *Fragilaria capucina.* No clear separation in the choice for moss species as habitat was observed. Samples with *Warnstorfia fontinaliopsis* (Müll. Hal.) Ochyra are only found in assemblage A but both assemblages B and C show similar number of samples dominated by the three other moss species.

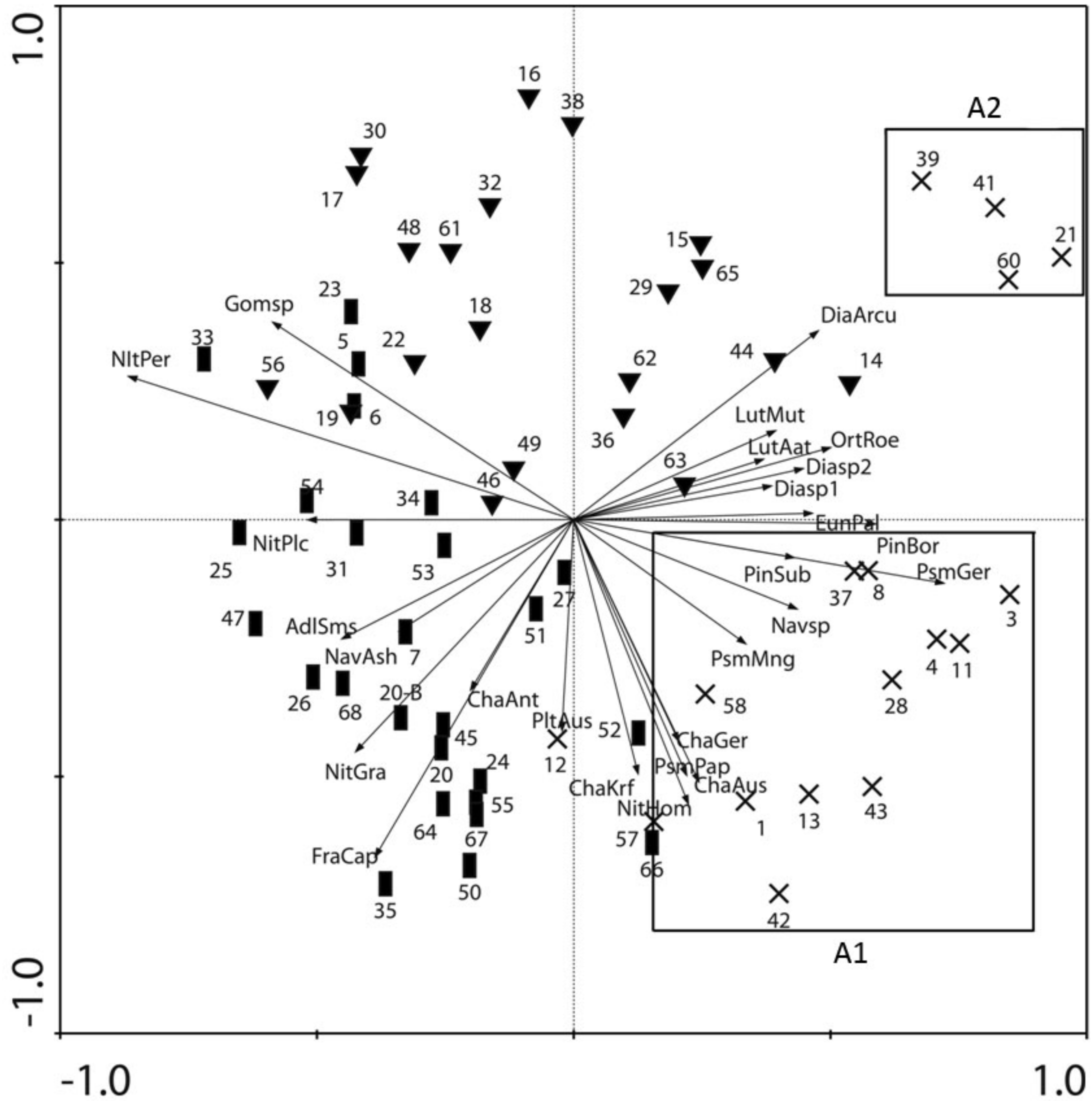

FIGURE 7.4 – Principal Corespondence Analysis (PCA) of the Livingston Island sample set. Division into the three groups (**group C** *–square*; **group B** *–inverted triangle*; **group A** *–cross)* and subdivision of the group A is indicated. The first two axes are shown. The codes of species names are given in Appendix 7.2.

TABLE 7.3 – Characteristics of the four groups obtained using PCA analysis.

	Assemblage A1	Assemblage A2	Assemblage B	Assemblage C
Number of samples	13	4	21	26
Mean moisture content range	FIII-FIV	FIII-FIV	FIII-FIV	FII-FIII
Mean altitude of sample	11 ± 13	55 ± 36	50 ± 23	36 ± 21
Number of samples with biotic influence	10	0	0	0
Mean number of taxa	30 ± 8	23 ± 9	21 ± 7	27 ± 8
Mean diversity	2.5 ± 0.3	1.9 ± 1.0	2.0 ± 0.6	2.4 ± 0.4
Mean eveness	0.73 ± 0.07	0.58 ± 0.26	0.65 ± 0.13	0.73 ± 0.07
Number of lake samples	1	1	2	8
Number of pool samples	1	0	3	6
Number of stream samples	1	0	0	1
Number of terrestrial samples	10	3	16	11
Number of samples with dominant:				
Bryum pseudtriquetrum	1	0	4	6
Sanionia georgicouncinata	4	2	6	4
Warnstorfia fontinaliopsis	2	0	0	0
Warnstorfia sarmentosa	3	1	10	12
other mosses	3	1	1	4
present in n% of samples # mean rel. abundance (%) in these samples				
Brachysira minor	75 # 0.7	54 # 1.0	76 # 3.9	58 # 1.3
Chamaepinnularia australomediocris	0 # 0.0	54 # 2.4	14 # 0.2	50 # 0.9
Chamaepinnularia krookiiformis	25 # 1.7	100 # 9.8	86 # 2.1	96 # 4.4
Diadesmis arcuata	75 # 44.1	69 # 1.4	76 # 4.0	88 # 1.3
Diadesmis inconspicua	75 #3.3	30 # 1.3	29 # 3.9	35 # 0.6
Diadesmis sp1	75 # 5.8	30 # 2.3	43 # 0.6	50 # 0.5
Diadesmis sp2	75 # 9.2	54 # 0.6	29 # 0.4	23 # 0.4
Diadesmis tabellariaeformis	25 # 0.4	62 # 1	38 # 3.5	8 # 0.1
Fragilaria capucina s.l.	0 # 0.0	92 # 5	81 # 4.5	88 # 16.2
Gomphonema spp	75 # 0.9	77 # 1.5	90 # 11.9	100 # 5.0
Navicula australoshetlandica	0 # 0.0	46 # 1	33 # 1.1	73 # 4.4
Navicula dobrinatemniskovae	25 # 0.1	39 # 0.3	14 # 0.4	50 # 2.2
Navicula gregaria	0 # 0.0	8 # 1.6	5 # 0.0	50 # 0.4
Nitzschia gracilis	0 # 0.0	69 # 1.3	67 # 1.3	100 # 7.9
Nitzschia homburgensis	25 # 0.4	100 # 12.8	71 # 1.3	85 # 3.1
Nitzschia paleacea	25 # 0.0	15 # 0.2	38 # 1.6	77 # 4.3
Nitzschia perminuta-complex	50 # 0.9	77 # 1.6	100 # 20.2	100 # 20
Pinnularia borealis	100 # 3.9	62 # 3.3	33 # 0.3	23 # 0.2
Pinnularia subantarctica var. *elongata*	75 # 1.3	92 # 5.8	76 # 2.7	54 # 0.8
Planothidium australe	0 # 0.0	69 # 2.1	24 # 0.4	69 # 1.2
Planothidium rostro/lanceolatum	25 # 0.3	62 # 1.8	57 # 5.9	65 # 2.2
Psammothidium germainii	75 # 1.8	77 # 1.3	19 # 0.4	12 # 0.1
Psammothidium incognitum	50 # 0.3	77 # 4.3	90 # 15.6	46 # 1.2
Psammothidium papilio	25 # 0.2	92 #6.0	57 # 2.4	85 # 2.5
Psamothidium sp	75 # 9.6	69 #10.2	38 # 0.2	27 # 0.2

Discussion

Species composition and general biogeography

This study focused on the moss-inhabiting diatoms of two islands located on both sides of the Antarctic Peninsula and therefore undergoing different climatological and ecological influences. Livingston Island is a typical example of the Maritime Antarctic Region with relatively high precipitation rates reflected in a higher number of aquatic habitats with a more luxuriant wet bryophyte vegetation compared to James Ross Island that has a much drier climate. On the latter island, the extent of aquatic and/or wet terrestrial moss vegetation is rather limited. This is clearly reflected in the observed diatom composition. Whereas the sampled moss-inhabiting communities on James Ross Island are dominated by only typical terrestrial taxa such as *Pinnularia borealis*, *Hantzschia amphioxys* and *Diadesmis arcuata*, known for their preference of drier environments (Petersen 1935, Van de Vijver & Beyens, 1997), dry terrestrial moss vegetations were hardly present and therefore not sampled on Livingston Island resulting in a lower proportion of these terrestrial diatom species in the samples. Based on these differences in sampling effort and habitat types, comparing the species richness between both islands (58 on JRI vs. 128 on LI) is rather difficult.

It is generally accepted that a decreasing diversity trend when going southwards is clearly present in the Antarctic Region (Jones 1996, Van de Vijver & Beyens 1999). This is confirmed by the similarity analysis. The bryophytic diatom communities in the sub-Antarctic Region show almost a double amount of species compared to Livingston Island (Van de Vijver & Beyens 1997b, Van de Vijver et al. 2004, 2008). The main reason for this decreasing diatom diversity is the lower variability in their microhabitat. On the sub-Antarctic islands, the moss vegetation dominates all parts of these islands (Van de Vijver et al. 2002a) forming thick layers in the valleys, on slopes and even fell fields, whereas in the Maritime Antarctic Region, mosses are restricted to the wet areas around lakes, seepage areas and streams. Given the particular dry nature of the James Ross Island samples, it is not entirely sure whether the results in the present study provide a trustful overview of the moss-inhabiting diatom flora of this island. However, the absence of their typical wet moss habitat on James Ross Island is probably one of the main reasons for the lack of epiphytic diatoms on this island. On the nearby Antarctic Continent, the bryophyte flora is restricted to 30 moss species (Lewis Smith

1984), most of them being poikilohydric indicating that they are only wet during periods of snow melts in the summer months (Robinson et al. 2000). Based on the low annual precipitation (Láska et al. 2011a), mosses on James Ross Island apparently undergo a similar desiccation, providing a quite unstable environmental situation for the epiphytic diatoms living on these mosses. Only typical dry-terrestrial diatom taxa are able to overcome these periods of temporal dryness and hence the moss diatom flora on James Ross Island has a lower species richness compared to Livingston Island were mosses remain continuously wet near the numerous lakes and pools on Byers Peninsula.

In the past, Antarctic diatom taxa were force-fitted into European and North-America relatives, which led to the incorrect conclusion that the Antarctic diatom flora is mostly cosmopolitan (Toro et al. 2007, Vinocur & Maidana 2009). However, the recent revisions of the non-marine diatom flora from the entire Antarctic Region based on a narrower species concept and a more fine-grained taxonomy (e.g., Van de Vijver et al. 2010, 2011b, Zidarova et al. 2012) resulted in the description of a large number of typical Antarctic taxa, many of which observed in the moss-inhabiting flora. This current revised taxonomy contradicts the Ubiquity Theory developed by Finlay & Clarke (1999) which stated that microorganisms, due to their large population size and small body size can be easily dispersed throughout the world reducing their overall diversity and possible local endemism. Antarctic diatoms clearly show a rather restricted distribution with a lot of endemic taxa. This is confirmed by the results of the similarity analysis. Less than 25% of the taxa found on Livingston Island and James Ross Island are shared with the moss-inhabiting diatoms from the sub-Antarctic islands (on which a similar taxonomic revision was performed), even with localities situated in the southern Atlantic Ocean (South Georgia). Most of the species in common between these islands are mainly cosmopolitan taxa such as *Navicula gregaria* and *Pinnularia borealis*. It is however unclear whether these taxa are truly cosmopolitan since recent studies analysing the genetic similarities and differences between several Antarctic populations of *P. borealis* and *Hantzschia amphioxys* indicate a high degree of cryptic diversity (Souffreau et al. 2013). Together with the rather high number of still unidentified taxa (9–20%) for which further morphological and taxonomic analyses will be necessary to clarify their biogeographical preferences, the proportion of typical Maritime Antarctic taxa will likely increase, confirming the highly specific nature of the Antarctic diatom flora.

Moss-inhabiting diatom communities

It is well known that diatom communities living in the Antarctic Region are significantly influenced by their environment. The composition of freshwater diatom communities in the Maritime Antarctic Region is determined by the amount of nutrients and the conductivity of their habitat (Jones 1993, Kopalová & Van de Vijver 2013, Kopalová et al. 2013) while on the Antarctic Continent lake communities seem to be more influenced by salinity (e.g., Verleyen et al. 2003, Gibson et al. 2006). The moisture availability of the moss habitat presents an additional stress factor for the diatom communities living on these moss vegetations. Moss-inhabiting communities on the sub-Antarctic islands are controlled by moisture and mineral content of the moss habitat (Van de Vijver & Beyens 1997, 1999, Van de Vijver et al. 2004, 2008, Vinocur & Maidana 2010). A similar result was found for the moss communities on Livingston Island. The first two axes of the PCA analysis most likely represent these two determining factors: axis one seems to be a biotic axis whereas axis 2 represents a moisture axis.

Biotic stress seems to play a first important role in determining the species composition in the Livingston moss diatom communities separating assemblage A1 from the other assemblages. Marine mammals are frequently found on the shores of this island and show a marked influence on the areas where they often stay for several weeks during their moulting period (Cruwys & Davis 1995). With their excrements, these animals considerably alter the diatom habitat by increasing both the salinity and the nutrient concentrations. Although these parameters were not measured for the moss samples, aquatic samples collected near these moss vegetations show a similar result (Kopalová& Van de Vijver 2013). Assemblage B clearly represents wet terrestrial moss-inhabiting diatom communities. *Psammothidium incognitum*, originally described from wet mosses on southern Patagonia (Krasske 1939) was found to be one of the dominant terrestrial bryophytic species on South Georgia (Van de Vijver & Beyens 1997b) and also on the sub-Antarctic islands in the southern Indian Ocean, the species was mostly found in wet terrestrial moss vegetations (Van de Vijver et al. 2002a) whereas it is less present in aquatic moss vegetations. The assemblage shows also a clear similarity with a South Georgian moss assemblage although some typical sub-Antarctic moss diatoms such as *Psammothidium confusum* (Krasske) Van de Vijver & Beyens are completely missing in the Maritime Antarctic Region (Van de Vijver &

Beyens 1997b). The more aquatic moss assemblage on the other hand shows a large similarity with the epilithic and epipelic aquatic diatom community that was found in lakes on Byers Peninsula (Kopalová & Van de Vijver 2013) indicating that microhabitats in these permanent lakes apparently have only a minor influence on the diatom composition in these lakes. Most *Nitzschia* and *Navicula* species in the Antarctic Region are exclusively aquatic species, hardly found outside permanent waterbodies (Van de Vijver et al. 2011b, Kopalová & Van de Vijver 2013). The results of this study confirm this observation since almost all species of these two genera were found only in the aquatic moss assemblage and not in the terrestrial moss group. Comparison with older data is hardly possible due to the taxonomic revision that started a couple of years ago (Van de Vijver et al. 2011b).

Conclusion

In general, a better knowledge of moss-inhabiting diatoms on the Maritime Antarctic islands is important not only from a taxonomical point of view, but also for further ecological and paleoecological research as some of these moss vegetations present a typical habitat in which diatoms are able to survive, even during more stressful periods.

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APPENDIX 7.1 – List of samples with characteristics used in this paper. Habitat type: 1 = lake; 2 = pond; 3 = stream; 4 = terrestrial. ND = not determined. For more details, see text.

Sample	Sampling date	Site	GPS	F-value	Altitude (m)	Biotic influence	Habitat type	Dominant moss species in the sample
Livingston Island								
BYM001	9/01/2009	Sealer's Hill	6240275/06106560	I	10	1	2	*Warnstorfia fontinaliopsis* (Müll. Hal.) Ochyra
BYM002	9/01/2009	Sealer's Hill	6240275/06106560	IV	10	1	4	*Warnstorfia fontinaliopsis* (Müll. Hal.) Ochyra
BYM003	9/01/2009	Sealer's Hill	6240213/0617259	IV	5	1	4	*Bryum pseudotriquetrum* Gärtner et al.
BYM004	9/01/2009	Sealer's Hill	6240213/0617259	IV	5	1	4	*Brachithecium austrosalebrosum* (C. Muell.) Kindb.
BYM005	9/01/2009	Sealer's Hill	6240102/06107512	V	5	0	4	*Bryum pseudotriquetrum* Gärtner et al.
BYM006	9/01/2009	Sealer's Hill	6240102/06107512	V	5	0	4	*Sanionia georgicouncinata* (Müll. Hal.) Ochyra
BYM007	9/01/2009	Sealer's Hill	6240102/06107512	V	5	0	4	*Brachithecium austrosalebrosum* (C. Muell.) Kindb.
BYM008	9/01/2009	plain before Pinguinera	6240113/06108453	III	5	1	1	*Warnstorfia fontinaliopsis* (Müll. Hal.) Ochyra
BYM009	10/01/2009	Byers Camping Site	ND	VI	5	1	4	*Andreaea gainii* Cardot.
BYM010	10/01/2009	Byers Camping Site	ND	VI	5	1	4	*Sanionia georgicouncinata* (Müll. Hal.) Ochyra
BYM011	10/01/2009	Byers Camping Site	ND	VI	5	1	4	*Andreaea gainii* Cardot.
BYM012	10/01/2009	Byers Camping Site	6239453/06105585	II	11	0	3	*Warnstorfia sarmentosa* (Wahlenb.) Hedenäs
BYM013	10/01/2009	Byers Camping Site	6239453/06105585	IV	11	0	4	*Sanionia georgicouncinata* (Müll. Hal.) Ochyra
BYM014	10/01/2009	Byers Camping Site	6239453/06105585	VI	11	0	4	*Sanionia georgicouncinata* (Müll. Hal.) Ochyra
BYM015	10/01/2009	Second flag from Camping site	6239357/06106243	II	61	0	2	*Warnstorfia sarmentosa* (Wahlenb.) Hedenäs
BYM016	10/01/2009	Second flag from Camping site	6239357/06106243	V	61	0	4	*Warnstorfia sarmentosa* (Wahlenb.) Hedenäs
BYM017	10/01/2009	rock desert on Central Plateau	6239317/06106480	V	66	0	4	*Bryum pseudotriquetrum* Gärtner et al.
BYM018	10/01/2009	rock desert on Central Plateau	6239317/06106480	II	66	0	2	*Warnstorfia sarmentosa* (Wahlenb.) Hedenäs
BYM019	10/01/2009	rock desert on Central Plateau	6239241/06106489	II	60	0	1	*Warnstorfia sarmentosa* (Wahlenb.) Hedenäs
BYM020	10/01/2009	Central Plateau	6239118/06106210	II	59	0	3	*Warnstorfia sarmentosa* (Wahlenb.) Hedenäs
BYM021	10/01/2009	Central Plateau	6239114/06106194	I	62	0	1	*Sanionia georgicouncinata* (Müll. Hal.) Ochyra
BYM022	10/01/2009	Central Plateau	6239114/06106194	V	62	0	4	*Sanionia georgicouncinata* (Müll. Hal.) Ochyra
BYM023	10/01/2009	Central Plateau	6239135/06106045	VI	68	0	4	*Bryum pseudotriquetrum* Gärtner et al.
BYM024	11/01/2009	behind Cerro Smellie	6239041/06107518	II	38	0	1	*Sanionia georgicouncinata* (Müll. Hal.) Ochyra

APPENDIX 7.1 – (continued)

Sample	Sampling date	Site	GPS	F-value	Altitude (m)	Biotic influence	Habitat type	Dominant moss species in the sample
Livingston Island								
BYM054	15/01/2009	Asa lake	6237524/06106300	IV	38	0	4	*Bryum pseudotriquetrum* Gärtner et al.
BYM055	15/01/2009	Asa Lake area	6237417/06106304	I	40	0	1	*Warnstorfia sarmentosa* (Wahlenb.) Hedenäs
BYM056	15/01/2009	Asa Lake area	6237417/06106304	V	40	0	4	*Bryum pseudotriquetrum* Gärtner et al.
BYM057	15/01/2009	Beach near Camp Site	6239148/06104215	V	20	0	4	*Warnstorfia sarmentosa* (Wahlenb.) Hedenäs
BYM058	17/01/2009	Refugio Lake area	6239414/06100264	III	4	1	4	*Warnstorfia sarmentosa* (Wahlenb.) Hedenäs
BYM059	17/01/2009	Refugio Lake area	6239414/06100264	V	4	1	4	*Warnstorfia sarmentosa* (Wahlenb.) Hedenäs
BYM060	17/01/2009	Cerro Negro	6239217/06100104	V	93	0	4	*Warnstorfia sarmentosa* (Wahlenb.) Hedenäs
BYM061	17/01/2009	Cerro negro area	6238345/06100395	III	80	0	4	*Warnstorfia sarmentosa* (Wahlenb.) Hedenäs
BYM062	17/01/2009	Cerro negro area	6238345/06100395	V	80	0	4	*Sanionia georgicouncinata* (Müll. Hal.) Ochyra
BYM063	17/01/2009	Nordic Plain	6238276/06100446	III	40	0	4	*Warnstorfia sarmentosa* (Wahlenb.) Hedenäs
BYM064	18/01/2009	Camp site	6239440/06105538	I	11	0	2	*Warnstorfia sarmentosa* (Wahlenb.) Hedenäs
BYM065	18/01/2009	Camp site	6239440/06105538	IV	11	0	4	*Warnstorfia sarmentosa* (Wahlenb.) Hedenäs
BYM066	18/01/2009	Camp site	6239344/06105512	II	12	0	2	*Warnstorfia sarmentosa* (Wahlenb.) Hedenäs
BYM067	18/01/2009	Camp site	6239453/06105482	II	11	0	2	*Sanionia georgicouncinata* (Müll. Hal.) Ochyra
BYM068	18/01/2009	Camp site	6239442/06105493	II	12	0	2	*Warnstorfia sarmentosa* (Wahlenb.) Hedenäs

APPENDIX 7.1 – (continued)

Sample	Sampling date	Site	GPS	F-value	Altitude (m)	Biotic influence	Habitat type	Dominant moss species in the sample
James Ross Island								
M1	10/02/2012	Lagoons Mesa	6357309/5754179	ND	264	0	4	*Hypnum revolutum* (Min.) Lindb.
M2	10/02/2012	Lagoons Mesa	6357264/5754287	ND	274	0	4	*Bryum pseudotriquetrum* Gärtner et al.
M3	10/02/2012	Lagoons Mesa	6357200/5754139	ND	260	0	4	ND
M4	10/02/2012	Lagoons Mesa	6357163/5754112	ND	255	0	4	ND
M21	11/02/2012	Lagoons Mesa	6358391/5753444	ND	22	0	4	ND
M22	11/02/2012	Lagoons Mesa	6358364/5753463	ND	17	0	4	*Bryum pseudotriquetrum* Gärtner et al.
M23	11/02/2012	Lagoons Mesa	6358216/5753581	ND	83	0	4	*Brachithecium austrosalebrosum* (C. Muell.) Kindb.
M24	11/02/2012	Lagoons Mesa	6358157/5754030	ND	111	0	4	*Distichium capillaceum* (Hedw.) Bruch & Schimp.
M25	11/02/2012	Lagoons Mesa	6358097/5754094	ND	154	0	4	ND
M26	12/02/2012	Lagoons Mesa	6358001/5754047	ND	181	0	4	*Syntrichia saxicola* (Card.) Zand.
M27	11/02/2012	Lagoons Mesa	ND	ND	ND	0	4	ND
V3M1	8/02/2012	Lagoons Mesa	6395931/5790226	ND	247	0	4	*Bryum pseudotriquetrum* Gärtner et al.
V3M2	8/02/2012	Lagoons Mesa	6395873/5790169	ND	247	0	4	ND
V3M3	8/02/2012	Lagoons Mesa	6357305/5754057	ND	245	0	4	*Schistidium antarcticii* (Card.) L. I. Savicz & Smirnova
M Black lake	12/02/2012	Lagoons Mesa	6357569/5752592	ND	222	0	4	*Bryum pseudotriquetrum* Gärtner et al.
M Anna pool	11/02/2012	Lagoons Mesa	6357543/5754378	ND	194	0	4	ND

APPENDIX 7.2 – List of all observed species with their acronyms in the investigated moss samples from James Ross Island and Livingston Island. Distribution: **C** – Cosmopolitan; **MA** – Maritime Antarctic Region; **A** – Antarctic Region; **U** – Unknown. Marine species are marked with an *****.

Taxon name	Acronyms	Distribution
Achnanthes coarctata (Brébisson) Grunow	AchCoa	C
Achnanthes muelleri Carlson	AchMue	A
Achnanthidium sp1	AchMin	MA
Achnanthidium sp2	AchMin2	MA
Achnanthidium exiguum (Grunow) D. B. Czarnecki	AchExg	C
Adlafia submuscora Van de Vijver et al.	AdlSms	MA
Halamphora sp1	AmpVen	MA
Halamphora oligotraphenta (Lange-Bertalot) Levkov	AmpOlg	C
Brachysira minor (Krasske) Lange-Bertalot	BraMin	MA
Caloneis bacillum (Grunow) Cleve	CalBac	C
Chamaepinnularia antarctica Van de Vijver et al.	ChaAnt	MA
Chamaepinnularia australomediocris (Lange-Bertalot & Schmidt) Van de Vijver	ChaAus	A
Chamaepinnularia gerlachei Van de Vijver & Sterken	ChaGer	MA
Chamaepinnularia krookii (Grunow) Lange-Bertalot & Krammer	ChaKrk	C
Chamaepinnularia krookiiformis (Krammer) Lange-Bertalot & Krammer	ChaKrf	C
Cocconeis spp.	Cocsp	*
Diadesmis arcuata (Heiden) Lange-Bertalot	DiaArcu	A
Diadesmis australis Van de Vijver & Sabbe	Dia Aus	MA
Diadesmis gallica Smith	DiaGal	C
Diadesmis inconspicua Kopalova & Van de Vijver	DiaInc	MA
Diadesmis langebertalotii Le Cohu & Van de Vijver	DiaLng	A
Diadesmis sp1	Diasp1	MA
Diadesmis sp2	Diasp2	MA
Diadesmis tabellariaeformis (Krasske) Lange-Bertalot & Wojtal	DiaTab	MA
Eolimna jamesrossensis Kopalova & Van de Vijver	EolJrs	MA
Eolimna minima (Grunow) Lange-Bertalot	EolMin	C
Eucocconeis sp.	Eucsp	U
Eunotia paludosa Grunow	EunPal	C
Eunotia sp.	Eunsp	MA
Fistulifera saprophila (Lange-Bertalot & Bonik) Lange-Bertalot	FisSap	C
Fragilaria capucina s.l. Desmazières	FraCap	C
Fragilariopsis nana (Steemann Nielsen) Paasche	FrgNan	*
Gomphonema spp	Gomsp	U
Gomphonemopsis sp.	Gmpsp	*
Hantzschia abundans Lange-Bertalot	HanAbu	C
Hantzschia amphioxys (Ehrenberg) Grunow	HanApx	C
Hantzschia confusa Van de Vijver & Zidarova	HanCon	MA
Hantzschia hyperaustralis Van de Vijver & Zidarova	HanHyp	MA
Hippodonta hungarica (Grunow) Lange-Bertalot, Metzeltin & Witkowski	HipHun	C
Licmophora sp.	Licmsp	*
Luticola amoena Van de Vijver, Kopalová, Zidarova & Levkov	LutAmo	MA
Luticola austroatlantica Van de Vijver, Kopalová, Spaulding & Esposito	LutAat	MA
Luticola cohnii (Hilse) Mann	LutCoh	C
Luticola doliiformis Kopalová & Van de Vijver	LutDlf	MA
Luticola evkae Kopalová	LutEvk	MA
Luticola gigamuticopsis Van de Vijver	LutGmu	MA
Luticola higleri Van de Vijver, Dam & Beyens	LutHig	MA

APPENDIX 7.2 – (continued)

Taxon name	Acronyms	Distribution
Luticola katkae Van de Vijver & Zidarova	LutKat	MA
Luticola muticopsis (Van Heurck) Mann	LutMut	A
Luticola nivalis (Ehrenberg) D.G.Mann	LutNiv	C
Luticola pusilla Van de Vijver, Kopalová, Zidarova & Levkov	LutPus	MA
Luticola sp1	Lutsp1	U
Luticola tomsui Kopalová	LutTms	MA
Luticola truncata Kopalová & Van de Vijver	LutTru	MA
Luticola vandevijveri Kopalová, Zidarova & Levkov	LutVdv	MA
Luticola vermeulenii Van de Vijver	LutVrm	MA
Mayamaea excelsa (Krasske) Lange-Bertalot	MayExc	C
Mayamaea josefelsterii Kopalová, Nedbalová & Van de Vijver	MayJos	MA
Mayamaea atomus (Hustedt) Bruder & Medlin	MayAtm	C
Mayamaea permitis (Hustedt) Bruder & Medlin	MayPer	C
Microcostatus australoshetlandicus Van de Vijver et al.	MicAsh	MA
Microcostatus naumannii (Hustedt) Lange-Bertalot	MicNau	C
Muelleria aequistriata Van de Vijver & Spaulding	MueAeq	MA
Muelleria algida Spaulding & Kociolek	MueAlg	MA
Muelleria austroatlantica Van de Vijver & Spaulding	MueAst	MA
Muelleria kristinae Van de Vijver	MueKrs	MA
Muelleria regigeorgiensis Van de Vijver & Spaulding	MueRgg	MA
Muelleria sabbei Van de Vijver & Spaulding	MueSab	MA
Muelleria sp1	MueNog	MA
Muelleria sp2	Muesp	U
Navicula australoshetlandica Van de Vijver	NavAsh	MA
Navicula bicephaloides Van de Vijver & Zidarova	NavBic	MA
Navicula cremeri Van de Vijver & Zidarova	NavCre	MA
Naviculadicta sp.	Ndicsp	U
Navicula dobrinatemniskovae Zidarova & Van de Vijver	NavDot	MA
Navicula gregaria Donkin	NavGre	C
Navicula sp.	Navsp	*
Navicula seibigeana (Ehrenberg) Ralfs	NavSbg	C
Nitzschia debilis (Arnott) Grunow	NitDeb	C
Nitzchia gracilis Hantzsch	NitGra	C
Nitzschia homburgensis Lange-Bertalot	NitHom	C
Nitzschia inconspicua Grunow	NitInc	C
Nitzschia paleacea Grunow	NitPlc	C
Nitzschia perminuta (Grunow) Peragallo	NItPer	U
Nitzschia cf. *vitrea* G.Norman	NItVit	U
Orthoseira roeseana (Rabenhorst) O'Meara	OrtRoe	C
Pinnularia australoborealis Van de Vijver & Zidarova	PinAbo	MA
Pinnularia australodivergens Zidarova et al.	PinAdi	MA
Pinnularia australoglobiceps Zidarova et al.	PunAglo	MA
*Pinnularia australomicrostauron*Zidarova et al.	PinAmic	MA
Pinnularia australorabenhorstii Van de Vijver	PinArab	MA
Pinnularia australoschoenfelderi Zidarova et al.	PinAsch	MA
Pinnularia austroshetlandica Carlson	PinAsh	A
Pinnularia borealis Ehrenberg	PinBor	C
Pinnularia borealis var. *pseudolanceolata* Van de Vijver & Zidarova	PinBorl	MA
Pinnularia magnifica Zidarova et al.	PinMag	MA
Pinnularia microcarteri Zidarova, Kopalová & Van de Vijver	PinMcr	MA
Pinnularia microstauroides Zidarova et al.	PinMcs	MA
Pinnularia obaesa Van de Vijver	PinOba	MA

APPENDIX 7.2 – (continued)

Taxon name	Acronyms	Distribution
Pinnularia perlanceolata Van de Vijver & Zidarova	PinPerl	MA
Pinnularia strictissima Manguin	PinStr	C
Pinnularia subaltiplanensis Zidarova et al.	PinSlt	MA
Pinnularia subantarctica var. *elongata* (Manguin) Van de Vijver & Le Cohu	PinSub	A
Placoneis australis Van de Vijver & Zidarova	PlaAus	MA
Planothidium australe (Manguin) R. Le Cohu	PltAus	A
Planothidium frequentissimum (Lange-Bertalot) Round & Bukhtiyarova	Pltfrq	C
Planothidium haynaldii (Schaarschmidt em. Cleve) Haw & Kelly	PltHay	C
Planothidium lanceolatum (Brébisson) Round & Bukhtiyarova	PltLan	C
Planothidium renei (Lange-Bertalot & Schmidt) Van de Vijver	PltRen	A
Planothidium rostrolanceolatum Van de Vijver & C.Wetzel	PltRL	MA
Psammothidium abundans (Manguin, Bourelly & Manguin) Bukhtiyarova	PsmAbu	A
Psammothidium aretasii (Manguin) Le Cohu	PsmArt	A
Psammothidium cf *germainii* (Manguin) Sabbe	PsmGer	A
Psammothidium incognitum (Krasske) Van de Vijver	PsmIng	A
Psammothidium manguinii (Hustedt) Van de Vijver	PsmMng	A
Psammothidium papilio (Kellogg et al.) Kopalová & Van de Vijver	PsmPap	MA
Psamothidium sp.	PsmRG	MA
Psammothidium subatomoides (Hustedt) Bukhtiyarova & Round	PsmSatm	C
Rhabdonema sp.	Rhasp	*
Sellaphora nana (Hustedt) Lange-Bertalot et al.	SelNan	C
Sellaphora seminulum (Grunow) Mann	SelSem	C
Stauroforma exiguiformis (Lange-Bertalot) Flower	StaExg	C
Stauroneis huskvikensis Van de Vijver & Lange-Bertalot	StrHus	MA
Stauroneis jarensis Lange-Bertalot et al.	StrJar	C
Stauroneis latistauros Van de Vijver & Lange-Bertalot	StrLat	A
Stauroneis obtusa Lagerstedt	StrObt	C
Stauroneis pseudomuriella Van de Vijver & Lange-Bertalot	StrPmu	A
Stauroneis pseudoschimanskii Van de Vijver & Lange-Bertalot	StrPsch	MA
Stauroneis subgracilior Lange-Bertalot et al.	StrSgla	C
Staurosira sp.	Strsp	MA
Staurosirella sp.	Strlsp	MA
Thalassiosira sp.	Thasp	*

CHAPTER 8

General discussion

A synthesis is made based on the observed diatom flora in the different sampled habitats on James Ross Island and Livingston Island, with specific attention for the taxonomy of the recorded diatom species, their biogeography and their ecology. During this study, three distinct habitat types (lakes, streams and seepage areas, mosses) were analysed, each characterised by specific diatom communities. Species accumulation curves are calculated to judge how completely the sampling effort represented the total diatom flora. Furthermore, the biogeography of the lake diatom flora observed in this thesis is put in a broader perspective and compared with diatom communities from other Antarctic localities (sub-Antarctic islands, Antarctic Continent), to evaluate the character of the diatom flora of the Maritime Antarctic Region.

General overview of the studied material

As stated in the introduction, the main objective of this thesis is the study of the actual diversity, ecology and biogeography of the diatom flora of two islands from the Maritime Antarctic Region, located on opposite sides of the Antarctic Peninsula: Livingston Island and James Ross Island. Therefore, a total of 250 samples has been analysed and in each sample a standard quantity of 400 diatom valves was counted (except stream and seepage samples where due to the specific nature of the samples, only 300 valves were counted), resulting in the observation of a total number of 178 diatom species used for further statistical and biogeographical analysis.

Three different habitats (lakes, streams and mosses) were sampled on both islands. An additional set of 13 samples from seepages were analysed from James Ross Island. Several new species were described and a reflection of this work is presented in chapters 2 & 3 and in Appendices. The analyses of the freshwater diatom communities are presented in chapters 4, 5 & 6 whereas moss-inhabiting diatoms are discussed in chapter 7. In some of the habitats, a series of physico-chemical variables was measured (when possible) to allow a specific determination of the ecological preferences of the observed diatom taxa. The obtained ecological information (especially the conductivity) of James Ross Island lake diatom communities was used to construct a transfer function, which might be interesting for further paleo-ecological studies in this area.

In several chapters, the diatom flora of both islands was compared with other localities from the Antarctic Region, to evaluate changes in diatom diversity and to gain insight into the biogeographical distribution patterns of diatoms.

Diatoms from Livingston Island and James Ross Island

The combined diatom flora of Livingston Island and James Ross Island obtained during the different studies revealed a total of 178 species belonging to 43 genera. At the end of this chapter, an overview is presented of all observed taxa, including 38 unidentified ones, together with their distribution in the Antarctic Region and their presence on the investigated islands (Appendix 8.1). The identification of the diatom taxa was based on the morphological features of their silica valves using light and scanning electron microscopy, thereby taking into account the natural variability within each taxon. Twelve taxa (6.8%) had a marine origin and were further not identified to the species level, as they fell outside the scope of this thesis. Fifteen unidentified taxa, such as for instance two taxa from the genus *Achnanthidium*, three unknown *Diadesmis* taxa, one *Halamphora* taxon and one *Muelleria* taxon, are currently under taxonomical revision and will be described as new species in due course. Also the genus *Gomphonema* present in the investigated samples is likely to form a complex of at least three and maybe even four new species and will be the subject of a more thorough morphological analysis. Figure 8.1 shows the biogeographical distribution of the diatom flora observed on Livingston Island and James Ross Island.

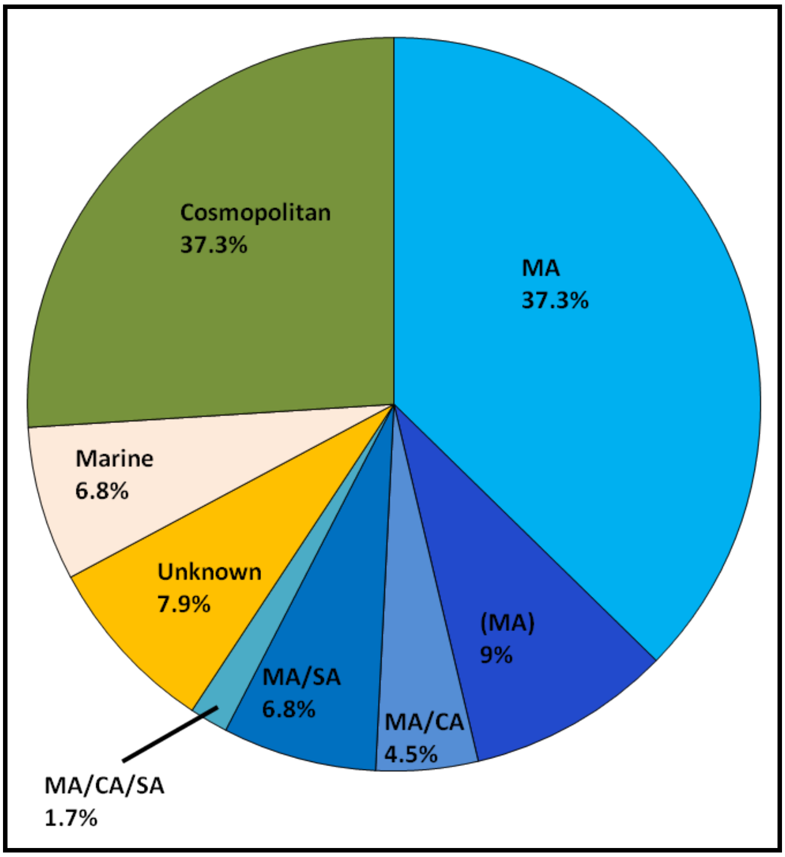

FIGURE 8.1 – Biogeographical distribution of the species recorded during this study. (MA = Maritime Antarctic Region, (MA) = Maritime Antarctic Region but yet undescribed, MA/CA = Maritime and Continental Antarctic Region, MA/SA = Maritime and Sub- Antarctic Region, MA/SA/CA = entire Antarctic Region).

Following the application of a more fine-grained taxonomy, it is clear that almost 60% of all observed taxa showed a restricted Antarctic distribution with a majority of 46.3% confined only to the Maritime Antarctic Region, whereas only 26% have a typical cosmopolitan distribution. The results also reveal that 4.5% of the observed species are only in common with the Antarctic Continent (MA/CA), 6.8 % only with the sub-Antarctic islands (MA/SA) and only 1.7% of the species are present within the entire Antarctic Region. This is in strong contrast to previous reports of the biogeographical features of the Antarctic diatom flora stating that a majority of the composing Antarctic diatom flora had a cosmopolitan nature (Jones et al. 1993, Van de Vijver & Beyens 1999a, Toro et al. 2007, Maidana & Vinocur 2010), a statement that based on our current knowledge can no longer be accepted. Similarities with the other parts of the Antarctic Region are quite low, contradicting the past ideas about the ubiquity of diatoms (Finlay & Clarke 1999).

Species composition

Figure 8.2 shows the most important genera (based on the number of recorded taxa) observed in the diatom flora of James Ross Island and Livingston Island. Despite clear differences in the composition between both islands, taxa from the genera *Luticola* and *Pinnularia* dominate. The most diverse genus on James Ross Island is obviously *Luticola*, whereas on Livingston Island *Pinnularia* counts the highest number of species. Within the subdominant genera such as *Diadesmis*, *Nitzschia* and *Stauroneis*, less differences can be noted, although the genus *Psammothidium* is more diverse on Livingston Island.

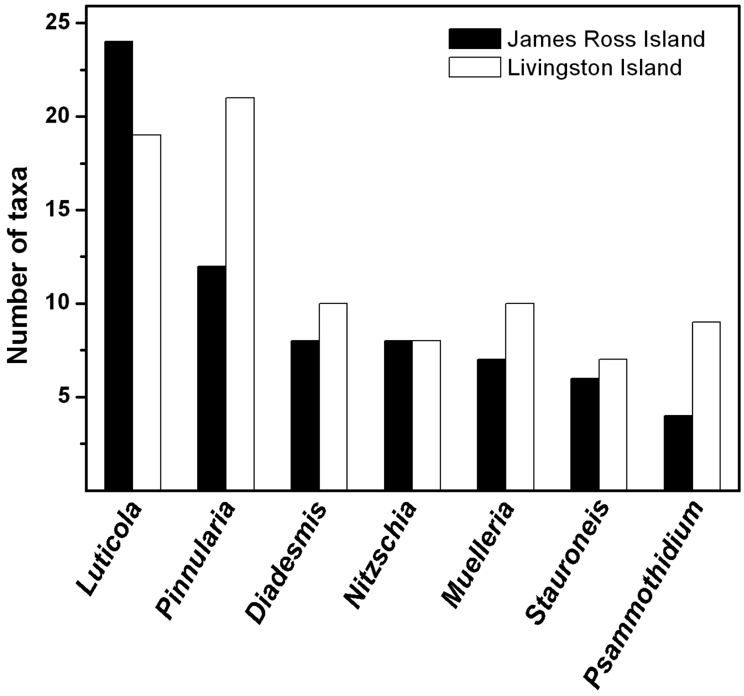

FIGURE 8.2 – The most important genera based on species richness on James Ross Island and Livingston Island.

The pattern observed in Fig. 8.2 is most likely the result of the general habitat characteristics of both islands. Semi-aquatic and moist terrestrial moss habitats, in which the genera *Pinnularia* and *Psammothidium* are often encountered (Krammer 2000, Van de Vijver et al. 2002a) are less abundantly present on James Ross Island, whereas on Livingston Island, this habitat is quite common. On the other hand, *Luticola* taxa are quite common in and on soil and barren grounds (Bock 1963, Levkov et al. in press) and are often also present on the sediment surface in Antarctic lakes. Compared to other parts of the Antarctic Region, the dominance of *Psammothidium* and *Pinnularia* on mosses is confirmed and even more distinct on the sub-Antarctic islands as this habitat is one of the most common in this region (Van de Vijver & Beyens 1997a, 1999a). On the Antarctic Continent, however, mosses are almost absent reducing the number of *Psammothidium* and *Pinnularia* species to only a few taxa (Sabbe et al. 2003).

TABLE 8.1 – Overview of the 10 most abundant diatom taxa based on whole dataset from James Ross Island and Livingston Island.

Diatom taxon	**total number of diatoms counted**	**total relative abundance (%)**
Nitzschia perminuta-complex	16508	17.4
Fragilaria capucina s.l.	7433	7.9
Nitzschia homburgiensis	6450	6.8
Nitzschia gracilis	5843	6.2
Gomphonema spp	3736	3.9
Nitzschia paleacea	3683	3.9
Psammothidium papilio	3321	3.5
Diadesmis arcuata	2666	2.8
Eolimna jamesrossensis	2644	2.8
Fistulifera saprophila	2208	2.3

The Sørensen similarity analysis indicates that the diatom floras of Livingston Island and James Ross Island show a 70% similarity whereas the similarity with other Antarctic localities is much lower (see chapters 5, 6 and 7).

TABLE 8.2 – Overview of the 10 most abundant diatom taxa given separately for James Ross Island and Livingston Island.

James Ross Island	total number of diatoms counted	total relative abundance (%)
Nitzschia perminuta-complex	8452	21.2
Nitzschia gracilis	3572	9
Nitzschia homburgiensis	3153	7.9
Eolimna jamesrossensis	2501	6.3
Fragilaria capucina s.l.	2225	5.6
Nitzschia paleacea	2024	5.1
Fistulifera saprophila/pelliculosa	1925	4.8
Mayamaea permitis	1795	4.5
Pinnularia borealis	1332	3.3
Hantzschia amphyoxis	1021	2.5

Livingston Island	total number of diatoms counted	total relative abundance (%)
Nitzschia perminuta-complex	8056	14.7
Fragilaria capucina s.l.	5208	9.5
Nitzschia homburgiensis	3297	6
Gomphonema spp	3093	5.6
Psammothidium papilio	2568	4.7
Nitzschia gracilis	2271	4.1
Diadesmis arcuata	1914	3.5
Psammothidium incognitum	1914	3.5
Nitzschia paleacea	1659	3
Chamaepinnularia krookiiformis	1643	3

Although the *Nitzschia perminuta*-complex (Grunow) Peragallo is not only clearly the overall most abundant taxon in the study but also the dominant diatom taxon on each of the studied islands separately, clear differences between the two islands can be noted when less frequent taxa are taken into account. Some taxa, such as *Eolimna jamesrossensis* Kopalová & Van de Vijver, *Fistulifera saprophila* (Lange-Bertalot & Bonik) Lange-Bertalot*, Mayamaea permitis* (Hustedt) Bruder & Medlin and *Pinnularia borealis* Ehrenberg dominate the flora on James Ross Island but do not appear among the ten most abundant taxa on Livingston Island, whereas *Psammothidium papilio* (Kellogg et al.) Kopalová & Van de Vijver, *Psammothidium incognitum* (Krasske) Van de Vijver, *Chamaepinnularia krookiiformis* (Krammer) Lange-Bertalot & Krammer, *Diadesmis arcuata* (Heiden) Lange-Bertalot and the *Gomphonema*-group dominate the species composition on Livingston Island. Table 8.1 shows the 10 most abundant diatom taxa encountered in all 250 samples, together with the total number of diatom valves per species and their corresponding relative abundances. Table 8.2 presents the same data but for each island separately.

Species diversity and accumulation curves

Species richness per sample ranged from 4 to 53 (Fig. 8.3). The average number of diatom taxa encountered in a sample for both islands together was 23 ± 10. The distribution of species number per sample clearly differs between both islands. The average number of taxa per sample on Livingston Island was 28 ± 9, whereas it was 17 ± 8 on James Ross Island. The highest numbers of taxa were mainly observed in lake samples from Livingston Island, in contrast, the lowest species richness was found mostly in samples from streams and seepages on James Ross Island, which can be probably explained by the unstable environment and ephemeral existence of these habitats.

The species richness is much lower than on the sub-Antarctic islands. For instance in moss samples on the Prince Edward Islands in the southern Indian Ocean, it ranged between 4 and 60 (Van de Vijver et al. 2008), whereas in soils on Ile de la Possession, the principal island of the Crozet Archipelago, the average number was 33 with a maximum of 84 in one sample (Van de Vijver et al. 2002d). On the other hand, on nearby Deception Island, Fermani et al. (2007) report a similar species richness as on Livingston Island while on the Antarctic Continent, the species richness per sample is much lower, even on aquatic sites (Gibson et al. 2006).

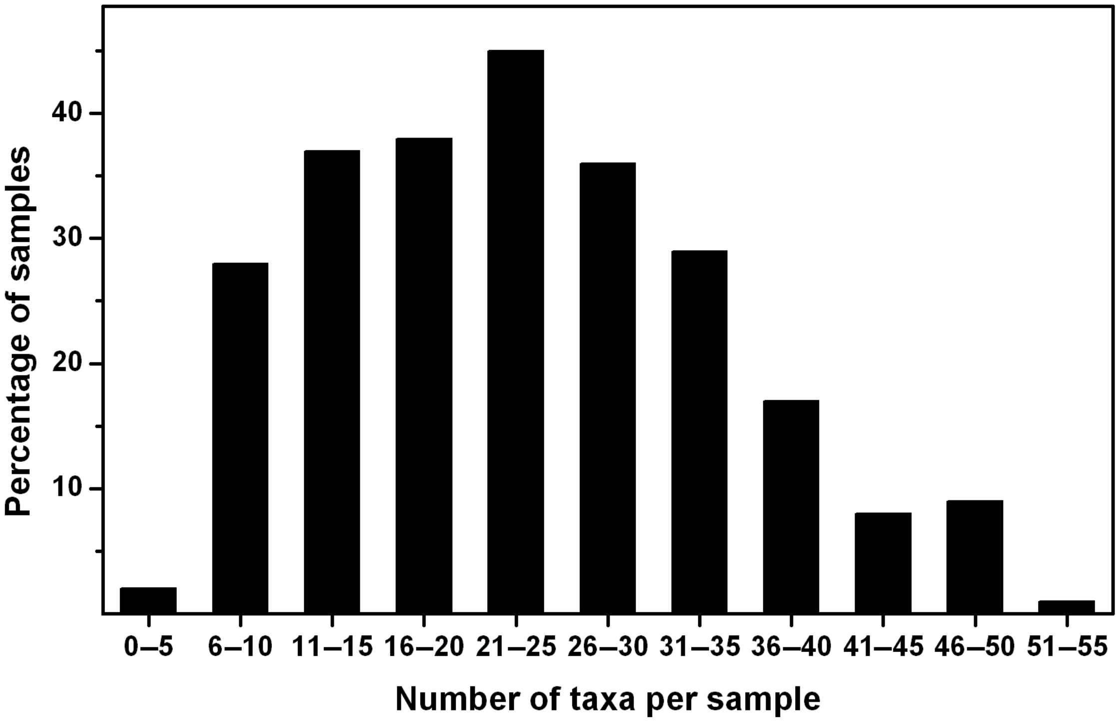

FIGURE 8.3 – Distribution of species richness per sample for the total sample set.

The Shannon-Wiener diversity ($\log_{10}$-based) of the studied samples ranged from 0.058 to 1.376 with a mean diversity per sample of 0.84 ± 0.29 and a median of 0.89. The evenness calculated for the studied samples ranged from 0.083 to 0.87 with a mean value 0.637 ± 0.16. The low diversity is not surprising for such a high latitude. It is generally accepted that a decreasing diversity trend when going southwards is clearly present in the Antarctic Region (Jones 1996, Van de Vijver & Beyens 1999a). This is confirmed by the similarity analysis in each of the previous chapters. One of the reasons for this decreasing diatom diversity is probably the lower variability in their (micro)-habitat. However, as can be seen in Table 8.3. species diversity and species evenness differ between habitats, although it is not clear what triggered this difference in diversity. In general, streams and seepages form a less diverse habitat type, which is clearly separated in my analysis from the other habitats (see chapter 4). This can be easily explained by its temporary character and high disturbance levels (Komárek & Elster 2008).

To evaluate the extent to which our sampling effort represented the diatom flora in the overall dataset and in the different habitats, the expected accumulation curves (sample based rarefaction curves; Colwell et al. 2009), the estimates of total species richness by means of an Incidence Based species richness Estimator (ICE; Chao et al. 2000) and the mean Chao2 richness estimator (Chao 1984), using the program EstimateS (Colwell 2013) have been calculated. The results of the sample based rarefaction curves are presented in Fig 8.4., whereas the estimates are shown in Table 8.4.

TABLE 8.3 – Diversity characteristics of different habitats.

	Lakes	Mosses	Streams/seepages
Mean diversity	0.9 ± 0.3	0.9 ± 0.23	0.6 ± 0.25
Mean evenness	0.6 ± 0.17	0.7 ± 0.11	0.6 ± 0.14
Species richness range	5–47	7–46	4–27
Number of samples	118	79	53

TABLE 8.4 – Estimates of total species richness (ICE) and mean richness estimates (Chao2) for the total sample set and the different habitats. Only species present in counts were added.

	Total	Lake samples	Moss samples	Streams/Seepages samples
Number of samples	250	118	79	53
Number of species	167	146	128	59
ICE	175	157	138	68
Chao2	173	153	137	75
% of max. richness (ICE)	95.4	92.9	92.7	86.7
% of max. richness (Chao2)	96.5	95.4	93.4	78.6

The flattening (towards the end) of the species accumulation curve for the total sample set indicates that a large part of the diatom flora has been collected (250 samples). Since it is always possible that new species might be introduced to the islands or some microhabitats were not sampled, no matter how many samples have been collected and counted, this species accumulation curve will never be completely flat. The estimation of the expected total species richness of the diatom flora of the total sample set and the different sampled habitats on the island suggests that between 78.6% and 96.5 % of all (theoretically present) species were represented in the studied sample set (Table 8.4).

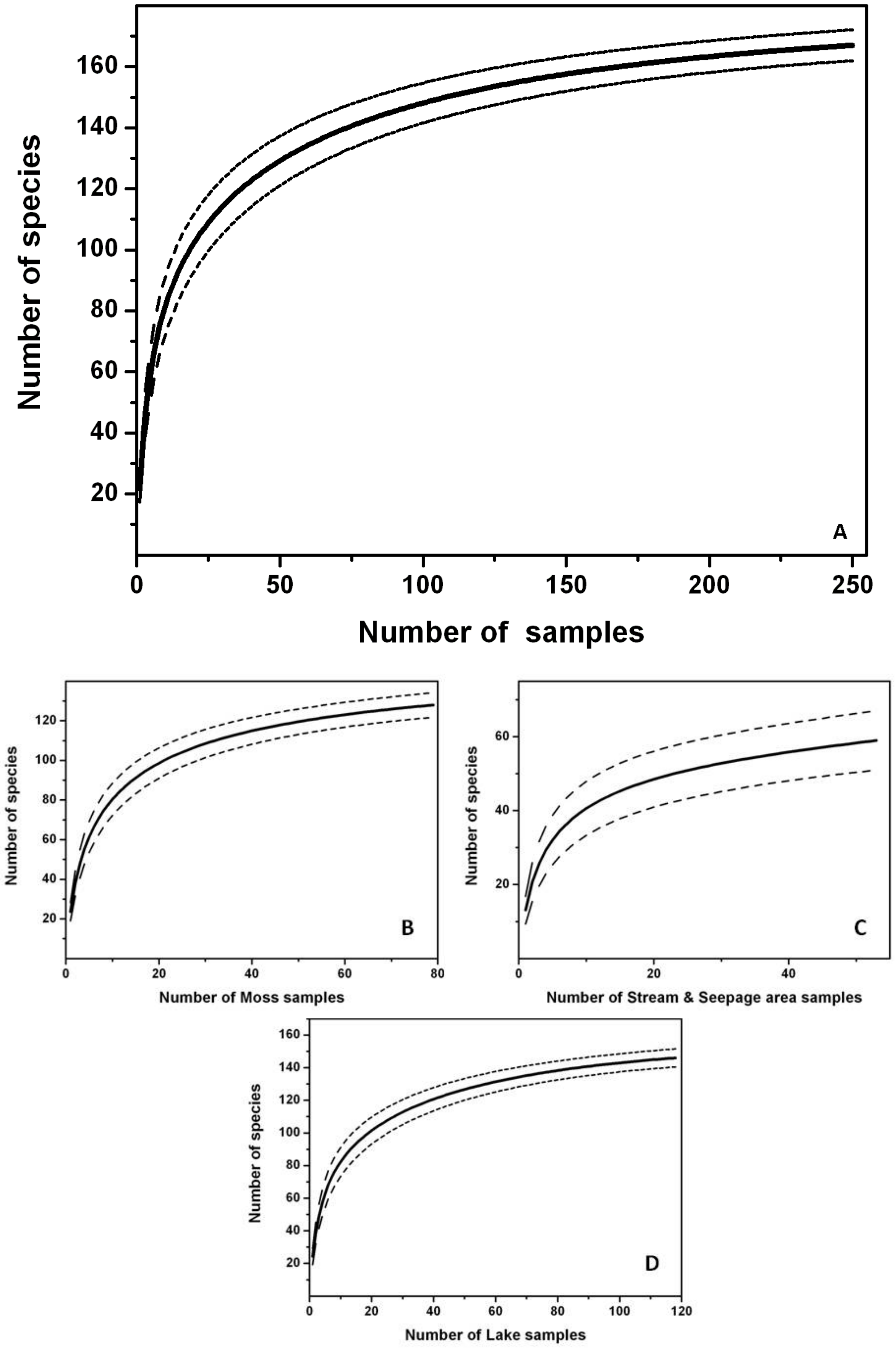

FIGURE 8.4 – Expected species accumulation curves (sample based rarefaction curves for the total sample set **(A).** the moss samples **(B)**. the stream & seepage samples **(C)** and the lake samples **(D)**. Each time the 95% confidence interval is given.

Based on the results of the species accumulation curves, it is possible to have an idea of the number of species that might be found when the sampling effort would be higher, however, the data do not give an indication of the total number of species that is present on the islands, but only a theoretical number based on the sample set. For each habitat, a doubling of the number of samples would reveal only ± 10 extra species, it means that for the total sampling set, the theoretical analysis of 500 samples might bring an extra 30 species. All these estimations are very approximate, but most probably the results presented in this thesis cover more than 95% of the present diatom species richness, although the sampled habitats do not contain the same amount of samples.

Comparison of communities on both islands

Although Livingston Island and James Ross Island both seem to belong to the Maritime Antarctic Region as will be shown below, the diatom communities on both islands also show some differences. A Principal Component Analysis (PCA) based on species composition was performed in Canoco 4.5 (ter Braak & Šmilauer 2002) of Hellinger transformed data and the samples from the three investigated habitats were differently labelled to visualize differences in diatom community structure between the different habitats (Fig. 8.5). A similarity profile routine (SIMPROF) in Primer-E 6.0 program (Clarke & Gorley 2006) was run to assess the significance of the groups identified in the ordination.

Two conclusions can be drawn from this analysis. First, it is clear that the communities of both islands are separated from each other with only a very sparse overlap. Considering the previous analyses and results obtained in the diversity and similarity analysis, this is not surprising. Secondly, it is clear that on James Ross Island, the habitats are separated from each other while on Livingston Island, moss samples and lake samples are intermixed. This is not surprising since most moss samples on Livingston Island were taken in or nearby larger lakes. On James Ross Island, almost no moss samples originate from lakes. On James Ross Island, there is a clear difference between seepage/stream samples and lake samples. Unfortunately, it was not possible to test this for Livingston Island as no samples were available from the seepage/stream habitat on this island. Further research (including new sampling) will be necessary to verify whether the habitat is really different in the Maritime Antarctic Region.

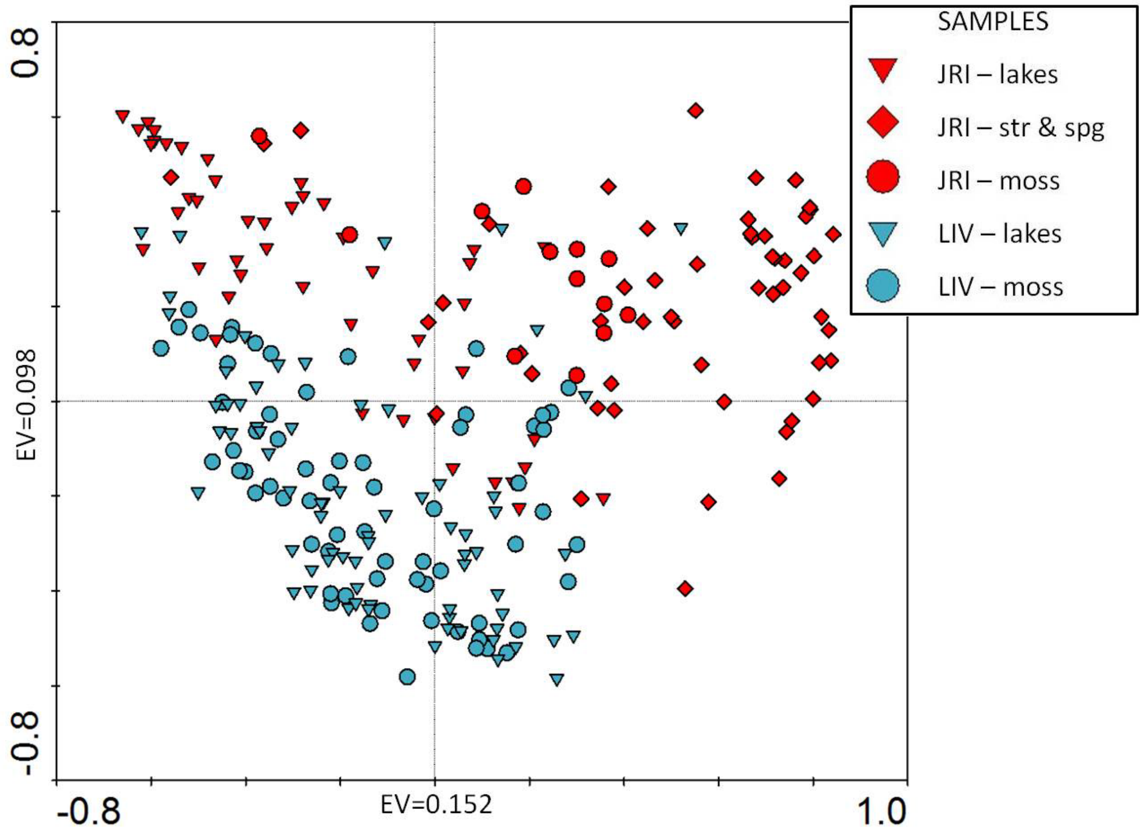

FIGURE 8.5 – PCA analysis of all samples of Livingston Island (LIV) and James Ross Island (JRI). The three habitats on the islands are differently labelled. Streams and seepages indicated as 'str & spg'.

Waterbodies and moss vegetation create important habitat in the Antarctic Region, and the results of my study show obvious differences in diatom species composition between these habitats (Table 8.5). These differences are based not only on the number of taxa present in the habitats, but also on their relative abundances. In contrast to lake ecosystems from sub-Antarctic Islands (Van de Vijver et al. 2008), Table 8.5 clearly shows that the diatom flora of lakes, representing the most diverse habitat, is led by the *Nitzschia perminuta*-complex, followed by *Nitzschia homburgiensis* Lange-Bertalot, *Fragilaria capucina* s.l. Desmazières and *Nitzschia paleacea* Grunow as dominant species, whereas *Nitzschia paleacea* is not present in streams and seepages and the other species appear only in lower relative abundances.

As was already shown in chapter 4, the species composition of streams and seepages is dominated by *Nitzschia gracilis* Hantzsch and especially by *Eolimna jamesrossensis* that do not occur in mosses at all and play an insignificant role in lakes. On the other hand, for example *Psammothidium incognitum, Psammothidium germanii* Manguin Sabbe - rostrate form and *Navicula dobrinatemniskovae* Zidarova & Van de Vijver, do not occur in stream and seepage samples at all. Moss habitats contain a lot of Maritime Antarctic endemic species belonging to typical terrestrial genera such as *Luticola* and *Diadesmis*.

TABLE 8.5 – Relative abundances of the most important species representing different habitats. Streams and seepages indicated as 'str/spg'.

Taxon name	overall	lakes			mosses			str/spg
		all lake samples	James Ross Island	Livingston Island	all moss samples	James Ross Island	Livingston Island	James Ross Island
Brachysira minor	1.48	0.89	0.14	0.75	0.55	-	0.55	0.04
Diadesmis arcuata	2.82	0.74	0.04	0.69	**1.76**	0.43	1.33	0.32
Diadesmis australis	1.37	**1.02**	0.83	0.19	0.35	0.18	-	-
Diadesmis inconspicua	1.44	0.45	0.13	0.32	0.73	0.20	0.54	0.26
Diadesmis sp.	0.76	0.76	0.23	0.53	-	-	-	-
Eolimna jamesrossensis	2.79	0.14	0.01	0.12	0.03	-	0.03	**2.62**
Fistulifera saprophila/pelliculosa	2.33	0.35	0.07	0.28	0.03	0.01	0.02	1.95
Fragilaria capucina s.l.	7.85	**3.32**	0.27	3.05	**2.45**	-	2.45	**2.08**
Gomphonema spp	3.95	**2.15**	0.58	1.57	**1.71**	0.02	1.70	0.08
Hantzschia abundans	0.66	0.08	0.06	0.02	0.39	0.36	0.02	0.19
Hantzschia amphyoxis	1.15	0.09	0.07	0.02	0.65	0.59	0.06	0.41
Chamaepinnularia krookiiformis	1.78	0.52	0.02	0.50	**1.25**	0.01	1.23	0.01
Luticola austroatlantica	0.65	0.042	0.03	0.01	0.16	0.11	0.05	0.45
Luticola muticopsis	0.77	0.08	0.04	0.05	0.22	0.16	0.06	0.47
Mayamaea atomus	0.24	0.05	0.05	0.001	0.01	-	0.01	0.18
Mayamaea permitis	2.32	**1.14**	0.73	0.41	0.08	0.07	0.01	1.10
Navicula dobrinatemniskovae	1.46	**1.16**	-	1.16	0.30	-	0.30	-
Nitzschia gracilis	6.17	**2.01**	0.67	1.34	**1.06**	-	1.06	3.10
Nitzschia homburgiensis	6.81	**4.65**	2.34	2.31	**1.40**	0.22	1.18	0.76
Nitzschia inconspicua	1.06	0.80	0.53	0.27	0.26	0.02	0.25	-
Nitzschia paleacea	3.89	**3.27**	2.14	1.13	0.62	-	0.62	-
Nitzschia perminuta-complex	17.44	**11.60**	7.18	4.42	**4.58**	0.49	4.09	1.25
Pinnularia borealis	1.77	0.09	0.02	0.07	**1.65**	1.36	0.29	0.03
Pinnularia subantarctica var. elongata	0.84	0.18	-	0.18	0.66	-	0.65	-
Planothidium australe	1.06	0.77	-	0.77	0.28	-	0.28	0.001
Planothidium rostrolanceolatum	1.70	0.83	0.02	0.81	**0.87**	-	0.87	0.001
Psammothidium incognitum	2.02	0.23	-	0.23	**1.79**	-	1.79	-
Psammothidium papilio	3.51	**2.60**	0.72	1.89	0.86	0.04	0.82	0.04
Psamothidium germanii-rostrate form	1.03	0.17	-	0.17	0.86	0.04	0.82	-
Stauroneis latistauros	0.45	0.29	0.24	0.04	0.01	-	0.01	0.15

While one of the initial subjects of this thesis was the question whether specific habitats would be characterized by particular groups of diatoms, it is already clear, as can be seen in

Table 8.5 and the previous chapters, that some diatom taxa tolerate a broad range of habitat characteristics whereas others show more restricted habitat preferences. Based on the latter, usually subdominant taxa, it is possible to characterize the different habitats.

Biogeographical position of the diatom flora within the Antarctic Region

To assess the position of the diatom flora of James Ross Island and Livingston Island in the whole Antarctic Region, the obtained data of 118 lakes from Livingston Island and James Ross Island were finally added to the global Antarctic diatom database that has been constructed during the past few years (Verleyen et al., unpublished results) and used in a PCA analysis to visualize the biogeographical position of the two islands in the Antarctic Region (Fig. 8.6). This database contains so far the diatom counts of more than 500 lakes sampled on various localities in the Antarctic Region ranging from the sub-Antarctic islands in the southern Indian Ocean to several Maritime Antarctic sites and the Antarctic Continent (mainly sites in East-Antarctica such as the Larsemann Hills and the Rauer Islands). All data were obtained during previous diatom studies (e.g. Van de Vijver et al. 2001, 2002a; Verleyen et al. 2003, Sterken et al. 2012). To allow a biogeographical analysis on a broad scale, the diatom taxonomy in all the investigated samples has been made entirely consistent based on the latest taxonomic results.

The new results collected during the present PhD study added valuable information to this database as recent reliable data from the Maritime Antarctic Region were missing so far. The database was then analysed using Principal Component Analysis (PCA) performed by the computer program Primer-E 6.0 program (Clarke & Gorley 2006) on two different taxonomic levels: species and genus level. The results are shown in Figs 8.6 and 8.7. The diagrams show clearly the separation of the three main sub-regions within the Antarctic Region as defined by Chown & Convey (2007). Each sub-region, i.e. Continental Antarctica, Maritime Antarctica and Sub-Antarctica, is characterised by its own typical diatom flora showing a high degree of endemism and specific diatom communities.

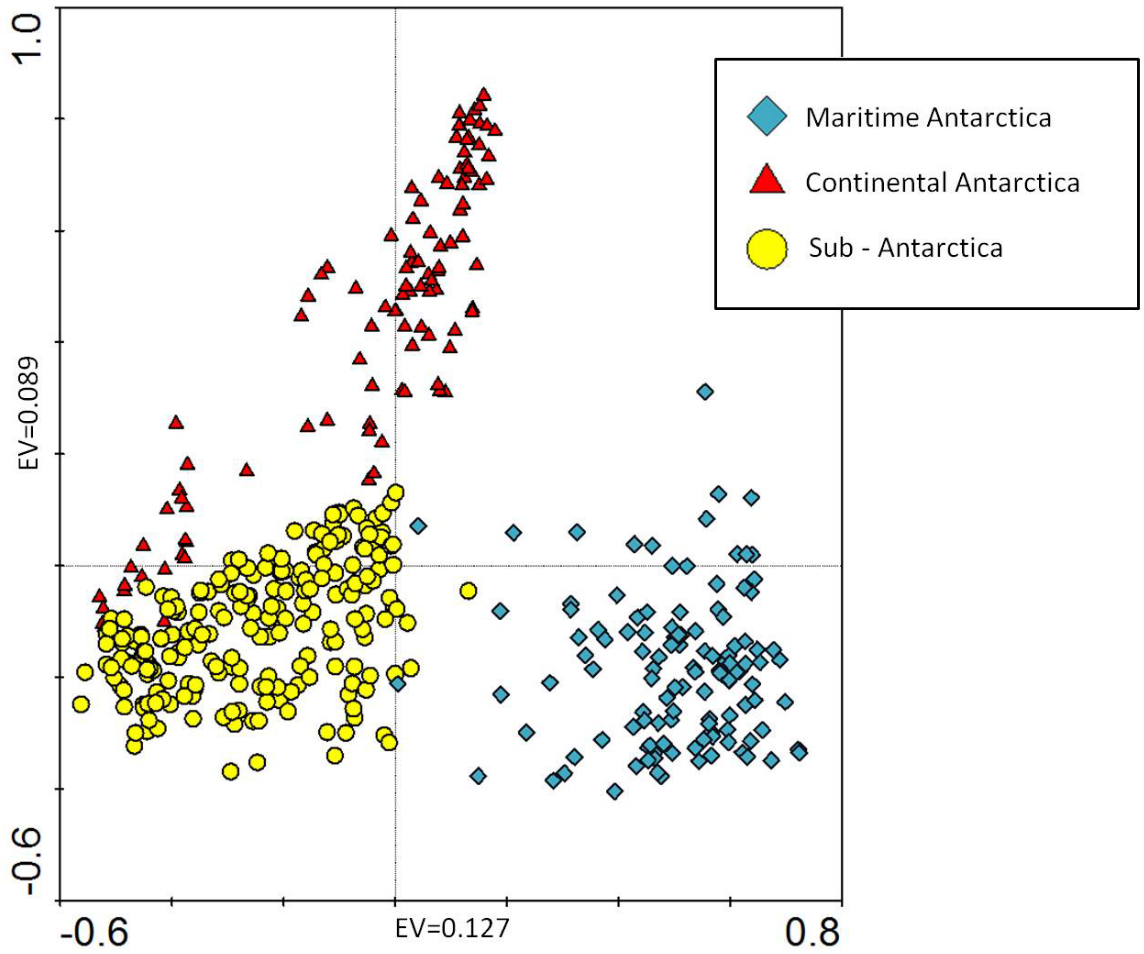

FIGURE 8.6 – PCA analysis performed on species level showing the separation of the three main sub-regions within the Antarctic Region defined by Chown & Convey (2007). Samples from Maritime Antarctica present data obtained during my PhD on James Ross Island and Livingston Island. Sub-Antarctica contains samples from Iles Crozet, Prince Edward Islands, Heard Island, Iles Kerguelen and South Georgia. Continental Antarctica contain samples from a.o. The Larsemann Hills, Rauer Islands and Schirmacher Oasis.

Considering the recent diatom research efforts in this region, this result is hardly surprising. As previously stated, a thorough revision of the diatom flora of the Antarctic Region started in the past few years. In each region, this led to the description of a large number of new taxa usually showing a very restricted and even endemic distribution (e.g. Kopalová et al. 2011, Van de Vijver et al. 2010a, 2011a, Zidarova et al. 2010, 2012). Detailed morphological investigations have indeed shown that a major part of the so-called cosmopolitan diatom taxa on the species lists should be replaced in fact by Antarctic taxa. These results clearly contradicted the generally accepted theories in microbial biogeography (Finlay 2002) that predicted that polar habitats should share the same microbial communities since allopatric speciation is expected to be rare among micro-organisms as a result of their unlimited dispersal capacities (Finlay 2002). If this theory had proven to be correct for the Antarctic diatom flora, this would have resulted in a non-structured scattering of the lake samples in the diagram, preventing any biogeographical clustering of the different regions. The multivariate analysis revealed, however, that the geographical structuring of the diatom biodiversity is similar to that of macroscopic organisms (Chown & Convey 2007). Various studies on multicellular organisms, such as lichen, tardigrade and dipteran species have shown that approximately 50% of the fauna is endemic to Antarctica as are the majority of mites and springtails and possibly all nematodes (Allegrucci et al. 2006. Stevens et al. 2007, Convey et al. 2008).

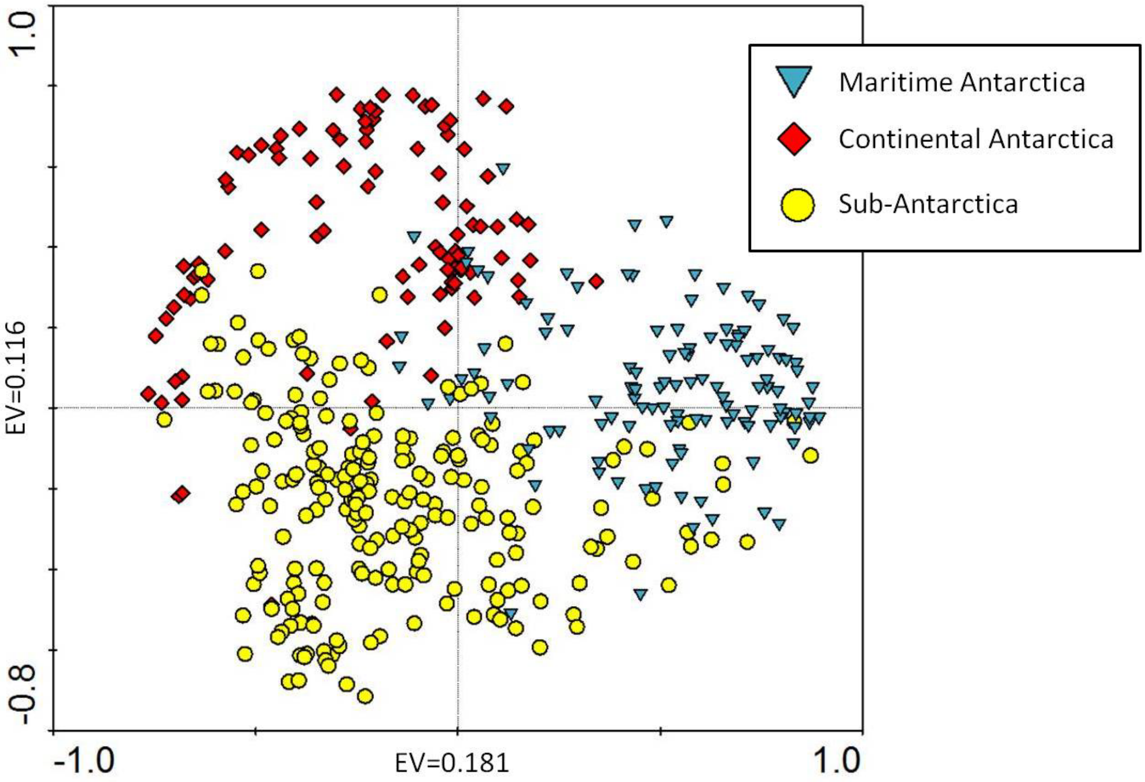

FIGURE 8.7 – PCA analysis performed on genus level showing the separation of the three main sub-regions within the Antarctic Region defined by Chown & Convey (2007). Samples from Maritime Antarctica present data obtained during my PhD on James Ross Island and Livingston Island. Sub-Antarctica contains samples from Iles Crozet, Prince Edward Islands, Heard Island, Iles Kerguelen and South Georgia. Continental Antarctica contain samples from a.o. The Larsemann Hills, Rauer Islands and Schirmacher Oasis.

It should nevertheless be noted that the obtained estimate of endemism in Antarctic diatoms is rather conservative since based on classical morphological analyses and a rather narrow species concept. The separation of taxa can therefore be judged as rather subjective. However, given the widespread presence of (pseudo)cryptic species in diatoms (Beszteri et al. 2007, Evans et al. 2008), molecular phylogenetic analyses have been recently applied to some ubiquitous taxa found in the Antarctic Region. One such study revealed the occurrence of a substantial cryptic diversity within the globally distributed morphospecies *Pinnularia borealis* Ehrenberg (Souffreau et al. 2013). In this paper, the time-calibrated phylogeny clearly confirmed that the continental Antarctic strains of this cosmopolitan species belonged to a separate lineage that diverged 7.67 Ma ago from its closest relatives. This observation might indeed point to a (large) underestimation of the endemicity of the Antarctic diatom flora. As long as the complete Antarctic diatom flora will not be analysed on the molecular level, it will be difficult to entirely understand its biogeographical patterns.

On the other hand, using the potentially subjective narrower species concept may also overemphasize our current ideas on the biogeography of the Antarctic diatom flora. In order to overcome this semblance of subjectivity, the data were also analysed on a higher taxonomic level: species were assigned to genera according to the most up-to-date classification (Fourtanier and Kociolek 2011). Nevertheless, the PCA analysis showed the same separation of the three sub-regions defined by Chown & Convey (2007) (Fig. 8.7).

OVERALL CONCLUSIONS

This thesis focused on the ecological characterisation of aquatic, semi-aquatic and moss-inhabiting diatom communities from two Maritime Antarctic islands (James Ross Island and Livingston Island) located in the Antarctic Peninsula Region.

Main results:

- In total, 250 samples were analysed and 178 diatom taxa were identified during this PhD study.
- The different investigated habitats on James Ross Island and Livingston Island (lakes, mosses, seepages and streams) were studied and a clear relationship between the diatom communities and their habitats was found.
- Both islands are inhabited by a unique diatom flora not only within the entire Antarctic Region but more specifically also in the Maritime Antarctic Region itself.
- A large number of endemic species were observed and several new species were described.
- The comparative analysis of the diversity and composition of the diatom communities of the two different island resulted in a clear separation, showing an influence of the Antarctic Continent in shaping their diatom composition.
- The biogeographical analysis of the position of the two island in the entire Antarctic Region clearly confirmed their position in the Maritime Antarctic Region with a specific and diverse diatom flora showing a high degree of local endemicity.

This PhD research means a further step forward in our attempt to unravel the ecological and biogeographical characteristics of the entire Antarctic diatom flora. Although only two islands were taken into consideration, the obtained results will hopefully be of high value for further biogeographical, ecological and paleo-ecological research within the Antarctic region and also proved that the study of the actual taxonomy and biodiversity of the Antarctic diatom flora is important and valuable.

APPENDIX 8.1 – List of all observed species in the investigated samples from James Ross Island and Livingston Island. Distribution: C – Cosmopolitan; MA – Maritime Antarctic Region; (MA) – Maritime Antarctic Region but yet undescribed; A – Antarctic Region; MA/CA – Maritime and Continental Antarctic Region; MA/SA – Maritime and Sub- Antarctic Region; MA/SA/CA – entire Antarctic Region); U – Unknown. Marine species are marked with an *.

Taxon name	**Distribution**		
	Region	**Livingston Island**	**James Ross Island**
**Achnanthes* sp1	*	x	x
Achnanthes coarctata (Brébisson) Grunow	C	x	x
Achnanthes muelleri Carlson	MA/SA	x	x
Achnanthes taylorensis D.E.Kellogg Stuiver T.B.Kellogg & G.H.D.Denton	MA/CA		x
Achnanthidium exiguum (Grunow) D. B. Czarnecki	C	x	x
Achnanthidium lailae Van de Vijver	MA		x
Achnanthidium sp1	(MA)	x	
Achnanthidium sp2	(MA)	x	
Adlafia submuscora Van de Vijver Kopalová Zidarova & Cox	MA	x	x
Brachysira minor (Krasske) Lange-Bertalot	MA	x	x
Caloneis bacillum (Grunow) Cleve	C	x	x
Cavinula pseudoscutiformis (Hustedt) D.G.Mann & Stickle	C		x
Chamaepinnularia antarctica Van de Vijver Kopalová Zidarova & Cox	MA	x	x
Chamaepinnularia australomediocris (Lange-Bertalot & R.Schmidt) Van de Vijver	MA/SA	x	x
Chamaepinnularia gerlachei Van de Vijver & Sterken	MA	x	x
Chamaepinnularia krookii (Grunow) Lange-Bertalot & Krammer	C	x	
Chamaepinnularia krookiiformis (Krammer) Lange-Bertalot & Krammer	C	x	x
Chamaepinnularia sp1	U	x	x
**Cocconeis* spp	*	x	x
**Coscinodiscus* sp1	*		x
Craticula antarctica Van de Vijver & Sabbe	MA/CA	x	x
Craticula glaberrima (W. & G.S. West) Van de Vijver Kopalová Zidarova & Cox	MA/CA		x
Craticula subpampeana Van de Vijver & Sterken	MA		x
Denticula rainierensis Sovereign	C		x
**Denticula* sp.	*	x	
Diadesmis arcuata (Heiden) Lange-Bertalot	MA/SA	x	x
Diadesmis australis Van de Vijver & Sabbe	MA	x	x
Diadesmis gallica W.Smith	C		x
Diadesmis inconspicua Kopalová & Van de Vijver	MA	x	x
Diadesmis langebertalotii Le Cohu & Van de Vijver	MA/SA	x	
Diadesmis sp1	(MA)	x	x
Diadesmis sp2	(MA)	x	x
Diadesmis sp3	(MA)	x	x
Diadesmis sp4	U	x	
Diadesmis sp5	U	x	x
Diadesmis tabellariaeformis (Krasske) Lange-Bertalot & Wojtal	MA	x	
Eolimna jamesrossensis Kopalová & Van de Vijver	MA	x	x
Eolimna minima (Grunow) Lange-Bertalot	C	x	x
Eunotia paludosa Grunow	C	x	
Eunotia sp1	(MA)	x	
Fistulifera saprophila (Lange-Bertalot & Bonik) Lange-Bertalot	C	x	x
Fragilaria capucina s.l. Desmazières	C	x	x

APPENDIX 8.1 – (continued)

Taxon name	Distribution		
	Region	Livingston Island	James Ross Island
**Fragilariopsis nana* (Steemann Nielsen) Paasche	*	x	x
**Fragilariopsis* sp.	*		x
Geissleria gabrielae Van de Vijver & Zidarova	MA	x	x
Gomphonema spp	(MA)	x	x
**Gomphonemopsis* sp.	*	x	
Halamphora oligotraphenta (Lange-Bertalot) Levkov	C	x	x
Halamphora sp1	(MA)	x	
Hantzschia abundans Lange-Bertalot	C	x	x
Hantzschia acuticapitata Zidarova & Van de Vijver	MA	x	
Hantzschia amphioxys (Ehrenberg) Grunow	C	x	x
Hantzschia confusa Van de Vijver & Zidarova	MA	x	x
Hantzschia hyperaustralis Van de Vijver & Zidarova	MA/CA	x	x
Hantzschia incognita Zidarova & Van de Vijver	MA	x	
Hippodonta hungarica (Grunow) Lange-Bertalot. Metzeltin & Witkowski	C	x	
**Licmophora* sp.	*	x	
Luticola amoena Van de Vijver. Kopalová. Zidarova & Levkov	MA	x	x
Luticola australomutica Van de Vijver	MA	x	x
Luticola austroatlantica Van de Vijver. Kopalová. S.A.Spaulding & Esposito	MA/CA	x	x
Luticola caubergsii Van de Vijver	MA	x	x
Luticola cf. *nivalis* (Ehrenberg) D.G.Mann	C	x	x
Luticola cohnii (Hilse) D.G.Mann	C	x	x
Luticola desmetii Kopalova & Van de Vijver	MA		x
Luticola doliiformis Kopalová & Van de Vijver	MA		x
Luticola evkae Kopalová	MA		x
Luticola gaussii (Heiden) D.G.Mann	MA/CA		x
Luticola gigamuticopsis Van de Vijver	MA	x	x
Luticola higleri Van de Vijver. Van Dam & Beyens	MA	x	x
Luticola katkae Van de Vijver & Zidarova	MA	x	x
Luticola muticopsis (Van Heurck) D.G.Mann	MA/CA/SA	x	x
Luticola muticopsis f. *reducta* W.& G.S. West	MA/CA/SA	x	
Luticola muticopsis f. *revoluta* W.& G.S. West	MA/CA/SA		x
Luticola permuticopsis Kopalová & Van de Vijver	MA	x	x
Luticola pusilla Van de Vijver. Kopalová. Zidarova & Levkov	MA	x	x
Luticola quadriscrobiculata Van de Vijver	MA	x	
Luticola sp1	U	x	x
Luticola sp2	U		x
Luticola sp3	U		x
Luticola sp4	U		x
Luticola tomsui Kopalová	MA		x
Luticola truncata Kopalová & Van de Vijver	MA	x	x
Luticola vandevijveri Kopalová. Zidarova & Levkov	MA	x	x
Luticola vermeulenii Van de Vijver	MA	x	x
Mayamaea atomus (Hustedt) Bruder & Medlin	C	x	x
Mayamaea excelsa (Krasske) Lange-Bertalot	C		x
Mayamaea josefelsterii Kopalová Nedbalová & Van de Vijver	MA	x	x
Mayamaea permitis (Hustedt) Bruder & Medlin	C	x	x

APPENDIX 8.1 – (continued)

Taxon name	Distribution		
	Region	Livingston Island	James Ross Island
Mayamaea sp.	U	x	x
*Microcostatus australoshetlandicus*Van de Vijver. Kopalová. Zidarova & Cox	MA	x	
Microcostatus naumannii (Hustedt) Lange-Bertalot	C	x	x
Muelleria aequistriata Van de Vijver & S.A.Spaulding	MA	x	
Muelleria algida S.A.Spaulding & Kociolek	MA	x	
Muelleria austroatlantica Van de Vijver & S.A.Spaulding	MA	x	
Muelleria kristinae Van de Vijver	MA	x	
Muelleria luculenta S.A.Spaulding & Stoermer	MA/SA	x	x
Muelleria regigeorgiensis Van de Vijver & S.A.Spaulding	MA	x	x
Muelleria rostrata Van de Vijver & S.A.Spaulding	MA	x	
Muelleria sabbei Van de Vijver & S.A.Spaulding	MA	x	x
Muelleria sp1	U		x
Muelleria sp2	(MA)		x
Muelleria sp3	U	x	x
Muelleria tumida Van de Vijver & S.A.Spaulding	MA	x	
Muelleria variolata S.A.Spaulding & Kociolek	MA		x
Navicula australoshetlandica Van de Vijver	MA	x	
Navicula bicephaloides Van de Vijver & Zidarova	MA	x	
Navicula cremeri Van de Vijver & Zidarova	MA	x	x
Navicula dobrinatemniskovae Zidarova & Van de Vijver	MA	x	
Navicula gregaria Donkin	C	x	x
Navicula seibigeana (Ehrenberg) Ralfs	C	x	x
**Navicula* spp	*	x	x
Neidium nyvltii Hamilton de Haan Kopalová Zidarova & Van de Vijver	MA		x
Nitzschia cf. *pusilla* Grunow	C	x	x
Nitzschia cf. *vitrea* G.Norman	U	x	
Nitzschia commutata Grunow	C		x
Nitzschia debilis (Arnott) Grunow	C	x	x
Nitzchia gracilis Hantzsch	C	x	x
Nitzschia homburgiensis Lange-Bertalot	C	x	x
Nitzschia inconspicua Grunow	C	x	x
Nitzschia paleacea Grunow	C	x	x
Nitzschia perminuta (Grunow) Peragallo	U	x	x
Orthoseira roeseana (Rabenhorst) O'Meara	C	x	x
Pinnularia australoborealis Van de Vijver & Zidarova	MA	x	x
Pinnularia australodivergens Zidarova. Kopalová & Van de Vijver	MA	x	x
Pinnularia australoglobiceps Zidarova. Kopalová & Van de Vijver	MA	x	
*Pinnularia australomicrostauron*Zidarova. Kopalová & Van de Vijver	MA	x	x
Pinnularia australorabenhorstii Van de Vijver	MA	x	x
Pinnularia australoschoenfelderi Zidarova Kopalová & Van de Vijver	MA	x	x
Pinnularia austroshetlandica Carlson	MA/SA	x	
Pinnularia borealis Ehrenberg	C	x	x
Pinnularia borealis var. *pseudolanceolata* Van de Vijver & Zidarova	MA	x	x
Pinnularia cf. *krammeri* Metzeltin	U	x	
Pinnularia laterotundata Van de Vijver & Zidarova	MA		x

APPENDIX 8.1 – (continued)

Taxon name	Distribution		
	Region	**Livingston Island**	**James Ross Island**
Pinnularia magnifica Zidarova Kopalová & Van de Vijver	MA	x	
Pinnularia microcarteri Zidarova Kopalová & Van de Vijver	MA	x	
Pinnularia microstauroides Zidarova Kopalová & Van de Vijver	MA	x	
Pinnularia obaesa Van de Vijver	MA	x	
Pinnularia perlanceolata Van de Vijver & Zidarova	MA	x	x
Pinnularia quesadae Van de Vijver & Zidarova	MA	x	
Pinnularia rabenhorstii Hilse	C	x	
Pinnularia sergiplaiana Zidarova. Kopalová & Van de Vijver	MA	x	
Pinnularia splendida Hustedt	MA/SA		x
Pinnularia strictissima Manguin	C	x	x
Pinnularia subaltiplanensis Zidarova Kopalová & Van de Vijver	MA	x	
Pinnularia subantarctica var. *elongata* (Manguin) Van de Vijver & Le Cohu	MA/SA	x	x
Placoneis australis Van de Vijver & Zidarova	MA	x	x
Planothidium australe (Manguin) R. Le Cohu	MA/SA	x	x
Planothidium frequentissimum (Lange-Bertalot) Round & Bukhtiyarova	C	x	x
Planothidium haynaldii (Schaarschmidt em. Cleve) Haw & Kelly	C	x	x
Planothidium renei (Lange-Bertalot & Schmidt) Van de Vijver	MA/SA	x	x
Planothidium rostrolanceolatum Van de Vijver. Kopalová & Zidarova	MA	x	x
Psammothidium abundans (Manguin. Bourelly & Manguin) Bukhtiyarova	C	x	
Psammothidium aretasii (Manguin) Le Cohu	C	x	
Psammothidium germainii (Manguin) Sabbe	MA/SA	x	x
Psammothidium incognitum (Krasske) Van de Vijver	C	x	
Psammothidium manguinii (Hustedt) Van de Vijver	MA/SA	x	
Psammothidium papilio (Kellogg et al.) Kopalová & Van de Vijver	MA/CA	x	x
Psammothidium sp1	(MA)	x	x
Psammothidium sp2	(MA)	x	
Psammothidium subatomoides (Hustedt) Bukhtiyarova & Round	C	x	x
**Pseudostaurosira* sp1	*	x	
**Rhabdonema* sp1	*	x	
Sellaphora nana (Hustedt) Lange-Bertalot. Cavacini. Tagliaventi & Alfinito	C	x	x
Sellaphora seminulum (Grunow) Mann	C	x	x
Stauroforma exiguiformis (Lange-Bertalot) Flower. Jones & Round	C	x	
Stauroneis pseudoschimanskii Van de Vijver & Lange-Bertalot	MA	x	x
Stauroneis acidoclinata Lange-Bertalot & Werum	C	x	
Stauroneis huskvikensis Van de Vijver & Lange-Bertalot	MA		
Stauroneis jarensis Lange-Bertalot. Cavacini. Tagliaventi & Alfinito	C	x	x
Stauroneis latistauros Van de Vijver & Lange-Bertalot	MA/CA	x	x
Stauroneis pseudomuriella Van de Vijver & Lange-Bertalot	MA/SA	x	x
Stauroneis sp1	U		x
Stauroneis sp2	(MA)	x	
Stauroneis sp3	(MA)	x	x
Staurosira sp1	(MA)	x	
Staurosirella sp1	(MA)	x	x
Staurosirella sp2	(MA)		
**Thalassiosira* spp	*	x	x

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APPENDICES

The following appendix contains five taxonomic papers revising several important diatom groups from the Maritime Antarctic Region and my Curriculum Vitae. These papers are the result of the scientific efforts of the research team that is currently analysing the entire non-marine diatom flora of the South Shetland Islands and James Ross Island. These efforts will lead to the publication of a comprehensive well-illustrated guidebook on the diatom flora of the studied localities, that is scheduled for early 2014 and of which I will be co-author.

This research team is mainly composed of Dr. Ralitsa Zidarova (St."Kliment Ohridski" University of Sofia, Bulgaria), Prof. Dr. Bart Van de Vijver (National Botanic Garden of Belgium & University of Antwerp, Belgium) and myself. Although not being first author on these papers, my contribution to the analyses justified my co-authorship on these papers. For several papers, international specialists such as Dr. Paul Hamilton (Museum of Nature, Ottawa, Canada), collaborated to obtain better results for taxonomically difficult groups.

All five papers are included in the Appendix to prove my involvement in this international research team and to show my ability to collaborate with diatom experts from all over the world.

APPENDIX 1

Four new freshwater diatom species (Bacillariophyceae) from Antarctica

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Published as: *Zidarova R., Van de Vijver B., Mataloni G., Kopalová K. & Nedbalová L. (2009) Four new freshwater diatom species (Bacillariophyceae) from Antarctica. Cryptogamie Algologie 30(4): 295–310.*

Four new diatom species belonging to the genera Achnanthidium, Placoneis, Geissleria *and* Stauroneis *were observed during a survey of the non-marine diatom flora of several islands in the Maritime Antarctica and South Georgia. Following both light and scanning electron microscopy observations, the following species were described as new:* Achnanthidium lailae *Van de Vijver sp. nov.,* Placoneis australis *Van de Vijver & Zidarova sp. nov.,* Geissleria gabrielae *Van de Vijver & Zidarova sp. nov. and* Stauroneis nikolayi *Zidarova sp. nov. The new species are compared to other morphologically similar species from Europe, South America and the (sub-)Antarctic region. Data on their ecology and biogeography are added.*

Key words: *diatoms, South Shetland Islands, James Ross Island, South Georgia, Antarctica, new species*

Introduction

The terrestrial habitat in the southern ocean between South America and the Antarctic Continent is restricted to a few islands and archipelagos on the Scotia arch (e.g. South Georgia, South Sandwich Islands, South Shetland Islands) and the islands around the Antarctic Peninsula such as James Ross Island and Horseshoe Island. Apart from South Georgia, almost all of these islands and archipelagos belong to the Maritime Antarctic Province as defined by Stonehouse (1982).

The species diversity of the non-marine diatom flora of these islands and archipelagos is not very high when compared to more tropical and temperate islands such as New Caledonia (Moser et al. 1998), the Seychelles (Coste & Ricard 1982) or Tahiti (Coste & Ricard 1990). Based on (recent) literature data, most species found in this region are cosmopolitan and not exclusive from the region (e.g. Toro et al. 2007). Recent taxonomic research however has shown that this vision of an almost cosmopolitan character of the Antarctic diatom flora is not entirely correct (Sabbe et al. 2003, Van de Vijver et al. 2005). During the survey of the non-marine diatoms from some of these islands (South Georgia, Deception Island, Livingston Island, James Ross Island), a large number of new species have been found belonging to the genera *Hantzschia*, *Luticola*, *Navicula*, *Pinnularia* and *Stauroneis*. Most of them have been described or are currently under description (Van de Vijver et al. 2004, 2006, Esposito et al. 2008, Van de Vijver 2008, Van de Vijver & Mataloni 2008, Kopalová et al. 2009, Zidarova et al. unpublished results). Several others still await description. The present paper describes four new species belonging to four different genera: *Achnanthidium, Geissleria, Placoneis* and *Stauroneis*. Some of these species, e.g. *Placoneis australis* Van de Vijver & Zidarova sp. nov., have been reported numerous times from this region but force-fitting (Tyler 1996) due to the use of European and North American identification books for the Antarctic species, caused it to be misidentification as other already known species. In this paper, these species are now formally described and the differences with their European/American morphologically similar counterparts are discussed.

Materials and Methods

During several austral summers, samples for diatom analysis have been collected from various locations in the Maritime Antarctic Region (Livingston Island, Deception Island, King George Island and James Ross Island) and South Georgia.

The diatom samples were prepared following different methods. Part of each sample was treated following the method of Van der Werff (1955): Small sub-samples were cleaned by adding 37% H_2O_2 and heating to 80 °C for about 1h whereafter the reaction was completed by addition of $KMnO_4$. Following digestion and centrifugation (three times 10 minutes at 3700 x g), the resulting clean material was diluted with distilled water to avoid excessive concentrations of diatom valves that may hinder reliable observations. Another part of the samples was prepared according to the method described in Hasle & Fryxell (1974): Small sub-samples were cleaned using concentrated H_2SO_4 followed by the addition of $KMnO_4$. The samples were then faded with $H_2C_2O_4$ and washed with distilled water eight times. In both cases, clean diatom valves were mounted in Naphrax®.

Light microscope observations were made using an Olympus BX51 microscope equipped with Differential Interference Contrast (Nomarski) optics. For scanning electron microscopy (SEM), part of the suspension was filtered through polycarbonate membrane filters with a pore diameter of 1 µm, pieces of which were fixed on aluminium stubs after air-drying. The stubs were sputter-coated with 50 nm of Au and studied in a JEOL–5800LV at 20 kV. SEM micrographs of the figures A1.42 & 43 were taken using a JEOL JSM–5510 by Dr. Nikola Dimitrov at the Faculty of Chemistry, University of Sofia, Bulgaria.

Comparisons are based mainly on information in Lange-Bertalot (2001), Cox (2003), Reichardt (2004), Van de Vijver et al. (2004), Metzeltin et al. (2005) and Ponader & Potapova (2007). Terminology follows Hendey (1964) and Round et al. (1990). The type slide of *Placoneis paraelginensis* (Van Heurck Types 43, National Botanic Garden of Belgium) was checked for the comparison with the new *Placoneis* species.

Samples and slides are stored at the National Botanic Garden of Belgium and the Central Laboratory of General Ecology in Sofia, Bulgaria.

New taxon description

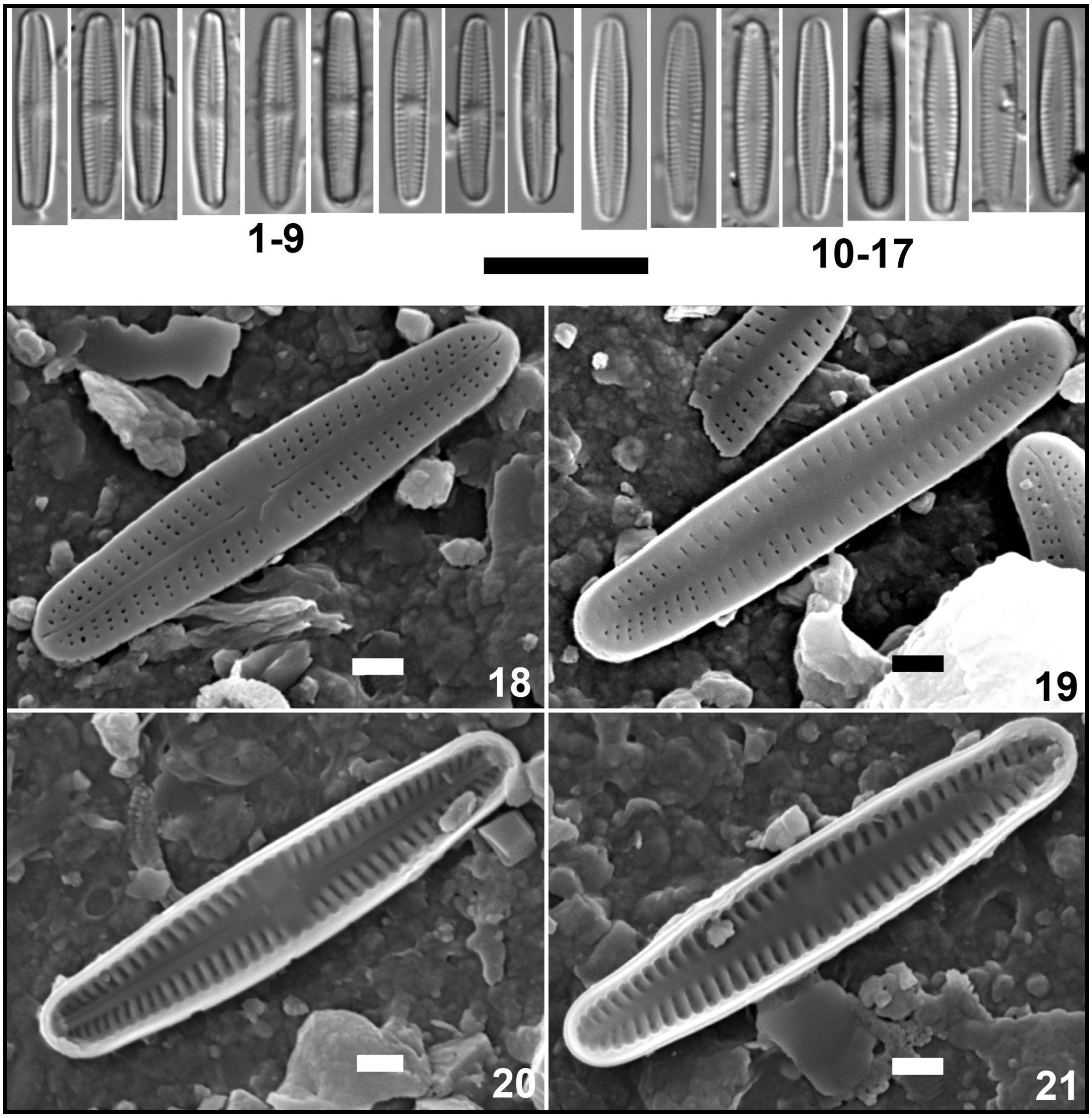
Achnanthidium lailae **Van de Vijver sp. nov.** (Figs A1.1–A1.21)

Valvae lineares ad lineares-lanceolatas marginibus parallellis apicibusque late rotundatis sed numquam protractis. Longitudo 9–13.5 µm, latitudo 2–2.25 µm. Area axialis in araphovalva moderate lata, claro lanceolataque. Area centralis formans apicaliter elongata, non formans fasciam. Striae transapicales, 28–30 in 10 µm, parallellae ad leviter radiatae in aream centralem, magis radiatae ad polos. Raphe in raphovalva recta, filiformis poris centralibus inconspicuis, fissures terminalibus unilateraliter deflexis, non visibilibus in microscopio photonico. Area axialis angusta, linearis ad linearis-lanceolata. Area centralis formans fasciam rectanularem. Striae 30–33 in 10µm, leviter radiatae in media parte valvae, magis radiatae ad polos.

LM observations: Valves are linear to (rarely) linear-lanceolate with almost parallel margins. Some valves are sometimes weakly dorsiventrally bent. Valve apices are broadly rounded but never protracted, rostrate nor capitate. Valve length 10–12.5 µm, valve width 2–2.5 µm. Raphe–bearing valve (Figs A1.1–A1.9): axial area is rather narrow, linear to linear-lanceolate, widening towards the central area. The central area is a typical rectangular fascia reaching the valve margins. Shortened striae border the central area. The raphe appears straight to weakly undulating with inconspicuous straight central pores. Terminal raphe fissures are not discernible in LM. The striae are weakly radiate near the valve center, becoming more radiate towards the apices, 30–33 in 10 µm. Rapheless valve (Figs A1.10–A1.17): axial area moderately broad, clearly lanceolate, widening near the valve center to form an apically elongated central area. Fascia absent due to the presence of several striae near the central area. The striae are parallel to weakly radiate near the valve center, becoming more radiate towards the apices, 28–30 in 10 µm.

SEM observations: The striae of the raphe-bearing valve (Fig. A1.18) are composed of 2–3 small, rounded areolae. Sometimes, the two outer areolae are fused forming an transapically elongated slit. The raphe is slightly undulating with almost straight, inconspicuous central pores and deflected terminal raphe fissures. Internally (Fig. A1.20), the striae are sunken between raised, thickened rims, giving the impression of being one continuous slit obscuring that way the view on the individual areolae. The central raphe endings are deflected to opposite directions terminating each in a thickened central pore.

The striae of the rapheless valve are composed of 2-3 rounded to slitlike external areola openings (Fig. A1.19). Internally, the striae are sunken between raised rims (Fig. A1.21).



FIGURES A1.1–A1.21 – *Achnanthidium lailae* Van de Vijver *sp. nov.* Frustules from the type population. **Figs. A1.1–A1.9.** LM. External view of the raphe bearing valve**. Figs A1.10–A1.17.** LM. External view of the rapheless valve. **Fig. A1.18.** SEM. Extrenal view of the raphe bearing valve. **Fig. A1.19.** SEM. External view of the raphless valve. **Fig. A1.20.** SEM. Internal view of the raphe bearing valve. **Fig. A1.21.** SEM. Internal view of the rapheless valve. Scale bar = 10 µm except for Figs A1.18–A1.21 where scale bar = 1 µm.

Holotype: BR–4160 (National Botanic Garden, Meise, Belgium)**Isotype:** PLP–130 (UA, University of Antwerp, Belgium), BRM–ZUH7/02 (Hustedt Collection, Bremerhaven, Germany)

Type locality: Katia Lake, James Ross Island, sample JRI2008–13 (Coll. Nedbalová, coll. date 01 February 2008)

Etymology: This taxon is named after Mrs. Laila Willems to thank her and the entire crew of the TV–program 'Canvascrack' for the most enjoyable time I could spend with them in May 2009.

Ecology and associated diatom taxa: *Achnanthidium lailae* was found living on the sediment of several lakes on James Ross Island. The largest population was observed in Katia lake, a circumneutral (pH = 7.05), oligotrophic lake with a high specific conductance (660 µS/cm). Co-dominant species in this lake were *Diadesmis* sp., *Gomphonema* sp. and *Nitzschia perminuta* (Grunow) Perag. Another large population was found in lake Katia II having similar physico-chemical characteristics, dominated by *Diadesmis* sp., *Gomphonema* sp., *Nitzschia perminuta* and *N. homburgiensis* Lange-Bert.

Confirmed distribution records: So far only found on James Ross Island, although it is not to exclude that certain records of *Achnanthidium minutissimum* (Kütz.) Czarn. from the Antarctic Region in fact represent *A. lailae*.

Geissleria gabrielae **Van de Vijver & Zidarova sp. nov.** (Figs A1.22–A1.43)

Valvae lineares-ellipticae ad ellipticas-lanceolatas apicibus leviter protractis, late rotundatis, rostratis in valves minoribus, subcapitatis in valvae maioribus. Longitudo 15.3–23.8 µm, latitudo 5.3–6.2 µm. Area axialis angusta, linearis. Area centralis lata, transversaliter expansa formans subfasciam rectangularem. Stigma abest in area centrale. Raphe filiformis, recta poris centralibus inconspicuis. Striae transapicales leviter curvatae, radiatae omnino, 14–16 in 10 µm. Puncta non distinguibilia in microscopio photonico, ca 50 in 10 µm.

LM observations: Valves are linear-elliptic to elliptic-lanceolate. Larger valves tend to have slightly convex to almost parallel margins whereas in smaller valves, the margins are clearly convex (Figs A1.24, A1.25, A1.26). The valve apices are weakly protracted and broadly rounded, rostrate in smaller valves to subcapitate in larger valves. Valve length ranges from 15.3 to 23.8 µm; valve breadth is 5.3–6.2 µm, mostly about 5.8 µm. The axial area is narrow and linear. The central area is large and transversally expanded forming a rectangular subfascia, bordered by 1–3 short striae, more widely spaced than the other striae. A stigma is absent in the central area. The raphe is filiform, straight, with almost indistinct central pores. The transapical striae are slightly curved, radiate throughout the entire valve, 14–16 in 10 µm. The puncta are not discernible in LM. The "annuloid" structure at the valve poles is more or less distinct in larger valves, but barely visible in smaller valves.

SEM observations: The raphe is located on a typical raphe sternum, bordered by narrow, irregularly shaped shallow grooves (Fig. A1.42), in which the normal areolae structure of the striae continues. Near the central area, the grooves disappear connecting the raphe sternum with the central subfascia. The raphe itself is straight with slightly undulating central endings, terminating in weakly expanded central pores. The terminal raphe fissures are unilaterally deflected to the same side and seem not to continue onto the valve mantle (Figs A1.42, A1.43). Striae are interrupted near the valve face/mantle margin by a hyaline zone but continue after the interruption on the valve mantle where 2–3 rounded areolae are present. The areolae are almost circular to slightly transapically elongated, ca 50 in 10 µm. Near the valve apices, on both sides of the raphe, one transapically orientated slit can be seen, as is often the case in the genus *Geissleria*. The "annuloid" structure at the valve poles is composed mainly of one or two pairs of apical slits although sometimes a third single slit can be present between the annuloid structure and the last striae. Other usually two transversally orientated slits present at both sides of the raphe at the valve pole near the valve mantle (Figs A1.42, A1.43).

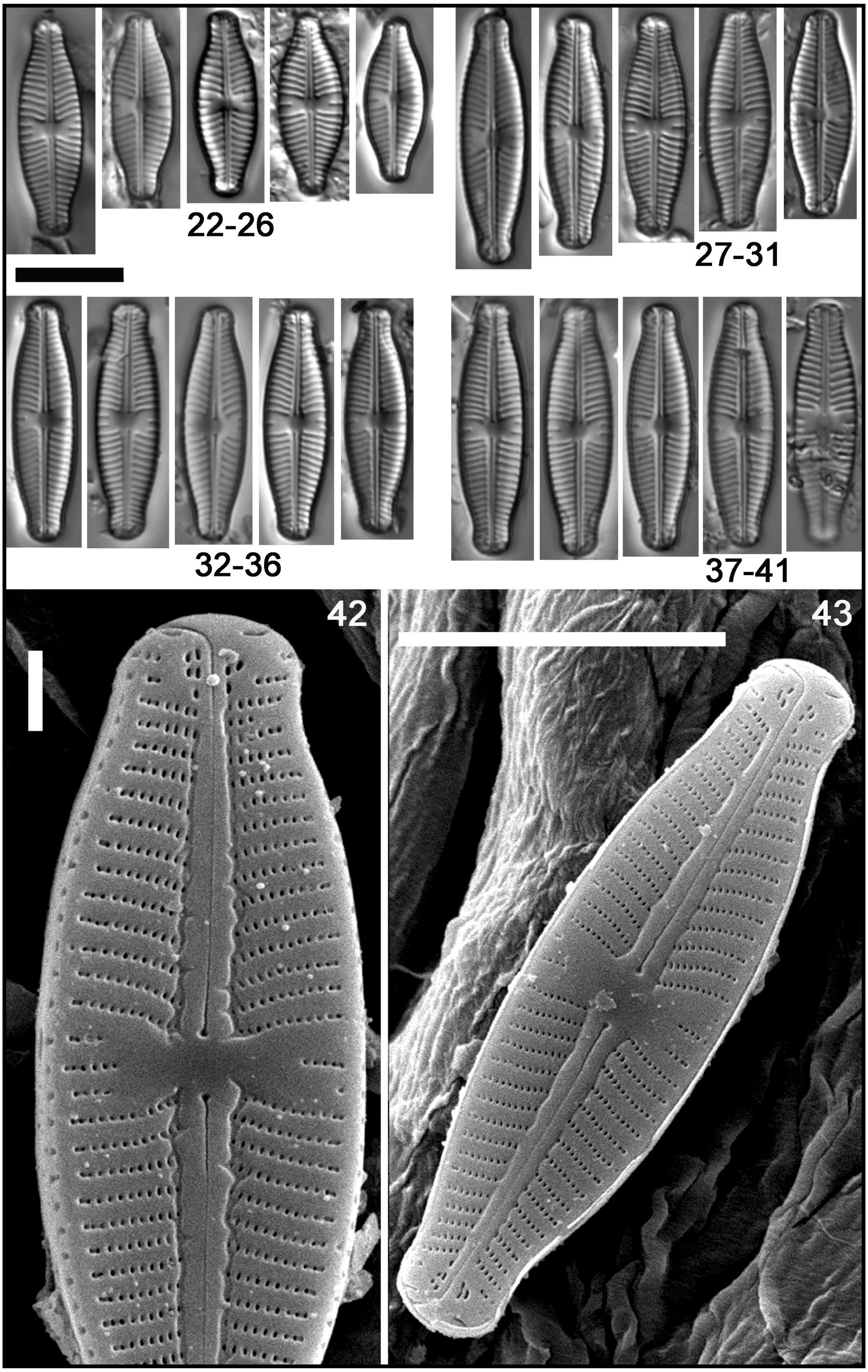
Holotype: BR–4161 (National Botanic Garden, Meise, Belgium)

Isotype: PLP–131 (UA, University of Antwerp, Belgium), BRM–ZUH7/03 (Hustedt Collection, Bremerhaven, Germany)

Type locality: South Shetland Islands, Deception Island. Sample CR, near Crater Lake (coll. Mataloni., coll. date 14 February 2002).

Etymology: This taxon is named after our colleague and dear friend Dr. Gabriela Mataloni, University of Buenos Aires, Argentina.

Ecology and associated diatom flora: The type population of *Geissleria gabrielae* was found in a sample containing dark, slightly acid (pH = 6.7) mineral soil collected on a steep slope, disturbed by volcanic eruptions c. 150 years ago. It is a very diatom-rich sample. Apart from several other *Luticola* species (see below), the sample is dominated by *Stauroneis latistauros* Van de Vijver & Lange-Bert., *Hantzschia hyperborea* (Grunow) Lange-Bert. and *Chamaepinnularia krookiiformis* (Krammer) Lange-Bert. & Krammer.



FIGURES A1.22 – A1.43 – *Geissleria gabrielae* Van de Vijver & Zidarova *sp. nov.* Frustules from several populations showing the variability of the species. **Figs A1.22–A1.26.** LM. Valves from the Byers Peninsula (Livingston Island) population. **Figs A1.27–A1.31.** LM. Valves from the Hurd Peninsula (Livingston Island) population. **Figs A1.32–A1.36**. LM. Valves from the type population, Deception Island. **Figs A1.37–A1.41.** LM.

Valves from the South Georgia population. **Fig. A1.42.** SEM. External valve view showing the raphe sternum, the irregularly shaped grooves, bordering the raphe, the areolae and the "annuloid" structure. **Fig. A1.43.** SEM. External view of an entire valve. Scale bar = 10 µm except for Fig. A1.42 where scale bar = 2 µm.

In other samples, it is found in low abundance in wet soils and on very wet to moist mosses around small pools. The species is accompanied by *Achnanthes coarctata* (Bréb.) Grunow*, Pinnularia borealis* var. *scalaris* (Ehrenb.) Rabenh., *Luticola muticopsis* (Van Heurck) D.G. Mann*, Luticola higleri* Van de Vijver, Van Dam & Beyens*, Diadesmis* spp., *Muelleria* spp. and *Hantzschia* spp.

Confirmed distribution records: South Shetland Islands (Livingston Island, King George Island, Deception Island.), James Ross Island, South Georgia.

Placoneis australis **Van de Vijver & Zidarova sp. nov.** (Figs A1.44–A1.58, 62–64)

Valvae lineares ad lineares-ellipticas marginibus parallellis ad leviter convexes, apicibusque subcapitatis, numquam rostratis vel subrostratis. Longitudo 20.4–30.0 µm, latitudo 6.1–7.9 µm. Area axialis angusta, linearis-lanceolata. Area centralis variabilis, rotunda ad rectangularem vel ad instar papilionaceam formans subfasciam acute angulatam. Raphe filiformis, leviter undulata ad paene rectam poris centralibus leviter expansis, 1.1–1.8 µm inter se distantes. Striae transapicales claro radiatae omnino, 15–18 in 10 µm. In media parte valvae, striae magis geniculatae sed ad apices, striae curvatae ad rectas. Areolae non distinguibiles in microscopio photonico, ca 40 in 10 µm.

LM observations: The valves are linear to linear-elliptical. Larger specimens tend to have more parallel margins whereas smaller individuals present slightly convex margins. The valve apices are always subcapitate, never rostrate or subrostrate with a width varying between 2.4 and 3.1 µm. Valve length ranges from 20.4 to 30.0 µm whereas the valve width varies between 6.1 and 7.9 µm. The axial area is narrow and linear-lanceolate, only slightly and gradually widening from the valve apices towards the central area. The central area itself varies in shape from rounded (Fig. A1.54) in some specimens to almost rectangular (Figs A1.44, A1.49, A1.51, A1.53, A1.58) and even butterfly-shaped (Figs A1.45–A1.47, A1.52, A1.54, A1.55), forming an acute-angled sub-fascia, clearly widening towards the valve margins. A real fascia is never formed since three to five shortened striae always border the central area. The raphe is filiform, slightly undulating (Figs A1.44–A1.48, A1.51–A1.53, A1.57), although in some specimens a straight raphe is visible (Figs A1.49, A1.51, A1.58). The central pores are almost straight and only weakly expanded, 1.1–1.8 µm distant from each other. The striae are clearly radiate throughout the entire valve, 15–18 in 10 µm. Near the valve middle, striae tend to become more geniculate while near the apices, striae are curved to even straight. The areolae are not discernible in LM. Due to fixation with formaldehyde, the observation of the plastid structure, an important feature however in the genus *Placoneis*, was not possible.

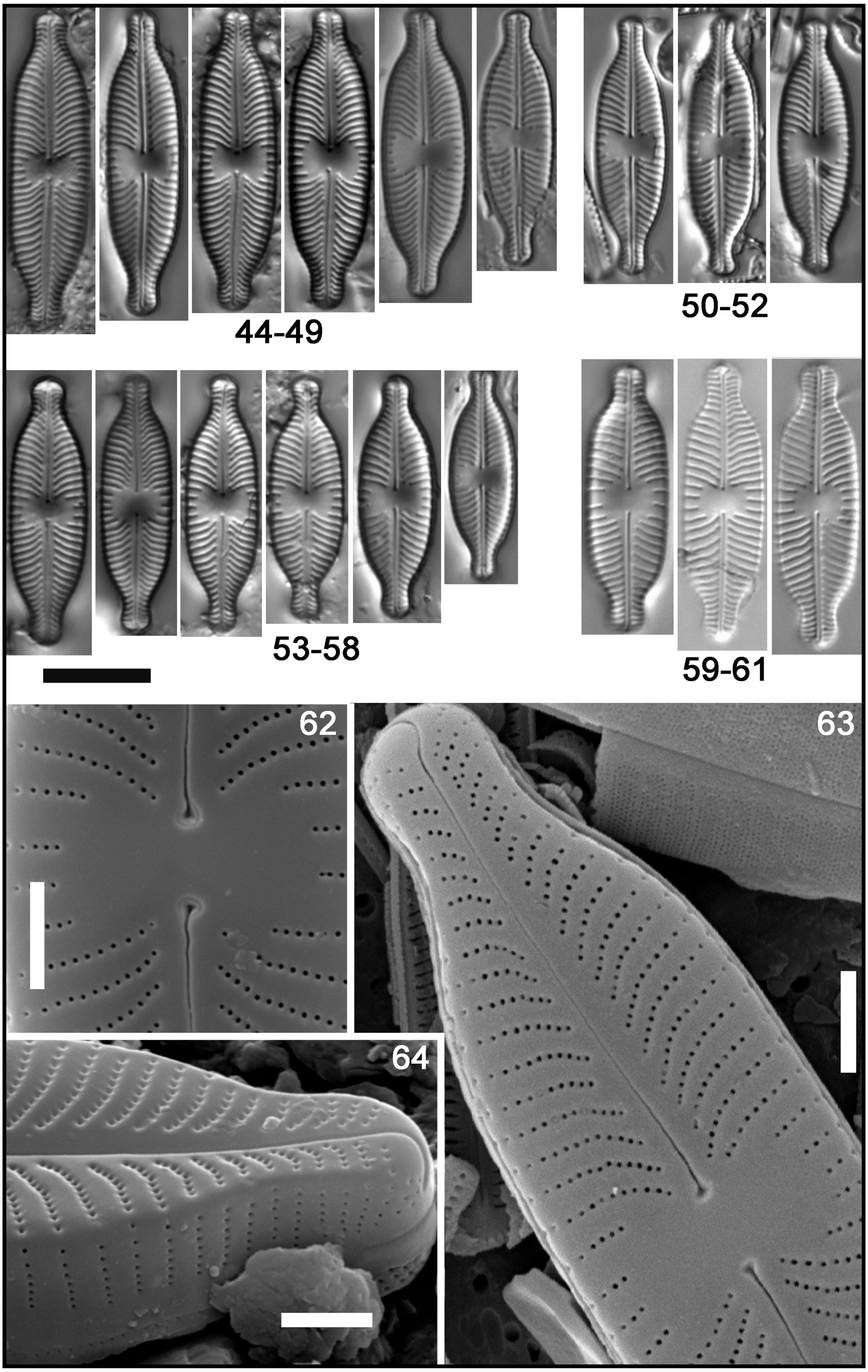
SEM observations: The ultrastructure of this species (Fig. A1.63) does not differ too much from the typical *Placoneis* structure. The proximal raphe endings are unilaterally weakly deflected to almost straight with weakly expanded, shallow central pores (Fig. A1.62). The terminal fissures are typically unilaterally hooked (Fig. A1.63). The striae are interrupted near the valve face/mantle margin by a narrow hyaline zone (Fig. A1. 64). The areolae are small, rounded poroids, ca 40 in 10 µm. On the valve mantle (Fig. A1.64), the striae continue composed of 6–8 small, rounded areolae.

Holotype: BR–4162 (National Botanic Garden, Meise)

Isotype: PLP–132 (UA, University of Antwerp), BRM–ZUH7/04 (Hustedt Collection, Bremerhaven)

Type locality: Livingston Island (South Shetland Islands), sample 12–1/2008 (coll. Natcheva, coll. date 22 February 2008)

Ecology and associated diatom flora: The type locality is a small pond surrounded by *Sanionia georgico-uncinata* (Müll. Hal.) Ochyra & Hedenäs, situated north from the Bulgarian Antarctic Base. The species is accompanied mainly by *Diadesmis* spp., *Muelleria* spp., *Luticola higleri* and *Pinnularia subantarctica* var. *elongata* (Manguin) Van de Vijver & Le Cohu. *Placoneis australis* is usually found in very low numbers in different aquatic habitats, such as streams, lakes and their outflows, ponds and, only occasionally, on wet soil and mosses in and around water basins.



FIGURES A1.44–A1.58 – *Placoneis australis* Van de Vijver & Zidarova *sp. nov.* Frustules from several populations. Scale bar = 10 µm. **Figs A1.44–A1.49.** LM. Valves from the Byers Peninsula (Livingston Island). **Figs A1.50–A1.52.** LM. Valves from the King George Island population. **Figs A1.53–A1.58**. LM. Valves from the type population, Hurd Peninsula, Livingston Island. Scale bar = 10 µm**. Figs A1.59–A1.61.** *Placoneis paraelginensis*

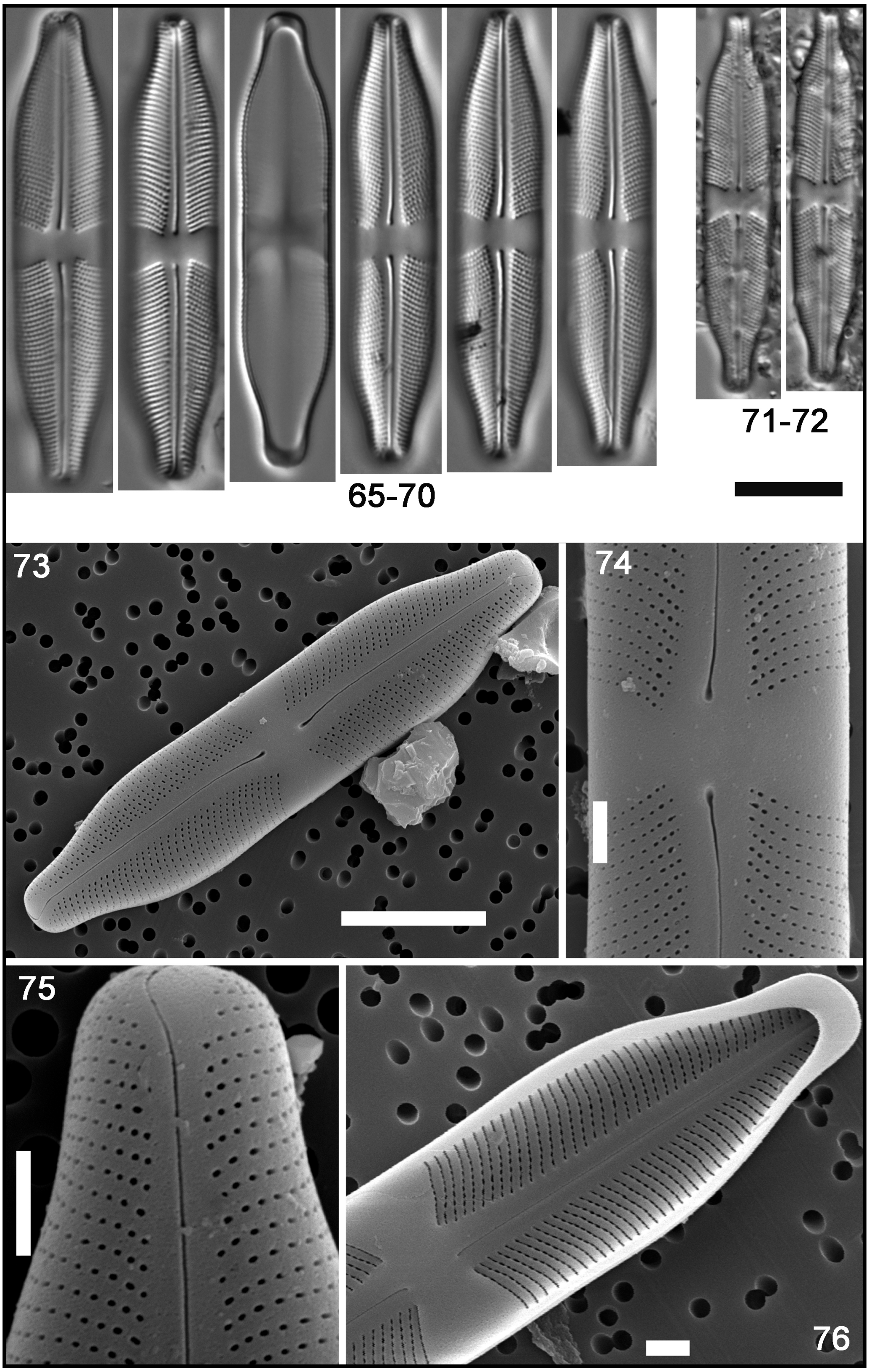
Lange-Bertalot. LM view of three valves from the type population (VH Types 43) A1.60 & A1.61 represent internal view. Scale bar = 10 µm. **Figs A1.62–A1.64.** *Placoneis australis* Van de Vijver & Zidarova *sp. nov.*, SEM. **Fig. A1.62.** External view showing the central area, raphe endings and central pores. **Fig. A1.63.** External view showing the valve ultrastructure. **Fig. A1.64.** Detail from the valve mantle and the apex. Scale bar = 2 µm.

Confirmed distribution records: This new species has been frequently reported under the name of *Navicula elginensis* (W. Greg.) Ralfs or *Placoneis elginensis* (W. Greg.) Cox (see Kellogg & Kellogg (2002) for more distribution data on *P. elginensis*). In our material, *P. australis* was observed in samples taken on the South Shetland Islands (King George Island and Livingston Island) and James Ross Island, although on the latter location, the species was only rarely observed.

Stauroneis nikolayi **Zidarova sp. nov.** (Figs A1.65–A1.70, A1.73–A1.76)

Valvae stricte lineares marginibus parallellis, leviter constrictis in media parte valvae, apicibusque breviter protractis, rostratis, late rotundatis. Pseudosepta adsunt. Longitudo 42–45 µm, latitudo 7.5–8.3 µm. Area axialis angusta, dilatata deltoidea prope fasciam. Area centralis fasciam latam formans valde dilatata ad margines versus. Raphe leviter lateralis, terminationibus centralibus unilateriler deflexis, leviterque expansis poris centralibus guttiformibus. Fissurae terminales raphis fortiter uncinatae. Striae transapicales curvatae, fortiter radiatae omnino, 19–21 (22) in 10 µm. Areolae striarum vix visibiles in microscopio photonico, 30–35 in 10 µm.

LM observations: The valves are strictly linear with parallel to slightly undulated margins, somewhat constricted in the middle. The valve apices are shortly protracted, rostrate with bluntly rounded ends. Pseudosepta are always present (Fig. A1.67). The valve length varies between 42 and 45 µm whereas the valve breadth ranges from 7.5 to 8.3 µm. The axial area is narrow, deltoidely widened near the central area. The central area forms a broad, wedge-shaped fascia, strongly expanding towards the valve margins. The raphe is slightly lateral with clearly unilaterally deflected central endings and only very weakly expanded, droplike central pores. The terminal raphe fissures are strongly, unilaterally hooked. The transapical striae are curved and strongly radiate throughout the entire valve, 19–21(22) in 10 µm. The areolae of the striae are almost no discernible in LM.



FIGURES A1.65–A1.70 – *Stauroneis nikolayi* Zidarova *sp. nov.* LM view of six valves from the type population. **Fig. A1.67** shows the pseudosepta. Scale bar = 10 µm. **Figs A1.71–A1.72.** *Stauroneis husvikensis* Van de Vijver & Lange-Bertalot. LM view of two valves from the type population of South Georgia (sample M331). Scale bar = 10 µm. **Figs A1.73–A1.76.** *Stauroneis nikolayi* Zidarova *sp. nov.* SEM. **Fig. A1.73.** External view of an entire valve. **Fig. A1.74.** Detail from the central area showing the unilaterally deflected central raphe endings. **Fig. A1.75.** Detail from the valve apex showing the terminal raphe fissure. **Fig. A1.76.** Internal view showing the pseudosepta and the central raphe endings. Scale bar = 2 µm except for Fig. A1.73 where scale bar = 10 µm.

SEM observations: The valve face is slightly convex (Figs A1.73, A1.74). The raphe branches are curved with drop-like central pores. Both central pores terminate before the striae in the central area (Fig. A1.74). The terminal raphe fissures are typically "?"-shaped, unilaterally hooked (Fig. A1.75), towards the opposite side of the central endings (Fig. A1.73). The striae consist of very small, rounded to slightly transversally elongated areolae, about 30–35 in 10 µm. The areolae tend to become smaller towards the valve margins. Internally (Fig A1.76), large pseudosepta are present at each valve pole. The central raphe endings are weakly deflected and rather inconspicuous.

Holotype: BR–4163 (National Botanic Garden, Meise, Belgium)

Isotype: PLP–133 (UA, University of Antwerp, Belgium), BRM–ZUH7/05 (Hustedt Collection, Bremerhaven, Germany)

Type Locality: Livingston Island (South Shetland Islands), close to the Bulgarian Antarctic Base, Hurd Peninsula, sample LIV–1a/2003 (coll. Metcheva, coll. date February 2003).

Etymology: The species is named after my dear friend Dipl. eng. Nikolay Stanchev from the Bulgarian Antarctic Institute.

Ecology & associated diatom flora: The species is described from soil below a *Deschampsia antarctica* Desv. vegetation, on a rock close to the sea. The sample is mainly dominated by *Pinnularia borealis* Ehrenb. s.l.

Confirmed distribution records: So far only known from Livingston Island (South Shetland Islands) and Signy Island (South Orkney Islands).

Discussion

All four species described in this paper represent taxa that have probably been misidentified in the older literature. Detailed morphological analysis however, revealed enough discriminating features to separate these four taxa from similar taxa.

Achnanthidium lailae is a typical species belonging to the group around *Achnanthidium minutissimum*. The species is most similar to *Achnanthidium strictum* Reichardt, described from a spring in Austria (Reichardt, 2004), and can only be distinguished with 100% certainty based on the ultrastructure of the valves. Both species can be separated from the *A. minutissimum* s.s. group by the weakly deflected terminal raphe fissures (Ponader & Potapova 2007). In *A. minutissimum* and its related species such as *A. eutrophilum* (Lange-Bert.) Lange-Bert., the terminal raphe fissures are straight whereas species such as *A. alpestre* (Meister) Lange-Bert. and *A. gracillimum* (Lowe & Kociolek) Lowe & Kociolek have longer, deflected terminal fissures (Ponader & Potapova 2007). Moreover, both species present a characteristic valve outline with almost no protracted valve apices and almost straight valve margins. *A. strictum* has a very typical striae and areolae structure, which is absent in *A. lailae*. Each stria of the raphe valve in *A. strictum* is composed of one rounded areola and one slit-like areola. Contrary to this, the striae in *A. lailae* are composed of three small rounded areolae without any slit-like areolae. Internally, both species can also be separated on the basis of the typical raised rims bordering the striae in *A. lailae*. These rims seem to be absent in *A. strictum*.

Geissleria gabrielae shares features with several other *Geissleria* species, such as *G. dolomitica* (Bock) Lange-Bert. & Metzeltin, *G. boreosiberica* Lange-Bert., Genkal & Vekhov, *G. punctifera* (Hust.) Metzeltin, Lange-Bert. & García-Rodríguez and related taxa such as *G. aikenensis* (R.M.Patrick) Torgan & Oliveira and *G. schmidiae* Lange-Bert. & Rumrich. Morphologically, the most similar species to *G. gabrielae* is *G. dolomitica*, known only from the Italian Dolomites (Lange-Bertalot 2001). Although type material for SEM analysis was not available, both the analysis of the iconographic material from the type slide (Bock, 1970) and pictures from the type slide kindly provided by D. Metzeltin showed that *G. dolomitica* has more linear-elliptic to elliptic-lanceolate valves with weakly protracted, bluntly to broadly rounded and almost never subcapitate ends (see also the description of the species in Lange-Bertalot 2001, p.124). The striae in *G. dolomitica* are almost straight, not curved, and more spaced than in *G. gabrielae*. *G. gabrielae* has 14–16 striae in 10 µm, while *G. dolomitica* has 16–19 striae in 10 µm according to Lange-Bertalot (2001) Stria counts on pictures from the type slide showed 16–18 striae in 10 µm (Zidarova, pers. observation). The central area is usually defined by only one very short stria at each side. The Siberian *G. boreosiberica*

(Lange-Bertalot & Genkal 1999) shows the same striae density (14–16) as *G. gabrielae,* but is larger (length 23–29 µm vs. 15.3–23.8 µm, breadth 7.5–8.5 vs. 5.3–6.2 µm) with abruptly protracted and almost capitate ends, and slightly radiate to parallel striae (Lange-Bertalot, 2001). Other species that resemble *Geissleria gabrielae* are *Geissleria punctifera*, *G. aikenensis* and *G. schmidiae*. According to Metzeltin et al. (2005) *G. aikenensis* should be considered as a synonym of *G. punctifera.* The authors pointed out that *G. schmidiae,* known from Chile and Ecuador, might also be conspecific with *G. punctifera.* When comparing *G. aikenesis* to *G. schmidiae,* Torgan & Oliveira (2001) already concluded that the latter was a synonym of *G. aikenensis.* Although we were not able to investigate the type material of these three *Geissleria* species, according to the existing iconographic material and descriptions in the literature (e.g. Rumrich et al. 2000, Torgan & Oliveira 2001, Metzeltin et al. 2005), it is clear that they all differ from *G. gabrielae* by having a small central area with one or more stigma and almost parallel to slightly radiate striae, as well as a different "annuloid" structure. In *G. gabrielae* the "annuloid" structure is similar to that in *G. ignota* (Krasske) Lange-Bertalot & Metzeltin. However, with its linear valves with triundulated margins (Lange-Bertalot 2001), the latter has a completely different outline and could not be confused with *G. gabrielae.*

Placoneis australis clearly belongs to the group around *Placoneis elginensis* (Gregory) Cox. Table A1.1 compares the new species with similar members of this group such as *P. elginensis*, *P. paraelginensis* Lange-Bertalot, *P. rostrata* (A. Mayer) Cox and *P. abiskoensis* (Hustedt) Lange-Bertalot & Metzeltin. These four taxa can be distinguished by having a different striation pattern. *P. australis* has very radiate, curved to even geniculate striae, a feature never observed in any of the four species. The stria density is higher, 15–18 against the number generally reported in other species, for instance 10–11 in *P. abiskoensis,* around 11 in *P. elginensis* and 11–12 in *P. paraelginensis* and *P. rostrata* (Table A1.1). *Placoneis* abiskoensis, *P. elginesis* and *P. rostrata* could also be differentiated because of their larger dimensions. According to Cox (2003) and Rumrich et al. (2000), these species have wider apices (5 vs. 2.4–3.1 µm). The valve length of *P. abiskoensis* ranges from 37–46 µm (instead of 20.4–30) and the breadth is 9–12 (vs. 6.1–7.9). Based on Rumrich et al. (2000), *P. rostrata* is again larger and broader (valve length 37 µm and breadth of around 9 µm), the valve apices are rostrate and never subcapitate. Apart of the striation pattern, *Placoneis elginensis* differs with larger width (9–10 vs 6.1–7.9), wider apices (4–4.5 vs 2.4–3.1) and a straight raphe. A straight raphe and wider apices (up to 3.5 µm) are also observed in *P. paraelginensis* (Figs A1.59–A1.61 and Table A1.1).

TABLE A1.1 – Comparable features of *Placoneis australis* and other similar *Placoneis* species [1 Based on Cox (2003) 2 Based on Rumrich et al. (2000)].

	P. australis	*P. elginensis*[1]	*P. paraelginensis*[1]	*P. abiskoensis*[1]	*P. rostrata*[2]
valve outline	linear to linear elliptic	linear	linear	linear to slightly undulate	linear
valve length (µm)	20-30	30-36	25-27	37-46	37
valve width (µm)	6.1-7.9	9-10	~7	9-12	~9
apex shape	subcapitate	subcapitate	subcapitate	subcapitate	rostrate
apex width (µm)	2.4-3.1	4-4.5	3-3.5	5	5
raphe	slightly curved only occasionally almost straight	straight	straight	slightly curved	slightly curved
central ending separation	1.1-1.8	~2	<2	2.5	~ 3
central area shape	rounded to almost rectangular and butterfly-shaped	bow-tie	transverse – bow-tie (to transverse-broadly elliptic)	transverse ellipse	transverse
central area width	> ½ valve	> ½ valve	> ½ valve	> ½ valve	~ ½ valve
number of striae in 10 µm	15-18	~ 11	11-12	10-11	11-12
puncta visible in LM	no	no	no	yes	no
alternating longer/shorter striae	no	no	no	no	no

Stauroneis nikolayi could only be confused with *Stauroneis husvikensis* Van de Vijver & Lange-Bert., recently described from South Georgia (Van de Vijver et al*.* 2004). The latter however is shorter and narrower (length 33–36 µm, breadth 6.5–7.5) with straight margins and more protracted rostrate-subcapitate ends (Figs A1.71, A1.72). The central raphe endings in *S. husvikensis* are almost straight whereas in *S. nikolayi* they are clearly deflected. Both species can also be separated based on a different striae density with a higher number of striae in *S. husvikensis* (24–27 vs. 19–22 in 10 µm) composed of less puncta (25 vs. 30–35 in 10 µm), that are clearly visible in LM. There are records in the Antarctic literature of unidentified *Stauroneis* species presenting very similar features. Broady (1979) reported *Stauroneis* cf. *lapponica* Cleve from samples of soil below *Deschampsia antarctica* on Signy Island (South Orkney Islands). Based on the description and picture presented (Broady, 1979, p. 59, fig. 14c), it is clear that *Stauroneis* cf. *lapponica* from Signy Island represents in fact *Stauroneis nikolayi*. According to the original description of *Stauroneis lapponica* in Cleve (1895), the latter has a different valve outline with more rounded and less rostrate or capitate apices, smaller dimensions (length 20–35 µm vs. 42–45 µm, breadth 4–7 µm vs. 7.5–8.3 µm), a straight raphe and a higher striae density (24 vs 19–22 in 10 µm). Moreover, the striae in *S. lapponica* are clearly punctate.

Acknowledgments

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APPENDIX 2

The genus *Pinnularia* (Bacillariophyta) excluding the sectio *Distantes* on Livingston Island (South Shetland Islands) with the description of twelve new taxa

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During the ongoing revision of the non-marine diatom flora of Livingston Island (South Shetland Islands) the taxonomy and morphology of all Pinnularia *taxa, excluding the section* Distantes*, present in the samples from Livingston Island, have been analysed. Seventeen different* Pinnularia *taxa have been recorded. Apart from those previously described from the Antarctic Region and the Andes, thirteen unknown taxa have been found. Based on their unique morphological features, twelve are described as new in this paper.:* P. australodivergens *sp. nov.,* P. australoglobiceps *sp. nov.,* P. australomicrostauron *sp. nov.,* P. australoschoenfelderi *sp. nov.,* P. hamiltonii *sp. nov.,* P. livingstonensis *sp. nov.,* P. magnifica *sp. nov.,* P. microstauroides *sp. nov.,* P. pseudolaucensis *sp. nov.,* P. sergiplaiana *sp. nov.,* P. subcarteri *sp. nov. and* P. subaltiplanensis *sp. nov. For one, only a few specimens have been found and at present they cannot be identified with 100% certainty.*

Key words: *Bacillariophyta,* Pinnularia*, new species, Byers Peninsula, Hurd Peninsula, Maritime Antarctic Region, morphology*

Introduction

Based on the diatom records listed in Kellogg & Kellogg (2002), 195 different taxa belonging to the genus *Pinnularia* Ehrenb*.,* one of the largest non-marine diatom genera in the world (Krammer 2000), have been reported from the Antarctic and sub-Antarctic Regions. Although several of these have been reassigned to other genera, such as *Chamaepinnularia* Lange-Bert. & Krammer in Lange-Bert. & Metzeltin (1996), or should be considered synonyms of earlier published names, it is clear that most of the records belong to species with a cosmopolitan distribution. Recent results show that data in the older literature do not always reflect true diatom diversity, inevitably leading to incorrect interpretations of the biogeography and ecology of diatoms in Antarctic regions (Sabbe et al. 2003, Van de Vijver et al. 2005). Distinct (Antarctic) forms were sometimes lumped together as one single, morphologically variable species (see also Mann 1999) and many taxa were force-fitted into either European or North American species (Tyler 1996, Sabbe et al. 2003, Van de Vijver et al. 2005, Van de Vijver & Mataloni 2008). Taxa such *Pinnularia borealis* Ehrenb. (1843: 420), *P. divergens* W. Sm. (1853: 57) and *P. obscura* Krasske (1932: 117) are widespread in the entire Antarctic Region (Kellogg & Kellogg 2002). On the islands in the southern Indian Ocean such as the Crozet archipelago and Iles Kerguelen, more than 30 new species of *Pinnularia* were described (Bourrelly & Manguin 1954, Van de Vijver 2008, Van de Vijver et al. 2002, 2004a, 2009, 2012, Van de Vijver & Gremmen 2006) bringing the total number for these islands to 63 and reducing the number of typical cosmopolitan species to less than 25% (Van de Vijver, unpubl. results).

A similar revision for the diatom flora on the islands in the southern Atlantic Ocean, started only a few years ago, resulted already in the description in several new taxa belonging, amongst others, to the genera *Navicula* Bory (Van de Vijver et al. 2011b), *Muelleria* (Freng.) Freng. (Van de Vijver et al. 2010), *Luticola* D.G. Mann in Round et al. (Van de Vijver & Mataloni 2008, Kopalová et al. 2011, Van de Vijver et al. 2011a) and *Hantzschia* Grunow (Zidarova et al. 2010). Recently, Van de Vijver & Zidarova (2011) reviewed the *Distantes* section of *Pinnularia* during a diatom survey of Livingston Island (South Shetland Islands). Five new taxa were described and six others discussed and illustrated.

This paper presents a discussion of the remaining *Pinnularia* species recorded during that survey. Based on thorough studies of the observed *Pinnularia* populations, several specimens could not be identified using currently available literature and are hence described as new. Comparisons are made with morphologically similar taxa.

Study Area

Livingston Island (974 km²) is the second largest island of the South Shetland Islands, (62°34’35”-62°10’35”S/60°54’14”-61°13’07”W), located at 110 km north of the Antarctic Peninsula and 830 km from the tip of South America (Cape Horn). The archipelago belongs to biogeographical Maritime Antarctic Province (Chown & Convey 2007). The climate on Livingston Island is maritime and less extreme than on the Antarctic Continent with a mean annual temperature of -4 °C and a maximum temperature in summer of +7.5 °C (Chipev & Veltchev 1996). Precipitation is much higher than on the Continent with mean annual values of 700–1000 mm (Bañón 2001). Glaciers and icecaps cover most of the island leaving only 10% ice-free during summer, mostly situated in the coastal areas. The largest ice-free area on Livingston Island, Byers Peninsula, is situated in the western part of island and has a surface of 60.6 km². The central part of the Peninsula is a plateau with a gently undulating relief culminating at a maximum elevation of 265 m (Cerro Start). More than 100 lakes and ponds of variable size are scattered over the entire peninsula, covering about 1.5% of its area (López-Martínez et al. 1996a, b). More information about the geology and hydrography of Byers Peninsula can be found in Toro et al. (2007).

Hurd Peninsula is smaller, located at the southern part of Livingston Island between two large bays: South Bay and False Bay. The Peninsula has an area of about 20 km^2 and a maximum elevation of 400 m a.s.l. near its southern end (López-Martínez et al. 1992). Most of the Peninsula is occupied by a dome glacier (Chipev & Veltchev 1996), leaving only the coastal area free of ice and snow during summer. In contrast to Byers Peninsula, a few lakes and large ponds exist on Hurd but snow and ice melting in summer result in a number of smaller and larger streams and brooks, small ponds and puddles that are scattered mostly at the coastal area. The terrestrial vegetation on the island is rather sparse and mainly composed of lichens (more than 50 species) and mosses (over 29 species) (Sancho et al. 1999). Only two vascular plants, *Deschampsia antarctica* Desv. and *Colobanthus quitensis*

(Kunth) Bartl. can be found on the beaches and lowlands. The fauna is restricted to several marine mammals and birds such as southern elephant seals [*Mirounga leonina* (L.)] and gentoo penguins [*Pygoscelis papu*a (J.R. Forster)].

Material & Methods

During several austral summers (2004–2009), material for diatom analysis has been sampled from various lakes, ponds, seepage areas and terrestrial moss carpets of Livingston Island, mainly from Hurd Peninsula and Byers Peninsula. Diatom samples from Byers Peninsula were prepared following the method described in Van der Werff (1955). Small parts of the samples were cleaned by adding 37% H_2O_2 and heating to 80°C for about 1h. The reaction was completed by addition of $KMnO_4$. Following digestion and centrifugation (three times 10 minutes at 3700 x g), cleaned material was diluted with distilled water to avoid excessive concentrations of diatom valves on the slides. Samples obtained from Hurd Peninsula were prepared according to the method described in Hasle & Fryxell (1970). Small subsamples were cleaned using concentrated H_2SO_4 followed by the addition of $KMnO_4$. The samples were then bleached with $H_2C_2O_4$ and washed several times with distilled water. Cleaned diatom material was mounted in Naphrax®. The slides were analysed using an Olympus BX51 microscope, equipped with Differential Interference Contrast (Nomarski) and the Colorview I Soft Imaging System. No observations were made using scanning electron microscopy. Valves of *Pinnularia* taxa are usually covered by external hymenes covering most of the external ultrastucture (Krammer 2000) hence reducing the potential useful information that can be derived from these observations. Only in very eroded valves can the structure of the alveoli and thepores be made visible. Additionally, the often complex structure of the raphe is better visualised in LM than in SEM.

Samples and slides are stored at the National Botanic Garden (Belgium) and the Faculty of Biology, University of Sofia (Bulgaria).

Type material of *Pinnularia krasskei* var. *ventricosa* Hust. (in A. Schmidt 1934: 391) and *P. krasskei* Hust. (in A. Schmidt 1934: 391) was investigated (sample 91/32 R.S. Südgeorgien, Grytviken, See, 8 from the Hustedt Collection, Bremerhaven, Germany). Slide AD9087 (Kerguelen N° 179, Tourbière) from the Manguin collection in Paris, France was used to examine the correct identity of *P. kolbei* Manguin (in Bourrelly & Manguin 1954: 35).

Morphological terminology follows Hendey (1964), Round et al. (1990) and Krammer (2000). The morphology of the new species were compared to known European, Antarctic or South American species (Cleve 1895, Bourrelly & Manguin 1954, Krammer 1992, 2000, Le Cohu & Maillard 1986, Manguin 1964, Rumrich et al. 2000, Metzeltin et al. 2005, Metzeltin & Lange-Bertalot 2007, Van de Vijver et al. 2002, 2009).

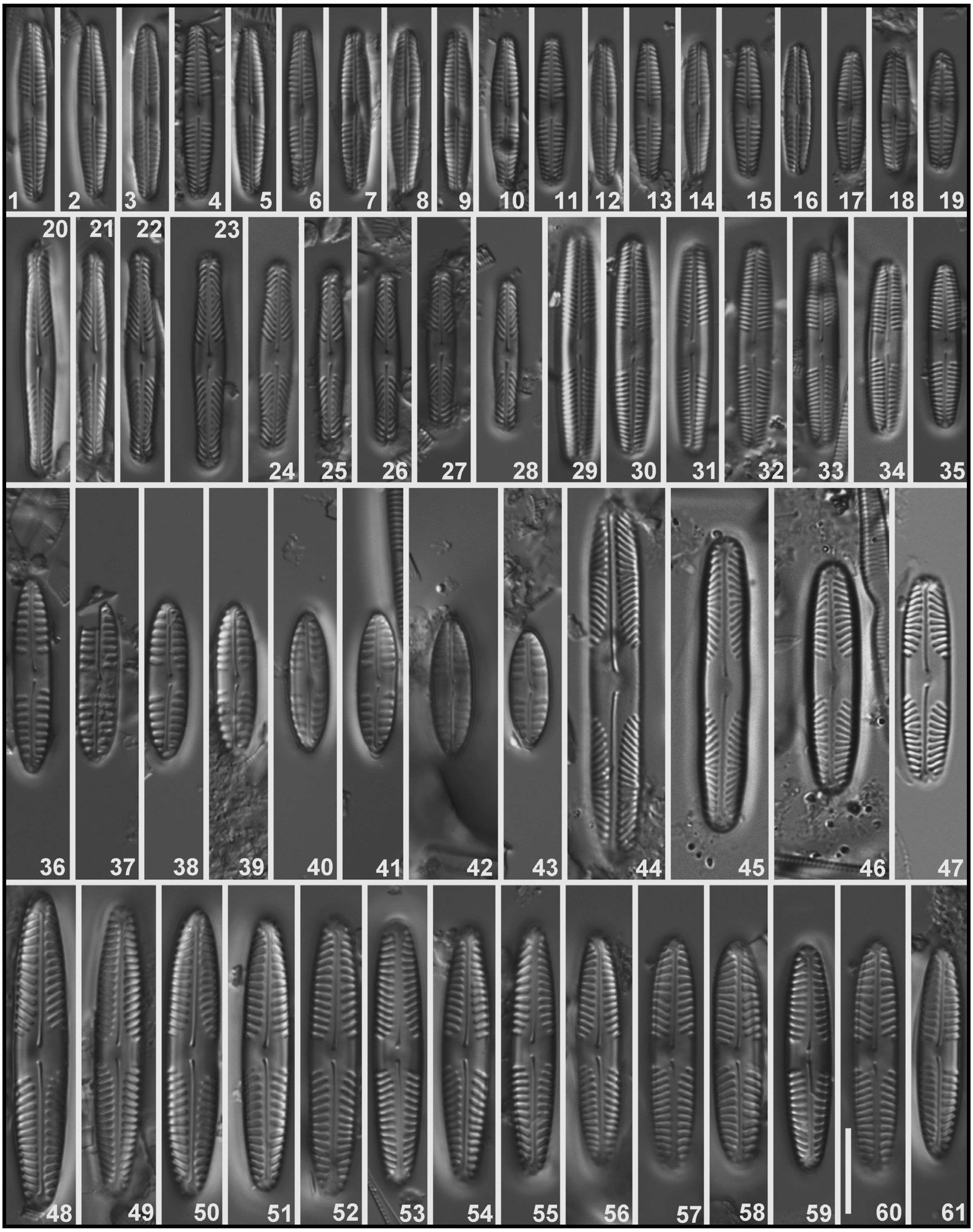
The biogeographical distribution of each *Pinnularia* taxon on Livingston Island was assessed relative to the verified records in Fukushima et al. (2001), Kawecka et al. (1998), Sabbe et al. (2003), Van de Vijver & Beyens (1996, 1997a, b), Van de Vijver et al. (2001, 2002, 2004b, 2008, 2009, 2012) and Wasell & Håkansson (1992) and on unpublished records from James Ross Island, Signy Island and South Georgia (Kopalová et al., unpubl. res., Sterken et al. unpubl. res.).

New taxon descriptions

Seventeen different *Pinnularia* taxa [excluding those from the section *Distantes* (see Van de Vijver & Zidarova 2011)] have been observed during the Livingston Island diatom survey. After a thorough morphological analysis, twelve could not be identified and are described as new. Only four were already known: *Pinnularia subantarctica* var. *elongata* (Manguin in Bourrelly & Manguin 1954: 36) Van de Vijver & Le Cohu (in Van de Vijver, Frenot & Beyens 2002: 96) and *P. gemella* Van de Vijver (in Van de Vijver et al. 2009: 432) were previously described from the Antarctic Region (Bourrelly & Manguin 1954, Van de Vijver et al. 2009) and have never been observed elsewhere; *P. strictissima* Manguin (1964: 84) was described from the Peruvian Andes; the taxonomic status of *P. austroshetlandica* (Carlson 1913: 16) Cleve-Euler (1948: 35), has been revised. A few valves could not be identified but have been given a provisional identification as *Pinnularia* sp1. until further observations can be made.

***Pinnularia pseudolaucensis* sp.nov.** (Figs A2.1–A2.19)

Valvae lineares ad lineares-lanceolatae marginibus leviter convexis, apicibus aliquando subrostratis. In speciminibus minoribus, apices paene non protracti. Longitudo 15–22 µm, latitudo 2.8–3.7 µm. Area axialis angusta, linearis, non dilatans in aream centralem. Area centralis formans fasciam rectangularem, potius latam. Raphe filiformis, ramis rectis. Terminationibus raphis proximales extensae solum leviter supra strias centrales cum poris *parvis, distantibus inter se. Fissurae raphis distales non discernandae in microscopio photonico, probabiliter falcatae. Striae parallelae ad leviter radiatae in media parte valvae, moderate convergentes ad apices, 16–18 in 10 µm. Lineae speciosae longitudinales non aspectabiles in microscopio photonico.*



FIGURES A2.1–A2.47 – *Pinnularia pseudolaucensis* sp. nov., *Pinnularia subcarteri* sp. nov., *Pinnularia subaltiplanensis*, *Pinnularia strictissima* and *Pinnularia* sp1 from Livingston Island. **Figs A2.1–A2.19.** LM of *P.*

pseudolaucensis sp. nov. **Figs A2.20–A2.28.** LM of *P. subcarteri* sp. nov. **Figs A2.29–A2.35.** LM of *P. subaltiplanensis*. **Figs A2.36–A2.43.** LM of *P. strictissima.* **Figs A2.44–A2.47.** LM of *Pinnularia* sp1. Scale bar = 10 µm.

Valves linear to narrowly linear-lanceolate with weakly convex margins and usually subrostrate apices. Smaller valves with almost non-protracted apices. Valve dimensions (n=28): length 15–22 µm, width 2.8–3.7 µm. Axial area narrow, linear, not widened towards the central area. Central area forming a rather large rectangular fascia. Raphe straight, proximal raphe endings extending only slightly beyond the last central striae. Raphe pores small and distant. Distal raphe fissures indistinct, probably sickle-shaped. Striae parallel to weakly radiate in the middle, moderately convergent towards the ends, 16–18 in 10 µm. Longitudinal lines not visible in LM.

Type: Byers Peninsula, Livingston Island, South Shetland Islands, sample BY068, leg. B. Van de Vijver, coll. date 18/01/2009, slide no. BR-4251 (holotype BR, slide PLP-196 (isotype University of Antwerp, Belgium), slide ZU8/25 (isotype BRM).

Habitat: The type population of *P. pseudolaucensis* was sampled from the sandy bottom of a small pool near the southern beaches, with an almost circumneutral pH (7.2) and a low specific conductance (<100 µS/cm) value.

Etymology: The specific epithet refers to the close resemblance to *P. laucensis* Lange-Bert., Rumrich & Krammer (in Rumrich et al. 2000: 200).

Observations: The type population of *P. pseudolaucensis* has a comparable valve outline and dimensions as the type of *P. laucensis* although the valves are somewhat narrower (width 2.8–3.7 vs 3.3–4.0 µm in the type popultion), have a higher stria density (16-18 vs 11–14 striae in 10 µm in *P. laucensis*) and a much smaller central area with the proximal raphe endings extending only slightly beyond the last striae. *Pinnularia altiplanenis* Lange-Bert., Krammer & Rumrich (in Rumrich et al. 2000: 197) differs in having a larger valve width (3.5–4.5 µm vs. 2.8–3.7 µm), as well as more radiate striae and a larger central area. Furthermore, the latter can also be separated based on its more linear outline with parallel margins. *Pinnularia pseudolaucensis* also resembles *P. amaniana* (Krammer 2000: 121) Kulikovskiy, Lange-Bert. & Metzeltin (2010: 364) but the latter is wider (4.7–6.1 µm) with a wide axial area (Krammer 2000). *Pinnularia schoenfelderi* Krammer (1992: 70) is much larger (width 5–

7 µm) (Krammer 2000). Other small-celled *Pinnularia* species such as *P. bertrandii* Krammer (2000: 122) and *P. perirrorata* Krammer (2000: 41) differ sufficiently in valve outline and axial area to exclude all conspecificity.

Pinnularia subcarteri **sp. nov.** (Figs A2.20–A2.28)

Valvae anguste lanceolatae, margines leviter convexae in media parte valvae, graduatim decrescentes in apices capitatos, anguste rotundatos. Longitudo 17–30 µm, latitudo 3.0–4.5 µm. Area axialis angustissima, linearis, dilatans in aream centralem. Area centralis formans fasciam latam, cuneiformem. Raphe filiformis, ramis rectis, terminationibus raphis proximalibus unilateraliter leviter deflexis cum poris guttiformibus expansis, relative distantibus inter se. Terminationes raphis distales paene non discernandae in LM, falcatae. Striae fortiter radiatae in media parte valvae, abrupte convergentes ad apices, 12–14 in 10 µm. Lineae speciosae longitudinales nullae.

Valves narrowly lanceolate, slightly convex in the middle and gradually narrowing towards the capitate, narrowly rounded valve apices. Valve dimensions (n=19): length 17–30 µm, width 3.0–4.5 µm. Axial area very narrow, widening towards the central area. Central area forming a broad, wedge-shaped fascia. Raphe filiform, straight with only slightly deflected central endings terminating in clearly droplike expanded, relatively distant, central pores. Terminal fissures almost indistinct in LM, probably sickle-shaped (Figs A2.22–A2.23). Striae strongly radiate in the middle, becoming abruptly strongly convergent at the apices, 12–14 in 10 µm. Longitudinal lines absent.

Type: Byers Peninsula, Livingston Island, South Shetland Islands, sample BY068, leg. B. Van de Vijver, coll. date 18/01/2009, slide no. BR-4252 (holotype BR, slide PLP-197 (isotype University of Antwerp, Belgium), slide ZU8/28 (isotype BRM).

Habitat: *Pinnularia subcarteri* is a rare species on Livingston Island and was found in a few samples. The type population was sampled from the sandy bottom of a small pool near the southern beaches, with an almost circumneutral pH (7.2) and a low specific conductance (<100 µS/cm) value. The species was also observed in the surrounding moss vegetation. On Hurd Peninsula, the species was occasionally observed mostly on moss vegetations surrounding small water basins and in a small brook, flowing out from a shallow melt-water pool, with low specific conductance values (58 µS/cm).

Etymology: The specific epithet refers to the close resemblance to *P. carteri* Krammer (2000: 48).

Observations: *Pinnularia subcarteri* shows some similarities to *P. diversa* Østrup (1901: 273) and *P. carteri*. Both *P. diversa* and its variety *subcapitata* Krammer & Lange-Bertalot (in Krammer 2000: 46) differ, however, in having a larger width (5–6 µm vs 3.0–4.5) and a lower stria density (10–12 vs. 12–14 in 10 µm). *Pinnularia carteri* is also distinctly wider (4.8–5.2 µm) with a coarser striation pattern (10–11 striae in 10 µm) and has large central pores that are close together, in contrast to *P. subcarteri*, which has distant central pores. Rumrich et al. (2000, plate 144, figs A2.17–A2.20) illustrate several valves identified as *P. martinii* Krasske (1939: 394) that are probably conspecific with *P. subcarteri*. However, comparison with type material of *P. martinii* (Van de Vijver et al., unpubl. res.) indicated that the illustrated valves in Rumrich et al. (2000) certainly do not belong to *P. martinii* sensu Krasske. The latter is characterized by more convex, less tumid valve margins, an axial area that is clearly widened towards the central area and a much larger central area (Lange-Bertalot et al. 1996, Van de Vijver et al., unpubl. res.).

Pinnularia subaltiplanensis sp. nov. (Figs A2.29–A2.35)

Valvae lineares ad angustissime lanceolatae, marginibus parallelis ad leviter convexis. Apices in speciminibus maioribus leviter protractae, late subrostratis, in speciminibus minorobus late rotundatae. Longitudo 21–28 µm, latitudo 3.6–4.5 µm. Area axialis angusta, linearis, non dilatans in aream centralem. Area centralis formans fasciam latam, aliquando asymmetricam. Raphe filiformis, ramis rectis, terminationibus raphis proximalibus unilateraliter leviter deflexis cum, extensis in aream centralem. Terminationes raphis distales paene non discernandae in LM, falcatae. Striae leviter ad moderate radiatae in media parte valvae, convergentes ad apices, 16–19 in 10 µm. Lineae speciosae longitudinales nullae.

Valves linear to narrowly lanceolate with parallel to slightly convex margins. Apices in larger specimens slightly protracted and broadly subrostrate, in smaller valves clearly broadly rounded. Valve dimensions (n=10): length 21–28 µm, width 3.6–4.5 µm. Axial area narrow, linear, almost not slightly widened towards the valve middle. Central area forming a large, occasionally asymmetrical, fascia, about ¼ to ⅓ of the valve length. Raphe straight with weakly deflected proximal endings, extending well beyond the last central striae, terminating in clearly expanded central pores, moderately distantly spaced. Distal raphe fissures barely visible, probably sickle-shaped. Striae weakly to moderately radiate near the centre, convergent at the apices, 16–19 in 10 µm. Longitudinal lines not visible in LM.

Type: Hurd Peninsula, Livingston Island, South Shetland Islands, sample A24/2006, leg. R. Zidarova, coll. date 27/12/2005, slide no. BR-4261 (holotype BR, slide PLP-206 (isotype University of Antwerp, Belgium), slide ZU8/27 (isotype BRM).

Habitat: The largest populations of *P. subaltiplanensis* was observed on Hurd Peninsula where the species was found in low abundances in a small brook flowing out from a shallow lake with a low specific conductance (58 µS/cm) value and pH of 6.3. Occasionally the species was found in a wet moss vegetation growing around small puddles. On Byers Peninsula, only a few valves were observed.

Etymology: The specific epithet refers to its close resemblance to *P. altiplanensis* Lange-Bert., Krammer & Rumrich in Rumrich, Lange-Bert., & Rumrich 2000: 197).

Observations: *Pinnularia subaltiplanensis* is most similar to *P. altiplanensis* but the valves are narrower than the type population of *P. altiplanensis* from the Chilean Altiplano (3.6–4.5 vs. 4–6 µm in *P. altiplanensis*) giving them a more slender outlook. The central raphe endings in *P. subaltiplanensis* are more distantly spaced than in *P. altiplanensis*. *Pinnularia laucensis* is smaller, with a maximum length of up to 20 µm and a valve width of 3.3–4.5 µm compared to 21–28 µm and 3.6–4.5 µm in *subaltiplanensis*, and has less radiate, widely spaced striae (11–14 vs. 16–19 in 10 µm). Other similar species are *P. schoenfelderi, P. frauenbergiana* Reichardt (1985: 182) and *P. kuetzingii* Krammer (1992: 104), all known from Europe (Krammer 2000). *Pinnularia schoenfelderi* can be easily separated based on the larger valve width (5–7 µm vs 3.6–4.5 µm) and lower stria density (13–16 vs 16–19 in 10 µm), as well as the smaller central area, less distantly spaced central raphe endings and a more lanceolate valve outline. *Pinnularia frauenbergiana* has comparable valve dimensions but a more elliptic-lanceolate valve outline and more densely spaced striae (18–22 in 10 µm). *Pinnularia kuetzingii* differs by having a higher stria density of 18–20 in 10 µm (vs. 16–19 in 10 µm) and less distantly spaced proximal pores. Finally, *P. bertrandii*, according to Rumrich et al. (2000)

is similar to *P. altiplanensis,* has broad subcapitate valve ends and an axial area that is clearly widens towards the central area (Krammer 2000).

Pinnularia strictissima Manguin (1964: 84, pl. 16, fig. 8) (Figs A2.36–A2.43)

Valves linear with almost straight margins and non-protracted, cuneate obtuse apices. Valve dimensions (n=10): length 14–23 µm, width 4.3–5.0 µm. Axial area narrow, linear, not widened towards the central area. Central area forming a large rectangular, asymmetrical fascia due to irregular shortening of striae near the central area. Raphe straight. Proximal raphe endings clearly deflected with expanded, drop-like raphe pores. Distal raphe fissures moderately large, sickle-shaped. Striae parallel, weakly convergent towards the ends 10–12 in 10 µm. Central striae bordering the central area, weakly radiate. Longitudinal lines absent.

Habitat: *Pinnularia strictissima* has been only found in one sample on Byers Peninsula. This population was sampled from the sandy bottom of a small pool near the southern beaches, with an almost circumneutral pH (7.2) and a low specific conductance (<100 µS/cm) value.

Observations: The Antarctic population of *Pinnularia strictissima* matches exactly the description provided by Manguin (1964), described from the Peruvian Andes in a swamp at an altitude between 4000 and 4100 m. The species can be confused with several small-celled *Pinnularia* species with a low stria density, a rather large fascia and an almost parallel striation pattern, such as *P. intermedia* (Lagerstedt 1873: 23) Cleve (1895: 80), *P. lagerstedtii* (Cleve 1895: 87) Cleve-Euler (1934: 57), *P. schimanskii* Krammer (2000: 32), *P. cuneorostrata* (Manguin in Bourrelly & Manguin 1954: 36) Van de Vijver & Le Cohu (in Van de Vijver et al. 2002: 83), *P. incognita* Krasske (1939: 397), *P. palatina* Lange-Bert. & W. Krüger (in Werum & Lange-Bert. 2003: 171) and even *P. obscura*. The most similar species is *P. intermedia* but the latter can be distinguished in having typical capitate to rostrate apices (in contrast to the cuneate obtuse apices in *P. strictissima*), large valve dimensions (length: 18–40 µm vs. 14–23 µm) and less distinct distal raphe fissures. Moreover, the striae in *P. intermedia* are radiate in the middle whereas in *P. strictissima*, the striae are almost entirely parallel. *Pinnularia lagerstedtii*, *P. schimanskii* and *P. incognita* have usually longer, more elongated valves (up to 35 µm) with more broadly rounded valve apices. *Pinnularia cuneorostrata*, up to now only found on the sub-Antarctic islands in the southern Indian Ocean, has a lower valve width (2.5–4.5 µm vs. 4.3–5.0) resulting in more elongated, thinner valves. Recently *P. palatina* was described from a spring in Germany but represents valves with bluntly rounded valve apices, a more elongated valve outline and less parallel striae. Finally, *P. obscura* has a different striation pattern with clearly radiate striae changing into distinctly convergent near the apices. The valve outline differs with typical rostrate apices.

***Pinnularia* sp1** (Figs A2.44–A2.47)

Valves linear with parallel or, in larger specimens, weakly undulated margins, and non-protracted, broadly rounded apices. Valve dimensions (n=11): length 25–35 µm, width 5.0–6.5 µm. Axial area narrow, linear, clearly widening towards the central area. Central area forming a large rhombic fascia, about 1/3 to 1/4 of valve length, expanded to the margins. Raphe slightly curved. Central raphe endings extending into the central area well beyond the last central striae, unilaterally deflected and finishing in relatively distant drop-like pores. Terminal fissures almost indistinct, ?-shaped. Striae strongly radiate in the middle, abruptly changing their direction to convergent toward the valve ends, 11–13 in 10 µm. Longitudinal lines absent.

Habitat and distribution: This is an extremely rare species on Livingston Island. Only a few valves were found on Hurd Peninsula, in streams, in a vegetation of wet mosses close to streams, brooks or puddles.

Observations: These Antarctic specimens belong to the complex of species around *P. divergentissima* (Grunow in Cleve & Möller 1879: 186) Cleve (1895: 77) sensu Krammer (2000). *Pinnularia divergentissima* and its varieties can be separated based on a different valve outline, having mostly convex margins and smaller subrostrate to capitate valve ends, as well as by a slightly higher number of striae (according to Krammer 2000: 12–14 vs 11–13 in 10 µm) and a smaller central area. The most similar species is *P. krammeri* Metzeltin (in Lange-Bertalot & Metzeltin 1996: 98), described from Finland. The main differences between the Antarctic population and *P. krammeri* include a larger valve width of *P. krammeri* (6.7–7.8 µm vs. 5.0–6.5 µm), a comparably smaller central area and more closely spaced proximal raphe endings. Since only a few valves have been observed, it is too early to conclude whether they should be described as an independent species or belong to *P. krammeri*.

Pinnularia australoschoenfelderi **sp. nov.** (Figs A2.48–A2.74)

Valvae lineares ad lineares-lanceolatae, marginibus parallellis ad leviter convexis in media parte valvae, graduatim decrescentibus in apices non-protractos, anguste rotundatos. Longitudo 25–38 µm, latitudo 4.6–6.0 µm. Area axialis angusta, linearis, aliquando dilatans in aream centralem. Area centralis formans fasciam latam, cuneiformem ad rectangularem. Raphe filiformis, ramis leviter curvatis. Terminationes raphis proximales extensae ultra strias centrales, deflexae cum poris parvis expansis. Fissurae raphis distales paene non discernandae in LM,similes signo interrogationis. Striae radiatae in media parte valvae, convergentes ad apices, 10–12 in 10 µm. Lineae speciosae longitudinales nullae.

Valves linear to linear-lanceolate with parallel to weakly convex margins, gradually narrowing towards the non-protracted, narrowly rounded apices. Valve dimensions (n=25): length 25–38 µm, width 4.6–6.0 µm. Axial area narrow, linear, occasionally widening towards the central area. Central area forming a large, bowtie-shaped to rectangular fascia. Raphe filiform with weakly curved raphe branches. Proximal raphe endings extending well beyond the last central striae, deflected and terminating in small, expanded raphe pores. Distal raphe fissures difficult to resolve in LM, ?-shaped. Striae radiate near the valve middle, becoming convergent towards the apices, 10–12 in 10 µm. Longitudinal lines absent.

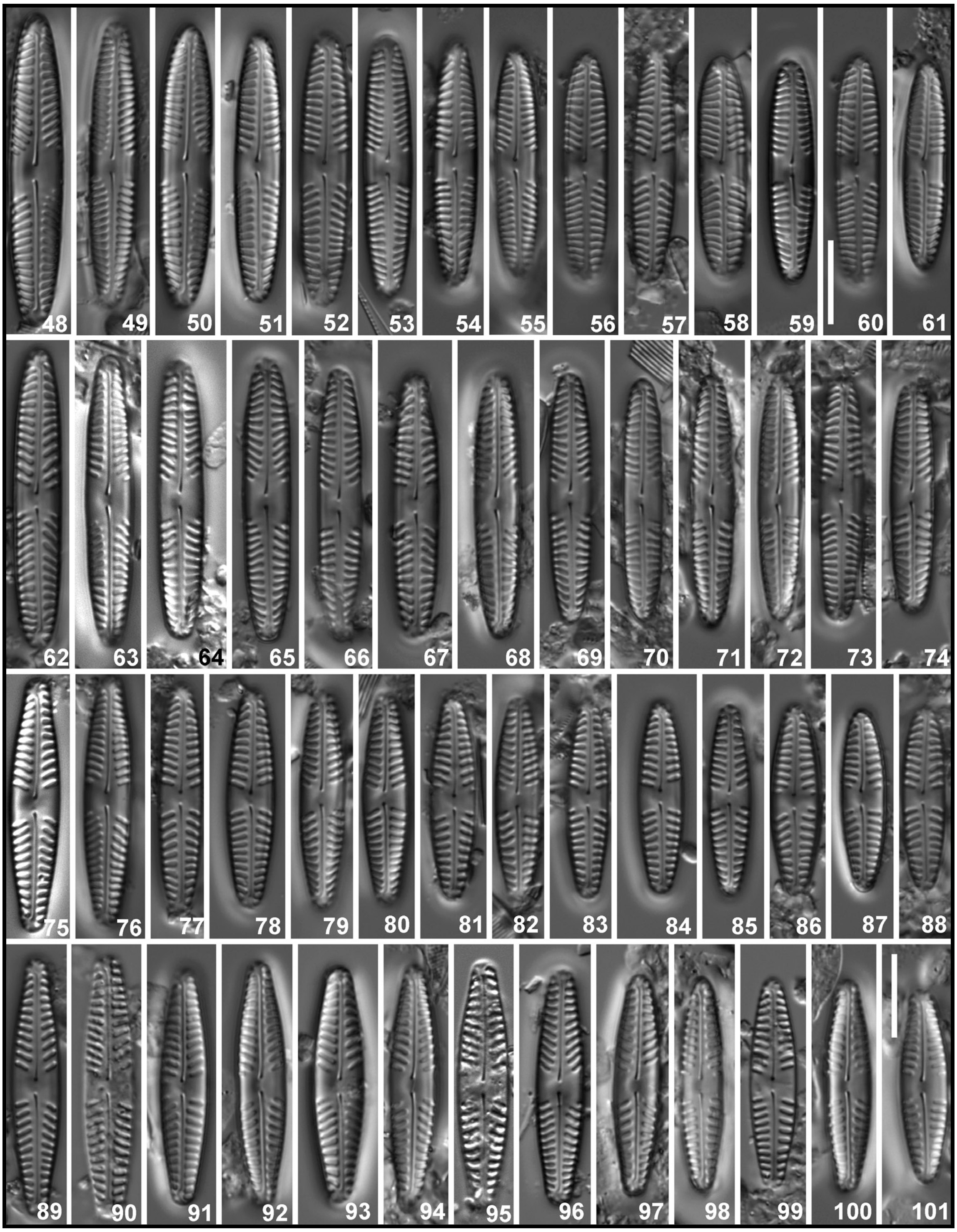
Type: Byers Peninsula, Livingston Island, South Shetland Islands, sample BY068, leg. B. Van de Vijver, coll. date 18/01/2009, slide no. BR-4253 (holotype BR, slide PLP-198 (isotype University of Antwerp, Belgium), slide ZU8/20 (isotype BRM).

Habitat: The type population of *Pinnularia australoschoenfelderi* was sampled from the sandy bottom of a small pool near the southern beaches on Byers Peninsula, with an almost circumneutral pH (7.2) and a low specific conductance (<100 µS/cm) value. The species was also found on Hurd Peninsula, usually rare but more abundant in soil under wet moss vegetations and among wet mosses surrounding shallow pools.

Etymology: The specific epithet refers to the geographic distribution of the species (Latin ‘*australis*’ meaning southern) and to its similarity to *Pinnularia schoenfelderi*.

Observations: *Pinnularia australoschoenfelderi* can be confused with *P. schoenfelderi*; the latter differs in having a higher stria density (13–16 in 10 µm vs. 10–12 in 10 µm) giving the species a finer striation pattern. *Pinnularia frauenbergiana* has even more striae per 10 µm

(18–22 vs. 10–12 in 10 µm). *Pinnularia obscura* has a more irregular striation pattern with a clear shift in stria direction halfway between the central area and apices. *Pinnularia obscuriformis* Krammer (2000: 51) has comparable dimensions but more linear valves with acutely rounded apices.



FIGURES A2.48–A2.101 – *Pinnularia australoschoenfelderi* sp. nov. and *Pinnularia magnifica* sp. nov. from Livingston Island. **Figs A2.48–A2.74**. LM of *P. australoschoenfelderi* sp. nov. **Figs A2.75–A2.101**. LM of *P. magnfica* sp. nov. Scale bar = 10 µm.

Pinnularia magnifica sp. nov. (Figs A2.75–A2.101)

Valvae clare lanceolatae ad etiam rhombicae-lanceolatae marginibus semi-rhomboidalibus ad convexis, apicibus leviter ad moderate protractis,cuneiformibus. Longitudo 22–32 µm, latitudo 4.9–6.0 µm. Area axialis angusta, linearis, aliquando dilatans in aream centralem. Area centralis formans fasciam cuneiformem latam. Raphe filiformis, ramis leviter curvatis. Terminationes raphis proximales leviter unilateraliter deflexae cum poris paene indistinctis. Fissurae raphis distales similes signo interrogationis. Striae moderate ad fortiter radiatae in media parte valvae, moderate ad fortiter convergentes ad apices, 9–10 in 10 µm. Lineae speciosae longitudinales nullae.

Valves clearly lanceolate to even rhombic-lanceolate with semi-rhomboidal to convex margins and cuneiform, weakly to moderately protracted apices. Valve dimension (n=33): length 22–32 µm, width 4.9–6.0 µm. Axial area narrow, linear, slightly widened towards the central area. Central area large, forming a bowtie-shaped fascia. Raphe filiform with weakly curved raphe branches. Proximal raphe endings slightly deflected to one side, with small, almost indistinct central pores. Terminal fissures ?-shaped. Striae moderately to strongly radiate in the middle, becoming moderately to strongly convergent towards the ends, 9–10 in 10 µm. Longitudinal lines absent.

Type: Byers Peninsula, Livingston Island, South Shetland Islands, sample BYS012, leg. B. Van de Vijver, coll. date 14/01/2009, slide no. BR-4254 (holotype BR, slide PLP-199 (isotype University of Antwerp, Belgium), slide ZU8/23 (isotype BRM).

Habitat: *Pinnularia magnifica* was frequently found on Livingston Island in small streams, pools and seepage areas with an alkaline pH and low specific conductance.The species has not been recorded in larger lakes. It is also observed in very low abundance on semi-wet and moist moss vegetation surrounding shallow water pools and on soil.

Etymology: The specific epithet represents the esthetical appreciation of the authors for this species (Latin *magnificus* means splendid, magnificent).

Observations: *Pinnularia magnifica* can hardly be confused with other *Pinnularia* species, based on its combination of radiate striae, low stria density and large, bowtie-shaped fascia. *Pinnularia acoricola* Hust. (in A. Schmidt 1934: 390) has a different striation pattern with a sudden shift in direction halfway down the valve and a higher stria density (13–16 in 10 µm vs. 9–10 in 10 µm). *Pinnularia obscura* shows a comparable shift in stria direction to *P. acoricola* and has a different valve outline with more rostrate apices. Another similar species is *P. cuneola* Reichardt (1981: 501) but it is larger (width 6–8 µm vs. 4.9–6 µm) with less protracted apices. The closely related *P. insidiosa* Manguin (1964: 81), described from the Peruvian Andes, has a similar striation pattern and a similar stria density but shows a different valve outline with less protracted apices (Manguin 1964).

Pinnularia microstauroides **sp. nov.** (Figs A2.102–A2.125)

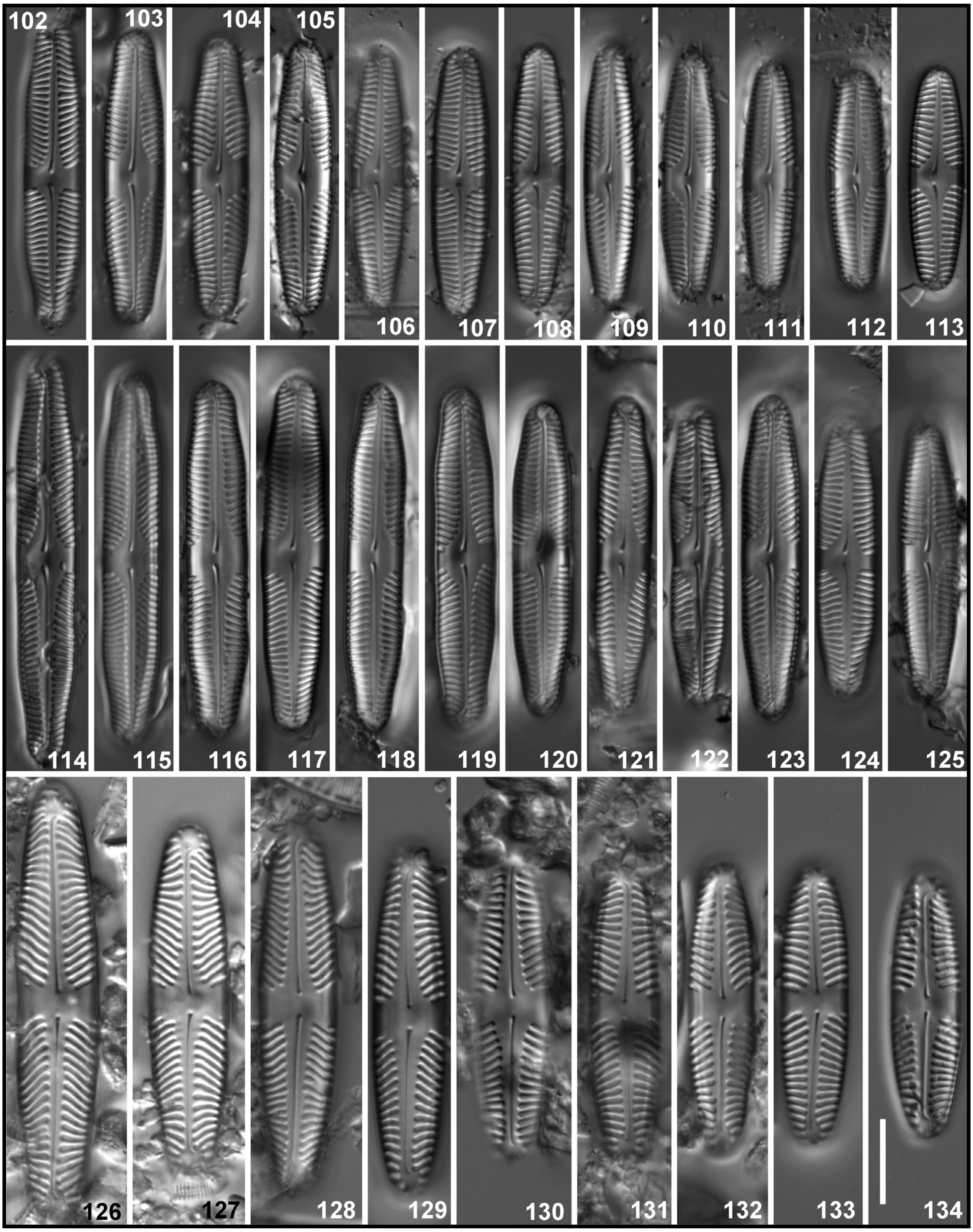
Valvae lineares marginibus plerumque undulatis, parallelis ad leviter convexis, apicibus late rotundatis, leviter protractis, rostratis ad subcapitatis. Longitudo 26–50 µm, latitudo 5.3–6.7 µm. Area axialis moderate lata, lanceolata, dilatans in aream centralem. Area centralis formans fasciam angustam ad moderate latam, rhomboidem, asymmetricam. Raphe filiformis, ramis leviter curvatis. Terminationes raphis proximales leviter unilateraliter deflexae cum poris expansis, guttiformibus. Fissurae raphis distales falcatae. Striae moderate radiatae in media parte valvae, convergentes ad apices, 12–14 in 10 µm. Lineae speciosae longitudinales nullae.

Valves linear with usually undulating, parallel to weakly convex margins and weakly protracted, rostrate to subcapitate, broadly rounded apices. Larger specimens with undulated margins. Valve dimensions (n=25): length 26–50 µm, valve breadth 5.3–6.7 µm. Axial area relatively large, lanceolate, widening toward the central area. Central area forming a narrow to moderately broad, rhomboid, usually asymmetrical fascia. Striae gradually becoming shorter towards the valve middle. Raphe filiform with slightly curved raphe branches. Proximal raphe endings clearly deflected with expanded droplike pores. Terminal fissures distinct, sickle-shaped. Striae moderately radiate in the middle, convergent at the ends, 12–14 in 10 µm. Longitudinal lines absent.

Type: Byers Peninsula, Livingston Island, South Shetland Islands, sample BY003, leg. B. Van de Vijver, coll. date 09/01/2009, slide no. BR-4262 (holotype BR, slide PLP-207 (isotype University of Antwerp, Belgium), slide ZU8/24 (isotype BRM).

Habitat: *Pinnularia microstauroides* was frequently observed in larger lakes on Byers Peninsula and only occasionally on Hurd Peninsula, where it was previously reported from as

P. microstauron var. *rostrata* Krammer (Zidarova 2008: 30, fig. 27). The largest populations were found in coastal lakes on Byers Peninsula with a higher specific conductance (150–250 µS/cm) and higher nutrients due to the presence of marine mammals and penguins.



FIGURES A2.102–A2.134 – *Pinnularia microstauroides* and *Pinnularia hamiltonii* sp. nov. from Livingston Island. **Figs A2.102–A2.125**. LM of *P. microstauroides*. **Figs A2.126–A2.134**. LM of *P. hamiltonii* sp. nov. Scale bar = 10 µm.

Observations: *Pinnularia microstauroides* clearly belongs to the complex of species around *P. microstauron* (Ehrenb. 1843) Cleve (1891: 28). The latter is a highly variable species and probably represents a complex rather than a single species. *Pinnularia microstauron*, based on the account in Krammer (2000), is larger with a valve breadth of 10.0–12.4 µm and usually with a lower stria density (9–11 in 10 µm vs. 12–14 in 10 µm). The undulating margins in *P. microstauroides* are also rarely observed in *P. microstauron*. A large number of varieties (later raised to the species level by Kulikovskiy et al. 2010), have already been described within the *P. microstauron*-complex, usually reflecting the local variability of the species. However, according to the original description in Krammer (2000), some of these varieties have a higher valve width and/or a lower stria density: *P. nanomicrostauron* Kulikovskiy, Lange-Bert. & Metzeltin (2010: 361) has a width of 6.0–7.0 µm with 10–11 striae in 10 µm whereas *P. microstauropsis* Kulikovskiy, Lange-Bert. & Metzeltin (2010: 361) has a width of 6.5–8.0 µm and 10–12 striae in 10 µm.

Pinnularia hamiltonii **sp. nov.** (Figs A2.126–A2.134)

Valvae ellipticae-lanceolatae ad anguste ellipticae marginibus convexis, graduatim decrescentibus in apices, apicibus non-protractis,obtuse rotundatis. Longitudo 30–53 µm, latitudo 7.3–9.3 µm. Area axialis moderate lata, lanceolata, clare dilatans in aream centralem. Area centralis formans fasciam cuneiformem potius latam. Raphe filiformis, ramis leviter curvatis. Terminationes raphis proximales deflexae cum poris expansis, guttiformibus. Fissurae raphis distales falcatae. Striae fortiter radiatae in media parte valvae, graduatim sed non abrupte convergentes ad apices, 9–10 in 10 µm. Lineae speciosae longitudinales nullae.

Valves elliptic-lanceolate to narrowly elliptic in smaller valves with convex margins gradually tapering towards the bluntly rounded, non-protracted apices. Valve dimensions (n=10): length 30–53 µm, width 7.3–9.3µm. Axial area moderately broad, lanceolate, clearly widening towards the central area. Central area forming a bowtie-shaped, rather large fascia. Raphe filiform with slightly curved raphe branches. Proximal raphe endings deflected terminating in droplike, expanded pores. Distal raphe fissures sickle-shaped. Striae strongly radiate near the valve middle, gradually but not abruptly becoming convergent towards the apices, 9–10 in 10 µm. Longitudinal lines absent.

Type: Byers Peninsula, Livingston Island, South Shetland Islands, sample BYS012, leg. B. Van de Vijver, coll. date 14/01/2009, slide no. BR-4255 (holotype BR, slide PLP-200 (isotype University of Antwerp, Belgium), slide ZU8/21 (isotype BRM).

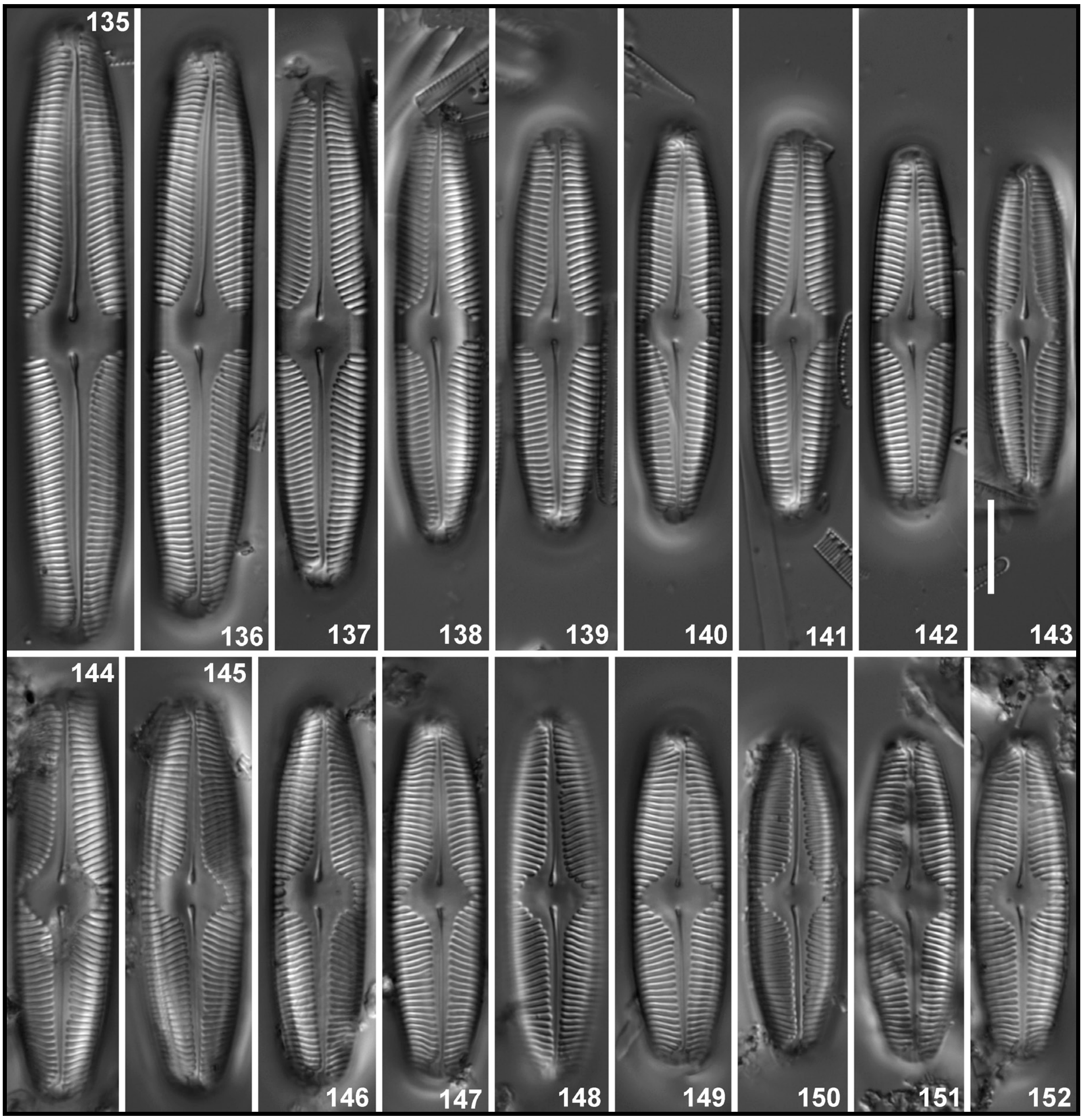
Habitat: Small populations of *P. hamiltonii* have been observed in several samples collected in wide variety of habitats on Byers Peninsula ranging from small pools and streams to lakes and seepage areas with a pH-range of 7.3–7.9 and a specific conductance <100 µS/cm.

Etymology: The species is named after our colleague Paul Hamilton (Museum of Nature, Ottawa, Canada) in recognition of his taxonomic work on diatoms.

Observations: *Pinnularia hamiltonii* can hardly be confused with other *Pinnularia* taxa. Only a few species are similar to *Pinnularia hamiltonii* : *P. suchlandtii* Hust. (in A. Schmidt 1934: 388), *P. superdivergentissima* Chaumont & Germain (1976: 587–588), *P. cuneola*, *P. acutobrebissonii* Kulikovskiy, Lange-Bert. & Metzeltin (2010 : 361) and *P. crozetii* Van de Vijver & Le Cohu (in Van de Vijver et al. 2002: 82). The most similar species is probably *P. crozetii*, described from the sub-Antarctic Crozet archipelago (Van de Vijver et al. 2002), but the latter differs in being usually larger (valve width up to 10.5 µm) with gradually shortening striae in the central area whereas *P. hamiltonii* lacks these shorter striae. *P. acutobrebissonii* is larger (width 10–11.4 µm vs. 7.3–9.3 µm) with more acutely rounded apices and a smaller central area (Krammer 2000). *P. superdivergentissima* has strictly linear valves with parallel margins (Chaumont & Germain 1976) and both *P. suchlandtii* and *P. cuneola* have a more rhombic-lanceolate valve outline (Krammer 2000).

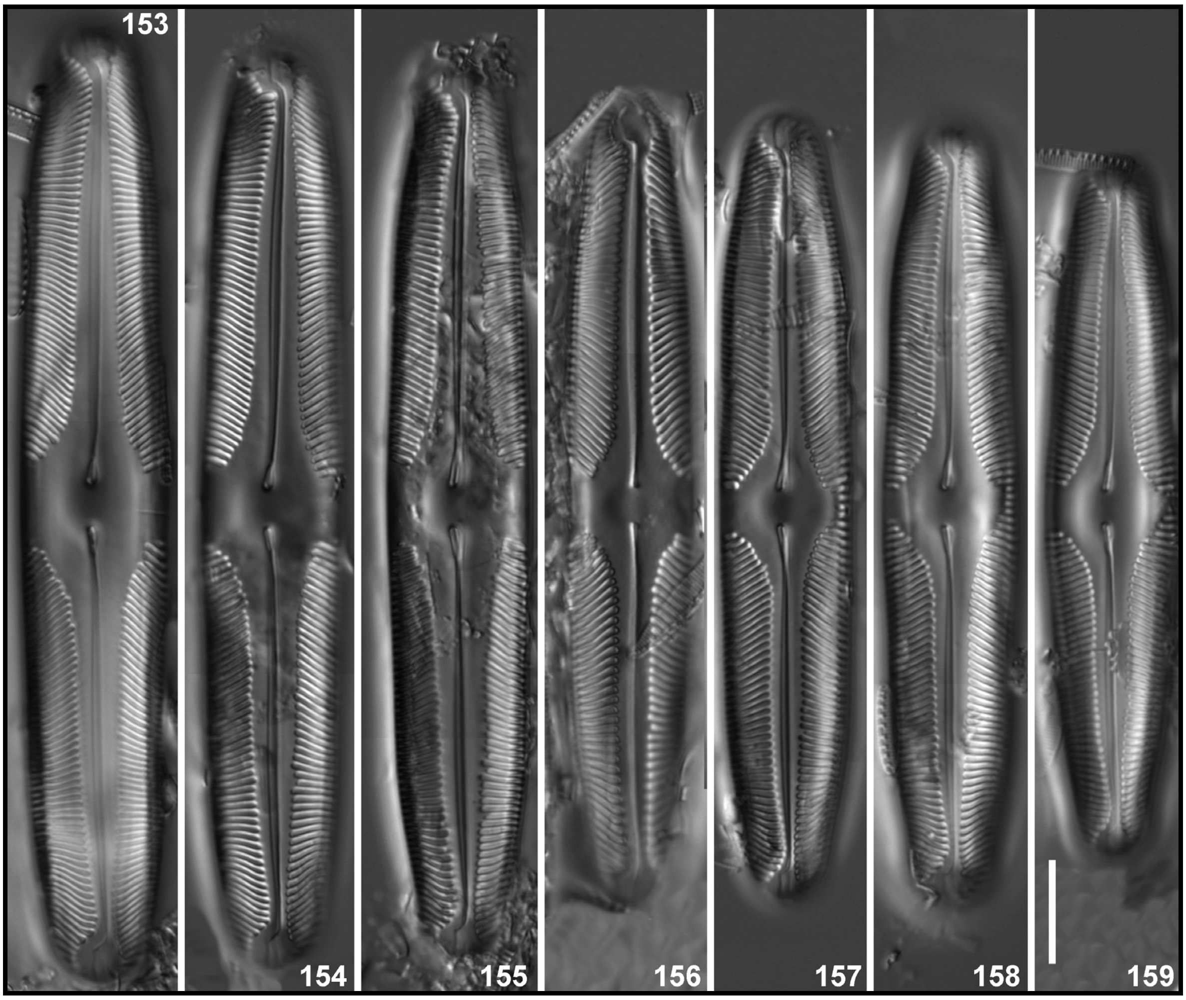
***Pinnularia australomicrostauron* sp. nov.** (Figs A2.135–A2.159)

Valvae lineares in speciminibus maioribus ad lineares-ellipticae in speciminibus minoribus marginibus parallellae ad moderate convexis. Specimina marginibus leviter undulates. Apices late subrostrati-subcapitati, leviter protracti ad late rotundati in specimibus minoribus. Longitudo 30–93 µm, latitudo 8.4–14.6 µm. Area axialis distincte lanceolata, angusta in apicibus, dilatans in aream centralem. Area centralis formans fasciam rhombicam, plerumque asymmetricam in speciminibus majoribus, latam. Striae centrales nonnullae abbreviatae in area centrali speciminum maiorum. Raphe lateralis terminationibus raphis proximalibus deflexis cum poris magnis guttiformibus. Fissurae raphis distales falcatae. Striae leviter ad moderate radiatae in media parte valvae, parallelae ad moderate convergentes ad apices, 12–15, pro parte maxima 13–14 in 10 µm. Lineae speciosae longitudinales nullae.



FIGURES A2.135–A2.152 – *Pinnularia australomicrostauron* sp. nov. from Livingston Island. **Figs A2.135–A2.152**. LM of *P. australomicrostauron*, smaller forms. Scale bar = 10 µm.

Valves linear in larger specimens to linear-elliptic in smaller specimens with parallel to moderately convex margins. Larger valves with weakly undulated margins. Valve apices broadly subrostrate-subcapitate, weakly protracted to broadly rounded in smaller ones. Valve dimensions (n=45): length 30–93 µm, width 8.4–14.6 µm. Axial area distinctly lanceolate, narrow near the apices and widening towards the central area. Central area forming a large rhombic, usually asymmetrical, fascia in larger specimens. Smaller specimens only with rhombic to rounded central area with shortened striae bordering the area. Raphe lateral with deflected proximal raphe endings terminating in droplike large pores. Distal raphe fissures sickle-shaped. Striae weakly to moderately radiate in the middle, almost parallel to moderately convergent towards the apices, 12–15, mostly 13–14, in 10 µm. Longitudinal lines absent.



FIGURES A2.153–A2.159 – *Pinnularia australomicrostauron* sp. nov. from Livingston Island. **Figs A2.153–A2.159**. LM of *P. australomicrostauron*, larger forms. Scale bar = 10 µm.

Type: Byers Peninsula, Livingston Island, South Shetland Islands, sample BY061, leg. B. Van de Vijver, coll. date 17/01/2009, slide no. BR-4256 (holotype BR, slide PLP-201 (isotype University of Antwerp, Belgium), slide ZU8/19 (isotype BRM).

Habitat: *Pinnularia australomicrostauron* is one of the most common species of *Pinnularia* on Livingston Island, often forming very large populations in a wide variety of habitats, both aquatic (pools and larger lakes) and terrestrial (e.g. wet soil and mosses around small water bodies).

Etymology: The specific epithet refers to the geographic distribution of the species (Latin: '*australis*' meaning southern) and the similarity to *Pinnularia microstauron*.

Observations: *Pinnularia australomicrostauron* mostly resembles *P. ventricodecrescens* Kulikovskiy, Lange-Bert. & Metzeltin (2010: 365), *P. microstauron* and *P. rhombarea* Krammer (in Metzeltin & Lange-Bertalot 1998: 185); it has been reported from Antarctica as *P. microstauron. Pinnularia microstauron* was originally described by Ehrenberg from plant roots in Brazil and until recently it was believed to be a polymorph species. Krammer (2000) suggested, however, that its plasticity might not be so large. According to his assumption, *P. microstauron* var. *microstauron* lacks undulated margins and has broadly rostrate to wedge-shaped ends. Parts of the *Pinnularia australomicrostauron* populations clearly show valves with undulated margins and ends that are broadly subrostrate to subcapitate. The new species has a higher stria density than normally observed in *P. microstauron* (9–11, rarely 15 in 10 µm vs. 13–14 in 10 µm in *P. australomicrostauron*). The most distinctive feature separating the two species is the distance between the central raphe endings,which is much larger in the *P. australomicrostauron* when compared to *Pinnularia microstauron* s.s. *Pinnularia microstauron* var. *nonfasciata* Krammer (2000: 74) usually lacks a fascia, in contrast to *P. australomicrostauron,* where only in smaller individuals is a fascia absent. Other varieties of *P. microstauron* listed in Krammer (2000) are small enough not to be confused with *P. australomicrostauron*. *Pinnularia rhombarea* has a rather similar valve outline but is generally wider (width 10.5–16.o µm vs. 8.4–14.6 µm) with a lower stria density (9–11 in 10 µm vs. 13–14 in 10 µm). Probably the most similar species is *P. ventricodecrescens*, originally described from South Georgia as *P. krasskei* var. *ventricosa*. Analysis of the type material indicated that in the latter, also the larger specimens lack a fascia, the valves have a higher valve width (13–16 µm vs. 8.4–14.6 µm) and clearly subcapitate apices. The longest specimens of *P. australomicrostauron* closely resemble *P. krasskei*, also described from South Georgia (Krammer 2000). However, based on the analysis of type material, the latter always has strictly parallel margins with broadly rounded, never protracted apices, a larger valve width (15–16 µm vs. 14.6 in the largest specimens of *P. australomicrostauron*) and a lower stria density (9–11 in 10 µm vs. 12–15 in 10 µm).

Pinnularia australodivergens **nov. sp.** (Figs A2.160–A2.165)

Valvae lineares marginibus paene parallelis, apicibus non-protractis, late rotundatis. Longitudo 66–110 µm, latitudo 14–19 µm. Area axialis linearis-lanceolatae, potius lata, dilatans in aream centralem. Area centralis rhombica formans fasciam rectangularem potius *parvam, maculis rotundatis in marginibus. Raphe lateralis, ramis leviter undulatis. Terminationes raphis proximales rectae. Pori centrales annicibus lateralis. Fissurae raphis distales unciformes. Striae moderate radiatae in media parte valvae, graduatim fortiter convergentes ad apices, 9–11 in 10 µm. Lineae speciosae longitudinales nullae.*

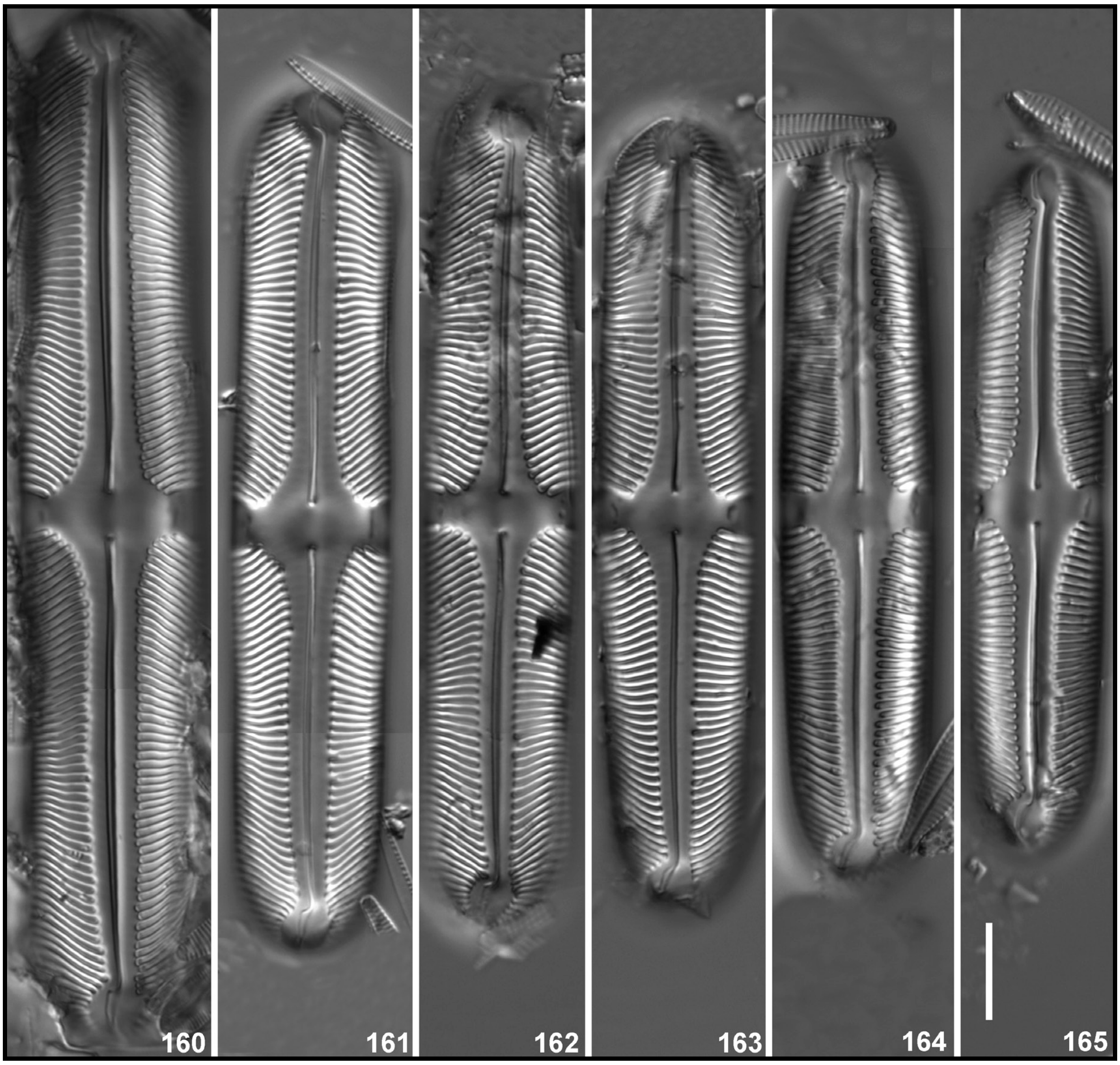
Valves linear with almost parallel margins and broadly rounded, non-protracted apices. Valve dimensions (n=12): length 66–110 µm, width 14–19 µm. Axial area linear-lanceolate, rather broad, widening toward the central area. Central area rhomboid, forming a rather narrow, rectangular fascia with rounded thickenings at the margins, visible in LM. Raphe lateral, slightly undulating with straight proximal raphe endings. Central pores with lateral annexes. Distal raphe fissures bayonet -shaped. Striae moderately radiate in the middle, gradually becoming strongly convergent near the apices, 9–11 in 10 µm. Longitudinal lines absent.

Type: Byers Peninsula, Livingston Island, South Shetland Islands, sample BY047, leg. B. Van de Vijver, coll. date 14/01/2009, slide no. BR-4257 (holotype BR, slide PLP-202 (isotype University of Antwerp, Belgium), slide ZU8/17 (isotype BRM).

Habitat: *Pinnularia australodivergens* could be found in a few large lakes on the central plateau of Byers Peninsula near Limnopolar lake. The lakes are characterized by a weakly alkaline pH (7.2–7.6) and a low specific conductance (<100 µS/cm).

Etymology: The variety epithet refers to the geographic distribution of the species (Latin: '*australis*' meaning southern).

Observations: *Pinnularia australodivergens* clearly belongs to the *P. divergens* W. Smith (1853: 57)-complex based on the valve outline, dimensions and the typical rounded thickenings in the central area. The species shows some similarity with several other species and varieties in this complex, some recently raised to species rank (Kulikivskiy et al. 2010) such as *P. canadodivergens* Kulikovskiy, Lange-Bert. & Metzeltin (2010: 360), *P. divergens* var. *sublineariformis* Krammer 2000: 62) and *P. biconstrictoides* Kulikovskiy, Lange-Bert. & Metzeltin (2010: 360). *P. canadodivergens* can be distinguished by its more swollen middle part, the typical markings along the axial area and the lower number of striae (8–10 vs. 9–11 in 10 µm). *Pinnularia divergens* var. *sublineariformis* is much smaller with a lower valve width (11.0–13.5 µm vs. 14–19 µm). Finally, *P. biconstrictoides* has a different valve outline with clearly swollen central and terminal parts of the valve, a large, rhomboid, central area and usually larger valve dimensions.



FIGURES A2.160–A2.165- *Pinnularia australodivergens* sp. nov. from Livingston Island. Scale bar = 10 µm.

Pinnularia sergiplaiana **sp. nov.** (Figs A2.166–A2.173)

Valvae lanceolatae ellipticae-lanceolatae marginibus convexis, apicibus graduatim decrescentibus, aliquando leviter protractis, late rotundatis. Longitudo 50–65 µm, latitudo 10–13 µm. Area axialis moderate lata, lanceolata, graduatim dilatans in aream centralem. Area centralis rhombica formans fasciam cuneiformem moderate latam, maculis rotundatis in marginibus. Raphe lateralis, ramis clare undulatis. Terminationes raphis proximales rectae ad leviter deflexae. Pori centrales annicibus lateralis. Fissurae raphis distales unciformes.

Striae fortiter radiatae in media parte valvae, distincte convergentes ad apices, 10–12 in 10 µm. Lineae speciosae longitudinales nullae.

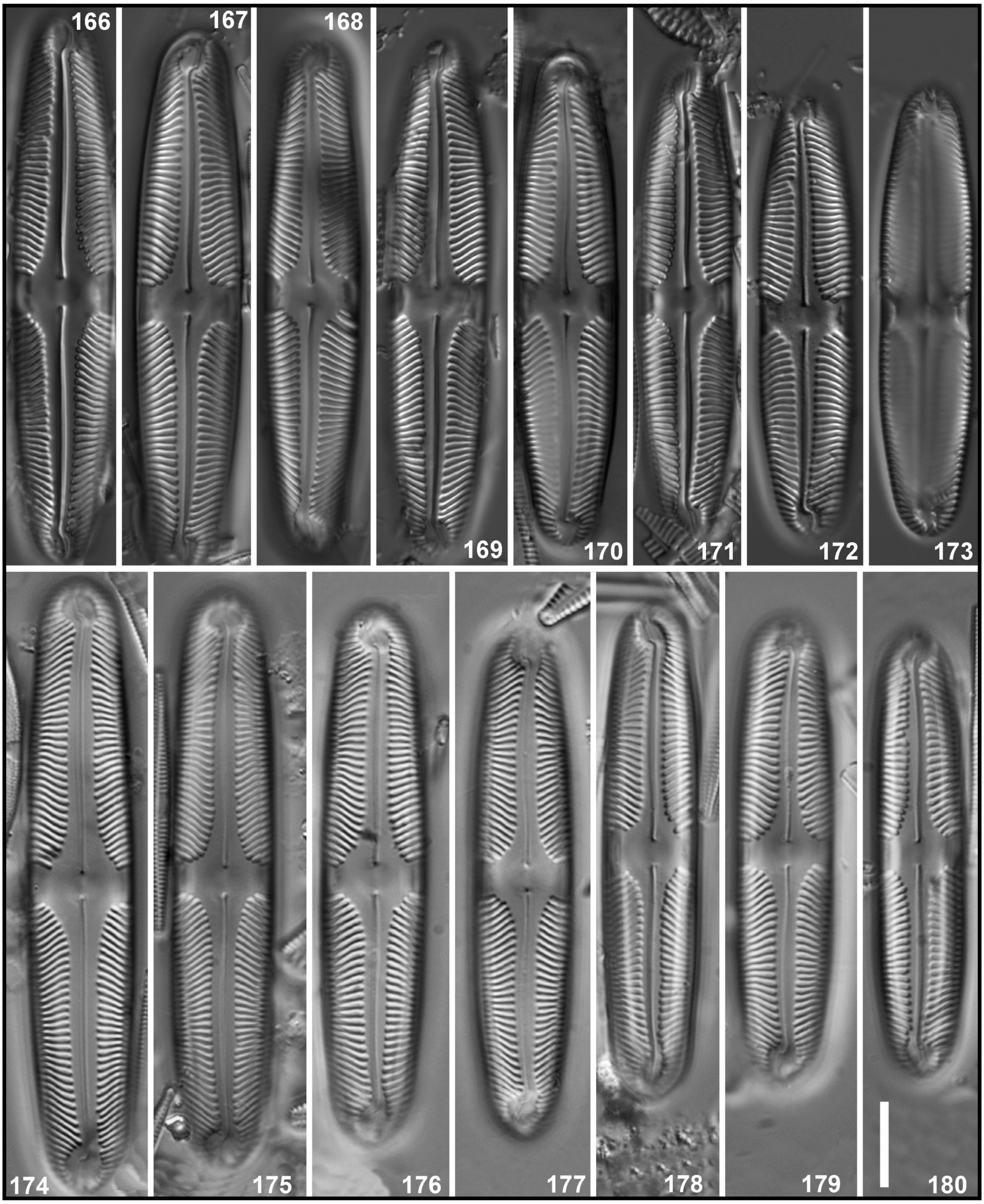
Valves lanceolate to elliptic-lanceolate with convex margins and broadly rounded, gradually narrowing, sometimes slightly protracted apices. Valve dimensions (n=10): 50–65 µm, width 10–13 µm. Axial area moderately large, lanceolate, gradually widening towards the central area. Central area rhomboid, forming a bowtie-shaped moderately large fascia with rounded thickenings at the margin. Raphe lateral, clearly undulating with straight to weakly deflected proximal raphe endings. Raphe pores with lateral annexes. Distal fissures bajonet-shaped. Striae strongly radiate near the valve centre, becoming distinctly convergent towards the apices, 10–12 in 10 µm. Longitudinal lines absent.

Type: Byers Peninsula, Livingston Island, South Shetland Islands, sample BY047, leg. B. Van de Vijver, coll. date 14/01/2009, slide no. BR-4258 (holotype BR, slide PLP-203 (isotype University of Antwerp, Belgium), slide ZU8/26 (isotype BRM).

Habitat: *Pinnularia sergiplaiana* could be found in several large lakes on the central plateau of Byers Peninsula near Limnopolar lake. The type population was sampled from the sediment of a large lake, characterized by a weakly alkaline pH (7.4) and a low specific conductance (108 µS/cm). So far, the species has been rarely found on Hurd Peninsula where from it was previously reported as *P. media* (Krammer 2000: 61) Kulikovskiy, Lange-Bert. & Metzeltin (2010: 359) (Zidarova 2008, p. 30, fig. 24).

Etymology: The species is named in honor of our colleague Sergi Pla (Madrid, Spain), in recognition of his contribution to the knowledge of Antarctic algae.

Observations: This new species clearly belongs to the complex of taxa around *P. divergens*, based on the presence of the typical rounded thickenings in the central area and the lateral annexes to the proximal raphe pores. Most of the species and varieties belonging to this complex are usually larger (Krammer 2000). *Pinnularia divergens* has a valve width of 14–19 µm (vs. 10–13 µm) and has clearly capitate to subcapitate apices. *Pinnularia media* has similar valve dimensions but is characterized by clearly capitate apices and lacks the typical fascia. *Pinnularia livingstonensis* sp. nov. (see below) can be distinguished by its typical parallel margins and its broadly rounded apices. *Pinnularia crozetii* lacks the rounded thickenings in the central area and has a more lanceolate valve outline. *Pinnularia* *divergentissima* (Kütz.1844: 93) Rabenh. (1864 : 222) has a somewhat similar valve outline but lacks the central thickenings.



FIGURES A2.166–A2.180 – *Pinnularia sergiplaiana* sp. nov. and *Pinnularia livingstonensis* sp. nov. from Livingston Island. **Figs A2.166–A2.173**. LM of *P. sergiplaiana* sp. nov. **Figs A2.174–A2.180**. *P. livingstonensis* sp. nov. Scale bar = 10 µm.

Pinnularia livingstonensis **sp. nov.** (Figs A2.174–A2.180)

Valvae lineares marginibus paene parallelis, apicibus late rotundatis, non-protractis. Longitudo 44.7–72.3 µm, latitudo 10–12.8 µm. Area axialis potius lata, linearis-lanceolata, dilatans in aream centralem. Area centralis formans fasciam rhombicam latam, maculis rotundatis in marginibus. Raphe lateralis, ramis leviter undulatis. Terminationes raphis proximales leviter deflexae cum poris indistinctis. Pori centrales annicibus lateralis. Fissurae raphis distales unciformes. Striae moderate ad fortiter radiatae in media parte valvae, graduatim moderate ad fortiter convergentes ad apices, 11–12 in 10 µm. Lineae speciosae longitudinales nullae.

Valves linear with almost parallel margins and very broadly rounded, non-protracted apices. Valve dimensions (n=53): length 44.7–72.3 µm, width 10.0–12.8 µm. Axial area linear-lanceolate, rather broad, widening toward the central area. Central area forming a large, rhomboid fascia with rounded thickenings at the margin, visible in LM. Raphe lateral, only slightly undulating with straight to only very weakly deflected proximal raphe endings and inconspicuous central pores, bearing small lateral annexes. Distal raphe fissures bajonet-shaped. Striae moderately to strongly radiate in the middle, gradually becoming moderately to strongly convergent towards the ends, (10) 11–12 in 10 µm. Longitudinal lines absent.

Type: Hurd Peninsula, Livingston Island, South Shetland Islands, sample 5b/05, leg. R. Zidarova, coll. date 25/01/2005, slide no. BR-4259 (holotype BR, slide PLP-204 (isotype University of Antwerp, Belgium), slide ZU8/22 (isotype BRM).

Habitat: *Pinnularia livingstonensis* is most abundant in a sample taken on Hurd Peninsula from very wet mosses close to a brook running down on a rocky surface, at about 70m from the sea shore near Caleta Argentina Bay. The species was previously misidentified and reported as *P. divergens* var. *sublinearis* P.T. Cleve (1895: 79) (Zidarova 2008: 30, figs 25 & 26) whereas the larger forms were earlier reported as *P. divergens* f. *biconstricta* (Cleve-Euler 1939: 15) Cleve-Euler (1955: 53), which probably represent initial cells of the same species.

Etymology: The specific epithet refers to Livingston Island where the species was first discovered.

Observations: *Pinnularia livingstonensis* belongs to the *P. divergens*-complex based on the central rounded thickenings and the annexes to the proximal raphe pore (Krammer 2000). *Pinnularia divergens* var. *subbacillaris* Krammer (2000: 62) has a similar valve outline but is narrower (width 7.6–9.0 µm vs. 10.0–12.8 µm) with a higher stria density (12–14 vs. 11–12 in 10 µm). *Pinnularia canadodivergens* has slightly larger dimensions, a lower stria density (8–10 vs. 11–12 in 10 µm) and a smaller fascia. *Pinnularia divergens* var. *sublineariformis,* described from Bavaria, Europe, has comparable dimensions but a lower stria density (10 vs. 11–12 in 10 µm). All other varieties of *Pinnularia divergens,* listed in Krammer (2000), are easily distinguished from the Antarctic species by outline, dimensions and shape of the central area. Somewhat similar in outline to *P. livingstonensis* is *P. parvulissima* Krammer (2000: 95) but the latter has typical depressions in the central area and lacks the rounded thickenings.

Pinnularia austroshetlandica **(Carlson 1913: 16, pl. 1, fig. 25)** (Figs A2.181–A2.188)

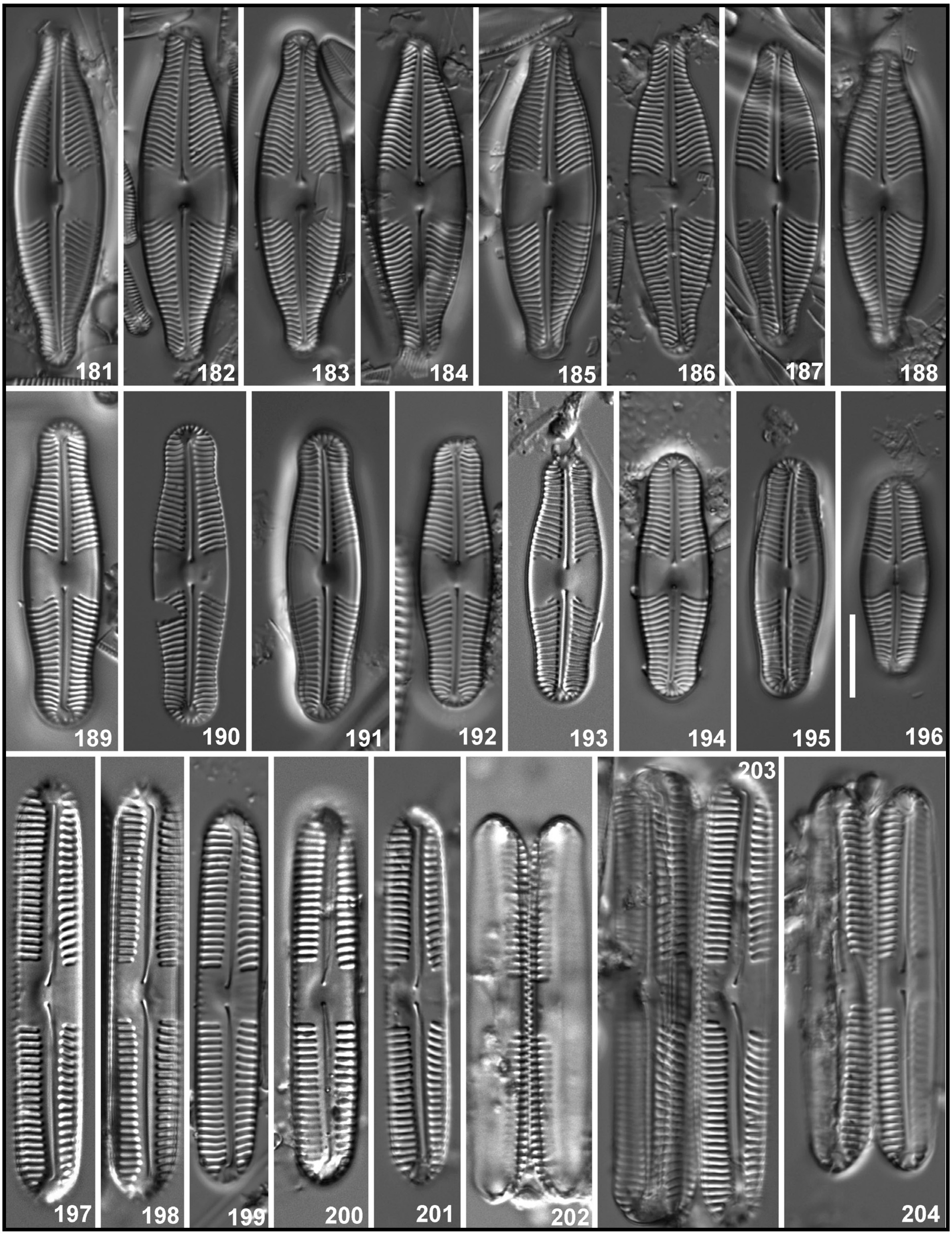
Synonymy: *Pinnularia kolbei* Manguin (in Bourrelly & Manguin 1954: 35) non *P. kolbei* Mölder (1952: 27), *P. parakolbei* Fukushima, Ko-Bayashi & Yoshitake (Fukushima et al. 2001: 108), *P. bottnica* Krammer (2000: 78) sensu Van de Vijver et al. (2002), *Navicula nivorum* Peragallo (1921: 20), *Navicula nivorum* var. *elongata* Peragallo (1921: 20).

Valves broadly elliptic-lanceolate with clearly convex margins and protracted, rostrate ends. Valve dimensions (n = 25): length 32–42 µm, width 9.7–11.3 µm. Axial area linear to linear-lanceolate, narrow, slightly widening towards the central area. Central area a large, bow-tie-shaped fascia. Raphe filiform with weakly curved branches. Central raphe endings deflected to the secondary side with large, almost triangular-shaped, central pores. Terminal fissures bent to one side, opposite to the central endings. Striae geniculate, radiate near the centre, becoming convergent near the valve ends, 13–15 in 10 µm. Longitudinal lines absent.

Habitat: The species is rather rare on Livingston Island. On Hurd Peninsula, it was found relatively abundantly in only one sample taken from a *Sanionia georgico-uncinata* vegetation, growing around a periodically drying shallow brook close to the sea. On Byers Peninsula, the species was more common. The largest population was found on wet soil close to the sea with a clear presence of elephant seal input (Van de Vijver, pers. obs.). The species seems to prefer more aerial circumstances influenced by biogenic input such as penguin rookeries and elephant seal wallows (Van de Vijver et al. 2002).

Observations: There is much confusion about the correct taxonomic identity of *Pinnularia austroshetlandica*. In 1954, Manguin (in Bourrelly & Manguin 1954) described a new species of *Pinnularia* he named *P. kolbei*. The name *kolbei* had already been used by Mölder (1952: 27; see Fukushima et al. 2001: 107) making a new name for Manguin's species necessary; Fukushima et al. proposed *P. parakolbei* Fukushima, Ko-Bayashi & Yoshitake (Fukushima et al. 2001: 108) as a substitute name. However, populations observed from the Falkland Islands did not entirely conform to Manguin's original description as they lacked the typical rostrate apices, a feature clearly stated ('*étirées rostrées aux extrémités*') and illustrated by Manguin (in Bourrelly & Manguin 1954: fig. 52).

Van de Vijver et al. (2002) separated the non-rostrate forms from *P. kolbei* identifying them as *P. bottnica*. Examination of type material of *P. kolbei* (Van de Vijver, unpubl. res., slide number AD9087), both rostrate and non-rostrate specimens are present in the same population; no other morphological or biometrical differences could be found. Additionally, detailed analysis of some large populations from other southern Indian Ocean islands yielded the same result (Van de Vijver, unpubl. res.). Therefore, it can be concluded that the *P. bottnica* populations of Ile de la Possession (Van de Vijver et al. 2002) and the *P. parakolbei* population from the Falkland Islands (Fukushima et al. 2001) are conspecific and the name *parakolbei* should be used for both the rostrate and the non-rostrate specimens. Fukushima et al. (2001) considered *Pinnularia austroshetlandica* to be similar to but distinct enough from *P. parakolbei* since the strongly protruding ends and the almost straight raphe distinguished the former. Type material of *Navicula austroshetlandica* (the basionym of *Pinnularia austroshetlandica*) has not yet been located. A careful examination of the description and drawing in Carlson (1913) and its comparison with specimens from different *parakolbei*-populations from the entire (sub-) Antarctic Region did not reveal any significant differences between *P. austroshetlandica* and *P. parakolbei*. Thus, *P. austroshetlandica*, *P. parakolbei* and *P. kolbei* sensu Manguin are considered synonyms and *P. austroshetlandica* should therefore be given priority. Another name that may need adding *Navicula nivorum* and its variety *elongata*. Although the original material is apparently no longer available, the descriptions and drawings match clearly *P. austroshetlandica*.



FIGURES A2.181–A2.204 – *Pinnularia austrosthetlandica*, *Pinnularia australoglobiceps* sp. nov. and *Pinnularia gemella* from Livingston Island. **Figs A2.181–A2.188**. LM of *P. austroshetlandica*. **Figs A2.189–A2.196**. LM of *P. australoglobiceps* sp. nov. **Figs A2.197–A2.204**. LM of *P. gemella*. Scale bar = 10 µm.

Pinnularia australoglobiceps **sp. nov.** (Figs A2.189–A2.196)

Valvae lineares-lanceolatae ad ellipticae-lanceolatae in speciminibus minoribus marginibus clare convexis, apicibus late capitatis, semper distincte angustioribus quam media parte valvae. Longitudo 25–37 µm, latitudo 8.4–9.6 µm. Area axialis angusta, leviter dilatans in aream centralem. Area centralis formans fasciam cuneiformem latam. Raphe filiformsi, ramis leviter curvatis. Terminationes raphis proximales leviter deflexae cum poris indistinctis. Fissurae raphis distales unilateraliter flexae. Striae in media parte valvae curvatae, moderate ad fortiter radiatae, parallelae ad leviter convergentes ad apices, 13–15 in 10 µm. Striae abbreviatae nonnulae in area centrali. Lineae speciosae longitudinales nullae.

Valves linear-lanceolate to elliptic-lanceolate in smaller individuals, with clearly convex margins and broadly capitate apices, always distinctly narrower than the valve middle; in smaller specimens barely offset. Shoulders between apices and valve middle absent. Valve dimensions (n=20): length 25–37 µm, width 8.4–9.6 µm. Axial area narrow, only slightly widened towards the central area. Central area forming a large bowtie-shaped fascia. Raphe filiform with slightly curved branches and straight to slightly deflected central endings bearing simple raphe pores. Distal raphe fissures, bent to one side. Striae in the valve middle curved, moderately to strongly radiate, becoming parallel to weakly convergent near the apices, 13–15 in 10 µm. Shortened striae sometimes present near the central area. Longitudinal lines absent.

Type: Byers Peninsula, Livingston Island, South Shetland Islands, sample BY066, leg. B. Van de Vijver, coll. date 18/01/2009, slide no. BR-4260 (holotype BR, slide PLP-205 (isotype University of Antwerp, Belgium), slide ZU8/18 (isotype BRM).

Habitat and Distribution: *Pinnularia australoglobiceps* is uncommon on Livingston Island and is mainly found in aquatic habitats. The type population was observed in a small lake near the southern beaches. The lake had an almost circumneutral pH (7.2) with a low specific conductance value (104 µS/cm). Occasionally, the species was found on wet soil and among mosses around streams and lakes, probably dispersed by wind or water sprays.

Etymology: The specific epithet refers to the geographic distribution of the species (Latin '*australis*' meaning southern) and its similarity to *Pinnularia globiceps*.

Observations: The species most similar to *P. australoglobiceps* are *P. globiceps* Gregory (1856: 10), *P. iatriaensis* Foged (1970: 169), *P. lundii* Hustedt (1954: 474) and *P. bottnica. Pinnularia globiceps* has a lower valve width (5.0–7.5 µm vs 8.4–9.6 µm) with larger capitate ends, usually as wide as the valve middle or only slightly narrower (Krammer 2000). The northern hemisphere species *P. iatriaensis* has a linear (and not an elliptic-lanceolate) valve outline with slightly undulating (and not convex) margins and a coarser striation pattern with 11–12 (vs. 13–15) striae in 10 µm (Foged 1970, Krammer 2000). Moreover, the central area in *P. iatriaensis* is smaller than in *P. australoglobiceps*. *Pinnularia lundii* has typically capitate, well set-off apices, contrary to *P. australoglobiceps* and is usually much longer (40–60 µm vs. 25–37 µm). *Pinnularia bottnica*, known from the coast of northern Baltic Sea has a similar striation pattern and central area but a different valve outline with only weakly protracted and obtusely rounded valve ends. In Van de Vijver et al. (2002), valves identified as *P. bottnica* with similarities to *P. globiceps*, (see plate 102, Figs 12–15) are probably conspecific but have somewhat shorter apices. *Pinnularia austroshetlandica* possess a similar raphe structure and striation pattern but has narrower, shorter and clearly rostrate ends.

Carlson described the species *Caloneis austrogeorgica* Carlson (1913: 12) from South Georgia. Since type material has yet been located, only one drawing and a rather short description are available for comparison with *P. australoglobiceps*. The valve dimensions given for *C. austrogeorgica* are somewhat higher, especially the valve width, an important morphological character; this is almost 1/5 higher in the latter (12 µm vs. 8.4–9.6 µm in *P. australoglobiceps*). Until type material has been found and investigated, both species are considered independent.

Pinnularia gemella **Van de Vijver (in Van de Vijver et al. 2009: 432)** (Figs A2.197–A2.204)

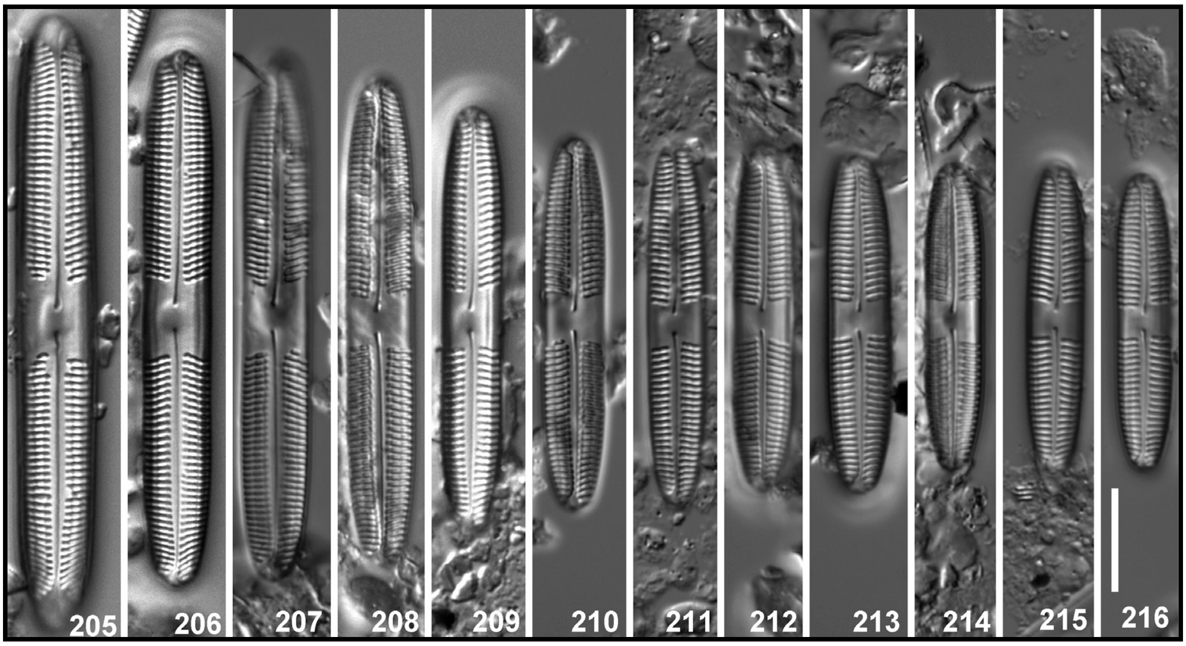
Valves linear with strictly parallel margins and broadly rounded, non-protracted apices. Valve dimensions (n=20): length 43–52 µm, width 7.3–8.8 µm. Axial area moderately broad, linear to linear-lanceolate, not, or only very slightly, widening towards the central area. Central area forming a rectangular, usually asymmetrical fascia. Raphe lateral with deflected proximal raphe endings terminating in weakly expanded pores. Distal raphe fissures bayonet-shaped. Striae almost parallel throughout the entire valve. Longitudinal lines absent. One single row of small spines visible on the primary side, 9–10 in 10 µm. Valves usually found in pairs, connected by linking spines, lying in juxtaposition.

Habitat: *Pinnularia gemella* was found in several larger lakes on the central plateau of Byers Peninsula. All lakes had a pH varying between 7.2 and 7.5 and a very low specific conductance level (<60 µS/cm). The species seems to be absent from Hurd Peninsula.

Observations: *Pinnularia gemella* cannot be mistaken with any other species of *Pinnularia* due to the presence of the spines on the primary side. Only a few *Pinnularia* species have spines or form colonies in juxtaposition. Van de Vijver et al. (2004a, 2009) reviewed all colony- and/or spine-forming species of *Pinnularia*. *Pinnularia subantarctica* var. *elongata* has a similar valve outline but higher stria density and lacks the typical spines of *P. gemella*.

Pinnularia subantarctica **var.** ***elongata*** **(**Manguin in Bourrelly & Manguin) Van de Vijver & Le Cohu in Van de Vijver, Frenot & Beyens (Figs A2.206–A2.217)

Valves linear to weakly linear-lanceolate with parallel to weakly convex valve margins and broadly rounded, subrostrate apices. Valve dimensions (n=25): length 27–59 µm, valve breadth 5.4–7.9 µm. Axial area narrow, near the centre weakly deltoid. Central area forming a broad almost rectangular, sometimes asymmetrical, fascia. Raphe slightly lateral with expanded and weakly deflected central pores. Terminal raphe fissures “?”-shaped. Striae slightly to moderately radiate in the middle, becoming convergent towards the apices, 14–15 in 10 µm. Longitudinal lines clearly present.



FIGURES A2.205–A2.216 – *Pinnularia subantarctica* var. *elongata* from Livingston Island. Scale bar = 10 µm.

Habitat: *Pinnularia subantarctica* var. *elongata* was most abundant among wet mosses in areas close to the sea and in larger lakes, usually near the shoreline where the presence of animals was clearly visible. PH ranges from 6.9 to 8.4 with a specific conductance varying from 34 to almost 250 µS/cm.

Observations: *Pinnularia subantarctica* var. *elongata* is one of the smallest *Pinnularia* taxa presenting a longitudinal line running across its striae due to the partly internal covering of the striae, leaving only a small opening. It cannot be confused with other species. *Pinnularia microstauron* has a unique valve outline with more rostrate apices and clearly convex margins.

Discussion

The past few years, there has been growing concern about taxonomic uncertainties in the Antarctic diatom flora. This concern has resulted in the revision of the flora and the subsequent description of a number of new taxa in the genera *Luticola*, *Navicula*, *Hantzschia*, *Muelleria* and *Diadesmis* (Van de Vijver et al. 2002, 2009, 2010, 2011, Van de Vijver & Mataloni 2008, Zidarova et al. 2010, Kopalová et al. 2011).

A similar revision of the genus *Pinnularia* started almost 10 years ago with the description of 14 new taxa from the sub-Antarctic Crozet archipelago (Van de Vijver et al. 2002) followed by the description of several new taxa from Marion Island (Van de Vijver & Gremmen 2006), King George Island (Van de Vijver 2008) and Amsterdam Island (Van de Vijver et al. 2012). Van de Vijver et al. (2012) revised all records for the sub-Antarctic Region resulting in a list of 63 *Pinnularia* taxa present on the five island/island groups of the southern Indian Ocean. However, at present a complete discussion on the biogeography of the genus in the sub-Antarctic region is not possible due to the lack of verified distribution records, undersampling and taxonomic uncertainty. For instance, the exact distribution of *P. australodivergens, P. livingstonensis* and *P. sergiplaiana* in the Antarctic region is unknown due to confusion with other taxa from the *P. divergens*-complex that have been recorded several times in the Antarctic Region (Kellogg & Kellogg 2002). Due to confusion with *P. microstauron*, the correct distribution of *P. australomicrostauron* is currently poorly known but based on the illustrations present in earlier studies (Van de Vijver & Beyens 1997b, Kawecka et al. 1998 and Sabbe et al. 2003) it is probably a widespread species on the islands in the southern Atlantic Ocean and on the Antarctic continent and absent from the sub-Antarctic islands in the southern Indian Ocean (Van de Vijver et al. 2012).

Several of the new taxa of *Pinnularia* described within within have been reported from Livingston Island and other (sub-)Antarctic or South American localities under different names: *Pinnularia subcarteri* was previously identified as *P. diversa* var. *subcapitata* Krammer & Lange-Bert. (in Krammer 2000: 46) (Zidarova 2008: 30, fig. 19); *Pinnularia australoschoenfelderi* was misidentified as *P. obscura* (Zidarova 2008); and *P. strictissima* may have been mistaken for small specimens of *P. intermedia.* Although it could not be confirmed that most records of *P. globiceps* and *P. lundii* in the Antarctic Region (Kellogg & Kellogg 2002) are conspecific with *P. australoglobiceps*, it has been reported from Livingston Island (Temniskova-Topalova & Chipev 2001: 312, fig. 51, as *P. lundii*, Zidarova 2008: 30, fig. 20, as *P.* cf. *globiceps*), King George Island (Kawecka et al. 1998), Deception Island (Van de Vijver, per. obs.) and the southern Indian Ocean Islands (Le Cohu & Maillard 1986, Van de Vijver et al. 2002). This force-fitting (Tyler 1996) is one of the major reasons why the correct (restricted) biogeography of the Antarctic diatom flora has been recognized only recently (Van de Vijver & Beyens 1999, Sabbe et al. 2003, Toro et al. 2007).

There is also much confusion regarding *P. austroshetlandica* and its distribution. The species is apparently widespread in the entire (sub-)Antarctic region. It has been reported under several different names: as *P. kolbei* Manguin (in Bourrelly & Manguin 1954: 35) on the islands in the southern Indian Ocean (Bourrelly & Manguin 1954, Le Cohu & Maillard 1986, Van de Vijver et al. 2001, 2002, 2004b, 2008), the Antarctic Peninsula (Van de Vijver & Beyens 1997), Livingston Island (Zidarova 2008) and Deception Island (Van de Vijver, pers. obs.); as *P. notata* var. *wulffii* (Petersen 1924: 315) Cleve-Euler (1955: 56) from the South Orkney Islands (Broady 1979, fig. 14b); as *P. parakolbei* Fukushima, Ko-Bayashi & Yoshitake (2001: 108) from the Falkland Islands (Fukushima et al. 2001) and as *Navicula austroshetlandica* Carlson (1913: 16) from Tierra del Fuego (Cleve-Euler 1948) and the Antarctic Continent (Negoro 1961, Fukushima et al. 1975).

Despite shortcomings in the knowledge of the distribution of *Pinnularia* species in Antarctica, some conclusions can be drawn. Table A2.1 shows the verified distributional records for all 28 *Pinnularia* taxa found on Livingston Island (including those in the section *Distantes*). Three are currently known only from Livingston Island and should considered endemic: *P. hamiltonii*, *P. perlanceolata* Van de Vijver & Zidarova (2011: 47) and *P. quesadae* Van de Vijver & Zidarova (2011: 47). Others occur in the South Shetland Islands [e.g., *P. obaesa* Van de Vijver (2008: 222)] or the southern Atlantic Ocean islands (e.g., *P. gemella*) in addition to Livingston Island. Only a few taxa are shared between Livingston Island and the Antarctic Continent (e.g., *P. australomicrostauron*) with several widespread throughout the entire Antarctic region (e.g., *P. austroshetlandica, P. subantarctica* var. *elongata, P. borealis*). *Pinnularia subantarctica* var. *elongata* was recorded from the sub-Antarctic islands in the southern Indian Ocean (Van de Vijver et al. 2002) to almost all islands in the southern Atlantic Ocean (Van de Vijver & Beyens 1997b, Broady 1979, as *P. molaris* Grunow: fig. 14a). *Pinnularia borealis*, its variety *scalaris* and *P. rabenhorstii*, are typical examples of cosmopolitan species that occur outside the Antarctic Region. However, recent studies have indicated that despite the morphological similarity between the different populations worldwide, it is highly likely that the Antarctic populations split off several million years ago to form a genetically different taxon (Souffreau et al. 2011, unpublished results). Further morphological research will be necessary to unravel this cryptic or semi-cryptic diversity.

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TABLE A2.1 – List of all *Pinnularia* species reported from Livingston Island with their biogeographical distribution. Species marked with * have only been found on Livingston Island.

	Southern Indian Ocean Islands					Southern Atlantic Ocean Islands								
								South Shetland Islands		Antarctic Peninsula	James Ross Island	Horseshoe Island	Antarctic Continent	South America
	Iles Crozet	Iles Kerguelen	Heard Island	Prince Edward Islands	Ile Amsterdam	South Georgia	Signy Island	King George Island	Deception Island					
P. australoborealis											X			
P. australodivergens							X							
P. australoglobiceps	X	X				X		X	X					
P. australomicrostauron							X	X	X	X	X	X	X	
P. australorabenhorstii								X		X	X			
P. australoschoenfelderi						?		?	?		X			
P. austroshetlandica	X	X	X	X	X		X	X	X	X			X	
P. borealis	X	X	X	X	X	X	X	X	X	X	X	X	X	
P. borealis var. pseudolanceolata								X	X		X			
P. borealis var. scalaris	X	X	X	X	X	X		X	X	X	X			
P. gemella												X		
*P. hamiltonii**														
P. laterotundata											X			
P. livingstonensis											X			
P. magnifica								?	X		X			
P. microstauroides						X	X					X		
P. obaesa								X						
*P. perlanceolata**														
*P. pseudolaucensis**														
*P. quesadae**														
P. rabenhorstii	X	X	X	X		X			X					
P. rabenhorstii var. subantarctica	X	X	X	X				X						
*P. sergiplaiana**														
P. strictissima							X							X
P. subaltiplanensis									X		X			
P. subantarctica var. elongata	X	X	X	X			X	X	X	X		X		
P. subcarteri									X					X
Pinnularia sp1								X				X		

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APPENDIX 3

The genus *Surirella* (Bacillariophyta) in the sub-Antarctic and Maritime Antarctic Region

Published as: *Van de Vijve B., Cocquyt C., de Haan M., Kopalová K. & Zidarova R. (2013) The genus* Surirella *(Bacillariophyta) in the sub-Antarctic and maritime Antarctic Region. Diatom Research 28: 93–108.*

A revision of taxa from the genus Surirella *from the Antarctic Region resulted in the description of three new taxa:* S. subantarctica *Van de Vijver & Cocquyt sp. nov.,* S. heardensis *Van de Vijver & Cocquyt sp. nov. and* S. australovisurgis *Van de Vijver, Cocquyt, Zidarova & Kopalová sp. nov. Detailed light (LM) and scanning electron microscope (SEM) observations are used to characterize these three new taxa. Comparisons with similar taxa and the ecological preferences of each species are added. The morphological characteristics of a fourth Antarctic* Surirella *taxon,* S. kerguelensis *Grunow is illustrated as this taxon was only known from a few hand drawings and LM pictures. Finally, a fifth taxon*, S. lapponica *A. Cleve was found on South Georgia and likewise illustrated. The revision of these species made clear that the genus* Surirella *showed similar biogeographical trends as other, previously revised genera indicating that a distinct Antarctic diatom flora exists.*

Key words: *Antarctica, Bacillariophyta, morphology, new species,* Surirella*, taxonomy*

Introduction

In the past fifteen years, significant progress has been made with respect to our knowledge of the diversity and recent taxonomy of the non-marine diatom flora from the (sub-) Antarctic region. It was clear that previous studies do not reflect the true Antarctic diatom diversity. Due to force-fitting (Tyler 1996) and species drift, the number of cosmopolitan diatoms on the different Antarctic localities has always been overestimated, which has led to an incorrect interpretation of the biogeography and ecology of diatoms in Antarctic regions (Sabbe et al. 2003,Van de Vijver et al. 2005). Ongoing taxonomic revision has resulted in the description of a considerable number of new species, mainly in the genera *Pinnularia* Ehrenberg (Van de Vijver et al.2002a, Van de Vijver 2008), *Diadesmis* Kützing (Le Cohu & Van de Vijver 2002, Van de Vijver et al. 2002b), *Luticola* D.G.Mann (Esposito et al. 2008, Van de Vijver & Mataloni 2008), *Muelleria* (Frenguellli) Frenguelli (Van de Vijver et al. 2010), *Hantzschia* Grunow (Zidarova et al. 2010) and *Navicula* Bory (Van de Vijver et al. 2011), confirming the presence of a distinct Antarctic diatom flora comprising of, currently accepted, more than 50% of specific Antarctic taxa (E. Verleyen et al., unpubl. data).

Kellogg & Kellogg (2002) compiled all the records of *Surirella* species in the Antarctic Region based on the literature (Table A3.1). Apart from *S. kerguelensis* Grunow, considered to be an endemic species from the Kerguelen Island (Bourrelly & Manguin 1954), only European and even African species were reported. Most species have been found in the Maritime Antarctic Region. The most reported species is *S. angusta* Kützing with records in almost all parts of the Antarctic Region. Almost all species however have only been reported once suggesting that an incorrect identification may be at the origin of these observations.

The discovery of a small population of an unknown *Surirella* species on Livingston Island, urged the need of a taxonomic revision of all *Surirella* populations found in a large sample set from various Antarctic localities in the southern Indian and Atlantic Ocean. Since no material was available from islands in the southern Pacific Ocean (e.g., Macquarie Island), no observations could be made of the species reported on these islands.

The present paper reports on the results of this revision and describes three new species, *S. subantarctica* Van de Vijver & Cocquyt sp. nov., *S. heardensis* Van de Vijver & Cocquyt sp.

nov. and *S. australovisurgis* Van de Vijver, Cocquyt, Zidarova & Kopalová sp. nov. Since the morphological structure of *S. kerguelensis* was only poorly studied in the past (Bourrelly & Manguin 1954, Le Cohu & Maillard 1986), a population from the Val Studer Region on Kerguelen was subject to a detailed morphological study based on light and scanning electron microscopy. Finally the morphology of a fifth species, *S. lapponica* A.Cleve, found in a sample on South Georgia, is briefly considered.

TABLE A3.1 – List of *Surirella* species reported in literature from the Antarctic Region (based on Kellogg & Kellogg 2002). The numbers refer to the number of records.

	Sub-Antarctica				
	South Georgia	Southern Indian Ocean	Macquarie Island	Maritime Antarctica	Antarctic Continent
S. angusta Kützing	4	3	2	3	7
S. angustata var. *constricta* Hustedt		7			
S. bifrons Ehrenberg			1		
S. brebissonii var. *kuetzingii* Krammer & Lange-Bertalot				1	
S. engleri f. *angustior* O. Müller			1		
S. kerguelensis Grunow		3			
S. linearis W. Smith				3	
S. linearis var. *helvetica* (Brun) Meister				1	
S. minuta Brébisson incl. *S. ovata* Kützing and *S. ovalis* var. *pinnata* (W. Smith) Van Heurck		2		5	1
S. ovalis Brébisson				1	
S. splendida (Ehrenberg) Kützing					1
S. striatula Turpin				1	

Material & Methods

During multiple sampling campaigns in the austral summers of 1992, 1998, 2004, 2008 and 2009 on South Georgia, Livingston Island (South Shetland Islands) and the four sub-Antarctic islands in the southern Indian Ocean, namely Prince Edward, Crozet, Kerguelen and Heard, diatom samples were taken from lake sediments, soils and mosses. All samples used in the present study are listed in Table A3.2.

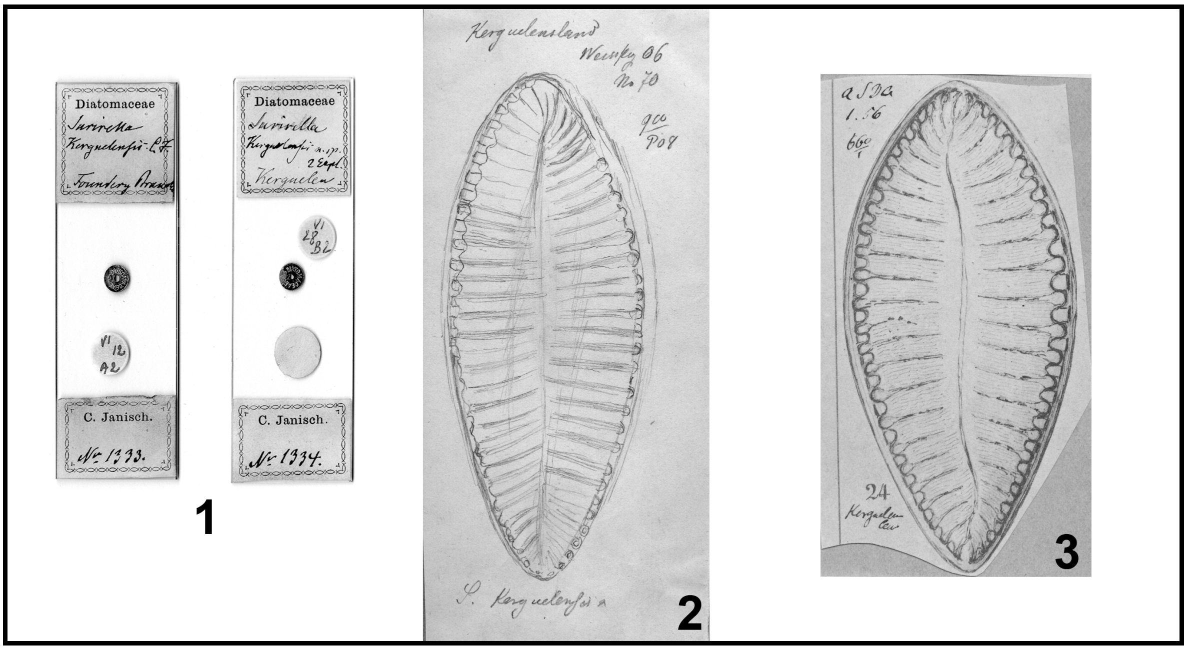
Diatom samples for LM observation were prepared following the method described in Van der Werff (1955). Small subsamples were cleaned by adding 37% H_2O_2 and heating to 80°C for about 1h. The reaction was completed by addition of $KMnO_4$. Following digestion and centrifugation (three times 10 min at 3700 x g), cleaned material was diluted with distilled water to avoid excessive concentrations of diatom valves on the slides. Cleaned diatom material was mounted in Naphrax®. The slides were analyzed using an Olympus BX51 microscope, equipped with differential interference contrast optics (Nomarski) and the Colorview I Soft Imaging System. For at least 10 valves of *S. subantarctica*, *S. heardensis* and *S. lapponica*, valve length and width have been measured, the number of alar canals, costae and/or striae in 10 µm has been counted and the width/length ratio has been determined.

TABLE A3.2 – List of samples used in this study.

Sample ID	Geographic locality	Source
G03-158	Prince Edward Island	Van de Vijver et al. 2008
BW386	Kerguelen	Van de Vijver et al. 2001
BA002	Crozet	Van de Vijver et al. 2002a
W384	South Georgia	Van de Vijver & Beyens 1996
BY-049	Livingston Island	Kopalová & Van de Vijver 2013
D19	Heard Island	Van de Vijver et al. 2004
D53	Heard Island	Van de Vijver et al. 2004
Q181/1	Heard Island	Van de Vijver et al. 2004

Samples and slides are stored at the National Botanic Garden of Belgium (BR). For scanning electron microscopy (SEM), parts of the oxidized suspensions were filtered through polycarbonate membrane filters with a pore diameter of 1 µm, pieces of which were fixed on aluminum stubs after air-drying. The stubs were sputter-coated (SCD020, Balzers Union, Balzers, Liechtenstein) at BR (Meise, Belgium) with approximately 50 nm of Au and studied in a JEOL-5800LV under accelerating voltages of25 kV. For observation with the ZEISS ultra scanning electron microscope (NHM, London, UK), stubs were sputter-coated (Cressington 208HR, Watford, UK) with an approximately 20 nm Au-Pd layer and observed under accelerating voltages of 3 kV.

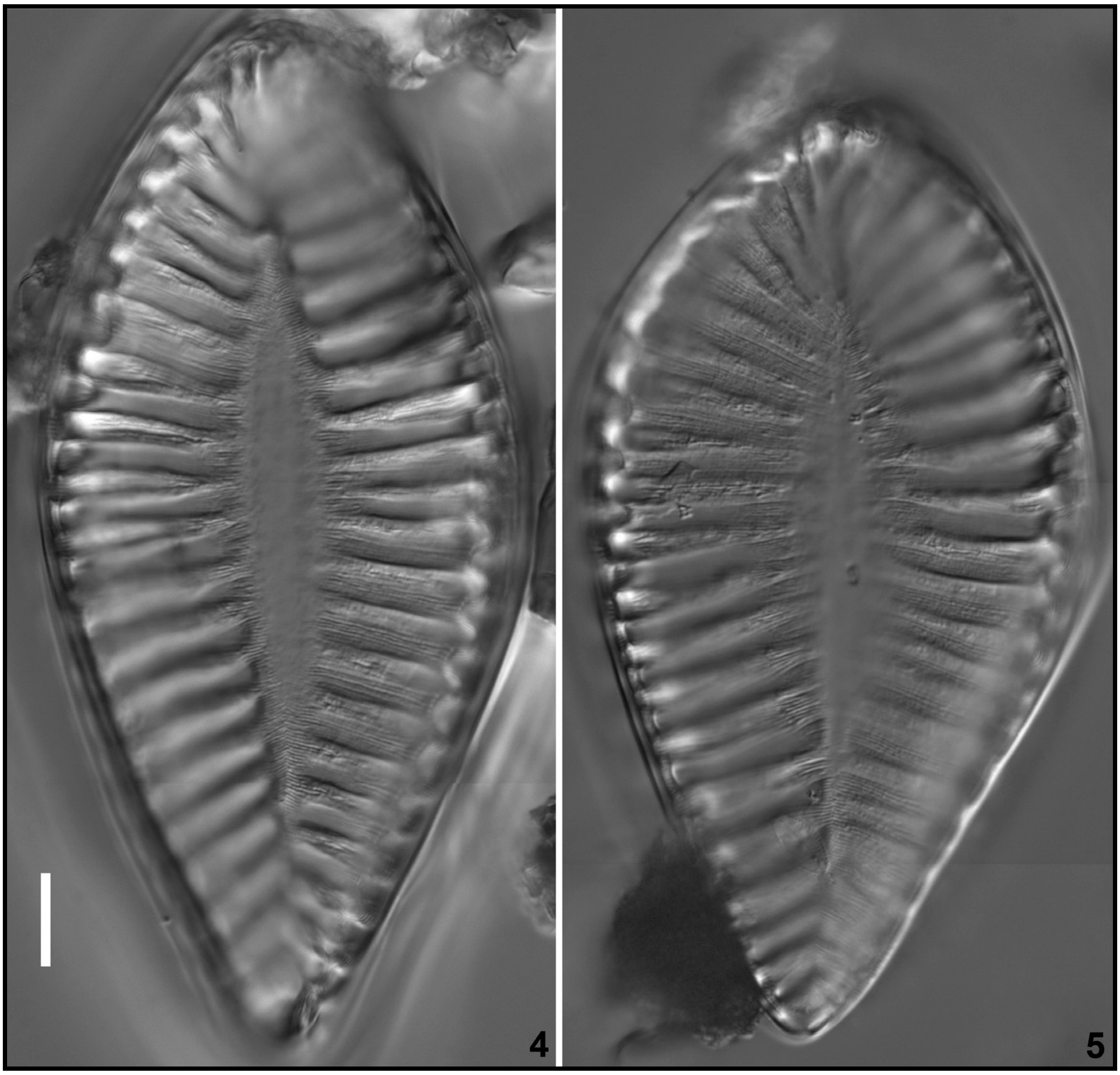
The Van Heurck diatom collection housed at the National Botanic Garden of Belgium includes the entire Janisch collection of the Gazelle expedition (Engler 1889). In this collection, two slides appeared to contain valves of *S. kerguelensis*. Both slides, VI-12-A2 and VI-28-B2, have been examined in this study (Fig. A3.1).



FIGURES A3.1–A3.3 – *Surirella kerguelensis* Grunow. **Fig. A3.1.** Investigated slides of *Surirella kerguelensis* Grunow from the Janisch collection present in the Van Heurck collection at BR. **Figs A3.2–A3.3.** *Surirella kerguelensis* Grunow. **Fig. A3.2.** Original pencil drawing by Grunow. **Fig. A3.3.** Drawing as published in A. Schmidt (1888) Atlas. Scale bar = 10 µm.

The type slide of *S. angusta* present in the Van Heurck diatom collection (slide VII-25-C1, BR, Meise, Belgium), was analyzed to compare *S. angusta* with some of the new species described in the present paper.

Morphological terminology follows Hendey (1964), Round et al. (1990), Bramburger et al. (2006) and Cocquyt & Jahn (2007). The morphology of the new species has been compared with the ultrastructure of known European, African, Indonesia nor South-American species (Cleve 1895, Krammer & Lange-Bertalot 1988, Rumrich et al. 2000, Bramberger et al. 2006). A critically revised list of all *Surirella*taxa present in the Antarctic and sub-Antarctic Regions has been compiled based on publications mentioned in Kellogg & Kellogg (2002) to delimit the biogeographical distribution of the different taxa.

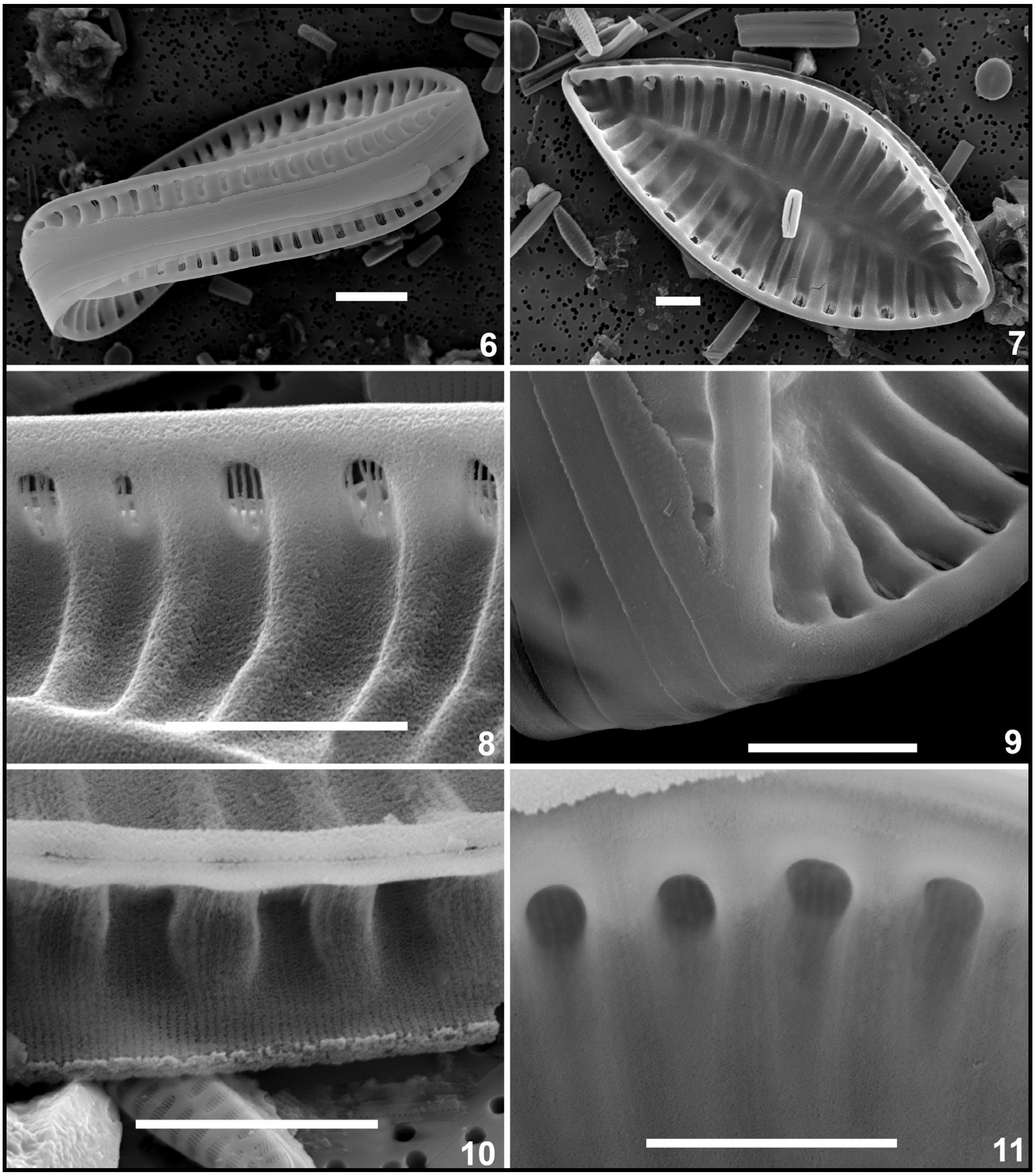


FIGURES A3.4–A3.5 – Figs A3.4–A3.5. *Surirella kerguelensis* Grunow. Valves of material BW386 from Iles Kerguelen, LM. Scale bar = 10 µm.

New taxon descriptions

Surirella kerguelensis **Grunow** (Figs A3.6–A3.11)

Cells heteropolar, apical pole and base pole slightly contorted along the apical axis (Fig. A3.6). Valves obovate with a somewhat pointed base pole and a more or less rounded apical pole (Figs A3.4–A3.5). Length 94–132 µm, width 48–50 µm and 1.4–2.0 alar canals in 10 µm. Striae on the valve face and the valve mantle uniseriate, composed of rounded poroids (Figs A3.10–A3.11), 25–26 in 10 µm, becoming biseriate near the opening to the fenestrae and then quadriseriate near the fenestrae (Fig. A3.11). Raphe canal smooth, elevated above the valve face on well-developed wings (alae) with barred fenestrae (Figs A3.6, A3.8).



FIGURES A3.6–A3.11 – *Surirella kerguelensis* Grunow, SEM of material BW386 from Kerguelen Islands. **Fig. A3.6.** External view showing slightly contorted valves, several girdle bands with at least one open band, almost surrounding the entire cell. **Fig. A3.7.** External valve view showing the smooth raphe canal, and the transapical valves undulations reaching the elevated rather large, linear lanceolate axial area. **Fig. A3.8.** External valve view showing alar canals and fenestrae of about the same width thin fenestral fibulae. **Fig. A3.9.** Straight and not enlarged external raphe fissures, smooth girdle bands. **Fig. A3.10.** External valve mantle view showing uniseriate striae, becoming biseriate near the opening to the fenestrae and then quadriseriate near the fenestrae. **Fig. A3.11.** Internal valve view showing the striation and the single row of portulae in the alar canals. Scale bars= 20 µm (Fig. A3.6), 10 µm (Figs A3.7–A3.11).

enestrae almost rectangular with rounded edges (Fig. A3.6) with 3–6 fenestral bars in each fenestra (Fig. A3.8), 25 in 10 µm. Alar canals about the same width as the fenestrae (Figs A3.7–A3.8). Axial area rather large, linear-lanceolate, occupying about one sixth of the valve surface near the broadest part, except near poles where it is reduced to a narrow line (Figs A3.4–A3.5, A3.7). Transapicalvalve undulations (porcae) reaching the elevated axial area, strongly radiate towards the poles (Figs A3.7–A3.9). External raphe fissures straight and not enlarged (Fig. A3.9). No ornamentations observed on the valve face, mantle or the raphe canal (Figs A3.7–A3.8, A3.10). Wing projection distinct, extending straight up from the valve face (Figs A3.4–A3.6). Internally the alae have a single row of portulae (Fig. A3.11). Several girdle bands; smooth without poroids or ornamentations (Figs A3.6, A3.9). At least one open band, almost surrounding the entire cell (Fig. A3.6).

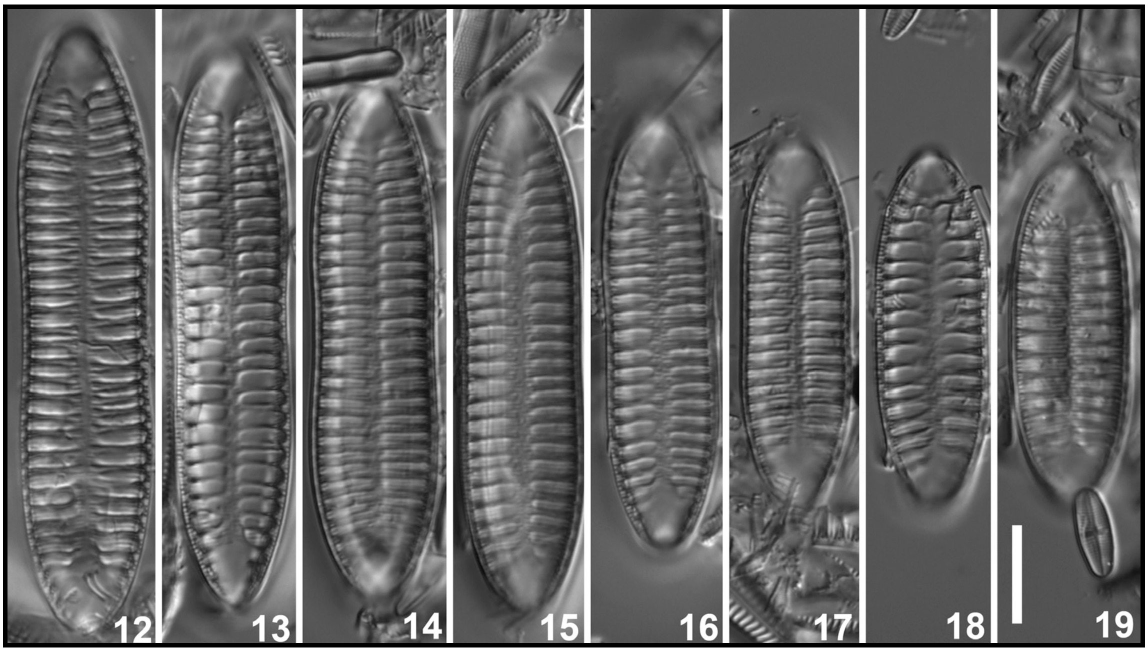
Ecology and distribution: *Surirella kerguelensis* is a very rare species and so far only found in some lakes and rivers on Iles Kerguelen. Originally described from Foundery Branch, there are only two other records of the species. Bourrelly & Manguin (1954) have reported the species to be present in Lake Marie Nicole in the northern part of the main island and in one sample taken from a peat area. Le Cohu & Maillard (1986) found the species in two rivers and two lakes. The largest population was observed during the present study in the sediments of a large pool at the southern edge of Lac Supérieur in the Studer Valley. The lake had a pH of 7.4 with a specific conductance value of 40 µScm^{-1}. The sample was dominated by *Stauroforma exiguiformis* (Lange-Bertalot) Flower, V.J. Jones & Round, *Cavinula pseudoscutiformis* (Hustedt) D.G. Mann & A.J. Stickle and *Staurosirella* aff. *pinnata* (Ehrenberg) D.M. Williams & Round. So far, *S. kerguelensis* has not been recorded at other Antarctic localities.

Surirella subantarctica **Van de Vijver & Cocquyt sp. nov.** (Figs A3.12– A3.26)

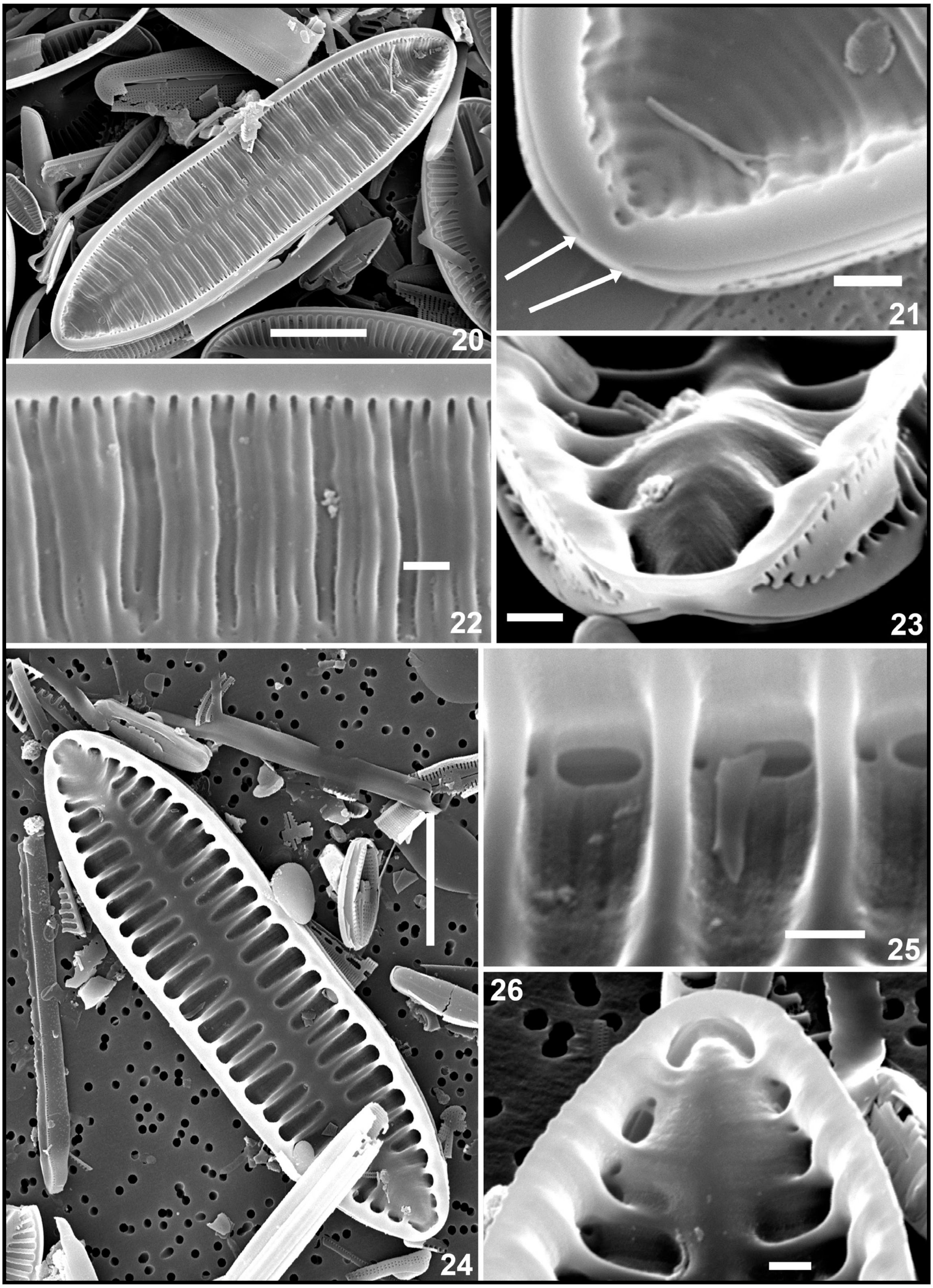
Synonym: *Surirella angusta* var. *constricta* Hustedt *sensu* Van de Vijver et al. 2002, *non sensu* Bourrelly&Manguin 1954.

Cellulae isopolares. Valvae paene lineares ad lineares-ellipticae polis cuneatis, marginibus querectis, leviter constrictis in media parte valvae. Longitudo 36.7–63.3 µm, latitudo 11.5–13.9 µm, ratio longitdinis/latitudinis 2.9–4.8. Fibulae fortes, 4–6 in 10 µm, attingentes aream *axialem. Striae positae in costis, distinctae in facie ivalvae internae, 22–23 in 10 µm, constantes ex tribus seriebus areolarum. Indentationes, ad instar areolarum magnarum, adsunt in faciei valvae in transitione ad canalem raphis. Facie svalvae cum depressionibus magnis prope polos, visibilis in microscopio photonico. Tres ad quattuor, rarissime quinque, costae elevatae in faciei valvae externae, formantes undulationem levem in apice. Omnis quarta vel quinta costa, rarissime sexta posita in depressione vadosa, congruens fibulas internas. Costae rectae, radiatae ad polos.*

Cells isopolar. Valves almost linear to linear-elliptical with cuneate poles, and with straight to slightly constricted margins mid-valve (Figs A3.12–A3.19). Length 36.7–63.3 µm, width 11.5–13.9 µm, length:width ratio 2.9–4.8. In somevalves a minor difference in the width of the broadest parts of the valve face (≥0.5 µm) was noted. Raphe canal smooth, not raised and wings poorly developed (Figs A3.20–A3.21). Indentations, giving the impression of large areolae, present on the valve face at the transition to the raphe canal (Fig. A3.23). Exterior valve face flat; on the interior of the valve face strong fibulae present, 4–6 in 10 µm, reaching the axial area (Figs A3.24–A3.25). Axial area internally thickened except near the poles where the valve face is internally elevated to the same high as the thick axial area (Figs A3.24, A3.26). Externally this is seen as a large depression near the poles (Figs A3.20–A3.21).



FIGURES A3.12–A3.19 – *Surirella subantarctica* Van de Vijver & Cocquyt sp. nov., LM showing the valve variability. **Fig. A3.15.** Valve representing the holotype. Slide BR 4264 of material G03-158 from Prince Edward Island. Scale bar = 10 µm.



FIGURES A3.20–A3.26 – *Surirella subantarctica* Van de Vijver & Cocquyt sp. nov., SEM of material G03-158 from Prince Edward Island. **Figs A3.20–A3.23.** External valve view showing a large depression near the poles and indentations on the valve face at the transition to the raphe canal. **Fig. A3.21.** Smooth raphe canal and straight and unenlarged terminal raphe fissures. **Figs A3.22– A3.23.** Raised costae forming the top of a slight undulation, and one costa in ashallow depression on the valve face. **Figs A3.24–A3.26.** Internal valve view. **Figs**

A3.25–A3.26. Striae composed of 3 rows of areolae. **Fig. A3.25.** Internal fibulae with portulae (only two of three portulae visible) in between two fibulae. **Fig. A3.26.** Detail of valve apex. Scale bar = 10 µm (Figs A3.20, A3.24), 1 µm (Figs A3.21–A3.23, A3.25–A3.26).

In LM these parts of the valve cannot be focused with the rest of the valve face (Figs A3.12–A3.19). Three to four, exceptionally five, costae are raised on the exterior valve face forming the top of a slight undulation (Figs A3.22–A3.23). Every fourth or fifth, exceptionally sixth, costa is located in the shallow depression, corresponding to the interior fibula (Figs A3.22–A3.23). Costae straight becoming radiate near the poles, almost reaching the narrow axial area (Fig. A3.20). Striae triseriate, located between the costae, distinct on the internal valve face, 22–23 in 10 µm (Fig. A3.25). Areolae about 120 in 10 µm. Between the internal fibulae, 3 portulae present: a central broad portula with on both sides a smaller one (Fig. A3.25, only one small side-portula visible). External raphe fissures straight and not enlarged (Fig. A3.21). Valve mantle deeply indented with strong costae, around 23–32 in 10 µm (Fig. A3.23). Ornamentations other than the costae absent on the valve face, mantle or the raphe canal (Fig. A3.20). Open advalvar girdle band present bearing a row of elongated poroids (Fig. A3.23).

Type: Albatross Valley, Prince Edward Island, southern Indian Ocean, sample G03-158 (46°38’05.8” S, 37°58’39.1” E), leg. N. Gremmen, collected 3 April 2003, slide BR-4264 (holotype BR), slide PLP-209 (isotype University of Antwerp, Belgium), slide BRM-ZU8/55(isotype BRM). The valve representing the holotype is here illustrated in Figure A3.15.

Etymology: the specific epithet refers to the geographic area where the species is found.

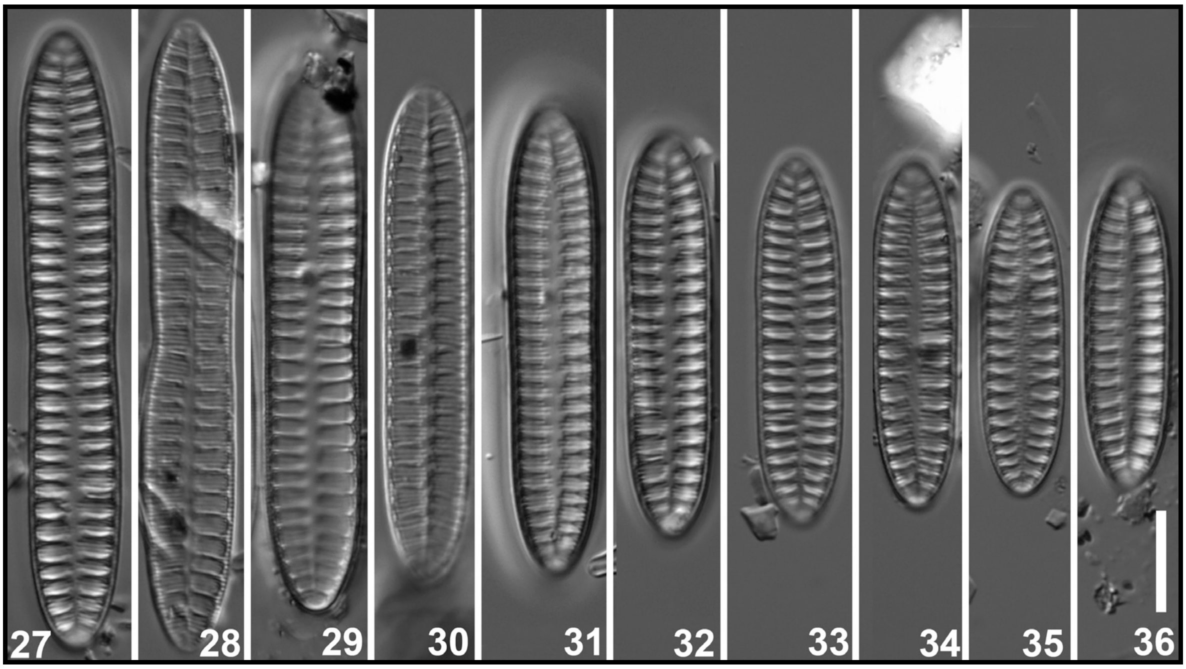
Ecology and distribution: The type population of *S. subantarctica* was found in a seepage area near Albatross Valley, northwest of Boggel on Prince Edward Island. The sample was taken from a steep mineral soil face and was dominated by *Psammothidium confusiforme* Van de Vijver & Beyens, *Chamaepinnularia soehrensis* var. *muscicola* (Petersen) Lange-Bertalot & Krammer and *Achnanthidium modestiforme* (Lange-Bertalot) Van de Vijver. The species was however not common and when found only solitary individuals were observed in semi-terrestrial conditions such as feldmarks, bogponds, mires and birdholes. The species was also observed in mostly terrestrial conditions on the nearby Crozet archipelago, where small populations were only found in mostly dry to semi-wet soil samples. So far the species has not been observed in lakes, ponds, rivers or living on wet moss vegetations. On the Kerguelen archipelago and on Heard Island, the species seems to be absent.

Surirella heardensis **Van de Vijver & Cocquyt sp. nov.** (Figs A3.27– A3.43)

Synonym: *Surirella angusta* var. *constricta* Hustedt *sensu* Bourrelly & Manguin 1954, *non sensu* Van de Vijver et al. 2002a.

Cellulae isopolares. Valvae paene lineares polis late rotundatis, marginibusque paene rectis, leviter constrictis in media parte valvae, rarissime magis constrictis. Longitudo 21.4–78.9 µm, latitudo 8.6–12.4 µm, ratio longitdinis/latitudinis 2.5–6.4. Striae 22–25 in 10 µm. Fibulae fortes, (4.5) 5–6 in 10 µm, attingentes aream axialem. Indentationes, ad instar areolarum magnarum, adsunt in faciei valvae in transitione ad canalem raphis.Tres ad quattuor costae elevatae in faciei valvae externae, formantes undulationem levem in apice. Omnis quarta costa, rarissime sexta posita in depressione vadosa, congruens fibulas internas. Costae rectae, radiatae ad polos, paene attingentes aream axialem angustam.

Cells isopolar. Valves almost linear with broadly rounded poles, and almost straight margins, slightly constricted mid-valve, infrequently distinctly constricted (Figs A3.27–A3.36). Length 21.4–78.9 µm, width 8.6–12.4 µm, length to width ratio 2.5–6.4. A minor difference in the width of the broadest parts of the valve face (≥0.5 µm) was noted. Raphe canal smooth, not raised and wings poorly developed (Fig. A3.37). Indentations, giving the impression of large areolae, present on the valve face at the transition to the raphe canal (Figs A3.38–A3.39). Exterior valve face flat (Fig. A3.37); on the interior of the valve face strong fibulae present, (4.5)5–6 in 10 µm, reaching the axial area (Fig. A3.40). Axial area internally thickened from one pole to the other (Figs A3.40, A3.42–A3.43). Three to four costae are raised on the exterior valve face forming the top of a slight undulation, and every fourth or fifth costa is located in the shallow depression, corresponding to the interior fibulae (Figs A3.38–A3.39). Costae straight becoming radiate near the poles, almost reaching the narrow axial area (Figs A3.37–A3.38). Striae located between the costae, distinct on the internal valve face, 22–25 in 10 µm consisting of 4 rows of areolae (Figs A3.41–A3.43). Areolae about 120 in 10 µm. Between the internal fibulae 3 portulae present: a central broad portula with on both sides a smaller one (Fig. A3.41). External raphe fissures straight and not enlarged (Fig. A3.38). Valve mantle deeply indented with strong costae, around 23–32 in 10 µm. Ornamentations other than the costae absent on the valve face, mantle or the raphe canal (Fig. A3.37). Open advalvar girdle band present bearing a row of elongated poroids and at least one other open girdle band present, almost surrounding the entire cell (similar to *S. subantarctica*). Valvocopula with fimbriate edge (Figs A3.39, A3.41).



FIGURES A3.27–A3.36 – *Surirella heardensis* Van de Vijver & Cocquyt sp. nov., LM showing the valve variability in material D19 from Heard Island. **Fig. A3.32.** Valve representing the holotype, slide BR-4266. Scale bar = 10 µm.

Type: Browns Lagoon, Heard Island, southern Indian Ocean, sample D19 (53°04’30.0”S,73°40’15.0” E), leg. N. Gremmen, collected 12 December 2000, slide BR-4266 (holotype BR), slide PLP-210 (isotype University of Antwerp, Belgium), slide BRM-ZU8/56 (isotype BRM). The valve representing the holotype is here illustrated in Figure A3.32.

Etymology: the specific epithet refers to Heard Island where the species is found.

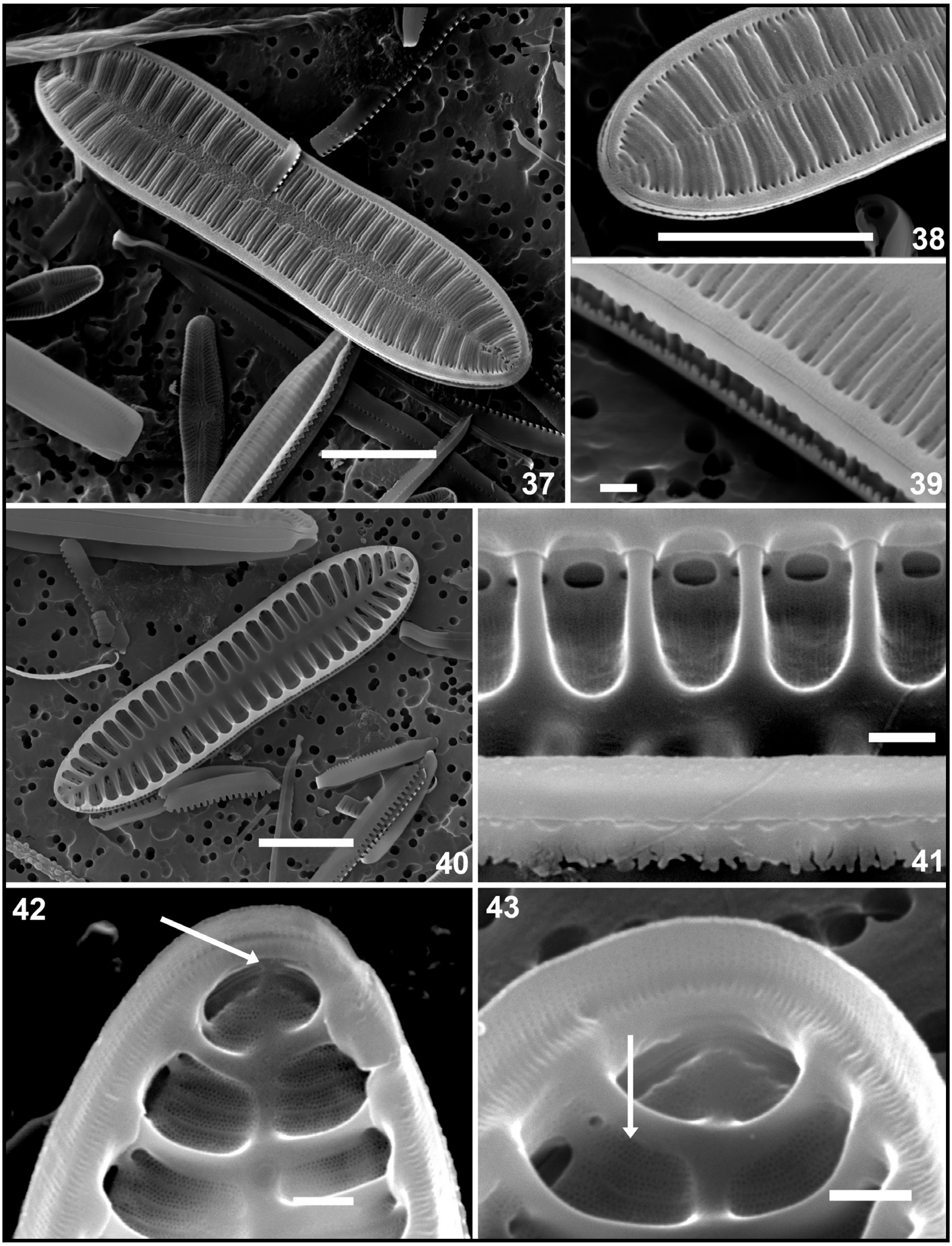
Ecology and distributio: *Surirella heardensis* was regularly found on Heard Island. The largest populations were found living in typical wet, terrestrial environments, such as on mosses in seepage areas, drainage systems and flush areas. The accompanying diatom flora was dominated by *Fragilaria capucina sensu lato* Desmazières, *Staurosira* cf. *alpestris* (Krasske ex Hustedt) Van de Vijver, *Adlafia bryophila* (J.B.Petersen) Gerd Moser, Lange-Bertalot & Metzeltin, *Sellaphora tumida* Van de Vijver & Beyens and *Planothidium lanceolatum* (Brébisson ex Kützing) Lange-Bertalot. The species was also reported from the nearby

Kerguelen archipelago. Bourrelly & Manguin (1954) showed a picture of *S. heardensis* (under the name *S. angusta* var. *constricta*). In recent material from Kerguelen, only a few valves were found (B. Van de Vijver, unpubl. data). On the Crozet archipelago and the Prince Edward Islands, the species was not observed.

Surirella lapponica **A.Cleve** (Figs A3.44–A3.50)

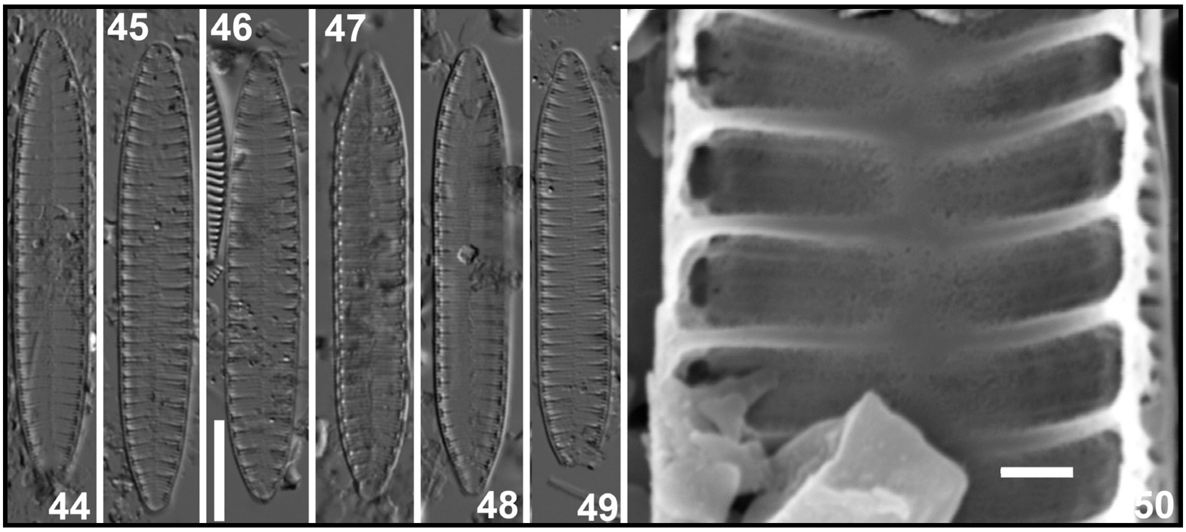
Cells isopolar. Valves linear with almost straight margins, sometimes slightly constricted mid-valve, becoming smaller near the poles. Poles bluntly rounded, wedge-shaped and not protracted (Figs A3.44–A3.49).Length 42.5–47.6 µm, width 7.3–8.0 µm, length to width ratio 5.6–6.1.Raphe canal not raised and no wings present. Exterior valve face flat; indentations, giving the impression of large areolae, present on the valve face at the transition to the raphe canal. Three to four costae are raised on the exterior valve face forming the top of a slight undulation, and every fourth or fifth costa is located in the shallow depression, corresponding to the interior fibulae (Figs A3.44–A3.50). Costae straight becoming radiate near the poles, reaching the narrow axial area (Figs A3.44–A3.49). Internally the fibulae almost reach the axial area, 6–7 fibulae in 10 µm (Fig. A3.50). Axial area not thickened (Fig. A3.50). Striae triseriate, distinct on the internal valve face, 24–27 in 10 µm (Fig. A3.50). Areolae about 120 in 10 µm. One large portulae present between the fibulae. Valve mantle indented with strong costae, around 24–27 in 10 µm; bundles of three to four costae separated by a deeper indented costa (Fig. A3.50).

Ecology and distribution: Only one population of *S. lapponica* has been found in the sediment of a small lake (Block Lake) in the Strømness Bay area on the South Georgia. The lake had a pH of 7.4 with a specific conductance value of 39 μScm^{-1}. The flora was dominated by *Staurosirella pinnata*, *Psammothidium confusum* (Manguin) Van de Vijver and *Achnanthidium minutissimum* (Kützing) Czarnecki. It is not clear, due to confusion with *S. angusta* (Carlson 1913, Hirano 1965, Schmidt et al. 1990) whether the species is more widespread in the Antarctic Region. Since both material and good illustrations are lacking, the reported observations cannot be verified.



FIGURES A3.37–A3.43 – *Surirella heardensis* Van de Vijver & Cocquyt sp. nov., SEM of material Q181/1 and D19 from Heard Island. **Figs A3.37–A3.39.** External valve view. **Fig. A3.38.** Detail of the undulated valve face with indentations at the transition to the raphe canal; of the costae on the top of the slight undulations, and one costa in the shallow depression; and of the straight, unenlarged raphe endings near the pole. **Fig. A3.39.** Detail of the deeply indented valve mantle. **Figs A3.40–A3.43.** Internal valve view. **Fig. A3.41.** Detail of the multiseriate striae and the portulae (one large central and two small side portulae) in between the fibulae.

Fig. A3.42. Detail of one pole with aninterrupted raphe slit (arrow). **Fig. A3.43.** Detail of the other pole on the same valve with anon interrupted raphe slit. The arrow indicates the multiseriate striae. Scalebars = 10 µm (Figs A3.37–A3.38, A3.40), 1 µm (Figs A3.39, A3.41–A3.43).

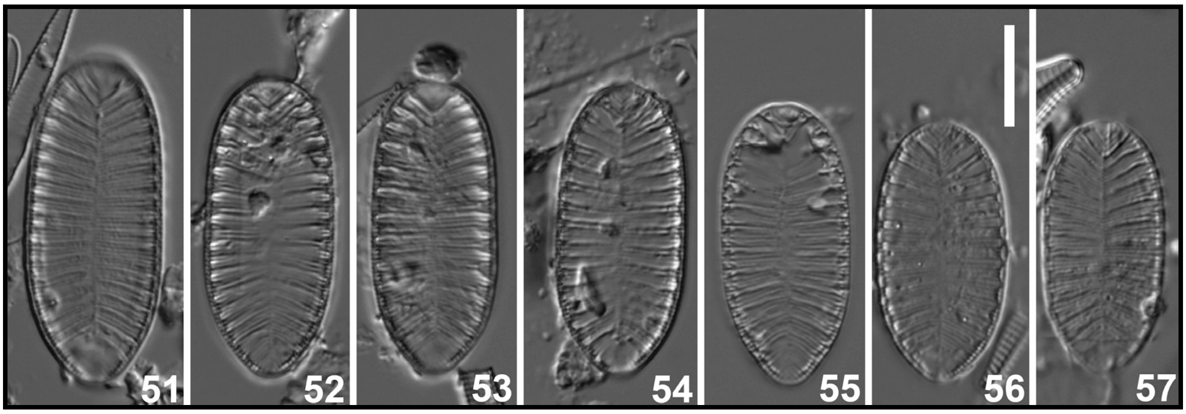


FIGURES A3.44–A3.50 – *Surirella lapponica* A.Cleve. **Figs A3.44–A3.49.** LM, showing the valve variability in material W384 from South Georgia. **Fig. A3.50.** SEM, detail of the unthickened axial area and the multiseriate striae. Scale bars = 10 µm (Figs A3.44–A3.49), 1 µm (Fig. A3.50).

Surirella australovisurgis **Van de Vijver, Cocquyt, Kopalová & Zidarova sp. nov.** (Figs A3.51–A3.64)

Cellulae leviter heteropolares. Valvae ovatae polo apicali late rotundato, poloque basi cuneato. Longitudo 26.1–34.0 µm, latitudo 12.5–14.4 µm. Fibulae 5–7 in 10 µm, non attingentes aream axialem, in valve interne binae dispositae. Costae 22–24 in 10 µm, rectae in media parte valvae, fortiter radiatae ad polos. Indentationes, ad instar areolarum magnarum, adsunt in faciei valvae in transitione canalis raphis.

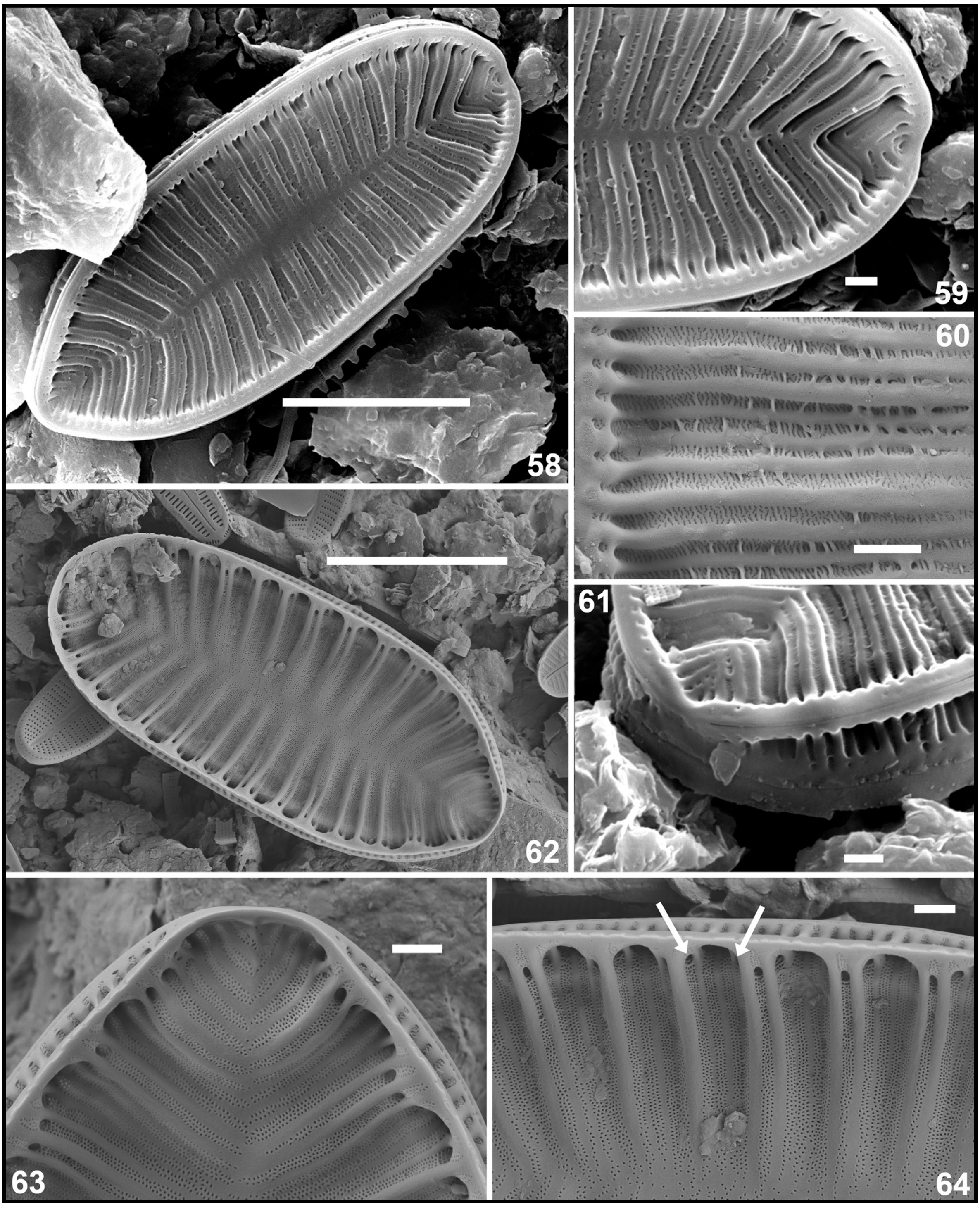
Cells slightly heteropolar. Valves ovate with broadly rounded apical pole and a cuneate base pole, and straight to slightly convex margins (Figs A3.51–A3.57). Length 26.1–34.0 µm, width 12.5–14.4 µm, length to width ratio 2.0–2.4. Raphe canal smooth, not raised and no wings present (Fig. A3.58). Indentations, giving the impression of large areolae, present on the valve face at the transition to the raphe canal (Figs A3.58–A3.59). Exterior valve face flat with a shallow depression near the poles (Fig. A3.58); on the interior of the valve face fibulae present, 5–7 in 10 µm, not reaching the axial area (Fig. A3.62). Axial area narrow, internally not ticked (Figs A3.62–A3.63). Bundles of two to three costae are raised on the exterior valve face; in the shallow depression one to two costae corresponding to the interior fibulae (Figs A3.58–A3.61). Costae 22–24 in 10 µm, straight mid-valve becoming strongly radiate near the poles (Fig. A3.58). Small silica ridges irregularly scattered on the external valve face connecting two nearby costae and almost parallel to the axial area (Fig. A3.60). Striae located between the costae, distinct on the internal valve face, consisting of 3–4 rows of areolae (Figs A3.63–A3.64); about 120 areolae in 10 µm. Internally fibulae often grouped in pairs; in between the fibulae three portulae: a central broad portula with on both sides a smaller one (Fig. A3.64, arrows). In between the two closely arranged fibulae a small portula is present on the elevation at the junction of the interior valve face and the mantle. External raphe fissures straight and not enlarged (Fig. A3.61). Valve mantle bearing strong costae; in between the bundles of three costae, one to two costae are deeply indented in the valve mantle (Fig. A3.61). Several girdle bands present with at least one open band surrounding almost the entire cell.



FIGURES A3.51–A3.57 – *Surirella australovisurgis* Van de Vijver, Cocquyt, Zidarova& Kopalová sp. nov., LM, showing the valve variability in material BY-049 from Livingstone Island. **Fig. A3.52.** Valve representing the holotype, slide BR 4267. Scale bar = 10 µm.

Type: Byers Peninsula, Livingston Island, South Shetland Islands, sample BY049 (62°38’43.1”S, 61°06’22.9”W), leg. B. Van de Vijver, collected 14 January 2009, slide BR-4267 (holotype BR), slide PLP-211 (isotype University of Antwerp, Belgium), slide BRM-ZU8/57 (isotype BRM). The valve representing the holotype is here illustrated in Figure A3.52.

Etymology: The specific epithet refers to the similarity with the northern hemisphere species *S. visurgis* Hustedt. The latin ‘*australis*’ means ‘southern’.



FIGSURES A3.58–A3.64 – *Surirella australovisurgis* Van de Vijver, Cocquyt, Zidarova & Kopalová, SEM. **Figs A3.58–A3.61.** External valve view. **Fig. A3.58.** Overview of an entire valve. **Fig. A3.59.** Detail of the apical pole, and of the valve face showing the raised bundled costae and one to two costae in a shallow depression. **Fig. A3.60.** Detail of the irregularly scattered silica ridges between the costae on the valve face as observed under the ZEISS Ultra scanning electron microscope. **Fig. A3.61.** Detail of the valve mantle. **Figs A3.62–A3.64.** Internal valve viewas observed under the ZEISS Ultra scanning electron microscope. **Fig. A3.62.** Overview of an entire valve. **Fig. A3.63.** Detail of the base pole showing the interrupted raphe slit. **Fig. A3.64.** Detail of the uniseriate striae and the portulae (smaller side portulae are indicated with arrows). Scale bars= 10 µm (Figs A3.58, A3.62), 1 µm (Figs A3.59–A3.61, A3.63–A3.64).

Ecology and distribution: *Surirella australovisurgis* has so far been found in one lake on Byers Peninsula. This relatively large lake is situated on the main central plateau next to Limnopolar Lake at an altitude of 75 m. The lake has a pH of 7.6 with a specific conductance value of 60 μScm^{-1}. Both nutrient and mineral levels are quite low (Kopalová & Van de Vijver in press). The sample is dominated by *Staurosirella pinnata*, *Fragilaria capucina* sensu lato, *Planothidium frequentissimum* (Lange-Bertalot) Round & Bukhtiyarova and *Psammothidium papilio* (Lange-Bertalot & Rol.Schmidt) Van de Vijver & Kopalová.The species was also found on South Georgia although only one valve has been observed in a small lake on the Tønsberg Peninsula. Its biogeographical distribution is probably larger but obscured by incorrect identifications. Kawecka et al. (1998) reported the presence of *S. brebissonii* var. *kuetzingii* Krammer& Lange-Bertalot and *S. ovalis* Brébisson, two species which can be easily confused with *S. australovisurgis*, from the nearby King George Island. Yang & Chen (1994) observed *S. minuta* Brébisson (as *S. ovate* Kützing) on King George Island but based on the illustrations, it is clear that the reported valves belong to *S. australovisurgis*. It is possible that other observations such as Vinocur& Unrein (2000) (*S. minuta*) on King George Island, Martinez-Macchiavello et al. (1996) [*S. ovalis* var. *pinnata* (W.Smith) Van Heurck] on King George Island and Oppenheim 1990 and Oppenheim & Greenwood (1990) (*S. ovalis* var. *pinnata)* on Signy Island represent all valves of *S. australovisurgis*. However, since no material and no illustrations were available for all these observations, it is impossible to determine with certainty its biogeographical distribution.

Discussion

The results of this study show clearly that a revision of the Antarctic *Surirella* species was highly necessary. The species inventory produced by Kellogg & Kellogg (2002) contained mostly cosmopolitan taxa. When possible, most of these records were revised and this revision demonstrated that due to misidentifications and force-fitting, none of the reported species in the Antarctic literature seemed actually be present in the Antarctic Region, apart from *S. kerguelensis* whose presence could be confirmed from the Antarctic Region. Detailed observations showed the morphological differences between the Antarctic taxa and the already established taxa.

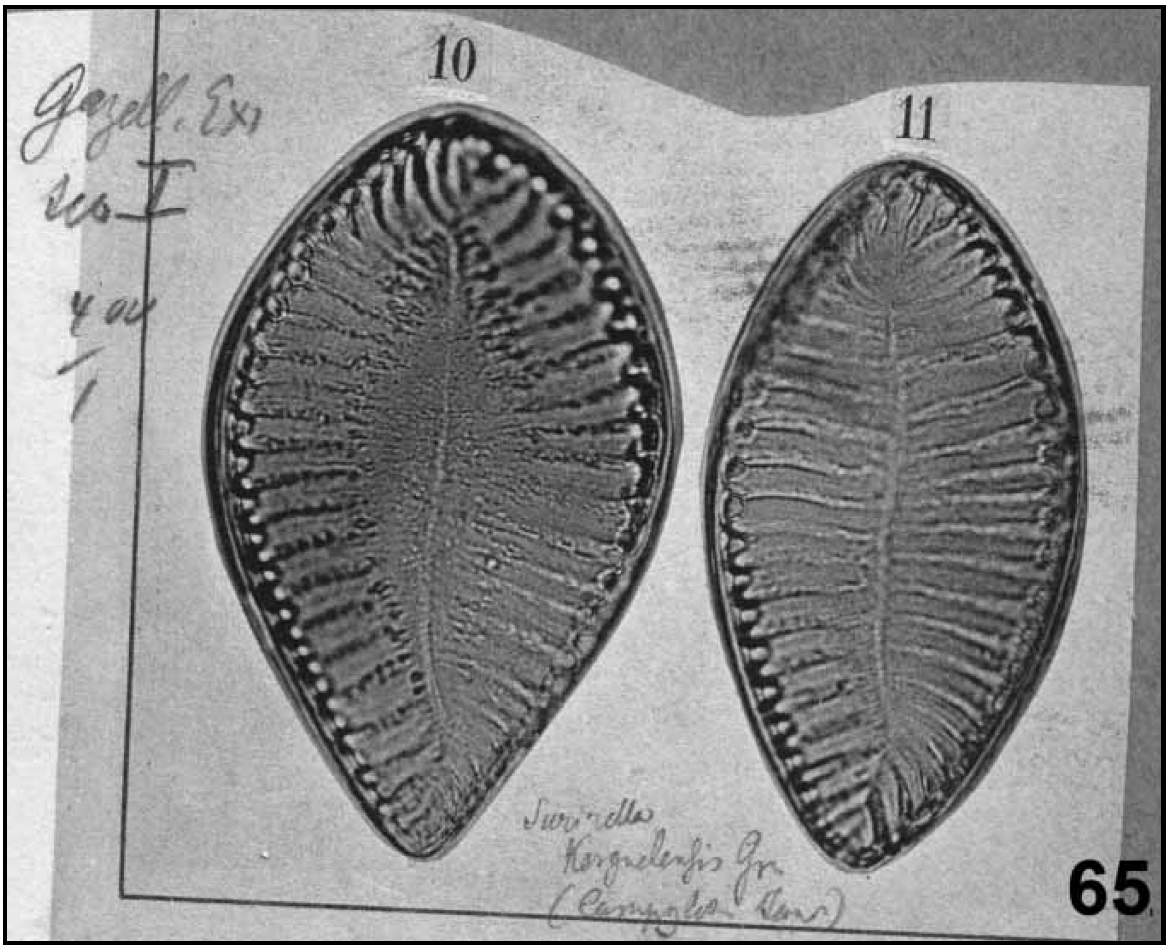


FIGURE A3.65 – Two valves of *Surirella kerguelensis* as shown in the diatom plates distributed by C. Janisch in 1888.

Surirella kerguelensis was originally described in Schmidt (1877, pl. 56, fig. 24) where only one single specimen was illustrated. In the Van Heurck diatom collection kept at the National Botanic Garden of Belgium, two slides are present in the Janisch collection of the Gazelle Expedition (Fig. A3.1). One slide contains one valve, while on the other slide two valves can be observed. It is unfortunately not clear whether these slides served as source for the drawing prepared by Schmidt (1877). Janisch never published the diatoms of the Gazelle Expedition but, he distributed in 1888 some unpublished plates with photographs of diatoms from the Expedition. One of these plates (pl. 1, figs 10–11) shows two valves of *S. kerguelensis*, corresponding to the specimens on slide VI-28-B2 (Fig. A3.65). Therefore, since both slides could not without doubt be connected to the original Grunow drawing and since the protologue of *S. kerguelensis* is based on one single drawing, this drawing is considered to be the holotype of the name according to article 9.1 of the International Code of Botanical Nomenclature (McNeill et al. 2006). Lectotypification is therefore not necessary. *Surirella kerguelensis* can hardly be confused with other *Surirella* taxa. The combination of the contorted valve, the absence of spines, the heteropolar valve outline, the distinct wings and the valve dimensions exclude all confusion with other taxa. Most *Surirella* taxa have a flat valve face or show very contorted valves such as *S. spiralis* Kützing, *S. tortilis* Bramburger & Hamilton or *S. spiraloides* Hustedt.

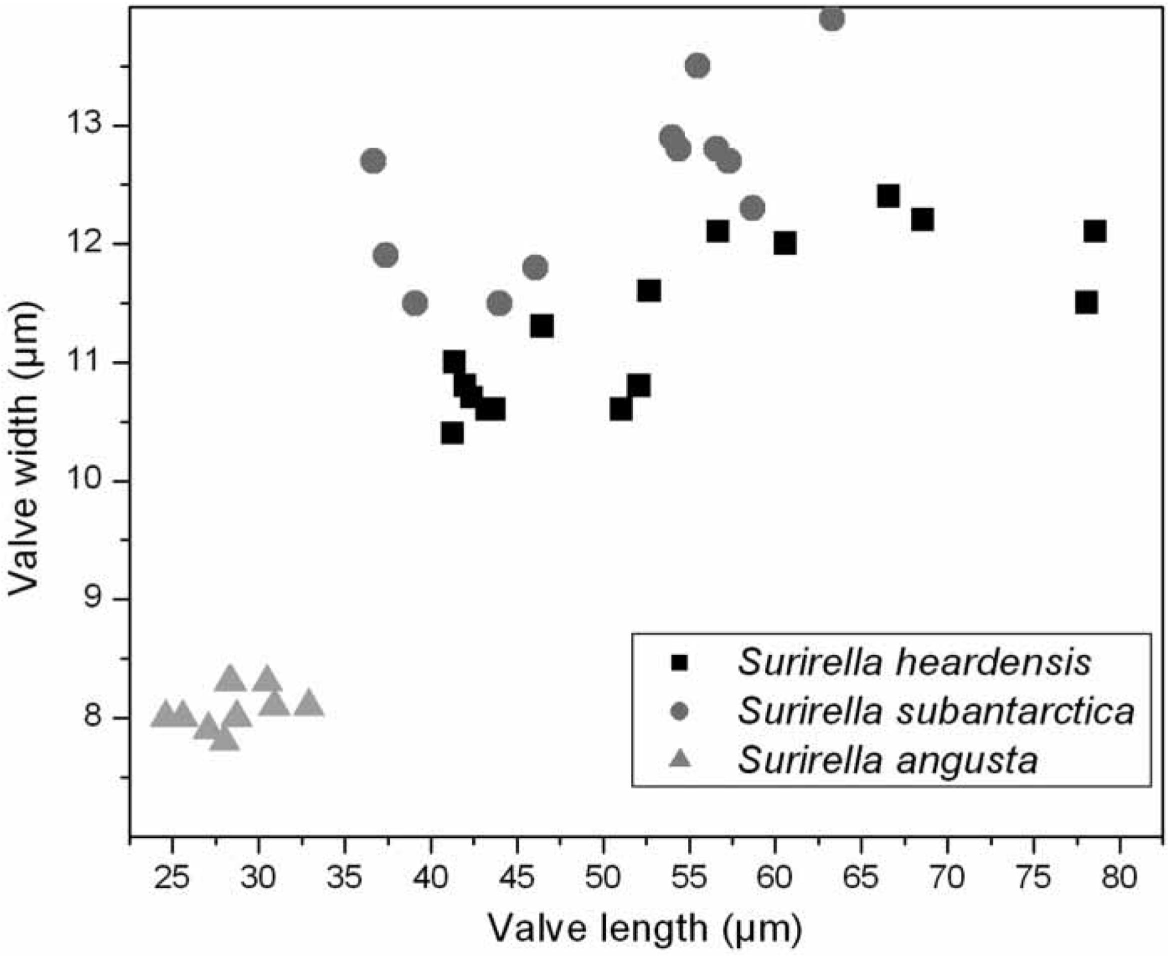


FIGURE A3.66 – Graph representing the length against the width for 10 valves measured of *Surirella subantarctica* (circles), *S. heardensis* (squares) and the type of *S. angusta* (triangles).

A tropical endemic species from Tanganyika Lake, *S. subcontorta* Hustedt, shows a similar valve contortion but is much larger (120–200 µm *versus* 94–132 µm) with a totally different striation pattern showing less pronounced striae near the axial area. *Surirella conversa* Hustedt, an endemic species of Sulawesi, shows similar contorted valves but possesses small spines scattered on the valve face, a narrower axial area compared to *S. kerguelensis* and a different valve outline with the largest width in the upper ¼ of the valve (Huber-Pestalozzi 1942, Bramburger et al. 2006) whereas in *S. kerguelensis*, the largest width is more situated near the valve middle or in the upper 1/3 of the valve. Based on valve outline, *S. robusta* Ehrenberg, *S. astridae* Hustedt and *S. capronii* Brébisson show some similarities but all species are much larger (up to more than 200 µm) and/or present large spines in their axial area (Krammer & Lange-Bertalot 1988).

Surirella australovisurgis has some affinities with *S. visurgis* Hustedt, a taxon widespread though never in large numbers in Europe (Krammer & Lange-Bertalot 1988). Both taxa can however be separated based on their morphometric data. Although both have rather similar valve dimensions with *S. australovisurgis* slightly wider (12.5–14.4 µm *versus* 11–13 µm in *S. visurgis*), *S. australovisurgis* has a higher number of striae (22–24 in 10 µm *versus* 15–17 in 10 µm) and fibulae (5–7 in 10 µm *versus* 3–4 in 10 µm). A typical feature of *S. visurgis* is the presence of very small spines and granules on the valve face. Valves of *S. australovisurgis* are completely devoid of such structures showing smooth valve faces with only irregularly placed silica bars between the costae. Several other *Surirella* taxa that can be confused with *S. austalovisurgis* include *S. ovalis*, *S. brebissonii* Krammer& Lange-Bertalot and its variety *kuetzingii*, *S. subsalsa* W.Smith and *S. minuta* Brébisson. *Surirella ovalis* shows much larger valves (valve width up to 45 µm) with a larger axial area and broadly rounded, convex valve margins, contrary to the almost parallel margins in *S. australovisurgis*. *Surirella brebissonii* and its variety *kuetzingii* have likewise typical convex valve margins with a larger and more lanceolate axial area. *Surirella subsalsa* has more elongate valves with a larger length:width ratio (2.5–2.9 *versus* 2.0–2.4) and convex, rarely parallel valve margins. Finally, *S. minuta* has a different valve outline with gradually tapering valve margins towards the more cuneately rounded basal pole. The fibulae are less radiate in *S. minuta* compared to *S. australovisurgis*.

Surirella subantarctica and *S. heardensis* are strongly related taxa but can nevertheless be easily separated from each other. The principal difference between the two taxa is the depression in the external valve face near both poles in *S. subantarctica*, a feature that can be well observed in LM. *Surirella heardensis* on the other hand lacks the depressions. Other differences between both taxa include a slightly lower valve width in *S. heardensis* and the presence of only three rows of areolae in the striae of *S. heardensis* whereas in *S. subantarctica*, always four rows of areolae were found. Both taxa show affinities with the *S.angusta*-complex and have been in the past confused with taxa from this complex. Bourrelly & Manguin (1954) identified *S. heardensis* on Kerguelen as *S. angusta* var. *constricta*, a species described by Skvortzow in 1929 from eastern Russia (but incorrectly attributed to Hustedt 1930). On the nearby Crozet archipelago, Van de Vijver et al. (2002a) used the same name but this time it was recognized as*S. subantarctica*. Most likely both incorrect identifications are based on the presence of constricted valves, the main diagnostic feature of *S. angusta* var. *constricta* (Skvortzow 1929). In both *S. heardensis* and *S. subantarctica*, larger valves tend to show a constriction near the middle of the valves. Smaller valves in the populations however show no constriction, indicating that this morphological feature should not be used as discriminating characteristic as was already stated for other *Surirella* species studied by Cocquyt & Jahn (2007). The morphometric data for *S. heardensis*, *S. subantarctica* and the type population of *S. angusta* present in the Van Heurck collection (BR) show clear length-to-width distributions (Fig. A3.66). Both sub-Antarctic species have larger valves than *S. angusta*. Especially the valve width shows marked differences with both sub-Antarctic taxa being 1/3 wider than *S. angusta*. *Surirella subantarctica* differs also in the presence of the depression near the poles of the external valve face. *Surirella angusta* shows difference in valve outline, especially the shape of the poles, which are more rostrate in *S. angusta* contrary to both sub-Antarctic taxa that have more broadly rounded, cuneate poles. *Surirella heardensis* has a slightly wider axial area compared to *S. angusta*. Another *Surirella* taxon that shows some affinities to either *S. subantarctica* or *S. heardensis* is *S. gracilis* Grunow. The latter however is larger (valve length up to 190 µm), lacks the typical depressions near the poles as could be found in *S. subantarctica* and has a lower number of striae in 10 µm (11–16 *versus* 22–25 in both sub-Antarctic species) (Krammer& Lange-Bertalot 1988).

Finally, the population of *S. lapponica*, recorded from South Georgia, seems to fit entirely within the original description of *S. lapponica* by Cleve (1895). The species can be distinguished from *S. angusta* by its longer and more slender appearance. Confusion with the two sub-Antarctic species *S. heardensis* and *S. subantarctica* can be excluded based on its lower valve width (7.3–8.0 µm *versus* 8.6–12.4 µm and 11.5–13.9 µm, respectively).

As shown before for almost all other revised diatom genera in the Antarctic flora such as *Stauroneis* Ehrenberg (Van de Vijver et al. 2005), *Hantzschia* (Zidarova et al. 2010) or *Navicula* (Van de Vijver et al. 2011), it is clear that the same biogeographical trend can be found for the genus *Surirella*: apart from *S. kerguelensis*, that was described from the sub-Antarctic region, all previously recorded *Surirella* species seemed to show a rather cosmopolitan distribution based on the literature data (Kellogg & Kellogg 2002). It was however clear that most observations resulted from force-fitting the specimens into their European or tropical relatives (Tyler 1996). The taxonomic analysis in the present study revealed therefore a completely different situation with four out of five recorded species having a restricted biogeographical distribution. Low numbers, as is the case for *Surirella* and other genera such as *Navicula sensu stricto* (Van de Vijver et al. 2011) in the Antarctic Region are in clear contrast with the Arctic Region (E. Verleyen et al., unpubl. data). The unbalanced diatom flora is probably the result of the patchiness of landmasses in the Antarctic Region and the fact that most islands and archipelagos have an oceanic origin. Moreover, the most species rich genera in the Antarctic Region belong to aerophilic genera such as *Luticola*, *Muelleria* or *Diadesmis* (Van de Vijver et al. 2002b, 2010). The sub-Antarctic islands of the southern Indian Ocean showed the largest diversity with three (regionally endemic) taxa whereas in the southern Atlantic Ocean, only two taxa could be found. Moreover, no taxa were shared between the different parts of the Antarctic Region. This is consistent with the results obtained in almost all other revised genera (see for instance the revision in the genus *Stauroneis*; Van de Vijver et al. 2005). These results also indicate that thorough taxonomic research is a *sine qua non* condition for good biogeographic research.

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APPENDIX 4

An evaluation of selected *Neidium* species from the Antarctic Region

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The presentation of three distinct Neidium *taxa from the sub-Antarctic and Maritime Antarctic Region after examining more than 1500 samples from a broad variety of aquatic and terrestrial (micro-)habitats suggests that taxa representing the genus* Neidium *Pfitzer are not only quite rare in these regions, but that the three species* (Neidium nyvltii *sp. nov.,* N. antarcticum *sp. nov. and* N. aubertii *Manguin) also represent well-defined biogeographical distributions*. Neidium nyvltii *is a benthic alkalophile growing in the Maritime Antarctic Region under high total phosphorus (TP) and moderately high chloride concentrations, while the closest taxa for comparison (*N. kozlowii *Mereschkowsky and its varieties) are also alkalophilic, growing under lower TP concentrations in northern temperate-Arctic regions.* Neidium aubertii *is an acidophile with a sub-Antarctic distribution, whereas the most comparable taxa are* N. bisulcatum *(Lagestedt) Cleve, and* N. bergii *(A. Cleve-Euler) Krammer & Lange-Bertalot both are alkalophiles with northern hemisphere distribution and commonly occurring in the Arctic.*

Keywords*: Antarctic Region, Bacillariophyta, biogeography, morphology,* Neidium*, new species*

Introduction

Significant advances have been made in our understanding of the diversity and species richness of the polar regions (e.g., Arntz et al. 1997, Eastman 1997, Sirenko 2001, Scott & Marchant 2005, Lovejoy et al. 2006, Wulff et al. 2009, Poulin et al. 2011, Naughton 2012, Rogers et al. 2012). With improved data collecting using vouchered materials and advanced molecular analyses, researchers have established the biologically unique nature of these polar environments, with countless studies highlighting the distinctive biodiversity between these two contrasting regions. There is a clear distinction in species richness and endemism between Arctic and Antarctic ecozones (Van de Vijver et al. 2005). In contrast, fewer studies have identified commonality in the species composition of bacteria, dinoflagellate and foraminifer communities (e.g., Darling et al. 2000, Brinkmeyer et al. 2003, Montresor et al. 2003). It is clear that the definition of a species along with a good understanding of genotypic and phenotypic expression within a species, coupled with the occurrence of cryptic species especially in eukaryotes, still need thorough study. In freshwater polar environments, the vouchered evidence in eukaryote studies suggests that there are clear differences in community and species composition between the poles (E. Verleyen et al., unpubl. data). Currently there is an increased interest in studying cryptic species and their relationship with genotypic expression, with less emphasis on phenotypic expression in populations (e.g., Lundholm et al. 2012). As a result the previous notion that the majority of diatom taxa in the Antarctic are cosmopolitan has been challenged (Sabbe et al. 2003, Vyverman et al. 2007, 2010). In the last 10 years, selected works in diatom biodiversity and biogeography further support the unique environment of the Antarctic and its distinction from the Arctic (Ross 1947, Patrick & Freese 1961, Le Cohu & Van de Vijver 2002, Van de Vijver et al. 2002a, b, 2005, 2010, 2011, 2013, Antoniades et al. 2008, Esposito et al. 2008, Zidarova et al. 2010).

The genus *Neidium* was established by Pfitzer (1871), with the separation of a small group of taxa away from *Navicula sensu lato* based on a bilobed chloroplast structure. Cleve (1895) later recognized unique valve features in the genus, such as the shape and form of the proximal and distal raphe endings and the interruption of the striae along the valve margin. It was not until 1927 that Boyer selected *N. affine* (Ehrenberg) Pfitzer (basionym: *Navicula affinis* Ehrenberg) as the representative type species for the genus. In the early 20th century, it was further recognized that the longitudinal bands along the valve margin were the primary distinctive valve feature for the genus (Hustedt 1935). Later, Sims & Paddock (1979) determined that these longitudinal bands corresponded to longitudinal canals within the valve wall. Recently, Hamilton & Jahn (2005) identified a lectotype for *N. affine* and emended the generic description. Since Boyer (1927), over 300 new taxa have been described or transferred to the genus *Neidium* (Cleve-Euler 1955, Patrick & Reimer 1966, Metzeltin & Lange-Bertalot 1998, 2007, Lange-Bertalot et al. 2003). More recently, two new genera were proposed, *Neidiopsis* Lange-Bertalot & Metzeltin and *Neidiomorpha* Lange-Bertalot & Cantonati, based primarily on the absence of lacinia, renilimbia, and the presence of simple proximal raphe fissures (Lange-Bertalot & Genkal 1999, Cantonati et al. 2010).

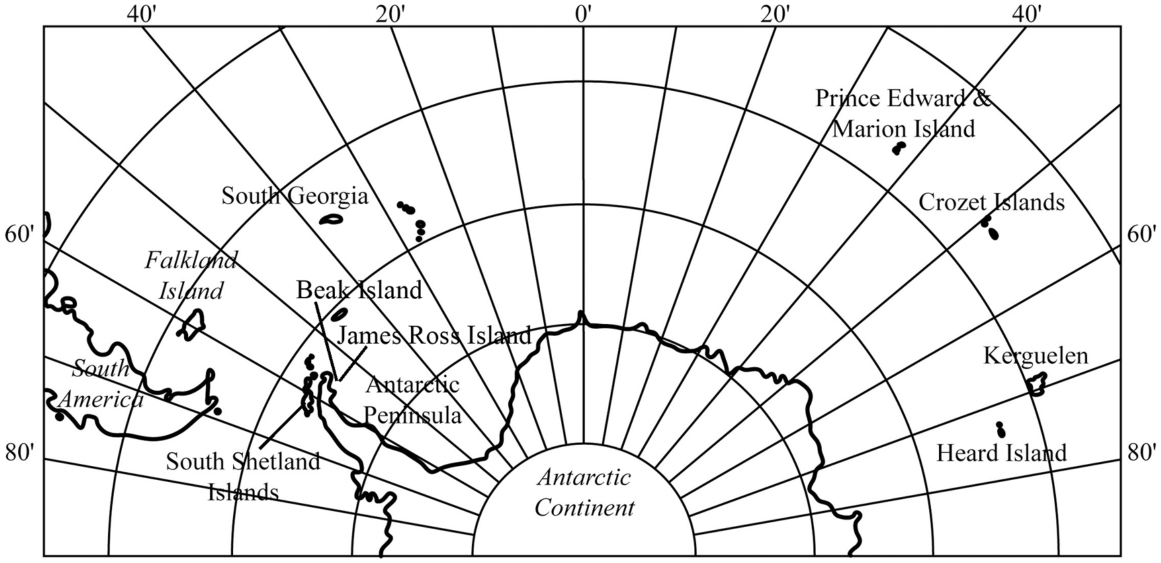


FIGURE A4.1 – Map of the Antarctic Peninsula and sub-Antarctic region showing sampling islands.

Prescott (1979), followed by an update by Kellogg & Kellogg (2002), compiled all records of *Neidium* taxa reported from the Antarctic (Table A4.1). In general, the genus *Neidium* is considered less speciose and poorly represented in the Antarctic. Apart from *N. aubertii* Manguin, a regionally endemic species from Kerguelen Island (Bourrelly & Manguin 1954), only 15 cosmopolitan taxa have been reported (Kellogg & Kellogg (2002). These records relate back to the broad species concept that was generally accepted at that time and which resulted in catch-all taxa, such as *N. affine*, to be mostly reported across the Antarctic. However, almost all the species have only been reported once in the Antarctic suggesting that an incomplete identification may be at the origin of these observations. Since most records date back to the beginning of diatom exploration in the Antarctic and, unfortunately, none of them included any iconography of the records, it is almost impossible to validate these reports. A detailed evaluation of *Neidium* taxa across the Antarctic would require access to more regional materials that are currently not available or not yet sampled. Thus, this paper reports on the distribution and description of two new regional species, *N. nyvltii* sp. nov. and *N. antarctica* sp. nov., from Livingston Island and James Ross Island in the Maritime Antarctic Region, and provides an emended description and lectotypification of *N. aubertii*.

TABLE A4.1 – List and number of published records of *Neidium* taxa reported from the Antarctic Region by Kellogg & Kellogg (2002).

	sub-Antarctica			Maritime Antarctica
	South Georgia	Southern Indian Ocean	Macquarie Island	
N. affine (Ehrenberg) Pfitzer	3	1	1	1
N. affine var. *amphirhynchus* (Ehrenberg) Cleve	3			
N. affine var. *longiceps* (W. Gregory) Cleve				2
N. aubertii Manguin		8		
N. bisulcatum (Lagerstedt) Cleve		1		1
N. iridis (Ehrenberg) Cleve		1		
N. productum (W. Smith) Cleve	3			

Materials and methods

Several moss and soil samples were collected during the past 15-year field campaigns in the southern Indian (Prince Edward, Marion, Heard, Crozet and Kerguelen islands) and Atlantic Oceans (Livingston Island in South Shetland Islands and James Ross Island) (Van de Vijver et al. 2001, 2002a, 2004, 2008, Kopalová et al. 2012, Kopalová & Van de Vijver 2013) (Fig. A4.1). More information on sampling and physico-chemical analyses can be found in the references cited above.

During past diatom surveys on these islands, species of *Neidium* were recorded and documented in low abundances. Therefore, more in-depth examinations of these samples containing *Neidium* species were conducted, namely at the National Botanical Garden of

Belgium (BR), the Canadian Museum of Nature (CANA) and the St. Kliment Ohridski University of Sofia (Bulgaria).

TABLE A4.2 – List of samples from the Antarctic used in this study. *, part of South Shetland Islands.

Sample	Location	Source
C-BM148	Crozet Archipelago	Van de Vijver et al. (2002a)
C-BW-140	Crozet Archipelago	Van de Vijver et al. (2002a)
C-BW149	Crozet Archipelago	Van de Vijver et al. (2002a)
C-BW509	Crozet Archipelago	Van de Vijver et al. (2002a)
He-D24	Heard Island	Van de Vijver et al. (2004)
He-H1612	Heard Island	Van de Vijver et al. (2004)
He-H546	Heard Island	Van de Vijver et al. (2004)
He-Q252	Heard Island	Van de Vijver et al. (2004)
PEI-D07	Prince Edward Islands	Van de Vijver et al. (2008)
LIV-BYS10	Livingston Island*	This study
LIV-A24	Livingston Island*	This study
JRI2009-CLW58	James Ross Island	This study
JRI2009-CLW60	James Ross Island	This study
JRI2008-32	James Ross Island	This study

For light microscope (LM) observation, diatom samples were prepared following Van der Werff (1955). In total, 14 sample sites and microhabitats were examined in this study, with all samples listed in Table A4.2. Subsamples of the original material were oxidized using 37% H_2O_2 and heating to 80 °C for 1 h. The reaction was further completed by the addition of $KMnO_4$. Following digestion and centrifugation (three times 10 min at 3700× g), the material free of organic matter was further diluted with distilled water for sample mounting to avoid excessive concentrations of diatom valves on the slides. A subsample from the organic-free material was mounted in Naphrax®. The slides were analyzed at BR using an Olympus BX51 microscope, equipped with differential interference contrast (DIC) optics (Nomarski) and Colorview I Soft Imaging System, at the University of Sofia using an Olympus BX53 microscope, and at CMN using a Leica DMR microscope equipped with DIC, phase contrast and reflective interference contrast optics, and a Nikon DXM1200F CCD camera. Diatom samples and slides are stored at BR.

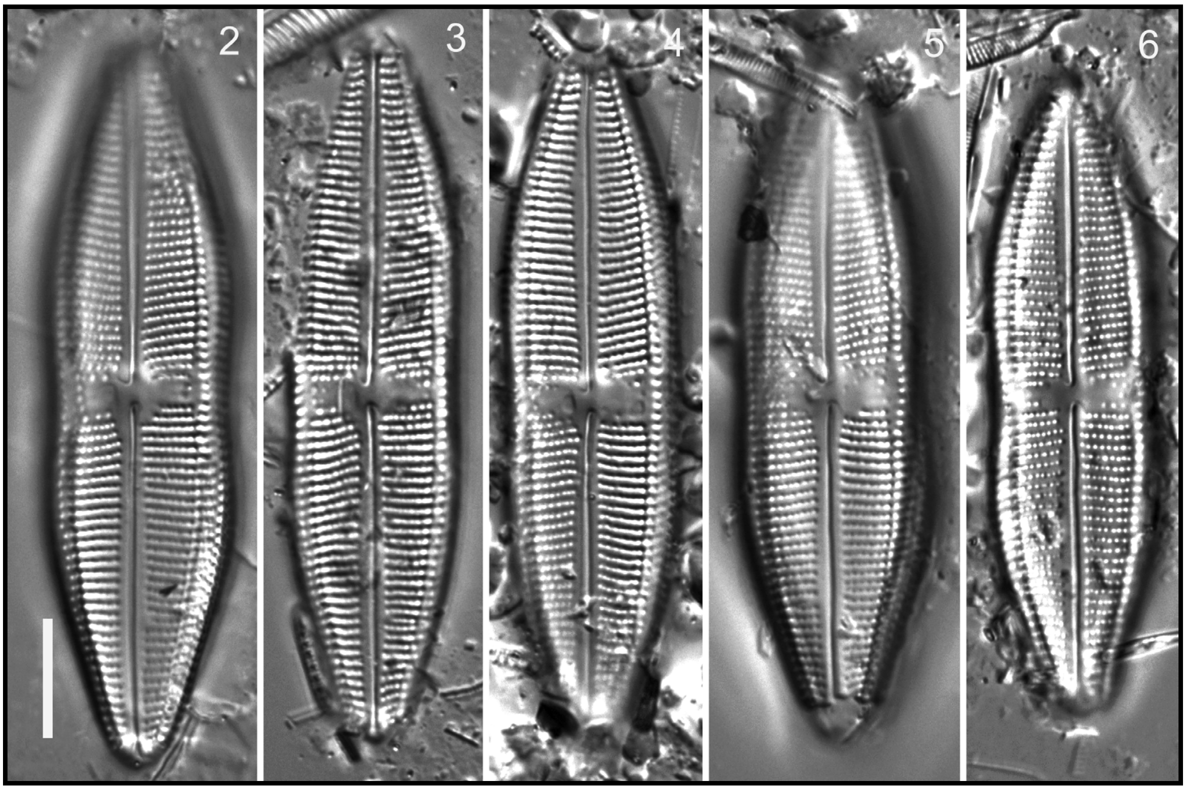
For scanning electron microscopy (SEM), aliquots of the oxidized suspensions were filtered through 1-µm pore size polycarbonate filters which were cut in small pieces and fixed on aluminum stubs after air-drying. The stubs were sputter-coated (SCD020, Balzers Union, Balzers, Liechtenstein) with 50 nm of Au and examined at BR using a JEOL-5800LV SEM at 25 kV. Additional materials were also sputter-coated with 10 nm of Au and examined at the University of Sofia using a JEOL JSM 5510 SEM operating at 10 kV, and with 50 nm of Au and examined at the Canadian Museum of Nature using a FEI XL30 ESEM operating at 15–20 kV and at the Natural History Museum (London, UK) using a Zeiss® Ultra plus SEM at 8 kV.

The original slides (AD9086 and AD9089) containing the type of *N. aubertii* from the Manguin Collection at the Muséum National d'Histoire Naturelle in Paris, France were examined (Bourrelly & Manguin 1954). In addition, a slide (ANSP 91506) containing type material split from the original material which is housed at the Academy of Natural Sciences in Philadelphia, USA was also examined.

New taxon descriptions

Neidium nyvltii **Hamilton, de Haan, Kopalová, Zidarova & Van de Vijver sp. nov.** (Figs A4.2–A4.16)

Frustules rectangular in girdle view. Valves linear-lanceolate with weak central constriction and rostrate to apiculate rounded apices (Figs A4.2–A4.6). Length: 50–57 µm, width: 11.5–14.0 µm, 10–12 striae in 10 µm, 16–18 areolae in 10 µm. One longitudinal canal runs from apex to apex on each valve margin with a row of small round pores opening on the valve face and another row on the mantle (Figs A4.2– A4.9, A4.11). Valve mantle at mid-valve with 8–12 areolae down to distal edge (Fig. A4.11). Mantle at apices narrower with fewer areolae (Fig. A4.11). Cingulum with 2–3 copulae, each with 2 rows of elliptical to linear-elliptical pores on pars exterior (Fig. A4.11). Axial area linear. Raphe filiform, linear externally with hooked proximal fissures (Figs A4.7–A4.9) and bifurcate lacinia down to mantle base (Figs A4.7, A4.10). Internally, raphe filiform, proximal and distal fissures with distinct helictoglossae (Figs A4.14–A4.15). Central area helictoglossae separate and not united (Fig. A4.14). Central area asymmetrical, rectangular to elliptical bordered by 3–4 striae with 1–4 areolae per stria at the margin (Figs A4.8–A4.9). Circular to elliptical depressions scattered in the central area (Fig. A4.8). Striae areolate, weakly oblique to radiate at center and parallel to convergent at apices (Figs A4.2–A4.6). Areolae in valve wall (Figs A4.8, A4.16), with small rounded external foramina (Figs A4.7–A4.10). Areolae opening into longitudinal canal sometimes with occluded cribra (Fig. A4. 12); internally, cribra covered with hymenes (Figs A4.13–A4.15). Renilimbia with hymen covers around areola and longitudinal canal openings (Figs A4.14–A4.15). Under hymen, 1–3 rows of pores open into valve wall chamber and longitudinal canals (Fig. A4.16).



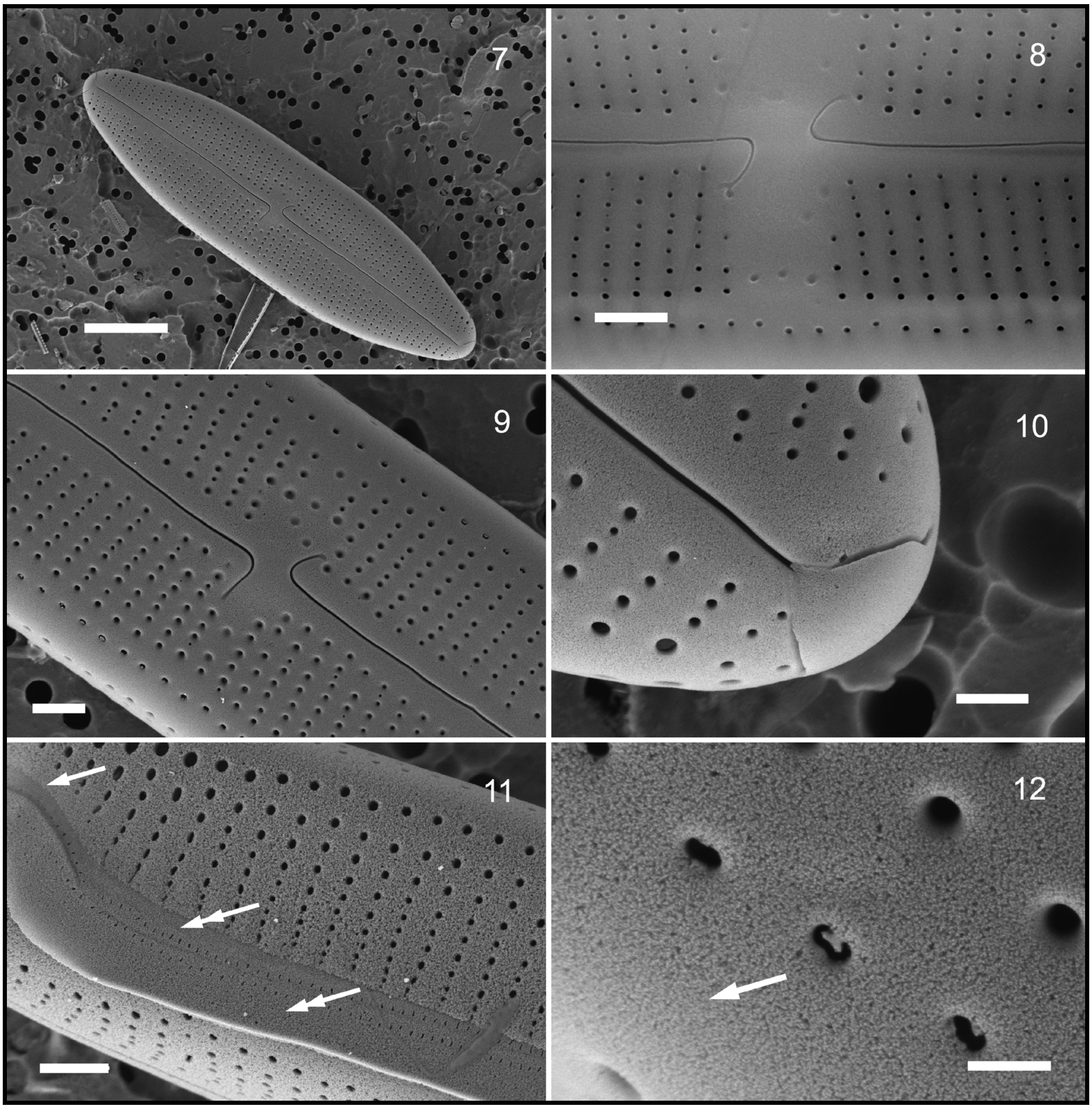
FIGURES A4.2–A4.6 – *Neidium nyvltii* sp. nov. from the type locality on James Ross Island, valves in LM. **Fig. A4.2.** Holotype specimen. Scale bar = 10 µm.

Holotype: *(here designated)*. Specimen circled on slide BR-4299, National Botanic Garden of Belgium, Meise, the holotype specimen represented by Figure A4.2.

Isotypes: Slides PLP-220, University of Antwerp, Belgium and CANA86151, National algal collection, Canadian Museum of Nature, Ottawa, Canada.

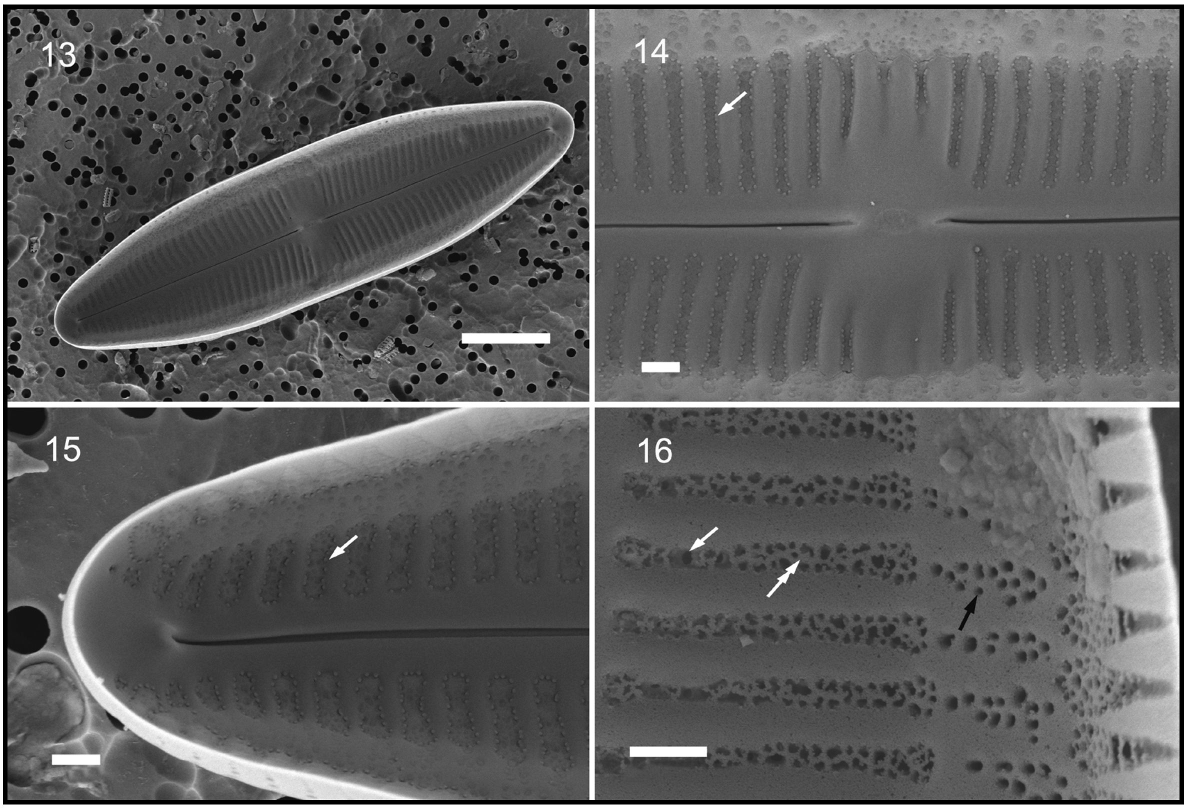
Type locality: Sample D58, Clearwater Mesa Lake 3, James Ross Island, North-West Weddell Sea (64°01’48.1”S, 57°42’49.5”W). Collected by L. Nedbalová, 9 February 2009.

Etymology: The specific epithet *nyvltii* is named after our colleague Dr. Daniel Nývlt from the Czech Geological Survey in Brno, Czech Republic for his contribution to Antarctic science.



FIGURES A4.7–A4.12 – *Neidium nyvltii* sp. nov. from the type locality on James Ross Island, SEM external views. **Fig. A4.7.** Whole valve. **Figs A4.8–A4.9.** Central areas showing variation in proximal raphe fissures. **Fig. A4.10.** Apex showing the lacinia. **Fig. A4.11.** Mantle close to apex. Note valve mantle narrower in depth at apex (arrow) and two copulae visible (double arrows), each with a row of linear-elliptical pores. **Fig. A4.12.** Details of longitudinal canal (arrow) and valve face areolae with some areolae over the longitudinal canal having c-shaped cribra. Scale bars = 10 µm (Fig. A4.7); 2 µm (Figs A4.8–A4.9, A4.11); 1 µm (Fig. A4.10); 500 nm (Fig. A4.12).

Distribution: The type population of *N. nyvltii* is located on the Clearwater Mesa plateau in the northern part of James Ross Island. The sample was taken from the epilithon of a stable shallow lake characterized by an alkaline pH (8.3), a moderately high specific conductance (480 µS cm^{-1}), high chloride (104 mg L^{-1}) and low nitrate (NO_3-N) (<5 µg L^{-1}) and total phosphorus (TP) (<15 µg L^{-1}). On Livingston Island, this species was observed in a wet seepage area near Limnopolar Lake. *Pinnularia australomicrostauron* Zidarova, Kopalová & Van de Vijver, *Nitzschia* aff. *perminuta* (Grunow) H. Peragallo, *Amphora* cf. *veneta* Kützing and *Placoneis australis* Van de Vijver & Zidarova dominated the diatom community in the type material sample.



FIGURES A4.13–A4.16 – *Neidium nyvltii* sp. nov. from the type locality on James Ross Island, SEM internal views. **Fig. A4.13.** Whole valve showing a raised central area and distinct longitudinal canals along the margin. **Fig. A4.14.** Central area slightly raised above valve face with clearly separated distal raphe endings. Note the renilimbia with hymen covers around areola (arrow). **Fig. A4.15.** Apex with helictoglossa, striation and longitudinal canals covered by rounded hymenes. Renilimbia (arrow) are positioned adjacent to the hymen covers forming linear-like rows next to the virgae and also along the longitudinal canals. **Fig. A4.16.** Corroded part of a valve without hymenes. External pore opening (white arrow) and poroid occlusions that are moderately eroded (double arrow). Between the pore occlusions and external pore opening is an open alveolate-like channel. Striae and longitudinal canals (black arrow) covered by 1–3 rows of pores. Scale bars = 10 µm (Fig. A4.13); 1 µm (Figs A4.14–A4.16).

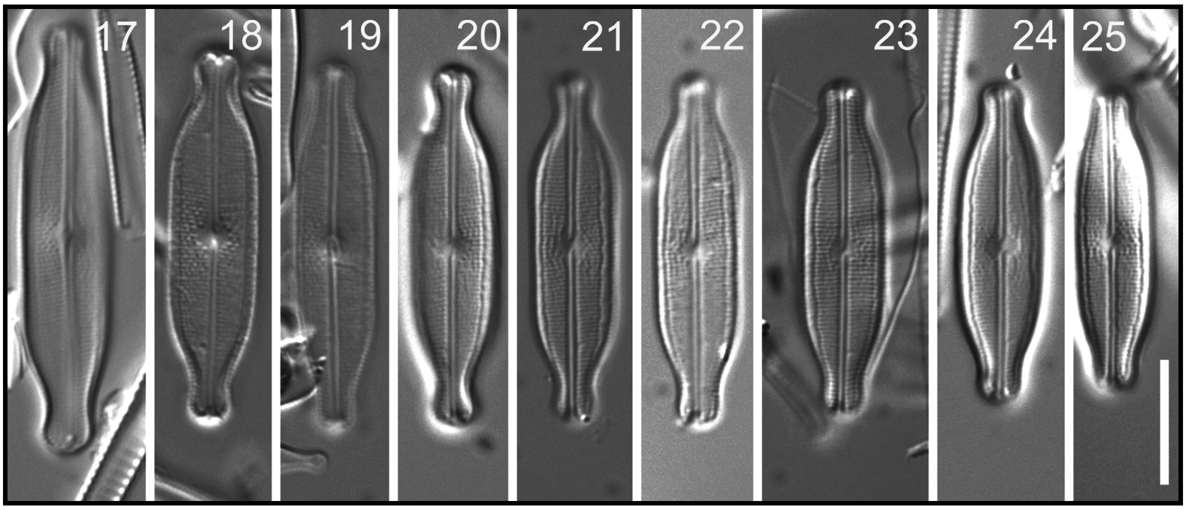
Main distinguishing characters: The valves are linear-lanceolate to centrally constricted with one longitudinal canal along each margin. They possess hooked proximal raphe fissures and lacinia covered terminal fissures. The areolae are chambered and distinct in LM. Ghost depressions are also present in the central area. Internally, the areolae and the longitudinal canal open through 1–3 rows of small pores.

Remarks: In LM, the valve of *N. nyvltii* is generally similar to *N. kozlowii* Mereschkowsky and its varieties *elliptica* Mereschkowsky and *parva* Mereschkowsky, and *N. bobmarshallensis* Bahls but the valves of this new species are linear-lanceolate with a central marginal constriction, the proximal raphe fissures are small and hooked (not deflected), and the central area is asymmetrically rectangular to elliptical not oblique in orientation. In contrast, *N. kozlowii* and *N. bobmarshallensis* have deflected (not hooked) proximal raphe fissures, oblique striae around the central area, oblique central areas, larger areolae, and do not have a mid-valve marginal constriction. It is evident that *N. nyvltii* is not what Ehrenberg considered to be *N. ampliatum* (Ehrenberg) Krammer, based on its holotype line drawings which show linear valves and rostrate apices.

Neidium antarcticum **Hamilton, de Haan, Kopalová, Zidarova & Van de Vijver sp. nov.**

(Figs A4.17–A4.31)

Frustules rectangular in girdle view. Valves linear to linear-lanceolate with capitate to rostrate-capitate apices (Figs A4.17–A4.25). Length: 25–35 µm, width: 6–7 µm, 28–32 striae in 10 µm, 28–32 areolae in 10 µm. Valve mantle deep with 6–8 areolae extending down to valve margin (Figs A4.27, A4.30). Cingulum with 2–3 copulae, each copula with one row of small elliptical pores. One longitudinal canal from apex to apex on each margin (Figs A4.26–A4.29) with row of small round pores opening on valve face (Figs A4.27–A4.28). Axial area narrow and linear. Raphe filiform, linear externally with small weakly deflected to hooked proximal fissures (Figs A4.26, A4.28) and bifurcate lacinia extending onto valve mantle (Fig. A4.29). Internally, proximal and distal raphe fissures end with helictoglossae. Proximal helictoglossae separate and not joined (Figs A4.27, A4.31). Central area elliptical to rounded bordered by 4–7 striae with 3–4 areolae per stria at the margin (Fig. 26). Striae areolate, oblique to parallel at center and parallel to weakly convergent at apices (Figs A4.18–A4.26). Areolae with rounded external foramina (Figs 26–29). Internal areolae covered by hymenes (Figs A4.30–A4.31). A single renilimbia on areolae align axial area and areolae openings over longitudinal canals (Figs A4.30–A4.31).



FIGURES A4.17–A4.25 – *Neidium antarcticum* sp. nov. from the type locality on Livingston Island, valves in LM. **Fig. A4.15.** Holotype specimen. Scale bar = 10 µm.

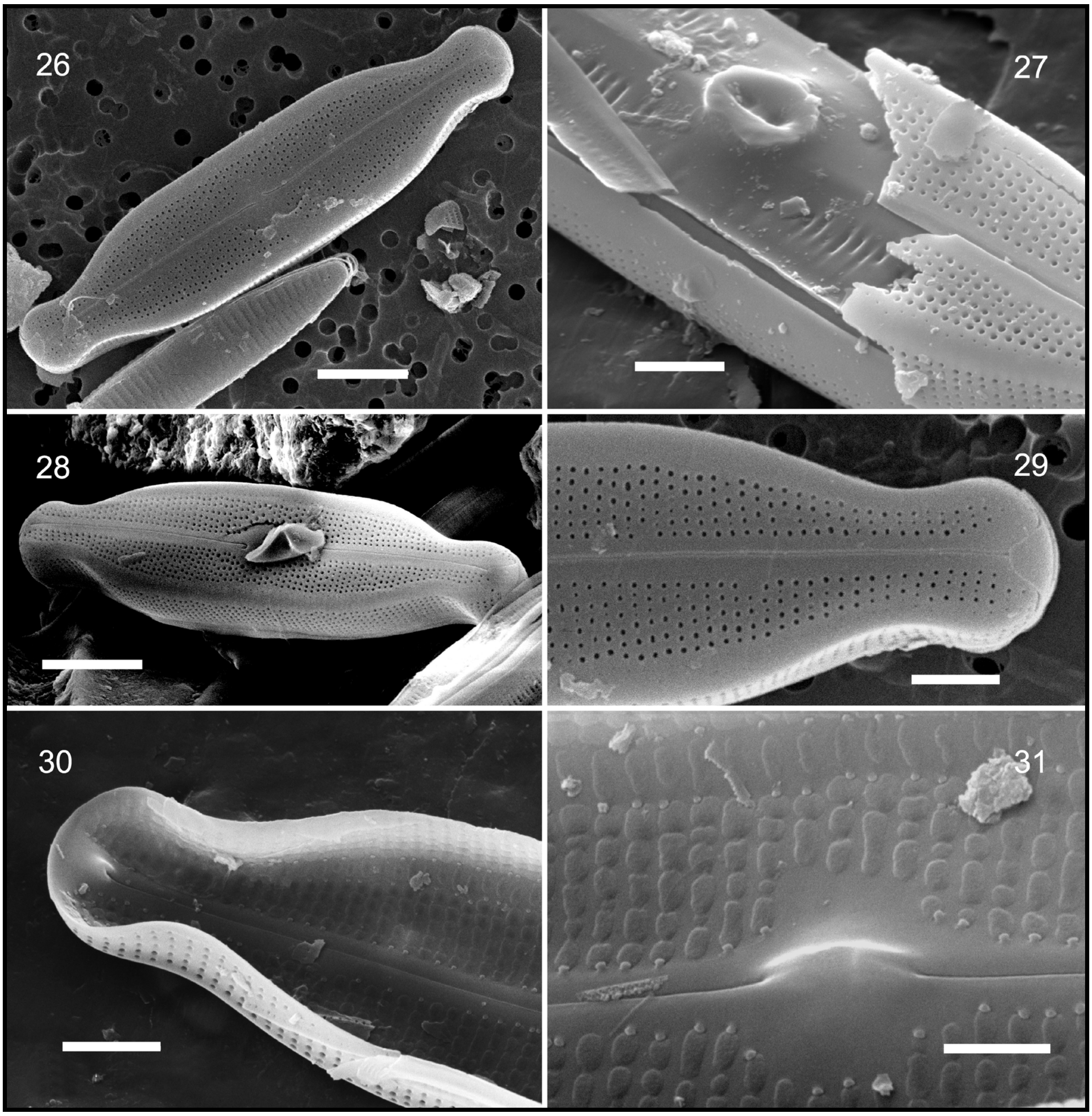
Holotype: *(here designated)*. Specimen circled on slide BR-4300, National Botanic Garden of Belgium, Meise, the holotype specimen is represented by Figure 15.

Isotypes: Slides PLP-221, University of Antwerp, Belgium and CANA86152, National algal collection, Canadian Museum of Nature, Ottawa, Canada.

Type locality: Sample LIV-24A, Caleta Argentina, Hurd Peninsula, Livingston Island, South Shetland Islands. Collected by R. Zidarova, 27 December 2005.

Etymology: The specific epithet refers to the geographical distribution of the species on several maritime Antarctic islands.

Distribution: The largest population of *N. antarcticum* was observed from a small stream flowing out from a shallow lake on Hurd Peninsula, Livingston Island, with a pH of 6.3, specific conductance of 58 µS cm^{-1}, and low phosphate (PO_4-P) (0.13 mg L^{-1}) and NO_3-N concentrations (0.70 mg L^{-1}). Accompanying taxa include: *Nitzschia homburgiensis* Lange-Bertalot, *Fragilaria capucina* Desmazières *sensu lato*, *Psammothidium papilio* (D.E. Kellogg, Stuiver, T.B. Kellogg & G.H.D. Denton) Kopalová & Van de Vijver, *Planothidium* cf. *lanceolatum* (Brébisson) Lange-Bertalot, *Chamaepinnularia krookiiformis* (Krammer) Lange-Bertalot & Krammer, *C. krookii* (Grunow) Lange-Bertalot & Krammer, and several *Gomphonema* and *Nitzschia* taxa. On James Ross Island, a small population of *N. antarcticum* was found in a geologically and geomorphologically stable, shallow lake on Ulu Peninsula, with high alkalinity (455 mmol L^{-1}), low specific conductance (<100 µS cm^{-1}) , high TP (>50 µg L^{-1}) and moderate total nitrogen (TN) concentrations (>0.5 mg L^{-1}). The population was dominated by *Nitzschia paleacea* (Grunow) Grunow, *Nitzschia* aff. *perminuta*, *Psammothidium papilio* and *Amphora* cf. *veneta*.



FIGURES A4.26–A4.31 – *Neidium antarcticum* sp. nov. from the type locality on Livingston Island, SEM external (**Figs A4.26, A4.28–A4.29**) and internal views (**Figs A4.30–A4.31**). **Fig. A4.26.** Whole valve showing a single longitudinal canal. **Fig. A4.27.** Fractured valve showing hypovalve in development, with hymenate striae and distinct proximal raphe ends with the central nodule surrounded by a thick siliceous ring. **Fig. A4.28.** Oblique view of whole valve showing deep mantle. **Fig. A4.29.** Apex showing the lacinia extending down the mantle. **Fig. A4.30.** Apex with helictoglossa and longitudinal canal. **Fig. A4.31.** Raised central nodule. Note striae covered by rounded to elliptical hymenes and renilimbia positioned at each areola along the axial area and on either side of the longitudinal canal. Scale bars = 5 µm (Figs A4.26, A4.28); 2 µm (Figs A4.27, A4. 29–A4.30); 1 µm (Fig. A4. 31).

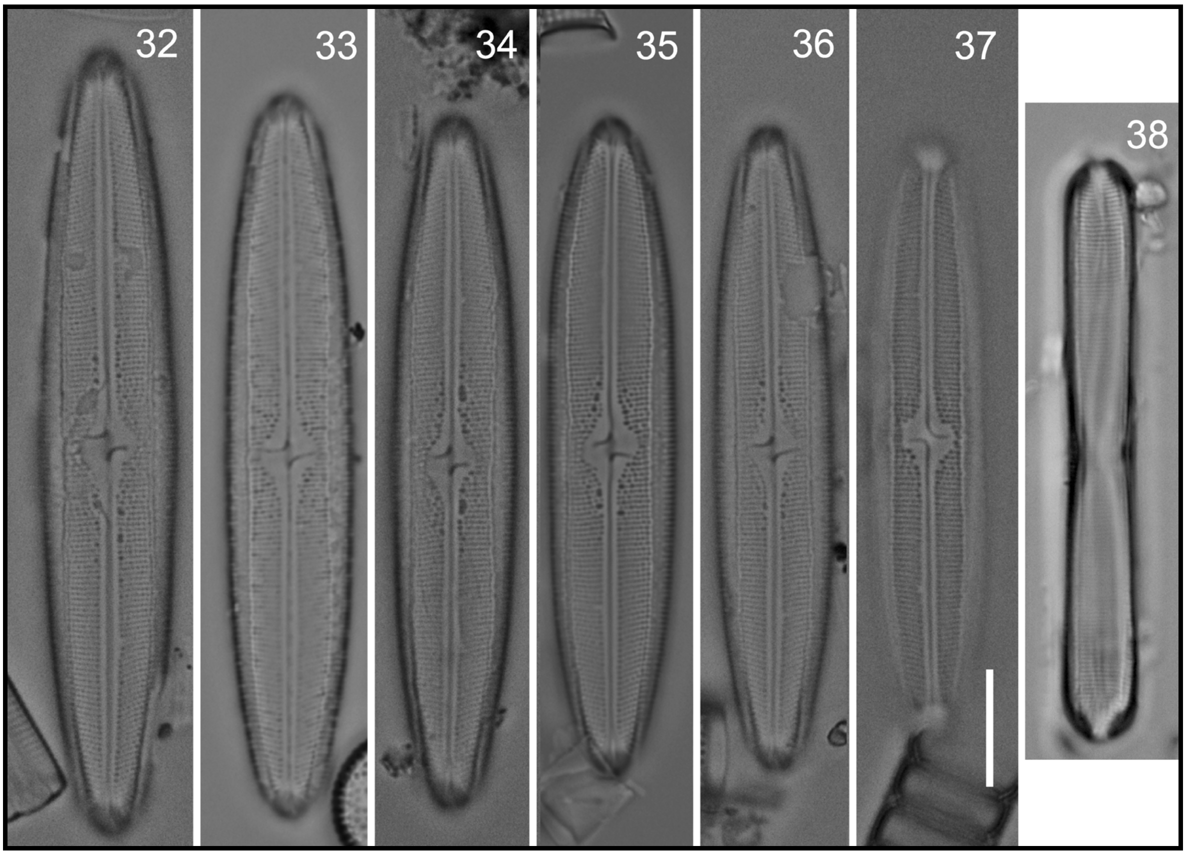
Main distinguishing characters: The linear valves have one distinct longitudinal canal along each margin with small surface pores. The proximal raphe fissures vary from simple deflected to small hooked endings. The terminal raphe ending is covered by a lacinia that extends to the base of the valve apex. Internally, the areolae have distinct hymen covers and renilimbia are aligned with the axial area and longitudinal canals.

Remarks: *Neidium antarcticum* can be compared to *N. longiceps* (W. Gregory) A. Cleve-Euler, but it differentiates from the latter by rostrate-capitate *versus* capitate apices and slightly higher stria density. *Neidium curtihamatum* Lange-Bertalot, Cavacini, Tagliaventi & Alfinito is also comparable in the general outline to this new species, but the valves are more elliptical, the apices rostrate and the central area is smaller with more areolae in the marginal striae surrounding the central area (Lange-Bertalot et al. 2003). Although similar in general outline to *N. fasciatum* Østrup, *N. antarcticum* does not have a prominent mid-valve constriction, the apices are capitate (not rostrate-capitate), the valves are smaller, the stria density is higher, and the proximal raphe fissures are smaller. *Neidium antarcticum* is separated from *N. affine* by its smaller size, the rostrate-capitate apices and one large longitudinal canal instead of 2–3 canals in *N. affine*. In a fractured valve capturing the hypovalve morphogenesis (Fig. A4.27), the wall is formed by a series of costal ribs (virgae) with a hymen cover (not fully formed). The proximal fissure openings and the formation of the central are under construction and surrounded by a thickened silica ring (Fig. A4.27).

Neidium aubertii **Manguin** (Figs A4.32–A4.48)

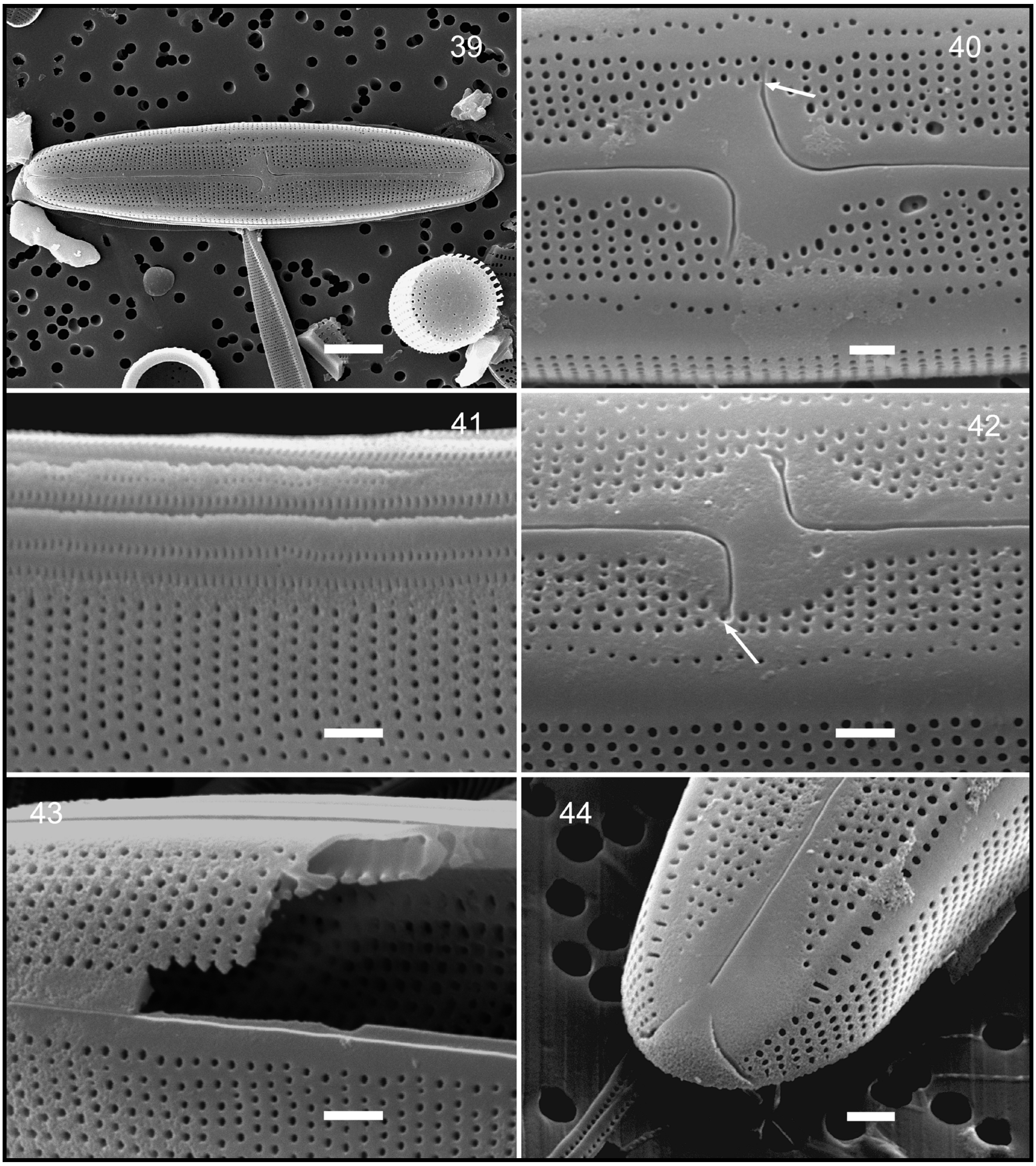
Frustules rectangular in girdle view (Fig. A4.33).Valves lanceolate to linear-lanceolate with protracted rounded apices (Figs A4.26–A4.32). Length: 42–64 µm, width: 8–10 µm, 24–28 striae in 10 µm, 30–33 areolae in 10 µm. Valve mantle deep with 6–9 areolae down to margin (Figs A4.41, A4.43–A4.44). Cingulum with 4 open copulae; each copula with one or two rows of linear to linear-elliptical areolae (Fig. A4.41). One large longitudinal canal from apex to apex on each margin with row of round pores opening on valve face (Figs A4.32–A4.37, A4.39–A4.44). Longitudinal canal broader at mid-valve narrowing towards apices (Figs A4.33–A4.37). Internally, valve with single row of linear-elliptical openings to longitudinal canal (Figs A4.45–A4.46). Axial area narrow and linear, expanding into large triangular to elliptical distal areas (Figs A4.39, A4.44). Raphe lateral, linear externally with deflected to broadly hooked proximal fissures extending to the edge of the central area (Figs

A4.35, A4.37); bifurcate lacinia extend to base of valve mantle (Fig. A4.44). Internally, distal raphe fissures with horseshoe-shaped helictoglossae (Fig. A4.47), proximal raphe fissures with adjacent but separate helictoglossae (Fig. A4.46). Central area large, asymmetrical, rounded to elliptical (Figs A4.32–A4.37, A4.40, A4.42); 7–10 striae with 1–4 areolae per stria at the margin (Figs A4.40, A4.42). Striae areolate, parallel to oblique at center and parallel to convergent at apices (Figs A4.32–A4.37). Areolae chambered with rounded external foramina (Figs A4.40, A4.43). Internal covers of the areolae and presence/absence of renilimbia not observed due to deterioration of internal surface covers of valves from type material. Internal areola openings with recessed depressions (Fig. A4.48).



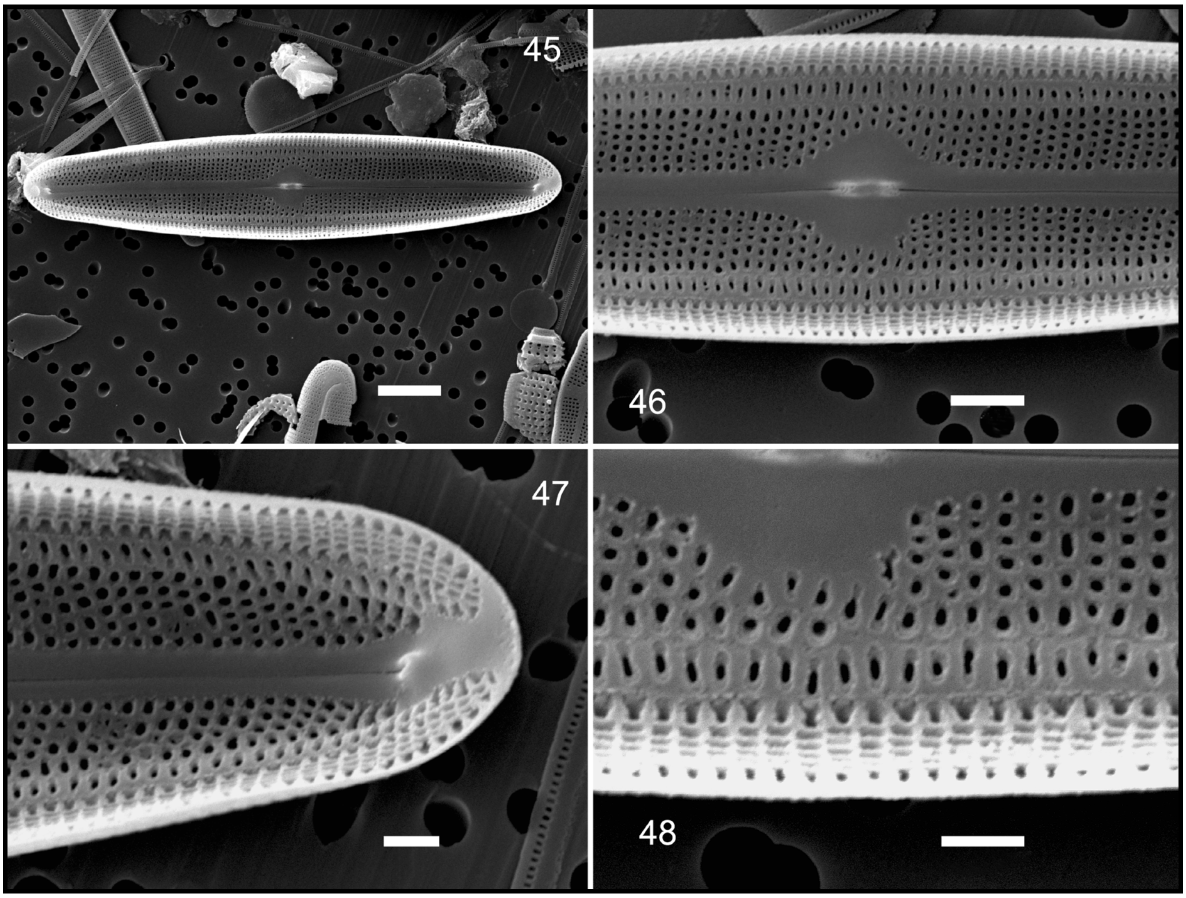
FIGURES A4.32–A4.38 – Specimens of *Neidium aubertii* from the type locality, LM. **Figs A4.32–A4.37.** Valve views. **Fig. A4.38.** Girdle view of frustule. Scale bar = 10 µm.

Neidium aubertii has so far only been found on the islands in the southern Indian Ocean with records from the Prince Edward Islands (Van de Vijver et al. 2008), the Crozet Archipelago (Van de Vijver et al. 2002a), Kerguelen Islands (Le Cohu & Maillard 1986, Van de Vijver et al. 2001) and Heard Island (Van de Vijver et al. 2004). The largest populations (with a relative abundance of 2–5%) were found in the sediment of small acidic lakes with a pH range of 5–6.5 and low specific conductance (<100 µS cm^{-1}).



FIGURES A4.39–A4.44 – *Neidium aubertii*, Heard Island HE-Q252, SEM external views. **Fig. A4.39.** Valve. **Fig. A4.40.** Central area raised above the valve face. Note proximal raphe fissure with an expanded surface depression (arrow). **Fig. A4.41.** Valve mantle with four copulae. Each copula with a row of elongated pores. **Fig. A4.42.** Central area raised above the valve face showing proximal raphe fissure expanded with recessed pore (arrow) at the terminus. **Fig. A4.43.** Broken valve showing the tongue and groove raphe and section of the longitudinal canal. Note external and internal areola openings from the canal. **Fig. A4.44.** Valve apex showing an incompletely formed lacinia and the triangular shape of the terminal area. The longitudinal canal ends at the lacinia. Scale bars = 5 µm (Fig. A4.39); 1 µm (Figs A4.40–A4.44).

The species was also present in seepage areas, wet mosses and wet soils although its abundance in these habitats never exceeded a few valves. *Neidium aubertii* was found in assemblages with high percentages of *Aulacoseira principissa* Van de Vijver, *Chamaepinnularia soehrensis* var. *muscicola* (J.B. Petersen) Lange-Bertalot & Krammer, *Diadesmis ingeae* Van de Vijver, *Psammothidium abundans* (Manguin) Bukhtiyarova & Round, *P. confusum* (Manguin) Van de Vijver, *P. manguinii* (Hustedt) Van de Vijver and *P. stauroneioides* (Manguin) Bukhtiyarova.



FIGURES A4.45–A4.48 – *Neidium aubertii*, Heard Island HE-Q252, SEM internal views. **Fig. A4.45.** Whole valve. **Figs A4.46.** Mid-valve showing the central area and apically raised proximal raphe endings. **Fig. A4.47.** Apex with helictoglossa and ending region of the longitudinal canal. **Fig. A4.48.** Areola opening distinctly recessed. Scale bars = 5 µm (Fig. A4.45); 2 µm (Fig. A4.46); 1 µm (Figs A4.47–A4.48).

Type locality: Sample 179, peat moss, Kerguelen Island. Collected by R. Arétas, 10 March 1950.

Main distinguishing characters: The valves are lanceolate to linear-lanceolate with one distinct longitudinal canal decreasing in size from mid-valve to apex. The raphe is lateral with hooked proximal fissures that are deflected and extend to the edge of the central area.

Remarks: This species is comparable to *N. bisulcatum* (Lagestedt) Cleve but it differs from the latter by linear-lanceolate to lanceolae valves, rostrate to rounded apices, narrowing longitudinal canals towards the apices, enlarged external openings of selected areolae and broader axial areas at apices. *Neidium bisulcatum* has linear to undulating valve margins, with broadly rounded apices and smaller axial areas at apices. *Neidium bergii* (A. Cleve) Krammer has the same lanceolate valve outline with narrowing longitudinal canals, but is distinguished from *N. aubertii* by smaller valves with lower stria and areola densities.

Lectotypification: On 4 February or 2 April 1957, C.W. Reimer (marked in ink on the slide label) circled several specimens of *N. aubertii* on slide AD9086 from peat moss sample 179, Kerguelen Island without formally lectotypifying the species. Here, slide AD9086 from the Muséum National d'Histoire Naturelle, Paris, France is designated as the lectotype for *N. aubertii* Manguin.

Discussion

These three distinct *Neidium* taxa were reported from a wide variety of aquatic and terrestrial microhabitats in sub-Antarctic and Maritime Antarctic regions. Since the start of the taxonomical, floristic and environmental study of Antarctic diatoms in 1996, in total more than 1500 samples were examined from the entire region and during this analysis, only a few *Neidium* populations were found, this suggests that the genus is not only rare in this polar region, but these taxa also represent a well-defined and restricted geographical distribution. In total, seven taxa have been identified from the Antarctic Region (Table A4.1), however, only three taxa are suspected to be present. Although our knowledge of *Neidium* taxa across the Antarctic is rather poor, it is still possible to make some general remarks on morphological similarities between these confirmed and vouchered taxa. The three species presented here are characterized by linear to linear-lanceolate valves with rostrate to capitate apices, a single prominent longitudinal canal along the valve margins and lacinia covering the distal raphe fissures. At present, these three taxa are considered biogeographically unique to the Antarctic Region.

Neidium nyvltii is a benthic alkalophilic species present in the Maritime Antarctic region, while the closest taxa for comparison, such as *N. kozlowii* and its varieties, are also benthic alkalophilic taxa but from northern temperate–Arctic regions (Antoniades et al. 2008). The other benthic acidophilic species, *N. aubertii*, from the sub-Antarctic islands shows some resemblance with the acidophilic *N. bisulcatum* and alkalophilic *N. bergii* from the northern hemisphere commonly occurring in the Arctic (Antoniades et al. 2008). Indeed, there may be some misidentification of specimens attributed to *N. bisulcatum* from the Southern Indian Ocean and Maritime Antarctic regions (Table A4.1) which could possibly be in fact *N. auberti*. As with *Pinnularia* (e.g., *P. quadratarea* var. *antarctica* (H. Peragallo) Frenguelli & Orlando and var. *kerguelensis* (Cleve & Grunow) Cleve from Antarctica only, and *P. quadratarea* (A.W.F. Schmidt) Cleve and many varieties from the Arctic only), there is evidence of similarities in valve forms between the polar northern and southern Hemisphere taxa. This similarity in diatom morphology from the contrasting poles has also been observed in other diatom genera, such as *Luticola* D.G. Mann (Antoniades et al. 2008, Esposito et al. 2008, Van de Vijver & Mataloni 2008), *Pinnularia* Ehrenberg (Antoniades et al. 2008, Zidarova et al. 2012), *Stauroneis* Ehrenberg (Van de Vijver et al. 2005) and *Muelleria* (Frenguelli) Frenguelli (Antoniades et al. 2008, Van de Vijver et al. 2010). It is however recognized that biogeographic distributions are distinct for diatoms at the genus level (Vyverman et al. 2007). They have observed that the geographic isolation accounts for a significant component of diatom distributions. *Neidium aubertii* has only been observed in acidic waters with a pH range of 5–6, conductance <100 µS cm^{-1} whereas *N. nyvltii* is an alkaline species favouring habitats with pH around 8.3 and a preference for moderate to high conductivity (> 450 µS cm^{-1}). *Neidium bergii* and *N. kozlowii* are also known as circum-neutral to alkaline species with the following environmental conditions: pH of 8.0–8.3 (±0.7), specific conductance of 130–326 µS cm^{-1} (±50–707) and dissolved organic carbon of 3–12 mg L^{-1} (±2.3), according to Antoniades et al. (2008) which may suggest sharing the same ecological niche as *N. nyvltii* but in opposite hemispheres.

Neidium antarcticum is most comparable to *N. longiceps*, which is currently reported as cosmopolitan, and to *N. curtihamatum* reported only from Sardinia (Lange-Bertalot et al. 2003). Specimens identified as *N. affine* var. *longiceps* (W. Gregory) Cleve from the Maritime Antarctic are likely to be *N. antarcticum* (Table A4.1), therefore, making it difficult to associate *N. antarcticum* with a comparable Arctic species. It is however worth noting that specimens from an unknown taxon associated with *N. longiceps* have been observed from the Arctic (P.B. Hamilton, pers. obs.). Although the circumpolar terrestrial Arctic region has been more thoroughly studied (dating back to the late 1800's), it is evident that the Arctic *Neidium* flora is much more species rich than its Antarctic counterpart. Similar conclusions can be drawn for the cymbelloid genera. In the Arctic, more than 40 different taxa can be found (Van de Vijver et al. 1999, Antoniades et al. 2008) whereas in the Antarctic, less than 10 taxa are present (Van de Vijver et al. 2002a), mainly confined to the sub-Antarctic region. At present, no cymbelloid taxa are known from the Maritime Antarctic region (Kellogg & Kellogg 2002). In contrast, *Luticola*, *Diadesmis* and *Muelleria* occurring in the Antarctic are more speciose than the Arctic flora (Van de Vijver et al. 2002a, b, 2010, 2011, Van de Vijver & Mataloni 2008, Kopalová et al. 2011). The significance of this needs further investigation, however, these observations, in part support the findings of Vyverman et al. (2007) indicating that the bipolar ecozones are selective in the diversity of taxa within diatom genera.

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APPENDIX 5

Analysis of the type material of *Achnanthidium lanceolatum* Brébisson ex Kützing (Bacillariophyta) with the description of two new *Planothidium* species from the Antarctic Region

Published as: *Van de Vijver B., Wetzel C., Kopalová K., Zidarova R. & Ector L. (2013) Analysis of the type material of* Achnanthidium lanceolatum *Brébisson ex Kützing (Bacillariophyta) with the description of two new* Planothidium *species from the Antarctic Region. Fottea (In press)*

The type material of Achnanthidium lanceolatum *(transferred in 1999 to the genus* Planothidium*) is investigated to reveal the identity of several* Planothidium *populations from the Antarctic Region. The morphology and the ultrastructure was analysed using light and scanning electron microscopy. The results of this analysis revealed the presence of two so far undescribed* Planothidium *species in the investigated Antarctic material. Both species are described as new to science:* P. rostrolanceolatum *Van de Vijver, Kopalová & Zidarova sp. nov. and* P. subantarcticum *Van de Vijver & C.E.Wetzel sp. nov. The new species can be differentiated based on differences in valve outline and the shape and size of the central area.* Planothidium lanceolatum *is formally lectotypified. Notes on the ecology and distribution of the new Antarctic species are added.*

Key words: Achnanthidium lanceolatum*, Antarctic Region, morphology, new species,* Planothidium*, type material*

Introduction

Achnanthidium lanceolatum was originally described in 1846 [and not in 1849: see Lange-Bertalot (1999)] by Kützing based on material that Louis Alphonse de Brébisson sent him from Falaise, a city situated near Caen, Calvados department, Basse-Normandie region, north-western France. The species is often referred to as *A. lanceolatum* Brébisson ex Kützing since Kützing in 1849 added '*De Brébisson in litt.*'. In the original text (Kützing 1846), the species is described as "*A. a latere secundario elliptico-lanceolato; apicibus obtusis, rotundatis. – Long. 1/140''' – Falaise Brébisson!*", an *Achnanthidium* with an elliptic-lanceolate secondary side and broadly rounded apices. Length 16 µm. According to Lange-Bertalot & Krammer (1989), showing four light microscopy pictures of the type material ("*Typenmaterial, Coll. Eulenstein, Species originale 61, Falaise/ Frankreich*"), there is no controversy about the identity of the species due to the presence of the type material. The original Kützing material was conserved in two places: the British Museum in London and the Van Heurck Collection (formerly in Antwerp, Belgium, now at the National Botanic Garden in Meise, Belgium) (Cox 1995). Moss & Carter (1982) showed the first SEM images illustrating two internal valves of the type material, prepared from the material present in the British Museum [Kützing Collection n°1237 (BM18442)]. In the latter paper, a clear distinction was made in the terminology of the characteristic horseshoe in the central area. In the group of species around *P. lanceolatum* (Brébisson ex Kützing) Lange-Bertalot, the horseshoe shaped structure is a simple depression, called a 'sinus' whereas in other taxa [in the group of *P. frequentissimum* (Lange-Bertalot) Lange-Bertalot], a hollow chamber covers the horseshoe shaped structure in the valve interior for which the name 'cavum' was used (Moss & Carter 1982).

Since the original description, almost a hundred infraspecific taxa (subspecies, varieties and formas) have been described to separate *lanceolatum*-populations with differences in valve outline or structure of the horseshoe-shaped spot in the central area (Fourtanier & Kociolek 2011). Unfortunately, a thorough study of the type of *Achnanthidium lanceolatum* was never published. The species was transferred several times to different genera. Grunow placed the species within the genus Achnanthes in 1880 (Cleve & Grunow 1880). When the catch-all genus *Achnanthes* was split in a large number of (usually newly described) genera (Bukhtiyarova & Round 1996, Round & Bukhtiyarova 1996), two new genera were erected almost simultaneously for the species-complexes of *A. lanceolata* and *A. delicatula* (Kützing) Grunow; *Planothidium* Round & Bukhtiyarova and *Achnantheiopsis* Lange-Bertalot (Round & Bukhtiyarova 1996, Lange-Bertalot 1997). Based on the priority rule, the latter can only be considered as a synonym of *Planothidium*. The original transfer of *A. lanceolatum* to *Planothidium* in 1996 by Round & Bukhtiyarova was declared invalid based on the absence of the publication of the basionym, which was rectified by Lange-Bertalot in 1999.

During a survey of the freshwater diatom flora in the Antarctic Region, large *Planothidium* populations from various Antarctic and sub-Antarctic localities were identified as *Achnanthes lanceolata* or *Planothidium lanceolatum.* Kellogg & Kellogg (2002) list more than 50 (sub-)Antarctic references for *Achnanthes lanceolata*. Analysis of some of these records revealed that most of them in fact represent two different taxa (e.g., Le Cohu & Maillard 1983, Van de Vijver et al. 2002) although the valves in Oppenheim (1994) most likely belong to *P. lanceolatum* s.s. These incorrect identifications increased the uncertainty on the biogeography of this taxon, at the moment apparently considered being cosmopolitan. The type material of this species has been investigated by Patrick & Reimer (1966, 10 LM drawings of valves), Moss & Carter (1982, two SEM internal views illustrated), Lange-Bertalot & Krammer (1989, four LM valves) and Krammer & Lange-Bertalot (1991, eight LM valves and one SEM internal view).

The present paper discusses the morphology of the type of *Achnanthidium lanceolatum* using both light (LM) and scanning electron microscopy (SEM) observations. Additionally, several large Antarctic populations are reviewed and two new *Planothidium* taxa, *Planothidium rostrolanceolatum* Van de Vijver, Kopalová & Zidarova sp. nov. and *Planothidium subantarcticum* Van de Vijver & C.E.Wetzel sp. nov. are described based on LM and SEM observations.

Material and Methods

A duplicate made by Eulenstein (Cox 1995) of the original raw material of *Achnanthidium lanceolatum* was found in the Eulenstein Collection deposited in the Van Heurck Collection, housed at the National Botanic Garden (Meise) of Belgium. From this material, i.e. Eul. Diat. spec. typ. 61 in Cent. I, Eulenstein made a large number of slides that have been sent all over the world. Three slides are present in the Van Heurck collection. One of these slides (acc. n° IV-2-C6) has been investigated using LM. A subsample from the original raw material deposited in the Van Heurck Collection in Meise was prepared for SEM analysis.

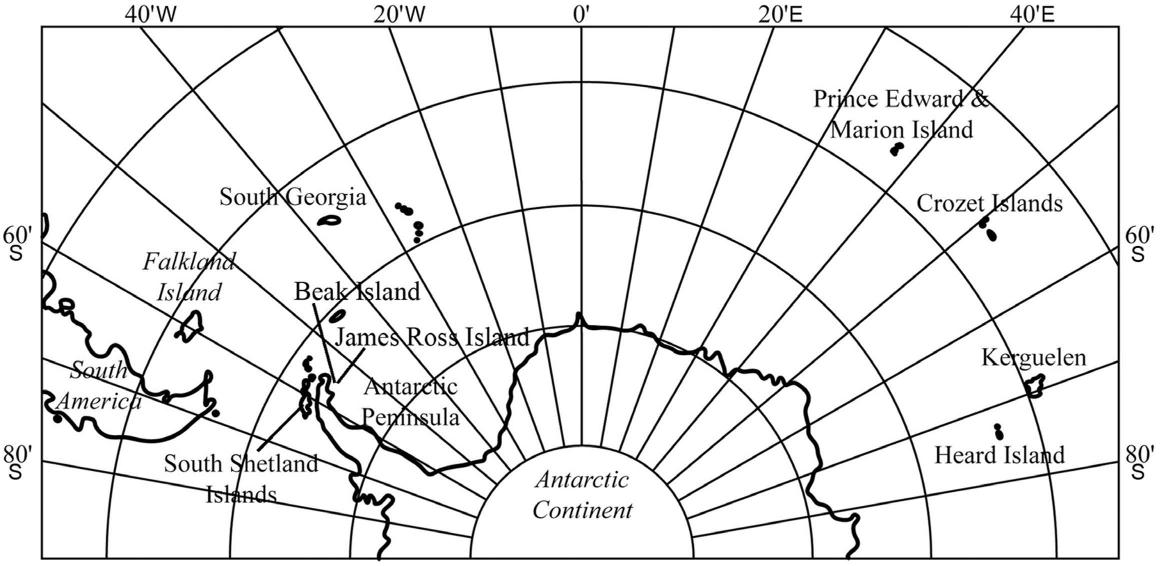


FIGURE A5.1 – The Antarctic region with the location of the sampled islands and archipelagos.

The past 15 years, aquatic, moss and soil samples were collected during several field campaigns on islands in the southern Indian and southern Atlantic Ocean [Livingston Island (South Shetland Islands), James Ross Island, Prince Edward Islands, Iles Crozet, Iles Kerguelen and Heard Island] (Fig. A5.1).

Diatom samples for LM observation were prepared following the method described in Van der Werff (1955). In total 26 samples were examined (Table A5.1). Subsamples of the original material were oxidized using 37% H_2O_2 and heating to 80°C for approximately 1h. The reaction was further completed by the addition of $KMnO_4$. Following digestion and centrifugation (three times 10 minutes at 3700x g), the material free of organic matter was diluted with distilled water for sample mounting to avoid excessive concentrations of diatom valves and frustules on the slides.

A subsample from the organic-free material was mounted in Naphrax$^{®}$ for diatom community studies. The slides were analyzed using an Olympus BX51 microscope, equipped with Differential Interference Contrast (Nomarski), and the Colorview I Soft Imaging System.

TABLE A5.1 – List of samples used in this study

Sample ID	Geographic locality	Source
C-BA27	Crozet	Van de Vijver et al. (2002)
C-BA56	Crozet	Van de Vijver et al. (2002)
C-BM173	Crozet	Van de Vijver et al. (2002)
C-BM213	Crozet	Van de Vijver et al. (2002)
C-BM230	Crozet	Van de Vijver et al. (2002)
C-BM271	Crozet	Van de Vijver et al. (2002)
C-BM274	Crozet	Van de Vijver et al. (2002)
He-D16	Heard Island	Van de Vijver et al. (2004)
He-D27	Heard Island	Van de Vijver et al. (2004)
He-D53	Heard Island	Van de Vijver et al. (2004)
K-NK782	Kerguelen	unpublished data
K-N4.2	Kerguelen	Gremmen et al. (2007)
K-N22	Kerguelen	Gremmen et al. (2007)
PEI-D055	Prince Edward Islands	Van de Vijver et al. (2008)
PEI-D061	Prince Edward Islands	Van de Vijver et al. (2008)
PEI-D305	Prince Edward Islands	Van de Vijver et al. (2008)
PEI-D364	Prince Edward Islands	Van de Vijver et al. (2008)
PEI-G03-164b	Prince Edward Islands	Van de Vijver et al. (2008)
PEI-G03-196	Prince Edward Islands	Van de Vijver et al. (2008)
SG-W381	South Georgia	Van de Vijver & Beyens (1996)
SG-W387	South Georgia	Van de Vijver & Beyens (1996)
SG-W393	South Georgia	Van de Vijver & Beyens (1996)
LIV-BY028	Livingston Island	Kopalová & Van de Vijver (2013)
LIV-BY037	Livingston Island	Kopalová & Van de Vijver (2013)
LIV-BY065	Livingston Island	Kopalová & Van de Vijver (2013)
JRI2008-D11	James Ross Island	unpublished data

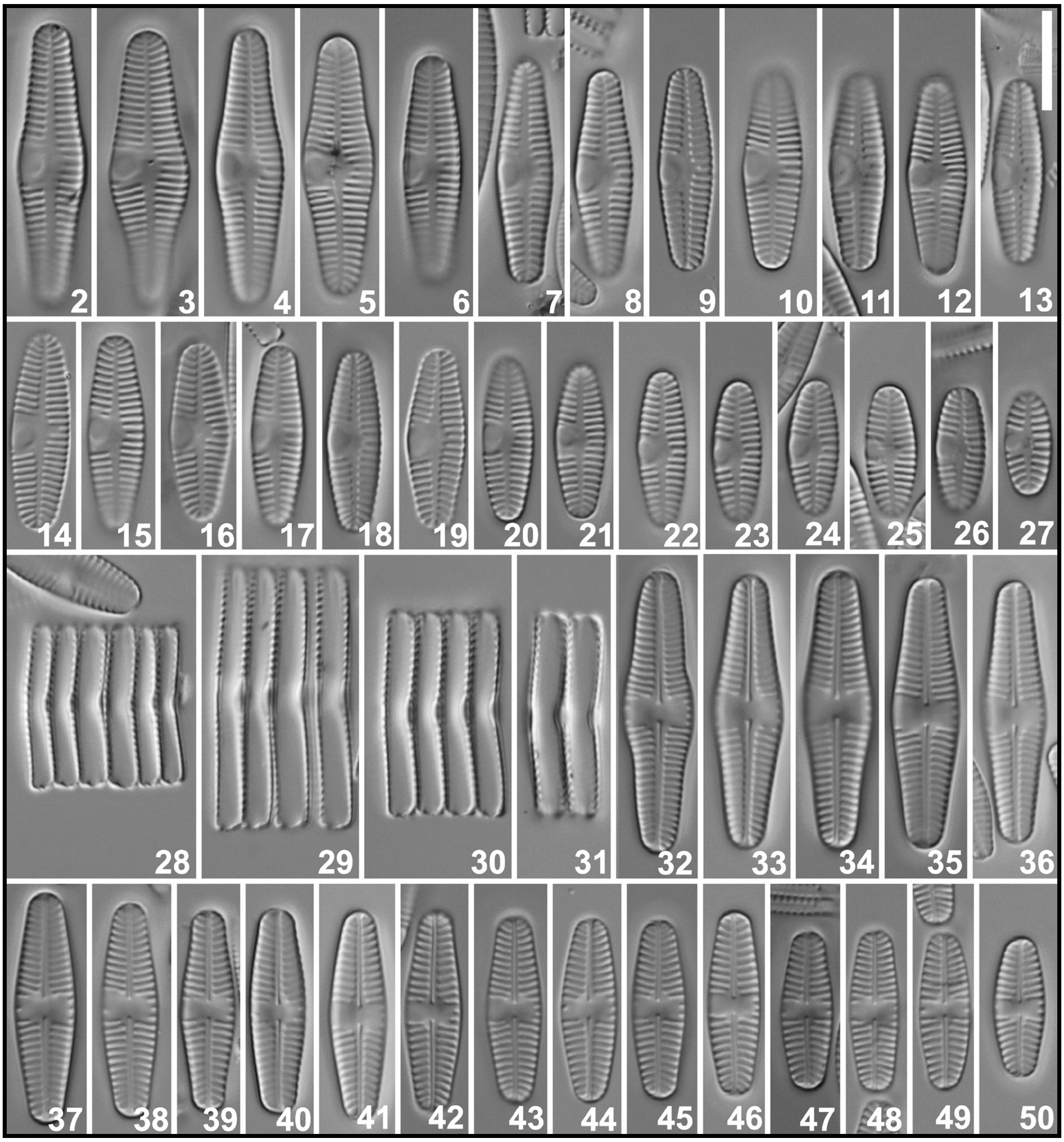
For scanning electron microscopy (SEM), parts of the oxidized suspensions were filtered and rinsed with additional deionized water through a 3-µm Isopore™ polycarbonate membrane filter (Merck Millipore). Filters were mounted on aluminum stubs and coated with platinum using a BAL–TEC MED 020 Modular High Vacuum Coating System for 30 s at 100 mA. An ultra-high-resolution analytical field emission (FE) scanning electron microscope Hitachi SU–70 (Hitachi High-Technologies, Europe, GmbH) operated at 5 kV and 10 mm distance was used for the analysis. SEM images were taken using both upper (SE-U) lower (SE-L) detector signal. Micrographs were digitally manipulated and plates containing light and scanning electron microscopy images were created using CorelDraw X5®. Diatom terminology follows Ross et al. (1979) and Round et al. (1990). Comparison of the new species was made based on Lange-Bertalot & Krammer (1989), Krammer & Lange-Bertalot (1991) and Rumrich et al. (2000).

New taxon descriptions

Planothidium lanceolatum **(Brébisson ex Kützing) Lange-Bertalot 1999** (Figs A5.2–A5.60)

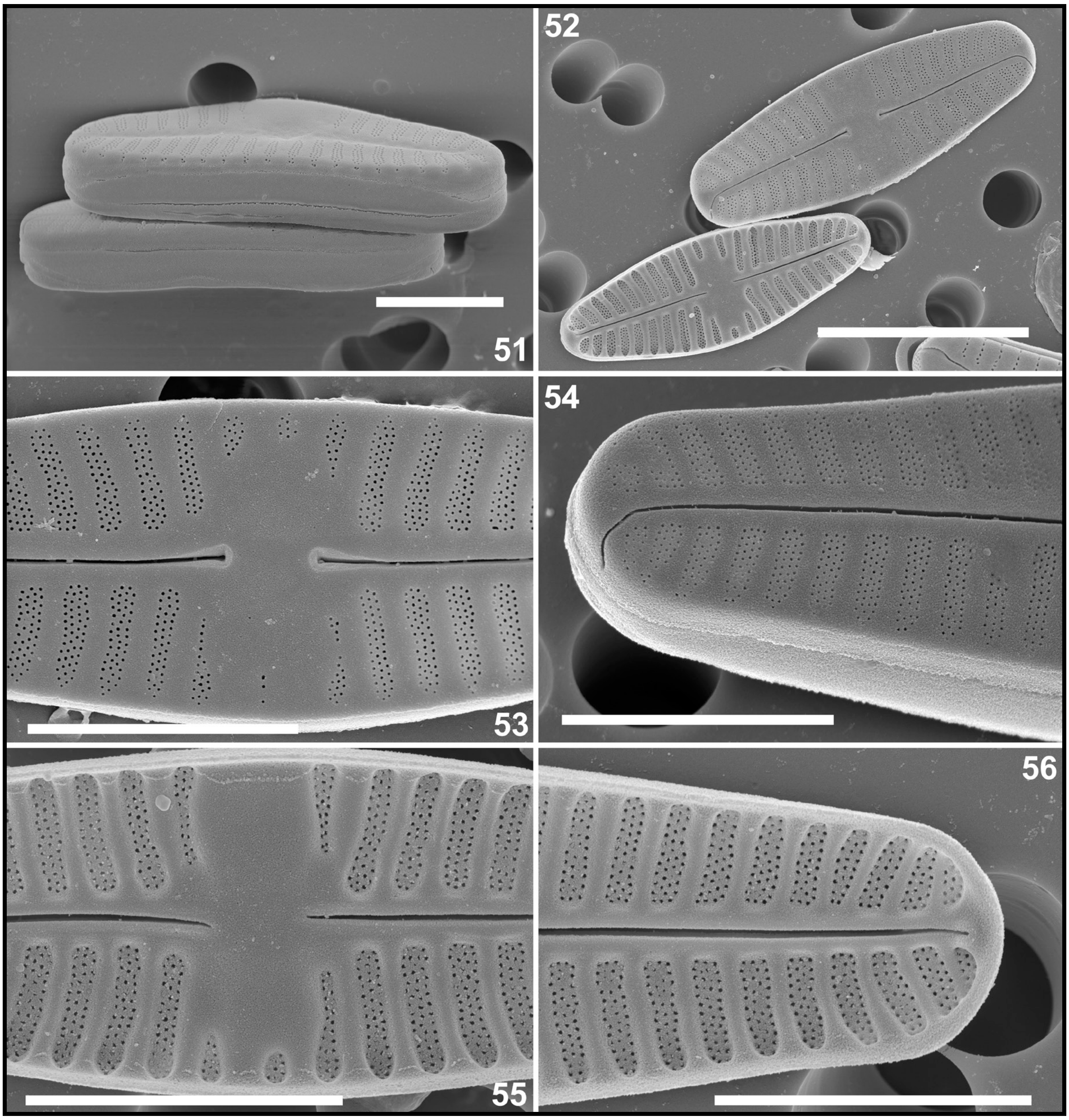
LM (Figs A5.2– A5.50): Frustules in girdle view rectangular forming short chains of up to 6 cells, clearly bent in the middle making the view somewhat V-shaped (Figs A5.28–A5.31). Valves narrowly rhombic-lanceolate to lanceolate in larger valves to broadly lanceolate and even elliptical in smaller valves. Valve margins clearly convex, in larger valves even gibbous in the center. Apices obtusely rounded, rarely protracted although in some valves weakly rostrate. Valve dimensions (n=45): length 10–30 µm, width 4.5–8.5 µm. Rapheless valve (Figs A5.2–A5.27): Axial area narrow, 1/10 of valve width, lanceolate, gradually widening from the apices towards the central area. Central area with a large horseshoe-shaped hyaline area on one side and 1-3 slightly shortened striae forming a small circular area on the other side. Striae almost parallel to weakly radiate in the centre, becoming distinctly radiate towards the apices, 12–14 in 10 µm. Raphe valve (Figs A5.32–A5.50): Axial area very narrow, less than 1/10 of valve width, linear to slightly lanceolate, widening near the central area. Central area forming a rectangular to bow-tie shaped fascia, on one side bordered by 1-3 clearly shortened striae. Raphe branches straight with expanded, drop-like proximal raphe endings. Distal raphe fissures unilaterally deflected. Striae radiate becoming distinctly radiate towards the apices, 12–15 in 10 µm. Areolae never discernible in LM.

SEM (Figs A5.51–A5.60): Proximal raphe endings straight to very weakly deflected, expanded (Figs A5.52, A5.53). Distal raphe fissures clearly bent, continuing shortly onto the valve mantle (Fig. A5.54). Striae sunken between raised virgae (Figs A5.55–A5.56, A5.59–A5.60), composed of 3–4 rows of small, rounded poroids (Figs A5.53, A5.58). Striae continuing on the valve mantle by one or two irregularly organised areolae (Figs A5.51, A5.57). Internally, areolae probably covered by individual hymenes but due to erosion hymenes removed in all observed valves (Figs A5.55–A5.56, A5.59–A5.60). Proximal raphe endings not coaxial, short and very weakly deflected (Fig. A5.55). Distal raphe endings terminating in very faint helictoglossae (Fig. A5.56).



FIGURES A5.2–A5.50 – *Planothidium lanceolatum*. LM. Valve views. Lectotype slide IV-2-C6: Falaise, Caen, Calvados department, Basse-Normandie region, France, Eulenstein Diat. Spec. typ. N° 61 (coll. n° IV-2-C6) in the National Botanic Garden of Belgium (Belgium). **Figs A5.2–A5.27.** Rapheless valves. **Figs A5.28–A5.31.** Girdle views. **Figs A5.32–A5.50.** Raphe valves. Scale bar represents 10 µm.

Formal lectotypification: Despite numerous records of *Planothidium lanceolatum* in the literature, a formal lectotype was never designated for this taxon. Therefore, the slide with accession number IV-2-C6 in the Van Heurck Collection, made from the Eulenstein Diat. Spec. typ. N° 61, was chosen to be the lectotype for this species.

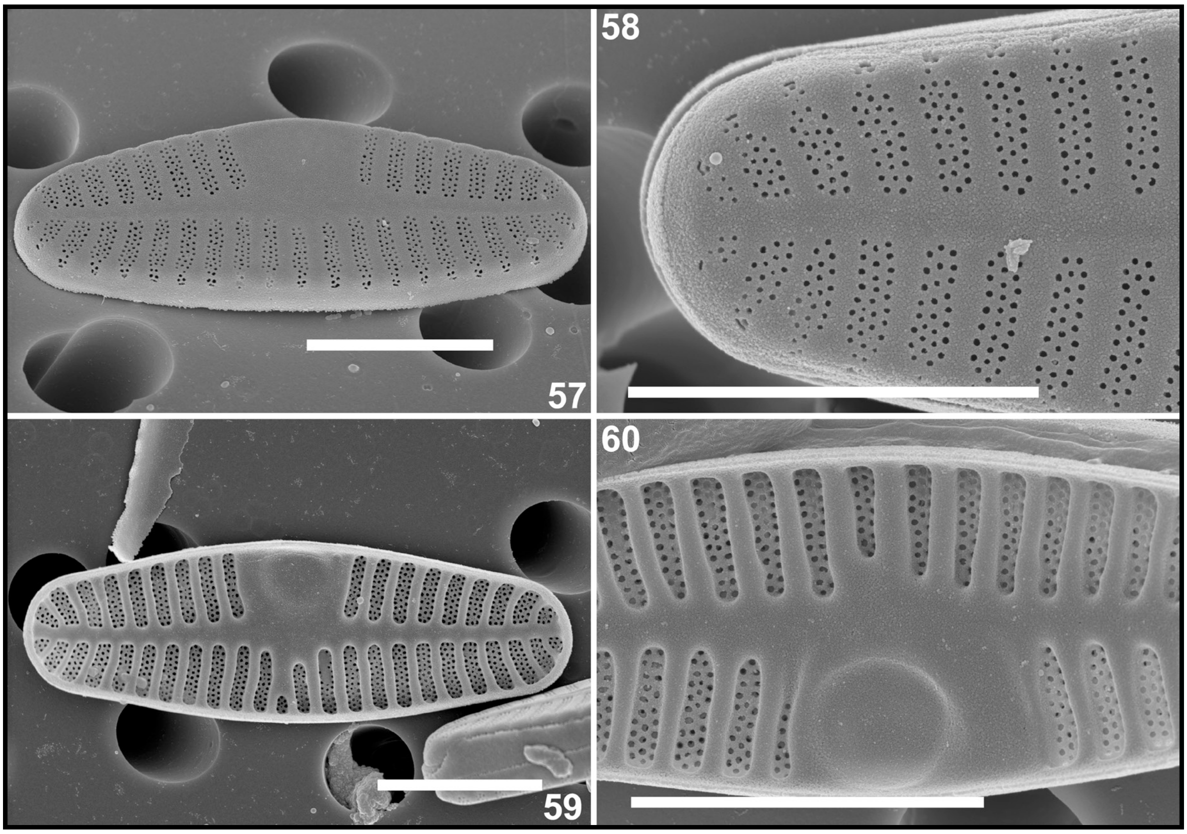


FIGURES A5.51–A5.56 – *Planothidium lanceolatum*. SEM views. Falaise, Caen, Calvados department, Basse-Normandie region, France, Eulenstein Diat. Spec. typ. N° 61 (coll. n° IV-2-C6) in the National Botanic Garden of Belgium (Belgium). **Fig. A5.51.** Girdle view of two frustules, the upper valve is a rapheless valve. **Fig. A5.52.** Valve views of two raphe valves, one view (a) represents an outside view, the other (b) is an inside view. **Fig. A5.53.** External view of a raphe valve, detail of the central area. **Fig. A5.54.** External view of a raphe valve, detail of the valve apex. **Fig. A5.55.** Internal view of a raphe valve, detail of the central area. **Fig. A5.56.** Internal view of a raphe valve, detail of the valve apex. Scale bar represents 10 µm except for Figs A5.53–A5.56 where scale bar = 5 µm.

Lectotype (designated here): Slide IV-2-C6, Eulenstein Diat. Spec. typ. N° 61, Van Heurck Collection, National Botanic Garden of Belgium, Meise, Belgium.

Lectotype locality: Falaise, Caen, Calvados department, Basse-Normandie region, France.

Basionym: *Achnanthidium lanceolatum* Brébisson ex Kützing 1846, Botanische Zeitung 4, p. 27



FIGURES A5.57–A5.60 – *Planothidium lanceolatum*. SEM views. Falaise, Caen, Calvados department, Basse-Normandie region, France, Eulenstein Diat. Spec. typ. N° 61 (coll. n° IV-2-C6) in the National Botanic Garden of Belgium (Belgium). **Fig. A5.57.** External view of an entire valve. **Fig. A5.58.** External view, detail of the valve apex. **Fig. A5.59.** Internal view of an entire valve. **Fig. A5.60.** Internal view, detail of the central area. Scale bar represents 10 µm except for Figs A5.58 & A5.60 where scale bar = 5 µm.

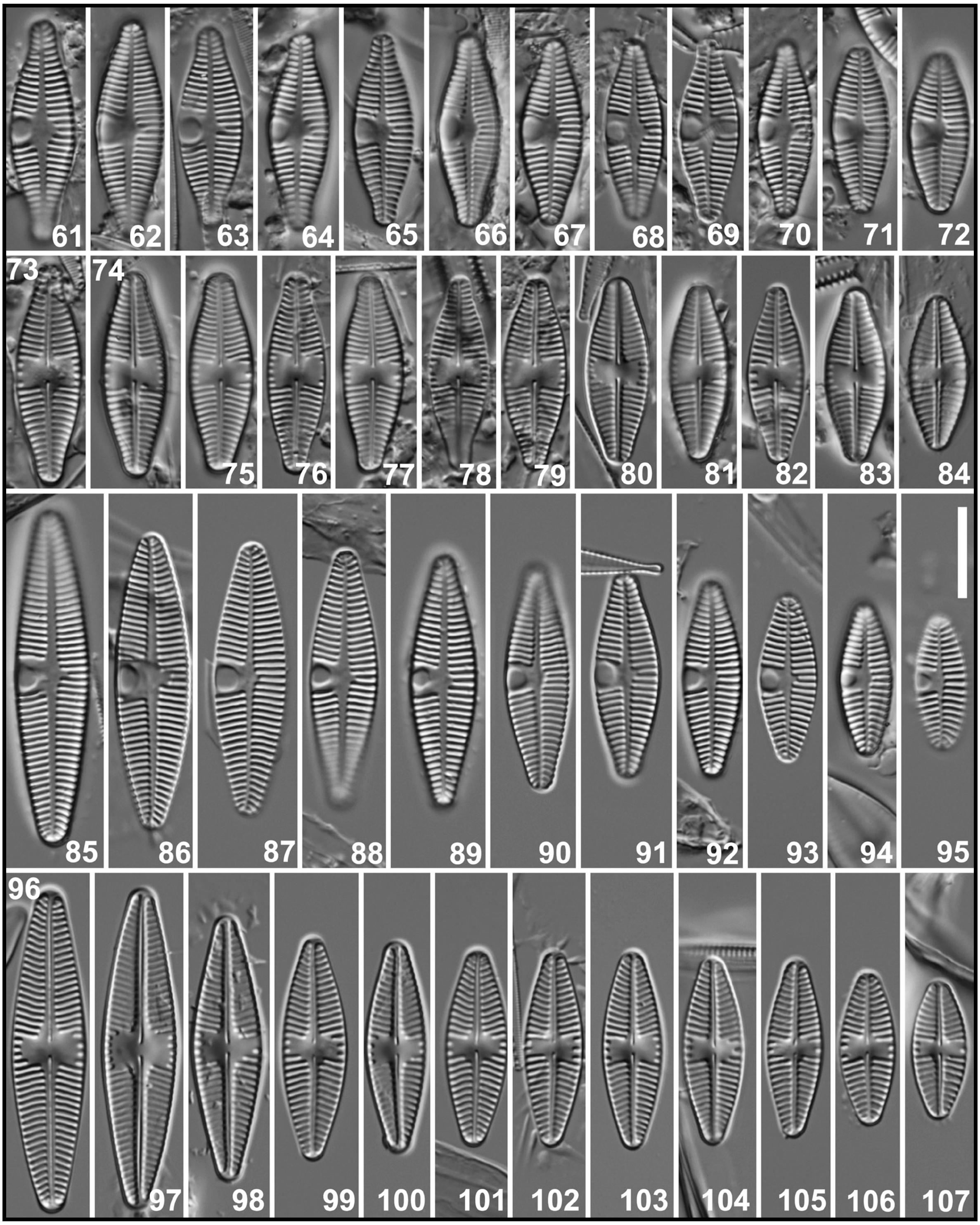
Synonyms: *Achnanthes lanceolata* (Brébisson ex Kützing) Grunow in Cleve & Grunow 1880, *Microneis lanceolata* (Brébisson in Kützing) Frenguelli 1923, *Achnantheiopsis lanceolata* (Brébisson ex Kützing) Lange-Bertalot 1997

Antarctic Distribution: The species was identified with certainty in all samples from Heard Island (Van de Vijver et al. 2004) and in several samples from Iles Kerguelen (Gremmen et al. 2007, Van de Vijver et al. 2001). On Iles Crozet and the Prince Edward Islands, the species was reported as being present (Van de Vijver et al. 2002, 2008) but careful analysis revealed that all populations have to be identified as *P. subantarcticum* Van de Vijver & C.E.Wetzel sp. nov. (see below). On Livingston Island, the species was identified by Oppenheim (1994) although in later studies (Kopalová & Van de Vijver 2013), the reported populations are described below as *P. rostrolanceolatum* Van de Vijver, Kopalová & Zidarova sp. nov.

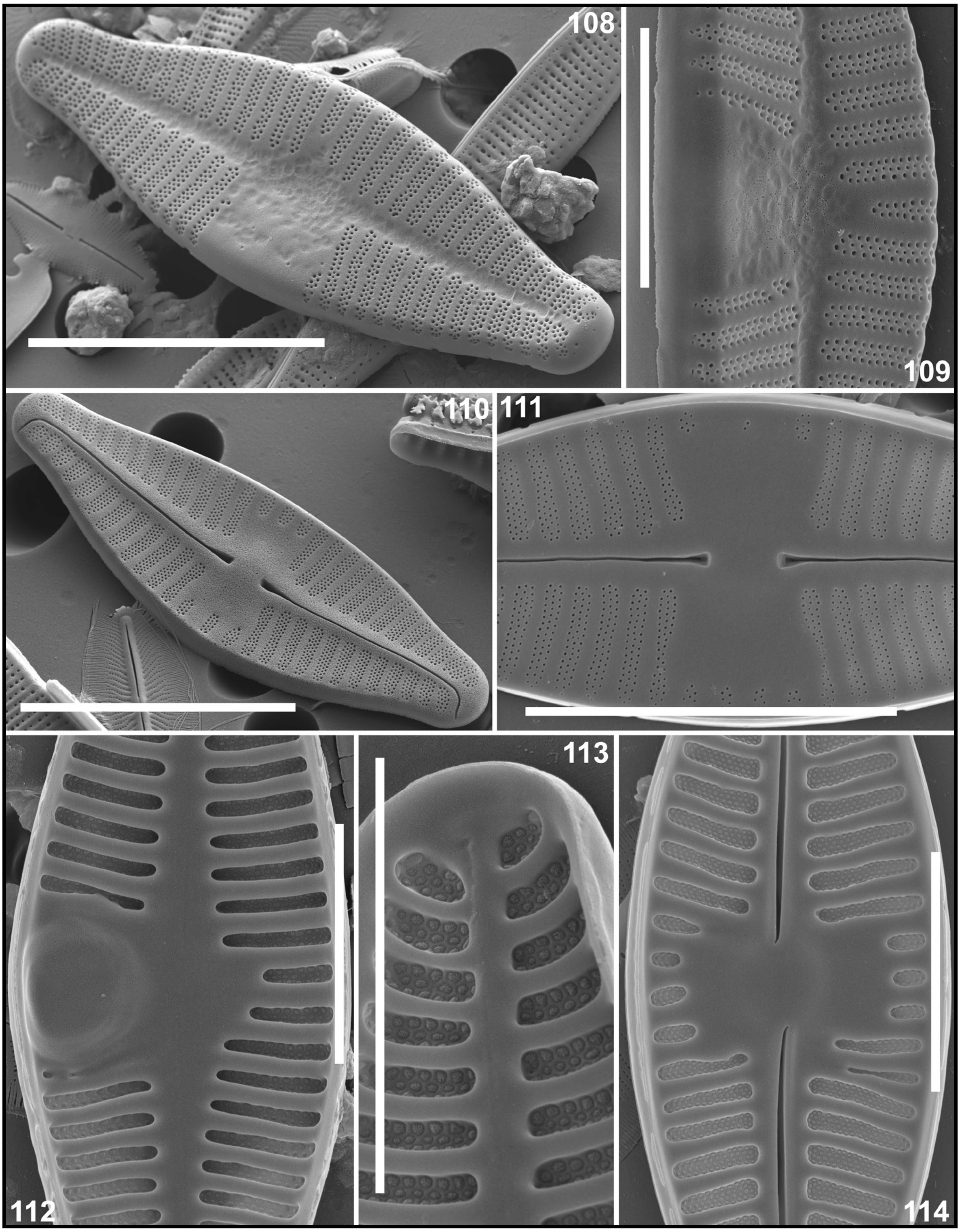
Planothidium rostrolanceolatum **Van de Vijver, Kopalová & Zidarova sp. nov.** (Figs A5.61–A5.84, A5.108–A5.114)

LM (Figs A5.61–A5.84): Valves lanceolate to elliptic-lanceolate with clearly convex margins and rostrate, protracted apices, in smaller valves sometimes with subrostrate apices. Valve dimensions (n=45): length 15–28 µm, width 5.6–7.8 µm. Rapheless valve (Figs A5.61–A5.72): Axial area narrow, 1/10 of total valve width, linear, very slightly widening towards the central area. Central area with a large horseshoe-shaped hyaline area on one side. On the other side, striae either not shortened or 1–2 slightly shortened striae forming hence a small circular area. Striae weakly radiate almost throughout the entire valve, becoming distinctly radiate near the apices, 14–16 in 10 µm. Raphe valve (Figs A5.73–A5.84): Axial area narrow, less than 1/10 of total valve width, linear, widening near the central area. Central area rectangular to bow-tie shaped bordered on each side by 2–5 clearly shortened striae. Real fascia never present. Raphe branches straight with expanded, drop-like proximal raphe endings. Distal raphe fissures unilaterally deflected, hard to observe in LM. Striae radiate throughout the entire valve, becoming more distinctly radiate near the apices, 13–15 in 10 µm. Areolae not discernible in LM.

SEM (Figs A5.108–A5.114): Striae of the rapheless valve composed of three rows of small rounded poroids, the inner row being much smaller than the two outer rows (Figs A5.108–A5.109). Near the central area, striae often with only two rows or three rows, the middle one being reduced to a few areolae (Fig. A5.109). Striae continuing shortly on the valve mantle (Fig. A5.109). Striae of the raphe valve broader than the virgae, composed of four rows of rounded areolae (Figs A5.110–A5.111), near the central area of only three rows of areolae (Fig. A5.111). Striae clearly sunken between raised virgae (Figs A5.112–A5.114). Areolae covered by individual perforated hymenes (Fig. A5.113). Proximal raphe endings straight terminating in expanded pores (Figs A5.110–A5.111).



FIGURES A5.61–A5.107 – New *Planothidium* species from the Antarctic Region. **Figs A5.61–A5.72.** *Planothidium rostrolanceolatum*, rapheless valves. **Figs A5.73–A5.84.** *Planothidium rostrolanceolatum*, raphe valves. **Figs A5.85–A5.95.** *Planothidium subantarcticum*, rapheless valves. **Figs A5.96–A5.107.** *Planothidium subantarcticum*, raphe valves. Scale bar represents 10 µm.



FIGURES A5.108–A5.114 – *Planothidium rostrolanceolatum*. SEM views. **Fig. A5.108.** External view of an entire rapheless valve. **Fig. A5.109.** External view of the central area of a rapheless valve. Note the shallow markings in the central area. **Fig. A5.110.** External view of an entire raphe valve. **Fig. A5.111.** External view of the central area of a raphe valve. **Fig. A5.112.** Internal view of the central area of a rapheless valve. **Fig. A5.113.** Internal view of the apex of a rapheless valve. **Fig. A5.114.** Internal view of the central area of a raphe valve. Scale bar represents 10 µm except for Figs A5.109, A5.111–A5.114 where scale bar = 5 µm.

Distal raphe fissures clearly bent, continuing shortly onto the valve mantle (Fig. A5.110). Internally, central nodule raised (Fig. A5.114). Proximal raphe endings deflected to opposite sides, terminating inconspicuously (Fig. A5.114). Distal raphe endings terminating on faint helictoglossae, shortly continuing on the valve mantle. Irregular shallow depressions present in the central and axial area (Figs A5.108–A5.109). Horseshoe-shaped sinus clearly present on the rapheless valve, forming a shallow circular depression on one side of the central area (Fig. A5.112).

Holotype (designated here): BR-4307 (National Botanic Garden, Meise, Belgium).

Isotypes (designated here): PLP-222 (University of Antwerp, Belgium), BRM-ZU8/99 (Hustedt Collection, Bremerhaven, Germany).

Type locality: Byers Peninsula, Livingston Island, South Shetland Islands, sample BY028 (Leg. B. Van de Vijver; coll. date 11/01/2009).

Etymology: The specific epithet refers to the rostrate valve ends in combination with the close relationship with *P. lanceolatum*.

Ecology and distribution: So far, the species seems to be restricted to the South Shetland Islands. Large populations were found on Livingston Island, Deception Island and King George Island, usually reported under the name of *P. lanceolatum*. The largest populations on Byers Peninsula (Livingston Island) were found living epilithically in several smaller rivers and brooks with an almost circumneutral to slightly alkaline pH (7.5) and low specific conductance levels (75-100 µS/cm). Smaller populations (< 5% of total diatom count) were present in lakes. Dominant taxa in the samples include *Nitzschia perminuta* s.l. (Grunow) Peragallo, *Psammothidium papilio* (D.E.Kellogg, Stuiver, T.B.Kellogg & Denton) Van de Vijver & Kopalová, *Fistulifera pelliculosa* (Brébisson) Lange-Bertalot and *N. gracilis* Hantzsch. The species seems to be absent from the sub-Antarctic Region and the Antarctic Continent.

Planothidium subantarcticum Van de Vijver & C.E.Wetzel sp. nov. (Figs A5.85–A5.107, A5.115–A5.121)

LM (Figs A5.85–A5.107): Valves strictly lanceolate with convex margins, gradually tapering towards the only weakly protracted apices, acutely rounded apices. Some specimens within the population sometimes with subrostrate apices. Valve dimensions (n=30): length 11–43 µm, width 5.8–10.8 µm. Rapheless valve (Figs A5.85–A5.95): Axial area narrow, ca. 1/8 of total valve width, linear, very slightly widening towards the central area. Central area with a large horseshoe-shaped hyaline area on one side. On the other side, striae usually not shortened, in some specimens 1–2 slightly shortened striae forming hence a very small circular area. Striae weakly radiate almost throughout the entire valve, becoming more radiate near the apices, 13–14 in 10 µm. Raphe valve (Figs A5.96–A5.107): Axial area narrow, less than 1/7 of total valve width, clearly linear, gradually widening towards the central area. Central area rectangular to bow-tie shaped bordered on, each side by 2–6 clearly shortened striae. Real fascia never present. Raphe branches straight with straight to weakly deflected expanded proximal endings. Distal raphe fissures unilaterally deflected, hard to observe in LM. Striae distinctly radiate throughout the entire valve, 13–14 in 10 µm. Areolae not discernible in LM.

SEM (Figs A5.115–A5.121): Proximal raphe endings undulating, weakly deflected terminating in expanded pores (Figs A5.117–A5.118). Distal raphe fissures clearly bent, continuing shortly onto the valve mantle (Fig. A5.117). Striae of the rapheless valve always composed of three rows of small rounded areolae (Fig. A5.116), occasionally fourth row of small areolae near the valve margin inserted in each stria (Fig. A5.115). Areolae of equal size. Striae continuing shortly on the valve mantle (Fig. A5.115). Striae of the raphe valve broader than the virgae (Fig. A5.117), composed of four rows of rounded areolae, near the central area only three rows of areolae per stria present (Fig. A5.118). Striae broader towards the apices. Internally, central nodule raised (Fig. A5.121). Proximal raphe endings deflected to opposite sides, terminating inconspicuously (Fig. A5.121). Striae clearly sunken between raised virgae. Areolae covered by individual perforated hymenes (Fig. A5.119). Irregular shallow depressions present in the central and axial area (Fig. A5.115). Horseshoe-shaped sinus clearly present, forming a shallow circular depression on one side of the central area (Fig. A5.119). Girdle composed of several open copulae (Fig. A5.120).

Holotype (designated here): BR-4308 (National Botanic Garden, Meise, Belgium).

Isotypes (designated here): PLP-223 (University of Antwerp, Belgium), BRM-ZU8/100 (Hustedt Collection, Bremerhaven, Germany).

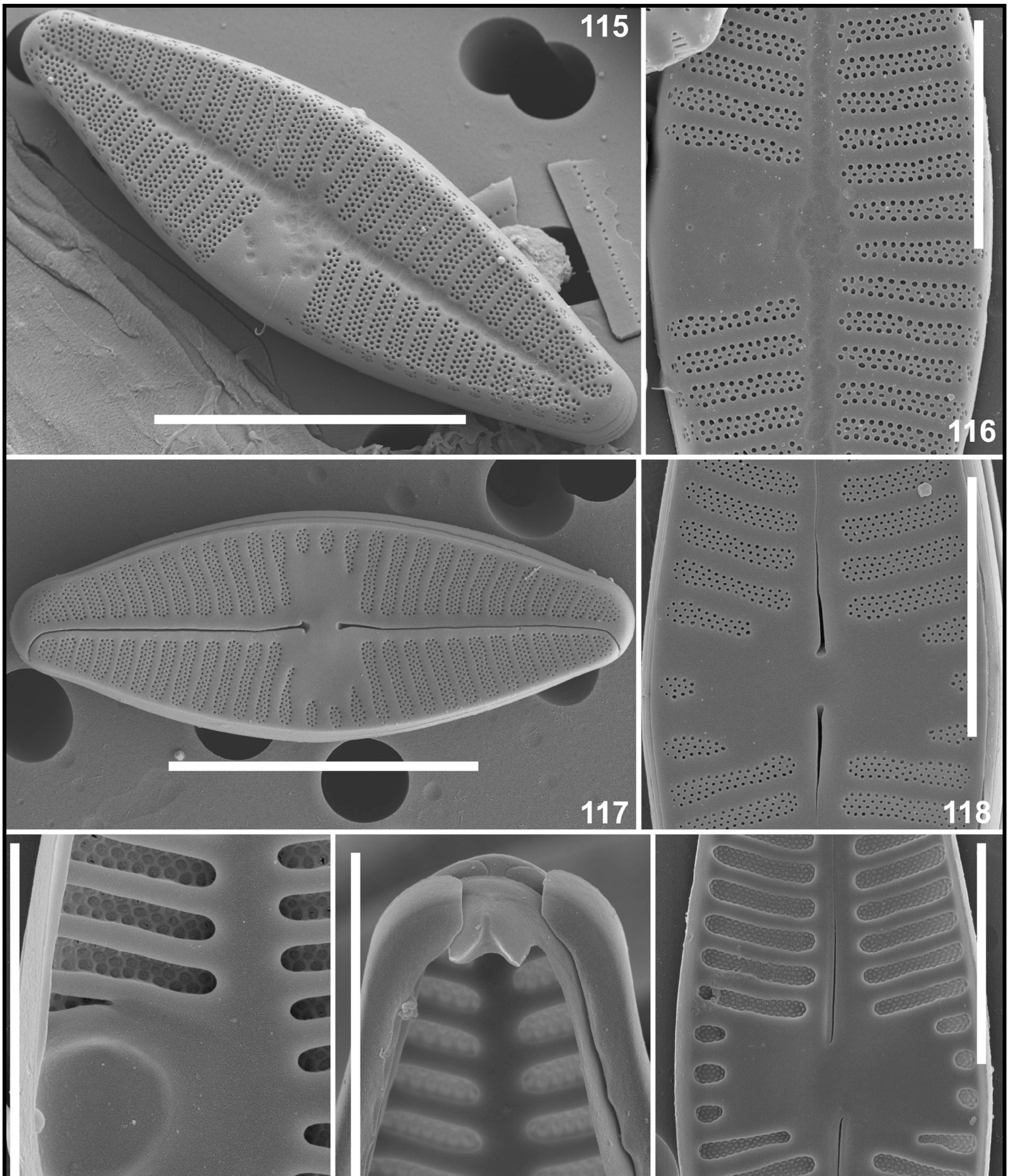
Type locality: Pointe de Bougainville, Ile de la Possession, Crozet Archipelago, sample BM173 (Leg. B. Van de Vijver; coll. date 24/12/1997).

Etymology: The specific epithet refers to the sub-Antarctic region where the species is abundantly present on all investigated localities.

Ecology and distribution: The new species is present on three islands in the southern Indian Ocean (Prince Edward Islands, Iles Crozet and Iles Kerguelen) and was reported under the name *Achnanthes lanceolata* var. *lanceolata* (Van de Vijver et al. 2001) or *P. lanceolatum* (Van de Vijver et al. 2002, 2008). It was abundantly found living epiphytically on wet to semi-wet mosses sampled in a wide variety of alkaline habitats ranging from small pools to lakes and rivers and in wet soils with a mean pH of 7.7 and a specific conductance range from 60-2000 µS/cm. Accompanying (sub-)dominant taxa include *P. cyclophorum* (Heiden) Van de Vijver, *Navicula gregaria* Donkin and *Fragilaria capucina* s.l. Desmazières.

Discussion

And although the correct identity of *Planothidium lanceolatum* has already been known for a long time, the species was rarely identified correctly in the Antarctic Region. Almost all records of *P. lanceolatum* in the Antarctic Region should be considered as a clear example of force-fitting these populations into European or North-American names (Tyler 1996). Only in Oppenheim (1994, 40-45,75-78) some valves were shown, recorded on Signy Island (South Orkney Islands), that without doubt belong to *P. lanceolatum* with lanceolate valves and clearly broadly rounded apices. Similar valves have never been observed in the investigated material from South Georgia, Livingston Island or James Ross Island. A careful comparison of the morphological features of the type of *Achnanthidium lanceolatum* and the Antarctic populations reveal sufficient differences to exclude conspecificity. *Planothidium rostrolanceolatum* was identified by Ko-Bayashi (1965) as *Achnanthes lanceolata* var. *lanceolata* f. *dubia* (Grunow) Ts.Kobay. Analysis of illustrations of the lectotype of the latter taxon in Krammer & Lange-Bertalot (1991, Plate 42, Figs 7-8) confirms that this identification cannot be accepted since the latter has a clearly elliptical valve outline with very short, acutely rounded, protracted apices, contrary to *P. rostrolanceolatum* that has gradually tapering apices. However, conspecificity between *P. rostrolanceolatum* and the Antarctic populations reported by Ko-Bayashi (1965) from South Georgia is highly likely based on a similar valve outline, valve dimensions and diminution series. Several populations from South Georgia (formerly identified as *A. lanceolatum*, Van de Vijver & Beyens 1996), have been investigated and could all be identified as *P. rostrolanceolatum*. Another species that showed some similarities is *P. cyclophorum*, usually reported under the name of *P. lanceolatoides* (Sovereign) Lange-Bertalot.



FIGURES A5.115–A5.121 – *Planothidium subantarcticum*. SEM views. **Fig. A5.115.** External view of an entire rapheless valve. **Fig. A5.116.** External view of the central area of a rapheless valve. Note the shallow markings in the central area. **Fig. A5.117.** External view of an entire raphe valve. **Fig. A5.118.** External view of the central area of a raphe valve. **Fig. A5.119.** Internal view of the central area of a rapheless valve. **Fig. A5.120.**

Internal view of the apex of a rapheless valve. Part of the (open) valvocopula is covering the valve. **Fig. A5.121.** Internal view of the central area

However, the larger valve width and the clearly elliptical valve outline of the latter clearly separate both taxa. *Planothidium rhombicuneatum* Lange-Bertalot & Rumrich, described in Rumrich et al. (2000) from the Chilean Altiplano, has clearly convex margins from the valve center up to the apices lacking the typical shoulders as is the case in *P. rostrolanceolatum*.

of a raphe valve. Scale bar represents 10 µm except for Figs A5.116, A5.118– A5.121 where scale bar = 5 µm.

Planothidium subantarcticum and *P. rostrolanceolatum* can be separated based on several morphological features, although they have a similar valve width. Both taxa differ in valve outline with *P. rostrolanceolatum* showing more elongated, protracted apices where in *P. subantarcticum*, the apices are less differentiated from the rest of the valve. The central area in *P. rostrolanceolatum* is generally more developed than in *P. subantarcticum* due to the shortening of several central striae whereas in P*. subantarcticum*, the central area is much less developed and in some specimens even absent. Due to its longer valves, *P. subantarcticum* always shows a more slender outlook whereas *P. rostrolanceolatum* is sturdier due to the presence of the more pronounced shoulders. The raphe valve in *P. subantarcticum* has a slightly smaller central area whereas in *P. rostrolanceolatum*, more central striae are shortened enlarging the central area. The ultrastructure of the proximal raphe endings also presents some differences with a more undulating course in *P. subantarcticum* whereas in *P. rostrolanceolatum*, these proximal endings are straight. The striae in *P. rostrolanceolatum* are generally less radiate than in *P. subantarcticum*, although no difference in stria density or structure can be observed. The latter is not surprising since a lot of *Planothidium* taxa show a similar stria structure with only 3-4 rows of small areolae, the inner ones, usually smaller than the outer rows (Lange-Bertalot & Krammer 1989).

The question is however whether these two taxa really represent independent species or whether they represent a rather broad phenotypic plasticity of only one species. Nevertheless, the past few years, it became more and more clear that diatom present a high degree of cryptic and semi-cryptic diversity. Recently, Souffreau et al. (2013) revealed the presence of seven different lineages within *Pinnularia borealis* Ehrenberg whereas based on classical morphological research, it was impossible to separate these seven morphotypes from each other. Similar studies were published by Beszteri et al. (2005) on *Cyclotella meneghiniana* Kützing, Poulíčková & Mann (2006) on *Navicula cryptocephala* Kützing, Evans et al. (2008) on *Sellaphora pupula* (Kützing) Mereschkowsky and Vanelslander et al. (2009) on *Navicula phyllepta* Kützing. In all cases, cryptic diversity was confirmed in these widespread taxa. It is therefore highly likely that the differences found between the Antarctic populations reflect a separation of these populations into two different species *P. rostrolanceolatum* and *P. subantarcticum*. But as long as molecular studies are lacking, all answers to this question will remain speculative.

Acknowledgements

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APPENDIX 6

CURRICULUM VITAE

Kopalová Kateřina

CURRICULUM VITAE

Name:	**KOPALOVÁ Kateřina**
Date and place of birth:	3th of July 1984; Duchcov (Czech Republic)
Nationality:	Czech
Private address:	Libušina 153 252 28 Černošice Czech Republic (Europe)
Current affiliation:	Charles University in Prague Department of Ecology Viničná 7 128 44Prague 2 Czech Republic (Europe)
	Academy of Sciences of the Czech Republic Institute of Botany, Section of Plant Ecology Dukelská 135 379 82 Třeboň Czech Republic (Europe)
	e-mail:k.kopalova@hotmail.com Phone: +420 605 537 378

Diplomas:

Ph.D. since 2009	*Ecology*, Faculty of Science, Charles University in Prague, Czech Republic & Universiteit Antwerpen, Belgium. Thesis: *'Taxonomy, ecology and biogeography of aquatic and limno-terrestrial diatoms in the Maritime Antartic Region'*
Mgr. 2007–2009	*Ecology,* Faculty of Science, Charles University in Prague, Czech Republic Thesis: *'Diversity, ecology and biogeography of diatoms (Bacillariophyta) from James Ross Island (Antarctica) and Gough Island (southern Atlantic Ocean)'*
Bc. 2004–2007	*Biology*, Faculty of Science, Charles University in Prague, Czech Republic Thesis: *'Adaptation of cyanobacteria and algae to extreme conditions of the polar regions'*

Study abroad:

Since 2007	Regular stays at the National Botanic Garden of Belgium (Algology lab, Prof. Dr. Bart Van de Vijver) in frame work of Bachelor, Master and Doctoral study
2011–2013	Two times half year stays at the University of Antwerp (Algology lab, Prof. Dr. Bart Van de Vijver at National Botanic Garden of Belgium) in the frame work of PhD (Erasmus grant)

Scientific career:

Since 2012	Scientific researcher & Assistant lecturer at the Centre for Polar Ecology, Faculty of Science, University of South Bohemia, České Budějovice (10%)
Since 2012	Phd Fellow at the Institute of Botany, Academy of Sciences of the Czech Republic, Třeboň (20%)

Awards:

First prize for the best poster presentation at the 40th Meeting of the Dutch-Flemish Society of Diatomists and 3rd Central European, Utrecht, Netherlands, 3/2009: Kopalová K., Nedbalová L. & Van de Vijver B.: The diatom flora of lakes on James Ross Island (Antarctica).

First prize for the best poster presentation at the 6th Central European Diatom Meeting, Innsbruck, Germany, 3/2012: Kopalová K., Zidarova R., Lowe R. & Van de Vijver B.: The genus *Diadesmis* in the Antarctic Region.

First prize for the best poster presentation at the 22nd International Diatom Symposium, Gent, Belgium, 8/2012: Kopalová K., Zidarova R., Cox E. J. & Van de Vijver B.: Four new small-celled naviculoid taxa from the Maritime Antarctic Region.

Second prize for the best student poster presentation at the 31ième ADLaF Meeting, Le Mans, France, 9/2012: Kopalová K., Nedbalová L., Zidarova R. & Van de Vijver B.: Diversité et biogéographie des diatomées limno-terrestres sur les îles James Ross et Livingston (Antarctique).

Second prize for the best student poster presentation at the Polar Ecology Conference, České Budějovice, Czech Republic, 10/2012: Kopalová K., Zidarova R, Cox E. J. & Van de Vijver B. (2012) Four new small-celled naviculoid taxa from the Maritime Antarctic Region.

Grant project:

2011–2013	Principal investigator: Benthic autotrophic assemblages in lakes on James Ross Island (Antarctica): characterization and key factors influencing their structure. GA UK 394211

Main research interests:

Ecology, taxonomy, diversity and biogeography of limno-terrestrial and aquatic diatoms (Bacillariophyceae) in polar and sub-polar regions

Ecology and paleoecology of protist communities in Arctic and sub-Antarctic ecosystems

Water quality monitoring based on diatoms and phytoplankton analysis

Main scientific results:

Description of several new species of non-marine diatoms

Complex evaluation of non-marine diatom flora from James Ross Island and Livingston Island, Antarctica

Educational skills:

Co-responsible for several theoretical and practical courses at the Charles University in Prague (Field course in ecology, Microscopical technics, Course in winter ecology, Algological course)

Assistant lecturer of the Polar Ecology field course (Svalbard) (summer 2011–2013)

Assistant lecturer IPGL (International Postgraduate UNESCO Training Course on Limnology)

Biology on Jaroslav Seifert‘s High school, Prague, (November–December 2007)

Field work in the last 3 years:

Hydrobiological survey of polar lakes:

2011–2013 Polar ecology field course, Petunia Bukta, Svalbard (Hydrology-limnology group)

2012 Field work in Maritime Antarctic Region (Marambio, James Ross Island)

Memberships of scientific associations:

Nederlands-Vlaamse Kring der Diatomisten (NVKD)
International Society for Diatom Research (ISDR)
Czech Society for Ecology
Czech Limnological Society

International collaboration:

Dr. Ralitsa Zidarova (University of Sofia, Bulgaria)
Laboratory of Protistology & Aquatic Ecology (Univeristy of Gent, Belgium)
Juan M. Lirio (Instituto Antartico Argentino–Dirección Nacional del Antárctico)
Luc Ector and Carlos Wetzel, Department of Environment and Agro-biotechnologies (EVA), Public Research Centre - Gabriel Lippmann Belvaux, Grand-Duchy of Luxembourg

Scientific skills:

Very good knowledge of different microscopical techniques: light microscopy (bright-field, phase-contrast, differential-interference-contrast) and scanning electron microscopy
Good experience with sediment coring techniques
Good experience with abiotic parameter analysis

Languages:

Czech: mother language
English: very good knowledge reading, good knowledge speaking and writing
French: basic knowledge reading and speaking
Dutch: basic knowledge reading and speaking

Organisatory skills:

Member of the organizing committee of the International Diatom Symposium, 26–31 August 2012, Ghent, Belgium. Number of participants: 230

Computer & technical skills:

Very good knowledge of computer packages PC Microsoft OFFICE (Word, Excel, Access, Powerpoint, Outlook)

Multivariate and statistical packages (CANOCO, MVSP, ESTIMATES)

Picture and image processing packages (Adobe Photoshop, Adobe Acrobat)

PUBLICATIONS IN PEER-REVIEWED JOURNALS

WOS: **Sum of the Times Cited**: 47 **h-index**: 4

2008:

Van de Vijver B. & **Kopalová K**. (2008) *Orthoseira gremmenii* sp. nov., a new aerophilic diatom from Gough Island (Southern Atlantic Ocean). Cryptogamie Algologie 29(2): 105–118.

Esposito R.M.M., Spaulding S.A., McKnight D.M., Van de Vijver B., **Kopalová K.**, Lubinski D., Hall B. &Whittaker T. (2008) Inland diatoms from the McMurdo Dry Valleys and James Ross Island, Antarctica. Botany 86(12): 1378–1392.

2009:

Kopalová K., Elster J., Nedbalová L. & Van de Vijver B. (2009) Three new terrestrial diatom species from seepage areas on James Ross Island (Maritime Antarctic Region). Diatom Research 24(1): 113–122.

Zidarova R., Van de Vijver B., Mataloni G., **Kopalová K**. & Nedbalová L. (2009) Four new freshwater diatom species (Bacillariophyceae) from Antarctica. Cryptogamie Algologie 30(4): 295–310.

2010:

Van de Vijver B., Sterken M.,Vyverman W., Mataloni G., Nedbalova L., **Kopalová K**., Elster J., Verleyen E. & Sabbe K. (2010) Four new non-marine diatom taxa from the Subantarctic and Antarctic Regions. Diatom Research 25(2): 431–443.

2011:

Kopalová K., Nedbalová L.,de Haan M. & Van de Vijver B. (2011) Description of five new species of the diatom genus *Luticola* (Bacillariophyta, Diadesmidaceae) found in lakes of James Ross Island (Maritime Antarctic Region). Phytotaxa 27: 44–60.

2012:

Kopalová K., Elster J., Komárek J., Veselá J., Nedbalová L. & Van de Vijver B. (2012) Benthic diatoms (Bacillariophyta) from seepages and streams on James Ross Island (NW Weddell Sea, Antarctica). PlantEcology and Evolution 145(2): 190–208.

Zidarova R., **Kopalová K**. & Van de Vijver B. (2012) The genus *Pinnularia* (Bacillariophyta) excluding the sectio Distantes on Livingston Island (South Shetland Islands) with the description of the new taxa. Phytotaxa 44: 11–37.

2013:

Kopalová K., & Van de Vijver B. (2013) Structure and ecology of freshwater benthic diatom communities from Byers Peninsula (Livingston Island, South Shetland Island). Antarctic Science 25(2): 239–253.

Kopalová K., Nedbalová L., Nývlt D., Elster J. & Van de Vijver B. (2013) Freshwater diatom communities from Ulu Peninsula (James Ross Island, NW Weddell Sea) with the construction of a diatom based conductivity transfer function. Polar Biology 36(7): 933–948.

Van de Vijver B., Cocquyt C., De Haan M., **Kopalová K**. & Zidarova R.(2013) The genus *Surirella* (Bacillariophyta) in the sub antarctic and Maritime antarctic region. Diatom Research 28(1): 92-108.

Van de Vijver B.,**Kopalová K**., Zidarova R. & Cox E. J. (2013) New and interesting small-celled naviculoid taxa from the Maritime Antarctic Region. Nova Hedwigia (published online DOI: 10.1127/0029-5035/2013/0101)

In press:

Hamilton P., De Haan M., **Kopalová K**., Zidarova R. & Van de Vijver B. (2013) An evaluation of selected *Neidium* species from the Antarctic Region. Diatom Research (In press)

Van de Vijver B., Wetzel C., **Kopalová K**., Zidarova R. & Ector L. (2013) Analysis of the type materialof *Achnanthidium lanceolatum* (Bacillariophyta) with the description of two new *Planothidium* species from the Antarctic Region. Fottea (In press)

Submitted:

Kopalová K., Ochyra R., Nedbalová L. & Van de Vijver B. (2013) Moss-inhabiting diatoms from two islands in the Maritime Antarctic Region. PlantEcology and Evolution (Submitted)

CONFERENCE CONTRIBUTIONS

Oral presentations:

Nedbalová L., Komárek J., **Kopalová K**. & Elster J. (2011) Benthic mats in lakes onJames Ross Island (Antarctica): characterization and key factors influencing their structure. Oral presentation on Symposium for European Freshwater Sciences, Girona, Spain 6-7/2011.

Elster J., Nedbalová L., Komárek J., Medová H., Vrba J., **Kopalová K.**, Van de Vijver B. (2011) Freshwater lakes of Ulu Peninsula (James Ross Island, NE Antarctic Peninsula): II. Planktic and benthic assemblages. Oral presentationat at the 4th International Conference on Polar and Alpine Microbiology, Ljubljana, Slovenia, 9/2011.

Van de Vijver B., **Kopalová K**., De Haan M. & Zidarova R. (2011) Les diatomées de la Région maritime antarctique. Oral presentation at 30ième ADLaF, Boulogne-sur-Mer, France, 9/2011.

Kopalová K., Veselá J., Elster J., Nedbalová L., de Haan M., Komárek J. & Van de Vijver B. (2011) Non-marine diatoms (Bacillariophyta) from Ulu Peninsula (James Ross Island, NW Weddell Sea, Antarctica). Oral presentation at the 21st NADS, Polson, Montana, USA, 9/2011.

Kopalová K., Veselá J., Elster J., Nedbalová L., de Haan M., Komárek J. & Van de Vijver B. (2012) The freshwater diatom flora from Ulu Peninsula (James Ross Island, NW Weddell Sea, Antarctica). Oral presentation at the NVKD meeting, Groningen, Netherlands, 5/2012.

Van de Vijver B., **Kopalová K.**& Zidarova R. (2013) Freshwater diatoms from the Maritime Antarctic Region: biodiversity hotspot or taxonomical artefact. Oral presentation at 22st NADS, Bar Harbor, Maine, USA, 8/2011.

Kopalová K. Nedbalová L. & Van de Vijver B. (2013) James Ross Island: diatom gate to two biogeographical zones. Oral presentation at 22st NADS, Bar Harbor, Maine, USA, 8/2013.

Kopalová K. (2013) James Ross Island: diatom gate to two biogeographical zones. Oral presentation at 7th CED Meeting, Thonon-les-Bains, France, 9/2013.

Posters:

Kopalová K., Elster J. & Nedbalová L. (2007) Diversity and ecology of diatoms in seepages of the James Ross Island (Antarctica). Poster presented at 1st CED Meeting, Berlin, Germany. 3/2007.

Kopalová K., Nedbalová L. & Van de Vijver B. (2008) New and interesting non-marine diatom species from James Ross Island (Antarctic Region). Poster presented at the 2nd CED Meeting, Trento, Italy, 6/08.

Kopalová K., Nedbalová L., Gremmen N.J.M. & Van de Vijver B. (2008) The diatom species described by John R. Carter (1962) from Tristan da Cunha and Gough Island. Poster presented at the 2nd CED Meeting, Trento, Italy, 6/08.

Kopalová K., Nedbalová L. & Van de Vijver B. (2008) La flore diatomique non-marine de l'Ile James Ross (Antarctique). Poster presented at the 27th ADLaF, Dijon, France, 9/08.

Kopalová K., Nedbalová L., Gremmen N.J.M & Van de Vijver B. (2008) Les diatomées décrites par John Carter (1962) de Tristan da Cunha et Gough. Poster presented at the 27th ADLaF, Dijon, France, 9/08.

Kopalová K., Nedbalová L. & Van de Vijver B. (2008) The non-marine diatom flora from James Ross Island (Antarctic Region). Poster presented at the 20th IDS, Dubrovnik, Croatia, 9/08.

Van de Vijver B., **Kopalová K**. & Mataloni G. (2008) Biogeography of the genus *Luticola* in the Antarctic Region. Poster presented at the 20th IDS, Dubrovnik, Croatia, 9/08.

Kopalová K., Nedbalová L. & Van de Vijver B. (2009) The diatom flora of lakes on James Ross Island (Antarctica). Poster presented at the 3th CED Meeting, Utrecht, Nederland, 3/2009.

Kopalová K., Veselá J., Elster J., Nedbalová L., Komárek J. & Van de Vijver B. (2011) Diatom communities in seepages and streams on James Ross Island (NW Weddell Sea, Antarctica). Poster presented at the 5th CED Meeting, Szczecin, Poland, 3/2011 and at the Antarctic biodiversity: status and trends., Liege, France, 5/2011.

Kopalová K., Zidarova R., Lowe R., de Haan M. & Van de Vijver B. (2011) Diversity of the genus *Diadesmis* in theAntarcticRegion. Poster presented at the 21st NADS, Polson, Montana, USA, 9/2011.

Kopalová K., Nedbalová L., de Haan M. & Van de Vijver B. (2011) Five new *Luticola* species from Ulu Peninsula (James Ross Island, NW Weddell Sea, Antarctica). Poster presented at the 21st NADS, Polson, Montana,USA, 9/2011.

Kopalová K., Zidarova R., Lowe R. & Van de Vijver B. (2012) The genus *Diadesmis* in the Antarctic Region. Poster presented at the 6th CED Meeting, Innsbruck, Austria, 3/2012.

Kopalová K., Zidarova R., Cox E. J. & Van de Vijver B. (2012) Four new small-celled naviculoid taxa from the Maritime Antarctic Region. Poster presented at the 22nd IDS, Gent, Belgium, 8/2012 and at Polar Ecology Conference, České Budějovice, Czech Republic, 10/2012.

Kopalová K., Elster J., Nedbalová L., Zidarova R. & Van de Vijver B. (2012) The freshwater diatom flora from two contrasting Antarctic localities Poster presented at the 22nd IDS, Gent, Belgium, 8/2012.

Zidarova R., **Kopalová K**., Levkov Z. & Van de Vijver B. (2012) Two unknown *Luticola* taxa from the Maritime Antarctic region. Poster presented at the 22nd IDS, Gent, Belgium, 8/2012

Zidarova R., **Kopalová K**. & Van de Vijver B. (2012) The genus *Stauroneis* on the Antarctic Livingston and James Ross Island. Poster presented at the 22nd IDS, Gent, Belgium, 8/2012.

Kopalová K., Nedbalová L., Zidarova R. & Van de Vijver B. (2012) Diversité et biogéographie des diatomées limno-terrestres sur les îles James Ross et Livingston (Antarctique). Poster presented at the 31ième ADLaF, Le Mans, France, 9/2012.

Kopalová K., Nedbalová L. & Van de Vijver B. (2013) James Ross Island: diatom gate to two biogeographical zones. Poster presented at 11th SCAR Biology Symposium, Spain, 7/2013.

Van de Vijver B., **Kopalová K**. & Zidarova R. (2013) Freshwater diatoms from the Maritime Antarctic Region: biodiversity hotspot or taxonomical artefact. Poster presented at 11th SCAR Biology Symposium, Spain 7/2013.

Van de Vijver B.,**Kopalová K.,** Zidarova R. & Levkov Z. (2013) The genus *Halamphora* in the Antarctic Region. Poster presented at 22st NADS, Bar Harbor, Maine, USA, 8/2013.

Van de Vijver B., Wetzel C., **Kopalová K**., Zidarova R. & Ector L. (2013) The *Planothidium lanceolatum* complex in the Antarctic Region. Poster presented at 22st NADS, Bar Harbor, Maine, USA, 8/2013.

Kopalová K., Nedbalová L., Ochyra R. & Van de Vijver B. (2013) Moss-inhabiting diatom communities from two islands in the Maritime Antarctic Region. Poster presented at 22st NADS, Bar Harbor, Maine, USA, 8/2011.

Kopalová K. (2013) Les diatomées bryophitiques de la Région antarctique maritime. Poster presented at 32ième ADLaF, Thonon-les-Bains, France 9/2013.

LIST OF PARTICIPATIONS ON INTERNATIONAL CONFERENCES

International Diatom Symposium (IDS)

22st IDS (August 2012, Gent, Belgium)

Colloque de l'Association des Diatomistes de Langue Française (ADLaF)

31ième ADLaF (September 2012, Le Mans, France)

32 ième ADLaF (September 2013,Thonon-les-Bains, France)

Meetings of the Nederlands-VlaamseKring der Diatomisten (NVKD)

NVKD workshop + meeting (May 2011, Lelystad, Netherlands)

NVKD workshop + meeting (May 2012, Groningen, Netherlands)

NVKD workshop + meeting (May 2013, Nijmegen, Netherlands)

Central European Diatmist Meeting (CED)

1st CED Meeting (March 2007, Berlin, Germany)

2nd CED Meeting (June 2008, Trento, Italy)

3rd CED Meeting (March 2009, Utrecht, Netherlands)

5th CED Meeting (March 2011, Szczecin, Poland)

6th CED Meeting (March 2012, Innsbruck, Austria)

7th CED Meeting (September 2013, Thonon-les-Bains, France)

North American Diatom Society (NADS)

21st NADS Symposium (September 2011, Polson, Montana, USA)

22nd NADS Symposium (August 2013, Bar Harbor, Maine, USA)

SCAR Antarctic Biology Symposium

11th SCAR Biology Symposium (July 2013, Barcelona, Spain)

Polar Ecology Conference (PEC)

1st Polar Ecology Conference (October 2012, České Budějovice, Czech Republic)