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REGULAR PAPER

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

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Background and aim – 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.
Methods – 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.
Key results – 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* (D.E.Kellogg, Stuiver, T.B.Kellogg & Denton) Kopalová & Van de Vijver comb. nov., is corrected.
Conclusions – 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

Limnoterrestrial 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 1999, 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 1999, 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 limnoterrestrial 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 limnoterrestrial 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 2,450 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 km²), 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 a permanent 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. 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 four streams) and seepage areas (nineteen samples from six 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. 1 (Czech Geological Survey 2009) with a detailed overview of the collected samples given in table 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 1 h. Oxidation of organic material was completed by addition of $KMnO_4$. Following digestion and oxidation, samples were rinsed three 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).

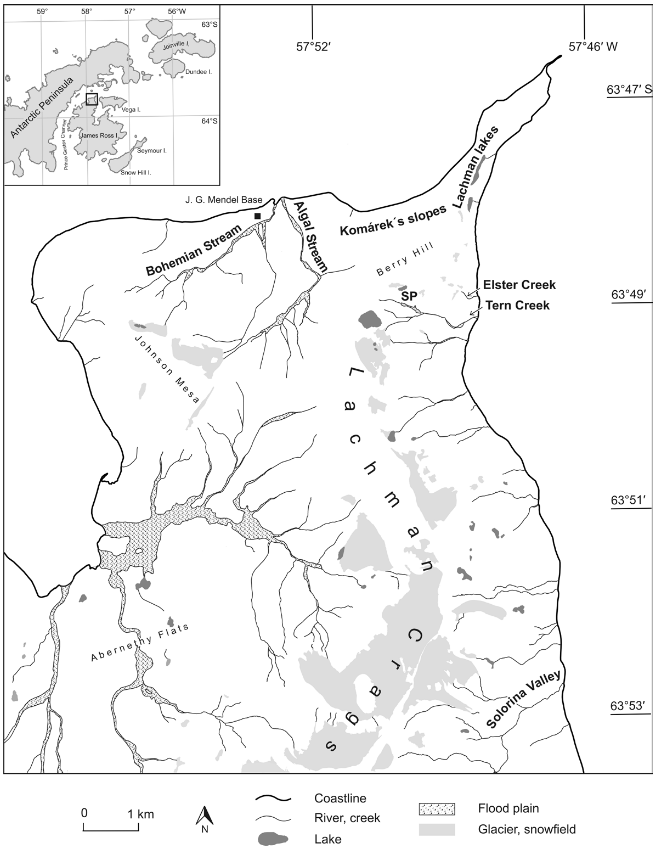

Figure 1 – Detailed map of Ulu Peninsula in the north of James Ross Island with the main sampled areas indicated. More than one sample was taken at a particular locality. The inset map shows the Antarctic Peninsula with the position of James Ross Island and Ulu Peninsula.

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 density (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, 2012). 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).

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 2 provides a full list of all taxa together with their biogeographic distribution.

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* (thirteen taxa), followed by *Pinnularia* (seven taxa), *Nitzschia* (six taxa) and *Diadesmis* (five 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 ten most important taxa accounted for almost 85% of all counted

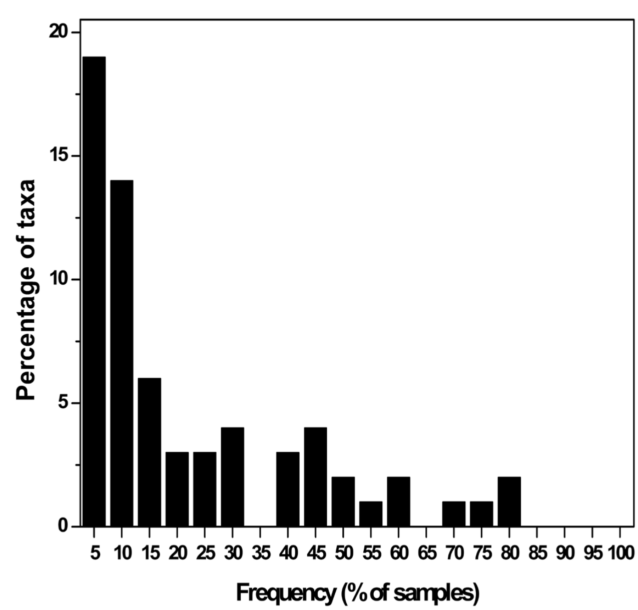

Figure 2 – Frequency classes of taxa occurrences in the samples analysed (e.g. 5 indicates 1–5% of all samples).

Table 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 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 2 (continued) – 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
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

valves (table 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* Desm. (12.4%) and *Fistulifera saprophila* (Lange-Bert. & Bonik) Lange-Bert. (11.6%). As seen in fig. 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 from 7 to 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. lat. Desm. are more frequent in stream samples.

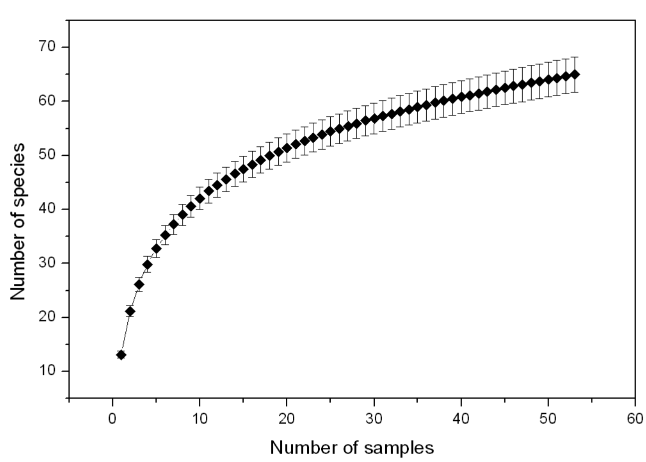

Figure 3 – Expected species accumulation curve for the total sample set.

The flattening (towards the end) of the species accumulation curve (fig. 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.

Twenty-eight taxa showed a cosmopolitan distribution (fig. 4A–AP), thirty were restricted to the Antarctic Region (fig. 5A–AY) and for eleven others, it was impossible to establish their correct taxonomical identity (fig. 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, Kopalová, S.A.Spaulding & Esposito (Esposito et al. 2008, Kopalová et al. 2009) and one species, *Luticola doliiformis* Kopalová & Van de Vijver

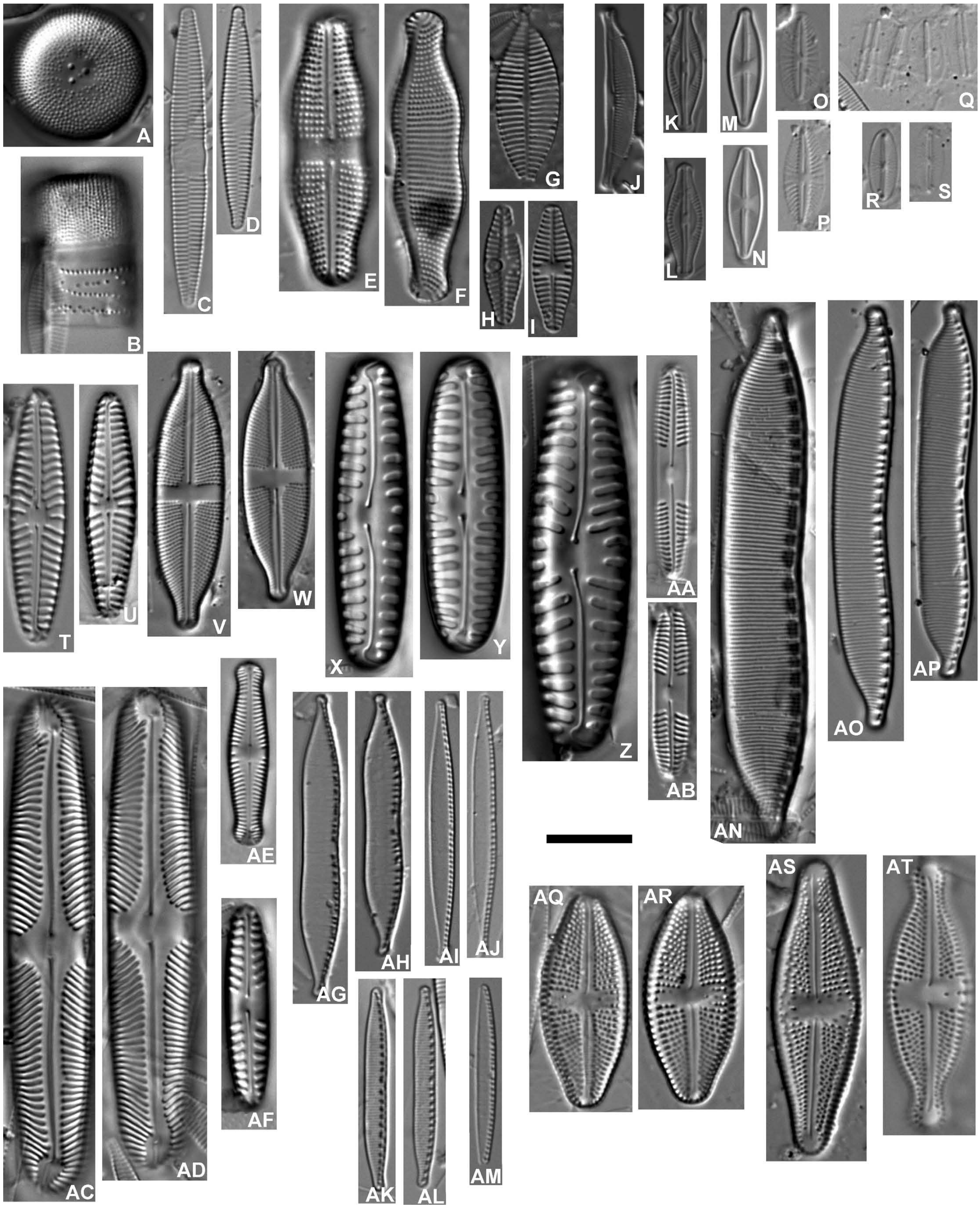

Figure 4 – LM micrographs of the taxa with a cosmopolitan or unknown biogeographic distribution found in the seepage and stream samples of James Ross Island: A & B, *Orthoseira roeseana*; C & D, *Fragilaria capucina* s. lat.; E, *A. coarctata*, raphe valve; F, *A. coarctata*, rapheless valve; G, *Planothidium delicatulum*, rapheless valve; H, *P. frequentissimum* rapheless valve; I, *P. frequentissimum* raphe valve; J, *Amphora* sp.; K & L., *Microcostatus naumanii*; M & N, *Sellaphora nana*; O & P, *Mayamaea atomus*; Q, *Fistulifera saprophila*; R & S, *Mayamaea permitis*; T & U, *Navicula seibigeana*; V & W, *Stauroneis jarensis*; X & Y, *Pinnularia borealis* var. *scalaris*; Z, *P. borealis* var. *islandica*; AA & AB, *P. subaltiplanensis*; AC & AD, *P. microstauron*; AE, *Chamaepinnularia krookiiformis*; AF, *Pinnularia intermedia*; AG & AH, *Nitzschia homburgiensis*; AI & AJ, *N. gracilis*; AK & AL, *N. perminuta*; AM, *N. paleaecea*; AN, *Hantzschia abundans*; AO & AP, *H. amphioxys*; AQ & AR, *Luticola* sp. 1; AS, *Luticola* sp. 2; AT, *Luticola* sp. 3. Scale bar represents 10 µm.

Table 3 – Relative abundances 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

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.

Achnanthes muelleri G.W.F.Carlson
Fig. 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* 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 Halozytes 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, Stuiver, T.B.Kellogg & G.H.D.Denton
Fig. 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 its 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.

Brachysira minor (Krasske) Lange-Bert.
Fig. 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).

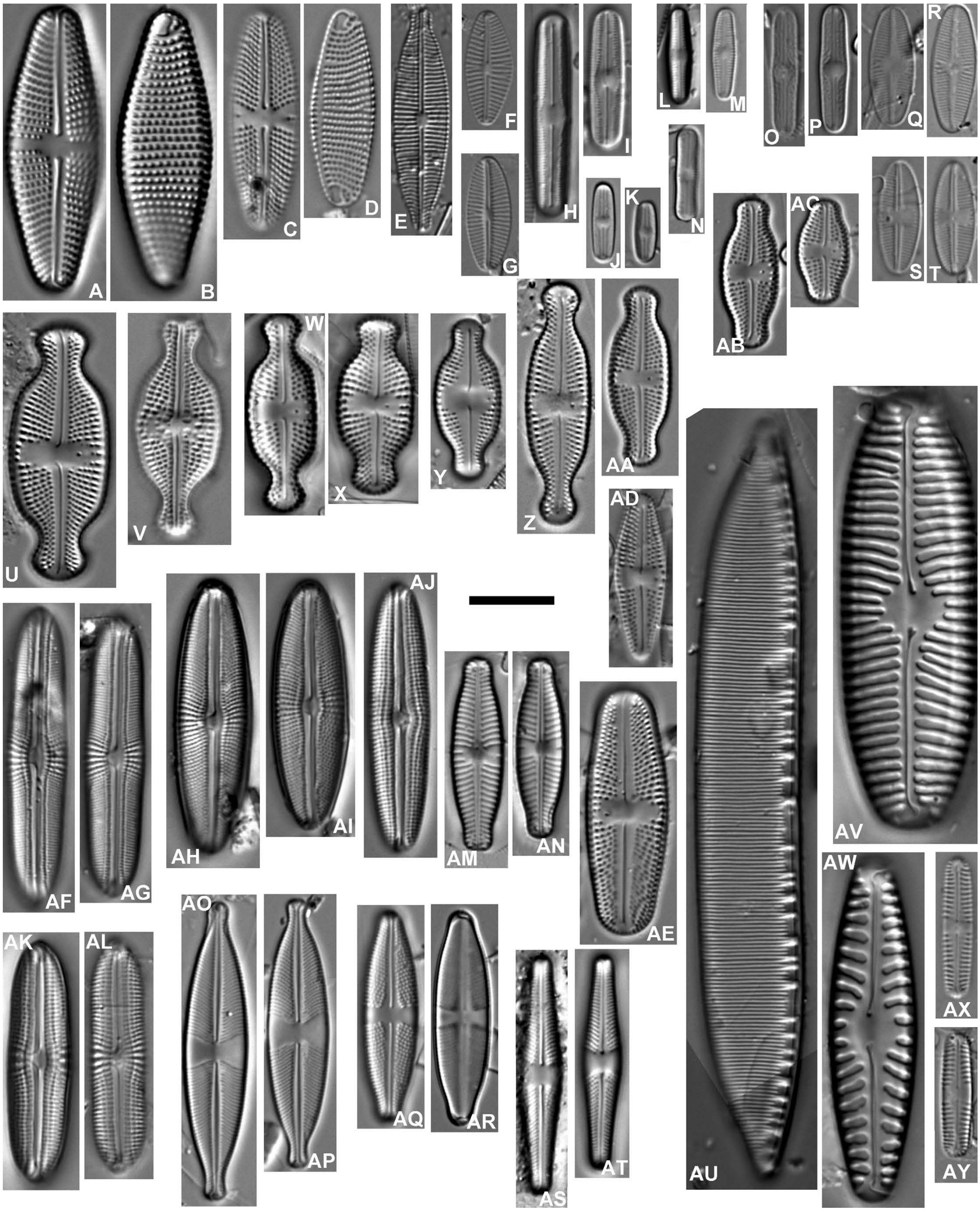

Figure 5 – LM micrographs of the taxa with an Antarctic biogeographic distribution found in the seepage and stream samples of James Ross Island: A, *Achnanthes muelleri*, raphe valve; B, *A. muelleri*, rapheless valve; C, *A. taylorensis*, raphe valve; D, *A. taylorensis*, rapheless valve; E, *Craticula antarctica*; F & G, *Eolimna jamesrossensis*; H & I, *Diadesmis arcuata*; J & K, *D. inconspicua*; L & M, *D. comperei*; N, *D. ingeae*; O & P, *Brachysira minor*; Q & R, *Psammothidium papilio*, rapheless valve; S & T, *P. papilio*, raphe valve; U, *Luticola gigamuticopsis*; V, *L. katkae*; W & X, *L. muticopsis*; Y, *L. doliiformis*; Z & AA, *L. austroatlantica*; AB & AC, *L. truncata*; AD, *L. australomutica*; AE, *L. vermeulenii*; AF & AG, *Muelleria luculenta*; AH & AI, *M. regigeorgiensis*; AJ, *M. aequistriata*; AK & AL, *M. regigeorgiensis*; AM & AN, *Geissleria gabrielae*; AO & AP, *Stauroneis latistauros*; AQ & AR, *S. pseudoschimanskii*; AS & AT, *S. pseudomuriella*; AU, *Hantzschia hyperaustralis*; AV, *Pinnularia australorabenhorstii*; AW, *P.* cf. *borealis* var. *pseudolanceolata*; AX & AY, *Chamaepinnularia gerlachei*. Scale bar represents 10 µm.

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
Fig. 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 now, 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. 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 (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).

Diadesmis arcuata (Heiden) Lange-Bert.
Fig. 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
Fig. 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
Fig. 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. 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. res.).

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
Fig. 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. res.). 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
Fig. 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, National Botanic Garden of Belgium, pers. obs.).

Hantzschia hyperaustralis Van de Vijver & Zidarova
Fig. 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. 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, Kopalová, S.A. Spaulding & Esposito
Fig. 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. 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 Lake 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* S.A.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. 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. 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. str. 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. 2011a).

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
Fig. 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. lat., the exact distribution of *L. muticopsis* s. str. 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 tot semi-wet soils (Van de Vijver & Mataloni 2008, Zidarova 2008).

Luticola truncata Kopalová & Van de Vijver
Fig. 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. str. 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 a moss tundra seepage at a rather high altitude.

Luticola vermeulenii Van de Vijver
Fig. 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. 2011a). 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. 2011a), 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. 2011a). 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. 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* (West & 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
Fig. 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
Fig. 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.Müll.) Freng. 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
Fig. 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. 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, National Botanci Garden of Belgium, unpubl. res.). 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. 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, Stuiver, T.B.Kellogg & Denton) Van de Vijver & Kopalová, **comb. nov.**
Fig. 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: 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* (M.H.Hohn & Hellerman) Lange-Bert., a characteristic 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.
Fig. 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. 2004). 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. 2004).

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. 2004, 2005). On the sub-Antarctic islands, the species has so far not been found (Van de Vijver et al. 2002a).

Autecology – *Stauroneis latistauros* is a 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. 2004). Zidarova (2008) recorded the species in several aquatic and wet terrestrial habitats.

Stauroneis pseudomuriella Van de Vijver & Lange-Bert.
Fig. 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* J.W.G.Lund is somewhat similar but can be separated by its lower valve dimensions and the denser striation (Van de Vijver et al. 2004).

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. 2004). 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. 2004). 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. Fig. 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. 2004).

Distribution – *Stauroneis pseudoschimanskii* was originally described from the sub-Antarctic island of South Georgia in the southern Atlantic Ocean (Van de Vijver et al. 2004) 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. 2004). 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 since 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 eighteen samples collected in fourteen different soil sites. Older studies mention lower numbers such as Kawecka & Olech (1993) with only 74 in seven 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 and 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 thirteen 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 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* (West & 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 Peninsular 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.).

CONCLUSIONS

Seepage areas and streams form an important habitat in the Antarctic Region. 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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