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European diatoms in freshwater habitats near Arctowski Station, King George Island, maritime Antarctica

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Abstract: Diatom assemblages collected from ponds and pools surrounding Arctowski Station (King George Island, South Shetland Islands) have been investigated. The study focused on two groups of samples: archival samples collected in the 1990s and contemporary samples collected in 2015. All samples were analysed following the revised taxonomy. A total of 118 diatom taxa representing 38 different genera were identified. The diatom flora consisted of both species typical of the maritime Antarctica (47% of all taxa), as well as cosmopolitan species (21% of all taxa). Four European taxa (*Adlafia minuscula, Nitzschia palea, Nitzschia perminuta*, *Surirella angusta*), that have not been previously observed in Antarctica, have been recorded. The potential sources of their presence in Antarctica are discussed.

Keywords: Antarctic, South Shetland Islands, Bacillariophyta, ecology, taxonomy, human impact.

Introduction

Since the establishment of permanent research stations in Antarctica became common in the 1950s, this region has been impacted by widespread, long-term, and ongoing human activity. Research efforts and associated support, and logistical operations adversely affect the natural environment (Chown *et al.* 2012). These impacts may include greenhouse gas emissions, disturbances or displacements of wildlife, habitat destruction, the introduction of non-native species, and the release of contaminants into water, air, and soil (Chown *et al.* 2012; Hughes *et al.* 2023 and references therein).

In Antarctica, more than 100 research stations operate either year-round or seasonally, accommodating approximately 5000 people each year (Chwedorzewska 2009; Chwedorzewska *et al.* 2013a, 2013b). Most of these stations, usually situated on ice-free locations, are sheltered from the wind and have access to freshwater, making them appealing to local flora and fauna due to their favorable microclimate. Scientific activities in polar regions are consistently supported by infrastructure and extensive facilities, requiring the annual transport of huge amounts of cargo and people (Chwedorzewska *et al.* 2013a). Containers and lightweight contain seeds, spores, soil microorganisms, even live organisms and their propagules. Food is a rich source of invertebrates, seeds and fungi, while on clothes, shoes and luggage mostly seeds are transported (Hughes *et al.* 2005, 2010, 2011; Chwedorzewska 2008, 2009; Osyczka 2010; Chown *et al.* 2012; Lityńska-Zając *et al.* 2012; Huiskes *et al.* 2014). Another significant and widespread consequence of human activity is chemical pollution, including fuel spills, exhaust fumes (Bargagli

2005) as well as the management of waste and wastewater (Connor 2008). Wastewater discharge can impact the local marine ecosystem and present a serious danger of environmental degradation (Stark *et al.* 2015, 2016; Szopińska *et al.* 2021). It can also influence soil and water (Hughes 2003a, 2003b) often leading to the eutrophication of naturally oligo-mesotrophic ecosystems, which in consequence may also promote the development of alien species (freshwater and soil algae and bacteria), especially in the vicinity of research stations (Broady and Smith 1994; Kashyap and Shukla 2001).

A good example of an anthropogenic introduction and subsequent rapid expansion in the maritime Antarctica is the annual bluegrass *Poa annua* L. The first recorded appearance of this species in Antarctica was in 1953 (Skottsberg 1954). Because of its excellent adaptation to environmental stress and unstable habitats *P. annua* is considered an invasive species spread across the Antarctic Peninsula region. The expansion of this species in the vicinity of Arctowski Station is well documented (Chwedorzewska 2008; Olech and Chwedorzewska 2011; Chwedorzewska *et al.* 2015).

Microorganisms (bacteria, fungi, and algae) that have a significant share in the biomass of terrestrial biocenoses, represent the most challenging group to monitor. Knowledge about both taxonomy and the level of endemism of this group in general is rather low, due to technical difficulties in conducting research (Vincent 2000). It can be challenging to determine whether a specific species was introduced by humans or is a cosmopolitan species that naturally occurs in the Antarctica. Since the onset of human activities, various items such as food, wood, and other materials have been introduced to Antarctica. These items can serve as significant vectors for microorganisms, including fungi (Kerry 1990; Arenz *et al.* 2010), bacteria (Vigo *et al.* 2011) and algae (Broady and Smith 1994).

Diatoms (Bacillariophyta) are considered to be one of the most abundant and productive algal groups in Antarctic and Sub-Antarctic inland waters, and terrestrial environments (Jones 1996; Sabbe *et al.* 2003; Verleyen *et al.* 2021 and references therein). As a part of a unique flora, diatoms develop in freshwater lakes, ponds, small water bodies on glacial moraines, in streams and creeks, often ephemeral, whose occurrence depends on melting snow and ice cover. They also grow abundantly on terrestrial mosses and inhabit the surface layer of moist soil, where they often play a dominant role (Zidarova *et al.* 2016).

In the maritime Antarctica, numerous surveys on the diatom flora, combined with an extensive revision of all genera, resulted in the first freshwater diatom identification guide, in which freshwater and terrestrial diatom from this region are illustrated and discussed (Zidarova *et al.* 2016 and references therein). However, these studies have not exhausted the topic related to the uniqueness of the Antarctic diatom flora.

With the establishment of Arctowski Station, diatom research was also facilitated in this part of King George Island. Several floristic and ecological diatom studies were published in at the turn of the 20th and 21st centuries and discussed the freshwater diatom flora in streams, creeks and puddles on the western shore of Admiralty Bay (Kawecka and Olech 1993; Luścińska and Kyć 1993; Kawecka *et al.* 1996, 1998; Noga and Olech 2004). Although all these data indicate a large diatom diversity, many of the recorded species were identified as typical European taxa. Luścińska and Kyć (1993) made the first general algal survey of the diversity around Arctowski Station, reporting the presence of more than 120 diatom taxa, including, however, typical European taxa such as *Asterionella formosa* Hassall (Hassall 1850) or *Gomphonema parvulum* (Kützing) Kützing (Kützing 1849). In the same year Kawecka and Olech (1993) studied diatom communities in two creeks (Vanishing and Ornithologist creeks) and recorded 74 diatom taxa, and few years later Kawecka *et al.* (1998) discussed diatoms in small waterbodies at Arctowski Station. Despite the unique nature of the Antarctic diatom flora, none of these studies indicated the presence of endemic species, but instead reported the presence of both typical European species, as well as some unknown species that could not be identified based on the (mainly European) literature available at the time. Only one study discussed the morphological variability of one of the most typical Antarctic diatoms, *Luticola muticopsis* (Van Heurck) D.G.Mann (Kawecka *et al.* 1996).

Diatom studies published before the taxonomic revision that started around 2010, see Zidarova *et al.* (2016) and references therein, were based on a less fine-grained species concept, mainly driven by the Ubiquity hypothesis (Finlay and Clarke 1999) stating that most diatom taxa in Antarctica have a cosmopolitan distribution (Jones 1996). This resulted in lumping morphologically variable species as one single taxon and/or force-fitting other taxa into European or North American species names (Tyler 1996), which consequently led to incorrect interpretations of the diversity, biogeography as well as ecology of the Sub-Antarctic diatoms (Sabbe *et al.* 2003; Van de Vijver *et al.* 2005).

During the last years, several ecological and taxonomical studies based on the refined taxonomy as proposed in Zidarova *et al.* (2016) were published on the diatom freshwater and terrestrial assemblages on King George Island (Kochman-Kędziora *et al.* 2018a, 2022; Noga *et al.* 2020). The uniqueness and high degree of endemism of the observed diatom flora were confirmed by the description of several new species from this region (Kochman-Kędziora *et al.* 2016, 2017, 2018, 2020a, 2020b, 2022)

The present study discusses the actual diatom communities in waterbodies within the area of Arctowski Station based on the revised diatom flora according to Zidarova *et al.* (2016). In order to study potential changes in diatom communities, diatom samples collected in the 1990s were reanalyzed and compared to samples obtained two decades later, *i.e.*, in 2015. Potential reasons for the presence of typically European species in the examined material were also discussed.

Study area

Arctowski Station (62°09’41”S, 58°28’10”W; Fig. 1) was founded in 1977 and is located in a small (about 4.2 km^2) ice-free oasis on the western shore of Admiralty Bay on King George Island, (61°54’ to 62°16’S and 57°35’ to 59°02’W), the largest island of the South Shetland Archipelago. The station consists of several facilities mostly constructed in 1977, although some of them were rebuilt in later years. It is a year-round scientific station occupied by scientists and support personnel, and regularly visited by tourists since the early 1980s (Chwedorzewska and Korczak 2010).

The climate of the island is typical for the maritime Antarctica, transitional between the Antarctic Continent and the Sub-Antarctic islands (Marsz and Rakusa-Suszczewski 1987) with small annual variations in air temperature, relatively high humidity and constant cloud cover. The multi-annual mean air temperature during 1977–1998 was −1.6°C, while during 2013–2017 was −1.7°C (Marsz and Styszyńska 2000; Plenzler *et al.* 2019). The average amount of precipitation in this area is 600–700 mm (Wen *et al.* 1994; Rakusa-Suszczewski 2002; Peter *et al.* 2008; Liu *et al.* 2011). The mean annual precipitation during 1977–1998 was 499.8 mm, whereas in 2017 the precipitation sum was 491.2 mm (Marsz and Styszyńska 2000). The investigated pools around the station were situated behind a storm ridge and represent shallow coastal water bodies.

Methods

The study included samples from various waterbodies adjacent to station buildings collected during three Antarctic Scientific Expeditions. In total, 18 samples were obtained

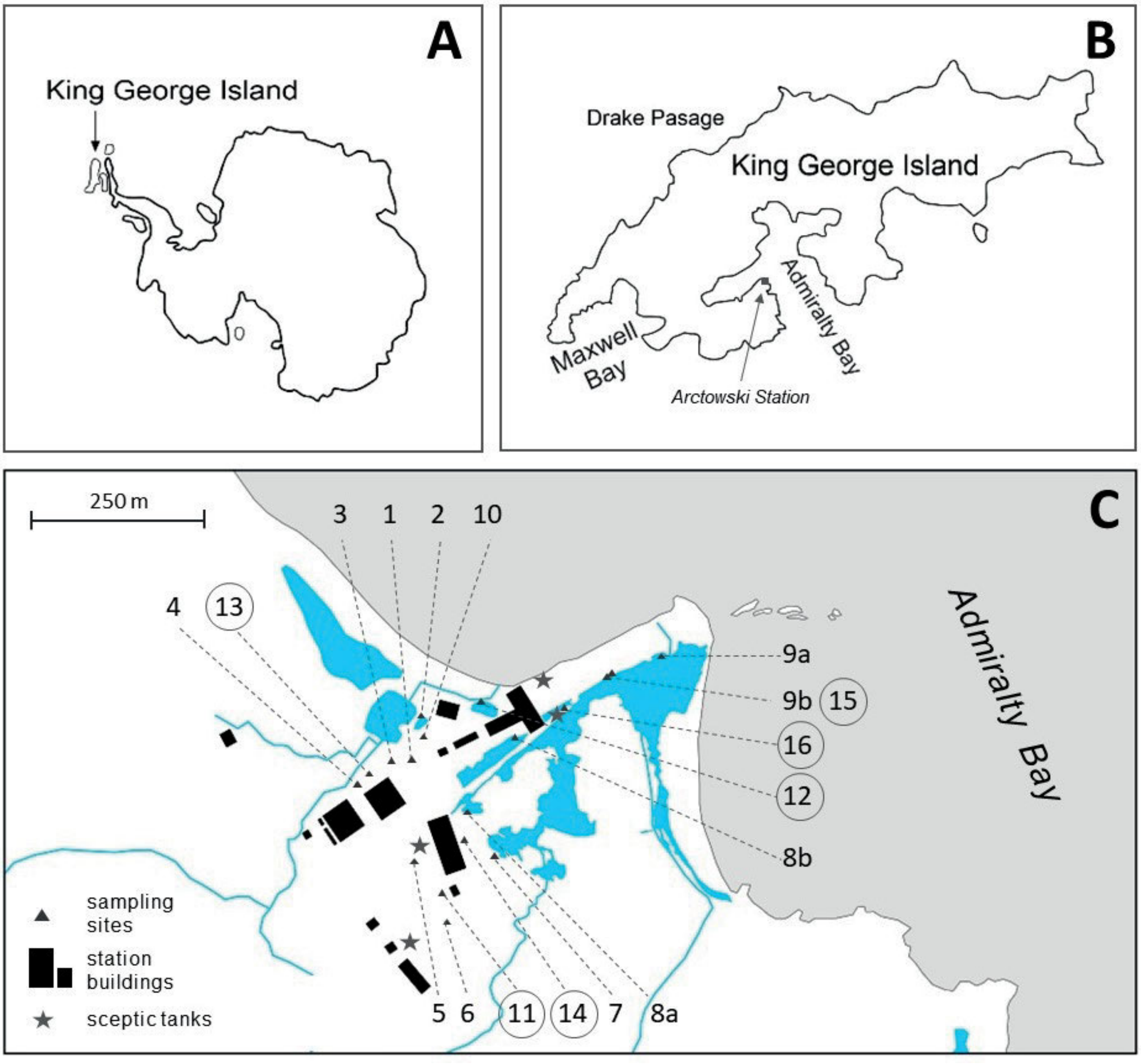

Fig. 1. Study area. The map of Antarctica showing the position of King George Island (**A**) and Arctowski Station (**B**). Sampling sites (1–16) in the area of Arctowski Station (**C**). Samples collected in the 1990s (6 samples) marked with a grey circle, samples collected in 2015 (12 samples). Position of septic tanks according to Szopińska *et al.* (2021).

by scraping of submerged boulders (epilithon) or by collecting a thin layer of surface sediment (epipelon) and fixed by adding concentrated ethanol for preservation. Six samples were collected in 1990s. Among them one sample (12) was obtained from epipelon of small, shallow puddle next to the main building during austral summer of 1991–1992. Five samples (11 and 13–16) were collected during the austral summer of 1995–1996 from various types of water-bodies: puddle (sample 11), small ponds (samples 13, 14, 16), and lake (sample 15).

Twenty years later, during the Antarctic Expedition 2014–2015 another 12 samples were collected. Four of them were collected from lakes, two from ponds with a surface area of 40 to 100 square meters and five from small ponds (surface area < 40 m²). One sample (10) was obtained from aa creek, meaning a small, occasionally drying stream. Detailed information about all samples is provided in Table 1.

Due to logistic constraints, only a few physico-chemical parameters could be measured *in situ* in 2015. Water

Table 1. List of samples with detailed physico-chemical information per sample. Type of water-body: lake, pond (surface area < 100 m²), small pond (surface area < 40m²), puddle (ephemeral shallow water-body), creek (small, occasionally drying stream).
ND - not determined, T - temperature, EC - conductivity.

Sample	Sampling date	Sample nature	Water-body type	GPS coordinates	Depth (cm)	Water pH	T (°C)	EC ($\mu S\ cm^{-1}$)
1	12.02.2015	epilithon / epipelon	small pond	62°09'34.5"S 58°28'24.3W"	5–10	8.7	11.3	127
2	12.02.2015	epilithon / epipelon	small pond	62°09'33.0"S 58°28'24.1W"	-	8.5	10.5	155
3	12.02.2015	epipelon	pond	62°09'34.6"S 58°28'24.6W"	30–40	8.5	10.8	126
4	12.02.2015	epipelon	small pond	62°09'35.0"S 58°28'27.2W"	10–15	7.8	10.7	84
5	13.02.2015	epipelon	small pond	62°09'36.8"S 58°28'24.7W"	20–30	9.0	16,9	476
6	13.02.2015	epipelon	pond	62°09'38.1"S 58°28'23.5W"	10–15	9.1	16.1	487
7	13.02.2015	epipelon / algal mats	small pond	62°09'37.0"S 58°28'20.7W"	5–10	8.8	14.7	235
8a	13.02.2015	epipelon	lake	62°09'36.1"S 58°28'21.0W"	10–50	8.6	14.1	291
8b	13.02.2015	epilithon		62°09'33.7"S 58°28'15.8W"	20	8.7	11.5	298
9a	14.02.2015	epilithon	lake (Wujka Lake)	62°09'29.7"S 58°27'59.5W"	70	8.7	6.5	310
9b	14.02.2015	epilithon / epipelon		62°09'30.9"S 58°28'05.4W"	40	8.3	6.9	328
10	12.02.2015	epipelon	creek	62°09'33.3"S 58°28'24.1W"	5-10	8.0	10.4	125
11	19.01.1996	epipelon	puddle	ND	ND	ND	ND	ND
12	15.01.1992	epipelon	puddle	ND	ND	ND	ND	ND
13	02.03.1996	epipelon	small pond	ND	ND	ND	ND	ND
14	02.03.1996	epipelon	small pond	ND	ND	ND	ND	ND
15	02.03.1996	epilithon / epipelon	lake (Wujka Lake)	ND	ND	ND	ND	ND
16	02.03.1996	epilithon / epipelon	small pond	ND	ND	ND	ND	ND

temperature, pH, and conductivity (EC) were measured using a MARTINI PH65 meter and a MARTINI EC59 meter. Geographical coordinates of each sampling location in 2015 were recorded using a handheld GPS. No geographic coordinates had been recorded and no physicochemical measurements had been performed in 1992 and 1995–1996.

Slide preparation and diatom identification

Samples for diatom analysis were prepared according to the method used by Kawecka *et al.* (1998) and Kawecka (2012). In order to obtain cleaned diatom valves part of each sample was digested using a mixture of concentrated sulfuric and chromic acid, then cleaned and centrifuged (5 times 5 minutes at 2 500 rpm). Excess inorganic soil matter was removed by sedimentation. Cleaned suspension was mounted in Pleurax (refractive index 1.75) and observed at 1000x magnification using a Nikon ECLIPSE 80i light microscope equipped with Differential Interference Contrast (Nomarski) optics and a Carl Zeiss Axio Imager A2. Diatom images were captured using the Zeiss ICC 5 camera. For scanning electron microscopy (SEM), part of the cleaned suspension was filtered through a 3 μm Isopore™ polycarbonate membrane filter (Merck Millipore), air–dried and attached to aluminum stubs. The stubs were sputter-coated with a 20 nm gold layer using the Turbo-Pumped Sputter Coater Quorum Q 150OT ES. Diatoms were studied in a Hitachi SU8010 microscope at 5 kV at University of Rzeszow (Poland).

Diatom identification was based on Zidarova *et al.* (2016 and references therein), Lange-Bertalot *et al.* (2017), Bulínová *et al.* (2018), Van de Vijver (2019), Kochman-Kędziora *et al.* (2020, 2022). Marine taxa were identified using Witkowski *et al.* (2000) and Al-Handal and Wulff (2008).

Data analysis

The species composition of each sample was determined by counting valves on randomly selected transects up to sum of 400 (Kopalová *et al.* 2014, 2019). After the count, the rest of the slide was examined for rare species that were not observed during the counting. Species with a share of 5% or more in a diatom assemblage were defined as dominants. A geographical distribution of noted taxa according to Van de Vijver *et al.* (2011a, 2011b, 2014, 2016, 2018), Zidarova *et al.* (2016), Bulínová *et al.* (2018), Van de Vijver (2019) and Kochman-Kędziora *et al.* (2020b, 2022).

The Shannon-Wiener diversity index ($\log_{10}$-based) and Hill's evenness index were calculated using the statistical package MVSP 3.2 (Kovach Computing Services 2002). To clarify patterns in the species composition, ordination techniques were applied. Detrended correspondence analysis was used to estimate gradient length. The analysis showed gradient lengths for the first four axes of 0.2586, 0.1608, 0.1267 and 0.0873 suggesting that methods based on linear models (PCA: Principal Components Analysis) should be applied for all subsequent ordinations of the dataset (ter Braak and Prentice 1988). All statistical analyses were performed using CANOCO version 5.03 (ter Braak and Šmilauer 1998) and are described in full detail in Jongman *et al.* (1995).

Results

Water samples collected in 2015 were characterized by alkaline pH, ranged from 7.8 (sample 4) to 9.1 (sample 6). The lowest conductivity value (84 μS cm^{-1}) was measured in small pond (sample 4), whereas the highest in the pond (sample 6) surrounded by mosses (487 μS cm^{-1}) (Table 1).

A total of 118 diatom taxa, including species and varieties as well as marine taxa, belonging to 38 different genera were identified in the freshwater samples. A full list of all observed taxa is provided in Table 2. Samples collected in 1990s had a slightly lower diversity (86 taxa) comparing to 2015 with 96 recorded taxa (Table 3). Among all recorded taxa, eleven had a marine origin, consisting of 0.13% of all counted valves. The number of taxa observed per sample ranged from 17 to 51 (mean 33). The highest species diversity was recorded in sample 15 collected in 1996, whereas only 17 taxa were noted in sample 6 (sampled in 2015). The average number of species for samples collected in the 1990s was 37 and 31 for samples from 2015. Table 3 presents the main similarities and differences in diatom communities for samples collected in the 1990s and 2015.

The most species-rich genus was *Luticola* (14 taxa), followed by *Pinnularia* (12 taxa), *Nitzschia* (9 taxa) and *Psammothidium* (6 taxa). The first three genera were common in both groups of samples: collected in 1990s and 2015 (Table 3).

The most abundant taxa were *Nitzschia gracilis* Hantzsch (13.3% of all counted valves), *Nitzschia paleacea* (Grunow) Grunow (11.4%), *Planothidium australe* (Manguin) Le Cohu (7.1%), *Navicula gregaria* Donkin (6.9%) and *Nitzschia homburgiensis* Lange-Bertalot (6.6%). In the samples from the 1990s, the second most abundant species was *Nitzschia stelmachpessiana* Hamsher *et al.* (12.0% of counts).

Analysis of all species geographical distribution showed the majority of recorded species (61%) have a distribution restricted to Antarctica, with almost 47% of them being endemic for the maritime Antarctica. On the other hand, 21% of recorded taxa (25 taxa) are considered to be cosmopolitan (Table 2). An additional 7.6% (9 taxa) have an uncertain taxonomical status (taxa with a 'cf.' qualifier, meaning "confer" meaning "compare with") and their distribution was designated as "unknown". The division of taxa in term of geographical distribution was similar for samples collected in the 1990s and in 2015 (Table 3).

On the list of all observed cosmopolitan taxa in the present study, four typical European species have pre-

Table 2. List of all observed species in samples collected in 1990s and 2015. The presence of taxa is marked with "+". Confirmed distribution: C – cosmopolitan; MA – maritime Antarctica; CA – continental Antarctica; SA – Sub-Antarctica; U – unknown. Marine species are listed at the end of the table.

		Samples collected in	
Taxon	Distribution	2015	1990s
Achnanthes coarctata (Brébisson) Grunow	C		+
Achnanthes muelleri G.W.F. Carlson	MA	+	+
Adlafia minuscula (Grunow) Lange-Bertalot	C	+	
Adlafia submuscora Van de Vijver, Kopalová, Zidarova and E.J.Cox	MA	+	
Adlafia cf. *submuscora* Van de Vijver, Kopalová, Zidarova and E.J.Cox	U		+
Brachysira minor (Krasske) Lange-Bertalot	C	+	+
Caloneis australis Zidarova, Kopalová and Van de Vijver	MA	+	+
Chamaepinnularia australomediocris (Lange-Bertalot and Rol.Schmidt) Van de Vijver	MA/SA	+	+
Chamaepinnularia gerlachei Van de Vijver and Sterken	MA	+	+
Chamaepinnularia krookiformis (Krammer) Lange-Bertalot and Krammer	C	+	+
Craticula australis Van de Vijver, Kopalová and Zidarova	MA	+	
Craticula antarctica Van de Vijver and Sabbe	MA/CA		+
Eunotia pseudopaludosa Van de Vijver, M. de Haan and Lange-Bertalot	MA		+
Fistulifera pelliculosa (Brébisson) Lange-Bertalot	C	+	+
Fragilaria cf. *parva* Tuji and Williams	U	+	+
Gomphonema maritimo-antarcticum Van de Vijver *et al.*	MA	+	+
Gomphonema sp.	U		+
Halamphora ausloosiana Van de Vijver and Kopalová	MA	+	+
Hantzschia abundans Lange-Bertalot	C	+	+
Hantzschia acuticapitata Zidarova and Van de Vijver	MA	+	
Hantzschia amphioxys (Ehrenberg) Grunow	C	+	+
Hantzschia australabundans Bulínová, Kochman-Kędziora, Kopalová and Van de Vijver	MA	+	+
Hantzschia hyperaustralis Van de Vijver and Zidarova	MA/CA	+	
Hippodonta hungarica (Grunow) Lange-Bertalot, Metzeltin and Witkowski	C	+	+
Humidophila inconspicua (Kopalová and Van de Vijver) R.L.Lowe, Kociolek, J.R.Johansen, Van de Vijver, Lange-Bertalot and Kopalová	MA	+	+
Humidophila keiliorum Kopalová	MA	+	
Humidophila sceppacuerciae Kopalová	MA	+	
Humidophila tabellariaeformis (Krasske) R.L.Lowe *et al.*	C	+	+
Humidophila vojtajarosikii Kopalová, Zidarova and Van de Vijver	MA	+	+
Luticola australomutica Van de Vijver	MA	+	+
Luticola austroatlantica Van de Vijver *et al.*	MA/CA	+	+
Luticola bogaertsiana Zidarova, Levkov and Van de Vijver	MA		+
Luticola contii Zidarova, Levkov and Van de Vijver	MA	+	+
Luticola higleri Van de Vijver, Van Dam and Beyens	MA	+	+
Luticola muticopsis (Van Heurck) D.G.Mann	A	+	+
Luticola kaweckae Kochman-Kędziora, Noga, Olech and Van de Vijver	MA		+
Luticola truncata Kopalová and Van de Vijver	MA	+	
Luticola olegsakharovii Zidarova, Levkov and Van de Vijver	MA		+

Table 2 continued

		Samples collected in	
Taxon	Distribution	2015	1990s
Luticola puchalskiana Kochman-Kędziora, Zidarova, Noga, Olech and Van de Vijver	MA		+
Luticola quadriscrobiculata Van de Vijver	MA	+	+
Luticola vandevijveri Kopalová, Zidarova and Levkov	MA	+	
Luticola vermeulenii Van de Vijver	MA		+
Luticola sp.	U	+	+
Mayamaea cf. *atomus* (Hustedt) Bruder and Medlin	U	+	+
Mayamaea excelsa (Krasske) Lange-Bertalot	C		+
Mayamaea permitis (Hustedt) Bruder and Medlin	U	+	+
Mayamaea sweetloveana Zidarova, Kopalová and Van de Vijver	MA	+	
Microcostatus australoshetlandicus Van de Vijver *et al.*	MA	+	
Muelleria aequistriata Van de Vijver and S.A.Spaulding	MA	+	+
Muelleria algida Spaulding and Kociolek	MA	+	
Muelleria australoatlantica Van de Vijver and S.A.Spaulding	MA	+	+
Muelleria kristinae Van de Vijver	MA	+	
Muelleria nogae Van de Vijver, Zidarova and Kopalová	MA	+	+
Muelleria sabbei Van de Vijver and S.A.Spaulding	MA		+
Navicula australoshetlandica Van de Vijver	MA	+	+
Navicula bicephaloides Van de Vijver and Zidarova	MA	+	+
Navicula dobrinatemniskovae Zidarova and Van de Vijver	MA		+
Navicula gregaria Donkin	C	+	+
Navicula romanedwardii Zidarova, Kopalová and Van de Vijver	MA	+	
Navicula sp.	U	+	
Nitzchia gracilis Hantzsch	C	+	+
Nitzschia homburgiensis Lange-Bertalot	C	+	+
Nitzschia kleinteichiana Hamsher *et al.*	MA	+	+
Nitzschia palea (Kützing) W.Smith	C	+	+
Nitzschia paleacea (Grunow) Grunow	C	+	+
Nitzschia perminuta Grunow	C	+	
Nitzschia soratensis E.Morales and M.L. Vis	C	+	+
Nitzschia stelmachpessiana Hamsher *et al.*	MA	+	+
Nitzschia vandeputteana Hamsher, Kopalová, Kociolek, Zidarova and Van de Vijver	MA		+
Orthoseira sp.	U	+	+
Pinnularia australodivergens Zidarova, Kopalová and Van de Vijver	MA	+	
Pinnularia australoglobiceps Zidarova, Kopalová and Van de Vijver	MA/SA	+	+
Pinnularia australomicrostauron Zidarova, Kopalová and Van de Vijver	MA/CA	+	+
Pinnularia australoschoenfelderi Zidarova, Kopalová and Van de Vijver	MA	+	+
Pinnularia austroshetlandica (G.W.F. Carlson) A. Cleve	MA/SA	+	+
Pinnularia borealis Ehrenberg	C	+	+
Pinnularia borealis var. *pseudolanceolata* Van de Vijver and Zidarova	MA	+	+
Pinnularia magnifica Zidarova, Kopalová and Van de Vijver	MA	+	

Table 2 continued

		Samples collected in	
Taxon	Distribution	2015	1990s
Pinnularia microstauroides Zidarova, Kopalová and Van de Vijver	MA	+	+
Pinnularia perlanceolata Van de Vijver and Zidarova	MA	+	
Pinnularia subantarctica var. *elongata* (Manguin) Van de Vijver and Le Cohu	MA/SA	+	+
Pinnularia cf. *strictissima* Manguin	U		+
Pinnunavis gebhardii (Krasske) Van de Vijver	C	+	
Placoneis australis Van de Vijver and Zidarova	MA	+	+
Planothidium australe (Manguin) Le Cohu	C	+	+
Planothidium lanceolatum (Brébisson) Lange-Bertalot	C	+	+
Planothidium rostrolanceolatum Van de Vijver, Kopalová and Zidarova	MA	+	+
Psammothidium antarcticum Van de Vijver	MA/SA		+
Psammothidium germainii (Manguin) Sabbe	MA/SA		+
Psammothidium germainioides Van de Vijver, Kopalová and Zidarova	MA		+
Psammothidium incognitum (Krasske) Van de Vijver	MA/SA	+	
Psammothidium papilio (D.E.Kellogg *et al.*) Kopalová and Van de Vijver	MA/SA	+	+
Psammothidium rostrogermainii Van de Vijver, Kopalová and Zidarova	MA/CA		+
Psammothidium subatomoides (Hustedt) Bukhtiyarova and Round	C	+	
Sellaphora antarctica Zidarova, Kopalová and Van de Vijver	MA	+	+
Sellaphora gracillima Zidarova, Kopalová and Van de Vijver	MA	+	
Stauroforma inermis Flower, V.J. Jones and Round	MA/SA	+	+
Stauroneis acidojarensis Zidarova, Kopalová and Van de Vijver	MA	+	
Stauroneis huskvikensis Van de Vijver and Lange-Bertalot	MA	+	
Stauroneis latistauros Van de Vijver and Lange-Bertalot	A	+	+
Stauroneis minutula Hustedt	C		+
Stauroneis pseudomuriella Van de Vijver and Lange-Bertalot	MA/SA	+	
Staurosira pottiezii Van de Vijver	MA	+	+
Staurosira sp.	U		+
Surirella australovisurgis Van de Vijver, Cocquyt, Kopalová and Zidarova	MA	+	+
Surirella angusta Kützing	C	+	+
Tryblionella debilis Arnott	C	+	+
marine species			
Cocconeis costata W. Gregory group	marine	+	+
Cocconeis costata var. *antarctica* Manguin	marine	+	
Cocconeis japonica var. *antarctica* Van Heurck	marine	+	
Cocconeis pinnata var. *matsi* Al-Handal, Riaux-Gobin and Wulff	marine	+	
Cocconeis schuettii Van Heurck	marine	+	
Fragilariopsis sp.	marine	+	
Licmophora sp.	marine	+	+
Navicula perminuta Grunow complex	marine		+
Petroneis sp.	marine	+	
Pseudogomphonema sp.	marine	+	+
Thalassiosira gracilis (Karsten) Hustedt	marine	+	+

Table 3. A comparison of samples collected in 1990s and in 2015. NO = not observed, CHKF – *Chamaepinnularia krookiformis*, NGRE – *Navicula gregaria*, NIGR – *Nitzschia gracilis*, NIHO – *N. homburgiensis*, NIPC – *N. paleacea*, NIST – *N. stelmachpessiana*, PLAU – *Planothidium australe*, PLRL – *Planothidium rostrolanceolatum*.

	All samples	1990s	2015
Number of samples	18	6	12
diatom assemblages			
Number of recorded taxa	118	86	96
Number of taxa recorded only in 1990s/2015	-	22	32
Highest diversity	51	51 (sample 15)	45 (sample 9a)
Lowest diversity	17	18 (sample 13)	17 (sample 6)
Average number of species per sample	33	37	31
Most species-rich genus (number of taxa)	*Luticola* (14), *Pinnularia* (12), *Nitzschia* (9), *Psammothidium* (7)	*Luticola* (12), *Pinnularia* (9), *Nitzschia* (8), *Psammothidium* (5)	*Luticola* (9), *Pinnularia* (11), *Nitzschia* (8), *Hantzschia*, *Humidophila*, *Muelleria*, *Navicula* (5)
Most abundant taxa (% of all counted valves)	NIGR (13.3%) NIPC (11.4%) PLAU (7.1%) NGRE (6.9%) NIHO (6.6%)	NIGR (13.5%) NIST (12.0%) NIPC (11.1%) NIHO (8.6%) CHKF (8.5%)	NIGR (13.1%) NIPC (11.4%) NGRE (7.1%) PLAU (7.1%) PLRS (6.9%)
distribution			
Cosmopolitan	21 % of all taxa	24.4% of all taxa	23% of all taxa
Restricted to maritime Antarctica	46 % of all taxa	43% of all taxa	46.9% of all taxa
Restricted to Antarctica (including regional endemism)	61 % of all taxa	59.3% of all taxa	60.4% of all taxa
Marine	9.3% of all taxa (0.13% of counts)	5.8% of all taxa (0.16% of counts)	10.4% of all taxa (0.11% of counts)
Discussed European species			
Adlafia minuscula		NO	in 5 samples (maximum share: 5.3%)
Nitzschia palea		in 2 samples as single specimens	in 6 samples (maximum share: 1.5%)
Nitzschia perminuta		NO	in 7 samples (maximum share: 28.3%)
Surirella angusta		in 2 samples (maximum share: 6.3%)	in 10 samples as single specimens

viously not been observed in both freshwater and terrestrial diatom assemblages of the maritime Antarctica according to the revised taxonomy of Antarctic diatoms. These include three dominant species: *Adlafia minuscula* (Grunow) Lange-Bertalot, *Nitzschia perminuta* Grunow, *Surirella angusta* Kützing (Table 4) and one species forming a smaller population: *Nitzschia palea* (Kützing) W. Smith. All species were studied in detail using both LM and SEM (Fig. 2). No morphological differences could be observed between the recorded Antarctic populations and populations from Europe. *Surirella angusta* and *N. palea* were noted in both the 1990s and 2015 samples, whereas the three other species were recorded only in samples from 2015. Their numbers in the samples ranged from single specimens (*Nitzschia palea*) to dominance with a maximum share reaching over 28% (*N. perminuta*) (Table 3).

Twenty-four of all observed species were considered as dominants. Among them, 7 reached 5% or more in only one sample. On the other hand, 5 taxa dominated assemblages in at least half of samples (Table 4).

The Shannon-Wiener diversity index calculated for all samples ranged from 0.51 (sample 12) to 1.12 (sample 1; mean 0.84 ± 0.18). Diversity analysis also revealed a slightly lower mean Shannon-Wiener diversity index for

Table 4. The dominant diatom taxa (occurrence ≥ 5% in at least one sample). "+" - rare species, observed as a single individual together with confirmed geographical distribution (CD) and Shannon-Wiener diversity index calculated for each sample. Confirmed distribution (CD): C – cosmopolitan; MA – maritime Antarctica; CA – continental Antarctica; SA – Sub-Antarctica; U – unknown. Marine species are listed at the end of the table.

		Sample																	
	Species	1	2	3	4	5	6	7	8a	8b	9a	9b	10	11	12	13	14	15	16
CD	Diversity index	1.12	1.01	0.61	1.02	0.71	0.67	0.89	1.02	0.70	1.05	0.82	0.93	0.87	0.51	0.91	0.52	0.89	0.95
C	*Adlafia minuscula*		+		+					+									
MA	*Adlafia submuscora*																		
C	*Chamaepinnularia krookiformis*			+			+			+			+						
MA	*Gomphonema maritimo-antarcticum*			+		+	+						+		+		+	+	
A	*Luticola muticopsis*					+		+	+		+	+			+		+	+	+
U	*Mayamaea permitis*								+										
MA	*Mayamaea sweetloveana*																		
MA	*Navicula australoshetlandica*														+				
MA	*Navicula dobrinatemiskovae*																		
C	*Navicula gregaria*					+						+		+					
C	*Nitzchia gracilis*	+												+	+				
C	*Nitzschia homburgiensis*									+									
MA	*Nitzschia kleinteichiana*										+				+				
C	*Nitzschia paleacea*	+													+				
C	*Nitzschia soratensis*														+		+		
MA	*Nitzschia stelmachpessiana*			+															
C	*Nitzschia perminuta*	+																	

Table 4 continued

		Sample																	
MA/CA	*Pinnularia australomicrostauron*	+	<5	+	+	+	+	<5	5–20	+	<5	<5	+	5–20	<5	<5	<5	+	<5
MA	*Placoneis australis*	<5	+	+	+	+	+	+	5–20	+	<5	+	+	+	+		<5	+	+
C	*Planothidium australe*	5–20	5–20	<5	5–20			<5	<5	5–20	5–20	20–50	<5	+	+	<5	<5	5–20	20–50
MA	*Planothidium rostrolanceolatum*	20–50	20–50	<5	5–20	+	<5	+	<5			+	20–50	<5	+	5–20	+	<5	
MA	*Staurosira pottiezii*	+	+						<5		20–50	20–50			+		+	20–50	5–20
MA	*Surirella australovisurgis*	<5	5–20	<5		<5	<5	+	+						+	+	+		
C	*Surirella angusta*	<5	<5			<5	5–20	<5	<5	+	+	+	+	+			+		

Occurrence (%): <5; 5–20; 20–50; >50

samples collected in 1990s (0.77 ± 0.2), compared to the diversity value for samples collected in 2015 (0.88 ± 0.17; Table 4).

Some differences in the composition of diatom assemblages could be observed. The first two ordination axes of the Principal Components Analysis (Fig. 3) (PCA) explained 42% (25.9% for axis 1 and 16.1% for axis 2) of the cumulative variation in the diatom data set with an additional 21.4% on the next two axes. The groups of points visible in the diagram (A, B, and C) correspond to sites that are adjacent to each other or located a short distance away within the research station. Group A is composed of samples collected from the epipelon of small ponds in the southern part of the Arctowski Station area (Fig. 1), distinguished by a large population of two *Nitzschia* species: *N. gracilis* and *N. homburgiensis*. Samples grouped in the lower left corner of the diagram (group B) were collected from the epipelon of sites located between the station buildings (a small stream and a source of drinking water) (Fig. 1). These samples were dominated by *Nitzschia* species, such as *N. paleacea* (sample 2, 4, 10, 13) and *N. perminuta* (samples 3, 4) as well as *Planothidium rostrolanceolatum* Van de Vijver *et al.*, the dominant species in almost all samples of this group, except for sample 3 (where it reached only 3% of the counts). The latter sample was collected from a pond, whereas all other samples originate from smaller water-bodies (small ponds) and from the creek (sample 10).

Most of the samples from group C on the PCA diagram were collected from the largest water bodies located closest to the waters of Admiralty Bay with an exception of sample 16 collected from a small pond. All samples however were collected from the epilithon or epilithon/epipelon.

A distinctive species of this group was *Staurosira pottiezii* Van de Vijver. It reached an abundance of 8.8 % in sample 16 mounting to about 30% in samples 9a and 9b collected from the same lake. Although *S. pottiezii* was not recorded in sample 8b, also collected from the lake, it was the dominant species in all other samples in this group. It is also worth mentioning that in the other groups (A and B) the species was not observed or was recorded only as a single specimen (Table 4). Additionally, group C counted the highest number of marine taxa.

Samples 9a and 9b (group C) were collected in 2015 from Wujka Lake, the largest waterbody in the study area. Both samples have an almost identical species composition, differing only in the dominance of *Nitzschia soratensis* E. Morales and Vis in sample 9b (27%), compared to only 1% in sample 9a, which was collected closer to Admiralty Bay, next to the lighthouse (Table 4).

Larger differences were observed between samples 8a and 8b, although collected from the same lake, located close to the main station building (Fig. 1). Both samples differed in their species richness with 32 taxa observed in sample 8a (diversity index 1.02), but only 22 in sample 8b (diversity index 0.7). Six taxa could be classified as dominant in both samples, although only 2 of them (*Navicula australoshetlandica* Van de Vijver and *N. gregaria*) were common to

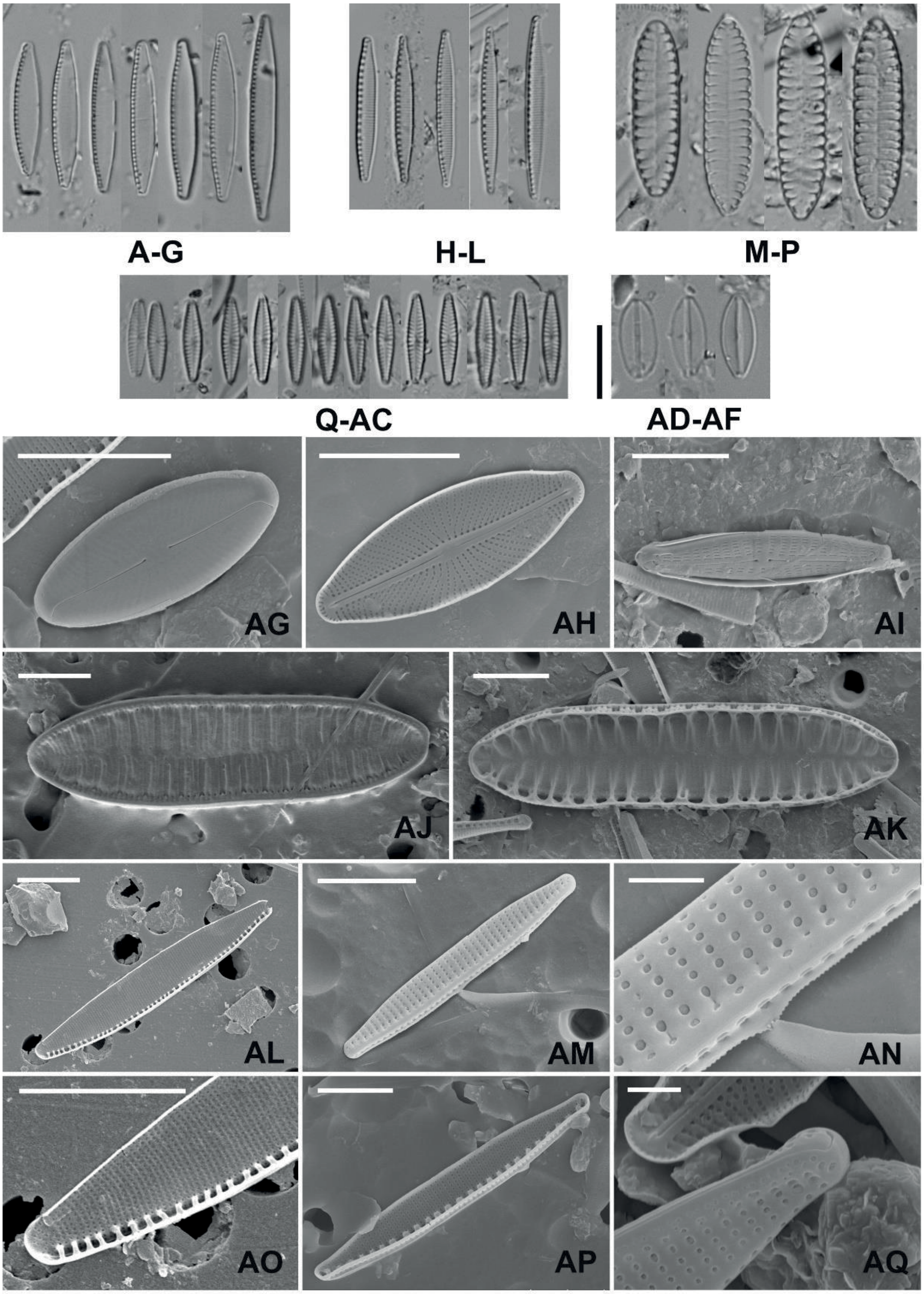

Fig. 2. LM (A–AF) and SEM (AG–AQ) micrographs of selected diatom taxa. **A–G, AL,** *Nitzschia palea*, **AO**, detailed view of *Nitzschia palea*, **H–L,** LM views of *Nitzschia perminuta*, **M–P, AJ–AK**, *Surirella angusta*, **Q–AC, AI,** *Navicula* sp., **AD–AH** *Adlafia minuscula*, AM–AN, External and internal views of *Nitzschia perminuta*, **AN**, external detail of the raphe of *Nitzschia perminuta*, **AQ**, external detail of the apex and terminal raphe ending of *Nitzschia perminuta.* Scale bars represent 5 μm, except for AN and AQ, where scale bare is 1 μm.

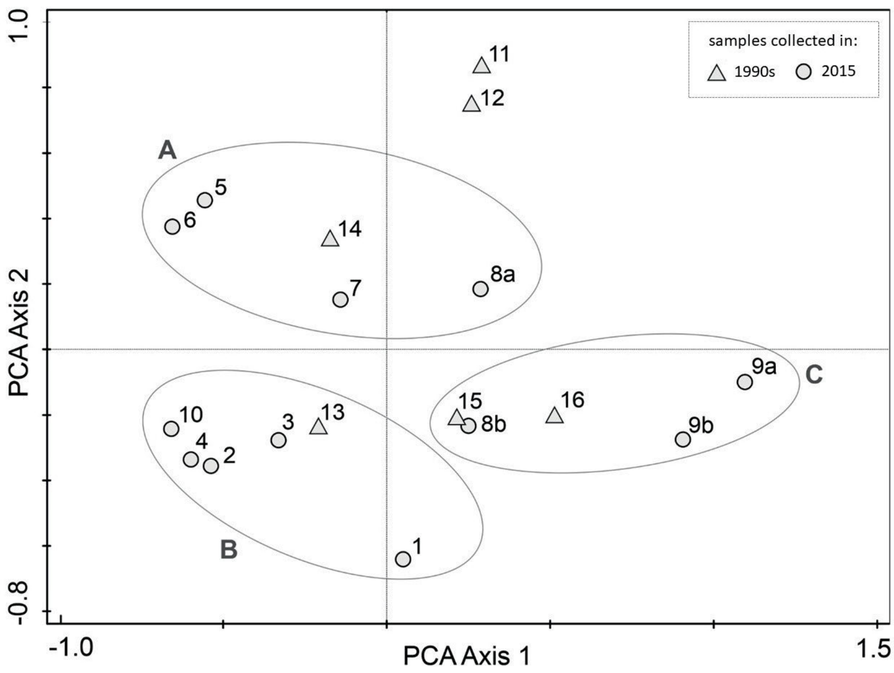

Fig. 3. PCA ordination plot for diatom data. Three groups of assemblages (A, B, C) are indicated based on the location of sampling sites. Samples 1–10 collected in 2015 are marked with grey circle, whereas grey triangle indicate samples 11–16 collected in 1990s.

both samples. The share of both species was higher in sample 8a (32.5% and 11%, respectively) than in sample 8b, where both species reached only 5.5%. The remaining dominant species differed between the two samples. The co-dominants in sample 8a included *Pinnularia australomicrostauron* (19%), following by *N. gracilis* (5%), *N. homburgiensis* (6.5%) and *Placoneis australis* Van de Vijver and Zidarova (5.5%). Sample 8b was dominated by 6 species, of which *Mayamaea permitis* and *N. soratensis*, reached together 75% of the counts. Sample 8a was collected from the site directly adjacent to the fuel tanks (traces of fuel were visible on the surface). Sample 8b was collected from the opposite site of the waterbody, next to the main building, approximately 100 m from site 8a.

The exceptions to the distribution pattern are two outlier samples located entirely on top in the middle of the diagram (samples 11 and 12, both collected in 1990s). Both samples were collected from the epipelon of small, shallow puddles located in different parts of the study area Sampling site 12 was located next to the main station building, whereas site 11 was situated the most southernly from the rest (Fig. 1). In sample 12, *N. stelmachpessiana* reached 73% of all counted valves, with *Chamaepinnularia krookiformis* (Krammer) Lange-Bertalot and Krammer and *N. homburgiensis* considered as subdominant. *Chamaepinnularia krookiformis* reached 32.5% in sample 11 but only 6.25% in the sample 12, whereas *N. homburgiensis,* reached 31.5% and 12% in samples 11 and 12, respectively (Table 4).

Discussion

Over the past two decades, considerable progress has been made in our knowledge about the diversity, taxonomy (Kopalová and Van de Vijver 2013) and geographic distribution (Kociolek *et al.* 2017) of the Antarctic diatom flora. Based on the results of numerous studies investigating freshwater and terrestrial diatom assemblages (Zidarova *et al.* 2016 and references therein), our results show that the general diversity of diatom assemblages in water bodies located in and around Arctowski Station is quite similar to the flora that was observed in other localities of the maritime Antarctica (Kopalová and Van de Vijver 2013; Kopalová *et al.* 2013; Kochman-Kędziora *et al.* 2018). Kopalová and Van de Vijver (2013) recorded 143 taxa in various freshwater samples collected from Livingston Island (the second largest island of the South Shetlands). A slightly lower species richness (123 taxa) was observed in samples from Ulu Peninsula (James Ross Island; Kopalová *et al.* 2013), located, however, more to the south and on the opposite (south) side of the Antarctic Peninsula in the Weddell Sea. During the latest study from small pools and creeks (occasionally drying streams) on the Ecology Glacier Forefield, south of Arctowski Station, 122 diatom taxa were noted in 18 samples (Kochman-Kędziora *et al.* 2018).

The investigated waterbodies near Arctowski had a similar physico-chemistry (pH and conductivity values) to those in the aforementioned studies. Water samples studied by Kopalová and Van de Vijver (2013) as well as by Kochman-Kędziora *et al.* (2018) had a circumneutral to alkaline pH, similar to our results (pH values ranging from 7.8 to 9.1). Kawecka *et al.* (1998) and Nędzarek and Pociecha (2010) reported an alkaline pH for Wujka Lake (samples 9a and 9b in our study) during the summer seasons of 1987/1988 and 2003/2004. The pH-gradient is not very strong, probably due to the dominance of alkaline soils similar to several other Maritime Antarctic locations (Kopalová and Van de Vijver 2013; Vinocur and Unrein 2000).

The electrolytic conductivity (EC) values were more diverse, ranging from 84 µS/cm (sample 4) to 487 $\mu S\ cm^{-1}$

(sample 6), similar to the measurements made on the neighboring Ecology Glacier Forefield (Kochman-Kędziora *et al.* 2018). In older studies from the same area, Nędzarek and Pociecha (2010) and Kawecka *et al.* (1998) measured higher conductivity values for the Wujka Lake (corresponding to our samples 9a, 9b), reaching even 665 µS cm^{-1} and 2600 µS cm^{-1}, respectively. According to Pociecha (2008), EC values for Wujka Lake can reach even 37 600 µS cm^{-1}, which is related to the location on the seashore and therefore a direct influence of sea water and marine aerosols (Nędzarek and Rakusa-Suszczewski 2007; Nędzarek and Pociecha 2010). Contrary, EC values measured in lakes and pools situated further inland on Livingston Island were low and did not exceed 300 µS cm^{-1} (Kopalová and Van de Vijver 2013).

Despite a similar species richness between our studies and others from the maritime Antarctica, differences in species composition between the studied diatom assemblages can be noted. The proportion of the genus *Nitzschia* reached 45%, with two most abundant species, *N. gracilis* and *N. paleacea* showed a frequency of 13.3% and 11.4%, respectively. The genus *Nitzschia* also dominated the diatom flora in small pools and creeks (occasionally drying streams) on the Ecology Glacier Forefield with 40.5% of all counted valves (Kochman-Kędziora *et al.* 2018). Apart from King George Island, *Nitzschia* species formed large population in pools on the nearby Livingston Island (31.7% of all counted valves; Kopalová and Van de Vijver 2013). *Nitzschia gracilis* is commonly observed in both lentic and lotic habitats, often dominates also diatom assemblages in larger lakes and seepages, and prefers neutral to alkaline pH and a low conductivity value (Zidarova *et al.* 2016). The second most abundant *Nitzschia* species observed in this study was *N. paleacea*, considered to be a typical taxon for Antarctic pools and lakes (Kopalová *et al.* 2013; Kopalová and Van de Vijver 2013). The species, however, were not observed in samples collected from the waterbodies on the Ecology Glacier Forefield (Kochman-Kędziora *et al.* 2018). *Nitzschia gracilis* was originally described from Germany but a detailed analysis of the type material is actually lacking, obstructing a good morphological comparison between the Antarctic and European populations (Lange-Bertalot *et al.* 2017). In France, the species was observed in circumneutral environments with a high oxygen level (Bey and Ector 2010). The same applies also to *N. paleacea*, observed in eutrophic to polytrophic freshwater habitats with medium to high electrolyte content (Lange-Bertalot *et al.* 2017). The present investigation is not the first one conducted in the area of Arctowski Station. As part of the general limnological characterization of the largest water-body in this area (Lake Wujka), Nędzarek and Pociecha (2010) recorded 17 diatom species, some of them identified only to the genus level. Kawecka *et al.* (1998) also studied various waterbodies (ponds, puddles, and slow-flowing waters), and some of the sampling sites overlap with our studies (ponds I and II in Kawecka *et al.* 1998 correspond to sites 9 and 8, respectively). However, comparison of those (historical) studies with contemporary ones is not always possible mostly due to unreliable taxa identifications in studies published before 2000 as well as and underestimation of the actual species diversity of this region as shown by more recent works (Zidarova *et al.* 2016 and references therein, Verleyen *et al.* 2021).

Unexpectedly, four typical European species were observed in the studied samples, which were not recorded in other newest studies from the Antarctica. In older literature data, all were reported from various samples in Antarctica (Kellogg and Kellogg 2002). *Nitzschia palea* was the most recorded *Nitzschia* in Antarctica, followed by *N. perminuta*. Based on literature data, both species have been observed both from Sub-Antarctica (*e.g.*, South Orkneys, South Georgia, Crozet Archipelago, Kerguelen Island) as well as from South Shetlands in the maritime Antarctica. However, recent revisions of European type materials showed that due to taxonomic drift, *i.e.*, the continuous broadening of a species description, several of these species became morphologically very variable. On the other hand, for a lot of common European species, such a revision is still lacking. For instance, the type material of *N. perminuta* has never been properly investigated. Unpublished results show that the species is actually a complex of (yet undescribed) taxa (Van de Vijver unpublished). A taxonomical revision of the Antarctic *N. perminuta* species complex revealed the presence of several taxa that were split off from the European *N. perminuta* as illustrated in literature (Hamsher *et al.* 2016). It is clear that a better knowledge of the European *N. perminuta* populations will result in even more Antarctic taxa to be split off (Van de Vijver personal communication). *Surirella angusta* was found on several Sub-Antarctic Islands such as Crozet, Kerguelen and South Georgia but these records have been revoked and corrected (Van de Vijver *et al.* 2013). As a result, all populations formerly identified as *S. angusta* in the Sub-Antarctica have now been renamed, making it clear that the species does not occur in this region. The same most likely applies to the records of the maritime Antarctica, although most of them could no longer be verified since based solely on written (and not illustrated) records. For instance, Schmidt *et al.* (1990) observed *S. angusta* on King George Island, and Wasell and Hakansson (1992) and Wasell (1993) reported the species from on Horseshoe Island. In order to revoke these records, the original material of both papers should be reanalysed, which is at present unfortunately no longer possible (Van de Vijver, personal communication) *A. minuscula* was reported as *N. minuscula* from King George Island by Nikolajev (1980) and Schmidt *et al.* (1990). However, in the light of current knowledge, these records should be regarded as unverified. Several European records have been checked and revised the past decade. All revisions resulted in a rejection of the European names and the description of the Antarctic taxa as new species. Examples include *Aulacoseira principissa* Van de Vijver, a common Sub-Antarctic *Aulacoseira* species that was always identified as *A. alpigena* (Grunow) Krammer (Van de Vijver 2012), and

Staurosira vandenbusscheana Van de Vijver that was identified in older records as *Fragilaria alpestris* Krasske described from Germany (Van de Vijver *et al.* 2020). These four European species, considered cosmopolitan, however, do not share the same ecological preferences as they thrive in different habitats. *Adlafia minuscula* and *N. perminuta* develop in streams with good to very good water quality. Additionally, *N. perminuta* prefers circumneutral to slightly acidic waters (Lange-Bertalot *et al.* 2017). On the other hand, *N. palea* and *S. angusta* prefer more eutrophic to strongly eutrophic waters with a moderate to high electrolyte content. In addition, *S. angusta* develops in waters with low organic matter content, but rich in nutrients (Lange-Bertalot 2001; Lange-Bertalot *et al.* 2017). These species were all observed by Kawecka *et al.* (1998) as single specimens in several samples. *Nitzschia palea* is recognised as a species capable of growing in untreated sewage and heavily polluted habitats (Lange-Bertalot *et al.* 2017). According to data presented by Kawecka *et al.* (1998), only *S. angusta* was noted in the first study conducted in the vicinity of Arctowski Station. *Nitzschia perminuta* was recorded in samples collected in 2002 from Moss Creek, flowing next to Arctowski Station (Noga and Olech 2004).

A fifth possibly European taxon was initially identified as *N. vilaplanii* (Lange-Bertalot and Sabater) Lange-Bertalot and Sabater, a small-celled, narrow species described in 1990 from Spain (Sabater *et al.* 1990). One of the typical features of *N. vilaplanii* is the conspicuous white point visible in LM in the central area between the central raphe endings. However, careful analysis of the Antarctic specimens revealed that this expression of the central nodule is missing, indicating that the Antarctic population is not conspecific with *N. vilaplanii*. Van de Vijver *et al.* (2011b) presented a revision and overview of all *Navicula* species observed with certainty in Antarctica. Unfortunately, none of the reported species showed sufficient morphological similarity leading to the only possible conclusion that the Antarctic population identified as *N. vilaplanii* (listed in Table 2 as *Navicula* sp.) represents an as yet undescribed species.

The observed species are most likely accidentally introduced to Antarctica. Given the very limited number of records and specimens, it is unlikely that they are part of the natural Antarctic flora. If accidentally introduced, their development was most likely possible due to favorable, more fertile conditions in the microhabitats in vicinity of the research station, related to human activities, not found anywhere else in the oligotrophic ecosystems of Antarctica. Recent research indicates that freshwater diatoms in Antarctica are limited in their dispersal and the composition of the diatom flora is primarily influenced by local environmental factors (Verleyen *et al.* 2021). This statement makes natural dispersal of these five European species highly unlikely and a contamination of the Antarctic flora via introduction of non-native species has to be suspected. It may also explain why these species were not found in other samples, even after a thorough taxonomic revision. Moreover, the probability of contamination of the studied samples during transport and/or laboratory work of the samples is negligible, given the variable ecological preferences of the five species. All fixed samples were kept in firmly closed vials until slide preparation in a laboratory intended exclusively for working on Antarctic material.

It is, however, possible that the proportion of cosmopolitan species present in Antarctica may be higher than previously estimated. Most studies on Antarctic diatoms focused on valuable natural areas with much less human impact or devoid of the influence. At present, while the sewage from Arctowski Station complies with the Protocol requirements, the effects on the sensitive ecosystems in close proximity to the research station are not entirely understood. There is a need to conduct a comprehensive study of various micropollutants to accurately evaluate wastewater pollution associated with Arctowski Station (Szopińska *et al.* 2019). Despite the strong geographic isolation of Antarctica, it cannot be ruled out that diatoms are also able to colonise suitable more eutrophic habitats, particularly near research stations. As indicated by Cowan *et al.* (2011), despite the geographic isolation, the Antarctic Continent has never been microbiologically isolated. Recent molecular research has revealed an additional endemism among diatoms typically regarded as cosmopolitan. In the case of the terrestrial diatom *Pinnularia borealis* Ehrenberg (1843), molecular studies have demonstrated the existence of regionally restricted cryptic species in the Antarctic and other areas (Pinseel *et al.* 2020). A similar situation may occur with observed European species. Especially, *N. palea* or *S. angusta* can represent complexes of cryptic species, undistinguishable based only on the morphological analysis, requiring molecular research. To confirm these assumptions, further research is required, not only in valuable natural areas such as the ice-free Antarctic oases but also in regions currently impacted by ongoing human activity. Broady and Smith (1994) emphasised the significance of assessing the presence, dispersion, and potential colonisation of non-indigenous algae within Antarctica.

Conclusions

A high diversity of freshwater diatom species has been observed near Arctowski Station. The obtained results have confirmed the unique nature of the diatom flora in maritime Antarctica and have provided enhanced insights in the nature of freshwater aquatic environments. However, among all taxa four European species, that have not been previously observed in Antarctica, have been recorded in samples collected near Arctowski Station. Our observations suggest that, despite numerous studies that have been conducted for over 20 years as comprehensive taxonomic revision of diatoms in Antarctica, there are still areas requiring more detailed research. Specifically, this includes zones directly adjacent to research stations which are exposed to the presence and diverse human activity, which may impact Antarctic ecosystems. Therefore, it is necessary to monitor the habitats in the immediate vicinity of Arctowski Station, particularly in light of the ongoing construction of new station facilities.

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References

Al-Handal A.Y. and Wulff A. 2008. Marine epiphytic diatoms from the shallow sublittoral zone in Potter Cove, King George Island, Antarctica. *Botanica Marina* 51: 411–435, doi: 10.1515/BOT.2008.053.

Arenz B.E., Held B.W., Jurgens J.A. and Blanchette R.A. 2010. Fungal colonization of exotic substrates in Antarctica. *Fungal Diversity* 49: 13–22, doi: 10.1007/s13225-010-0079-4.

Bargagli R. 2005. *Antarctic ecosystems: environmental contamination, climate change, and human impact*. Springer, Berlin.

Bey M-Y. and Ector L. 2010. Atlas des diatomées des cours d'eau de la région Rhône-Alpes, Tome 1-6. Direction régionale de l'Environnement, de l'Aménagement et du Logement Rhône-Alpes, Lyon.

Broady P.A. and Smith R.A. 1994. A preliminary investigation of the diversity, survivability and dispersal of algae introduced into Antarctica by human activity. *Proceedings of the NIPR Symposium on Polar Biology* 7: 185–197.

Bulínová M., Kochman-Kędziora N., Kopalová K. and Van de Vijver B. 2018. Three new *Hantzschia* species (Bacillariophyta) from the maritime Antarctic region. *Phytotaxa* 371: 168–184, doi: 10.11646/phytotaxa.371.3.2.

Chown S.L., Lee J.E., Hughes K.A., Barnes J., Barrett P.J., Bergstrom D.M., Convey P., Cowan D.A., Crosbie K., Dyer G., Frenot Y., Grant S.M., Herr D., Kennicutt M.C., Lamers M., Murray A., Possingham H.P., Reid K., Riddle M.J., Ryan P. G., Sanson L., Shaw J.D., Sparrow M.D., Summerhayes C., Terauds A. and Wall D.H. 2012. Challenges to the future conservation of the Antarctic. *Science* 337: 158–159, doi: 1126/science.1222821.

Chwedorzewska K.J. 2008. *Poa annua* L. in Antarctic – searching for the source of introduction. *Polar Biology* 31: 263–268, doi: 10.1007/s00300-007-0353-4.

Chwedorzewska K.J. 2009. Terrestrial Antarctic ecosystems at the changing world – an overview. *Polish Polar Research* 30: 263–273, doi: 10.4202/ppres.2009.13.

Chwedorzewska K.J. and Korczak M. 2010. Human impact upon the environment in the vicinity of Arctowski Station, King George Island, Antarctica. *Polish Polar Research* 31: 45–60, doi: 10.4202/ppres.2010.04.

Chwedorzewska K.J., Korczak-Abshire M., Olech M., Lityńska-Zając M. and Augustyniuk-Kram A. 2013a. Alien invertebrates transported to Antarctic by polar expeditions – potential threat. *Polish Polar Research* 34: 55–66, doi: 10.2478/popore−2013−0005.

Chwedorzewska K.J., Korczak-Abshire M., Olech M., Lityńska-Zając M. and Augustyniuk-Kram A. 2013b. Pressure of alien organisms on terrestrial ecosystems of maritime Antarctic. *Kosmos* 62: 351–358 (in Polish).

Chwedorzewska K.J., Giełwanowska I., Olech M., Molina-Montenegro M.A., Wódkiewicz M. and Galera H. 2015. *Poa annua* L. in the maritime Antarctic: an overview. *Polar Record* 51: 637–643, doi: 10.1017/S0032247414000916.

Connor M.A. 2008. Wastewater treatment in Antarctica. *Polar Record* 44: 165–171, doi: 10.1017/S003224740700719X.

Cowan D.A., Chown S.L., Convey P., Tuffin M., Hughes K.A., Pointing S. and Vincent V.F. 2011. Non- indigenous microorganisms in the Antarctic – assessing the risks. *Trends in Microbiology* 19: 540–548, doi: 10.1016/j.tim.2011.07.008.

Ehrenberg C.G. 1843. Verbreitung und Einfluss des mikroskopischen Lebens in Süd-und Nord-Amerika. *Abhandlungen der Königlichen Akademie der Wissenschaften zu Berlin* 1841: 291–445.

Finlay B.J. and Clarke K.J. 1999. Ubiquitous dispersal of microbial species. *Nature* 400: 828, doi: 10.1038/23616.

Hamsher S., Kopalová K., Kociolek J.P., Zidarova R. and Van de Vijver B. 2016. The genus *Nitzschia* on the South Shetland Islands and James Ross Island. *Fottea* 16: 79–102, doi: 10.5507/fot.2015.023.

Hassall A.H. 1850. *A Microscopic Examination of the Water Supplied to the Inhabitants of London and the Suburban Districts*. London: 1–66.

Hughes K.A. 2003a. Influence of seasonal environmental variables on the distribution of presumptive fecal coliforms around an Antarctic research station. *Applied and Environmental Microbiology* 69: 4884–4891, doi: 10.1128/AEM.69.8.4884–4891.2003.

Hughes K.A. 2003b. Aerial dispersal and survival of sewage-derived faecal coliforms in Antarctica. *Atmospheric Environment* 37: 3147–3155, doi: 10.1016/S1352-2310(03)00207-3.

Hughes K.A., Walsh S., Convey P., Richards S. and Bergstrom D.M. 2005. Alien fly populations established at two Antarctic research stations. *Polar Biology* 28: 568–570, doi: 10.1007/s00300-005-0720-y.

Hughes K.A., Convey P., Maslen N.R. and Smith R.I.L. 2010. Accidental transfer of non-native soil organisms into Antarctica on construction vehicles. *Biological Invasions* 2: 875–891, doi: 10.1007/s10530-009-9508-2.

Hughes K.A., Lee J.E., Tsujimoto M., Imura S., Bergstrom D.M., Ware C., Lebouvier M., Huiskes A.H.L., Gremmen N.J.M., Frenot Y., Bridge P.D. and Chown S.L. 2011. Food for thought: Risks of non-native species transfer to the Antarctic region with fresh produce. *Biological Conservation* 144: 2821–2831, doi: 10.1016/j.biocon.2011.03.001.

Hughes K.A., Boyle C.P., Morley-Hurst K., Gerrish L., Colwell S.R. and Convey P. 2023. Loss of research and operational equipment in Antarctica: Balancing scientific advances with environmental impact. *Journal of Environmental Management* 348: 119200, doi: 10.1016/j.jenvman.2023.119200.

Huiskes A.H., Gremmen N.J., Bergstrom D.M., Frenot Y., Hughes K.A., Imura S., Kiefer K., Lebouvier M., Lee J.E., Tsujimoto M., Ware C., Van de Vijver B. and Chown S.L. 2014. Aliens in Antarctica: Assessing transfer of plant propagules by human visitors to reduce invasion risk. *Biological Conservation* 171: 278–284, doi: 10.1016/j.biocon.2014.01.038.

Jones V.J. 1996. The diversity, distribution and ecology of diatoms from Antarctic inland waters. *Biodiversity and Conservation* 5: 1433–1449, doi: 10.1007/BF00051986.

Jongman R.H., Ter Braak C.J.F and Van Tongeren O.F.R. 1987. *Data analysis in community and landscape ecology*. Pudoc, Wageningen.

Kashyap A.K. and Shukla S.P. 2001. *Algal species diversity of Schirmacher Oasis, Antarctica: a survey*. Antarctic Biology in a Global Context, Abstracts of VIII SCAR International Biology Symposium, Amsterdam, Abstract S5P62.

Kawecka B. 2012. *Diatom diversity in streams of the Tatra National Park (Poland) as indicator of environmental conditions*. W. Szafer Institute of Botany, Polish Academy of Sciences, Kraków.

Kawecka B. and Olech M. 1993. Diatom communities in the Vanishing and Ornitologist Creek, King George Island, South Shetlands, Antarctica. *Hydrobiologia* 269/270: 327–333, doi: 10.1007/BF00028031.

Kawecka B., Olech M. and Nowogrodzka-Zagórska M. 1996. Morphological variability of the diatom *Luticola muticopsis* (van Heurck) D.G. Mann in the inland waters of King George Island, South Shetland Islands, Antarctic. *Polish Polar Research* 17: 143–150.

Kawecka B., Olech M., Nowogrodzka-Zagórska M. and Wojtuń B. 1998. Diatom communities un small water bodies at H. Arctowski Polish Antarctic Station (King George Island, South Shetland Islands, Antarctica. *Polar Biology* 19: 183–192, doi: 10.1007/s003000050233.

Kellogg T.B. and Kellog D.E. 2002. Non-marine and littoral diatoms from Antarctic and subantarctic regions. Distribution and updated taxonomy. *Diatom Monographs* 1: 1–795.

Kerry E. 1990. Microorganisms colonizing plants and soil subjected to different degrees of human activity, including petroleum contamination, in the Vestfold Hills and Mac. Robertson land. *Polar Biology* 10: 423–430, doi: 10.1007/BF00233690.

Kochman-Kędziora N., Noga T., Zidarova R., Kopalová K. and Van de Vijver B. 2016. *Humidophila komarekiana* sp. nov. (Bacillariophyta), a new limnoterrestrial diatom species from King George Island (Maritime Antarctica) *Phytotaxa* 272: 184–190, doi: doi.org/10.11646/phytotaxa.272.3.2.

Kochman-Kędziora N., Noga T., Van de Vijver B. and Stanek-Tarkowska J. 2017. A new *Muelleria* species (Bacillariophyta) from the Maritime Antarctic Region. *Fottea* 17: 264–268, doi: 10.5507/fot.2017.003.

Kochman-Kędziora N., Pinseel E., Rybak M., Noga T., Olech M. and Van de Vijver B. 2018. *Pinnularia subcatenaborealis* sp. nov. (Bacillariophyta) a new chain-forming diatom species form King George Island (Maritime Antarctica) *Phytotaxa* 364: 259–266, doi: doi.org/10.11646/phytotaxa.364.3.5.

Kochman-Kędziora N., Olech M. and Van de Vijver B. 2020a. A critical analysis of the type of *Navicula skuae* with the description of a new *Navicula* species (Naviculaceae, Bacillariophyta) from the Antarctic Region. *Phytotaxa* 474: 15–26, doi: 10.11646/phytotaxa.474.1.2.

Kochman-Kędziora N., Zidarova R., Noga T., Olech M. and Van de Vijver B. 2020b. *Luticola puchalskiana*, a new small terrestrial *Luticola* species (Bacillariophyceae) from the Maritime Antarctic Region. *Phytotaxa* 450: 85–94, doi: 10.11646/phytotaxa.450.1.6.

Kochman-Kędziora N., Noga T., Olech M. and Van de Vijver B. 2022. The influence of penguin activity on soil diatom assemblages on King George Island, Antarctica with the description of a new *Luticola* species. *PeerJ.* 10: e13624, doi: 10.7717/peerj.13624.

Kociolek J.P., Kopalová K., Hamsher S.E., Kohler T.J., Van de Vijver B., Convey P., McKnight D.M. 2017. Freshwater diatom biogeography and the genus *Luticola*: An extreme case of endemism in Antarctica. Polar Biology 40: 1185–1196, doi: 10.1007/s00300-017-2090-7.

Kopalová K. and Van de Vijver B. 2013. Structure and ecology of freshwater benthic diatom communities from Byers Peninsula (Livingston Island, South Shetland Islands). *Antarctic Science* 25: 239–253, doi: 10.1017/S0954102012000764.

Kopalová K., Nedbalová L., Nyvlt D., Elster J. and 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: 933–948, doi: 10.1007/s00300-013-1317-5.

Kopalová K., Ochyra R., Nedbalová L. and Van de Vijver B. 2014. Moss-inhabiting diatoms from two contrasting Maritime Antarctic islands. *Plant Ecology and Evolution* 147: 67–84, doi: 10.5091/plecevo.2014.896.

Kopalová K., Soukup J., Kohler T.J., Roman M., Coria S.H., Vignoni P.A, Lecomte K.L., Nedbalová L., Nývlt D. and Lirio J.M. 2019. Habitat controls on limno-terrestrial diatom communities of Clearwater Mesa, James Ross Island, Maritime Antarctica. *Polar Biology* 42: 1595–1613, doi: 10.1007/s00300-019-02547-8.

Kovach Computing Services 2002. *Multivariate statistical package, version 3.1. User's manual*. Kovach Computing Services, Pentraeth, Wales.

Lange-Bertalot H. 2001. *Navicula sensu stricto*. 10 genera separated from *Navicula sensu lato*. *Frustulia. In*: Lange-Bertalot H. (ed.) *Diatoms of Europe 2. Diatoms of the European inland waters and comparable habitats*. Ruggell: A.R.G. Gantner Verlag K.G.

Lange-Bertalot H., Hofmann G., Werum M. and Cantonati M. 2017. Freshwater benthic diatoms of Central Europe: over 800 common species used in ecological assessments. English edition with updated taxonomy and added species. *In*: M. Cantonati, M.G. Kelly, H. Lange-Bertalot (eds.), Koeltz Botanical Books, Schmitten-Oberreifenberg.

Lityńska-Zając M., Chwedorzewska K.J., Olech M., Korczak-Abshire M. and Augustyniuk-Kram A. 2012. Diaspores and phytoremains accidentally transported to the Antarctic Station during three expeditions. *Biodiversity and Conservation* 21: 3411–3421, doi: 10.1007/s10531-012-0371-6.

Liu X., Sun J., Sun L., Liu W. and Wang Y. 2011. Reflectance spectroscopy: A new approach for reconstructing penguin population size from Antarctic ornithogenic sediments. *Journal of Paleolimnology* 45: 213–222, doi: 10.1007/s10933-010-9493-6.

Luścińska M. and Kyć A. 1993. Algae inhabiting creeks of the region of "H. Arctowski" Polish Antarctic Station, King George Island, South Shetlands. *Polish Polar Research* 14: 393–405.

Marsz A. and Rakusa-Suszczewski S. 1987. Ecological characteristics of Admiralty Bay (King George Island, the South Shetland Islands) I: Climate and ice-free areas . *Kosmos* 36: 103–127 (in Polish).

Marsz A. and Styszyńska A. (eds.) 2000. The main features of the climate region the Polish Antarctic Station H. Arctowski (West Antarctica, South Shetland Islands, King George Island). Wyższa Szkoła Morska w Gdyni, Gdynia: 96–97 (in Polish).

Nędzarek A. and Pociecha A. 2010. Limnological characterization of freshwater systems of the Thomas Point Oasis (Admiralty Bay, King George Island, West Antarctica). *Polar Science* 4: 457–467, doi: 10.1016/j.polar.2010.05.008.

Nędzarek A. and Rakusa-Suszczewski S. 2007. Nutrients and conductivity in precipitation in the coast of King George Island (Antarctica) in relation to wind speed and penguin colony distance. *Polish Journal of Ecology* 50: 705–716.

Nikolajev V.A. 1980. Littoral diatoms from Fildes Peninsula, King George Island, South Shetland Islands (The Antarctic). *Botanical Journal (Leningrad)* 65: 1107–1112.

Noga T. and Olech M.A. 2004. Diatom communities in Moss Creek (King George Island, South Shetland Islands, Antarctica) in two summer seasons: 1995/96 and 2001/02. *Oceanological and Hydrobiological Studies* 33: 103–120.

Noga T., Kochman-Kędziora N., Olech M. and Van de Vijver B. 2020. Limno-terrestrial diatom flora in two stream valleys near Arctowski Station, King George Island, Antarctica. *Polish Polar Research* 4: 289–314, doi: 10.24425/ppr.2020.134793.

Olech M. and Chwedorzewska K.J. 2011. The first appearance and establishment of an alien vascular plant in natural habitats on the forefield of a retreating glacier in Antarctica. *Antarctic Science* 23: 153–154, doi: 10.1017/S0954102010000982.

Osyczka P. 2010. Alien lichens unintentionally transported to the „Arctowski" station (South Shetlands, Antarctica). *Polar Biology* 33: 1067–1073, doi: 10.1007/s00300-010-0786-z.

Peter H.-U., Büßer C., Mustafa O. and Pfeiffer S. 2008. *Risk assessment for the Fildes Peninsula and Ardley Island, and development of management plans for their designation as Specially Protected or Specially Managed Areas*. Dessau-Roßlau: Umweltbundesamt (in German).

Plenzler J., Budzik T., Puczko D. and Bialik, R. 2019. Climatic conditions at Arctowski Station (King George Island, West Antarctica) in 2013–2017 against the background of regional changes. *Polish Polar Research* 40: 1–27, doi: 10.24425/ppr.2019.126345.

Pinseel E., Janssens S.B., Verleyen E., Vanormelingen P., Kohler T.J., Biersma E.M., Sabbe K., Van de Vijver B. and Vyverman W. 2020. Global radiation in a rare biosphere soil diatom. *Nature Communications* 11: 2382, doi: 10.1038/s41467-020-16181-0.

Pociecha A. 2008. Density dynamics of *Notholca squamula salina* Focke (Rotifera) in Lake Wujka, a freshwater Antarctic lake. *Polar Biology* 31: 275–279, doi: 10.1007/s00300-007-0355-2.

Rakusa-Suszczewski S. 2002. King George Island – South Shetlands Islands, Maritime Antarctic. *In*: Bayer L. and Bölter M. (eds.) *Geology of Antarctic Ice–Free Landscapes. Ecological Studies.* Springer – Verlag, Berlin, Heidelberg: 23–36.

Sabater S., Tomas X., Cambra J. and Lange-Bertalot H. 1990. Diatom flora of the Cape of Creus, Catalonia, NE-Spain. *Nova Hedwigia* 51: 165–195.

Sabbe K., Verleyen E., Hodgson D.A., Vanhoutte K. and Vyverman W. 2003. Benthic diatom flora of freshwater and saline lakes in the Larsemann Hills and Rauer Islands, East Antarctica. *Antarctic Science* 15: 227–248, doi: 10.1017/S095410200300124X.

Schmidt R., Mäusbacher R. and Müller J. 1990. Holocene diatom flora and stratigraphy from sediment cores of two Antarctic lakes (King George Island). *Journal of Paleolimnology* 3: 55–74.

Skottsberg C. 1954. Antarctic vascular plants. *Botanisk Tidsskrift* 51: 330–338.

Stark J.S., Smith J., King C.K., Lindsay M., Stark S., Palmer A. S., Snape I., Bridgen P. and Riddle M. 2015. Physical, chemical, biological and ecotoxicological properties of wastewater discharged from Davis Station, Antarctica. *Cold Regions Science and Technology* 113: 52–62, doi: 10.1016/j.coldregions.2015.02.006.

Stark J.S., Corbett P.A., Dunshea G., Johnstone G., King C., Mondon J.A., Power M.L., Samuel A., Snape I. and Riddle M. 2016. The environmental impact of sewage and wastewater outfalls in Antarctica: An example from Davis station, East Antarctica. *Water Research* 105: 602–614, doi: 10.1016/j.watres.2016.09.026.

Szopińska M., Marek R., Bialik R.J. and Polkowska Ż. 2019. Examination of fresh water chemistry in maritime Antarctica during austral summer 2017. *AIP Conference Proceedings* 2186: 1–18, doi: 10.1063/1.5138041.

Szopińska M., Luczkiewicz A., Jankowska K., Fudala-Ksiazek S., Potapowicz J., Kalinowska A., Bialik R.J., Chmiel S. and Polkowska Ż. 2021. First evaluation of wastewater discharge influence on marine water contamination in the vicinity of Arctowski Station (Maritime Antarctica). *Science of the Total Environment* 789: 147912, doi: 10.1016/j.scitotenv.2021.147912.

Ter Braak C.J.F. and Prentice I.C. 1988. A theory of gradient analysis. *Advances in Ecological Research* 18: 271–317, doi: 10.1016/S0065-2504(08)60183-X.

Ter Braak C.J.F. and Šmilauer P. 1998. *CANOCO reference manual and users' guide to CANOCO for Windows*. Wageningen: Centre for Biometry.

Tyler P.A. 1996. Endemism in freshwater algae, with special reference to the Australian region. *Hydrobiologia* 336: 127–135, doi: 10.1007/BF00010826.

Van de Vijver B. 2012. *Aulacoseira principissa* sp. nov., a new "centric" diatom species from the sub-Antarctic region. *Phytotaxa* 52: 33–42, doi: 10.11646/phytotaxa.52.1.5.

Van de Vijver B. 2019. Revision of the *Psammothidium manguinii* complex (Bacillariophyta) in the sub-Antarctic Region with the description of four new taxa. *Fottea* 19: 90–106, doi: 10.5507/fot.2019.001.

Van de Vijver B., Gremmen N.J.M. and Beyens L. 2005. The genus *Stauroneis* (Bacillariophyceae) in the Antarctic region. *Journal of Biogeography* 32: 1791–1798, https://www.jstor.org/stable/i369089.

Van de Vijver B., Zidarova R. and de Haan M. 2011a. Four new *Luticola* taxa (Bacillariophyta) from the South Shetland Islands and James Ross Island (Maritime Antarctic Region). *Nova Hedwigia* 92: 137–158, doi: 10.1127/0029-5035/2011/0092-0137.

Van de Vijver B., Zidarova R., Sterken M., Verleyen E., de Haan M., Vyverman W., Hinz F. and Sabbe K. 2011b. Revision of the genus *Navicula* s.s. (Bacillariophyceae) in inland waters of the Sub-Antarctic and Antarctic with the description of five new species. *Phycologia* 50: 281–297, doi: 10.2216/10-49.1.

Van de Vijver B., Cocquyt C., de Hann M., Kopalová K. and Zidarova R. 2013. The genus *Surirella* (Bacillariophyta) in the sub-Antarctic and maritime Antarctic region. *Diatom Research* 28: 93–108, doi: 10.1080/0269249X.2012.739975.

Van de Vijver B., Zidarova R. and Kopalová K. 2014. New species in the genus *Muelleria* (Bacillariophyta) from the Maritime Antarctic Region. *Fottea* 14: 77–90, doi: 10.5507/fot.2014.006.

Van de Vijver B., Kopalová K. and Zidarova R. 2016. Revision of the *Psammothidium germainii* complex (Bacillariophyta) in the Maritime Antarctic Region. *Fottea* 16: 145–156, doi: 10.5507/fot.2016.008.

Van de Vijver B., Wetzel C.E. and Ector L. 2018. Analysis of the type material of *Planothidium delicatulum* (Bacillariophyta) with the description of two new *Planothidium* species from the sub-Antarctic Region. *Fottea* 18: 200–211, doi: 10.5507/fot.2018.006.

Van de Vijver B., Tusset E., Williams D.M. and Ector L. 2020. Analysis of the type specimens of *Fragilaria alpestris* (Bacillariophyta) with description of two new 'araphid' species from the sub-Antarctic and Arctic Region. *Phytotaxa* 471: 1–15, doi: 10.11646/phytotaxa.471.1.1.

Verleyen E., Van de Vijver B., Tytgat B., Pinseel E., Hodgson D. A., Kopalová K., Chown S.L., Van Ranst E., Imura S., Kudoh S., Van Nieuwenhuyze W., Sabbe K. and Vyverman W. 2021. Diatoms define a novel freshwater biogeography of the Antarctic. *Ecography* 44: 548–560. doi: 10.1111/ecog.05374.

Vigo G.B., Leotta G.A., Caffer M.I., Salve A., Bin-Sztein N. and Pichel M. 2011. Isolation and characterization of *Salmonella enterica* from Antarctic wildlife. *Polar Biology* 34: 675–681, doi: 10.1007/s00300-010-0923-8.

Vincent W.F. 2000. Evolutionary origins of Antarctic microbiota: Invasion, selection and endemism. *Antarctic Science* 12: 374–385, doi: 10.1017/S0954102000000420.

Vinocur A. and Unrein F. 2000. Typology of lentic water bodies at Potter Peninsula (King George Island, Antarctica) based on physical-chemical characteristics and phytoplankton communities. *Polar Biology* 23: 858–870, doi: 10.1007/s003000000165.

Wasell A. 1993. Diatom stratigraphy an evidence of holocene environmental changes in selected lake basins in the Antarctic and South Georgia. Stockholm University, Department of Quaternary Research, Ph.D. Thesis.

Wassell A. and Håkansson H. 1992. Diatom stratigraphy in a lake on Horseshoe Island, Antarctica: Marine-brackish-fresh water transition with comments on systematics and ecology of the common diatoms. *Diatom Reseach* 7: 157–194, doi: 10.1080/0269249X.1992.9705205.

Wen J., Xie Z., Han J. and Lluberas A. 1994. Climate, mass balance and glacial changes on small dome of Collins Ice Cap, King George Island, Antarctica. *Antarctic Research* 5: 52–61.

Witkowski A., Lange-Bertalot H. and Metzeltin D. 2000. Diatom flora of marine coasts I. *Iconographia Diatomologica* 7: 1–925.

Zidarova R., Kopalová K. and Van de Vijver B. 2016. Diatoms from the Antarctic Region. Maritime Antarctica. *Iconographia Diatomologica* 24: 1–504.