CZECH POLAR REPORTS 12 (1): 60-77, 2022

Moss inhabiting diatoms of Galindez Island, Argentine Islands (the maritime Antarctica) exhibit low diversity and pronounced differentiation

Barbora Chattová[1*], Andrii Zotov[2,3], Ivan Parnikoza[2,4]

[1]*Department of Botany & Zoology, Faculty of Science, Masaryk University, Kotlářská 2, 611 37, Brno, Czech Republic*
[2]*National Antarctic Scientific Center, Ministry of Education and Science of Ukraine, Shevchenko Ave 16, Kyiv, 01601, Ukraine*
[3]*Institute of Marine Biology, National Academy of Sciences of Ukraine, Pushkinska St. 37, 65125, Odesa, Ukraine*
[4]*Institute of Molecular Biology and Genetics NAS of Ukraine, Zabolotnogo Str. 150, Kyiv, 03143, Ukraine*

Abstract

The moss-inhabiting diatom flora has been surveyed for the first time on the Galindez Island, Argentine Islands, the maritime Antarctica. Altogether, 23 diatom taxa belonging to 9 genera were identified. Diatom taxa distribution exhibited considerable variability across the samples and lower species richness compared to the communities surveyed in other Antarctic regions studied earlier - South Shetland Islands and James Ross Island. A pronounced single-species dominance was revealed by the analysis of moss-inhabiting diatom communities' structure at the majority of moss substrates. The allocation of certain diatom species to the particular moss substrates was detected alongside their complete absence in some samples. The reasons for such moss-inhabiting diatom communities' variability should be further investigated in follow-up studies.

Key words: Antarctic region, Bacillariophyceae, diatoms, ecology, mosses

DOI: 10.5817/CPR2022-1-5

Introduction

Diatoms (*Bacillariophyceae*) play a vital role in both terrestrial and aquatic ecosystems of the Antarctica (Jones 1996, Van de Vijver and Beyens 1999a, Sabbe et al. 2003). The wide adaptive potential gives them capacity to live at different substrates

---

Received November 3, 2021, *accepted* August 5, 2022.

[*]Corresponding author: B. Chattová <barbora.chattova@gmail.com>

Acknowledgements: The authors would like to thank the Turkish Antarctic Program, ITU Polar Research scientific infrastructure and the crew of the Betanzos ship for their support. This study was carried under the auspices of the Presidency of Turkish Republic, supported by the Ministry of Industry and Technology, and coordinated by Istanbul Technical University (ITU) Polar Research Center (PolReC). Furthermore, the authors would like to thank to the Czech Antarctic Research Programme and its crew for provided data and support.

Compliance with Ethical Standards: This study was not accompanied by the emergence of potential conflicts of interest and did not include Human Participants or Animals.

under the water scarcity and even at the absence of water (Van de Vijver et al. 2002a, Pfister et al. 2017, Foets et al. 2020). Epiphytic diatoms inhabit the surface of bryophyte sprouts and lichens. Diatom vegetative cells were shown to exhibit higher tolerance to the extreme temperatures compared to the aquatic diatoms, when experimentally subjected to such extreme conditions, as freezing and drought (Souffreau et al. 2010, 2013, Hejduková et al. 2019).

Antarctic diatom incrustations on mosses are of high research interest, as their species composition, ecological and habitat preferences and their ecosystem role are still rather underexplored. The studies conducted in the sub-Antarctic regions indicated a significant diversity of diatom communities inhabiting the cushions of tall moss turf subformation surface. One of the first studies of sub-Antarctic mosses' epiphytes was focused on diatom communities on the Campbell Island and discovered 59 species (Hickman and Vitt 1974). The species composition and ecology of moss diatoms was extensively surveyed at sub-Antarctic islands in the next few years. The studies of moss-inhabiting diatoms were conducted at South Georgia (Van de Vijver and Beyens 1997), Ile de la Possession (Van de Vijver and Beyens 1999b), Heard Island (Van de Vijver et al. 2004b), Îles Kerguelen archipelago (Van de Vijver et al. 2001, Gremmen et al. 2007), Prince Edward Islands (Van de Vijver et al. 2008), and Ile Amsterdam (Chattová et al. 2021). The above-mentioned studies have initiated the revision of sub-Antarctic diatom flora taxonomy (Van de Vijver et al. 2004a, 2011, 2014a, b). It resulted in the discovery of a number of endemic species, that were previously mistakenly treated as cosmopolitan taxa (Tyler 1996, Sabbe et al. 2003).

Investigation of moss-inhabiting diatoms has just started in Antarctica, as opposed to sub-Antarctic regions. To date, the extensive studies were performed on the Livingston Island (South Shetland Islands) and James Ross Island, which revealed the presence of well-developed and island-specific diatom flora (Kopalová et al. 2014).

The present study aimed at the first-ever investigation of moss-inhabiting diatom flora on the Galindez Island (Argentine Islands, the maritime Antarctica), which is widely separated from the other locations of previous research.

Material and Methods

Study site

Galindez Island (65° 15′ S, 64° 15′ W) belongs to the Argentine Islands and is located at the shelf of the Western Antarctic Peninsula, at a distance of 5 – 6 km from the continent. Its total surface area is 0.8 km^2. The modest yearly temperature amplitude of 9 – 13°C and positive average temperature values are due to the predominance of mild and humid marine type climate (Aleksandrov and Ugrumov, 2014, Savenets et al. 2020).

The western Antarctic Peninsula has ranked among the fastest-warming places on Earth, experiencing a temperature increase 5 times greater than the global average over the past 50 years (Turner et al. 2014).

The topography of the Galindez Island is shaped by the Woozle Hill (51 m a.s.l.) and its surrounding ridges. The long-lasting erosion processes led to the transformations of the island's rocky surface into the system of distinct ridges, uplands and cliffs, which dominate over the ice or permanent snow cover.

The surface water of the Galindez Island is represented by the meltwater streams and by the range of small freshwater lentic and lotic water bodies. The lotic ponds occur in the natural cavities located on the way of meltwater streams. Besides, there are also drainless lakes that develop in depressions as a result of snow melt.

Different plant communities have developed there under the influence of a range of factors, namely the topography, light exposure, the snow-free period duration, humidity, distance from the seacoast, the amount of organic matter derived from birds. These communities can vary from those composed of vascular plants, with high prevalence towards the long vegetation period, to the crustose lichen communities, which can withstand the long-lasting snow cover of snowfields melting slowly within a single austral summer season. The highest continuous plant cover is attributed to the Tall moss turf subformation composed by *Polytrichum strictum* Brid and *Chorisodontium aciphyllum* (Hook. f. & Wilson) Broth. The Bryophyte carpet and mat subformation, and Short moss turf and cushion subformation, are also widely distributed on the Galindez Island, and are often found within the same area. Notably, the first sub-formation occupies the space between the rocks characterized by more humid conditions, whereas the second one is found in a more arid rocky environment. Specific plant communities can be found at the limpet (*Nacella concinna*) shells' deposits at seabirds activity sites, like kelp gull (*Larus dominicanus*). Algae subformation occur in the areas with high nitrogen load (Parnikoza et al. 2018).

All the mentioned plant communities are commonly spread from the seacoast to the islands inland area at elevated points located above the ice and snow level, that either thaw in summer season, or often remain exposed in the part of winter. Sometimes vegetation use shelter provided by artificial structures. It`s especially important in case of wind influence. The plant communities serve as breeding sites for kelp gulls and south polar skuas (*Stercorarius maccormicki*) with the last ones being more attracted by the Tall moss turf subformation. Currently, Galindez Island experiences the gentoo penguin (*Pygoscelis papua*) population expansion, which has already led to degradation of characteristic plant communities at the colonies (Parnikoza et al. 2018). Notably, the presence of birds creates an additional nitrification gradient. Another important factor is unfavorable weather conditions (snow cover, frosts *etc.*) that contribute to the reduction of moss communities in some areas.

Samples collection

22 bryophyte samples were collected during the season of 23rd Ukrainian Antarctic expedition and 2nd Turkish Antarctic expedition in February 2019. The sampling sites were selected based on differences in geology, elevation, moss cover and animal influence in order to maximize their variability. Each sample consists of at least 10 cm^3 of moss. Samples were collected in PVC bottles and fixed with 3% formaldehyde. Each sample was geographically localized using GPS, accompanied by a detailed site description (Appendix 1). Taxonomic assignment of the moss communities was performed as in the previous studies (Ochyra et al. 2008, Parnikoza et al. 2018). The sampling sites are represented in supplementary table (Appendix 1) together with their characteristics according to Chattová et al. (2021). The F-value, referring to the F-classification of Jung (1936), was selected as representative for moisture and used for each sample in order to determine its moisture content. The

humidity scale based on water content was as follows: FI = submerged mosses, FII = free floating mosses, FIII = very wet (water drips from the samples without pressure), FIV = wet (water drips with a slight pressure), FV = quasi-wet (water drips after moderate pressure), FVI = moist (little water produced after high pressure), FVII = quasi-dry (only a few drops of water can be squeezed out), FVIII = dry (contains no water).

Sample preparation and counting

Upon arrival in the Algological Laboratory (Masaryk University, Czech Republic), samples were prepared for further analysis following the method described in van der Werff (1955): small parts of the samples were cleaned by adding 37% H_2O_2 and heating to 80°C for about 1 h. The reaction was completed by addition of an excessive amount of saturated $KMnO_4$. Cleaned diatom valves were mounted in Naphrax® following digestion and centrifugation (three times 10 minutes at 3 700 rpm). The samples and slides are stored at the Department of Botany and Zoology, Masaryk University in Brno (Czech Republic). In each sample, 400 diatom valves were identified and enumerated on random transects by means of oil-immersion at 1,000× magnification using an Olympus BX51 microscope, equipped with Differential Interference Contrast (Nomarski) optics and the Olympus Stream Motion Imaging System. Diatoms were identified to species-level primarily using Zidarova et al. (2016 and references therein).

Data analysis

All samples were analyzed in order to find the relation to the moss species and their source communities. The studied moss communities varied according to the moisture gradient from the driest one - Short moss turf and cushion subformation represented by the samples of *Andreaea regularis* C.Müller to the water-logged one - Bryophyte carpet and mat subformation represented by the samples of *Warnstorfia fontinaliopsis* (Müll.Hal.) Ochyra.

The Community Coefficient of Sorensen was used for a pairwise comparison of the Galindez Island diatom flora with that of the sub-Antarctic and Antarctic islands. The Galindez Island moss inhabiting diatom flora was compared to the terrestrial and aquatic moss diatom flora from Ile Amsterdam (Chattová et al. 2021); Livingston Island, James Ross Island (Kopalová et al. 2014); Heard Island (Van de Vijver et al. 2004b), Prince Edward Islands (Van de Vijver et al. 2008) South Georgia (Van de Vijver and Beyens 1997). The datasets were made taxonomically consistent prior to the similarity analysis. ANOSIM test was used to assess statistically significant differences between the groups. Non-metric Multidimensional Scaling (NMDS) was performed to reduce the multidimensional species data matrix into two dimensions best reflecting site dissimilarities given by diatom species composition. NMDS was based on Bray-Curtis (Sørensen) dissimilarity calculated on square root transformed species data.

Results

Species composition and diversity

The analysis of 22 Galindez Island samples revealed the presence of 23 diatom taxa belonging to 9 genera (Table 1). 5 samples contained (almost) no diatoms, even after counting an entire slide. The distribution of species numbers per sample showed that most samples contained between 3 and 5 taxa per sample (Fig. 1). The average number of taxa per sample reached 4.2 with a median of 5. Species richness per sample ranged from 1 to 11. Three samples were entirely monospecific, composed of only *Pinnularia borealis* Ehrenberg (S2, P2 & S5). The highest species richness was recorded in samples A1 and S8 (11 taxa) (Fig. 3).

The 5 most abundant species accounted for 64.3% of all counted valves. The dominant species were *Pinnularia borealis* with more than 72% of all counted valves, followed by *Eunotia pseudopaludosa* Van de Vijver, De Haan & Lange-Bertalot (14%), *Planothidium subantarcticum* Van de Vijver & C. E. Wetzel (7.4%), *Luticola muticopsis* (Van Heurck) D. G. Mann (6.4%) and *Psammothidium germainii* (Manguin) Sabbe (5.9%). The genera *Pinnularia* (four taxa), *Luticola* (four taxa), *Nitzschia* (four taxa) and *Humidophila* (four taxa) were the most species-rich.

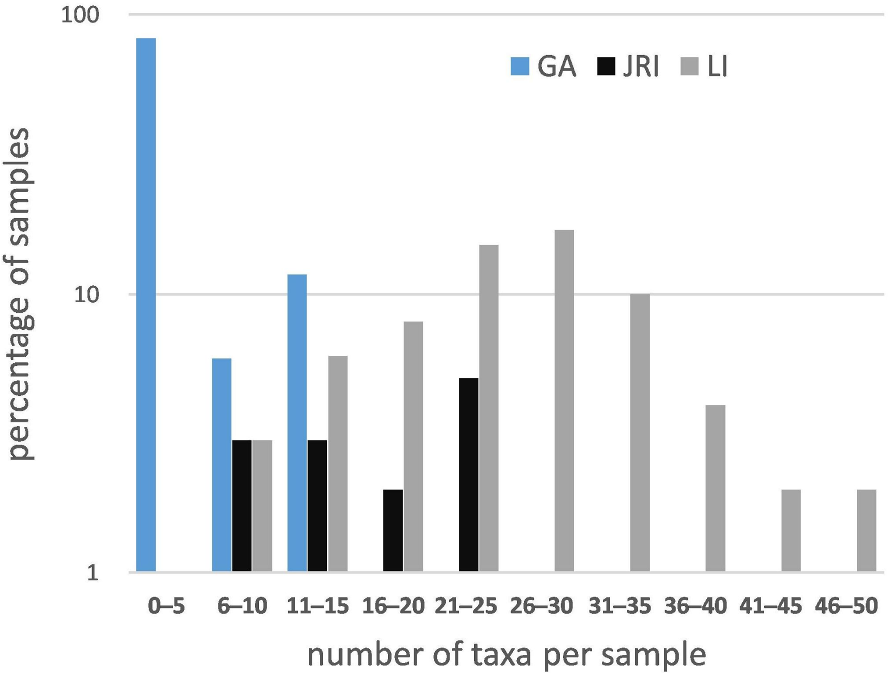

Fig. 1. Distribution of moss-inhabiting diatom samples for the sample sets based on species richness for different studied areas. *Note*: GA – Galindez Island, JRI – James Ross Island, LIV – Livingston Island; (JRI and LIV data - Kopalová et al. 2014).

An alphabetical list of all observed species together with their biogeographical distribution is provided in Table 1. Following the most recent taxonomic concepts (based on information provided by Zidarova et al. (2016a), 17 species (74% of all observed taxa) showed a restricted Antarctic distribution with a majority of species only confined to the Maritime Antarctic Region (MA) (11 species, representing 48% of all observed taxa). Six species (26%) had a typical cosmopolitan distribution (C).

Taxon name	Distribution
Achnanthidium indistinctum Van de Vijver & Kopalová	MA
Eunotia pseudopaludosa Van de Vijver, De Haan & Lange-Bertalot	MA
Hantzschia amphioxys (Ehrenberg) Grunow f. *muelleri* Ts. Kobayashi	CA/MA/AM
Hantzschia cf. *abundans* Lange-Bertalot	C
Humidophila australoshetlandica Kopalová, Zidarova & Van de Vijver	MA
Humidophila inconspicua (Kopalová & Van de Vijver) R.L.Lowe et al.	MA
Humidophila sceppacuerciae Kopalová	MA
Humidophila vojtajarosikii Kopalová, Zidarova & Van de Vijver	MA
Chamaepinnularia australomediocris Lange-Bertalot & Rol. Schmidt) Van de Vijver	MA/SA
Chamaepinnularia krookiformis (Krammer) Lange-Bertalot & Krammer	C
Luticola subcrozetensis Van de Vijver, Kopalová, Zidarova & Levkov	SH
Luticola olegsakharovii Zidarova, Levkov & Van de Vijver	MA
Luticola truncata Kopalová & Van de Vijver	MA
Luticola muticopsis (Van Heurck) D.G. Mann	SH
Nitzschia cf. *annewillemsiana* Hamsher, Kopalová, Kociolek, Zidarova & Van de Vijver	MA
Nitzschia gracilis Hantzsch	C
Nitzschia homburgiensis Lange-Bertalot	C
Nitzschia soratensis E.Morales & Vis	C
Pinnularia australomicrostauron Zidarova, Kopalová & Van de Vijver	MA/CA
Pinnularia australoschoenfelderii Zidarova, Kopalová & Van de Vijver	MA
Pinnularia borealis Ehrenberg	C
Pinnularia microstauroides Zidarova, Kopalová & Van de Vijver	MA
Psammothidium germainii (Manguin) Sabbe	SH

Table 1. Taxonomical list of the moss-inhabiting diatom taxa observed on Galindez Island, the maritime Antarctica. *Note*: CA = Antarctic Continent; MA = Maritime Antarctic Region; AM = South America; SH = Southern Hemisphere; C = widespread species in different regions of the world.

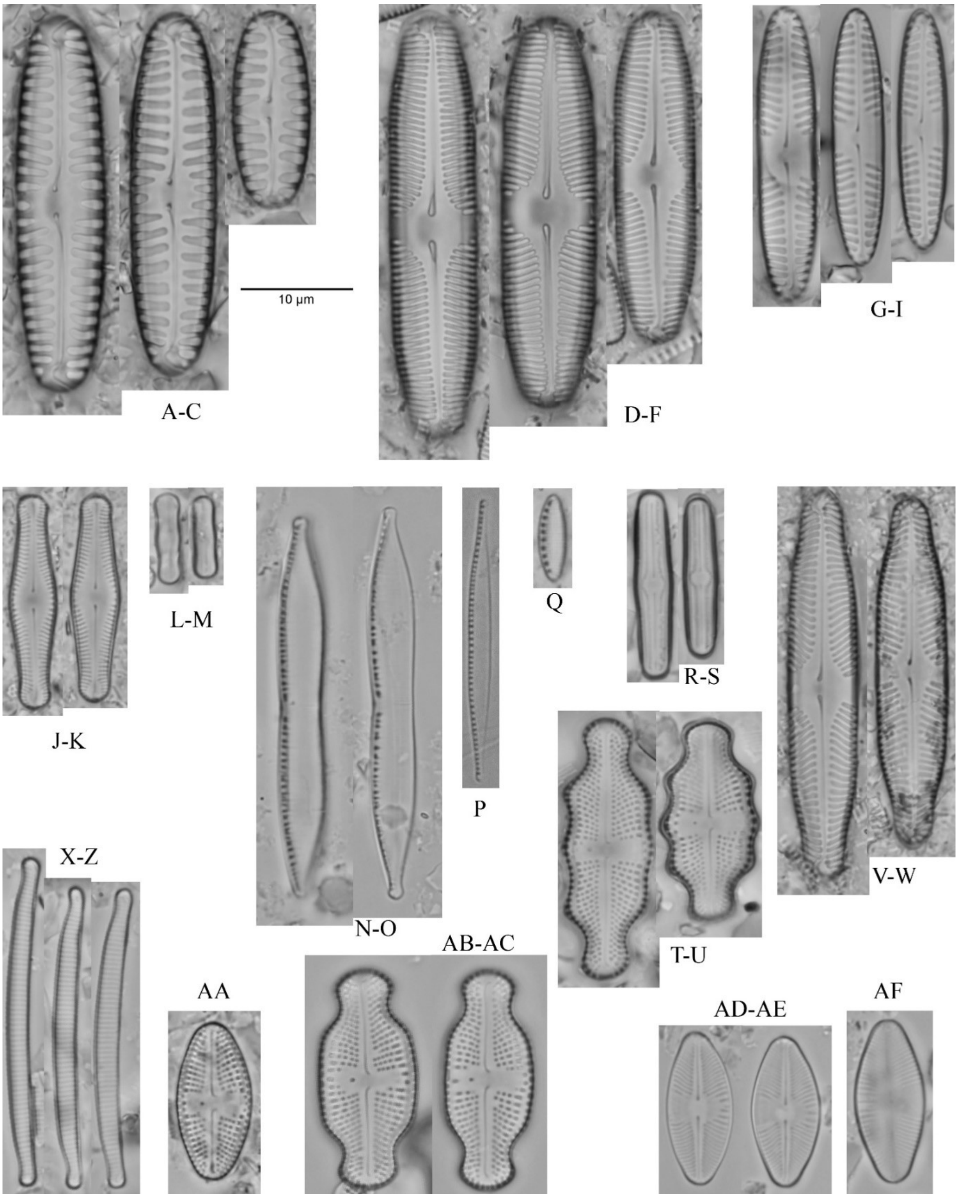

Fig. 2. Light microscope micrographs of selected taxa: A–C *Pinnularia borealis*, D–F *Pinnularia australomicrostauron,* G–I *Pinnularia australoschoenfelderii*, J–K *Chamaepinnularia krookiformis*, L–M *Humidophila sceppacuerciae*, N–O *Nitzschia homburgiensis*, P *Nitzschia gracilis,* Q *Nitzschia soratensis,* R–S *Humidophila australoshetlandica,* T–U *Luticola olegsakharovii*, V–W *Pinnularia microstauroides*, X–Z *Eunotia pseudopaludosa*, AA *Luticola subcrozetensis*, AB–AC *Luticola muticopsis*, AD–AE *Psammothidium germainii* raphe valve, AF *Psammothidium germainii* rapheless valve. Scale bar represents 10 µm.

Community analysis

The distribution of diatom valves was analyzed in relation to the bryophyte substrate species. The matrix of diatom distribution in different moss samples demonstrates the absence of valves in several samples of liverworts, *Polytrichum strictum* and *Chorisodontium aciphyllum* (Fig. 3).

The cosmopolitan *Pinnularia borealis* species was also characterized by the highest relative abundance (48–100%, 90% on average) in 13 out of 17 samples (Fig. 3). The other 4 samples were dominated by the following species: *Luticola muticopsis* accounted for 92% in *Sanionia* sp. (sample S1); *Psammothidium germainii* was the dominant one in *Warnstorfia fontinaliopsis* (87%) (sample W1); *Eunotia pseudopaludosa* dominated in *Sanionia* sp. (96%) (sample S4) and in liverworts (59%) (sample L3). *Pinnularia borealis* was sub-dominating in liverworts (41%) (Fig. 3). Similar situation was observed in *Sanionia* sp. (sample S3), where *Pinnularia borealis* and *Eunotia pseudopaludosa* contributed similarly to the diatom community (48 and 46% respectively) (Fig. 3).

Apart from the 4 mentioned dominants 19 species were detected, which contributed <4% to the total diatom abundance.

The diatom valves were absent in the samples of moss *Polytrichum strictum* (P1, P4, P6, P7), liverworts (L1, L2) and *Chorisodontium aciphyllum* (C1) (Fig. 3). These samples vary by such characteristics as m a. s. l., biotic class and salt class. Yet, they are similar in their low moisture content, as most of them belong to the VII and VIII humidity scale classes, and only two are affiliated to V class.

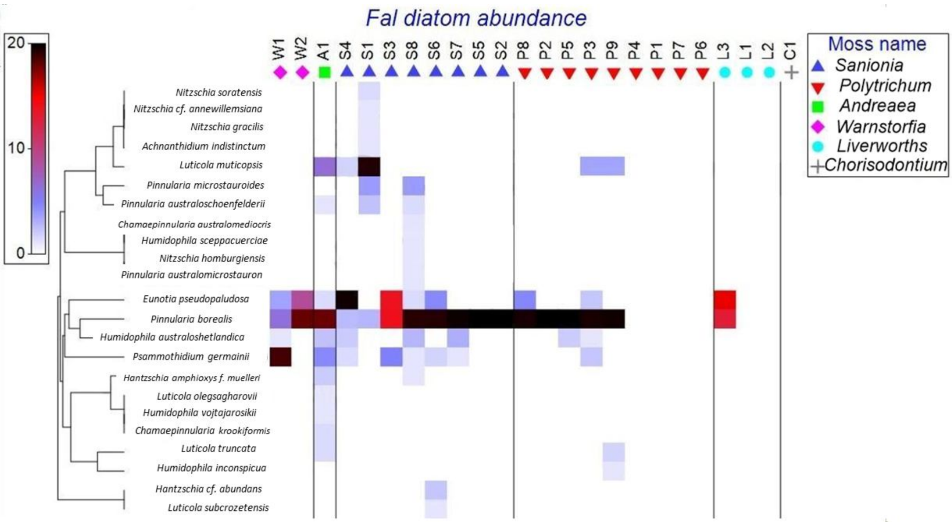

Fig. 3. Distribution of moss-inhabiting diatom species in samples from Galindez Island, the maritime Antarctica in relation to moss substrate taxonomy.

Some samples harbored unique species or species complexes that were not observed in the other samples. For instance, A1 sample of *Andreaea regularis* was characterized by the presence of *Humidophila vojtajarosikii* Kopalová, Zidarova & Van de Vijver*, Chamaepinnularia krookiformis* (Krammer) Lange-Bertalot & Krammer and *Luticola olegsakharovii* Zidarova, Levkov & Van de Vijver. The species of *Humidophila sceppacuerciae* Kopalová, *Chamaepinnularia australomediocris* Kopalová, Zidarova & Van de Vijver*,* *Nitzschia homburgiensis* Lange-Bertalot and *Pinnularia australomicrostauron* Zidarova, Kopalová & Van de Vijver were only detected in S8 sample; *Hantzschia* cf. *abundans* Lange-Bertalot and *Luticola subcrozetensis* Van de Vijver, Kopalová, Zidarova & Levkov – in S6 sample, *Achnanthidium indistinctum* Van de Vijver & Kopalová, *Nitzschia* cf. *annewillemsiana* Hamsher, Kopalová, Kociolek, Zidarova & Van de Vijver, *Nitzschia gracilis* Hantzsch and *Nitzschia soratensis* E. Morales & Vis – in S1 sample (*Sanionia* sp.). *Humidophila inconspicua* (Kopalová & Van de Vijver) R.L.Lowe et al. was only observed in *Polytrichum strictum* (P9 sample). Such differences might arise from the particular influence of substrate on the taxonomic distribution, yet interpretation of these specific cases needs further investigations.

The ANOSIM test on the valves from the moss substrates indicates the absence of statistically significant difference between the groups (R = 0.01). Similarly, there was no statistically significant impact of moss substrate species on the diatom community differentiation. Thus, for this set of samples the humidity and moss species factors do not contribute to diatom community taxonomic structure differentiation, when analyzed separately.

The same is indicated by the samples' distribution according to the results of CLUSTER analysis. The samples belonging to the same cluster originate from the groups with different moss substrates. The NMDS plot based on Bray-Curtis similarities indicates the mixed distribution, yet reveals the pronounced difference of the sample from *Andreaea* with the driest community and two samples from *Sanionia* sp. from the other samples (Fig. 4). Geographic location of studies focused on moss-inhabiting diatom flora mentioned in the text can be found in Fig. 5.

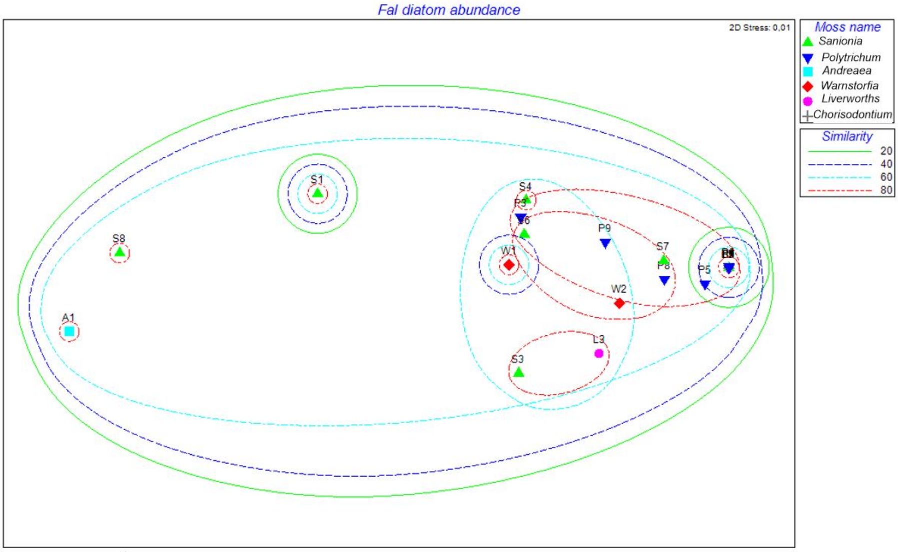

Fig. 4. Non-metric Multidimensional Scaling (NMDS) analysis of moss-inhabiting diatom communities on Galindez Island, the maritime Antarctica (moss substrate factor visualized).

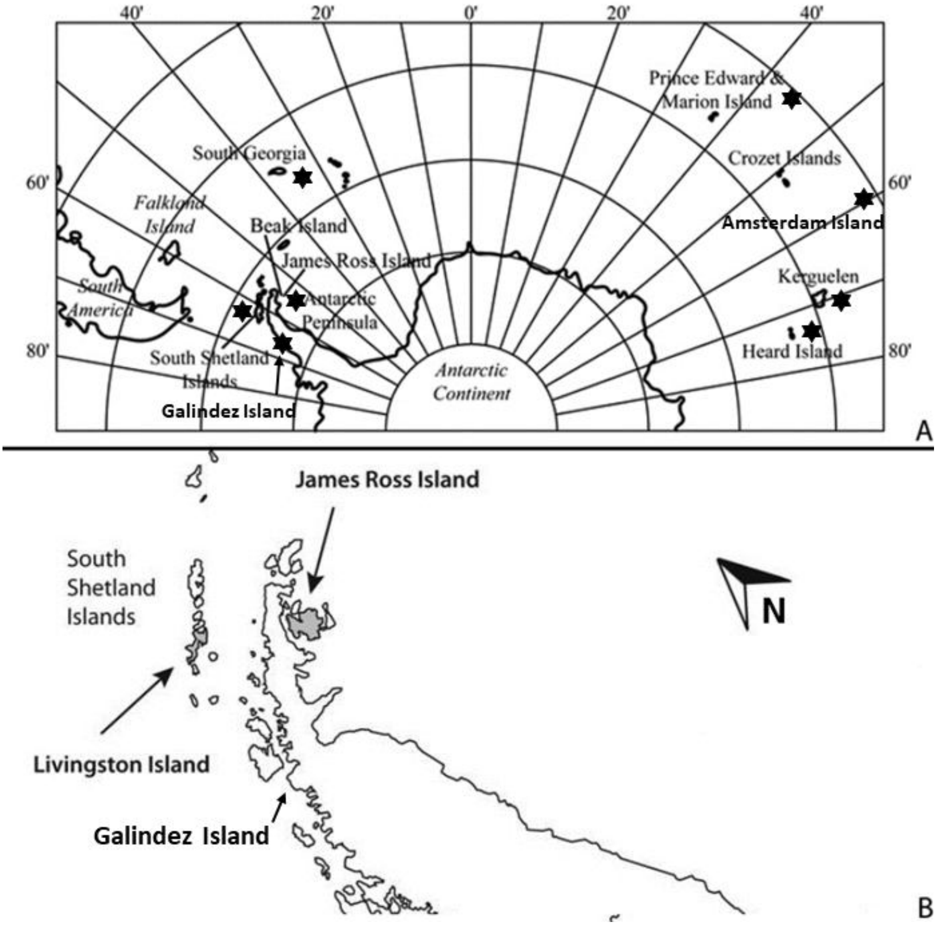

Fig. 5. Geographic location of studies focused on moss-inhabiting diatom flora in (sub)-Antarctica: A – overview of the southern hemisphere with the location of several islands and archipelagos mentioned in the text (marked with an asterisk); B – detailed map of Antarctic Peninsula region showing the position of James Ross Island, Livingston Island and Galindez Island.

	Livingston Island, James Ross Island	**Ile Amsterdam**	**Heard Island**	**Prince Edward Islands**	**South Georgia**
Number of taxa	123	125	181	198	101
Sørensen index	0.13	0.06	0.06	0.04	0.02

Table 2. Similarity analysis (Sørensen index) between Galindez Island and other sub-Antarctic and Antarctic localities. References to original datasets used for the similarity analysis: Ile Amsterdam (Chattová et al. 2021); Livingston Island, James Ross Island (Kopalová et al. 2014); Prince Edward Islands (Van de Vijver et al. 2008); Heard Island (Van de Vijver et al. 2004b); South Georgia (Van de Vijver and Beyens 1997).

Discussion

The diatoms' taxonomic distribution was notably different in the samples from the Galindez Island when compared to the previously studied Antarctic locations (*see* Fig. 1). Less than 5 taxa were found in the majority of the samples (14 out of 17). The number of diatom taxa in the remaining 3 samples ranged from 8 to 11. By contrast the average taxa number was 16 ranging from 7 to 24 in the samples from the James Ross Island (Kopalová et al. 2014). The samples collected on the Livingston Island had 25 taxa on average and 9 to 46 taxa per sample (Kopalová et al. 2014) (Fig. 1). Therefore, such low species number (1–5), as in 82% of the samples from the Galindez Island, has never been observed in the samples from the other Antarctic islands (Fig. 1). Even though the same methods were used for sampling and the sample processing, such prominent differences could have arised from either the small sample size, the different bryophyte species composition, or the specific environmental conditions on Galindez Island. The general species richness of moss-inhabiting diatoms from the sub-Antarctic islands is substantially higher than that observed on the Galindez Island. Indeed, 104 diatom taxa were revealed in the study of South Georgia mosses' epiphytes (Van de Vijver and Beyens 1997) and over 190 taxa were found in the mosses from Ile de la Possession (Van de Vijver and Beyens 1999b). The survey of moss-inhabiting diatoms from the Heard Island found 192 taxa (Van de Vijver et al. 2004b). Nearly 170 diatom taxa were observed on Îles Kerguelen archipelago (Van de Vijver et al. 2001, Gremmen et al. 2007), whereas 214 freshwater and moss-inhabiting diatom species were found on the Prince Edward Islands (Van de Vijver et al. 2008). The recent analysis of 148 samples from Ile Amsterdam revealed 125 taxa belonging to 38 genera (Chattová et al. 2021). 123 diatom taxa were found in 68 water-saturated and dry moss samples from the Antarctic Livingston Island (Kopalová et al. 2014), which is close to the average species richness observed on sub-Antarctic and Antarctic islands surveyed for moss-inhabiting diatoms. The lowest taxa number to date (57) was found on the James Ross Island, representing a transitional zone between Maritime and Continental Antarctic regions (Ambrožová et al. 2019), and known for the specific limited environmental conditions range (Kopalová et al. 2014). It should be noted that species diversity of moss-inhabiting diatoms from the James Ross Island was analyzed based on the limited number of samples (16) including both water-saturated and dry moss (Kopalová et al. 2014). Hence, the number of samples collected on the James Ross Island was lower than that from the Galindez Island.

Sørensen index calculated for the Galindez Island indicates the highest similarity of its diatom flora to that of the Livingston Island and James Ross Island (0.13) (*see* Table 2). Meanwhile, Sørensen index for the Galindez Island and the sub-Antarctic islands was considerably lower – 0.06 (for Ile Amsterdam and Heard Island) and 0.02 South Georgia (Table 2). Out of 15 diatom taxa shared between the Galindez Island and other Antarctic and sub-Antarctic islands, 6 are cosmopolitan species, 3 species are observed in the Southern Hemisphere, with the remaining 6 taxa belonging to the Maritime Antarctic Region, yet 3 of them have higher distribution range and can be found in South America and on the Antarctic Continent.

The pattern of affinity between the moss-inhabiting diatoms from the sub-Antarctic and Antarctic islands is characterized by substantial differences. Indeed, the Ile Amsterdam diatom flora demonstrated limited similarity to that of the other sub-Antarctic islands, while the Sørensen index ranged from 0.24 to 0.48 (Chattová et al. 2021). The similarity coefficients calculated for diatom flora of the other sub-Antarctic island - Prince Edward Island, were higher and varied between 0.69 for Kerguelen and 0.35 for Ile Amsterdam (Van de Vijver et al. 2008). The diatom flora similarity coefficients of Antarctic James Ross Island and Livingston Island compared to the sub-Antarctic islands in the Southern Indian and Atlantic Ocean were notably lower (Kopalová et al. 2014).

The similarity coefficient between the James Ross Island and Livingston Island amounted to 0.57, whereas for the sub-Antarctic islands it varied between 0.11 (James Ross Island - Prince Edward Island) and 0.19 (Livingston Island - Heard Island). The Sørensen index calculated for these islands and the Galindez Island were considerably lower and should be confirmed in the upcoming studies.

The Livingston Island species richness estimates were 138 (Chao2) or 142 (ICE) (Kopalová et al. 2014) meaning that from 87 to 89% of the theoretical total taxa number were covered by calculation. At the same time, 62% (ICE) - 69% (Chao2) taxa were quantified in the study of the James Ross Island (Kopalová et al. 2014). This raises the question, if 23 moss-inhabiting diatom species revealed in 22 samples from the Galindez Island represent the species richness of the studied region. To answer this question a new, more representative dataset of samples was taken during the XXVI Ukrainian Antarctic Expedition (2021-2022).

The relatively low species richness found in the studies of Antarctic moss-inhabiting diatoms compared to the sub-Antarctic is in line with the general trend of a decrease in biodiversity from the North to the South of the region (Jones 1996, Van de Vijver and Beyens 1999a). Firstly, this could be attributed to the decrease in variability of environmental conditions. The areas of moss distribution in the maritime Antarctica are typically limited to humid sites, which are elevated above the sea and ice level and subjected to thawing in summer. Meanwhile, the moss communities occupy almost the whole area of the sub-Antarctic islands irrespective of the topography (Van de Vijver et al. 2002a). The Antarctic Continent conditions shape the moss flora that is adapted to having a limited period of sufficient moisture availability during the summer snow thawing only (Robinson et al. 2000). Similar conditions are observed on the James Ross Island, which harbors considerably lower moss-inhabiting diatoms' diversity compared to the other Antarctic island - Livingston Island (Kopalová et al. 2014). The low yearly precipitation on the James Ross Island results in the periodic desiccation of moss, contrary to the Livingston Island with its continuously sufficient moisture (Kopalová et al. 2014). Only the typical terrestrial diatom taxa are capable of surviving the temporary dry periods, as the conditions of epiphytic diatom existence are limited (Kopalová et al. 2014). The conditions described for the James Ross Island are rather similar to those on the Galindez Island, which might be responsible for the corresponding decrease in species richness. However, the number of moss-inhabiting diatom species revealed on the Galindez Island is almost 3-fold lower than that on the James Ross Island. This highlights the necessity of further research focused on both spatial and temporal variability of moss-inhabiting diatoms' species richness.

The absence of diatoms in some samples is intriguing and is supposed to be attributed to the difference in substrate characteristics, such as its humidity. The algae are absent in *Chorisodontium aciphyllum* (C1) sample, in several *Polytrichum strictum* samples (presumably dry P1, P4, P6, P7), and in *liverworts* (L1 and L2). The L3 or 3-3 liverworts sample harbored particularly poor diversity, which evidences the above-mentioned trend. Additionally, it is corroborated by the fact that no algae were detected in some *Poly-*

trichum samples. For instance, no diatoms were found in uprooted *Polytrichum strictum* from the nest material. At the same time, they were observed in the dead *Polytrichum strictum*. This supports the idea of the moisture level being a limiting factor in the development of epiphytic diatoms.

The influence of moisture level on the moss-inhabiting diatom communities' structure is highlighted in a range of studies. Indeed, this factor was the most prominent one explaining the distribution of diatom communities at South Georgia, Ile de la Possession and Prince Edward Islands (Van de Vijver and Beyens 1997, 1999b; Van de Vijver et al. 2008). Yet, the moisture is the only factor that shapes the development of algae integrally.

The community structure of soil diatoms on Ile de la Possession is in accordance with both the moisture factor, and the nutrients' (phosphates and sulfates) availability (Van de Vijver et al. 2002b). pH was shown to influence moss-inhabiting diatom distribution on the Heard Island along with the other factors (Van de Vijver et al. 2004b). The altitude was the best predictor of the shifts in moss-inhabiting diatoms' taxonomic composition on Îles Kerguelen (Gremmen et al. 2007). The altitude, pH and conductivity were shown to be the key factors that determine the moss-inhabiting diatoms' community structure on Ile Amsterdam, besides the moisture factor (Chattová et al. 2021). The biotic stress factor, which is caused by marine birds and mammals and leads to increased salinity and nutrient content, is playing the key role in shaping the species composition of diatoms on the Antarctic Livingston Island and James Ross Island along with the moisture (Kopalová et al. 2014). Notably, no preferences towards the moss species as a habitat were revealed in the study of moss-inhabiting diatoms on the Livingston Island. Indeed, only one diatom complex was associated with *Warnstorfia fontinaliopsis* (Müll.Hal.) Ochyra, whereas the remaining two complexes were characterized by the prevalence of the other moss species (Kopalová et al. 2014).

The limited samples' set collected on the Galindez Island does not demonstrate any clear distribution pattern of the moss-inhabiting diatoms' community structure in accordance with the moisture factor. The moderate altitude of up to 50 m above the sea level did not show any significant effect either. The 3 *Sanionia* sp. samples (S1, S7, S8) cluster separately. Those are considerably different from the other samples in their conditions and are characterized by a combination of high biotic stress and significant moisture factor. S1 and S8 samples stand out in their relatively high species richness (11 and 8 taxa respectively). Yet, S1 is the only sample with the dominance of *Luticola muticopsis*, whereas S8 was dominated by the more abundant *Pinnularia borealis. Pinnularia borealis* was also dominant in S7 sample alongside the low abundance of accompanying species.

The maximum species richness (11) with the dominance of *Pinnularia borealis* was also detected for A1 sample of *Andreaea regularis* moss. Contrary to the S8 the A1 sample was characterized by drier conditions (F-value – 8) and zero biotic class and salt class value.

S3 and L3 samples stood out from the rest, as they were dominated by *Pinnularia borealis* and *Eunotia pseudopaludosa*. Yet, the absence of the common environmental factors' complex does not allow speculating about the reasons behind the observed taxonomic distribution. Therefore, we suggest that the future studies should be focused on more representative analysis of diatom communities of the central maritime Antarctica, and such factors, as moisture and biotic stress (which is caused by marine birds and mammals and leads to increased salinity and nutrient content, Van de Vijver et al. 2002b, Chattová et al. 2021), as those seem to play key role in shaping the moss-inhabiting diatoms taxonomic distribution.

Conclusion

1. 23 taxa of moss-inhabiting diatoms were revealed by the preliminary study on the Galindez Island. This species richness is lower than that of the other Antarctic localities, which is intriguing and highlights the necessity of further research.

2. The moss-inhabiting diatoms' taxonomic distribution is notably different in the samples from the Galindez Island and in those from the other Antarctic islands (James Ross Island and Livingston Island). Contrary to the other Antarctic localities, 80% of the samples from the Galindez Island are characterized by low species richness not exceeding 5 taxa.

3. Several distinct samples with relatively higher species richness stood out from the rest as a result of taxonomic distribution analysis. Those were characterized by drier conditions, or, in another instance, by a combination of high biotic class and salt class along with considerable moisture content.

4. The absence of algae in several samples is attributed to substrate peculiarities, such as moisture content. This statement is partially supported by the fact that no diatoms were detected in some *Polytrichum strictum* samples. For instance, no diatoms were found in uprooted *P. strictum* from the nest material. At the same time, they were observed in the dead *P. strictum*.

5. The diatom community structure, in particular it's taxonomy, is shaped by the set of ecological factors, such as moisture, which plays significant, but sometimes not the crucial role. This is supported by the homogeneous structure of communities inhabiting water-logged *Warnstorfia fontinaliopsis* moss, and heterogeneous structure of those from *Polytrichum strictum.* The peculiarities of microniche conditions of certain moss species are evidenced by the high species richness of diatom communities inhabiting the dry *Andreaea regularis* moss.

References

Aleksandrov, V. Ya., Ugrumov, A. I. (2014): *Klimat Antarcktyczeskogo Poluostrova i jego izmenenia* [Climate of antarctic Peninsula and its changes]. SPb.: RGGMU, 102 p.

Ambrožová, K., Láska, K., Hrbáček, F., Kavan, J. and Ondruch, J. (2019): Air temperature and lapse rate variation in the ice - free and glaciated areas of northern James Ross Island, Antarctic Peninsula, during 2013–2016. *International Journal of Climatology*, 39(2): 643-657.

Chattová, B., Lebouvier, M., Syrovátka, V. and Van de Vijver, B. (2021): Moss-inhabiting diatom communities from Ile Amsterdam (TAAF, southern Indian Ocean). *Plant Ecology and Evolution*, 154(1): 63-79. doi: 10.5091/plecevo.2021.1767

Foets, J., Wetzel, C.E., Teuling, A. J. and Pfister, L. (2020): Temporal and spatial variability of terrestrial diatoms at the catchment scale: controls on productivity and comparison with other soil algae. *PeerJ*, 8: e9198. doi: 10.7717/peerj.9198

Gremmen, N. J. M., Van de Vijver, B., Frenot, Y. and Lebouvier, M. (2007): Distribution of moss-inhabiting diatoms along an altitudinal gradient at sub-Antarctic Îles Kerguelen. *Antarctic Science*, 19(1): 17-24. doi: 10.1017/S0954102007000041

Hejduková, E., Pinseel, E., Vanormelingen, P., Nedbalová, L., Elster, J., Vyverman, W. and Sabbe, K. (2019): Tolerance of pennate diatoms (Bacillariophyceae) to experimental freezing: comparison of polar and temperate strains. *Phycologia,* 58(4): 382-392. doi: 10.1080/00318884.2019.1591835

Hickman, M., Vitt, D. H. (1974): The aerial epiphytic diatom flora of moss species from subantarctic Campbell Island. *Nova Hedwigia*, 24: 443-458.

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

JUNG, W. (1936): Thecamöben ursprünglicher lebender deutscher Hochmoore. *Abhandlungen aus dem Landesmuseum für Naturkunde zu Münster in Westfalen*, 7: 1-87.

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(1): 67-84. doi: 10.5091/plecevo.2014.896

OCHYRA, R., LEWIS SMITH, R. I. L. and BEDNAREK-OCHYRA, H. (2008): The illustrated moss flora of Antarctica. Cambridge: Cambridge University Press. 704 p.

PARNIKOZA, I., BEREZKINA, A., MOISEYENKO, Y., MALANCHUK, V. and KUNAKH V. (2018): Complex survey of the Argentine Islands and Galindez Island (maritime Antarctic) as a research area for studying the dynamics of terrestrial vegetation. *Ukrainian Anatarctic Journal*, 1(17): 73-101. doi: 10.33275/1727-7485.1(17).2018.34

PFISTER, L., WETZEL, C. E., KLAUS, J., MARTÍNEZ-CARRERAS, N., ANTONELLI, M., TEULING, A. J. and MCDONNELL, J. J. (2017): Terrestrial diatoms as tracers in catchment hydrology: A review. *WIREs Water*, 4(6): e1241. doi: 10.1002/wat2.1241

ROBINSON, S.A., WASLEY, J., POPP, M. and LOVELOCK, C.E. (2000): Desiccation tolerance of three moss species from continental Antarctica. *Australian Journal of Plant Physiology*, 27: 379-388. doi: 10.1071/PP99133

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(2): 227-248. doi: 10.1017/S095410200300124X

SAVENETS, M., PYSARENKO, L. and PISHNIAK, D. (2020): Microclimatic variations of land surface temperature on Galindez Island (western part of the Antarctic Peninsula). *Ukrainian Antarctic Journal*, 2: 3-15. doi: 10.33275/1727-7485.2.2020.648

SOUFFREAU, C., VANORMELINGEN, P., SABBE, K. and VYVERMAN, W. (2013): Tolerance of resting cells of freshwater and terrestrial benthic diatoms to experimental desiccation and freezing is habitat-dependent. *Phycologia*, 52(3): 246-255. doi: 10.2216/12-087.1

SOUFFREAU, C., VANORMELINGEN, P., VERLEYEN, E., SABBE, K. and VYVERMAN, W. (2010): Tolerance of benthic diatoms from temperate aquatic and terrestrial habitats to experimental desiccation and temperature stress. *Phycologia*, 49(4): 309-324. doi: 10.2216/09-30.1

TURNER, J., BARRAND, N. E., BRACEGIRDLE, T. J., CONVEY, P., HODGSON, D. A., JARVIS, M. and KLEPIKOV, A. (2014): Antarctic climate change and the environment: An update. *Polar Record*, 50(3): 237-259.

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., BEYENS, L. (1997): The epiphytic diatom flora of mosses from Strømness Bay area, South Georgia. *Polar Biology*, 17: 492-501. doi: 10.1007/s003000050148

VAN DE VIJVER, B., BEYENS, L. (1999a): Biogeography and ecology of freshwater diatoms in Subantarctica: A review. *Journal of Biogeography*, 26(5): 993-1000. doi: 10.1046/j.1365-2699.1999.00358.x

VAN DE VIJVER, B., BEYENS, L. (1999b): Moss diatom communities from Ile de la Possession (Crozet, Subantarctica) and their relationship with moisture. *Polar Biology*, 22: 232-240. doi: 10.1007/s003000050414

VAN DE VIJVER, B., BEYENS, L. and LANGE-BERTALOT, H. (2004a): The genus *Stauroneis* in the Arctic and (Sub-) Antarctic Regions. *Bibliotheca Diatomologica*, 51: 1-311.

VAN DE VIJVER, B., BEYENS, L., VINCKE, S. and GREMMEN, N. J. M. (2004b): Moss-inhabiting diatom communities from Heard Island, sub-Antarctic. *Polar Biology*, 27: 532-543. doi: 10.1007/s00300-004-0629-x

VAN DE VIJVER, B., DE HAAN, M. and LANGE-BERTALOT, H. (2014a): Revision of the genus *Eunotia* (Bacillariophyta) in the Antarctic Region. *Plant Ecology and Evolution*, 147(2): 256-284. doi: 10.5091/plecevo.2014.930

VAN DE VIJVER, B., FRENOT, Y. and BEYENS, L. (2002a): Freshwater diatoms from Ile de la Possession (Crozet Archipelago, Subantarctica). *Bibliotheca Diatomologica*, 46: 1-412.

Van de Vijver, B., Gremmen, N. J. M. and Smith, V. (2008): Diatom communities from the Sub-Antarctic Prince Edward Islands: Diversity and distribution patterns. *Polar Biology*, 31: 795-808. doi: 10.1007/s00300-008-0418-z

Van de Vijver, B., Kopalová, K., Zidarova, R. and Levkov, Z. (2014b): Revision of the genus *Halamphora* (Bacillariophyta) in the Antarctic Region. *Plant Ecology and Evolution* 147(3): 374-391. doi: 10.5091/plecevo.2014.979

Van de Vijver, B., Ledeganck, P. and Beyens, L. (2001): Habitat preferences in freshwater diatom communities from sub- Antarctic Iles Kerguelen. *Antarctic Science*, 13(1): 28-36. doi: 10.1017/S0954102001000050

Van de Vijver, B., Ledeganck, P. and Beyens, L. (2002b): Soil diatom communities from Ile de la Possession (Crozet, sub-Antarctica). *Polar Biology*, 25: 721-729. doi: 10.1007/s00300-002-0392-9

Van de Vijver, B., Zidarova, R., Sterken, M., Verleyen, E., de Haan, M., Vyverman, W., Hinz, F. and Sabbe, K. (2011): 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(3): 281-297. doi: 10.2216/10-49.1

Van der Werff, A. (1955): A new method for cleaning and concentrating diatoms and other organisms. *Verhandlungen der Internationalen Vereinigung für theoretische und angewandte Limnologie*, 12: 276-277.

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

Appendix 1

Sample	Sample*	Location	Date	Location/Sample type	GPS
Moss1	S1	Galindez Island, Vernadsky base	9.2.2019	near a pond at point D1 close to the Vernadsky base	S 65°14′41.4"; W 64°15′19,4"
Moss2a	S2	Galindez Island	9.2.2019	moss bank 1a	S 65°14′43.4"; W 64°15′14.6"
Moss2b	P1	Galindez Island	9.2.2019	moss bank 1a	S 65°14′43.4"; W 64°15′14.6"
Moss3a	S3	Galindez Island	9.2.2019	slightly wet spot close to the sea, "Karpaty"	S 65°14′46.0"; W 64°14′58.2"
Moss3b	P2	Galindez Island	9.2.2019	slightly wet spot close to the sea, "Karpaty"	S 65°14′46.0"; W 64°14′58.2"
Moss4a	S4	Galindez Island	9.2.2019	down the slope, under a terrace	S 65°14′48.1"; W 64°14′56.3"
Moss4b	P3	Galindez Island	9.2.2019	down the slope, under a terrace	S 65°14′48.1"; W 64°14′56.3"
Moss5	A1	Galindez Island	9.2.2019	path near WLF	S 65°14′46.7"; W 64°14′54.4"
Moss 6	P4	Galindez Island	9.2.2019	wet soil near a temporary pond, Smith moss bank	S 65°14′51.4"; W 64°15′01.9"
subsample 6a	W1	Galindez Island	9.2.2019	wet soil near a temporary pond, Smith moss bank	S 65°14′51.4"; W 64°15′01.9"
subsample 6b	L1	Galindez Island	9.2.2019	wet soil near a temporary pond, Smith moss bank	S 65°14′51.4"; W 64°15′01.9"
subsample 6c	L2	Galindez Island	9.2.2019	wet soil near a temporary pond, Smith moss bank	S 65°14′51.4"; W 64°15′01.9"
subsample6d	C1	Galindez Island	9.2.2019	wet soil near a temporary pond, Smith moss bank	S 65°14′51.4"; W 64°15′01.9"
subsample6e	P5	Galindez Island	9.2.2019	wet soil near a temporary pond, Smith moss bank	S 65°14′51.4"; W 64°15′01.9"
subsample6f	S5	Galindez Island	9.2.2019	wet soil near a temporary pond, Smith moss bank	S 65°14′51.4"; W 64°15′01.9"
Moss7	P6	Galindez Island	9.2.2019	"Garden" on the top	S 65°14′52.6"; W 64°14′58.2"
subsample7a	P7	Galindez Island	9.2.2019	"Garden" on the top	S 65°14′52.6"; W 64°14′58.2"
subsample7b	W2	Galindez Island	9.2.2019	"Garden" on the top	S 65°14′52.6"; W 64°14′58.2"
subsample7c	L3	Galindez Island	9.2.2019	"Garden" on the top	S 65°14′52.6"; W 64°14′58.2"
Moss8a	P8	Galindez Island	9.2.2019	dry dead moss, Dead moss ravine	S 65°14′54.4"; W 64°14′50.4"
Moss8b	S6	Galindez Island	9.2.2019	almost dry live moss, Dead moss ravine	S 65°14′54.4"; W 64°14′50.4"
Moss9	P9	Galindez Island	9.2.2019	almost dry, Woozie hill- top of the island	S 65°14′56.8"; W 64°14′46.1"
Moss10	S7	Galindez Island	9.2.2019	very wet soil near a pond, where penquins hatch	S 65°14′52.9"; W 64°14′34.7"
Moss11	S8	Galindez Island	9.2.2019	very wet soil near a pond, where penquins hatch	S 65°14′52.9"; W 64°14′34.7"

Sample	m a.s.l.	Vegetation	Biotic class	Salt class	Type of moss/Remark	F-value
Moss1	7	moss, Prasiola sp.	5	5	*Sanionia* sp., strongly affected by animals	IV
Moss2a	4	moss, lichens	0	4	*Sanionia georgico-uncinata*	V
Moss2b	4	moss, lichens	0	4	*Polytrichum strictum*	VIII
Moss3a	4	moss, lichens	0	4	*Sanionia georgico-uncinata*	VI
Moss3b	4	moss, lichens	0	4	*Polytrichum strictum*	VII
Moss4a	9	moss, lichens	0	0	*Sanionia georgico-uncinata*	VI
Moss4b	9	moss, lichens	0	0	*Polytrichum strictum*	VII
Moss5	8		0	0	*Andreaea regularis*	VIII
Moss 6	8	moss, lichens, liverworths	3	0	skuas	V
subsample 6a	8	moss, lichens, liverworths	3	0	*Warnstorfia fontinaliopsis*	V
subsample 6b	8	moss, lichens, liverworths	3	0	*Liverworth-Cephaloziella varians*	VII
subsample 6c	8	moss, lichens, liverworths	3	0	*Liverworth- Barbilophozia hatcheri*	V
subsample6d	8	moss, lichens, liverworths	3	0	*Chorisodontium aciphyllum*	VII
subsample6e	8	moss, lichens, liverworths	3	0	*Polytrichum strictum*	VII
subsample6f	8	moss, lichens, liverworths	3	0	*Sanionia georgico-uncinata*	VII
Moss7	30	moss, lichens, liverworths	0	0		VII
subsample7a	30	moss, lichens, liverworths	0	0	*Polytrichum strictum*	VII
subsample7b	30	moss, lichens, liverworths	0	0	*Warnstorfia fontinaliopsis*	V
subsample7c	30	moss, lichens, liverworths	0	0	*Liverworth-Cephaloziella varians*	V
Moss8a	34	dead moss	0	0	*dead moss- Polytrichum strictum*	VI
Moss8b	34	moss	0	0	live moss-*Polytrichum strictum*	VII
Moss9	50	moss, soil crust	0	0	*soil crust*	VII
Moss10	9	moss	5	4	*Sanionia* sp., strongly affected by animals	II
Moss11	9	moss with microbial mat	5	4	*Sanionia* sp., strongly affected by animals	I