Acta Societatis Botanicorum Poloniae

DOI: 10.5586/asbp.3598

Publication history
Received: 2018-10-08
Accepted: 2018-11-05
Published: 2018-12-31

Handling editor
Bronisław Wojtuń, Faculty of Biological Sciences, University of Wrocław, Poland

Authors' contributions
MR, TS, and MW planned the research and conducted field work; MW analyzed plant specimens; MW, MR, and TS wrote the manuscript

Funding
This study was funded by the National Science Center, Poland, grant number NCN 2015/17/B/NZ8/02475/ and, partly, through the statutory funds of the W. Szafer Institute of Botany, Polish Academy of Sciences. The data used in the paper were collected based on Henryk Arctowski Polish Antarctic Station.

Competing interests
MR served as guest editor of the issue; other authors: no competing interests have been declared

Citation
Wierzgoń M, Suchan T, Ronikier M. Two additions to the moss flora of the South Shetland Islands in the maritime Antarctic. Acta Soc Bot Pol. 2018;87(4):3598. https://doi.org/10.5586/asbp.3598

ORIGINAL RESEARCH PAPER

Two additions to the moss flora of the South Shetland Islands in the maritime Antarctic

Mariusz Wierzgoń[1]*, Tomasz Suchan[2], Michał Ronikier[2]

[1] Department of Botany and Nature Protection, Faculty of Biology and Environmental Protection, University of Silesia in Katowice, Jagiellońska 28, 40-032 Katowice, Poland
[2] Molecular Biogeography Group, W. Szafer Institute of Botany, Polish Academy of Sciences, Lubicz 46, 31-512 Kraków, Poland

* Corresponding author. Email: mariuszwierzgon@gmail.com

Abstract

Tortella fragilis (Drumm.) Limpr. (Pottiaceae) and *Bryum nivale* Müll. Hal. (Bryaceae) are recorded for the first time from the South Shetland Islands in the northern maritime Antarctic. They were discovered in the Admiralty Bay area on King George Island, the largest island of this archipelago. The two species are briefly characterized morphologically, their habitats are described, and their distribution in the Antarctic is mapped. Discovery of these species has increased the documented moss flora of King George Island to 67 species, strengthening it in the leading position among individual areas with the richest diversity of moss flora in Antarctica. Likewise, *T. fragilis* and *B. nivale* represent remarkable additions to the moss flora of the South Shetland Islands, which currently consists of 92 species and one variety, making this archipelago by far the richest bryofloristically amongst large geographic regions of the Antarctic. Comparison of recent (2018) and old (1985) photographs revealed a significant retreat of glacial cover and suggests that the collection site was likely opened for colonization only within the last several decades. The record of *T. fragilis* is biogeographically relevant, and constitutes an intermediate site between the species' occurrences in the Antarctic Peninsula and southern South America. The present record of *B. nivale* is the fourth discovery of the species worldwide, which may be helpful for the future designation of the distribution of this extremely rare species.

Keywords

biodiversity; bryophytes; deglaciation; King George Island; maritime Antarctic; Southern Hemisphere

Introduction

The South Shetland Islands are a group of 15 volcanic islands located in the northern maritime Antarctic. In the north, this peri-Antarctic archipelago is isolated from South America by the Drake Passage, which is about 770 km wide. In the southeast, the Bransfield Strait, at about 160 km wide, separates the archipelago from Trinity Peninsula, which is the northernmost part of the Antarctic Peninsula and is part of mainland Antarctica. The largest island in this archipelago is King George Island, which lies between latitude 61°50′–62°15′ S and longitude 57°30′–59°01′ W.

King George Island was one of the earliest discovered lands in Antarctica, and was the first area from which mosses were collected in this biome during the United States sealing voyage of 1829–1831. Two species collected by James Eights, a member of this voyage, *Polytrichastrum alpinum* (Hedw.) G. L. Sm. and *Sanionia uncinata* (Hedw.) Loeske, are preserved in the New York Botanical Garden Herbarium (NY) [1]. Mosses were subsequently collected from the Admiralty Bay area some 80 years later, on December 25–30, 1909, by M. Gain, a naturalist of the French Antarctic Expedition of 1908–1910.

A detailed account of the bryological exploration of King George Island is outlined in the first descriptive moss flora of this island [1], in which 61 species of moss were reported from this area. In the years following publication, two new species were described from King George Island, *Schistidium lewis-smithii* Ochyra [2] and *S. leptoneurum* Ochyra [3]; therefore, in *The illustrated moss flora of Antarctica*, 63 species and one variety of moss are recorded [4]. Since the publication of this fundamental work for Antarctic bryology, two further species have been recorded from King George Island, namely *Drepanocladus longifolius* (Mitt.) Paris [5] and *Bryoerythrophyllum rubrum* (Geh.) P. C. Chen [6,7], thus increasing the number of species to 65.

King George Island is heavily glaciated, and the total cover of open-ground areas is estimated to be approximately 21 km^2, i.e., only 8.74% of the land [8], although in subsequent years, the area of ice-free ground has increased significantly [9]. The largest ice-free areas on King George Island, which are suitable for colonization by terrestrial vegetation, are situated in the Maxwell Bay region, including Fildes Peninsula in the southeast of the island, and the Admiralty Bay region located in its central-south part [1]. In the latter area, the ice-free areas ("oases" and nunataks) are widespread along the coast, forming enclaves of various sizes.

One of such terrestrial "oases" is Klekowski Crag (Fig. 1), located on the western coast of Admiralty Bay, north of the entrance to Ezcurra Inlet, between Lange Glacier and Polar Committee Icefall. This small, steep rocky wall is built of terrestrial volcanic rocks, predominantly basic andesite lavas alternating with tuff and agglomerate. Within this formation, in the middle of Klekowski Crag, andesite, basalt, microdiabese and quartz microdiabese intrusions occur [10]. The moss flora of this crag was studied in the 1980s during comprehensive bryological investigations conducted in Admiralty Bay. Although its flora is rather poor in terms of the number of species, with only

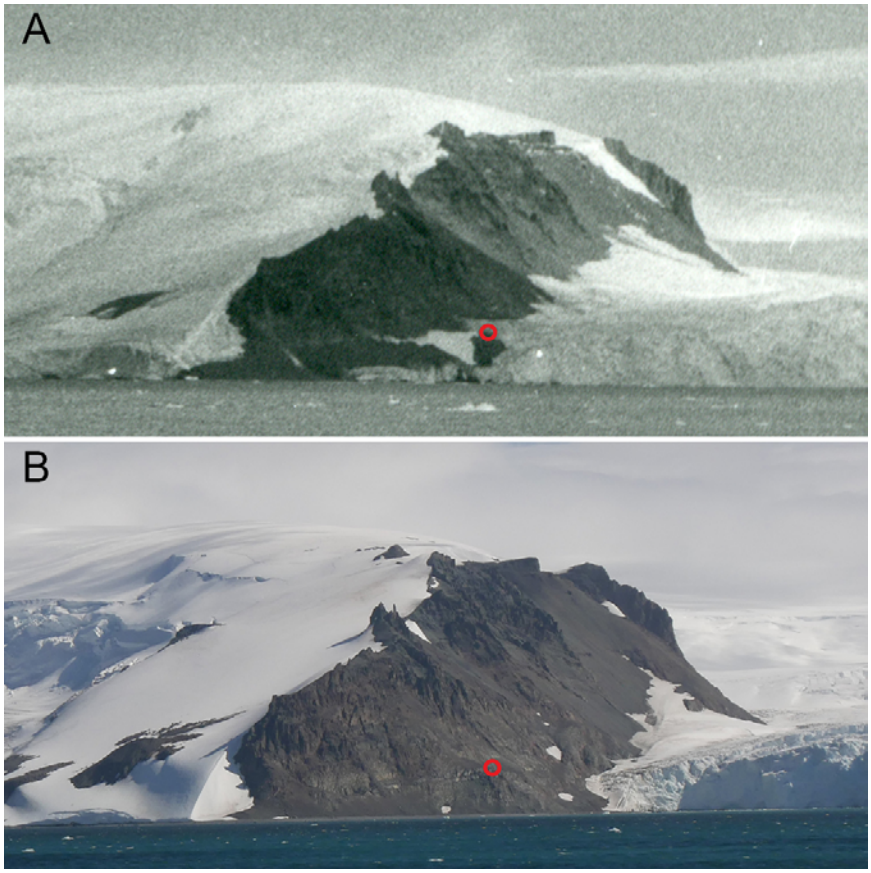

Fig. 1 The Klekowski Crag, crest, and northern slopes towards Lange Glacier and its cove seen from the western slopes of Wawel Mt on the opposite side of Admiralty Bay; 1985 (**A**) and 2018 (**B**). Significant retreat of the Lange Glacier and reduced glacial cover of slopes over a 33-year period can be observed. Approximate area where the populations of *Tortella fragilis* and *Bryum nivale* occur is indicated with a red ring on both photographs. Photo: Jacek Siciński (**A**) and Michał Ronikier (**B**).

two species of liverwort [11,12] and 16 species of moss [1] recorded, it includes such rarities as *Didymodon gelidus* Cardot, *Encalypta rhaptocarpa* Schwägr., and *Hypnum revolutum* (Mitt.) Lindb [1,13,14].

In February 2018 we carried out field work on King George Island, which primarily aimed to collect material for phylogeographical investigations on Antarctic endemic moss species. In the Admiralty Bay area, we focused, among others, on the isolated and poorly accessible cliff of Klekowski Crag. Our sampling effort resulted in the discovery of two species new to the island's moss flora, namely *Tortella fragilis* (Drumm.) Limpr. (Pottiaceae) and *Bryum nivale* Müll. Hal. (Bryaceae). In this article, the records of these two very rare species are described and discussed in the context of the diversity, taxonomy, and biogeography of the Antarctic moss flora.

Material and methods

The specimens were collected on Klekowski Crag in February 2018 during fieldwork on King George Island. The voucher collections are housed in the bryophyte herbarium in the W. Szafer Institute of Botany, Polish Academy of Sciences in Kraków (KRAM). Mosses were identified by routine microscopic and laboratory techniques. The specimens were carefully compared with those collected in the Antarctic and outside this continent. The current general topographical and glaciological context of the sampling site was compared with that reported over 30 years ago (approximately the time of earlier bryological fieldwork conducted in this area) based on photographs taken in 2018 and 1985 (Fig. 1). Distribution maps of species records in the Antarctic were also prepared.

Results

Klekowski Crag is a typical, highly-isolated terrestrial oasis in Admiralty Bay. Its southern part is almost entirely glaciated, with the exception of the summit ridge, whereas the northern side is mostly exposed, forming a steep cliff up to 200 m high, which in the summit part contains large expanses of stable rocks that change into extensive scree of weathered basalt rubble. Bryophytes mainly cover the faces of stable rocks and large boulders, and often grow in moist rock fissures and on moraines in the front of the glacier. When comparing the photographs of this area taken in 1985 and in 2018, some changes are clearly visible, indicating in particular significant retreat of the Lange Glacier (Fig. 1). This results in wider contact of this outcrop with the waters of Admiralty Bay, and a larger area of exposed land in the frontal area of the crag. The glacial cover of its higher slopes in the prospected eastern part seems to have undergone less pronounced changes.

The populations of mosses described in this article were discovered in the central part of the rocky slope facing the sea, in the direct vicinity of a characteristic convex rock formation (Fig. 1B). Based on a rough visual reconstruction, this steep, rocky outcrop appears to have been ice-free to some extent 33 years ago, while the screes above it were mostly covered by either permanent or seasonal snow layer (Fig. 1A). Based on the available large-scale images, it is not possible to unambiguously confirm whether the sites explored in 2018 were also exposed during earlier bryological studies.
The two new species records are presented in detail and discussed below.

Tortella fragilis

This species was found in the upper part of a rock ledge at the base of a sea-facing cliff. The population was very sparse, and the moss formed a loose tuft of less than 1 cm^2, which was growing on a pocket of soil within a rocky rubble. The only associated species was *Distichium capillaceum* (Hedw.) Bruch & Schimp. This *T. fragilis* habitat is consistent with those in other localities of the species in Antarctica [4].

The plants of *T. fragilis* from King George Island match other collections of this species from the Antarctic. Like elsewhere in this region, these plants are sterile but commonly produce vegetative propagules formed by caducous, thickened apices of young leaves. In Antarctica, such deciduous leaf apices are known only in *Tortella alpicola* Dixon and *Syntrichia sarconeurum* Ochyra & R. H. Zander; thus, *T. fragilis* is likely to be confused with these species. However, in the former, the propagules are segmented as a series of barrel-shaped constrictions, which fracture into several pieces, whilst in *T. fragilis*, they are a single solid unit. *Syntrichia sarconeurum* propagules also form a single unit; however, this species is distinct from both species of *Tortella* (Müll. Hal.) Limpr. by possessing the hyaline basal leaf cells that change gradually into chlorophyllose cells along an ill-defined junction line at approximately the same level across the lamina, or sometimes lower at the leaf margins than at the costa. In contrast, the hyaline basal cells in *Tortella* species extend up the leaf margins, forming a V-shaped basal region, which sharply demarcates from the upper chlorophyllose cells along the abrupt junction line.

A characteristic feature of *T. fragilis* is bistratose distal laminal cells. However, in the Antarctic specimens, they vary from being partially bistratose to entirely unistratose throughout, and such phenotypes are also represented by specimens from King George Island. Nevertheless, because the leaves are rigid and the margins in the leaf subula are distinctly bordered by smooth and pellucid cells, these plants are included in *T. fragilis*. Bistratosity of the laminal cells, often coupled with a salient costa and thickened, fleshy marginal limbidia in many moss species, especially aquatic species, are often considered as a structural adaptation to swiftly flowing water [15,16]. However, molecular data have shown that, for example, the plants once described as *Sciaromium lacustre* Herzog & P. Rich. [17] and characterized by variously polystratose distal laminal cells do not differ genetically from the plants known as *Drepanocladus longifolius* (Mitt.) Paris [18]. Hence, Antarctic populations of *T. fragilis* are ideal for genetic investigations, which should resolve their taxonomic status and provide further insight into the significance of the differences in laminal cell stratosity as a taxonomic character.

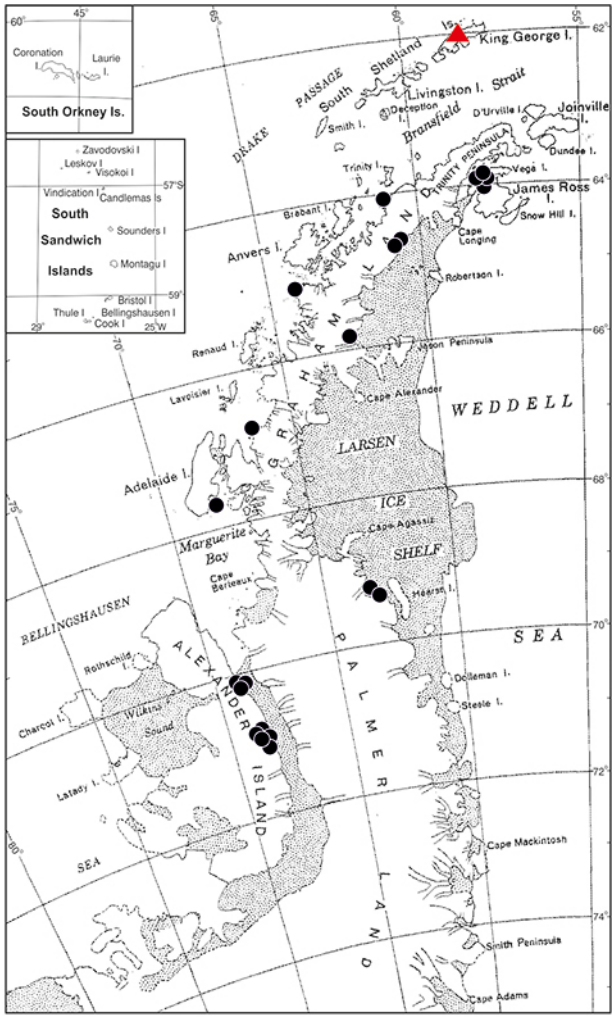

Fig. 2 Map of *Tortella fragilis* distribution in the Antarctic. New locality on King George Island is marked with a red triangle.

Tortella fragilis is a strict bipolar species, i.e., without intermediate localities in the tropical zone. It is widely distributed in the Southern Hemisphere but scattered in Lesotho in Southern Africa [19], in the South Island [20] and on the Campbell Islands [21] in New Zealand, in Tierra del Fuego [22], and on subantarctic South Georgia [23] and Îles Kerguelen [24]. In the Antarctic, *T. fragilis* has previously only been reported from the Antarctic Peninsula region where it occurs on the western coast, ranging from the Danco Coast to the Alexander Island, and on the eastern coast, from James Ross Island to the Wilkins Coast [4,25] (Fig. 2). The discovery of this species on King George Island reported here is new to the South Shetland Islands, and the first report in the peri-Antarctic archipelagoes. It may be considered a "geographic link" between the Antarctic Peninsula and southern South American populations of *T. fragilis*.

Specimen examined. Antarctica, South Shetlands Islands, King George Island, Admiralty Bay, in the upper part of a rock ledge at the base of Klekowski Crag cliff, latitude 62°07.442′S, longitude 58°29.259′W; altitude 110 m; on a pocket of soil amongst rocky rubble, associated with *Distichium capillaceum*, February 8, 2018, leg. M. Wierzgoń No. 174/2018 with M. Ronikier and T. Suchan; det. M. Wierzgoń, verified R. Ochyra (KRAM).

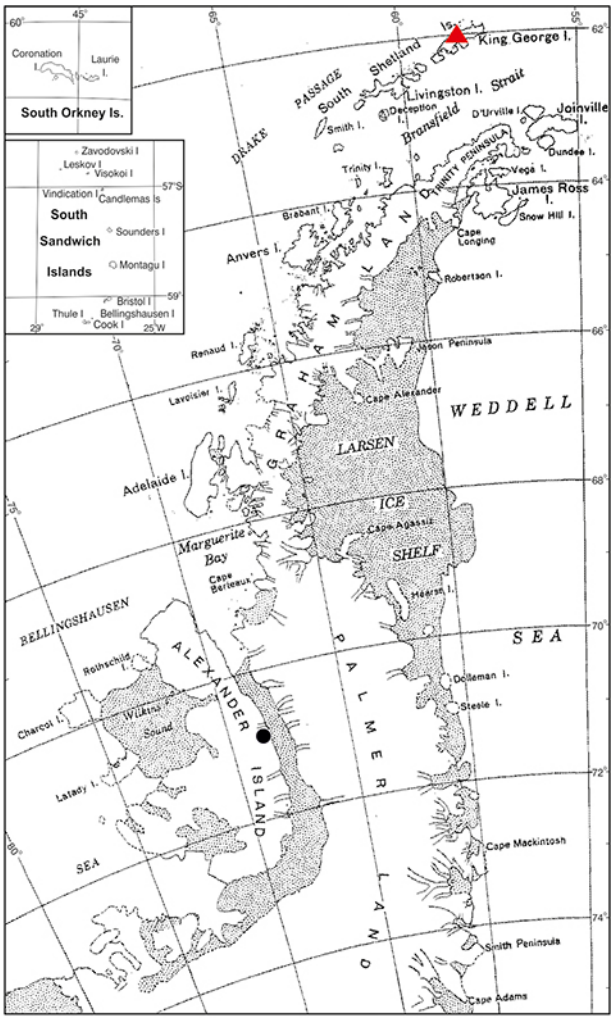

Fig. 3 Map of *Bryum nivale* distribution in the Antarctic. New locality on King George Island is marked with a red triangle.

Bryum nivale

This species was recorded on a border of a rock ledge at the base of the Klekowski Crag cliff. It was found in a sheltered site on a pocket of wet soil in a rock crevice where it formed a small (ca. 2 cm^2) pure tuft. The only other moss growing on this site was *Pohlia cruda* (Hedw.) Lindb., which formed loose patches.

Species of the genus *Bryum* Hedw. are prominent in the impoverished Antarctic moss flora, both in terms of their frequency and cover. However, like elsewhere, their identification is problematic, because most populations are notoriously sterile and sporophyte characters are usually critical for accurate species determination. To date, seven *Bryum* species are known to occur in Antarctica [4,25], and *B. nivale* is the rarest species of the genus in this biome, as it has only been collected once on Alexander Island. This species has deeply concave, broadly ovate to rounded leaves, which are broadly acute and obtuse to shortly apiculate. The leaves are indistinctly bordered, and the laminal cells are elongate-rhomboidal distally and rectangular below, widened and never red-tinged at the base. *Bryum nivale* remains insufficiently known taxonomically, mostly owing to its sterility and scarcity of material, although it is very distinct gametophytically from all other congeners in the austral polar regions. For a long time, this species was only known from the type collection from Bio-Bio Region of central Chile [26]. Later, it was discovered on Marion Island in the Subantarctic from whence it was first reported as *Bryum amblyolepis* Cardot [27] and from Alexander Island in the Antarctic [4,25]. The present record is the fourth discovery of this species (Fig. 3). *Bryum nivale* warrants special attention; careful searching during field work should contribute further specimens to allow better understanding and circumscription of this species.

The known geographical range makes it difficult to designate the pattern of *B. nivale* distribution. Until the species is found in more localities, it can be tentatively defined as a south-temperate Afro-American species deeply penetrating into the Antarctic. This type of distribution is demonstrated by a large number of mosses, primarily tropical lowland, montane, and altimontane species [28,29]; however, it also includes a relatively small group of south-temperate cool-adapted moss species [30–32].

Specimen examined. Antarctica, South Shetlands Islands, King George Island, Admiralty Bay, at the edge of a rock ledge at the base of Klekowski Crag cliff, latitude 62°07.429′ S, longitude 58°29.240′ W; altitude 107 m; on a wet pocket in rock crevices, associated with *Pohlia cruda*, February 8, 2018, leg. M. Wierzgoń No. 183/2018 with M. Ronikier and T. Suchan; det. R. Ochyra (KRAM).

Discussion

Tortella fragilis and *Bryum nivale* are remarkable additions to the moss flora of King George Island (the South Shetland Islands). Until recently, the moss flora of this island consisted of 65 species, representing the richest local diversity of moss flora in the Antarctic. The present discoveries further increase the moss flora of this island to 67 species. The small Signy Island, part of the South Orkney Islands, has the second richest diversity of moss flora, with 59 species. The next two areas with the richest diversity of

moss flora are two further islands of the South Shetland Islands archipelago, namely Deception and Livingston islands, which host 56 species each.

Tortella fragilis and *B. nivale* represent important contributions to the moss flora of the South Shetland Islands. Ninety-two species and one variety have so far been reported from this archipelago, making it the richest bryofloristically region in the entire Antarctic. The much smaller South Orkney Islands archipelago has the second richest moss flora, which, however, consists of only 59 species. Notably, the flora of the Antarctic Peninsula, which is a much larger territory than the South Shetland Islands, consists of only 67 species and two varieties.

In the case of new moss records in the Antarctic and subantarctic islands, a question remains on the origin of such new localities. It is unclear whether the small populations of the two species reported here were found in the newly open ground or if the location was ice-free in 1980. Analysis of available general photographic documentation (Fig. 1) does not allow a clear-cut conclusion, although at least part of the area explored in 2018 was open during previous investigations in 1980s. *Tortella fragilis* and *Bryum nivale* could have been easily overlooked during earlier studies considering the small populations of the two species and complicated microtopography of the area. Nevertheless, the gradual emergence of the site seems to be of recent origin. In the 1985 image, only a small part of the rock was ice-free, and it is likely that the whole area was glaciated within the last century. Considering the hypothesis that these species were recently established, it remains unclear whether there was local dispersal from other, yet unknown, populations within King George Island, or whether the populations were established via aerial long-distance transport of propagules from remote areas. Population genetic tools have the potential to discern long-term isolation from recent dispersal processes [33,34], and molecular analyses of Antarctic populations of these species may provide further information.

There has been speculation regarding the origin of the moss flora of Antarctica. It has been accepted that the moss flora generally established following the Holocene migration of species via aerial long-distance dispersal [35]. Unfortunately, paleobotanical data remain scarce for the Antarctic and subantarctic islands [36–40], which prevents the detailed reconstruction of Quaternary glacial history and development of flora and vegetation cover after the Last Glacial Maximum. However, there is strong indirect evidence that some moss taxa are pre-Pleistocene survivors that outlived the glacial epoch in situ on ice-free nunataks and oases. The prime candidates for such survivors are endemic species that do not appear to have close relatives outside the Antarctic; for example *Andreaea depressinervis* Cardot [4], *Schistidium lewis-smithii* [2], and *S. deceptionensis* Ochyra, Bedn.-Ochyra & R. I. L. Sm. [41]. It cannot be excluded that *Tortella fragilis* also belongs to this group, especially in the context of its morphological differences from extra-Antarctic plants. Phylogeographic studies using DNA markers may help to resolve such taxonomic and phytogeographical issues [18].

Acknowledgments

We are indebted to Professor Ryszard Ochyra (Kraków) for checking specimen determinations and for his valuable comments on the manuscript. Our thanks also to Professor Jacek Siciński (Łódź) for kindly sharing his photograph of Klekowski Crag taken in 1985, Katarzyna Biłyk (Kraków) for generating distribution maps, Joanna Plenzler (Warszawa) for her help with the literature and for valuable discussion, and to the crew of the Henryk Arctowski Polish Antarctic Station (42nd Polish Antarctic Expedition, 2017/2018) for their hospitality and logistic support during fieldwork.

References

1. Ochyra R. The moss flora of King George island, Antarctica. Kraków: W. Szafer Institute of Botany, Polish Academy of Sciences; 1998.
2. Ochyra R. *Schistidium lewis-smithii* (Bryopsida, Grimmiaceae) – a new species from the maritime Antarctic, with a note on the Australian *S. flexifolium*. Nova Hedwigia. 2003;77:363–372. https://doi.org/10.1127/0029-5035/2003/0077-0363

3. Ochyra R. *Schistidium leptoneurum* species nova from the South Shetland Islands, Antarctica. Cryptogam Bryol. 2004;25(2):125–130.
4. Ochyra R, Lewis Smith RI, Bednarek-Ochyra H. The illustrated moss flora of Antarctica. Cambridge: Cambridge University Press; 2008.
5. Li SP, Ochyra R, Wu PC, Seppelt RD, Cai MH, Wang HY, et al. *Drepanocladus longifolius* (Amblystegiaceae), an addition to the moss flora of King George Island, South Shetland Islands, with a review of Antarctic benthic mosses. Polar Biol. 2009;32:1415–1425. https://doi.org/10.1007/s00300-009-0636-z
6. Sollman P. The genus *Bryoerythrophyllum* (Musci, Pottiaceae) in Antarctica. Pol Bot J. 2015;60(1):19–25. https://doi.org/10.1515/pbj-2015-0004
7. Ellis LT, Aleffi M, Alegro A, Segota V, Asthana AK, Gupta R, et al. New national and regional bryophyte records, 48. J Bryol. 2016;38(3):235–259. https://doi.org/10.1080/03736687.2016.1206685
8. Marsz A, Rakusa-Suszczewski S. Charakterystyka ekologiczna rejonu Zatoki Admiralicji (Wyspa Króla Jerzego, Szetlandy Południowe). Kosmos. 1987;36(1):103–127.
9. Braun M, Gossmann H. Glacial changes in the areas of Admiralty Bay and Potter Cove, King George Island, maritime Antarctica. In: Beyer L, Bölter M, editors. Geoecology of Antarctic ice-free coastal landscapes. Berlin: Springer; 2002. p. 75–89. https://doi.org/10.1007/978-3-642-56318-8_6
10. Birkenmajer K. Mesozoic and Cenozoic stratigraphic units in parts of the South Shetland Islands and Northern Antarctic Peninsula (as used by the Polish Antarctic programmes). Studia Geologica Polonica. 2001;118:5–188.
11. Ochyra R, Váňa J. The hepatics of King George Island, with particular reference to the Admiralty Bay region (South Shetland Islands, Antarctica). Pol Polar Res. 1989;10(2):183–210.
12. Ochyra R, Váňa J. The hepatics reported from the Antarctic and an outline of their phytogeography. Pol Polar Res. 1989;10(2):211–229.
13. Ochyra R, Zander RH. The genera *Didymodon* and *Bryoerythrophyllum* (Pottiaceae) in Antarctica. J Bryol. 2002;24(1):33–44. https://doi.org/10.1179/037366802125000331
14. Jiménez JA, Ochyra R. Reinstatment of species rank for *Didymodon gelidus* (Bryophyta, Pottiaceae). Cryptogam Bryol. 2017;38(4):383–392. https://doi.org/10.7872/cryb/v38.iss4.2017.383
15. Ochyra R. *Koponenia*, a new pleurocarpous moss genus from Bolivia. J Bryol. 1985;13(4):479–486. https://doi.org/10.1179/jbr.1985.13.4.479
16. Ochyra R. On the taxonomy and family placement of the moss genus *Limbella* (C. Muell.) Broth. J Bryol. 1987;14(3):465–485.
17. Ochyra R. On the taxonomic position of *Sciaromium lacustre* Herz. & Rich. in Rich. J Bryol. 1986;14(1):109–115. https://doi.org/10.1179/jbr.1986.14.1.109
18. Saługa M, Ochyra R, Żarnowiec J, Ronikier M. Do Antarctic populations represent local or widespread phylogenetic and ecological lineages? Complicated fate of bipolar moss concepts with *Drepanocladus longifolius* as a case study. Org Divers Evol. 2018;18(3):263–278. https://doi.org/10.1007/s13127-018-0372-8
19. Magill RM. Sphagnaceae – Grimmiaceae. In: Leistner EO, editor. Flora of southern Africa which deals with the territories of South Africa, Transkei, Lesotho, Swaziland, Bophuthatswana, South West Africa/Namibia, Botswana and Venda. Bryophyta. Part 1. Mosses. 1. Pretoria: Botanical Research Institute; 1981.
20. Fife AJ. Records of new or otherwise interesting mosses in New Zealand, including a new species. N Z J Bot. 1984;22:1–6. https://doi.org/10.1080/0028825X.1984.10425229
21. Vitt DH. A key and synopsis of the mosses of Campbell Island, New Zealand. N Z J Bot. 1974;12:185–210. https://doi.org/10.1080/0028825X.1974.10428861
22. Hyvönen J. *Tortella fragilis* (Pottiaceae) reported for southern South America. Bryologist. 1991;94:416–418. https://doi.org/10.2307/3243835
23. Ochyra R, Bednarek-Ochyra H, Lewis Smith RI. New and rare moss species from subantarctic South Georgia. Nova Hedwigia. 2002;74:121–147. https://doi.org/10.1127/0029-5035/2002/0074-0121
24. Ochyra R, Poulsen R. Four new moss records from Îles Kerguelen. J Bryol. 2003;25:136–138. https://doi.org/10.1179/037366803235001814
25. Ochyra R, Bednarek-Ochyra H, Lewis Smith RI. New and rare

moss species from the Antarctic. Nova Hedwigia. 2008;87:457–477. https://doi.org/10.1127/0029-5035/2008/0087-0457

26. Müller C. Synopsis muscorum frondosorum omnium hucusque cognitorum. Pars prima – musci vegetationis acrocarpicae. Berolini: Sumptibus Alb. Foerstner; 1849. https://doi.org/10.5962/bhl.title.31
27. Ochyra R, Hertel H. Contribution to the moss flora of the subantarctic island Marion. Polish Botanical Studies. 1990;1:19–34.
28. Ochyra R, Bednarek-Ochyra H, Pócs T, Crosby MR. The moss *Adelothecium bogotense* in continental Africa, with a review of its world range. Bryologist. 1992;95:287–295. https://doi.org/10.2307/3243487
29. Bednarek-Ochyra H, Ochyra R, Buck WR. The genus *Racomitrium* (Grimmiaceae) in Brazil, with the first report of *R. subsecundum* in South America. Brittonia. 1999;51(1):93–105. https://doi.org/10.2307/2666564
30. Bednarek-Ochyra H, Ochyra R. A consideration of *Bucklandiella* (Bryophyta, Grimmiaceae) in South America, with a taxonomic re-assessment of *Racomitrium looseri*. Nova Hedwigia 2012;95(1–2):153–163. https://doi.org/10.1127/0029-5035/2012/0045
31. Ochyra R, van Rooy J. Distribution of *Bucklandiella lamprocarpa* (Grimmiaceae, Musci) in South Africa. Cryptogam Bryol. 2013;34(3):359–366. https://doi.org/10.7872/cryb.v34.iss3.2013.359
32. Bednarek-Ochyra H, Ochyra R. Diversity of Grimmiaceae subfam. Racomitrioideae in sub-Saharan Africa, including an addition of *Bucklandiella striatipila* to the moss flora of the continent. Cryptogam Bryol. 2013;34(1):3–12. https://doi.org/10.7872/cryb.v34.iss1.2013.3
33. Ronikier M, Schneeweiss GM, Schönswetter P. The extreme disjunction between Beringia and Europe in *Ranunculus glacialis* s. l. (Ranunculaceae) does not coincide with the deepest genetic split – a story of the importance of temperate mountain ranges in arctic–alpine phylogeography. Mol Ecol. 2012;21: 5561–5578. https://doi.org/10.1111/mec.12030
34. Sanz M, Schönswetter P, Vallès J, Schneeweiss GM, Vilatersana R. Southern isolation and northern long-distance dispersal shaped the phylogeography of the widespread, but highly disjunct, European high mountain plant *Artemisia eriantha* (Asteraceae). Bot J Linn Soc. 2014;174: 214–226. https://doi.org/10.1111/boj.12132
35. van der Putten N, Verbruggen C, Ochyra R, Verleyen E, Frenot Y. Subantarctic flowering plants: pre-glacial survivors or post-glacial immigrants? J Biogeogr. 2010;37:582–592. https://doi.org/10.1111/j.1365-2699.2009.02217.x
36. Birkenmajer K, Ochyra R, Olsson IU, Stuchlik L. Mid-Holocene radiocarbon-dated peat at Admiralty Bay, King George Island (South Shetland Islands, West Antarctica). Bulletin of the Polish Academy of Sciences, Earth Sciences. 1985;33:7–13.
37. Ingólfsson Ó. Quaternary glacial and climate history of Antarctica. In: Ehlers J, Gibbard PL, editors. Quaternary glaciation extent and chronology. Part III. South America, Asia, Africa, Australasia, Antarctica. Amsterdam: Elsevier; 2004. p. 3–43.
38. van der Putten N, Stieperaere H, Verbruggen C, Ochyra R. Holocene palaeoecology and climate history of South Georgia (sub-Antarctica) based on a macrofossil record of bryophytes and seeds. Holocene. 2004;14:382–392. https://doi.org/10.1191/0959683604hl714rp
39. van der Putten N, Verbruggen C, Ochyra R, Spassov S, de Beaulieu JL, de Dapper M, et al. Peat bank growth, Holocene palaeoecology and climate history of South Georgia (sub-Antarctica), based on a botanical macrofossil record. Quat Sci Rev. 2009;28:65–79. https://doi.org/10.1016/j.quascirev.2008.09.023
40. Hodgson DA, Graham AGC, Roberts SJ, Bentley MJ, Cofaigh CÓ, Verleyen E, et al. Terrestrial and submarine evidence for the extent and timing of the Last Glacial Maximum and the onset of deglaciation on the maritime-Antarctic and sub-Antarctic islands. Quat Sci Rev. 2014;100:137–158. https://doi.org/10.1016/j.quascirev.2013.12.001
41. Ochyra R, Bednarek-Ochyra H, Lewis Smith RI. *Schistidium deceptionense*, another new endemic moss species from the Antarctic. Bryologist. 2003;106(4):569–574. https://doi.org/10.1639/0007-2745(2003)106[569:SDANMS]2.0.CO;2