



## Polish botanical and mycological studies of the Antarctic terrestrial and fresh water ecosystems in 1977–2009: An overview

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**Abstract:** This paper recapitulates Polish botanical and mycological research on terrestrial and freshwater Antarctic ecosystems carried out between 1977 and 2009. The main results are briefly summarized. The references encompass nearly 200 papers on floristics, taxonomy, biogeography, ecology, cytology, biochemistry, physiology and genetics of lichens, mosses, fungi, algae and vascular plants inhabiting soils, rocks and inland waters in the Antarctic.

Key words: Antarctic, plants, fungi.

### Introduction

The Polish Antarctic *H. Arctowski* Station was opened on February 26th, 1977, on the shores of Admiralty Bay, King George Island, the South Shetland Islands. By 2009 as many as 33 Polish expeditions had worked at the Station. The date of opening of the Polish Polar Station on King George Island and the conclusion of the 4th International Polar Year constitute the temporal frame of this paper.

The Polish research program was linked with numerous international programs coordinated by the Scientific Committee on Antarctic Research (SCAR), including BIOTAS, RiSCC, ClicOPEN and Aliens in Antarctica. Polish botanical and mycological studies covered areas such as taxonomy, biogeography and ecology, including the following topics: plant adaptation to polar conditions, plant succession on the forefields of retreating glaciers, and changes in ecosystems caused by human activity.

Nearly 200 papers on plants and fungi of the terrestrial and freshwater ecosystems of the Antarctic have been published by Polish scientists. The majority of

these studies were devoted to lichenology and bryology, given the dominance of their representatives in the Antarctic. Among the most eminent achievements are several monographs and the description of many plant and fungal taxa new to science, as well as the discovery of numerous species hitherto not reported from the Antarctic. The present paper supplements the earlier overview by Rakusa-Suszczewski *et al.* (1998).

### Floristics, taxonomy and biogeography

The purpose of the floristic research was to create an inventory of taxa present in particular sites and study areas, as well as their geographical distribution (Ochyra 1983).

The studies started with the discovery of the lichen *Hypogymnia lugubris* (Pers.) Krog in the Admiralty Bay area on King George Island (Lindsay and Ochyra 1982). The lichen biota in this area of King George Island was then thoroughly studied and a total of 110 mainly bipolar species were found and new localities were recorded (Olech 1989a). As many as 61 species found in the Admiralty Bay area had not been observed before in that area, 35 were new for the South Shetland Islands, 15 were hitherto not recorded in the Antarctic region and 6 were recorded for the first time in the Southern Hemisphere. Several taxa formerly identified as an Arctic-alpine element were also recorded; apparently, these were bipolar species. An interesting lichen species, *Japewia tornoenensis* (Nyl.) Tønsberg, new to the Antarctic and to the Southern Hemisphere, was found on King George Island and Livingston Island (Olech 1991a). The lichen biota of SSSI no. 8 in the Admiralty Bay area was studied (Myrcha *et al.* 1991).

In the South Shetlands area, namely King George I., Livingston I., Greenwich I., and Deception I., the occurrence of 24 *Lecanora* species was recorded, including the first discovery of an Antarctic endemic, *Lecanora sverdrupiana* Øvstedal in Maritime Antarctic (Śliwa and Olech 2002). At least 22 lichen species of the genus *Caloplaca* have been recorded in the South Shetland Islands. Of these, almost 30% have a bipolar or cosmopolitan range. On the other hand, it is thought that maritime species typical of islands have probably evolved *in situ* (Søchting and Olech 1995). The lichenobiotas in the area of Bunger Oasis (Olech 1989b) and Schirmacher Oasis in continental Antarctica have been studied.

Olech (1989c) prepared a vegetation map of Livingston Island with an inventory of the area before the founding of the Spanish polar station.

In the area of SSSI no. 8 of King George Island, 9 *Umbilicaria* species were recorded; one of them, *Umbilicaria umbilicarioides* (Stein) Krog *et* Swinscow, was found for the first time in the Antarctic (Krzewicka and Smykla 2004).

Lichenological study was also performed in the Lions Rump protected area (SSSI no. 34, currently known as ASPA no. 151); 104 lichen species have been re-

corded there. Several ecological groups of lichens were identified (Olech 1994) and distribution maps of various lichen species and of plant communities of the Lions Rump ASPA were produced.

Critical species lists of Antarctic lichens and lichenicolous fungi have been published by Olech (2001) and afterwards, as a result of long-term research, a monograph on the King George Island lichen biota was prepared, describing a total of 294 lichenized fungal species (approximately 77% of all hitherto known Antarctic lichens), including two species new for the Antarctic, seven species new for the South Shetland Islands and 68 species new for King George I. (Olech 2004).

Macrofungi (Macromycetes) collected on King George I. and Livingston I. were investigated in detail. Four species were recognized; one of them, *Arrhenia salina* (Høiland) Bon et Courtecuisse, had not been previously recorded in the Antarctic (Gumińska *et al.* 1994). Soil mycoflora, especially of the genus *Penicillium*, was studied in the vicinity of the *Arctowski* Station. Depending on the environment the percentage of the *Penicillium* fungi in the general population of fungal biota varied from 8.5 to 90% (Czarnecki and Białasiewicz 1987; Zabawski 1995; Białasiewicz and Czarnecki 1999; Alias *et al.* 2008).

Polish bryological studies in the Antarctic produced 15 papers on the floristics and phytogeography of the Antarctic bryophyte species (Ochyra and Bell 1984; Ochyra 1986; Ochyra and Newton 1986; Ochi and Ochyra 1986; Ochyra and Ochi 1986; Ochyra and Lewis-Smith 1996, 1999; Bednarek-Ochyra *et al.* 1999; Ochyra *et al.* 2000, 2008a; Ochyra and Zander 2002; Ochyra and Tyshchenko 2006; Seppelt and Ochyra 2008; Ochyra and Singh 2008; Li *et al.* 2009).

An outline of the phytogeography of Antarctic liverworts has been published by Ochyra and Váňa (1989b), as a supplement to their paper on the taxonomy of 11 liverworts from King George Island (Ochyra and Váňa 1989a). An annotated guide to Antarctic bryophytes exsiccata was also published (Ochyra *et al.* 1986), as well as a paper on the history of the Antarctic moss flora research (Ochyra *et al.* 1998).

Two liverwort species, *Hygrolembidium ventrosum* (Mitt.) Grolle and *Scapania obcordata* (Berggr.) S. Arnell, were recorded for the first time in the Antarctic and the latter had only been known from the Arctic. Papers solving numerous detailed taxonomic questions concerning particular species of mosses were also published by Ochyra (1987, 1990, 1993a, b, c, 1996b, c, 1997, 1998c, 1999a, b, c, 2004a, b, d), Ochyra and Lewis-Smith (1998) and Ochyra and Zander (2007). In addition, new species of mosses were described, namely *Ditrichum gemmiferum* (Ochyra and Lewis-Smith 1998), *D. lewis-smithii* (Ochyra 1996a), *Schistidium deceptionense* (Ochyra *et al.* 2003), *S. halinae* (Ochyra 1998a), *S. leptoneurum* (Ochyra 2004c), *S. lewis-smithii* (Ochyra 2003) and *S. steerei* (Ochyra 1987).

Soil and freshwater cyanobacteria and algae, especially diatoms, were studied by Zabawski and Piasecki (1981), Kawecka and Olech (1993, 2003, 2004), Luścińska and Kyć (1993), Kawecka *et al.* (1996, 1998), Starmach (1995), Mrozińska *et al.* (1998b, 2007), and Noga and Olech (2004). Diatoms dominated

the freshwater algal communities (some 90 taxa) and were mostly eurytopic and cosmopolitan species.

Polish bryological studies performed in the South Shetland Islands area were summarized in a monograph of King George Island mosses (Ochyra 1998b) where taxonomic, phytogeographic and ecological analyses of 61 moss species were presented. A monograph, *The liverwort flora of Antarctica*, has been published by Bednarek-Ochyra *et al.* in 2000; it was the first critical survey of this group of plants on this continent. In this book 27 Antarctic liverwort species are discussed; three taxa, namely *Pachyglossa spegazziniana* (C. Massal.) Herzog and Grolle var. *exilis* Herzog and Grolle, *P. fissa* (Mitt.) Herzog and Grolle, and *Scapania gamundiae* R. M. Schust. were recorded for the first time in this part of the world. This monograph presents detailed morphological and anatomical characteristics of all the species; taxonomic and nomenclatural issues are discussed and maps presenting their distribution in the Antarctic are included.

Another impressive monograph, *The illustrated moss flora of Antarctica*, has been published by Ochyra *et al.* (2008b). All species of Bryophyta hitherto recorded in the Antarctic are treated there. The descriptions of 111 species of mosses are accompanied by detailed drawings and distribution maps; their reproductive biology and ecology in the Antarctic is also thoroughly discussed.

Polish studies on the taxonomy and systematics of Antarctic lichenicolous fungi were initiated in late 1980s. In the material collected between 1986 and 1996 by several expeditions to *Arctowski* Station and in 1988/1989 to *Bunger Oasis* in continental Antarctica, 65 species of lichenicolous fungi were identified; out of them numerous taxa were recorded from the Antarctic for the first time (3 genera and 31 species). Among others there were two new species described: *Dactylospora dobrowolskii* Olech *et* Alstrup and *Octospora arctowskii* Olech *et* Mleczko (Ascomycota) named in honour of two famous Polish scientists, A.B. Dobrowolski and H. Arctowski, the participants of the *Belgica* expedition (1897-99) (Olech and Alstrup 1990, 1995, 1996; Olech and Mleczko 2000).

Taxonomic studies on lichenized fungi resulted in the description of numerous new species, namely *Caloplaca buelliae* Olech *et* Söchting, *C. iomma* Olech *et* Söchting, *C. psoromatis* Olech *et* Söchting and *C. siphonospora* Olech *et* Söchting, *C. scolecomarginata* Söchting *et* Olech, *C. frigida* Söchting, *Bryoria forsteri* Olech *et* Bystrek, *Bacidia subcoprodes* Olech *et* Czarnota and *B. chrysocolla* Olech, Czarnota *et* Llop (Olech and Söchting 1993; Söchting and Olech 2000; Olech and Bystrek 2004; Olech and Czarnota 2009). In several papers (*e.g.* Śliwa and Olech 2002) difficult taxonomic problems within the lichen genus *Lecanora* were discussed.

Taxonomic and chemotaxonomic revision of *Cladonia* species from King George Island was undertaken. Fourteen species were found there including *Cladonia asahinae* J.W. Thomson, recorded for the first time (Osyczka and Olech 2004). A key for the identification of species belonging to the genus *Cladonia* was

also provided (Osyczka and Olech 2005b). Chemotaxonomic revision of the genus *Tephromela* (six species) was also published (Osyczka and Olech 2005a).

Lichenological material collected from the South Shetland Islands and from Schirmacher Oasis and Bunger Oasis on continental Antarctica led to the publication of new data on four species within the lichen genus *Lepraria* (Osyczka *et al.* 2009).

Several papers published by Polish scientists have been devoted to the taxonomy of algae. One new genus, one new species and several new varieties were described (Massalski *et al.* 1995, 1999b; Mrozińska *et al.* 1998a; Olech *et al.* 1998b; Kostikov *et al.* 2003).

### Morphology, anatomy, cytology, embryology, and biochemistry

Karyological and cytological studies on Antarctic liverworts were carried out by Ochyra *et al.* (1982) and on mosses by Kuta *et al.* (1982) and Przywara *et al.* (1984). Karyological analysis of 15 species was performed and, in several cases, the number of chromosomes was given for the first time. Rhizoid gemmae in a moss *Ditrichum brotherusii* were also described (Ochyra 1996d).

Morphological studies covered both flowering plants and algae. Anatomical, morphological and functional variability of *Deschampsia antarctica* from King George Island was studied. Significant differences between particular populations from various habitats were considered to be a result of the lack of interspecific competition in these habitats (Barcikowski *et al.* 2001, 2003; Chwedorzewska *et al.* 2008a). Anatomical studies on the ultrastructure of the leaves of *D. antarctica* and *Colobanthus quitensis* published by Giełwanowska (2005), Giełwanowska and Szczuka (2005), and Giełwanowska *et al.* (2005b, 2008a, b) helped to explain the adaptations of both species to extreme habitat conditions and their anatomical reaction to abiotic stress factors. New ultrastructural features were found in the mesophyll cells (Giełwanowska and Szczuka 2005). The morphology of pollen of *D. antarctica* and *C. quitensis* has been studied by Sadowska (1998), Giełwanowska *et al.* (2008c) and Szczuka *et al.* (2008).

Morphological diversity of some groups of algae and blue-green algae from King George Island was studied by Kawecka *et al.* (1996) (Bacillariophyta), Mrozińska *et al.* (1998b) (Chrysophyta), Massalski *et al.* (1994, 2001) (Chlorophyta), and Massalski *et al.* (1999a, b) (Cyanobacteria). The cell ultrastructure of *Xanthonema* (Xanthophyta) was analyzed in detail. Peculiar processes during mitosis and cytokinesis in this species were recorded by Massalski *et al.* (2009).

Biochemical studies on Antarctic mosses and the flowering plants, *D. antarctica* and *C. quitensis*, were studied by Czczuga *et al.* (1982, 1984) and Piotrowicz-Cieślak *et al.* (2005), who investigated the content of carotenoids and carbohydrates in those plants. The carotenoid content in the thalli of different Antarctic lichen species was examined by Xavier-Filho *et al.* (1986), Czczuga *et al.* (1986, 1996),

Czczuga and Xavier-Filho (1987), Czczuga and Olech (1989) and by Czczuga and Koch (1991). Lipids and insoluble carbohydrates in Antarctic lichens were also studied by Giełwanowska *et al.* (2008b) while the chemical composition of some dominating plants in the maritime Antarctic tundra was investigated by Fabiszewski and Wojtuń (2000).

## Physiology and reproduction

Changes in the chlorophyll content in selected moss species were investigated by Barcikowski and Loro (1999).

Many papers by Polish physiologists concerned the grass *D. antarctica*. Its response to temperature stress was studied by Bystrzejewska (2001), Giełwanowska (2003) and Bystrzejewska-Piotrowska and Urban (2009). The response of this grass to the concentration of biogenic substances in its habitats was investigated by Nędzarek and Chwedorzewska (2004). It was demonstrated that *D. antarctica* is highly tolerant to the extreme diversity of nitrogen and phosphorus concentrations both in soil and water. Pollen growth and pollination types in *C. quitensis* were studied by Giełwanowska *et al.* (2006, 2007) and Szczuka *et al.* (2008), while the biology and generative reproduction of *D. antarctica* was studied by Giełwanowska *et al.* (2005a).

The production of enzymes in hyphal fungi was investigated by Kasieczka-Burnecka *et al.* (2005); pectinolytic enzymes and tannases were found in these organisms. Ecophysiological studies of lichens were conducted by Schroeter *et al.* (1995). They examined the influence of microclimatic factors on primary production in *Usnea antarctica*. A mechanism of two-stage hydration/dehydration of the lichen thallus, extremely important during weather changes accompanied by frost, was discovered. The two-stage hydration mechanism is present only in fruticose lichens and was not observed in those crustose lichens forming a flat crust on the substratum (Harańczyk *et al.* 2009). The mechanism of resistance of lichens to low temperatures was also studied in detail. It appeared that the tightly bound water in lichen thalli usually does not freeze. It was found also that, when the temperature drops down, free water which would otherwise freeze in the thallus of a lichen turns into non-freezing bound water. This is possible due to the formation of a gel-like structure which traps the water (Harańczyk *et al.* 1998a, b, c, 2000a, b, 2001, 2003a, b, c, 2006, 2008, 2009).

## Ecology

The first Polish studies on plant communities in the area near to the *Arctowski* Station were performed in 1979/1980 (Furmańczyk and Ochyra 1982).

Terrestrial biotopes of the coastal Admiralty Bay ecosystem were also described in detail by Zarzycki (1993). The influence of wind on the spreading of diaspores in this region was also investigated (Hołdyński *et al.* 2003). The problem of the introduction of an alien grass species, *Poa annua* L. was studied by Olech (1996b) and Chwedorzewska (2008). High variability and high genetic diversity suggest that this grass originated from many different places, whereas its survival and growth in the Antarctic are possible due to the favourable conditions created by global climate warming.

Plant communities of King George Island, of South Shetland Islands and the Antarctic as a whole were described and discussed in the papers by Ochyra (1984) and Olech (1993, 1998a, 2002).

The growth rate and biomass production of *Deschampsia antarctica* in the Admiralty Bay area was studied by Barcikowski *et al.* (1999). The biomass of some species of mosses occurring on King George Island was studied by Barcikowski and Gurtowska (1999).

Diatom communities inhabiting streams and stagnant water bodies were also thoroughly investigated. Long term observations of the structure of these communities showed that they are changing, reflecting the unstable environmental conditions which are the result of the temperature rise and desiccation caused by climatic change (Kawecka and Olech 1993, 2004; Kawecka *et al.* 1998; Ochwanowski and Pocięcha 2005).

The ecology of algae, especially their colonization of glacial moraines as well as the influence of penguin colonies upon algae distribution, was analyzed by Mrozińska *et al.* (1998a, 2007).

Plant communities in abandoned penguin rookeries of King George Island and, in general, the influence of penguin guano on particular plant species, especially *Deschampsia antarctica*, were thoroughly studied by Tatur and Myrcha (1989), Olech (1990, 1996a, b, 1998a), Tatur *et al.* (1997), Pisarek *et al.* (2003), Chwedorzewska *et al.* (2004), Smykła (2005) and Smykła *et al.* (2006, 2007). The role of ornithogenic soils in the functioning of polar ecosystems was also discussed in the papers by Krywult *et al.* (2003), Barcikowski *et al.* (2005) and Smykła (2008). The colonization of deglaciated areas by plant communities was studied by Olech (1996b) and Olech and Massalski (2001). Plant biomass and seasonal changes in the concentration of some organic compounds, principally the chlorophyll, in mosses and vascular plants, were analyzed by Barcikowski and Luścińska (2001).

Human influence on the Antarctic environment was also studied, especially the trace element content, including heavy metals (particularly lead), in the thalli of lichens growing in the vicinity of polar stations (Olech 1991b, 1996a, 1997; Olech *et al.* 1993, 1998a, 2000; Osyczka *et al.* 2003, 2007; Smykła *et al.* 2005). The pollution of the Antarctic environment was also studied by means of the analysis of the amount of radionuclides in lichens and mosses (Schuch *et al.* 1993; Godoy *et al.* 1998; Mietelski *et al.* 2000, 2008; Gaca *et al.* 2003). In comparison

with other organisms occurring on King George Island the concentration of radionuclides was highest in lichens (Mietelski *et al.* 2008).

The initial stages of flora and plant-cover synanthropization were monitored by Olech (1994, 1998b). Special attention was paid to the invasive plants (Olech 1994, 1998b; Chwedorzewska *et al.* 2008b; Chwedorzewska 2009).

The study of samples from the soil from Coulman Island produced interesting information on propagules of the potential colonists of the Antarctic region (Lewis-Smith and Ochyra 2006).

Peat-forming vegetation of King George Island of extreme floristic poverty was studied by Fabiszewski and Wojtuń (1993, 1997). Using C-14 dating these authors demonstrated that these peat-banks developed some 4000 years ago.

Palynological (aerobiological) study was performed along a transect from Antarctica to Poland (4th March – 13th April 1990), from which a valuable collection of lichen propagules was sampled (Harmata and Olech 1991).

## Genetics

Genetic research on *Deschampsia antarctica* was recently undertaken. Intra-specific genetic variability and affinity between the populations from various islands of the South Shetlands archipelago, from islands neighbouring the Antarctic Peninsula and from the Falkland Islands was studied. A low genetic variability was found (Chwedorzewska and Nędzarek 2005; Kyryachenko *et al.* 2005; Chwedorzewska 2006; Chwedorzewska and Bednarek 2008).

Genetic studies of algae were also carried out by Rybalka *et al.* (2009). The endemism and genotypic diversity of the Antarctic algae of the family *Tribo-nemataceae* (*Xanthophyceae*) were analyzed. It was found that Antarctic populations differ from those inhabiting moderate climatic zones. Currently-identified morphospecies do not reflect the actual biodiversity within this group.

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