Folia Fac. Sci. Nat. Univ. Masarykianae Brunensis, Geographia 25 (2001): 111-119

PLANT COLONIZATION AND COMMUNITY DEVELOPMENT ON THE SPHINX GLACIER FOREFIELD

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ABSTRACT

Investigations on the processes of plant colonization and succession on the Sphinx glacier forefield in the region of Admiralty Bay, King George Island (South Shetlands) have been carried out. Field observations have been conducted in 1996 along the transect from the front of glacier to the bay shore, during Polish Academy of Sciences expedition to H. Arctowski station. The transects were laid out in such a way as to include various environmental gradients. Phytosociological records using the Braun-Blanquet method have been carried out on 1 m^2 areas. In the phytosociological lists the fungi, mosses, algae and vascular plants were taken into consideration. Environmental factors, particularly the chemistry of soils subjected to the plant succession, have also been investigated. The aim of investigations was to to become acquinted with the course of colonization and succession in the areas exposed by the retreating glacier under the conditions undisturbed by the animals (lack of intensive fertilization by the penguin guano), as well as to correlate the gradient of some environmental factors with the colonization process and the forming of plant communities. The preliminary analysis of the obtained results has shown that the colonization success in the areas of the Sphinx glacier forefield depends directly on the plant succession and the fluctuations caused by the glacial melt waters, so called braided streams, which very often change their river-beds within the glacier forefield.

KEY WORDS: King George Island - Sphinx Glacier forefield - soils - plant colonisation development

INTRODUCTION

There is an evidence that the summer temperatures in the maritime Antarctic have been steadily increasing for the last 45 years, and that the rate of increase has been much greater since 1980 (Fobert, Lewis Smith, 1994). As a result of climate warming glaciological changes, in particular the processes of deglaciation on the land, and the retreating of glaciers can be observed.

The retreating of glaciers in costal areas causes the exposure of new land areas. This offers a unique opportunity to study not only the biological colonization, but how the simple ecological systems (tundra ecosystems) are form, and how they function.These issues have become recently the subject of extensive studies in Antarctica (Corner, Lewis Smith, 1973; Lewis Smith, 1982, 1985, 1993, 1995; Walton, 1985; Longton, 1988; Davey, Rothery, 1993; Sancho, Valladares, 1993; Mrozińska, Olech, Massalski, 1998; Valladares, Sancho, 1995). All these questions are also included in the international programmes: BIOTAS (Biological Investigations of Terrestrial Antarctic Systems) and CS - EASIZ (Coastal and Shelf Ecology of the Antarctic Sea - Ice Zone).

This work presents preliminary studies on the colonization of marginal parts of Sphinx glacier. The aim of study was to learn the course of colonization and succession in the areas exposed by the retreating glacier, to learn the initial stages in the process of primary succession on the surfaces recently denuded from ice, and also to correlate the gradient of some ecological factors with the colonization process and the forming of plant communities.

Former studies concerning these subjects were usually limited to the particular groups of organisms (Lewis Smith, 1993, 1995; Davey, Rotherry, 1993; Sancho, Valladares, 1993).

In the present study all the main groups of organisms participating in the forming of plant cover of these regions were taken into consideration.

STUDY AREA

The Sphinx glacier forefield selected for this study (Fig.1) is situated within the Site of Special Interest (SSSI) N^0 8, on the shore of Admiralty Bay, King George Island, South Shetland Islands. The forefield is a bottom moraine made by the retreating glacier. Precise age of recently exposed surfaces has not been determined, but on the basis of aerial photographs (Furmańczyk unpublished data) the average distance from the edge of Sphinx glacier to the sea shore in 1979 was about 300 m. This distance has increased to about 600 m in 1996 (when the study on the transect from the glacier edge to the sea shore was carried out).

The majority of investigated area is flat, and it is situated only slightly above the sea level. Higher parts of area, localized in the immediate vicinity of glacier, reach 50 m. above the sea level.

The forefield surface is diversified by the presence of small moraine ramparts (the highest reaching up to 3 m.), and the depressions occurring between the ramparts (Fig.1).

The landscape of this glacier forefield is characterized by the presence of numerous braided stream originating from a sudden flow of the glacial melt waters. These streams flowing into the sea often change their river-beds, and the water level in them undergoes significant fluctuations. Therefore, the substratum is unstable, also due to the processes of solifluction occurring here.

Investigated area and the immediate neighbourhood is devoid of penguin colonies, and the single bird nests were also never observed. Thus, there is no direct influence of animal fertilization in this area.

MATERIALS AND METHODS

Field studies were carried out during the austral summer 1995/96 on the transect laid out from Sphinx glacier to the Admiralty Bay shore (Fig. 2).

Investigations were based on the Braun - Blanquet method. Phytosociological records were performed on 1 m^2 areas along the whole length of transect (600 m). Investigations considered: algae, fungi, lichens, bryophyta, and vascular plants. Field samples collection included plants or fungi difficult to identify in the field, the samples with visible growth of algae, and soil samples to be subsequently culture in the laboratory.

The collection was also extended to soil samples for determination of physico-chemical, and chemical properties. Chemical analysis were made in the laboratory at the Botany Institute, Jagiellonian University.

The range of analysis included:

- determination of mechanical composition using Prószynski method
- pH of soils (in the solutions: water, KCl and $CaCl_2$))
- total content of organic carbon (Tiurin method)
- total nitrogen (Kjeldahl method)
- C/N ratio
- exchangeable forms of Na, K, Mg, Ca and P (in 1 N solution of ammonium acetate) using the following methods: Photoradiation (spectrophotometer Flapho-n) for the content of Na, K, and Ca; Photocolorimetry (titan yellow method) for the content of Mg; Photocolorimetry (vanadium-molybdate method, spectrophotometer Spekol-11) for the content of P.

RESULTS

Soils

Diversity of mechanical composition of soils along the investigated transect is shown in Table 1. Soils of Sphinx forefield belong to the sandy-gravel type of light soils (regosols). These soils contain an average amount of rocky skeleton (above 70%), which displays a certain degree of rounding. The described soils are characterized by a very high pH (Table 2) fluctuating between 7,8 to 9,0 (pH H_2O) and 5,6 to 6,9 (pH KCl). There are relatively small pH fluctuations along the whole transect. In all analyzed samples the organic carbon content was low (0,1-0,4), and there were very small amounts of total nitrogen (Table 2). Along the whole transect neither an increase of organic carbon content nor significant changes of chemical properties were observed (Table 2). Close to the sea the white salt efflorescences can be observed.

Vegetation

A total of 65 taxa: 29 lichenes, 14 mosses, 18 algae, 2 vascular plants and 1 species of fungi, were found in 585 phytosociological records taken along the transect. The most common species are: *Caloplaca johnstonii* (Dodge) Olech & Soechting, *Lecanora dispersa* (Pers.) Sommerf. (lichens), *Bryum pseudotriquetrum* (Hew.) C. F. Gaertn., B. Mey and Schreb. (mosses), and *Colobanthus quitensis* (Kunth) Bartl. (vascular plants).

In relation to the habitat preference the terrestrial species predominate over the epilithic species. An almost complete absence of terrestrial lichens, apart from only 3 species namely: *Leptogium puberulum* Hue, *Psoroma hypnorum* (Vahl) S. F. Gray and *P. tenue* Henssen occurring in 6 records, is a characteristic phenomenon for the investigated transect.

Considering a general percentage of plant coverage, of 585 investigated squares as many as 314, that is about 54%, were devoid of vegetation (Figs. 3 and 4). These were the places, which were latest of all cleared from ice, or the places destroyed by the glacial melt waters. Squares with a total plant coverage over 75% are very infrequent (Fig. 3).

Mosses show the highest coverage percentage in the investigated squares (Fig.3). The highest plant coverage for any single species was 90%, which was reached by *Bryum pseudotriquetrum*. Squares with a relatively highest plant coverage occur at a large distance from the glacier.

The first lichen species possible to diagnose within the transect were found on a boulder, at a distance of 134 m from the glacier (Fig. 2). They were pioneer epilithic lichens: *Caloplaca johnstonii*, *Lecanora dispersa*. The next epilithic lichen *Lecidella sublapicida*

(Knight) Hertel. occurred at a distance of 280 m , and a representative of fruticose lichens *Usnea antarctica* Du Rietz was encountered at a distance 316 m.

The first colonizers on soil were the following: a vascular plant, the grass *Deschampsia antarctica* Desv., next was the moss *Bryum pseudotriquetrum*, both were found at a distance of 265 m from the glacier. At a distance of almost 550 m from the glacier edge a new species of fungus *Octospora arctowski* Olech & Mleczko (*Ascomycotina*) has been described (Olech, Mleczko in press).

Microtopography of the Sphinx glacier forefield (small moraine ramparts) causes slightly larger species differentiation.

On the rampart ridges most of all occur crustose epilithic lichens such as: *Caloplaca johnstonii, C. sublobulata* (Nyl.) Zahlbr., *C. citrina* (Hoffm.) Th. Fr., *Lecanora dispersa, Rhizoplaca melanophtalma* (D.C. in Lam & DC.) Leuck. Poelt, *Rhizocarpon geographicum* (L.) DC., and *Usnea antarctica.*

The bases of rampart slopes are colonized by the following species: *Caloplaca austroshetlandica* (Zahlbr.) Olech & Soechting, *Staurothele gelida* (Hook & Tayl.) Lamb (lichens), *Syntrichia princeps* (De Not.) Mitt. (mosses), and *Deschampsia antarctica* (vascular plants).

In the depressions between the ramparts dominant are mosses (mainly *Bryum pseudotriqetrum*), Cyanophyta (mainly *Phormidium spp*), algae (green algae and diatoms) and lichens on the boulders (*Lecidea lapicida* (Ach.) Ach., *Verrucaria elaeoplaca* Vain., *Aspicilia sp*).

Pioneer species occur along the whole transect. These are most of all the epilithic lichens such as: *Caloplaca johnstonii, Lecanora dispersa , Lecidella sublapicida.* Pioneer mosses, mainly *Bryum pseudotriquetrum* also occur along the whole transect, but mostly in the depressions.

From the phytosociological point of view the plant communities occurring on the investigated glacier forefield are in their initial stages of development. They have either very low or low degree of plant coverage, and they are indigent in species.

Taking into consideration the frequency of species occurrence, changes of species composition and the plant coverage in the squares, three transect zones can be distinguished:

Zone I. At a distance of 1-265 m from the glacier edge, the soil is devoid of plant cover. The pioneer epilithic crustose lichens begin to occur on the rock substratum (*Caloplaca johnstonii, Lecanora dispersa).*

Zone II. At a distance of 265 m from the glacier the first terrestrial species such as: *Deschampsia antarctica, Bryum pseudotriquetrum* can be observed. The colonization of terrestrial lichens begins in this zone. A large participation of the moss *Ceratodon purpureus* (Hedw.) Brid. is characteristic for this zone.The species occurrence and community differentiation depends on the area microtopography.

Zone III. At a distance of about 450 m the pleurocarpous moss *Brachytecium austrosalebrosum* (Müll. Hal.) Kindb. begins to occur. The occurrence of *Hennediella antarctica* (Angstr.) Ochyra & Matteri and *Octospora arctowski* community is also characteristic for the sites influenced by the vicinity of the sea.

DISCUSSION

In the majority studies on the colonization and development of plant communities in Antarcica (Lewis-Smith, 1993, Walton, 1990) the initial stages of succession processes are most often neglected. In the literature there is an absence of description of the initial succession communities, and there are relatively few studies concerning a true nature of the pioneer colonization (Lewis-Smith, 1993).

This work presents an example of the pioneer colonization on the forefield of the retreating glacier and the early stages of succession under the conditions undisturbed by the animals (absence of animal colonies). In the investigations the organisms such as: lichens, mosses, fungi, algae and vascular plants were considered - their qualitative and quantitative participation, and their role in colonization of areas denuded from ice.

Vegetation on the investigated area turned out to be indigent in comparison to the neighbouring areas without ice cover (Olech, 1993, 1994; Olech msk; Ochyra, 1998). Preliminary investigations revealed the absence of fully developed plant communities which can be observed on other recent moraines e.g. Ecology glacier (Olech msk). On the Sphinx glacier forefield the open communities, with small number of species and low or very low degree of plant coverage can be encountered. These are the communities in their initial stages of development (initial phase). Single patches of communities with higher degree of plant coverage can be occasionally seen in the places more distant from the glacier. This leads to the phenomenom of the irregular open-work ornamentation effect within the existing plant cover.

The species number is also relatively low in comparison to the neighbouring areas, although certain increase of species number as well as more diversified community composition in the distance gradient from the front of glacier can be observed. The occurence, development and species diversity of the initial stages of succession are influenced not only by the time when the substratum was denuded from ice (distance from the glacier), but also by the microtopography of the area. This phenomenom was also pointed out by the investigators of other regions (Schwarz, Green, Seppelt, 1992).

The communities and species diversity is also influenced by the immediate vicinity of the sea. A new for science species of fungus *Octospora arctowskii* has been described in the investigated area. This species was found in a very interesting community *Hennediella antarctica* - *Octospora arctowskii* (this community until now was not listed in the literature).

The stability of substratum also turned out to be a very important factor. The occurrence of frost solifluction phenomena limits the development of plant communities in this area. Similar phenomena can also be observed in other regions e.g. in Arctica (Fabiszewski, 1975; Pirożnikow, Górniak 1992). The instability of substratum is also caused by the braided streams.

The most attention was paid to the soils of the Sphinx glacier forefield where the succession takes place. These are regosols - the soils of skeleton type with a low content of floatable parts, and humus. They are occupied only by the pioneer communities.

Chemical properties of colonized soils do not change along with the age gradient. The high pH of soil characteristic for this area undergoes only small fluctuation. This phenomenon can be explained by the lack of plant cover. Similar situation can be observed on the youngest moraines of Ecology glacier (Boelter, 1996; Boelter, Blume, Erlenkeuser, 1995; Olech msk).

In the initial communities an important role play mosses, particularly *Bryum pseudotriquetrum,* and to a lower extent *Ceratodon purpureus*, whereas closer to the sea the species: *Hennediella antarctica* and *H. heimi* (Heww.) Zandi . The nitrophilous species are very infrequent, such as: *Acarospora macrocyclos* Vain., *Caloplaca sublobulata, C. citrina, Rhizoplaca melanophtalma* and are characteristic by their low frequency. The liverworts are completely absent. Considerable participation of Cyanophyta and algae (particularly the diatoms) occurring as a surface black crust is also very characteristic.

Indigence of plant cover on the Sphinx glacier forefield and its irregular open-work ornamentation can be explained not only by the influence of severe polar conditions, but most of all by the mechanical damage processes caused by the destructive action of braided streams, which results in the interruption of succession processes and limits the development plant communities.

The preliminary analyses of the obtained results have shown that the colonization success in the area of the Sphinx glacier forefield depends directly on the plant succession and the fluctuations caused by the braided streams.

Presented investigations are the basis for the further monitoring research on the constant delineated transects.

ACKNOWLEDGEMENTS

We wish to express our thanks to Prof. Dr. Jiři Komárek for his help in the identification of Cyanophyta. Thanks are also due to Msc. Małgorzata Matyjaszkiewicz for excellent technical assistance and to Msc. Mieczyslaw Langer for the soil analysis. This study was supported by a grant PB 319/PO 4/97/13 from the Science Research Committee (KBN).

Tab. 1 Mechanical composition in analysed soil samples.

Number of sample	Distance from glacier (m)	Height a.s.l. (m)	Content of fraction in mm (%)							Mechanical group		
			> 1,0	1,0–0,1	0,10 – 0,05	0,05 – 0,02	0,02 – 0,005	0,005–0,002	< 0,002	1,00 – 0,10	0,10 – 0,02	<0,002
B/O	–	–	± 70	63	5	14	8	5	5	63	19	18
SPH-1	28,5	50	± 70	64	9	11	11	3	2	64	20	16
SPH-2	101,0	50	± 70	76	6	9	5	3	1	76	15	9
SPH-3	114,0	50	± 70	74	6	9	5	3	3	74	15	11
SPH-5	188,5	30	± 70	59	11	8	13	4	5	59	19	22
SPH-6	228,0	20	± 70	83	6	5	3	2	1	83	11	6
SPH-7	260,0	15	± 70	90	6	2	1	0	1	90	8	2
SPH-8	275,0	15	± 70	52	12	14	11	8	3	52	26	22
SPH-10	320,0	0	± 70	68	7	9	11	3	2	68	16	16
SPH-11	370,0	0	± 70	63	13	8	9	3	4	63	21	16
SPH-15	427,0	0	± 70	86	5	3	3	1	2	86	8	2
SPH-16	441,0	0	± 70	78	8	5	5	1	3	78	13	9
SPH-18	482,0	0	± 70	73	11	5	6	2	3	73	16	11
SPH-19	510,0	0	± 70	79	7	8	2	1	3	79	15	6
SPH-20	530,0	0	± 70	72	7	7	8	3	3	72	14	14
SPH-21	565,0	0	± 70	81	12	4	1	1	1	81	16	3

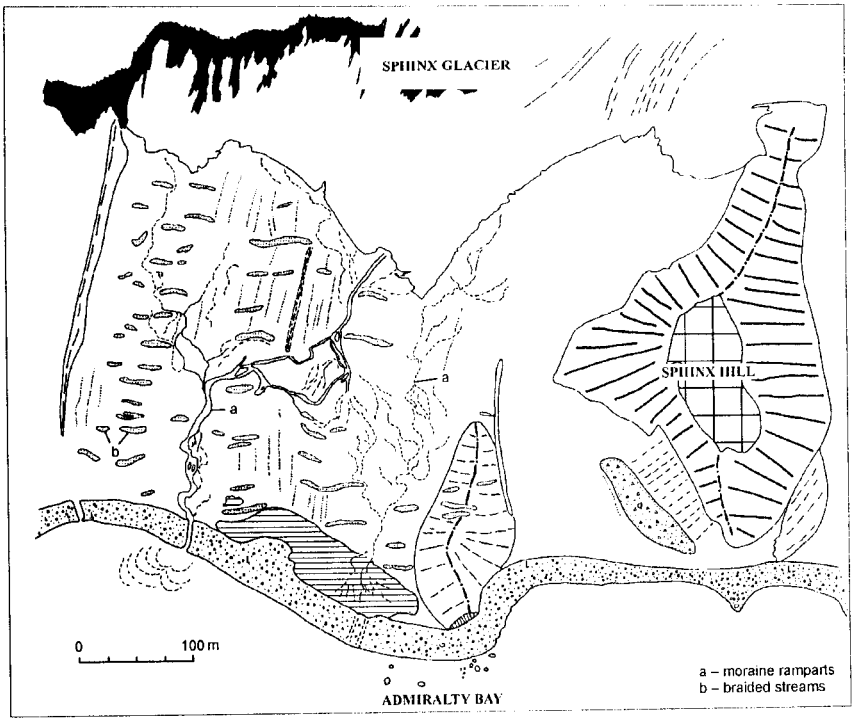

Fig. 1 Study area.

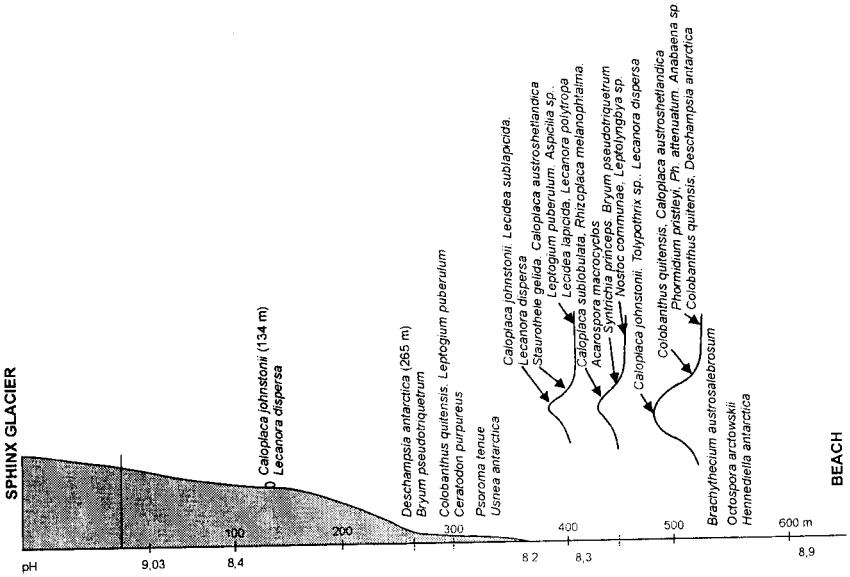

Fig. 2 Plant colonization on the Sphinx glacier forefield.

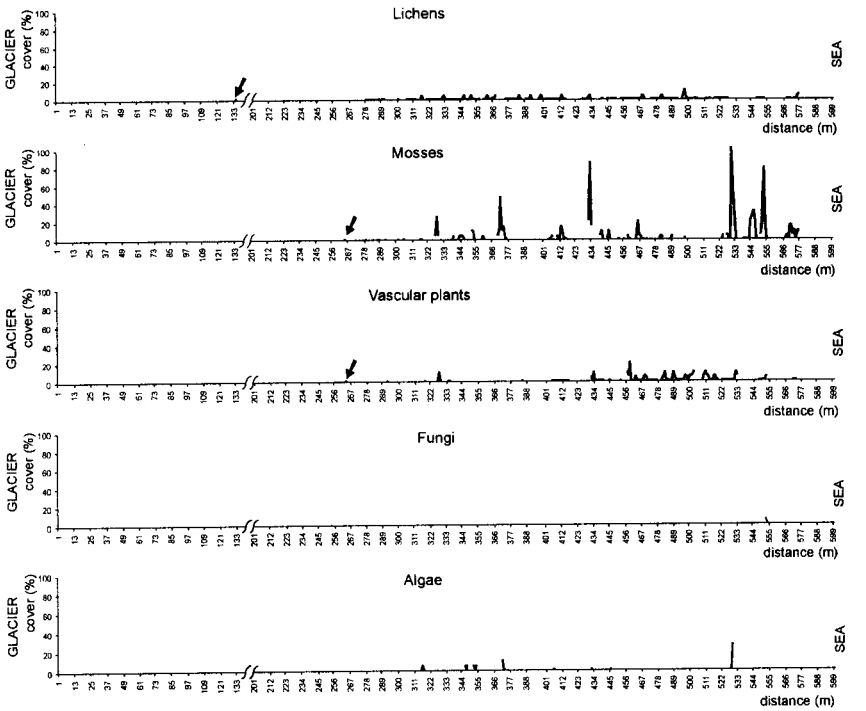

Fig. 3 Colonization of lichens, mosses, vascular plants, algae and fungi on the transect of the Sphinx glacier forefield.

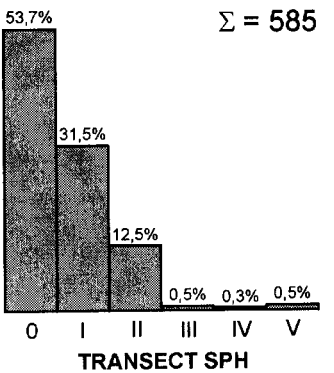

Fig. 4 General percentage of plant coverage on the transect of the Sphinx glacier forefield.

0 – squares devoid of vegetation
I < 5 % of plant coverage
II 5–25 % of plant coverage
III 25–50 % of plant coverage
IV 50–75 % of plant coverage
V > 75 % of plant coverage