—研究ノート—
Scientific Note

Establishment of Permanent Plots with Lichens and Mosses for Monitering Local Human Impact on Environment in Heimefrontfjella and Vestfjella, Dronning Maud Land, Antarctica

Göran THOR*

ドローニングモードランドにおける人為的環境変化による影響評価のための蘚苔・地衣類の永久方形区の設置

Göran THOR*

要旨: 西ドローニングモードランドにあるスウェーデンの3つの基地（ヴェストフェラのワサ基地と野外基地, ハイムフロントフェラのスベア野外基地）は人為的な環境変化に影響を受けやすい蘚苔・地衣類が豊富に生育している地域に設置されている. 基地活動による環境評価のプロジェクトの一環として, 蘚苔・地衣類を用いた長期的モニタリングが計画された. 120の永久方形区からなる11のライントランセクトが3つの基地に設置された. トランセクト上と方形区内の植物が記載され, 記録方法が示された. 方形区内で記録された種は将来の比較を容易にするように考慮され, その地域に代表して出現する地衣類だけを記録した. ハイムフロントフェラでは1293地点で18種の地衣類が記録され, ベストフェラでは704調査点で13種が記録された.

Abstract: Results from a biological investigation reveal that all three Swedish Antarctic stations in western Dronning Maud Land (*i.e.* the main station Wasa at Basen in Vestfjella, a small field station at Fossilryggen in Vestfjella, and the field station Svea at Haldorsentoppen in Heimefrontfjella) are located in areas having a rich and vulnerable lichen and moss vegetation. As part of a project to monitor local human environmental impacts associated with activities at the Swedish stations, a long-term monitoring study using lichens and mosses was designed. Eleven transects consisting of 120 permanent plots (and 3000 subplots) were established at different distances from the three stations. The transects and plots are described and the principles used in recording them are given. All records made within the plots are presented to facilitate future comparisons. The transects were not intended to be representative for all habitats at the nunataks. The species recorded in the plots thus represent only a selection of the lichens present within the study area. Eighteen lichen species were recorded within the plots in Heimefrontfjella from a total of 1293 observations, and in Vestfjella thirteen species were recorded from a total of 704 observations.

1. Introduction

It is now a requirement of the Antarctic Treaty that all human activities in the

* Section for Conservation Botany, Department of Conservation Biology, Swedish University of Agricultural Sciences, P.O. Box 7072, S-750 07 Uppsala, Sweden.

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Antarctic should be assessed with regard to their potential impact on the environment and its biota. During the Swedish Antarctic Research Programme (SWEDARP) expedition in the austral summer of 1991/1992, the author made biological investigations in Heimefrontfjella and Vestfjella in western Dronning Maud Land, Antarctica (Fig. 1). Lichens are the major component of the vegetation within the study area, even though often sparse and patchy. The lichens and mosses display a low species diversity, and typically cover only a few per cent of the ground areas. They are more abundant in areas having more favourable conditions, especially in sites in which water is present. Results from the investigation reveal that all three Swedish stations (the main station Wasa at Basen in Vestfjella, a small field station at Fossilryggen in Vestfjella and the field station Svea at

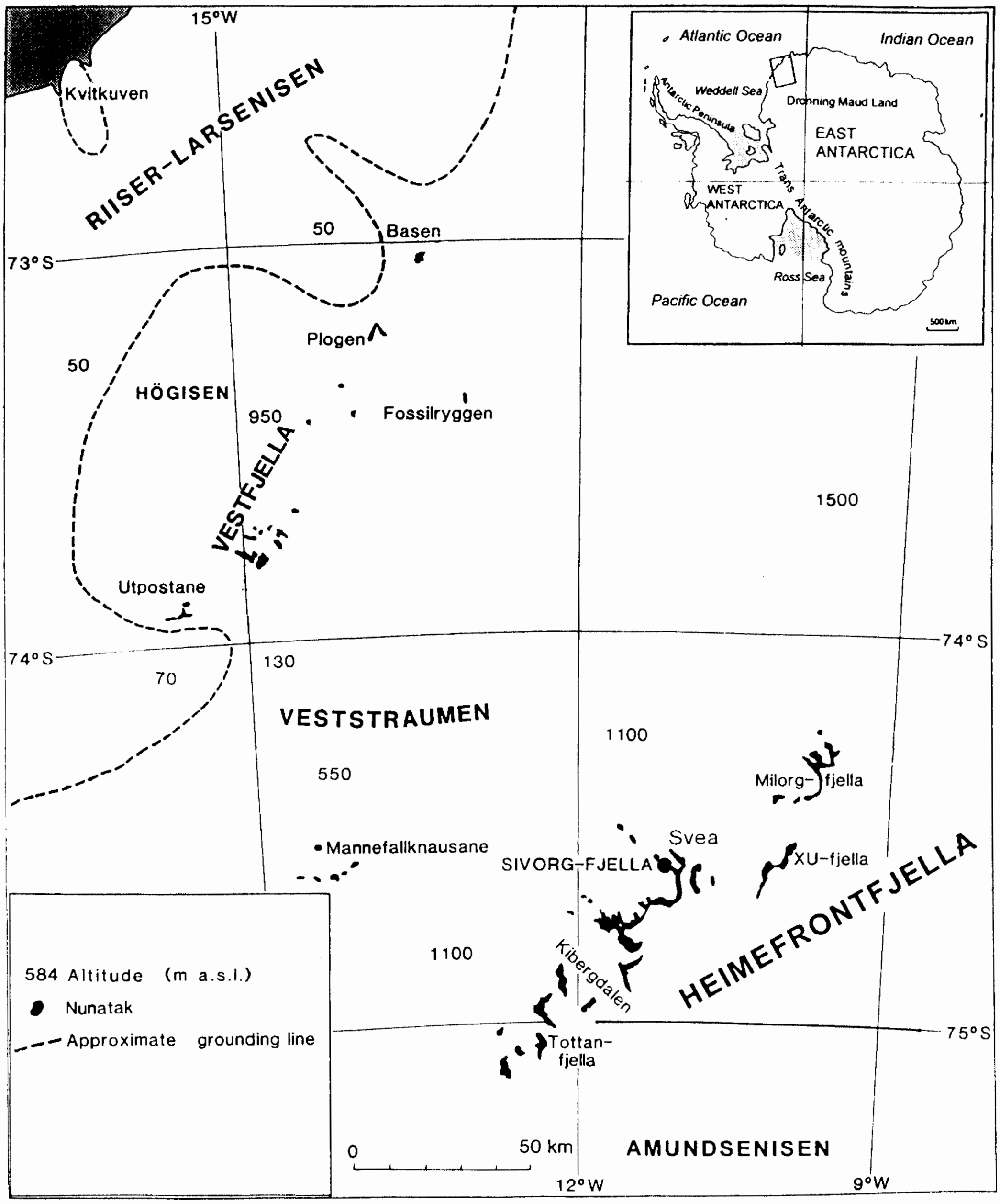

Fig. 1. The general location of the field area.

Haldorsentoppen in Heimefrontfjella) are located close to areas with rich and vulnerable lichen and moss vegetation's (THOR, in prep.). While Svea and the small field station at Fossilryggen are located < 100 m from such areas, Wasa is about 800 m (WSW) from such an area. The Finnish station Aboa is situated 200 m E of Wasa. As part of a project to monitor local human environmental impacts associated with activities at the Swedish stations, a long-term monitoring study using lichens and mosses was designed. Transects with permanent plots were established at different distances from the three stations. The plots will be regularly monitored (ERIKSSON, 1994). Information from the plots, combined with a biological inventory, provide baseline data for site management plans, as well as for codes of conduct for scientific and logistic activity. The aim of this paper is to describe the long-term monitoring study. The position and direction of all transects are described in detail. All records made within the plots are presented to facilitate future comparisons, and the principles adopted in recording the plots are described. A more comprehensive description of the study area and the climate, geology and topography will be presented elsewhere (THOR, in prep.).

2. Background

In the Antarctic reliable taxonomic concepts are requisite for environmental impact assessments (EIAs), identification of areas in need of protection because of their biodiversity, monitoring (both short-term and long-term), the preparation of management plans, floras, check-lists etc. (see also RUSSELL and SMITH, 1993). In order to make use of the full potential of lichens, we urgently need increased knowledge of taxonomy, abundance and dispersal. In continental Antarctic, crustose species predominate both by their frequency and in number of species, but the taxonomy and distribution of these species is still poorly known.

Although establishment and growth rates of most lichens in continental Antarctic appear to be slow, there are still few published data to confirm this assumption. Most existing data for the Antarctic derive from the Subantarctic South Georgia and maritime Signy Island, which have a climate very different from that in continental Antarctica (see SMITH (1984) for a summary of available data). Growth rates as low as 1 cm per 1000 years have been reported from continental Antarctica (ROSER *et al*., 1992). Thus, the vegetation is highly vulnerable, and is readily damaged by local human environmental impact (deliberate, incidental or accidental), as for example, by trampling, vehicle traffic, air pollution from hydrocarbon combustion, construction projects or discharge of black waste or grey wastewater. The unintentional introductions of organisms represents a further threat. Even scientific projects *per se,* and the consequences of the scientific method as such (*e.g*., effects on biota of sampling methods, degradation of valued pristine areas, the use of explosives in seismic surveys) can cause impact (BENNINGHOFF and BONNER, 1985; HARRIS, 1991). Because of the slow growth rates and slow rate of biological decomposition, such impacts are in evidence for a very long time.

Monitoring studies of lichens in Antarctica could provide critical information on environmental issues of global significance, and be useful in predicting the nature and scale of future environmental changes. Because nunataks in Antarctica and especially in Dronning Maud Land are within or near the centre of the Antarctic "ozone hole", lichens occurring here are subject to drastically increased levels of UV-B radiation. Lichens produce a number of cortical screening compounds, especially usnic acid, carotenoids and other pigments (*e.g.* melanin) which protect the sensitive photosystems of the lichen photobiont from damaging effects of radiation, and thus make lichens a potentially useful tool in monitoring long-term effects of ozone depletion (GALLOWAY, 1992). Lichens could also serve as monitors of climatic warming. In the harsh environment of continental Antarctica, small changes in temperature and/or moisture should be reflected in corresponding changes in population size, or changes in the species composition and/or changes in habitat associations. There is evidence of plants responding to increasing temperatures in the maritime Antarctic (FOWBERT and SMITH, 1994; SMITH, 1994, 1995) and changes to the flora and fauna on the subantarctic islands are reported to be attributed to the current warming trend (SMITH, 1990; RUSSELL and SMITH, 1993). Since the information from continental areas is even more scattered, there is greater uncertainty about whether there are any changes here.

Permanent plots with lichens to study local human environmental impact in continental Antarctica have been established at, for example, the South African station SANAE (STEELE *et al.*, 1993) and at the Sôya Coast near the Syowa Station (INOUE *et al.*, 1990; KANDA *et al.*, 1990) in Dronning Maud Land. The plots near the Syowa Station were established in 1975, and KANDA and INOUE (1994) reported no increase of lichen growth after 14 years.

3. Material and Methods

The study is based on field work by the author during the austral summer of 1991/1992. The author arrived at Wasa on 30 November 1991, and departed on 20 February 1992. The transects were investigated between 27 January and 10 February 1991. The names of undetermined lichens follows THOR (in prep.) in which morphological descriptions and a key to the species are given. Extensive lichen collections were made within the study area outside the plots, and are deposited at the Swedish Museum of Natural History, Stockholm (S). The length of the transects with plots were measured with a metal measuring-tape, and were oriented using an Antarctica improved 360° compass. The photographs were taken by the author.

4. Study Area

4.1. Geographical names and altitudes

The study was confined to Heimefrontfjella and Vestfjella in western Dronning Maud Land (Fig. 1). These are both 135 km long mountain ridges lying parallel to the coast and consisting of nunataks. Vestfjella is up to 1100 m high, and is 120 km from the coast, whereas Heimefrontfjella is up to 2500 m high, and is 300 km from the coast. Geographical names and the altitudes for Heimefrontfjella are in accord with a map from the Norsk Polarinstitutt 1988 (sheet D8, Heimefrontfjella Nord). The geographical names used for Vestfjella are in accord with a map from the Norsk Polarinstitutt 1972 (sheet C7, Vestfjella Aust). The altitudes for Basen accord with the map from the Swedish Polar Research Secretariat 1991, on which the altitudes are marked with an accuracy of 5 m. The altitudes for Fossilryggen are in accord with a map from the Norsk Polarinstitutt 1972 (sheet C7, Vestfjella Aust). The station Svea is situated at the northernmost end of the nunatak Haldorsentoppen (alt. 1245 m, 74°34′36″S, 11°13′24″W; measured by GPS), and the station Wasa in the south part of the nunatak Basen (alt. 450 m, 73°02′34″S, 13°24′50″W; measured by GPS) (Fig. 2). The small field station at Fossilryggen is situated east of the shale area in the central part of the nunatak (alt. 700 m, *c.* 73°23′S, 13°02′W).

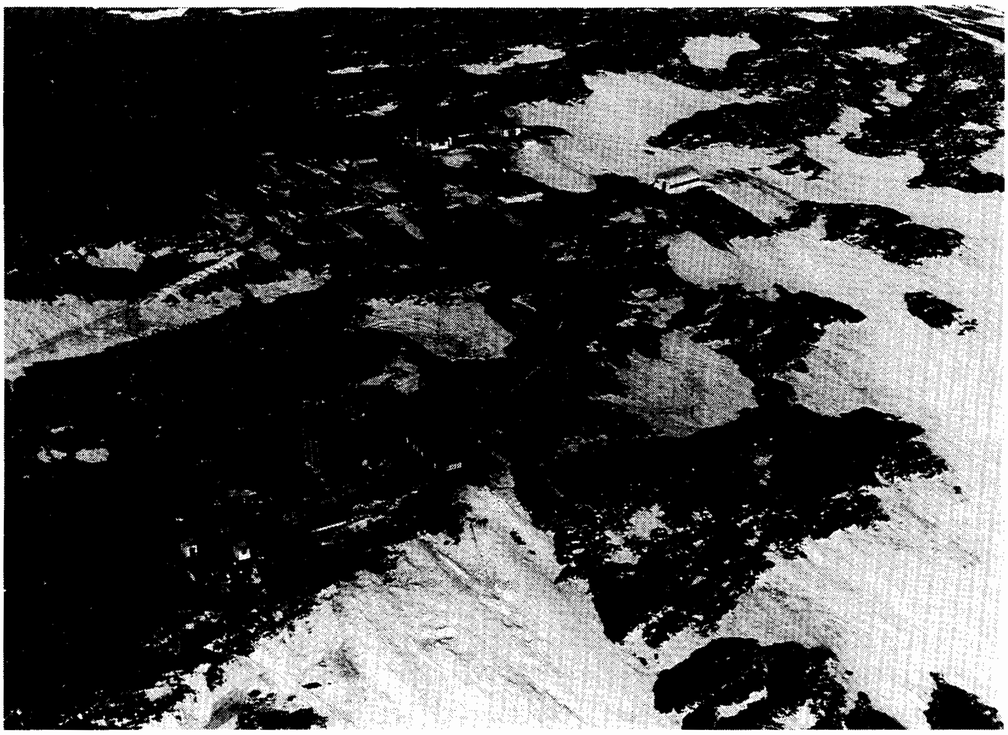

Fig. 2. Air photograph of the Swedish station Wasa (in the foreground) and the Finnish station Aboa (in the background). Transects 7 and 8 were established near the sewage treatment works to the right of the main building of Wasa.

4.2. Climate, geology and topography

The climate in the study area is continental according to the definition by Smith (1984) and is characterized by low temperatures, meagre precipitation and low humidity throughout the year. The annual mean temperature at Aboa is −16°C (data from Finnish Antarctic Expedition 1989/1990 in Isaksson, 1992). No annual mean temperature has been published for Heimefrontfjella, but it is certainly lower than that in Vestfjella, which is located farther north and at a lower altitude.

Basen, the northernmost nunatak in Vestfjella, is dominated by an elevated plateau, and thus differs from the rest of Vestfjella which consists of sharp peaks flanked by steep slopes. Basen is 3000 m long by up to 1500 m broad. The western, northern, north-eastern and, to a lesser extent, eastern portions of Basen terminate in precipices up to 400 m high. The bedrock consists of basalt and diabase with dolerite dikes, and is partly covered by a thin layer of Pleistocene glacial till consisting mainly of basalt and sometimes clay, which in turn is formed from weathered basalt. At least two sandstone horizons are found in the precipice in the westernmost part of Basen (Larsson, 1991).

Fossilryggen is a ridge with gentle sides 2200 m long by up to 400 m broad. It differs geologically from the rest of Vestfjella, and consists mainly of basalt, sandstone and black fissile shale (*e.g.* HJELLE and WINSNES, 1972; JONSSON, 1988; LARSSON, 1990, 1991).

The four massifs of the Heimefrontfjella Escarpment—Milorgfjella (Kottasberge), XU-fjella, Sivorgfjella and Tottanfjella—are each separated by outlet glaciers from the Amundsenisen Plateau (alt. 2500–3000 m) down to the Ritscherflya (alt. *c.* 1200 m near Heimefrontfjella). The present investigation is restricted to Sivorgfjella. The bedrock is mainly grey augengneiss and weakly metamorphic red granite. Weathered augengneiss and granite form coarse gravel and sand which cover most of the bedrock at all nunataks.

5. Description of the Long-term Monitoring Study

5.1. Description of the transects

Transects with permanent plots were established as close as possible to the three stations (*i.e.*, at the nearest site supporting lichens), and also at different distances from Svea and Wasa. The plots farthest away from the stations are referred to as reference plots. Where possible, these were established in areas having species compositions similar to those near the stations. The position of the transects were thus subjectively selected. The reference plots are intended to identify and distinguish local human environmental impacts from global human environmental impacts (*e.g.*, climate changes, increased UV-B radiation), as well as from random changes. To distinguish among the three factors, 11 transects were established.

Six transects (five 30 m in length and one 11.74 m) were established in Heimefrontfjella: one on the small rock mound on which Svea is situated, one on the north slope of the first hill south of Svea, one on the top of the second hill south of Svea, one on the south slope of the fourth hill south of Svea and one on the moraine hill south of Svea. One reference transect was established near the north-western end of Steinnabben, a site rarely visited by Swedish participants. The transect on the south slope of the fourth hill south of Svea should also be considered as a reference transect. Four transects (30 m in length) were established at Basen: two in line close to the sewage treatment works south of Wasa, and two on the hill northeast of Aboa. One transect was established at Fossilryggen *c.* 100 m southeast of the a small field station.

The start and end points of the transects were permanently marked by aluminium stakes (Fig. 3) or by 20 mm diameter holes drilled in the rock. The start point was always located at the northern end of the transect. Plots were usually established at 1 m, 4 m, 7 m, 10 m, 13 m, 16 m, 19 m, 22 m, 25 m and 28 m along the transect. Every second plot was positioned on the right side ("R") and every second on the left side ("L"). The first plot was on the right side beside transect 4 where it was on the left side.

Transect 1 (Table 1). On the north slope of the first hill south of Svea at Haldorsentoppen. The north end of the transect is close to the northern end of the snow-free part of the hill. Some subplots were covered with snow in the upper left part. The transect direction is initially 180°, though after 19.5 m it changes direction to 120°. The total length is 30 m, the altitude is 1250 m, and the difference in altitude along the transect is *c.* 6 m. Plots were established at: 1 m (R), 4 m (L), 7 m (R), 10 m (L), 13 m (R), 16 m (L), 19 m (R), 22 m (L), 25 m (R), 28 m (L). Extra plots were established at: 0 m (R), 4.2 m (R), 12

Table 1. Lichens found in the plots along transect 1 on the north slope of the first hill south of Svea at Haldorsentoppen. "R" indicates that the plot is positioned on the right side of the transect and "L" on the left side.

Species	0m(R)	1m(R)	4m(L)	4.2m(R)	7m(R)	10m(L)	12m(L)	13m(R)	16m(L)	16,5m(L)	18m(L)	19m(R)	22m(L)	22m(R)	25m(R)	26m(R)	28m(L)	28,5m(R)
Acarospora gwynnii			10		1; 16						4; 25			13; 15; 17		9; 11; 12		
Bacidia spp.	3; 19	2; 3; 7; 8; 9; 13; 15; 17; 20; 21 22; 23; 24 25	5; 21	1; 2; 3; 4; 5; 6; 7; 8; 9; 10; 11; 12; 15; 20	1; 2; 3; 4; 6; 7; 8; 9; 11; 12; 13 14; 16; 21		1; 2; 3; 4; 5; 6; 7; 8; 9; 10; 12; 13; 14; 15 16; 17; 18 19; 20; 21 22		1; 3; 4; 5; 7; 11; 12; 16; 17; 22	1; 2; 7; 14 16; 17; 18 19; 20; 21 22	13; 22; 23 25	4; 10; 19	6; 19; 22	18; 19; 22 23	3; 8; 12; 17	15	10	3; 4; 5; 6; 8; 9; 10; 11; 12; 13; 14; 15; 16; 17; 18; 19; 20; 21; 22; 23; 24; 25
Candelariella flava	6; 8	1; 2; 7; 8; 9; 10; 13; 15; 16; 17 18; 21; 22 23; 24; 25			1; 3; 4; 8; 9; 11; 12; 13; 14; 16 17; 18; 21 22; 23; 24				4; 10; 11; 12; 18	1; 2; 7; 12 13; 16; 17 18; 19; 21	3; 4; 8; 9; 22; 23; 25	25	1; 2; 8; 9; 19; 21; 22	4; 5; 7; 8; 9; 10; 13; 14; 19; 22 23	5; 11; 12; 23; 24	1; 3; 4; 5; 7; 9; 10; 11; 12; 15 17; 21; 22 23; 24; 25	9; 10	1; 6; 8; 11; 12; 13; 14; 15; 16; 17; 19; 20; 21; 24
Lecidea oroantarctica		16		9; 14	17						25		8; 9	4; 5; 9		9; 22		17; 25
Pleopsidium chlorophanum																	10	1; 3; 4; 5; 10; 13; 15; 17; 20
Rhizoplaca melanophthalma	3; 5; 8; 12	1; 2; 9; 17 22; 23; 24		4; 9; 12	1; 2; 5; 6; 7; 10; 12; 13; 14; 17 18; 22; 23				2; 9; 12; 14	13; 22	2; 3; 4; 5; 7; 8; 9; 22 25	10; 15	1; 2; 5; 8; 9; 16; 17; 21	1; 2; 4; 5; 7; 8; 9; 10 11; 14; 18	4; 12; 18; 23	4; 5; 7; 8; 9; 12; 13; 17; 22; 24 25	10	17; 25
Umbilicaria decussata													9	3	5	7; 12; 13; 17; 18; 23 24; 25		19
Xanthoria mawsonii		23																

Table 2. Lichens and mosses found in the plots along transect 2 at the peak of the second hill south of Svea at Haldorsentoppen.

Species	1m(R)	4m(L)	7m(R)	10m(L)	13m(R)	16m(L)	19m(R)	22m(L)	25m(R)	28m(L)
Acarospora sp.#1		11	7							
Caloplaca citrina	9; 12; 13; 14		1; 2; 3			19	17; 18; 20; 24	1; 2; 4; 6; 20	1; 6	14; 15
Caloplaca saxicola	15							1		
Lecanora expectans	9; 13; 15; 16		3			4; 7; 8; 9; 13; 19	16; 17; 18; 20; 24	6; 10; 17; 20	1; 6	15; 24
Lecidea oroantarctica				7				13		
Rhizoplaca melanophthalma				7; 11						
Umbilicaria decussata		6; 11							10	
Moss	8; 12; 13; 14; 15; 16; 20; 21		1; 2; 3			4	17; 18; 19	4		

m (L), 16.5 m (L), 18 m (L), 22 m (R), 26 m (R) and 28.5 m (R).

Transect 2 (Table 2). At the peak of the second hill south of Svea at Haldorsentoppen. The transect is parallel to the steep east slope and 5–8 m from the edge. The direction is 190°, the total length is 30 m, the altitude is 1250–1300 m, and the difference in altitude along the transect is a few metres. Plots were established at: 1 m (R), 4 m (L), 7 m (R), 10 m (L), 13 m (R), 16 m (L), 19 m (R), 22 m (L), 25 m (R) and 28 m (L).

Transect 3 (Fig. 4, Table 3). On the moraine ridge west of, and parallel with, the northernmost part of Haldorsentoppen. The transect starts 2 m south of a small gravel heap in the north end. The direction is 185°, the total length is 30 m, the altitude is 1250–1300 m, and the difference in altitude along the transect is 2–3 m. Plots were established at: 1 m (R), 4 m (L), 7 m (R), 10 m (L), 13 m (R), 16 m (L), 19 m (R), 22 m (L), 25 m (R) and 28 m (L).

Transect 4 (Fig. 5, Table 4). On the rock mound on which Svea is situated at Haldorsentoppen. The transect starts at the end of the snow-free rock in the northwest part. Initially the direction is 90°, though after 8.04 m it changes direction to 135°. The total length is 11.74 m, the altitude is 1245 m, and the difference in altitude along the transect is *c.* 3 m. Plots were established at: 0 m (L), 1 m (R), 2 m (L), 3 m (R), 4 m (L), 5 m (R), 6 m (L), 7 m (R), 8 m (L), 9 m (R), 10 m (L) and 11 m (R). Some of the plots were located partly under equipment (Fig. 5).

Transect 5 (Table 5). On the lower slope of the fourth hill south of Svea at Haldorsentoppen. The transect is parallel to the steep east slope and 15 m from the edge. The transect ends 10 m from the lowermost part between the fourth and fifth hill south of

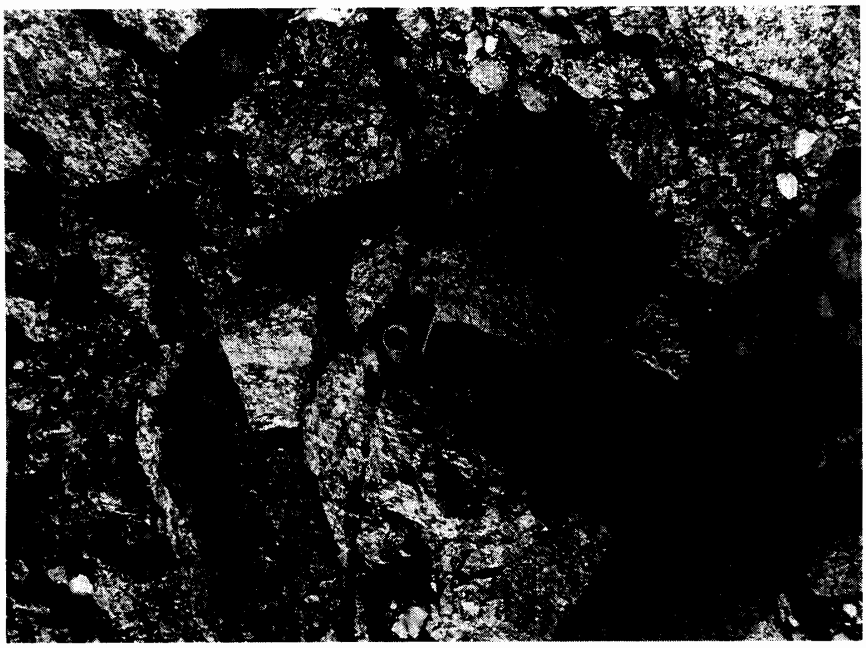

Fig. 3. *Aluminium stake marking the start or end point of a transect.*

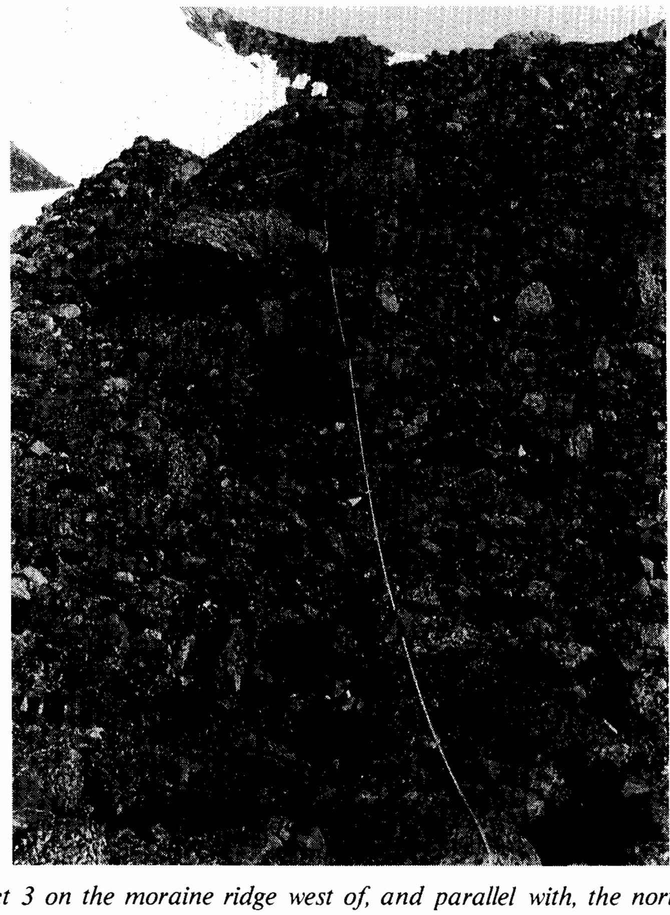

Fig. 4. *Transect 3 on the moraine ridge west of, and parallel with, the northernmost part of Haldorsentoppen. The metal measuring-tape shows the position of the transect.*

Table 3. Lichens and mosses found in the plots along transect 3 on the moraine ridge west of, and parallel with, the northernmost part of Haldorsentoppen.

Species	1m(R)	4m (L)	7m(R)	10m(L)	13m(R)	16m(L)	19m(R)	22m(L)	25m(R)	28m(L)
Caloplaca citrina	2; 15; 18; 19; 20; 21; 22; 23; 24; 25					17; 23		20; 21	12	
Candelariella flava		8; 9; 10; 13; 14; 15								
Lecanora expectans	18; 22; 23	6	19		4	1		19		
Lecidella siplei	1; 2; 4					12; 13; 17; 18; 22; 24		12; 13; 17; 18; 23	11; 16; 17	
Rhizoplaca melanophthalma		8; 15				20		1		
Moss						18		19	17	9

Svea. The direction is 185°, the total length is 30 m, the altitude is 1250–1300 m, and the difference in altitude along the transect is *c.* 3 m. Plots were established at: 1 m (R), 4 m (L), 7 m (R), 10 m (L), 13 m (R), 16 m (L), 19 m (R), 22 m (L), 25 m (R) and 28 m (L). An extra plot was established at 11 m (L). The accurate numbering of the subplots within the plots 1 m (R), 4 m (L) and 7 m (R) must be confirmed.

Transect 6 (Fig. 6, Table 6). On the northwestern end of Steinnabben (74°33′S, 11°15′ W) with the starting point 10 m from the end of the snow-free part. The transect was parallel with the nunatak. The direction is 120°, the total length is 30 m, the altitude is

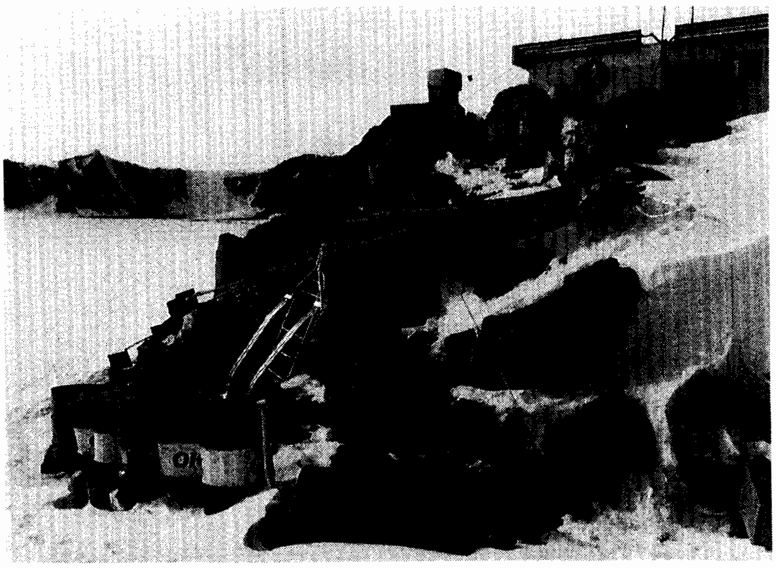

Fig. 5. Transect 4 on the rock mound on which the Swedish station Svea (in the background) is situated at Haldorsentoppen. The transect starts in the foreground. The metal measuring-tape shows the position of the transect.

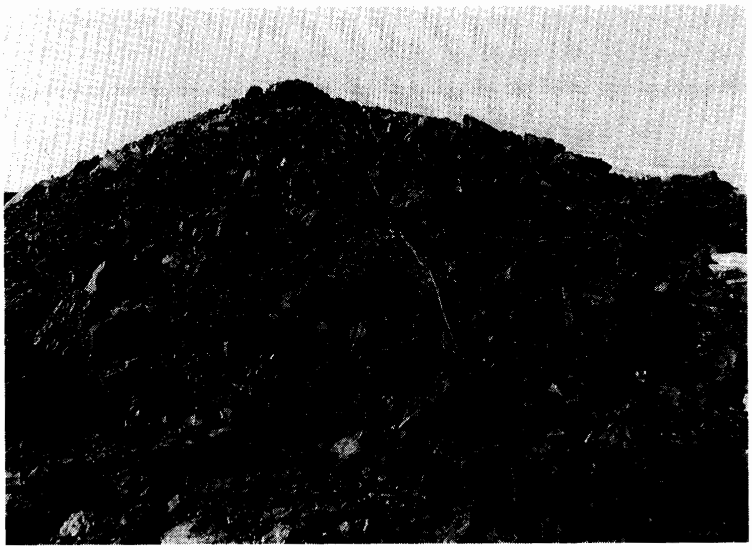

Fig. 6. *Transect 6 on the north-western end of Steinnabben. The metal measuring-tape shows the position of the transect.*

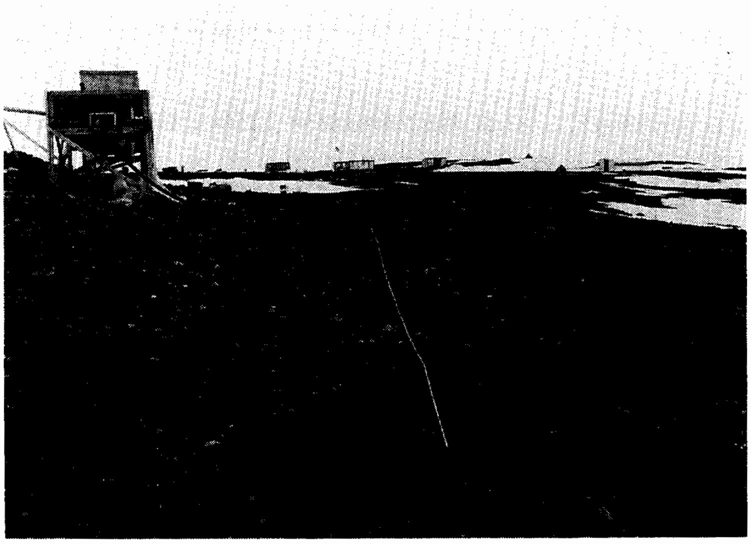

Fig. 7. *Transect 8 near the sewage treatment works south of the Swedish station Wasa (the Finnish station Aboa in the background). The metal measuring-tape shows the position of the transect.*

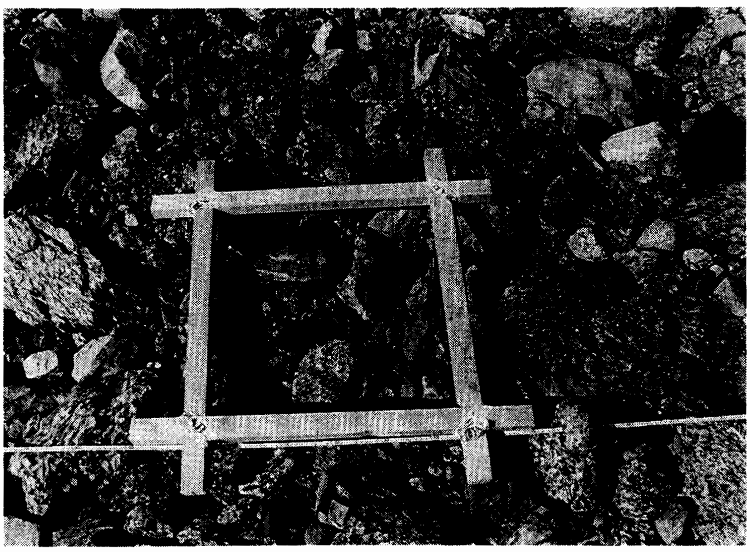

Fig. 8. *The wooden frame used as a plot with a grid of wires forming the subplots and the metal measuring-tape used to measure the length of the transects.*

Table 4. Lichens and mosses found in the plots along transect 4 on the rock mound on which Svea is situated at Haldorsentoppen

Species	0m(L)	1m(R)	2m(L)	3m(R)	4m(L)	5m(R)	6m(L)	7m(R)	8m(L)	9m(R)	10m(L)	11m(R)
Acarospora gwynnii								5				
Bacidia spp.	2; 7; 8; 9; 11; 12; 13; 14; 16; 17; 18; 19											
Buellia lignoides							9	1; 2; 3; 4; 7; 8; 9; 13; 14; 21; 22; 23	1; 2; 7		19; 25	1; 6; 7; 9; 10
Caloplaca citrina												13; 14; 18; 19
Candelariella flava	23; 24; 25							4; 5	16; 17; 19			
Lecanora expectans												14
Lecidea oroantarctica	18; 19	9					2; 9; 14	6; 8; 9; 11; 12	21; 24		4; 23; 24	5; 8
Lecidella siplei												6
Pseudephebe minuscula							2	2; 3; 7; 8; 16; 21; 22; 23				
Rhizocarpon geographicum							2; 9; 19; 20	13; 17; 21; 22; 23			19; 24	
Rhizoplaca melanophthalma	2	2; 9					2; 7	2; 3; 4; 5; 6; 7; 8; 9; 11; 12; 17	6; 16; 21; 24		4; 10; 14; 15; 23; 24	5; 7; 8; 12; 15; 21
Umbilicaria decussata		1; 9					2; 7; 19; 20	2; 3; 6; 9; 12; 13; 16; 17; 18; 21; 22; 23; 24	1; 2; 6; 10; 11; 12; 16; 17; 21		4; 5; 9; 10; 14; 15; 19; 20; 24; 25	1; 5; 6; 7; 17; 18
Xanthoria elegans							25	21; 22	6; 11			
Moss											4; 5; 9; 10; 14; 15	12; 13; 14; 18; 19; 20

Table 5. *Lichens and mosses found in the plots along transect 5 on the lower slope of the fourth hill south of Svea at Haldorsentoppen.*

Species	1m(R)	4m(L)	7m(R)	10m(L)	11m(L)	13m(R)	16m(L)	19m(R)	22m(L)	25m(R)	28m(L)
Acarospora sp.#1				20							
Caloplaca citrina		22		18							
Caloplaca saxicola	24; 25										
Candelariella flava	3; 4; 6; 7; 8; 9; 10; 12; 15; 16; 18; 19; 24; 25	1; 2; 3; 5; 6; 7; 8; 10; 13; 16; 17; 18; 19; 20; 24; 25	1; 5; 23	1; 3; 7; 11; 12; 17; 18; 20; 21; 22	1; 2; 3; 4; 5; 6; 7; 11; 16; 21; 23	1; 2; 5; 6; 7; 10; 11; 12; 14; 15; 16; 18; 19; 23; 24; 25	3; 4; 8; 9; 10; 20	19; 20	1; 2; 4; 5; 6; 7; 9; 10; 14; 15; 20; 23; 24	2; 3; 4; 6; 8; 12; 16; 18; 19; 21	1; 2; 3; 4; 5; 7; 9; 12; 13; 15; 19; 20
Lecanora expectans	1; 3; 4; 6; 15	2; 4; 5; 8; 17; 18; 19; 20; 22		1; 2; 3; 4; 7; 12; 16; 17; 18; 22	2; 3; 4; 5; 21; 23; 24	4; 6; 11; 12; 15; 19; 22; 23	4; 5		5; 6	2	2; 3
Lecidea oroantarctica	5; 6; 19; 24; 25	24			2						
Lecidella siplei	15										
Physcia caesia	15										
Pleopsidium chlorophanum								8			
Rhizoplaca melanophthalma	5; 6; 7; 11; 18; 19; 24; 25	8; 9; 19; 24; 25			1; 2; 7; 9; 11; 12	1; 4; 5; 6; 8; 9; 10; 11; 12; 13; 14; 15; 16; 17; 18; 19; 20; 22; 23; 24; 25	1; 4; 5; 8; 9	19	1; 2; 3; 4; 5; 6; 7; 9; 10; 20; 23; 24	2; 3; 9; 12; 14; 16; 21	2; 3; 4; 5; 7; 9; 10; 12; 13; 15; 17; 18; 19; 20; 25
Umbilicaria decussata	14						1; 18; 23	5	2; 7	13	2; 3; 5; 6; 7; 8; 10; 11; 12; 13; 15; 16; 17; 18; 19; 20; 21; 22; 24; 25
Xanthoria mawsonii	1; 2; 7; 9; 10; 12; 15; 16; 18	1; 2; 4; 7; 8; 10; 11; 15; 17; 18; 19; 20; 23; 24; 25	7	1; 2; 3; 7; 12; 17; 18; 21; 22; 23	1; 2; 3; 4; 5; 11; 15; 21; 23	1; 2; 4; 5; 6; 7; 8; 9; 10; 11; 12; 13; 15; 16; 17; 18; 19; 20; 21; 22; 23; 24; 25	3; 4; 5; 8; 9; 10	2; 13	1; 2; 4; 5; 6; 7; 8; 9; 10; 14; 15; 20	2; 7; 16	1; 2; 3; 4; 5; 6; 7; 19
Moss	1; 3; 4; 8; 9; 10; 12; 15	1; 2; 3; 4; 5; 7; 8; 9; 11; 13; 17; 18; 19; 20; 22; 24; 25	3	1; 2; 3; 7; 12; 13; 17; 20	11; 15	1; 2; 6; 7; 11; 15; 16; 19; 20; 24; 25			2; 5; 6	2	2; 3; 4; 12; 19

Table 6. Lichens and mosses found in the plots along transect 6 on the northwestern end of Steinnabben.

Species	1m(R)	4m(L)	7m(R)	10m(L)	13m(R)	16m(L)	19m(R)	22m(L)	25m(R)	28m(L)
Acarospora gwynnii			13							
Acarospora sp.#1			3; 7; 8; 12; 15; 20; 24		14	4; 21; 23	18	4; 8; 9; 15; 20	9; 13; 19; 22; 23; 24	
Caloplaca citrina										6; 7; 10; 11; 15; 16; 17; 18; 19; 20; 24; 25
Candelariella flava	3; 14; 19; 24	5; 9; 10; 25	2; 3; 5; 7; 8; 10; 12; 15; 16; 17; 18; 19; 20; 21; 22; 23; 24; 25	24			4; 7	8	4; 9; 13; 14	2; 3; 4; 5; 7; 8; 9; 11; 12; 13; 15; 17
Lecanora expectans										2; 3; 4; 5; 9; 10; 15; 18; 19; 24
Lecidea oroantarctica		2								
Rhizoplaca melanophthalma		2; 3; 7; 8	4; 5; 7; 8; 12; 18; 19; 20; 24			24			9; 13; 14; 17; 18	
Umbilicaria decussata		2			13					
Xanthoria mawsonii	2		3; 7; 8; 10; 12; 15; 16; 19; 20; 24; 25		9				4; 9; 13; 17; 18	1; 2; 3; 4; 5; 6; 7; 8; 9; 10; 11; 12; 13; 14; 15; 16; 17; 19; 20; 21; 22; 23; 24; 25
Moss										1; 2; 3; 4; 5; 6; 7; 8; 9; 10; 11; 12; 13; 14; 15; 16; 17; 18; 19; 20; 24; 25

Table 7. *Lichens found in the plots along transects 7 and 8 near the sewage treatment works south of Wasa.*

Species	1m(R)	4m(L)	7m(R)	10m(L)	13m(R)	16m(L)	19m(R)	22m(L)	25m(R)	28m(L)
Transect 7										
Rinodina sp.	11; 21; 22; 23	4; 5; 8; 9; 10; 13; 18	21	1; 6; 14; 19		5	6; 7; 10; 11; 17; 18; 19; 23; 24		6; 7; 8; 12; 13; 14; 15; 17; 18; 21; 22; 23; 24; 25	2; 7; 8; 10; 13; 14; 24
Transect 8										
Rinodina sp.	4; 5; 7; 10; 11; 13; 16; 17; 21		1; 4; 25		24				4; 6; 11; 12; 14; 15; 19; 20; 25	6; 7; 8; 9; 10

Table 8. *Lichens found in the plots along transect 9 c. 400 m ENE of Wasa at the hill northeast of Aboa.*

Species	1m(R)	4m(L)	7m(R)	10m(L)	13m(R)	16m(L)	19(R)	22m(L)	25m(R)	28m(L)
Acarospora gwynnii	24; 25	4; 8; 9; 13; 14; 17; 18; 22; 25	5; 7; 9; 11; 12; 16; 17; 21; 25	2; 3; 8; 10; 11; 17; 19; 20; 21; 22; 23; 24	20; 25	8; 12; 13; 14; 18; 20; 21; 22; 24	3; 7; 8; 9; 11; 12; 16; 17	2; 3; 5; 13; 14; 17; 18; 19; 21; 22; 24; 25		14; 18; 23
Buellis sp.#2	24; 25		16	16; 19	7; 8			8		
Calopaca aff. approximata								3		
Lecidea oroantarctica				8			3			
Rhizoplaca melanophthalma				8; 11			3	3; 7		
Rinodina sp.		11; 13; 17; 25	1; 2; 6; 7; 8; 9; 10; 11; 12; 13; 14; 15; 18; 19; 20; 21; 22; 23; 24	17; 22; 23	1; 11; 12	4; 5; 14; 19; 25	7; 9; 10; 12; 15; 16; 17; 19	2; 4; 5; 6; 7; 8; 9; 10; 11; 12; 13; 15; 16	2; 4; 7; 9; 10; 11; 14; 15	5; 10; 15; 19; 20; 25

Table 9. Lichens found in the plots along transect 10 c. 400 m ENE of Wasa at the hill northeast of Aboa.

Species	1m(R)	4m(L)	7m(R)	10m(L)	13m(R)	16m(L)	19m(R)	22m(L)	25m(R)	28m(L)
Acarospora gwynnii	1		6; 7; 10			12	5; 9; 10; 12	1; 4	1; 8	18; 21
Lecanora expectans			9							20
Lecidea oroantarctica		18; 21							10	10; 14; 18; 23
Rhizoplaca melanophthalma		18; 21			25		10	2	4; 5; 10	10; 14; 18; 23
Rinodina sp.	2; 3; 6; 7; 8; 11; 13; 14; 18; 19; 20; 25	3; 4; 14; 19; 20; 25	4; 9; 19; 20; 22; 23	2; 3; 5; 6; 7; 8; 9; 16; 21	1; 2	6; 7; 13; 21	6; 11; 16; 17; 20; 21; 22; 23	1; 3; 4; 5; 7; 8; 9; 10	8; 9; 10; 12; 13; 14; 15; 16; 17; 21	4; 9; 16; 17; 20; 25

Table 10. Lichens found in the plots along transect 11 at Fossilryggen c. 100 m southeast of the small field station which is situated east of the shale area in the central part of the nunatak.

Species	1m(R)	4m(L)	7m(R)	13m(R)	16m(L)	19m(R)	22m(L)	25m(R)	28m(L)
Acarospora gwynnii		12	1; 4; 12; 14; 15; 16; 17; 20; 21; 22; 25	4; 5; 10; 14; 15; 20; 24	3; 4; 12; 19; 22	1; 2; 5; 6; 11; 12; 17; 19; 22; 23; 24		16; 18; 20; 24	3; 4; 11; 19
Bacidia trachona	3; 17; 18		11; 18	12; 17					7; 8; 12; 15; 16; 17; 22
Buellia lignoides		25	2; 7	14; 21	10; 11			8; 13; 14; 22; 23	6; 11
Buellia sp.#2				16; 21					
cf. *Buellia* spp.		4; 6; 7; 8; 9; 10	9; 14	14; 16; 21	2				
Candelariella flava	13; 21; 22		1; 9; 17; 18; 19; 24	24; 25		1; 6		15; 20	16
Lecanora expectans		15							11
Lecidea oroantarctica	2; 3; 4; 5; 6; 7; 8; 9; 13; 14; 17; 18; 19; 24; 25	1; 2; 6; 7; 13; 14; 15; 16; 18; 19; 20	1; 4; 5; 8; 9; 10; 11; 13; 15; 19; 20; 22; 24; 25	1; 2; 3; 4; 7; 8; 9; 12; 13; 14; 15; 17; 18; 19; 20; 21; 22; 23; 24	3; 4; 6; 7; 8; 10; 11; 12; 13; 15; 19; 24; 25	1; 2; 6; 11; 12; 22	12; 16; 17; 22	3; 4; 5; 8; 9; 13; 14; 15; 18; 19; 21; 22; 23; 24; 25	2; 3; 4; 5; 7; 10; 12; 16; 20; 21; 22
Pleopsidium chlorophanum	7; 17; 18; 22; 23	18							
Psudephebe minuscula						1; 22; 23			
Rhizoplaca melanophthalma	1; 2; 3; 4; 5; 6; 7; 8; 9; 10; 11; 13; 14; 15; 16; 17; 18; 19; 20; 21; 22; 23; 24; 25	1; 2; 5; 6; 7; 8; 10; 11; 12; 13; 14; 15; 16; 17; 18; 19; 20; 21; 25	1; 2; 4; 5; 7; 8; 9; 10; 11; 12; 13; 14; 15; 17; 18; 19; 20; 21; 22; 23; 24; 25	1; 2; 3; 4; 5; 7; 8; 9; 10; 12; 13; 14; 15; 16; 17; 18; 19; 20; 21; 22; 23; 24	2; 3; 4; 6; 7; 8; 10; 11; 12; 13; 15; 17; 19; 22; 23; 24; 25	1; 2; 5; 6; 11; 12; 19; 20; 22; 23; 24	12; 16; 17; 22; 25	1; 2; 3; 4; 5; 6; 8; 9; 11; 13; 14; 15; 18; 19; 20; 21; 22; 23; 24; 25	2; 3; 4; 5; 7; 10; 12; 16; 20; 21; 22; 25

1200 m and the difference in altitude along the transect is *c*. 5 m. Plots were established at: 1 m (R), 4 m (L), 7 m (R), 10 m (L), 13 m (R), 16 m (L), 19 m (R), 22 m (L), 25 m (R) and 28 m (L).

Transect 7 and 8 (Figs. 2 and 7, Table 7). Two 30 m long transects forming a 60 m long line were established *c*. 30 m S of Wasa near the sewage treatment works south of Wasa. The direction is 240–230°, the altitude is 450 m, and the difference in altitude along both transects is 1–2 m. Plots in both transect 7 and transect 8 were established at: 1 m (R), 4 m (L), 7 m (R), 10 m (L), 13 m (R), 16 m (L), 19 m (R), 22 m (L), 25 m (R) and 28 m (L).

Transect 9 and 10 (Tables 8 and 9). Two 30 m long transects forming a 60 m long line were established *c*. 400 m ENE of Wasa at the hill northeast of Aboa. The direction is 260°, the altitude is 470 m, and the difference in altitude along both transects is almost 2 m. Plots in both transect 9 and transect 10 were established at: 1 m (R), 4 m (L), 7 m (R), 10 m (L), 13 m (R), 16 m (L), 19 m (R), 22 m (L), 25 m (R) and 28 m (L).

Transect 11 (Table 10). At Fossilryggen *c*. 100 m southeast of the small field station which is situated east of the shale area in the central part of the nunatak (see LARSSON, 1991 for a geological map of Fossilryggen). The bedrock is basalt till with some shale. The direction is about southwest, the total length is 30 m, the altitude is 700 m and the difference in altitude along the transect is less than 1 m (the transect was not oriented by compass). Plots were established at: 1 m (R), 4 m (L), 7 m (R), 13 m (R), 16 m (L), 19 m (R), 22 m (L), 25 m (R) and 28 m (L). No plots was established at 10 m (L).

5.2. Description of the plots

The plots, each 0.5×0.5 m, were positioned along the transects. Usually 10 plots are positioned along each transect, with the exception of transect 1 (with 18 plots), transect 4 (with 11 plots), transect 5 (with 11 plots), and transect 11 (9 plots). Each plot was divided in to 25 subplots, each 10×10 cm. 250 subplots were thus recorded along each transect apart from transect 1 (with 450 subplots), transect 4 (with 300 subplots), transect 5 (with 275 subplots), and transect 11 (with 225 subplots). In Heimefrontfjella 71 plots (1775 subplots) were investigated, and in Vestfjella 49 plots (1225 subplots), totalling 120 plots (and 3000 subplots). Owing to irregularities in surface details the plots are usually not horizontal; indeed, some are almost vertical.

A wooden frame was used as a plot with a grid of wires forming the subplots (Fig. 8). Each subplot was investigated for occurrence of lichens and mosses. The corners of all of the larger plots were marked with spray paint. The transect and plot markers should be regularly be checked to ensure their continued existence in spite of the harsh climate, trampling or cryoturbation (all transects except no. 4 were established in till).

The outer lower left end (if the plot was established on the right side) or right end (if the plot was established on the left side) of the wooden frame was placed at the given distance from the start of the transect. The wood in the wooden frame has a breadth of 43 mm. The plots were always recorded from the upper left corner to the lower right corner, such that the upper left corner of subplot no. 1, for example, is located 43+500 mm to the south and then 43 mm to the right of the given length of the transect if the plot is on right side on the transect or 43+500 mm to the south and 43+500 mm to the left of the given length of the transect if the plot is on left side on the transect. The marked start and end points of the transects are at distance from the plots in order to avoid local microclimate effects associated with marking them.

5.3. Principles adopted in recording the plots

(1) Thalli not attached to the ground are excluded.

(2) The lower side of pebbles were often examined, but the pebbles were returned to their original position.

(3) The host of the parasitic *Lecidea oroantarctica* Øvstedal is sometimes impossible to determine, and is then excluded.

(4) Dead thalli are excluded from consideration.

(5) In transects 1 and 4 in Heimefrontfjella, *Bacidia* spp. are not separated in the field.

(6) Mosses are not determined to species and are recorded only as "moss".

(7) Subplots covered with snow are excluded.

Inconspicuous species as, for example, *Arthonia molendoi* (Frauenf.) R. Sant. and some small *Buellia* species may have been overlooked; such species are not easily determined without microscopic examination. *Arthonia molendoi* was not noted from any of the transects, but *cf. Buellia* spp. in transect 11 probably include one or more *Buellia* species. Small specimens of *Buellia* sp. # 2 are also easily overlooked. *Buellia* sp. # 2 is recognised by the small, usually scattered, sorediate thallus granules, surrounded by a distinct black prothallus. *Buellia papillata* (Sommerf.) Tuck. and *Lecidella siplei* (C.W. Dodge and G.E. Baker) M. Inoue were not consistently distinguished during field work, and the observation of *L. siplei* in transects 3, 4 and 5 requires confirmation. *Acarospora* sp. # 1 is best distinguished from *A. williamsii* Filson by the larger ascospores ($3-5\times3\ \mu m$ ($\bar{X}=3.9\ \mu m$) *vs.* $3-4\times2\ \mu m$ ($\bar{X}=3.4\ \mu m$)), the larger thalli and the occurrence over sand, rather than over rock.

6. Results

As pointed out above, the transects were established as close as possible to the three stations, and are not intended to be representative of all habitats present on the nunataks. The species recorded in the plots thus represent only a selection of the lichens present within the study area.

Eighteen lichen species were recorded within the plots in Heimefrontfjella from a total of 1293 observations (the number of observations within parentheses after each species), *Acarospora gwynnii* C.W. Dodge and E.D. Rudolph (13), *Acarospora* sp. # 1 (26), *Bacidia* spp. (142), *Buellia lignoides* Filson (23), *Caloplaca citrina* (Hoffm.) Th. Fr. (54), *C. saxicola* (Hoffm.) Nordin (4), *Candelariella flava* (C.W. Dodge and G.E. Baker) Castello and Nimis (286), *Lecanora expectans* Darb. (89), *Lecidea oroantarctica* (42), *Lecidella siplei* (19), *Physcia caesia* (Hoffm.) Fürnr. (1), *Pleopsidium chlorophanum* (Wahlenb.) Zopf (11), *Pseudephebe minuscula* (Nyl. ex Arnold) Brodo and D. Hawksw. (9), *Rhizocarpon geographicum* (L.) DC. (11), *Rhizoplaca melanophthalma* (Ramond) Leuckert and Poelt (218), *Umbilicaria decussata* (Vill.) Frey (89), *Xanthoria elegans* (Link) Th. Fr. (5) and *X. mawsonii* C.W. Dodge (141) (Table 1-6). Mosses were recorded within all transects except no. 1 and from a total of 110 subplots. Ten of the 71 plots investigated had no lichens or mosses. The transects in Heimefrontfjella are all located rather close to or within (transect 6) colonies of snow petrels in which phosphorus and nitrogen are provided by guano from the birds. Lichen abundance in Heimefrontfjella and Vestfjella was higher in areas with snow petrel nests. Ornithocoprophilous species found within plots include *Caloplaca citrina, C. saxicola, Candelariella flava, Lecanora expectans, Physcia caesia* and *Xanthoria mawsonii*.

In Vestfjella, thirteen species were recorded from a total of 704 observations, *i.e.*, *Acarospora gwynnii* (124), *Bacidia trachona* (Ach.) Lettau (14), *Buellia lignoides* (14), *Buellia* sp. # 2 (10), cf. *Buellia* spp. (12), *Caloplaca* aff. *approximata* (Lynge) H. Magn. (1), *Candelariella flava* (16), *Lecanora expectans* (4), *Lecidea oroantarctica* (117), *Pleopsidium chlorophanum* (6), *Pseudephebe minuscula* (3), *Rhizoplaca melanophthalma* (17) and *Rinodina* sp. (366) (Tables 7-10). Mosses were not recorded, but are present in Vestfjella (Thor, in prep.). Seven of the 49 plots investigated had no lichens. The lichen vegetation within the plots is less species-rich than in Heimefrontfjella, with the most common species being *Rinodina* sp. (=the only species present in transects 7 and 8). This species is distinguished by the scattered to crowded whitish to greyish thallus areoles fastened to the substrate with long coarse rhizomorphs, and is found in dry till in the most exposed habitats. The transect at Fossilryggen has a high abundance of lichens, with *Lecidea oroantarctica* and *Rhizoplaca melanophthalma* being the dominant species.

7. Discussion

Large human impact in Heimefrontfjella and Vestfjella could adversely affect local environmental conditions, and also undermine future scientific research, *e.g.*, by causing localised extirpations of organisms or by irrevocably destroying biological remains (*e.g.* accumulations of regurgitation's from snow petrels) (see also Kriwoken, 1991). It is recommended that the reference plots should be visited exclusively in the context of scientific research. Further reference plots should also be established at Fossilryggen and at a greater distance from Wasa at Basen.

The long-term monitoring study in Heimefrontfjella and Vestfjella was primarily initiated and designed to measure local human environmental impact, but information on global human environmental impacts may also be gleaned especially from the reference transects.

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