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FACTORS INFLUENCING THE EXISTENCE OF LICHENS IN THE ICE-FREE AREAS NEAR SYOWA STATION, EAST ANTARCTICA

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Abstract: The factors influencing the existence of lichens in the ice-free areas along the Sôya Coast and Prince Olav Coast, Antarctica are discussed. Water supply is one of major factors. Lichens grow luxuriantly in the sites where an adequate moisture is maintained due to snow and ice brought by the "katabatic wind" through the surface of ice cap, while lichens are absent or poorly developed in the dry sites which are buffeted by cyclonic wind through the surface of sea ice. Moisture for lichens appears to be supplied not only from snow-melt water but also from air. The wind-blown sea spray is one of the unfavorable factors for lichens in the areas investigated. Well-developed lichens can be seen around the rookeries or nests of sea birds. However, they are absent around the rookeries which are influenced by the wind-blown sea spray.

1. Introduction

In conjunction with a 5-year study of terrestrial Antarctic ecosystems in the ice-free areas near Syowa Station, East Antarctica, the author carried out a study of lichens in several areas along the Sôya Coast and the Prince Olav Coast, 68°08′–69°54′S lat., 38°15′–42°42′E long. (Fig. 1). Under the project of the 27th Japanese Antarctic Research Expedition, the field work was done during January 1986 and February 1987. Fifty-one ice-free localities of various sizes were visited to collect lichens in order to determine the nature of the lichen flora.

The distribution and habitat of lichens in this region have been investigated by KASHIWADANI (1970, 1982), KOBAYASHI (1974) and NAKANISHI (1977, 1982). However, these works were based on the survey only in the austral summer season (January to February).

Lichens themselves can be seen in each ice-free locality along the coast except for the several islands where they are absent. However, lichens are absent or poorly developed in one part of the area, while they grow quite luxuriantly in another part of the same area. In this article an attempt is made to consider the relationships between the existence of lichens and the factors affecting them.

2. Outline of the Areas Investigated

In the Sôya Coast and Prince Olav Coast region, there extends a vast ice sheet of Enderby Land, of which the margin slopes gently down westwards or north-westwards.

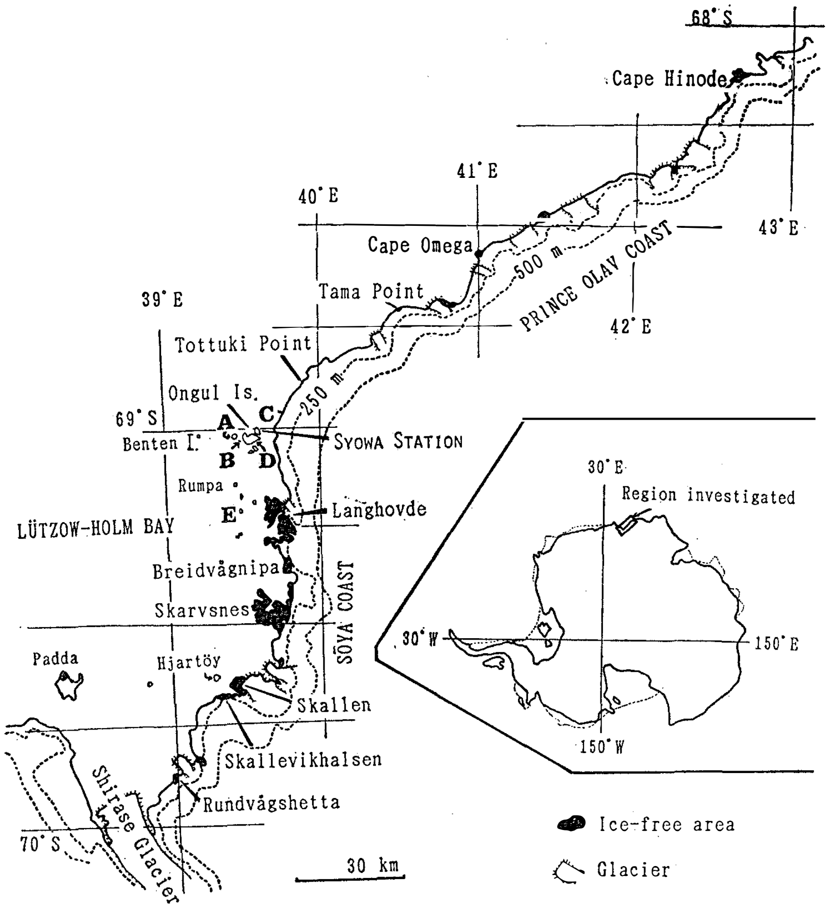

Fig. 1. A map showing the ice-free areas near Syowa Station, East Antarctica. A. Ongulkalven, B. Mame-zima Island, C. Matukawa Rock, D. West Ongul Island, E. Ytre Hovdeholmen.

Many ice-free areas are scattered along the coasts. The ice-free areas of the region can be divided into three categories; coastal islands, rocky areas abutting on the edge of the ice cap, and a few nunataks. About sixty coastal islands are scattered off the Sôya Coast (within 10 km or so), but no island exists along the Prince Olav Coast. Among them, Padda, West Ongul Island and Hjartöy are large and high (Table 1). However, a great number of remainders are small and lower, less than 1–2 km^2 wide and 50 m above sea level. Rocky areas such as Breidvågnipa, Langhovde, Skarvsnes and Skallen abutting on the edge of the ice cap are large and mountainous, and some of the peaks in these areas reaching 400 to 500 m above sea level (Table 1), while the other areas are mostly small and hilly. Unfortunately no nunataks were studied, though they are the important from ecological points of view.

A continuous climatological record has been obtained by the members of Japan Meteorological Agency since 1957 at Syowa Station located in East Ongul Island, about 4 km from the continent. The annual mean temperatures are between -12.1°C and -8.2°C. The mean summer temperatures (December–January) are between -2.5°C and 0.1°C, while the mean winter temperatures (August–September) are between -23.2°C and -14.1°C. The monthly mean of daily maximum temperatures in

Table 1. Size of major ice-free areas investigated, with altitude of the highest peak.

Name of area	Size (km^2)*	Altitude of the highest peak (m)	Date investigated
Skarvsnes	61.1	400.4	24–30. X. 1986
Langhovde	50.0	496.5	17. XI. 1986–16. I. 1987
Padda (I.)	22.8**	263.0	3–6. IX. 1986
Skallen	14.4	186.2	30. IX., 2. X. 1986
Breidvågnipa	11.4	316.1	17–18. X., 12. XI. 1986
West Ongul (I.)	8.0	47.7	28. I–4. II, 21–28. II. 1986, 21. I, 2. II. 1987
Hjartöy (I.)	7.6	100.0	3. X. 1986
Skallevikhalsen	7.6	277.0	29. IX, 1, 3. X. 1986
Cape Hinode	6.7	164.6	15–17. IX. 1986
Rundvågshetta	2.6	159.3	22–24. I. 1987
Cape Omega	2.3	98.8	21. IX. 1986

* After NATIONAL INSTITUTE OF POLAR RESEARCH (ed., 1985).

** This figure implies a size of the island, though the ice-free site covers only 3.1 km^2. The rest including the summit range is covered by snow and ice.

summer is between 0.2°C and 4.6°C. The monthly mean of daily minimum temperatures in summer is between −5.9°C and −1.7°C. The annual mean of wind speed is between 5.8 m/s and 7.0 m/s, while between 2.1 m/s and 7.5 m/s in summer (NATIONAL INSTITUTE OF POLAR RESEARCH, 1985).

In this region there are scattered nests or rookeries of the South polar skua (*Catharacta maccormicki*), Adélie penguin (*Pygoscelis adeliae*) and Snow petrels (*Pagodroma nivea*), and concomitant organic debris rich in nitrogenous matter.

Twenty species of lichens were known to occur in this region (KASHIWADANI, 1970, 1982), and more than 25 species (mainly crustose lichens) are expected to be added by the author. In general the ice-free areas of the continent have a rich lichen flora, whereas lichens of the islands are poor or absent. The occurrence of macrolichens, *Alectoria minuscula*, *A. pubescens*, *Physcia caesia*, *P. dubia*, *Umbilicaria decussata*, *U. aprina* and *Usnea sphacelata* (= *U. sulphurea*) is restricted to the continent with a few exceptions: *Alectoria* in Einstöingen (coll. KANDA) and Hjartöy; *Physcia* in Kaname Island (NAKANISHI and KASHIWADANI, 1976) and Hjartöy; *Umblicaria aprina* in West Ongul Island (only one locality of the island); *Umbilicaria decussata* in Einstöingen (coll. KANDA). It is interesting that all these macrolichens including *Usnea* are known to occur on Padda which is about 10 km from the continent. *Buellia frigida*, one of the well known continental Antarctic elements (LINDSAY, 1977), *Caloplaca athallina*, *Rinodina olivaceobrunnea* and some other crustose lichens are distributed in both continent and islands. They seem to have a wide ecological amplitude. It is remarkable that many lichens including macrolichens growing in this region are not covered with snow even during the severe winter season.

3. Methods

The field investigation routes in each area were selected from the ecological or geomorphological points of view. Various data concerning the habitat of lichens were recorded and many photographs were taken at the time. Among the areas investigated somewhat wide areas as shown in Table 1 are denoded with terms luxuriant, normal/poor, and vacant, were recorded in proportion to the degree of lichen flora and to the development of a lichen vegetation along the field investigation routes on the map. The distinction among them is not very strict. The term "luxuriant" refers to the vegetation that is almost continuous and consisting of floristically rich lichens. The term "normal/poor" refers to the vegetation developed discontinuously and consisting of a small number of lichens (actually the author distinguished "normal" from "poor" in the field, though the difference between them is ambiguous and not necessarily rational because "luxuriant" and "vacant" are more important). The term "vacant" is used for the lack of the plant cover.

The aerial photographs were taken from the following areas along the Sôya Coast for analyzing topography and the sites of snow dunes and drifts whose melt water provides the major source of moisture for terrestrial plants: Langhovde and Ongul Islands (19. I. 1986); Breidvågnipa, Ongul Islands and Skarvsnes (3. IV. 1986); Langhovde, Skallen and Skallevikhalsen (4. IV. 1986); several small areas from Tottuki Point to Langhovde and Ongul Islands (2. V. 1986); and all rocky areas scattered at the edge of ice cap, from Syowa Station to Rundvågshetta, about 105 km long (by a video recorder, SONY Betamovie BMC-600; 22. I. 1987).

4. Results and Discussion

The ice-free areas investigated can be divided into the following three groups by the growth of lichens.

1) The areas where lichens occur all over the area. This is divided into two sub-groups according to the difference in occurrence of lichens.

(a) Cape Omega, Breidvågnipa, Rundvågshetta, Skallevikhalsen, Padda, and small rocky areas such as Tottuki Point and Mukai Rocks clinging to the edge of the ice sheet. This sub-group is represented by a luxuriant lichen flora reaching 20–30 species or more and comprising both macrolichens and microlichens (Fig. 2).

(b) West Ongul Island and Hjartöy. Lichens occur all over the area. However, the flora is poorer than that of the preceding sub-group. Macrolichens can be hardly seen here.

2) Cape Hinode, Langhovde, Skarvsnes and Skallen. Each area belonging to this group is composed of two sites which form a marked contrast to each other; one site lacks lichen cover or, if present, the lichen flora is extraordinarily poor, while the other site has a rich lichen flora which contains more than 30 species of macrolichens and microlichens (Figs. 3–5).

3) Most islands of Ongul Islands and islands scattered off the west side of Langhovde. Lichen flora of the areas is absent or poor. If present, crustose lichens such as *Buellia frigida*, *Caloplaca athallina*, *Lecanora expectans* and *Rinodina olivaceobrunnea* are scarcely seen.

Figures 2–5 show the existence of lichens in each area belonging to groups 1)-(a) and 2). As shown in these maps, lichens, in general, grow luxuriantly in the places

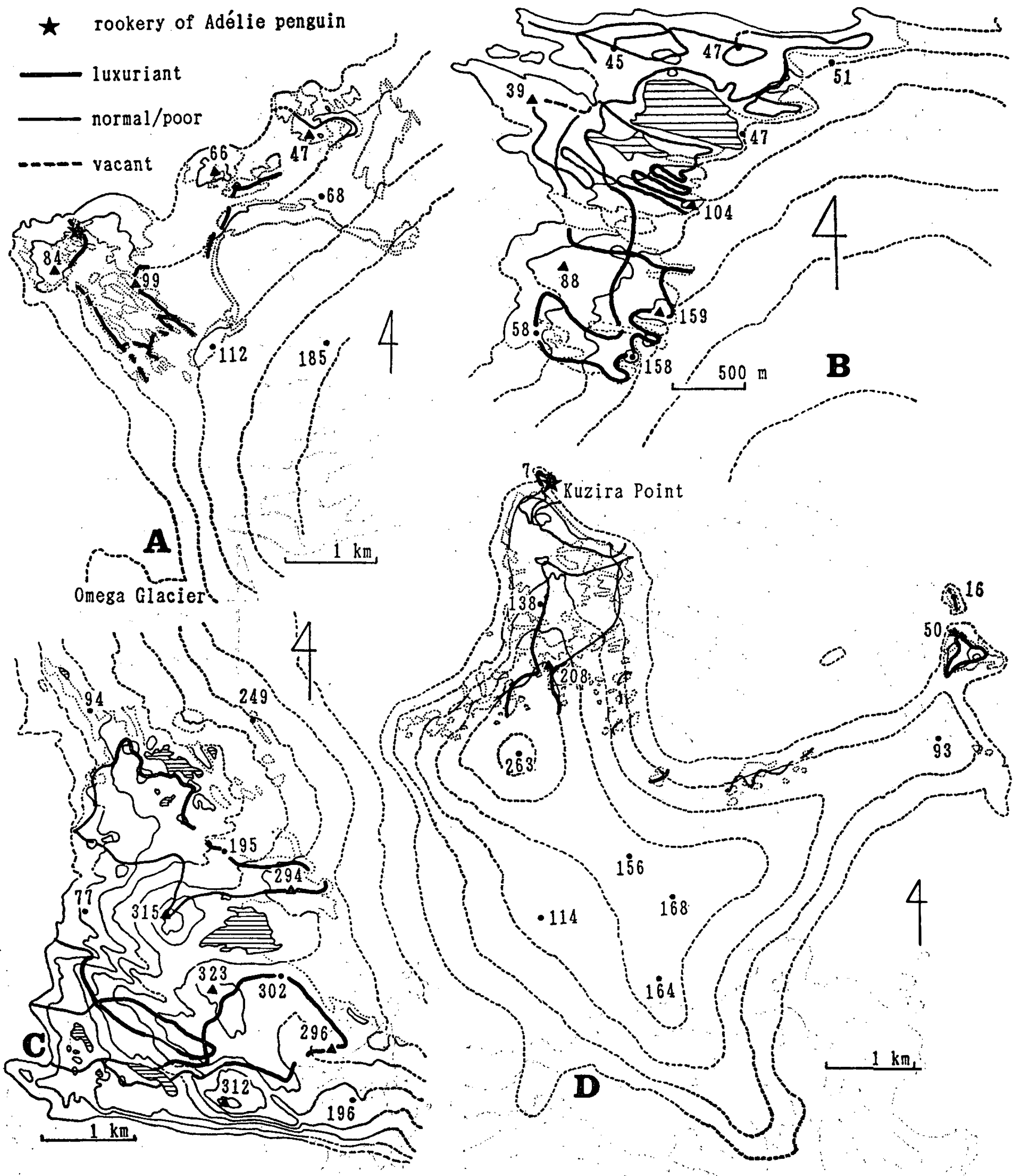

Fig. 2. The mode of existence of lichens along the field investigation routes in Cape Omega (A), Rundvågshetta (B), Breidvågnipa (C) and Padda (D).

abutting almost totally on the ice cap, but they are absent or poorly developed in the peninsula-like places protruding northwestwards into sea. Water, wind, wind-blown sea spray and rookeries or nests of sea birds appear to influence the existence of lichens as environmental factors.

4.1. Water

Water supply in continental Antarctica is one of the major factors controlling local lichen distribution. Water from melting snow and ice seems to provide the principal and often the only source of moisture for lichens as noted by earlier authors (DODGE, 1964; LLANO, 1965; GREENE and LONGTON, 1970; LAMB, 1970). The precipitation in

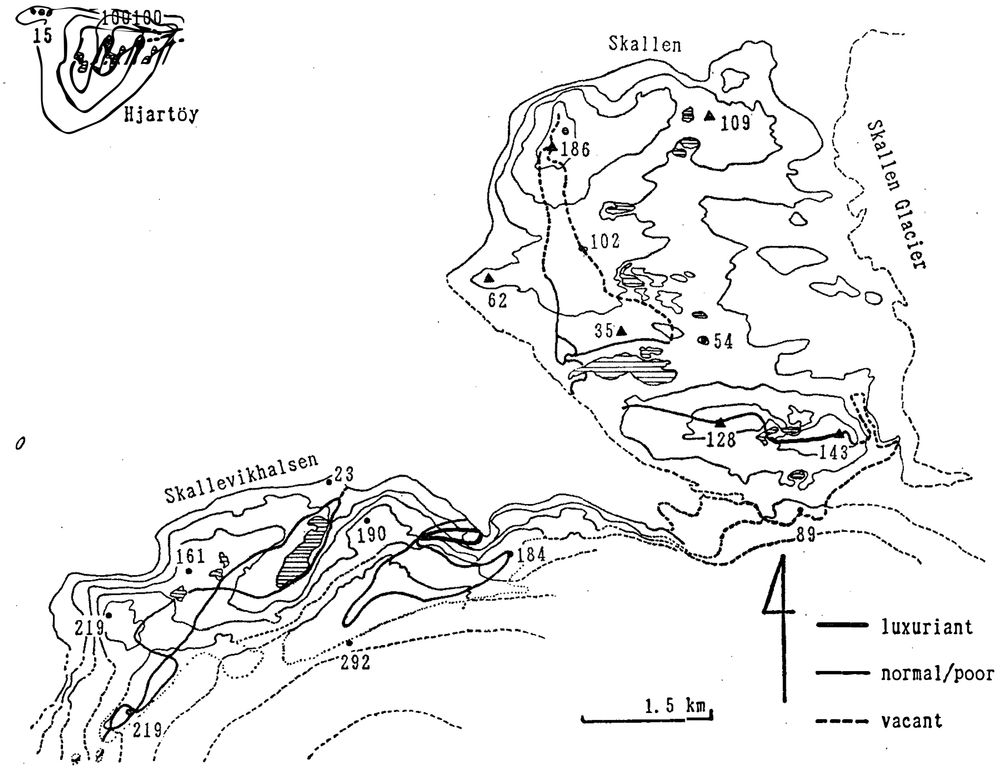

Fig. 3. The mode of existence of lichens along the field investigation routes in Skallen, Skallevikhalsen and Hjartöy.

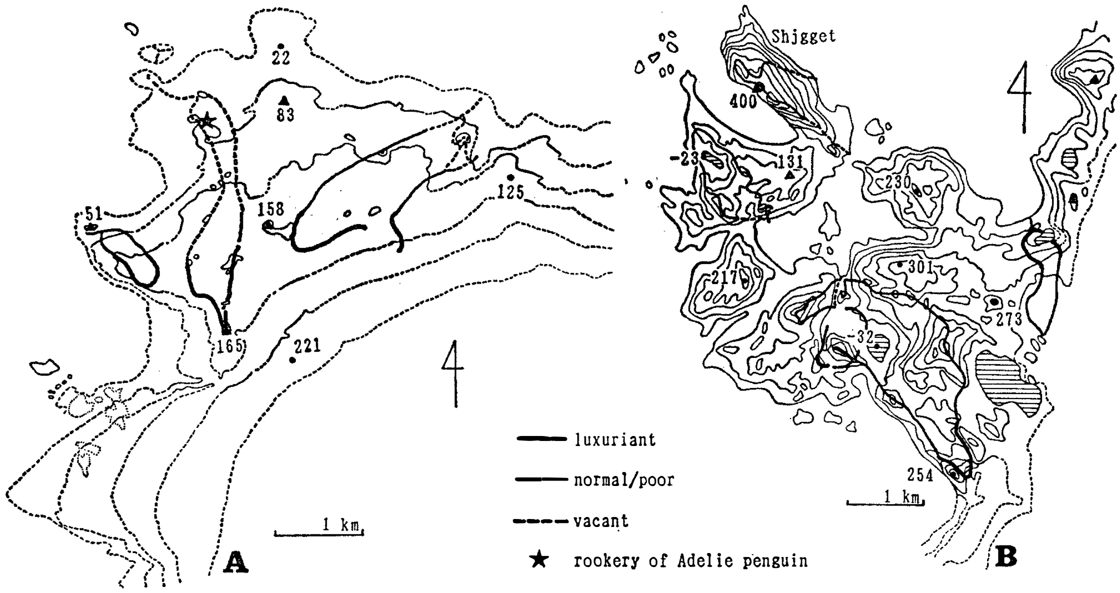

Fig. 4. The mode of existence of lichens along the field investigation routes in Cape Hinode (A) and Skarvsnes (B).

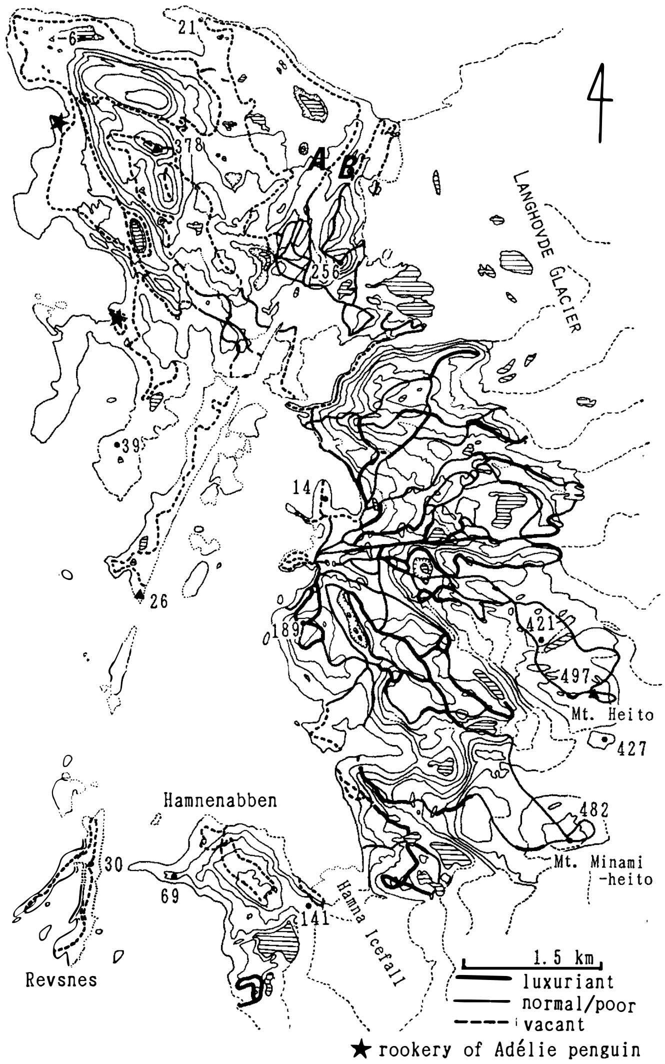

Fig. 5. The mode of existence of lichens along the field investigation routes in Langhovde.

this region might be very little though the definite climatological data are lacking, but the snow dunes or drifts are developed on the leeward of mountains, hills or slopes during winter and spring seasons. From the analysis of the aerial photographs in the vicinity of the Sôya Coast, ÔURA and YAMADA (1966) made a distribution map of snow dune orientations (Fig. 6) and reported that the snow dunes in this region were developed by two kinds of winds, one was cyclonic wind and the other was katabatic wind.

Both the results obtained by ÔURA and YAMADA (1966) and the present field observations show the evidence that the sites abutting almost totally on the ice cap appear to be influenced mainly by katabatic wind. Therefore, an adequate moisture for lichens is maintained by unlimited snow and ice brought through the surface of the ice cap. In contrast, the "peninsula-like sites" protruding northwestwards into sea seem to be buffeted by cyclonic wind through the surface of sea ice. Accordingly, the sites are very dry because of the limited snow and ice on the surface of sea ice. The results of

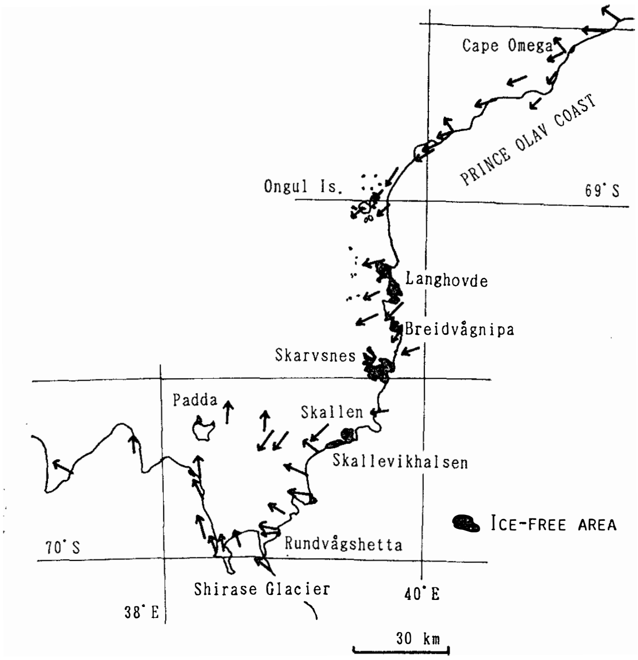

Fig. 6. Distribution of snow dunes and their orientations in the vicinity of the Sôya Coast. Based on ÔURA and YAMADA (1966, Fig. 5 with a slight modification).

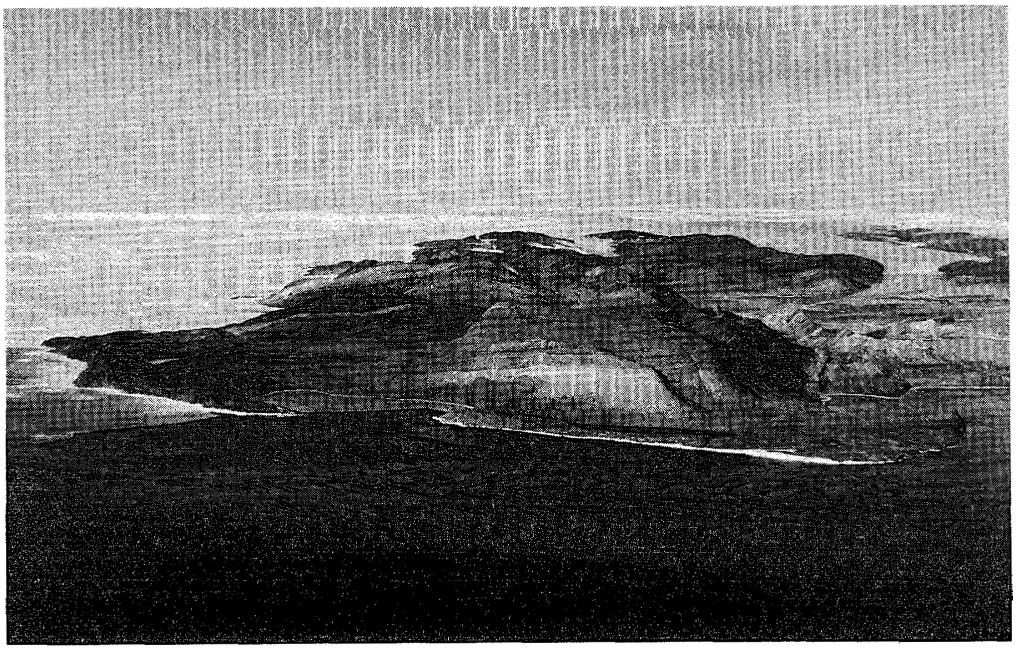

Fig. 7. Aerial photograph of Langhovde; Langhovde Glacier and ice cap on the left. Foreground: the northern part of Langhovde protruding northwestwards into sea. Background: the southern part of Langhovde abutting totally on the ice cap (4. IV. 1986).

analysis of the aerial photographs taken on 3–4th of April, 1986 from Breidvågnipa, Langhovde and Skarvsnes support this assumption; most snow dunes and drifts formed in the last seasons disappeared from the "peninsula-like sites", while some of them persisted in the sites abutting totally on the ice-cap (Fig. 7). This assumption, however, cannot apply to Padda and a northern Rundvågshetta.

It is interesting that Padda has luxuriant lichens and lichen flora similar to that of the ice-free areas situated on the edge of the ice cap (Fig. 2D). Ice-free areas of the island cover only 3.1 km^2, while the rest (19.7 km^2) including the summit range is covered by snow and ice (Table 1). It is not known whether the origin of snow and ice covering the island is the ice cap or not, but the meteorological study by AGETA (1971) offered the important implications to explain the present distribution of lichens there. Figure 8 shows the orientations of flow lines of prevailing winds based on the analysis of the orientations of sastrugis and pitted patterns in inland of the continent (AGETA, 1971). It is obvious that the convergent katabatic winds blow down along the vast valley of the Shirase Glacier and seem to bring snow and ice from the continent (Fig. 9).

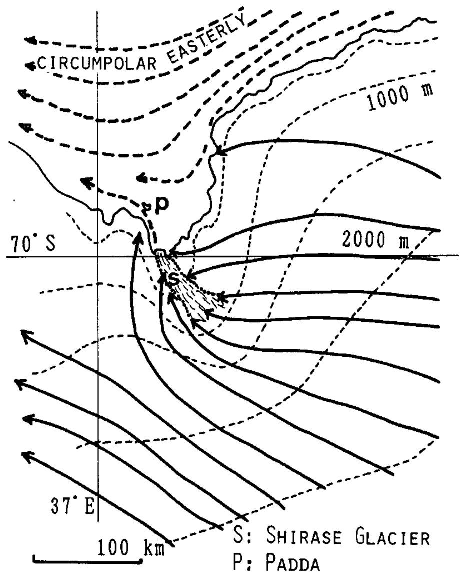

Fig. 8. Orientations of flow lines of prevailing winds in the vicinity of the Mizuho Plateau. Based on AGETA (1971, Fig. 3 with a slight modification).

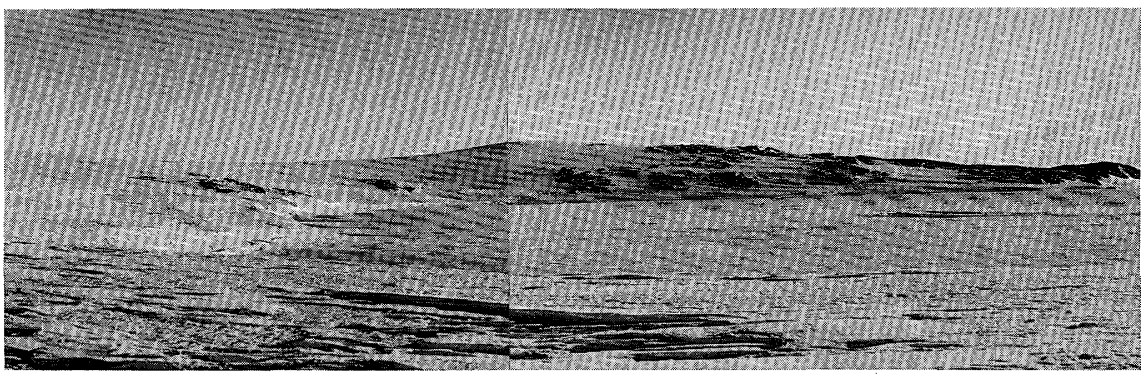

Fig. 9. A part of Padda; Kuzira Point on the right. Note that the snow dune orientations run northwards (5. IX. 1986).

The northern Rundvågshetta, where both macrolichens and microlichens are growing luxuriantly, protrudes northwestwards into sea (Fig. 2B). However, this site is also influenced by katabatic winds as ÔURA and YAMADA (1966) reported, because this area is located within the sphere of influence of prevailing wind from nearby Shirase Glacier. The analysis of the photographs obtained by the author supports this; the directions of snow dunes or drifts run from continental ice slope.

A question remains whether or not the source of moisture for lichens is only snow-melt water. In the sites where snow dunes or drifts are well developed, there are a wide variety of lichen habitats ranging from markedly wet bands along talus channels and around snow-melt water rock pools where they are seasonally inundated, to well-irrigated rocky slopes, to screes with local dry plains, and to dryer habitats like summit range or peaks where snow disappears early in summer. A continuous observations on the habitats of lichens in Langhovde (17. XI. 1986–16. I. 1987) revealed that lichens prefer semi-hydrophilic or dryer conditions to hydrophilic conditions though moss vegetation is remarkably lush in the hydrophilic conditions. Judging from the occurrence of *Usnea*, *Umbilicaria* and a lot of crustose lichens in dry habitats where snow disappears after the middle of November or early December, I cannot deny the possibility that katabatic wind itself might produce moisture during the summer season. Unfortunately, as WALTON (1984) pointed out, the moisture content of the air close to plant communities in Antarctic has been little studied.

GREENE and LONGTON (1970) mentioned: it should be noted that the prevailing low air temperatures combined with the higher temperatures within the vegetation will give substantial vapor pressure gradients between plants and their environment. In fact, the author observed the temperature 30–35°C at the bottom of terricolous *Rinodina*

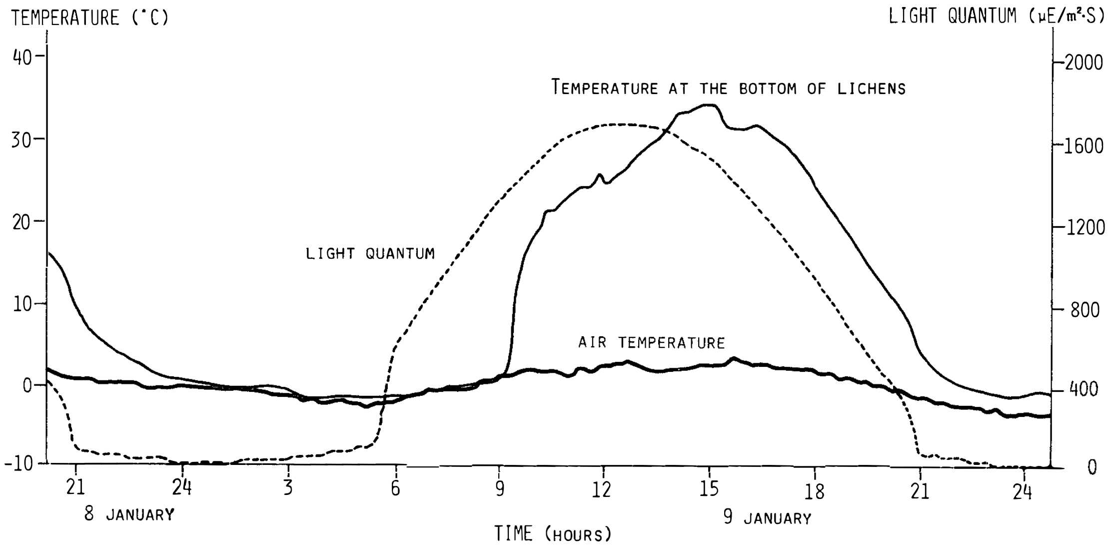

Fig. 10. Diurnal chanegs of light quantum, air temperature, and of the temperature at the bottom of Rinodina olivaceobrunnea *measured on January 8 and 9, 1987 in Langhovde. The sensor for light quantum (Koito Ind. Ltd.'s IKS-25), platinum resistance thermometer (Koito Ind. Ltd.'s MES-1102) and copper-constantan thermocouple (Koito Ind. Ltd.'s MES-1103) were employed respectively. Measurement was made every minute, and the average was taken average at intervals of fifteen minutes.*

Fig. 11. Distribution of Usnea *in Langhovde.*

olivaceobrunnea community in 1st, 2nd, 5th, 9th, 11th and 14th of January, 1987 at Langhovde (Fig. 10). This temperature may be sufficient for lichen growth if enough moisture were supplied. Figure 11 shows a distribution of *Usnea* in Langhovde based on my collections. *Usnea* has its distribution range almost corresponding to the range where lichen communities are well developed (Fig. 5). *Usnea* is one of the fruticose lichens attached to substrate only at the base, and often covers the dry bedrocks or boulders where snow disappears early in summer. It is plausible for me to conclude that moisture for the growth of *Usnea* appears to be supplied by air brought by the katabatic wind.

4.2. Wind

WALTON (1984) pointed out that a wind has three principal effects in the Antarctic: disturbance of local temperature and humidity profiles, abrasion damage by transport of ice crystals and mineral particles, and transport of living propagules on both micro and macro scales. These effects, especially the former two unfavorable factors for lichens, are well known (LLAMO, 1965; LAMB, 1970; FILSON, 1982).

The unfavorable effects mentioned above are also observed in the present region. For instance, as shown in Fig. 5, Mt. Heito (497 m alt.) and Mt. Minamiheito (482 m alt.), which are high in elevation and situated on the continental slopes, hence exposed to a strong wind in Langhovde, have not luxuriant lichen flora though adequate moisture for lichens might be maintained topographically. Especially, macrolichens, which easily suffer abrasion and desiccation by a strong wind, are poorly developed. Similar conditions could be seen in the sites of a similar topography in Skallevikhalsen and Rundvågshetta (Figs. 3, 2B). However, the wind in these areas appears to be mild, because microlichens and even macrolichens occur there commonly, though macrolichens are poorer than those of the sites where adequate moisture for lichens is supplied and the wind is not strong.

4.3. Wind-blown sea spray

Buellia frigida occurs everywhere and seems to have the widest ecological amplitude among the lichens in this region, but even this species can be hardly seen in the "peninsula-like sites" and several islands as stated before (group 3). Tables 2 and 3 show the occurrence of *Buellia frigida* along the two field investigation routes in northern Langhovde (Fig. 5A, B) where lichens are almost absent, or if present, very poorly developed. *Buellia frigida* is growing at the elevation, but its amount is decreasing gradually with a descent in slope and disappears below 100 m in altitude. A similar phenomenon was observed at Skjegget (400 m alt.) in Skarvsnes (Fig. 4B): *Buellia frigida* disappears below 200–210 m although it occurs everywhere above 210 m altitude (a few crustose lichens *Lecidella* sp., *Lecanora melanophthalma, Acarospora gywnii* and *Candelariella antarctica* can be seen restricted to the top of there). There is no difference in amount of water supply between low altitude and high altitude of this mountain.

The summit zone is exposed to a strong wind, which is one of the unfavorable factors for lichens, in comparison with the lower zones. It may be assumed that wind-blown sea spray seems to be one of the factors controlling the existence of lichens.

Lichens are absent or poor in most of Ongul Islands and in other islands scattered off the west side of Langhovde (group 3). These islands are small and hilly and seem to be buffeted by a cyclonic wind through the surface of sea ice. They might be very dry and influenced by the wind-blown sea spray.

Lichens occur almost all over West Ongul Island and Hjartöy (group 1-b) though they are not much prominent. Most of the lichens, which are crustose, are not saxi-

Table 2. Occurrence of Buellia frigida *along the field investigation route (marked "A" in Fig. 5) in Langhovde.*

Altitude (m)	152–130	130	120	100	100>
Size of habitat (cm)	*	3×3	100×10	3×3	—
Vegetational cover (%)	*	95	10	95	0

* *Buellia frigida* grows everywhere around the route. *Alectoria pubescens, Acarospora gywnii, Lecidea* sp. (closely related to *L. auriculata*) and *Xanthoria elegans*, are seen only scarcely.

Table 3. Occurrence of Buellia frigida *along the field investigation route (marked "B" in Fig. 5) in Langhovde.*

Altitude (m)	210–150	150	140	120	115	115>
Size of habitat (cm)	*	4×5	50×30	50×50	20×20	—
Vegetational cover (%)	*	95	60	10**	10	0

* *Buellia frigida* and *Acarospora gywnii* grow everywhere around the route, but they are small in number.

** Grows with *Lecanora melanophthalma* and *Lecidea* sp. (closely related to *L. auriculata*).

colous, but terricolous or muscicolous. These islands are buffeted by a cyclonic wind, but much snow dunes and drifts are seen everywhere, I visited West Ongul Island in the summer season (January–February) and made a distribution map of 15 species of lichens. I revisited there several times during the winter. Most lichens were covered by heavy snow in early May, and all lichens disappeared under the snow after middle of July (the author could not re-detect lichens until summer, because he did not revisit there after middle of August when all lichens were covered by snow). On the contrary, *Umbilicaria aprina*, *Buellia frigida* and other lichens, which are distributed on West Ongul Island, could be seen in the continental areas throughout the year. It is obvious that heavy snow, which is composed of snow and ice brought through the surface of the ice-cap and the sea ice, seems to provide favorable conditions for the microlichens: for example, heavy snow dilutes salinity of snow containing wind-blown sea spray.

4.4. Rookeries or nests of sea birds

Well-developed lichen communities can be seen around the rookeries of the Adélie penguin in Cape Omega and Padda (Fig. 2A, D). The lichen communities developed around the rookeries consist of somewhat a small number of species, though they form a dense vegetation (this suggests the existence of the species which cannot grow in this kind of habitat). *Buellia frigida*, *Lecanora melanophthalma*, *Lecanora* sp., *Lecidea* sp. (*cf. L. atrobrunnea*), *Physcia caesia*, *P. dubia*, *Rinodina* sp., *Xanthoria elegans* and *X. mawsonii* are recognized from "Kuzira Point penguin rookeries" in Padda. They are influenced by the organic nutrients supplied from the excreta of the penguins. However, it should be noted that lichens are absolutely absent around the rookeries at the sites, which are very dry and influenced by the wind-blown sea spray as stated before, in Cape Hinode (Fig. 4A), northern Langhovde (Fig. 5), Ongul Islands (Ongulkalven, Mame-zima Island and Benten Island) and islands scattered off the west side of Langhovde (Rumpa and Ytre Hovdeholmen) (Fig. 1).

Information on lichen habitats around the bird nests of South polar skur and Snow petrels is scarce except those of Langhovde. The author made a study during November 1986 and January 1987 at Langhovde. At least 13 large rookeries of Snow petrels and 7 nests of South polar skur were recognized in southern Langhovde which has a rich lichen flora. Well developed lichen communities could be seen around all rookeries. On the contrary, in northern Langhovde lichens are absent around three rookeries of Snow petrels and two nests of South polar skur (Fig. 5).

The moisutre and wind-blown sea spray appear to surpass the nutrient factor for existence of lichens.

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