Ecological Studies of the Moss and Lichen Communities in the Ice-free Areas near Syowa Station, Antarctica

Satoshi NAKANISHI*

昭和基地周辺の露岩地におけるコケ，地衣群落の組成と分布について

中西　哲*

要旨: 第16次南極地域観測の一環として1975年1月から2月にかけて，昭和基地周辺の露岩地に発達しているコケ類，地衣類の群落生態調査が行われた．本論文はこの調査によって得られた結果のうち，注目すべき2, 3の知見についてまとめたものである．

(1) 未報告の地衣類 *Physcia dubia* (HOFFM.) LETT., 蘚類の *Bryum antarcticum* HOOK. f. & WILS. と *Grimmia lawiana* WILLIS が産すること，また既報の種類のうち，種名の変更など分類学上の補正を必要とするものがいくつかあることが明らかとなった．(2) コケ群落は種類組成に基づいて6つの分群集に分類された．これら分群集のうち，多くのものは生育地の水供給のパターンと密接な関係をもって分布している．(3) スカルブスネスの中央地域では，海鳥の巣からもたらされる栄養塩が，地衣群落の種類組成や分布に決定的な影響を与えている．(4) 多くの群落は，西北西から南西の方位の斜面に発達しているが，立地の水供給のパターン，とくに吹き溜り型と流水・湧水型の違いによって分布の方位性に差がある．また最多分布方位は，露岩地ごとに少し異なっており，そこの卓越風の風向の違いを示唆している．

Abstract: Ecological investigations of the terrestrial vegetation were made as a part of the studies on the ecosystem to serve as the background for an evaluation of the effects of environmental contamination by human activities in the Antarctic. Under the project of the 16th Japanese Antarctic Research Expedition (JARE-16), field investigations were carried out in certain ice-free areas near Syowa Station during January and February 1975. The present paper includes some noteworthy results obtained in this field work.

(1) It became clear from floristic and taxonomical investigation that one lichen (*Physcia dubia* (HOFFM.) LETT.) and two mosses (*Bryum antarcticum* HOOK. f. & WILS. and *Grimmia lawiana* WILLIS) could be added to the flora of the areas, and also that there were some species which previously had been treated under wrong scientific names. (2) The moss communities were classified into six sociations on the basis of species composition. The distribution of the moss sociations was analyzed in relation to the pattern of water supply. From this investigation, it was ascertained that the distribution of some sociations was closely

* 神戸大学教育学部. Faculty of Education, Kobe University, 3–11, Tsurukabuto, Nada-ku, Kobe 657.

correlated with this pattern. (3) A remarkable relationship between lichen communities and bird nests was observed in the central region of Skarvsnes. It seems that the species composition and the distribution of the lichen communities are influenced decidedly by the organic nutrients supplied from the excrement of sea birds. (4) The direction of the habitat of each terrestrial community was examined in all ice-free areas. Most of the communities grew in habitats on the leeward side of wind-barriers facing from west-northwest to southwest, although the direction was somewhat determined by the pattern of water supply in their habitat. Further examination in detail, however, revealed that each ice-free area had the most frequent direction slightly different from that of the others. This seems to suggest that the direction of the prevailing wind may be different in each ice-free area.

1. Introduction

Studies of the ecosystem of ice-free areas to serve as the background for an understanding of the environmental contamination caused by human activities were projected as a part of the comprehensive studies of the total environment in Antarctica. The present research forms a part of this research project. In this study a special emphasis was put on the investigation of bryophyte and lichen communities in the ice-free areas near Syowa Station. The field work had two main objectives: to clarify the composition of the floras of bryophytes and lichens; and to analyze and record precisely the species composition and distribution of moss and lichen communities in each ice-free area.

Under the project of the 16th Japanese Antarctic Research Expedition, the field work was done between the middle of January and the 10th of February in 1975 in such areas as East and West Ongul Islands, Langhovde, Skarvsnes, and Akarui Point. From the various results obtained, the author reports in the present paper a few new facts about the flora and the relationship between the floristic composition of, or the distribution of, the communities and the environmental factors influencing them.

2. New Information about the Flora

2. 1. Lichens

In regard to the lichens in the ice-free areas near Syowa Station, KOBAYASHI (1961) reported an imperfect lichen with no exact scientific name. Then, KASHIWADANI (1970) gave a full account of the lichen flora of Prince Olav Coast and reported seventeen species in all, *i. e.*, thirteen species of crustose, two species of foliose, and two species of fruticose lichens.

Among them, it was found that *Parmelia coreyi* DODGE et BAKER and *Parmelia leucobrephala* DODGE et BAKER were synonymous with *Physcia caesia* (HOFFM.) HAMPE

(NAKANISHI and KASHIWADANI, 1976). Also it became certain that the species reported under the name of *Xanthoria* sp. actually were *Candelaria antarctica* (MURRY) POELT. Moreover, as a result of careful examination of spores, it was found that the species reported as *Catillaria cremea* DODGE et BAKER belonged to the genus *Lecidea*.

Furthermore, it was found that *Physcia dubia* (HOFFM.) LETT. could be reported from Kaname Island, Langhovde, and Skarvsnes (NAKANISHI and KASHIWADANI, 1976). Besides, some unreported crustose lichens in the genera *Caloplaca, Lecidea*, and *Rhizocarpon* were collected. At present, however, these lichens are still being examined and have not yet been fully determined.

2. 2. Mosses

Since the mosses of the continental Antarctic rarely produce sporophytes, one must usually depend on the characters of the gametophytic shoot to identify them. However, the characters of the shoot, especially of the leaf, tend to vary with environmental conditions of their habitats. Therefore, it is inferred that there should be considerable numbers of examples of the same species passing under different names or of different species reported under the same name. Our taxonomic knowledge of the genus *Bryum*, which is one of the large genera in the Antarctic, is incomplete yet and several problems need clarification. Under these conditions, HORIKAWA and ANDO (1961, 1967a, b) reported that there were three species of mosses in the ice-free areas near Syowa Station, *i. e.*, *Ceratodon purpureus* (HEDW.) BRID., *Bryum argenteum* HEDW., and *Bryum inconnexum* CARD.

Among the three mosses, *Bryum argenteum* was considered as an Antarctic plant which was different from the ordinary form found in Japan and Europe; for *Bryum argenteum* of Ongul Islands had the following distinctive features: leaf apex obtuse, sometimes acute or slightly apiculate; long costa reaching just below the apex; leaf usually chlorophyllose to the apex; and synoicous. Above all, the chromosome number of the Antarctic plant was observed as $n=20$ by TATSUNO (1963).

The ordinary form of *Bryum argenteum*, for reference, has an apiculate leaf which is characterized by the hyaline upper half and the weak costa ending about the middle. Moreover, the chromosome number is $n=10$, and it is dioecious. In regard to the relation between the Antarctic plant of *Bryum argenteum* and the ordinary plant, HORIKAWA and ANDO (1967 a, b) concluded that the Antarctic plant was a diploid race derived from ordinary plants of monoploid level.

However, in the course of this investigation the plants of *Bryum argenteum* which were very similar to the ordinary form in morphological characters of the leaf were collected in Langhovde and Skarvsnes. Besides, INOUE (1976) proved that the chromosome number of this plant was $n=10$. From these facts, it seems clear that the ordinary form of *Bryum argenteum* is also distributed in areas on the Prince Olav Coast.

Thus, it became necessary to examine the Antarctic plant of *Bryum argenteum* mentioned by HORIKAWA and ANDO (1967 a, b). From our present knowledge, the following two interpretations may be put on this problem. The first one is that the Antarctic plant of *Bryum argenteum*, at least the plant illustrated by HORIKAWA and ANDO (1961), should be a variation of *Bryum inconnexum* which is synoicous and has a chromosome number of n=20. Considering that *Bryum argenteum* makes a compact tuft mingling frequently with *Bryum inconnexum* and *Ceratodon purpureus*, and that *Bryum inconnexum* shows remarkable variability in its morphological characters, the conjecture mentioned above seems to be quite reasonable. The other interpretation is that the Antarctic plant might be an independent species which is neither *Bryum argenteum* nor *Bryum inconnexum*. In order to finally answer this question, a careful revision of all the Antarctic species of the genus *Bryum* would be required.

Recently, OCHI (1976) has made a taxonomical examination of *Bryum inconnexum* in detail, and he concluded that it is conspecific with *Bryum pseudotriquetrum* (HEDW.) GAERTN. In the present paper the author keeps uses the old name since the formal treatment of its nomenclature is not published.

It became clear that besides the three species reported by HORIKAWA and ANDO (1967 a, b), there were present *Grimmia lawiana* WILLIS and *Bryum antarcticum* HOOK. f. & WILS. The latter was once considered to be a variation of *Bryum inconnexum* (NAKANISHI, 1975). But the chromosome number was observed as n=26+2 (INOUE, 1976), and after a detailed re-examination it was identified as *Bryum antarcticum*. From several characters of the sporophytes which were collected in Skarvsnes, this moss is

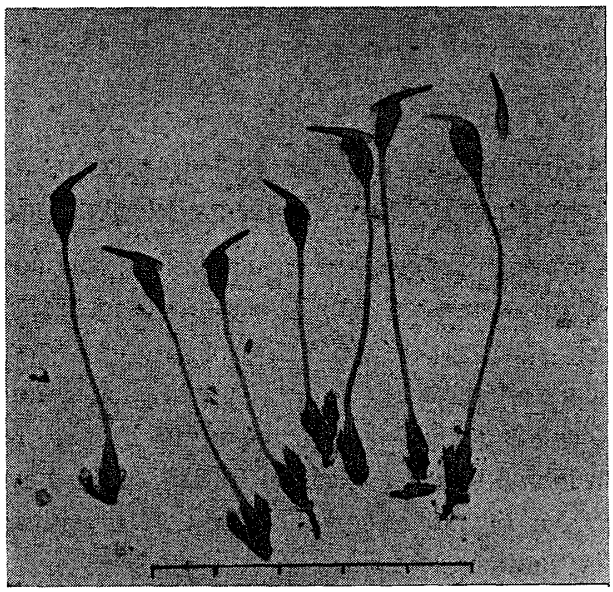

Fig. 1. Bryum antarcticum *with sporophyte collected in Skarvsnes, Antarctica. One scale indicates 2 mm.*

not considered to be a species of the genus *Bryum* but of the genus *Pottia* (*cf.* Fig. 1). The fact that nearly mature sporophytes were found seemed to imply that sexual reproduction occurs in the areas near Syowa Station.

At present although the exact identity of this species is still under investigation, the occurrence of two other mosses can be reported. One of them is a species of the genus *Desmatodon*. INOUE (1976) reported that the chromosome number of this moss was n=26. The other is a subaquatic moss which grows gregariously on the bottom of lakes (*cf.* Fig. 2). This moss is closely related to *Bryum korotkevicziae* or *B. korotkevicziae* var. *hollerbachii* described by SAVICZ-LJUBITZKAJA and SMIRNOVA (1959, 1960). However, it can be distinguished from *B. korotkevicziae* and its variety by the presence of the globose gemmae on their rhizoids.

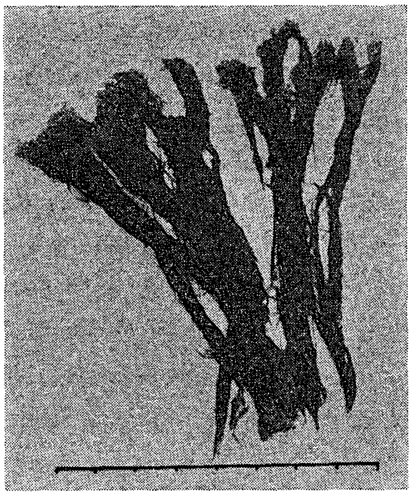

Fig. 2. A subaquatic moss collected at a lake in Skarvsnes, Antarctica. One scale indicates 1 cm.

3. Geographical Distribution of the Mosses and Lichens in the Prince Olav Coast and Sôya Coast

On the basis of previous reports and available data, the author summarized the geographical distribution of mosses and lichens in the ice-free areas of Prince Olav Coast and Sôya Coast.

The result for lichens is shown in Table 1. It became certain that two species of lichens, *Acrospora gwynii* and *Lecidea* sp. occur in the Yamato Mountains which was located at ca. 250 km inland from the coast of Lützow-Holm Bay. These two lichens were collected by Dr. M. MATSUMOTO who made field investigations in the Yamato Mountains during the summer of 1976.

Observations of the geographical distribution of lichens in the region indicate that the lichen flora of East and West Ongul Islands is extremely poor. The reason for

Table 1. Geographical distribution of lichens in ice-free areas of Prince Olav Coast and Sôya Coast.

Lichens \ Localities	Yamato Mts.	Kaname Is.	Austhovde	Padda Is.	Skarvsnes	Langhovde	Ongulkalven Is.	E. Ongul Is.	W. Ongul Is.	Sôya Coast	Akarui Point	Cape Hinode	Akebono Rock	Molodezhnaya
Caloplacaceae														
1. *Caloplaca elegans* var. *pulvinata*	.	.	.	.	++	+++*	.	.	+*	.	++	+**	.	+*
2. *Caloplaca* sp.	.	.	.	.	.	++	.	.	.	.	++	.	.	.
3. *Xanthoria mawsonii*	.	.	.	.	++	+++*	.	.	+	+**	++	+*	+*	++*
4. *Protoblastenia citrina*	.	.	.	.	++	+++*	×*	.	.	.	++	+*	+*	++*
Physciaceae														
5. *Physcia caesia* (Syn. *Parmelia coreyi* *P. leucobrephala*)	.	×	.	.	++	++*	.	.	.	+++*	++	.	.	+*
6. *Physcia dubia*	.	×	.	.	+	+	.	.	.	.	.	.	.	.
Buelliaceae														
7. *Buellia frigida*	.	.	.	×	+++	+++*	.	.	+	++*	+++	+*	+*	+*
8. *Rinodina archaeoides*	.	.	.	×	++	++*	.	+*	+*	+++*	++	++*	.	+**
Usneaceae														
9. *Usnea sulphurea*	.	.	×	×	++	+++*	.	.	.	+++*	++	+++*	++*	+++*
10. *Alectoria minuscula*	.	.	×	×	++	+++*	.	.	.	+++*	+	+++*	++*	+++*
Candelariaceae														
11. *Candelaria antarctica* (Syn. *Xanthoria* sp.)	.	.	.	.	+	+*	.	.	.	.	.	.	.	.
Lecanoraceae														
12. *Lecanora expectans*	.	.	.	.	++	++*	.	.	+	.	++	.	.	.
13. *Lecanora exsulans*	.	.	.	.	++	++*	×*	.	+*	+*	+	+*	+*	+++*
Acrosporaceae														
14. *Acrospora gwynii*	×	.	.	.	++	++*	.	.	.	.	.	+*	.	.
Umbilicariaceae														
15. *Omphalodiscus antarcticus*	.	.	.	×	++	+++*	.	.	+***	+++*	+++	+*	.	+*
16. *Omphalodiscus decussatus*	.	.	×	.	++	+++*	.	.	.	+**	+	+++*	+*	+++*
Lecideaceae														
17. *Lecidea* sp. 1 (Syn. *Catillaria cremea*)	×	.	.	.	+++	+++*	.	.	.	.	+++	+*	.	.
18. *Rhizocarpon flavum*	.	.	.	.	+	++	.	.	.	.	++	.	.	++*

Data derived from * Kashiwadani (1970), ** Kashiwadani (1973), *** Kobayashi (1974).
Abundance: + rare, ++ occasional, +++ frequent. ×: Presence regardless of abundance.

this poverty of species may be related to the fact that the two islands consist of ranges of low *roche moutonnée* and lack much topographical variation, and also there are few landforms such as ravines which are provided with a variable water supply. Another factor might be that the islands rarely seems to be supplied with organic nutrients provided by the excrement of sea birds.

Moreover, another interesting phenomenon is recognized: in Langhovde and Akarui Point each lichen plant occurs scattered individually along the water channel and rarely makes up a community with other species; in contrast, in the central region of Skarvsnes the common species of lichens are concentrated near bird nests.

The geographical distribution of mosses is shown in Table 2. The most interesting phenomenon is that *Bryum antarcticum* is the dominant species in Skarvsnes, though it rarely appears in the other ice-free areas. Besides, *Ceratodon purpureus* is found more frequently in Akarui Point than in any other ice-free area.

Table 2. Geographical distribution of mosses in ice-free areas of Prince Olav Coast and Sôya Coast.

Mosses \ Localities	Padda Is.	Skarvsnes	Langhovde	E. Ongul Is.	W. Ongul Is.	Akarui Point	Cape Hinode
Ditrichaceae							
1. *Ceratodon purpureus*	×	++	+++	++*	+++*	+++	×
Pottiaceae							
2. *Desmatodon* sp.	.	+	+	.	.	.	.
Grimmiaceae							
3. *Grimmia lawiana*	.	+	+	.	.	+	.
Bryaceae							
4. *Bryum inconnexum*	×	+++	+++	++*	+++	++	.
5. *Bryum antarcticum*	.	+++	+	.	.	.	.
6. *Bryum argenteum*	.	++	++	+*	+*	+	.

Data derived from * HORIKAWA and ANDO (1961 , 1967a).
Abundance: + rare, ++ occasional, +++ frequent. ×: Presence regardless of abundance.

For a final comparison and discussion of the distinctive features of each area regarding its flora, sufficient information is not available. However, it appears that each area has its own characteristic flora and no two are exactly the same. The localism seen in the large-scale distribution of mosses and lichens must be brought about not by a single factor but by various factors which influence each other. In the future it is necessary to investigate in more detail the actual state of the mosses and lichens in each ice-free area, and also to analyze the relationship between them and the nature of environmental factors operating in the region, such as the geology, the shape and size of the ice-free area, the length of time the habitats have been free from glaciers and ice sheets, the distance from the edge of the continental ice sheet, the availability of water, and the presence of nesting places of sea birds.

4. Species Composition and Ecological Distribution of Moss and Lichen Communities

Taxonomical studies of the mosses and lichens in the ice-free areas near Syowa Station have been ahead of other kinds of studies. At present, it can be said that the taxonomy of the main species has been almost established except for some unsettled problems. On the other hand, ecological investigations of the terrestrial communities have been undertaken a little later (MATSUDA, 1963, 1964 a, b, 1968; FUKUSHIMA, 1968).

However, studies of the classification of the terrestrial communities were somewhat delayed. On a basis of physiognomy, KASHIWADANI (1973) distinguished four communities, *i. e.*, Genuine moss community, Moss-Lichen community, Crustose lichen community, and Foliose and fruticose lichen community. From the same point of view, KOBAYASHI (1974) described five communities including one of algae.

In the present study the author classifies the vegetation from a phytosociological point of view emphasizing the species composition of the community, and tries to clarify the relationship between the structure or the distribution of each of the communities classified and the environments of their habitats. Several interesting facts gained by examining the vegetational data thus far obtained will be reported in the following part.

4. 1. Species composition and distribution of the moss communities

In many cases the mosses grow closely packed together and they make a compact cushion with a hummocky appearance. The size of the communities varies, being 100 m^2 in large ones and 0.5 m^2 in small ones depending on habitat conditions. Without reference to the size of the communities, the whole assemblage of mosses that spread like a mat was regarded as one quadrat. The species occurring within the quadrat were examined in detail, and the degree of dominancy of each species was recorded on the basis of the phytosociological methods given by BRAUN-BLANQUET (1964), following which samples were collected for laboratory studies. Moreover, the author evaluated the vitality of community according to the following scale.

Vitality 1: The green part of the moss community can not be seen in appearance. It looks largely moribund being heavily colonized by blue-green algae and an imperfect lichen. When one brushes the sand and pebbles off the surface, growing green moss can barely be seen beneath.

Vitality 2: A quarter of the community is green and shows proper growth. The rest looks blackish and moribund.

Vitality 3: A quarter to a half is green.

Vitality 4: Half to three quarters is green.

Vitality 5: Three quarters to the whole community is green.

The number of quadrats where moss communities were investigated was 164 in all, *i. e.*, 18 in Akarui Point, 27 in East and West Ongul Islands, 69 in Langhovde, and 50 in Skarvsnes. The locations of the quadrats in Langhovde and Skarvsnes are shown in Fig. 3 and Fig. 4 respectively.

After correcting the vagetational records by careful identification of species with a

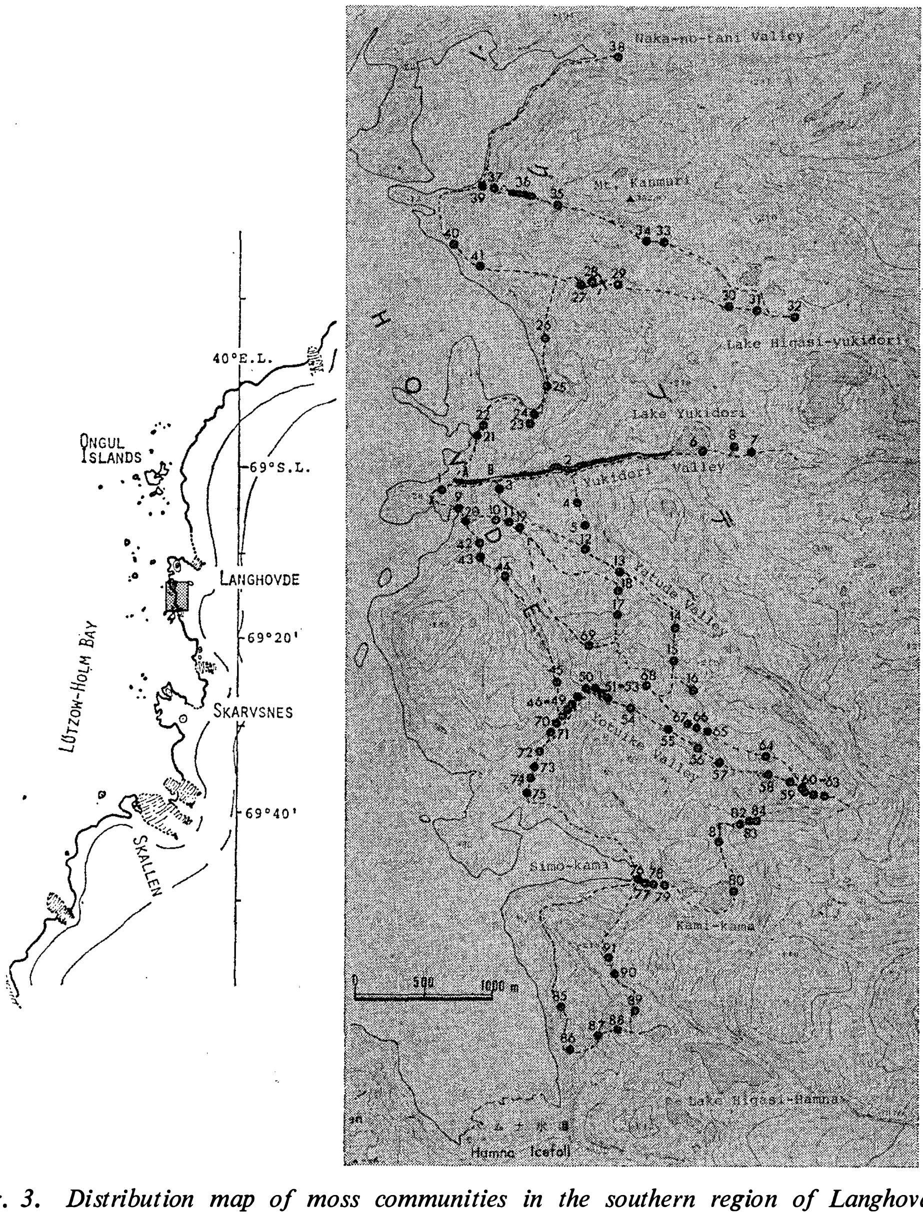

Fig. 3. Distribution map of moss communities in the southern region of Langhovde. The numbers in the map are the quadrat numbers. A and B show the sites for investigation of the distributional analyses of the mosses.

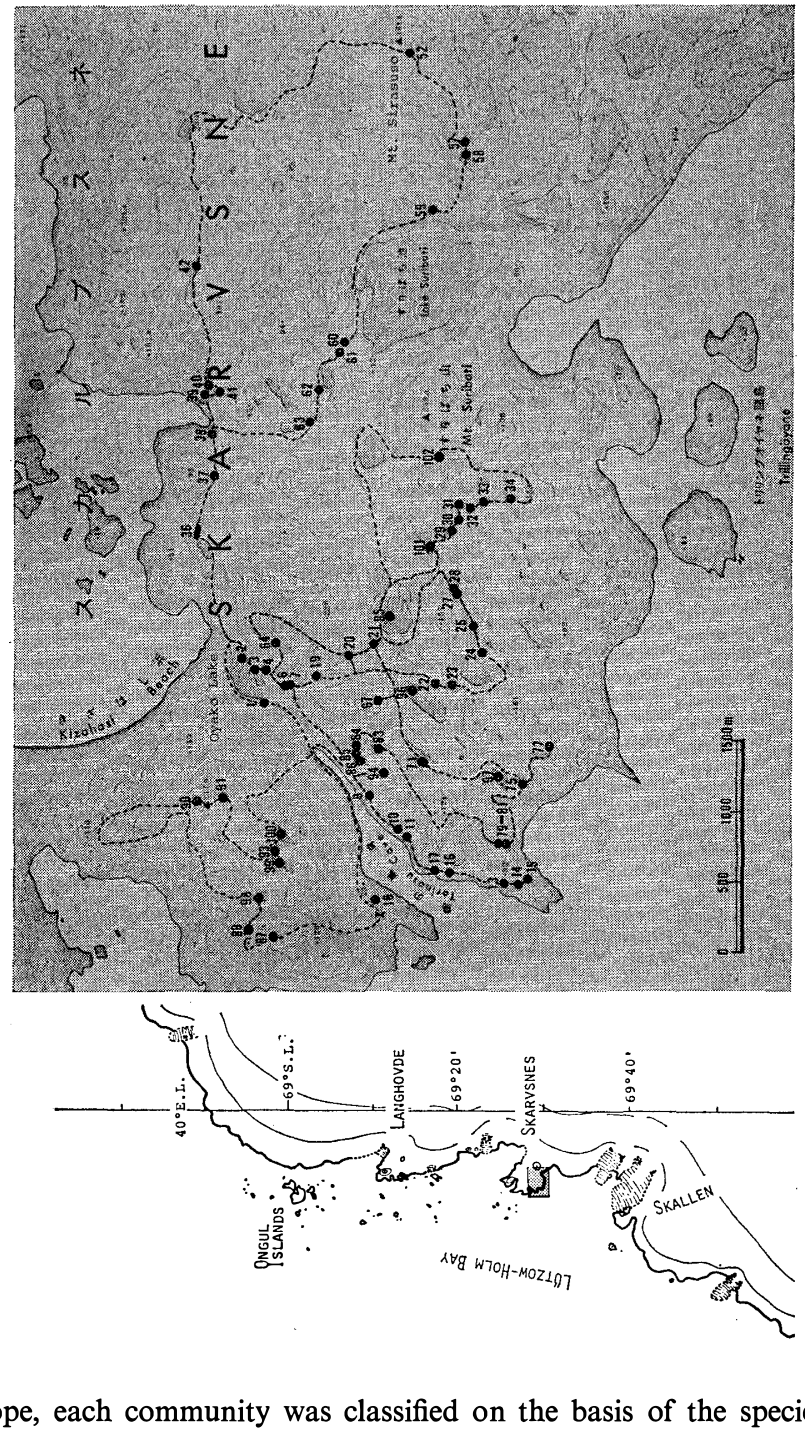

Fig. 4. Distribution map of moss communities in the central region of Skarvsnes. The numbers in the map are the quadrat numbers.

microscope, each community was classified on the basis of the species composition. As a result the following six communities were recognized. The moss communities classified are poor in the species composition, so that it may be suitable to adopt the term "Sociation" as the fundamental community unit.

1) *Ceratodon purpureus* Sociation (Table 3, Fig. 5)

The community is mainly composed of *C. purpureus*. It contains a community

Table 3. Species composition of Ceratodon purpureus *Sociation.*

Communities	*Grimmia* type			Typicum														
Localities*	L	L	A	A	A	A	A	L	L	L	L	L	O	O	O	O	O	O
Quadrat No.	59	60	7	8	12	13	18	26	35	62	65	68	7	8	22	28	29	37
Altitude (m)	245	250	135	125	125	65	50	50	220	250	210	230	15	20	10	15	15	25
	S	S	N	N	S	N	N	S	N	S	N	S	S	S	S	N	S	S
Exposition	47	25	63	63	85	80	67	10	60	53	59	63	8	67	45	56	81	55
	W	E	W	W	W	W	W	E	W	W	W	W	W	W	W	W	W	W
Vitality	1	1	3	2	2	1	2	3	2	1	1	1	1	2	1	3	1	1
Pattern of water supply	II	II	II	II	I	I	I	III	III	I	I	I	I	I	I	II	II	I
Grimmia lawiana	1	1	2															
Ceratodon purpureus	2	+	3	3	2	2	3	5	3	2	1	1	2	3	1	4	2	2
Imperfect lichen	1	1	1	1	2	1	2	+	.	1	2	1	.	1	.	.	1	+
Rinodina archaeoides			+	1	1		1				+	+						
Caloplaca sp. 1					+		+			1								
Physcia caesia							1											
Xanthoria mawsonii							r											
Caloplaca elegans v. *pulvinata*							r											

* A: Akarui Point, L: Langhovde, O: Ongul Islands, S: Skarvsnes.

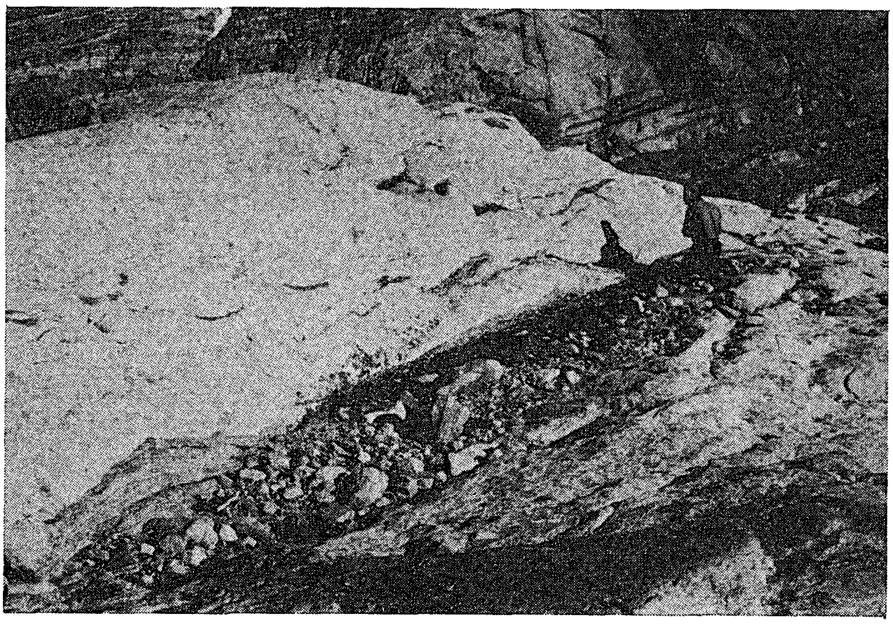

Fig. 5. An arid habitat of Ceratodon purpureus *Sociation where the snow drift had already melted.*

Table 4. Species composition of Bryum inconnexum *Sociation.*

Localities*	O	O	O	O	O	O	O	O	O	O	L	L	L	L	L	L	S	S	S	S	S	S	S	S
Quadrat No.	1	15	16	19	23	24	27	39	41	42	32	38	44	72	85	89	14	15	18	21	42	59	91	93
Altitude (m)	20	10	15	15	10	15	7	30	20	25	255	3	40	35	100	165	7	10	5	90	155	0	210	100
	S	S	N	S	S	S	S	N	S	S	N	N	N	S	S	S	S	N	S	S	S		N	N
Exposition	19	18	9	60	15	35	21	51	55	W	11	70	77	19	68	72	75	69	7	62	79	W	57	75
	W	E	E	W	W	W	W	W	W		W	W	W	W	W	W	W	W	E	W	W		W	W
Vitality	1	3	3	1	5	2	1	1	2	3	2	5	2	3	3	3	5	3	4	4	1	5	1	2
Pattern of water supply	I	IV	IV	I	II	I	I	I	I	I	II	II	I	III	II	II	I	I	V	VI	I	V	II	V
Bryum inconnexum	2	3	3	1	5	3	1	2	2	3	2	2	2	3	4	4	1	4	2	2	1	5	1	+
Imperfect lichen	.	.	.	.	.	.	+	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	1	.

* O: Ongul Islands, L: Langhovde, S: Skarvsnes.

Table 5. Species composition of Ceratodon

Localities*	A	A	A	A	A	A	A	A	A	A	A	A	O	O	O
Quadrat No.	1	2	3	4	9	10	11	16	17	19	20	21	2	3	4
Altitude (m)	35	40	40	50	140	140	125	60	55	50	50	40	20	15	17
Exposition	N 55 W	N 85 W	N 30 W	N 20 W	N 55 W	N 49 W	S 75 W	S 82 W	N 72 W	N 50 W	S 83 W	N 45 W	S 82 W	N 7 W	S 85 W
Vitality	3	3	4	4	2	2	2	3	5	3	2	2	2	5	2
Pattern of water supply	I	I	III	III	II	II	I	II	II	I	I	I	II	III	I
Ceratodon purpureus	3	5	5	5	3	3	3	4	4	3	3	3	3	1	5
Bryum inconnexum	+	+	1	+	1	1	+	1	3	2	1	1	+	4	1
Imperfect lichen	1	2	+	+	2	1	2	2	1	2	1	1	1	.	.
Rinodina archaeoides	+	1			1	+	1								
Caloplaca sp. 1	+	+								+					
Lecanora expectans		+								+	+				
Xanthoria mawsonii										+	+	r			
Protoblastenia citrina															

Localities*	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L
Quadrat No.	47	48	51	52	55	58	61	63	66	67	69	70	71	73	74
Altitude (m)	65	70	95	110	170	210	260	240	200	305	150	60	55	30	25
Exposition	S	S 45 W	N 25 W	N 37 W	S 45 W	S 58 W	S 79 W	S 55 W	S 12 W	S 75 W	S 69 W	N 70 W	S 39 W	S 21 W	S 4 E
Vitality	4	4	5	5	1	1	1	1	1	1	1	3	4	4	3
Pattern of water supply	V	V	III	VI	III	III	I	I	II	I	II	V	V	V	V
Ceratodon purpureus	2	4	1	2	2	+	2	2	+	+	2	+	1	1	3
Bryum inconnexum	4	1	4	3	1	2	1	+	2	2	+	3	4	3	1
Imperfect lichen	.	.	.	.	.	1	2	1	.	.	1	.	.	.	.
Rinodina archaeoides							1	+							
Caloplaca sp. 1							+				+				
Lecanora expectans							+				+				
Xanthoria mawsonii															
Protoblastenia citrina															

* A: Akarui Point, L: Langhovde, O: Ongul Islands, S: Skarvsnes. ** F: Flat.

type differentiated by the presence of *Grimmia lawiana.* Usually, its vitality is low and it is found in rather dry habitats.

2) *Bryum inconnexum* Sociation (Table 4)

The community is composed of only *B. inconnexum.* Generally, its vitality is high.

3) *Ceratodon purpureus-Bryum inconnexum* Sociation (Table 5, Fig. 6)

This sociation is to be found in every ice-free area. The vitality differs in places according to the amount of available water in the growing season.

purpureus–Bryum inconnexum *Sociation.*

O	O	O	O	O	O	O	O	L	L	L	L	L	L	L	L	L	L	L	L	L
5	11	32	33	34	35	36	40	4	10	13	15	22	25	33	34	36	37	40	42	46
20	15	30	30	40	35	20	25	55	40	60	200	15	5	230	220	160	65	15	75	65
N 7 E	S 65 W	N 5 W	S 71 W	S 85 W	N 67 W	S 71 W	W	N 88 W	S 40 W	N 87 W	N 5 W	N 80 W	N 75 W	F**	N 25 W	S 75 W	N 60 W	S 50 W	W	S 12 W
4	1	4	3	4	3	5	4	5	3	4	2	2	5	1	2	4	4	3	1	2
I	I	III	VI	II	III	VI	VI	II	II	III	I	I	VI	II	II	V	V	I	I	III
3	2	4	3	4	1	2	+	3	3	3	3	2	1	2	3	4	4	4	2	3
1	1	2	2	2	3	5	4	3	1	1	+	1	4	+	+	1	1	1	+	+
.	+	.	1	.	.	1	.	+	2	3	.	2	1	1	.	.	.	.	+	1
	+									+		+								
										+		+								
								1												
								2												
										r										

L	L	L	L	L	L	L	L	L	L	S	S	S	S	S	S	S	S	S	S
79	81	82	83	84	86	87	88	90	91	10	11	13	20	24	29	40	61	87	90
65	130	160	165	170	35	115	140	200	195	20	25	8	95	130	80	20—	10	110	190
N 75 W	S 5 W	W	W	N 97 W	S 15 W	S 20 W	S 15 W	S 65 W	N 60 W	S 69 W	N 88 W	N 88 W	S 75 W	N 47 W	S 25 W	S 60 W	S 5 W	S 80 W	N 55 W
4	2	3	2	3	2	2	2	2	3	1	1	2	1	2	2	5	3	2	2
VI	II	II	VI	VI	VI	II	II	II	II	I	I	I	V	II	V	V	V	V	I
3	3	1	1	3	+	+	2	4	3	1	+	2	1	2	2	+	1	+	4
2	1	2	3	1	2	3	+	+	3	1	1	2	1	3	1	5	4	1	1
.	3	.	.	1	.	.	.	1	3	+	+	+	+	2	3	.	+	.	3
														+					
														+					

4) *Bryum argenteum-Bryum inconnexum* Sociation (Table 6)

The community is characterized by *B. argenteum* mingled with *B. inconnexum* and *C. purpureus.* Its habitats are constantly supplied with water and mostly located near birds nests.

5) *Bryum antarcticum-Bryum inconnexum* Sociation (Table 7)

This community mainly appears at the edge of seepage and brooks in the central part of Skarvsnes. Generally, its vitality is high.

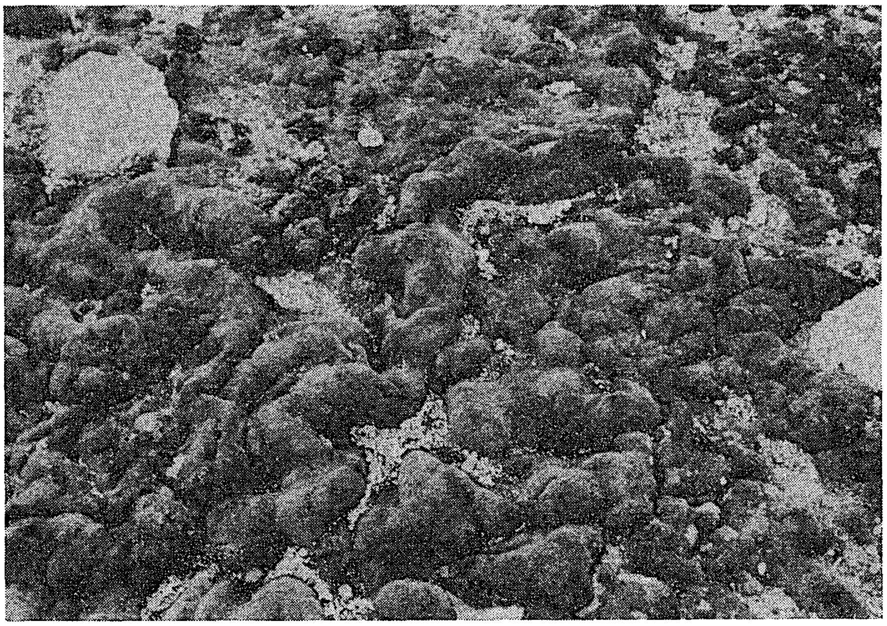

Fig. 6. A part of Ceratodon purpureus-Bryum inconnexum *Sociation in Langhovde.*

Table 6. Species composition of Bryum argenteum–Bryum inconnexum *Sociation.*

Localities*	A	L	L	L	L	L	L	L	L	L	L	L	S	S	S
Quadrat No.	5	9	11	16	23	49	50	53	76	77	78	80	32	33	34
Altitude (m)	70	5	40	195	15	75	90	115	5	15	25	80	110	100	120
Exposition	N 28 W	S 15 W	S	S 87 E	N 17 W	S 45 W	N 70 W	S 75 W	N 45 W	S 65 W	N 67 W	S 82 W	N 57 W	N 87 W	N 31 W
Vitality	5	3	2	1	4	5	5	5	2	4	4	4	4	5	5
Pattern of water supply	V	V	VI	VI	V	V	V	VI	VI	VI	V	VI	V	V	V
Bryum inconnexum	1	1	3	1	3	4	3	4	2	4	4	3	3	4	+
Bryum argenteum	+	+	+	+	+	1	3	1	+	1	1	+	1	2	4
Ceratodon purpureus	5	3	1	2	1	2	3	1	+	3	+	+	3	.	.
Lecanora expectans	.	.	.	.	+	.	.	+	+	+	+	.	.	+	.
Imperfect lichen	+	1	.	1	.	.	.	.	.	1	.	.	3	.	.
Xanthoria mawsonii								+						1	
Caloplaca sp. 1										+					
Bryum antarcticum														1	
Rinodina archaeoides				+											

* A: Akarui Point, L: Langhovde, S: Skarvsnes.

6) *Desmatodon* sp. -*Bryum inconnexum* Sociation (Table 8)

The community is characterized by the occurrence of *Desmatodon* sp. mixed with *B. inconnexum* and *B. antarcticum.* It is distributed mainly on lake shores or near seepages. It is akin to the above-mentioned community in ecology.

Table 7. Species composition of Bryum antarcticum–Bryum inconnexum *Sociation.*

Localities*	L	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
Quadrat No.	54	1	3	4	6	7	9	16	17	19	25	27	31	36	38	39	41	52	63	79	80	81	83	85	86
Altitude (m)	160	5	10	10	15	15	15	5	2	40	120	125	125	10	15	10	15	350	15	5	5	8	15	10	10
	N		N	N	N	N	S	N	N	N	S	S	N	S	S	S	N	S	S	N	N	N			
Exposition	55	F**		57	57	59	88	59	45	63	35	27	53	75	75	85	50	88	25	29	29	29	F	F	F
	W		W	W	W	W	W	W	W	W	E	E	W	W	E	W	W	W	E	W	W	W			
Vitality	3	1	4	5	2	3	3	4	3	1	2	3	4	3	3	5	4	2	4	4	4	4	5	5	3
Pattern of water supply	V	III	V	V	VI	VI	II	II	V	V	V	V	V	VI	V	V	V	V	VI	VI	VI	V	IV	V	V
Bryum inconnexum	2	1	1	4	3	1	3	4	2	2	2	2	+	3	3	5	4	2	3	4	4	5	5	5	5
Bryum antarcticum	3	1	3	2	1	3	+	1	+	1	1	2	3	2	3	+	2	1	2	+	1	1	1	1	+
Imperfect lichen								+					1					1							
Lecanora expectans	2																								
Xanthoria mawsonii	1																								

* L: Langhovde, S: Skarvsnes. ** F: Flat

Table 8. Species composition of Desmatodon *sp.*–Bryum inconnexum *Sociation.*

Localities*	L	L	L	L	L	L	S	S	S	S	S
Quadrat No.	27	30	31	45	57	75	2	60	62	84	94
Altitude (m)	30	215	250	65	170	15	10	20	10	15	15
Exposition	N 29 E	F**	N 65 W	N 69 W	S	S 29 W	S 55 W	S 19 W	S 45 W	F	F
Vitality	2	1	1	1	2	3	3	3	4	5	2
Pattern of water supply	IV	IV	IV	V	IV	V	IV	V	V	IV	V
Desmatodon sp.	1	+	+	1	1	1	1	+	1	1	1
Bryum inconnexum	2	2	2	1	1	3	1	2	2	4	2
Bryum antarcticum	.	2	.	.	.	.	2	3	2	1	1
Imperfect lichen	+	+	+	1	+	.	.	.	.	.	+
Lecanora expectans			+		+						
Ceratodon purpureus					1						
Xanthoria mawsonii			r								

* L: Langhovde, S: Skarvsnes. ** F: Flat.

Physiognomically, each of the sociations might correspond with either "Genuine moss community" or "Moss-Lichen community" reported by KASHIWADANI (1973) and KOBAYASHI (1974). However, these two communities cannot be distinguished so clearly by species composition. The Moss-Lichen community is equivalent to a part of the Genuine moss community where the mosses grow badly owing to the lack of water and they look withered and blackish due to the luxuriant growths of blue-green algae on them, or sometimes of an imperfect lichen or one of the crustose lichens such as *Rinodina archaeoides* as observed by KASHIWADANI (1971). It is more appropriate to consider such crustose lichens as members of the moss community.

Considering the abundance of *Bryum inconnexum*, these six sociations could be integrated into an association, *i. e.*, *Bryum inconnexum* Association. In its physiognomy and ecology, this association seems to be related to the Lichen encrusted *Bryum* spp. -*Ceratodon* spp. -*Pohlia nutans* Association described in some islands of the maritime Antarctic (GIMINGHAM and SMITH, 1970).

The composition and the vitality of each of the sociations classified seem to have a close relationship to water conditions and the amount of organic nutrients supplied by the excrement from sea birds. In order to confirm such relationships, the author investigated as to the habitat type in which each sociation mainly was found. Their habitats then were classified into the following six types according to the pattern of ground water supply, as shown diagrammatically in Fig. 7.

Habitat type I. Small snow drift type

The habitat of this type occurs on the leeward side of protruding rocks and ridges

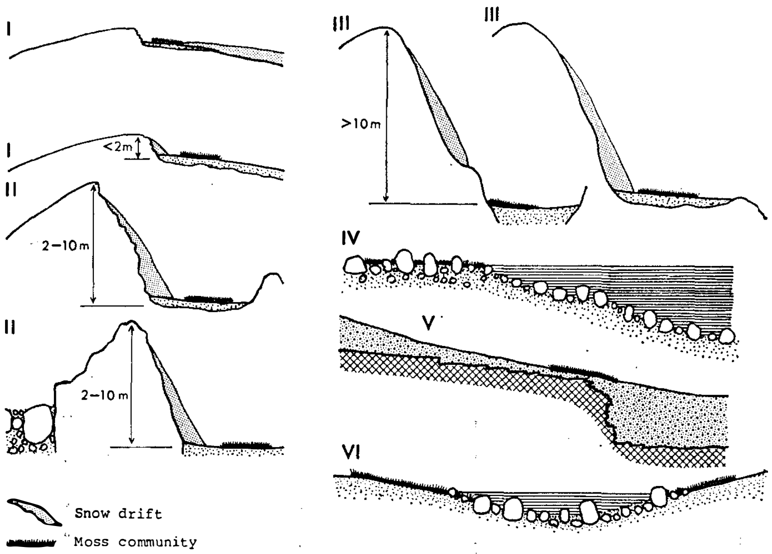

Fig. 7. Habitat types classified by the pattern of water supply.
I Small snow drift type. *IV Lake-shore type.*
II Medium snow drift type. *V Seepage type.*
III Large snow drift type. *VI Stream type.*

or in small hollows. As its source of water is a small snow drift, occasionally all the water evaporates before the end of the growing period of the mosses.

Habitat type II. Medium snow drift type

In the habitat of this type, the water is supplied from medium-sized drifts which are formed on the leeward side of slightly higher ridges or spurs. These drifts do not melt completely during the summer. However, such places are apt to be exposed to intermittent aridity, for the amount of melt water occasionally diminishes in the latter half of summer or water is supplied only during the limited period when the temperature is high in the daytime.

Habitat type III. Large snow drift type

This habitat type is developed below the large snow drifts which are formed on the leeward slope of a large barrier more than 10 m in height. Usually the drift has become snow ice, namely, permanent ice. In summer, the habitat in a sunny place is supplied with much melt water.

Habitat type IV. Lake-shore type

The habitat of this type is situated on the shore of a lake or pond and supplied with the water percolating from the body of water.

Habitat type V. Seepage type

The habitat of this type is supplied with the water that seeped out from a fault or a joint, or else, seeped out owing to the existence of an impermeable stratum.

Habitat type VI. Stream type

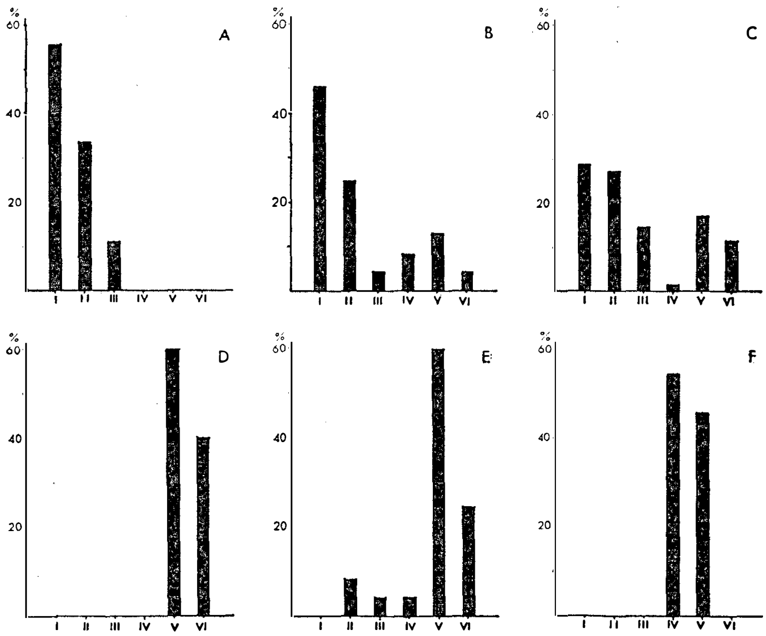

Fig. 8. Occurrence frequency of moss sociations in each habitat type. I–VI mean habitat types respectively.

A Ceratodon purpureus *Sociation*
B Bryum inconnexum *Sociation*
C Ceratodon purpureus-Bryum inconnexum *Sociation*
D Bryum argenteum-Bryum inconnexum *Sociation*
E Bryum antarcticum-Bryum inconnexum *Sociation*
F Desmatodon *sp.*-Bryum inconnexum *Sociation*

In this type, the water is constantly supplied from flowing streams throughout the growing season.

As is seen in Fig. 8, *Bryum inconnexum* Sociation and *Ceratodon purpureus-Bryum inconnexum* Sociation are found widely in various habitat types. In contrast, the distribution of other sociations are closely related to the pattern of water supply in their habitats. For instance, the *Ceratodon purpureus* Sociation is distributed more frequently in rather dry habitats of drift types. In contrast to this, *Bryum argenteum-Bryum inconnexum* Sociation, *Bryum antarcticum-Bryum inconnexum* Sociation, and *Desmatodon* sp.-*Bryum inconnexum* Sociation are developed mainly in the habitats with a constant supply of water.

Such analyses suggest that the principal mosses seem to have their own tolerance range in relation to water condition. Actually, GREENE *et al.* (1967) reported that in South Victoria Land and Ross Island *Bryum argenteum* grew on the most moist habitats, while *Bryum antarcticum* was mainly found on the drier part of the water channel; so that there was a difference between the reactions of the two mosses to water conditions.

In order to confirm such fact, the author investigated the precise occurrences of the mosses on the sandy bank of a brook where water condition changed gradually from the center of stream to the upper part of bank (*cf.* Fig. 9). The investigation sites were located at the downstream of Yukidori Valley in Langhovde (*cf.* Fig. 3).

Fig. 9. A moss community developed along melt stream in Yukidori Valley of Langhovde.

The result is indicated in Fig. 10. Two mosses, *i. e., Bryum inconnexum* and *Ceratodon purpureus* are growing there. In both places, *Bryum inconnexum* occupies mainly wet habitats moistened by the flowing water, while *Ceratodon purpureus* grows better in the more desiccated habitats on the upper part of bank. In other words, it can be said that each has its own habitat along the gradient of water availability

In addition, a similar phenomenon for these two species was observed in Yatude Valley of Langhovde and Akarui Point. These facts suggest that *Ceratodon purpureus* is more xerophilous than *Bryum inconnexum.*

4. 2. Relationship between terrestrial communities and bird nests

It was also reported in the Antarctic that the excrement of birds played an important role in determining the occurrence of particular mosses and lichens, and in the origin of so-called "ornithocoplophilic" communities (RUDOLPH, 1963; FOLLMANN, 1965; LAMB, 1970).

In the ice-free areas near Syowa Station, MATSUDA (1964b, 1968) reported that a large moss community at Naka-no-tani Valley in Langhovde was maintained by the nutrients from the excrement of the snow petrel which nested in the debris near here. Among the six moss sociations mentioned above, it seems that the most ornithocoplo-

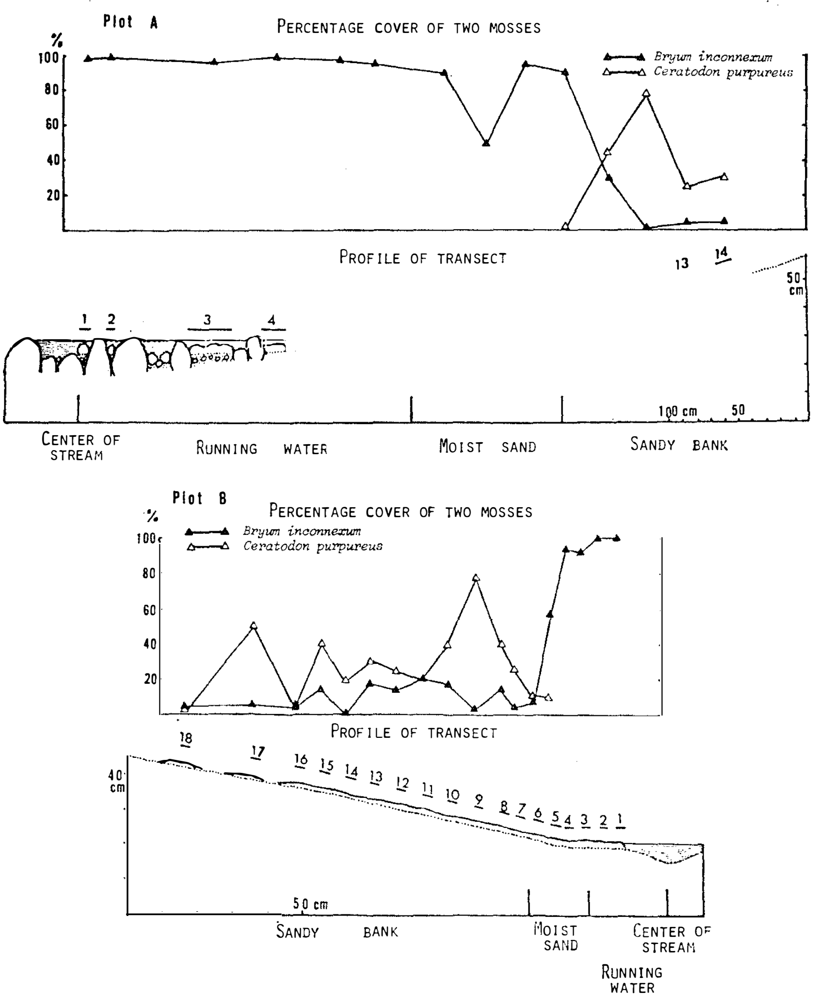

Fig. 10. Distribution of two mosses in relation to microtopography of a channel bank in Yukidori Valley, Langhovde.

philic one is the *Bryum argenteum-Bryum inconnexum* Sociation. It also seems that the *Bryum inconnexum* Sociation and the *Bryum antarcticum-Bryum inconnexum* Sociation have some relation to the excrement of birds.

A report has not been made so far on the lichen communities in the ice-free areas near Syowa Station. Actually, the author did not encounter outstanding examples in his field surveys in the southern part of Langhovde and Akarui Point. However, in the central region of Skarvsnes lichens were found mainly near the nests of birds such as snow petrel and Wilson's storm-petrel. Moreover, the lichen communities near nests were considerably different in their coverage and species composition from the lichen communities which were grown without a direct relationship to bird nests.

The lichen communities of Skarvsnes were classified into three community types on a basis of species composition, as shown in Table 9. The locations of the quadrats of these community types are shown in Fig. 12. It seems that each community type has its

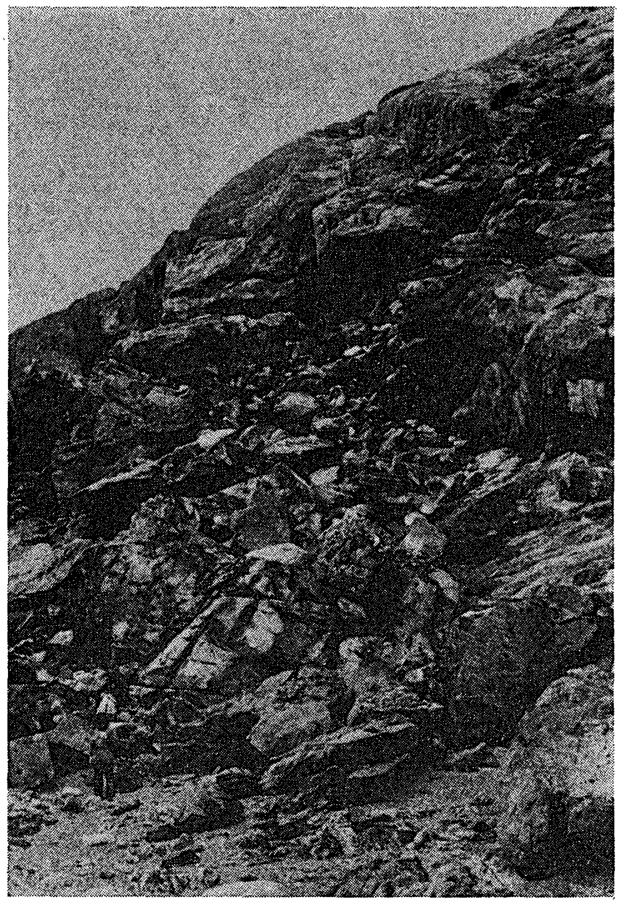

Fig. 11. Debris containing nests of snow petrel where an ornithocoplophilic lichen community is developed.

own definite relationship to the excrement of birds.

On the rock crevices in the waterway of the leeward slope where no bird nests were seen, there occurred a *Buellia frigida-Rhizocarpon flavum* Community which was composed of only a few lichens such as *Buellia frigida, Lecidea* sp. 1 (syn. *Catillaria cremea*), and *Omphalodiscus antarcticus*. *Rhizocarpon flavum* seemed also to have a tendency to grow frequently in such community.

On the other hand, on the rocks and rock faces located below bird nests where the melt water flowed down after dissolving chemicals in the excrement of birds, there appeared *Caloplaca elegans* var. *pulvinata, Physcia caesia, Protoblastenia citrina, Xanthoria mawsonii, Acrospora gwynii, Lecanora expectans, L. exsulans,* and *Omphalodiscus decussatus,* in addition to the dominant presence of *Buellia frigida, Lecidea* sp. 1, and *Omphalodiscus antarcticus.* The sandy places near nests were often colonized by cushions of *Bryum inconnexum, B. argenteum,* and *B. antarcticum.*

The lichen community mentioned above was named after the dominant occurrence of the deep orange-color lichen, *Caloplaca elegans* var. *pulvinata* which marks the pres-

Table 9. Table showing the species composition of ornithocoplophilic lichen community and

Communities	Non-ornithocoplophilic community *Buellia frigida-Rhizocarpon flavum* Comm.															Transitional Community									
Quadrat No.	41A	43	44	45	46	47	48	49	51	53	72	92	65	66	Presence	5	8	12	23	50	54	55	73	89	Presence
Altitude (m)	140	210	265	285	285	205	285	320	345	350	100	210	70	120		15	10	80	100	330	330	285	110	140	
Exposition	-	S 59 W	N 61 W	S 57 W	S	S 78 W	S 58 W	S 25 W	S 38 W	S 88 W	N 55 W	N 81 W	S 55 W	S 19 W		N 71 W	S 78 W	N 78 W	N 40 W	S 55 W	N 85 W	S 35 W	S 52 W	N 77 W	
Number of species	4	4	5	4	5	3	3	3	4	4	3	3	4	3		4	3	5	5	5	6	5	4	5	
Buellia frigida	2	1	2	3	2	2	3	2	3	2	1	1	1	1	V	2	+	2	3	2	3	3	1	1	V
Lecidea sp. 1	+	1	1	1	1	1	2	1	1	1	+	+	1	+	V	+	+	1	1	.	+	+	+	+	V
Omphalodiscus antarcticus	+	+	+	1	1	2	1	.	+	.	2	1	+	1	V	.	.	.	1	.	2	2	1	.	III
Alectoria minuscula	.	.	r	.	3	.	.	.	+	2	.	.	.	.	II	.	.	.	.	3	+	1	.	.	II
Rhizocarpon flavum	+	+	r	+	+	.	.	+	.	+	.	.	+	·	III	.	.	.	.	+	+	.	.	.	II
Caloplaca elegans var. *pulvinata*																1	+	3	3	.	.	.	.	1	III
Physcia caesia																.	.	1	.	.	.	.	+	.	II
Lecidea sp. 2																.	.	.	.	.	+	+	.	.	II
Protoblastenia citrina																.	.	.	+	.	.	.	.	+	II
Xanthoria mawsonii																+	.	+	.	.	.	.	.	.	II
Acrospora gwynii																.	.	.	.	+	.	.	.	.	I
Lecanora expectans																.	.	.	.	.	.	.	.	+	I
Omphalodiscus decussatus																.	.	.	.	1	.	.	.	.	I
Rinodina archaeoides																									
Lecanora exsulans																									
Lecidea sp. 3																									
Imperfect lichen																									
Lecidea sp. 4																									
Usnea sulphurea																									
Acrospora sp.																									
Candelaria antarctica																									
Physcia dubia																									
Lecidea sp. 5																									
Mosses																									
Bryum inconnexum																									
Bryum argenteum																									
Bryum antarcticum																									
Ceratodon purpureus																									
Grimmia lawiana																									

ence of this community (*cf.* Fig. 13).

Though not frequent, there was recognized a transitional community type which contained some members of the nitrophilous community. In many cases, they were found near abandoned bird nests or perching places of sea birds. It is likely that these are not provided with sufficient organic nutrients from the excrement for all members of the richer community.

Among the lichens that occur most commonly near the nests, *Caloplaca elegans* var. *pulvinata, Xanthoria mawsonii* and *Physcia caesia* have been said to be the typical ornithocoplophilic lichens in each place that they have been reported from in the *non-ornithocoplophilic one in the central region of Skarvsnes, Antarctica.*

Ornithocoplophilic community *Caloplaca elegans* var. *pulvinata* Comm.																									
22	24	25	26	28	30	32	33	34	35	37	56	57	58	64	68	69	70	74	75	76	77	78	82	88	Presence
100	130	120	120	125	110	110	100	120	145	55	285	265	245	100	110	90	70	100	100	100	115	90	120	110	
N 27 W	S 45 W	S 35 E	S 31 E	S 33 E	S 40 W	N 57 W	N 87 W	N 31 W	S 32 E	N 5 E	N 61 W	S 89 W	S 82 W	N 59 W	N 5 W	N 40 W	N 35 W	N 30 W	N 65 W	N 63 W	N 85 W	S 70 W	N 5 W	S 80 W	
12	11	11	15	13	18	18	16	14	11	12	9	17	14	15	13	9	11	10	11	8	20	11	11	11	
4	5	4	4	4	3	3	4	5	4	5	4	5	5	5	5	4	4	4	4	2	5	5	4	3	V
2	2	1	2	1	2	2	2	2	1	2	1	2	1	2	2	3	2	1	1	1	2	1	1	2	V
1	3	+	1	2	1	3	2	2	+	+	2	2	1	+	2	+	1	1	1	1	2	1	.	1	V
+	2	+	2	1	2	+	+	+	2	.	1	4	1	.	2	.	.	1	+	1	1	.	.	.	IV
														+											I
4	2	2	4	3	3	4	2	3	3	3	3	.	1	3	3	1	2	3	3	4	4	3	4	2	V
1	1	1	+	1	+	2	.	.	+	+	.	+	.	+	+	.	+	+	+	1	2	1	1	1	V
.	.	.	+	1	+	+	+	+	+	+	1	+	+	+	1	+	.	+	.	.	+	+	+	+	IV
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.	.	1	2	+	+	+	1	.	.	.	.	1	.	1	+	.	1	.	.	.	+	.	.	.	III
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Antarctic (SCHOFIELD and AHMADJIAN, 1972). This is also true in the ice-free areas near Syowa Station. From the author's investigations in Langhovde and Akarui Point, however, it seems that the position of some other lichens was not so clearly related to bird nests. Skarvsnes is the biggest ice-free area in the vicinity of Syowa Station, being 63 km² in area. The central region is considered as rather arid because it lacks many large-scale drifts; moreover, it is far from the edge of the continental ice-sheet. It seems that this peculiarity in the environment enables the development of ornithocoplophilic lichen communities which are rarely seen in other ice-free areas.

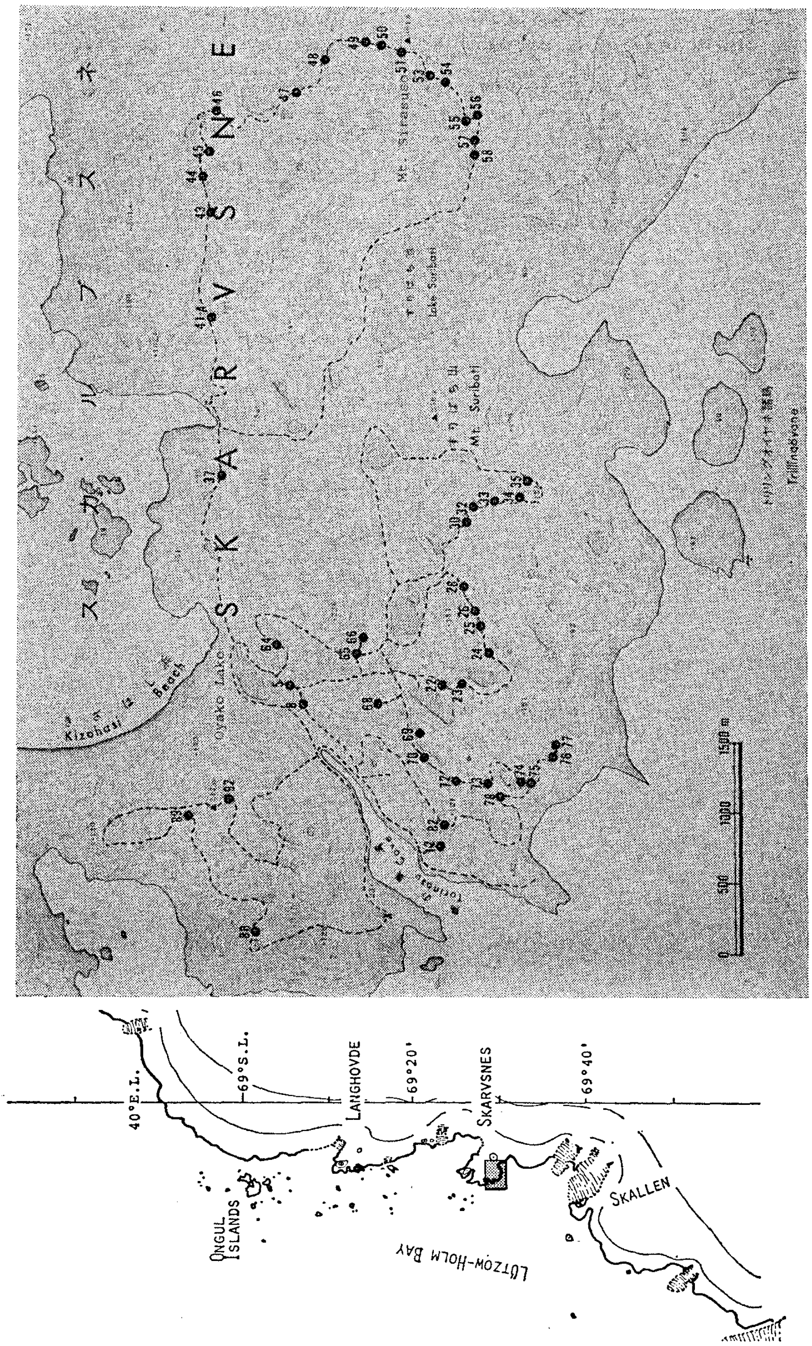

Fig. 12. Distribution map of lichen communities in the central region of Skarvsnes. The numbers in the map are the quadrat numbers.

4. 3. Direction preference of moss and lichen communities

The reports of MATSUDA (1963, 1968), FUKUSHIMA (1968), LINDSAY and BROOK (1971), and KOBAYASHI (1974) indicate that the wind plays an important role in the small-scale distribution of moss and lichen communities within an ice-free area.

The directions of the habitats where the moss and lichen communities were developed were classified as having sixteen directions. Generally speaking, the moss communi-

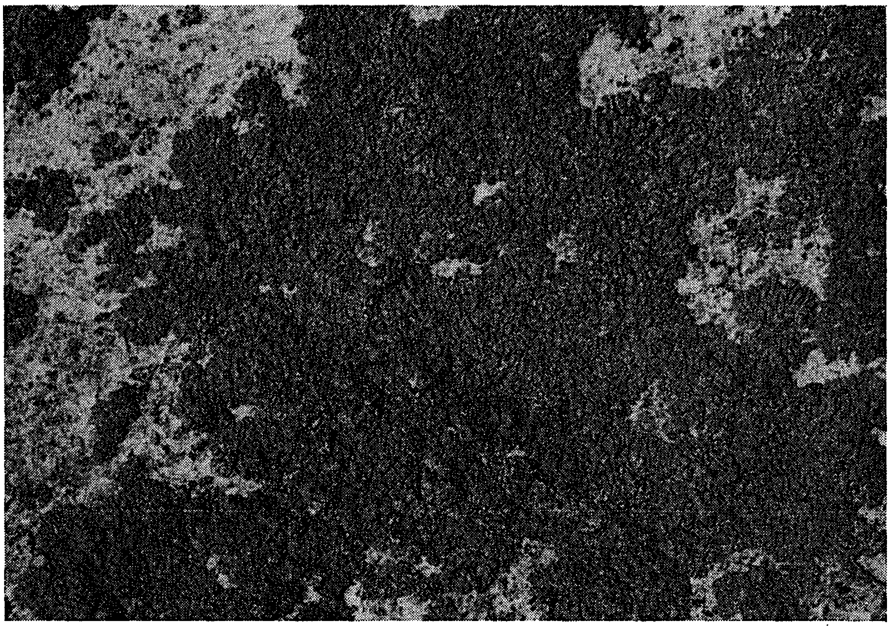

Fig. 13. One of the typical nitrophilous lichens, Caloplaca elegans *var.* pulvinata.

ties almost always develop in the leeward habitats, because the snow drifts and sands which are essential for growth of mosses mostly occur on the leeward side of such barriers as a ridge, spur, or large rock. Therefore, the communities which are supplied with water from drifts would be more concentrated on the leeward side and, on the other hand, the habitat exposure of the communities which are supplied with water from seepages and streams would be somewhat indefinite. This conjecture was investigated on the basis of the slope-aspect of eighty five moss communities located in Langhovde.

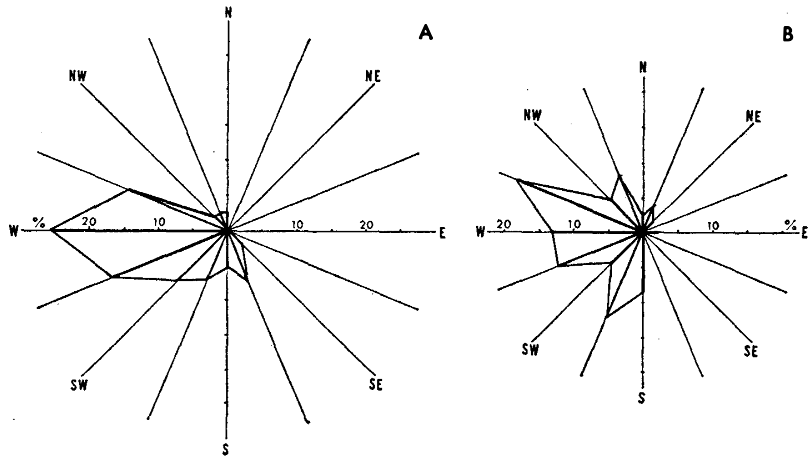

Fig. 14. Direction preference of moss communities in each different habitat type.
A. Habitat types I, II, III supplied intermittently with water from drifts.
B. Habitat types IV, V, VI supplied constantly with water.

The result is shown in Fig. 14. The communities which are supplied with water from drifts are mostly concentrated in the habitats facing nearly westward. But, the communities which occur near seepages or streams are not distributed in any definite direction but are scattered in various directions, occurring even in habitats facing east which must be the windward side.

Without regard to habitat types, the exposures of moss and lichen communities in each ice-free area were classified on a basis of sixteen directions. From the data seen in Fig. 15, it can be said that the communities are generally found in habitats facing from

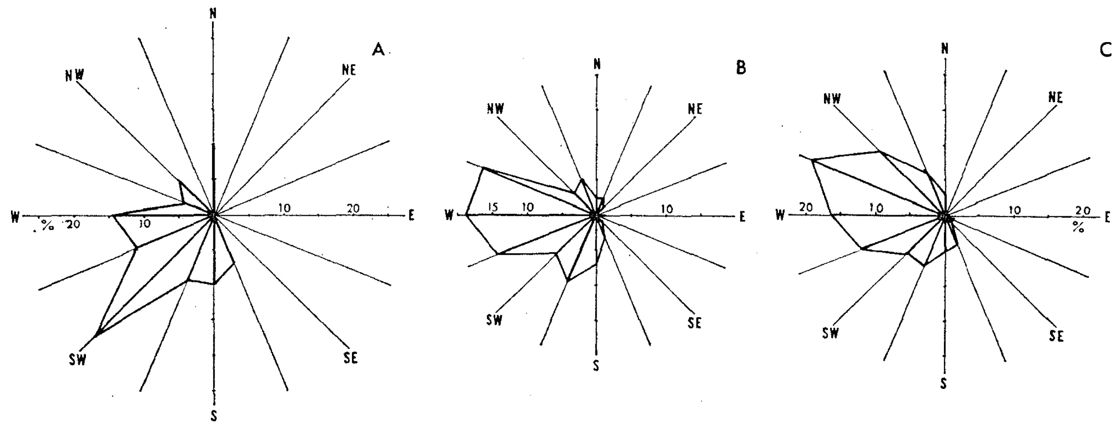

Fig. 15. Direction preference of moss and lichen communities in each ice-free area.
A. 41 quadrats of moss community in East and West Ongul Islands.
B. 85 quadrats of moss community in the southern region of Langhovde.
C. 91 quadrats of lichen and moss communities in the central region of Skarvsnes.

northwest to southwest. If the data are examined more precisely, it is clear that the more frequent direction of their habitats differs in each ice-free area. For instance, in East and West Ongul Islands the moss communities are mostly growing in habitats facing the southwest; in the southern region of Langhovde, west-northwest to west-southwest; and in the central region of Skarvsnes, west-northwest to west; each shifting a little toward north.

This phenomenon seems to have a close relationship to the flow lines of katabatic winds which are said to change along coastline (MORITA, 1973). Judging from the most frequent exposure of the moss and lichen communities in each ice-free area, it is assumed that the orientation of the prevailing winds changes from northeast to east and east-southeast toward the inside of Lützow-Holm Bay along the east coast of the bay. This assumption seems to correlate well with the flow lines of the prevailing winds which are drawn by AGETA (1971) on the basis of the orientations of sastrugis and pitted patterns.

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