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ECOLOGICAL MONITORING OF MOSS AND LICHEN VEGETATION IN THE SYOWA STATION AREA, ANTARCTICA

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Abstract: The ecological monitoring of moss and lichen vegetation was carried out in the Yukidori Valley, Langhovde, East Antarctica. The valley area was approved as a Site of Special Scientific Interest (SSSI) in 1987. In addition to the two permanent photo points for lichens set up in 1975, all lichen species in 23 quadrats and moss species in 24 quadrats were determined and ecologically described. No increase of lichen growth was detected over periods of 5 and even 14 years, and change in the moss vegetation is hardly detectable after three years. In the moss vegetation, the relations between the surface condition, epiphytic organisms like cyanobacteria and imperfect lichens, or sand cover are discussed.

The distribution pattern of mosses and lichens in the Langhovde region were shown. Vegetation is very sparse or absent in the north and northern-east part of the ice-free area. The pattern is probably influenced by wind-blown salt spray.

The current abundance and spatial distribution of key species and environmental factors provides essential baseline data for long-term monitoring of local and global impacts on the non-marine biota of the Langhovde regions.

1. Introduction

It is well known that cryptogamic land plants are effective in assessment of environmental changes, because these plants are sensitive indicators of atmospheric and aquatic pollutants (BATES and FARMER, 1992). In the harsh environment of the Antarctic, fundamental ecosystem processes such as community size, growth rate, species composition and vegetation cover are closely affected by changes of temperature, water availability, substrate stability, nutrient conditions, etc.

Environmental monitoring in the Syowa Station (69°00′S, 39°30′E) area, East Antarctica was first carried out by the Japanese Antarctic Research Expedition (JARE-15) in 1974. Research on terrestrial biology and geochemistry had been studied under the background of increasing human impacts on Antarctic natural environments. Botanists have carried out floral and vegetational studies around the Syowa Station area and shown that the vegetation is closely related to water conditions such as streams, ponds and lakes derived from snow drifts or the ice plateau, and rich nutrients leached from bird nests (NAKANISHI, 1977; SHIMIZU, 1977; KANDA, 1981, 1987a). A comprehensive ecological study of the cryptogamic

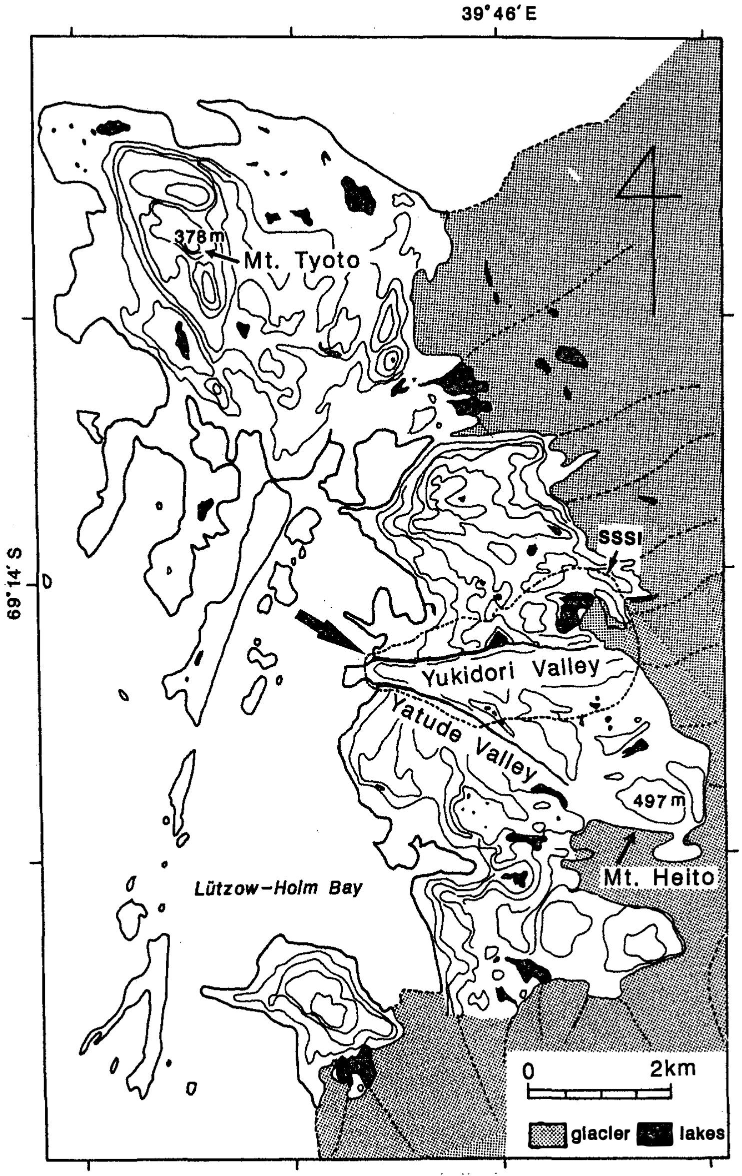

Fig. 1. The topographic and geographic map of the Langhovde region. Arrows point to the mouth of the Yukidori Valley, the area of SSSI and higher mountains. Contour interval is 50 m.

vegetation composed of mosses, lichens and fresh water algae has also been carried out. Some biologists also considered it necessary to monitor the changes of growth pattern of organisms and the environmental factors.

In 1984, the Yukidori Valley area, Langhovde was selected as the site for the ecological monitoring with special emphasis on mosses and lichens. The valley area was approved in 1987 as the Site of Special Scientific Interest (SSSI) (Figs. 1 and 2). The long-term monitoring study will contribute to the international program, "Biological Investigation of Terrestrial Antarctic Systems (BIOTAS)" (SMITH and WYNN-WILLIAMS, 1987), which was supported in 1986 by the Scientific Committee for Antarctic Research (SCAR).

The aim of long-term monitoring studies in the Yukidori Valley area is to assess the temporal and spatial changes of mosses and lichens in relation to the environmental changes. We discuss here about the ecological monitoring which has so far been carried out at the Syowa Station area and its significance.

2. Sites and Methods

The Yukidori Valley (69°14′30″S, 39°46′00″E) is well known as an ice-free area having the most prominent vegetation in the Syowa Station area (KANDA, 1987b; KANDA *et al.*, 1990; INOUE, 1991). All seven species of mosses and about 40 of the 57 species of lichens recorded from the Syowa Station area also occur within the Yukidori Valley (unpublished data). A series of approximately 30×30 cm lichen quadrats for long-term monitoring were established and the substrates, colony size, slope aspects and slope degree were described at 23 sites along the valley in 1986 (Fig. 2, Table 1: a). The vegetational changes in these quadrats were taken by photographs after five years. Otherwise, we reexamined the growth rate after fourteen years since the initial establishment by the late Dr. NAKANISHI in 1975 of two long-term observation points of *Physcia caesia,* and *Buellia frigida, Pseudephebe minuscula* and *Umbilicaria decussata* (Fig. 3: a, b).

In moss vegetation, 24 monitoring sites (30×30 cm) were established along

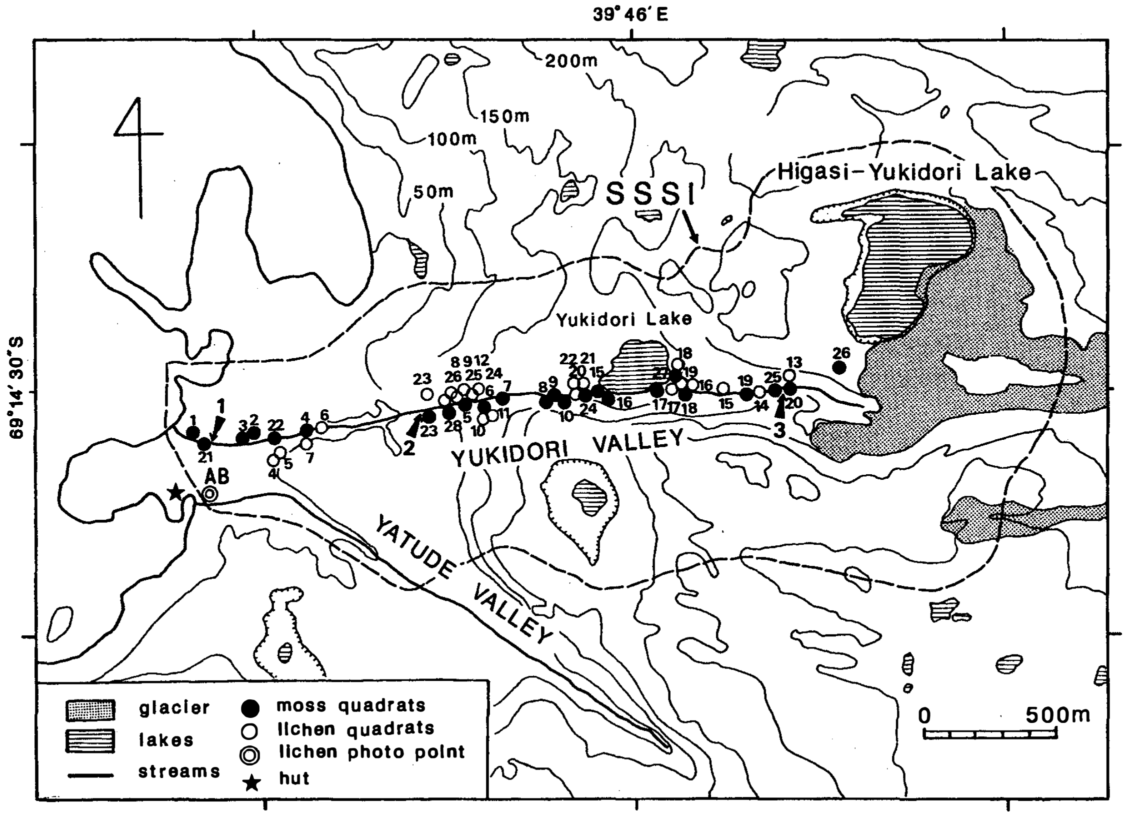

Fig. 2. The SSSI and sites selected for long-term monitoring. Boundary of SSSI is indicated by dashed line (----). Arrows show sites for the microclimate observations (1–3). 1; Microclimate station at the lower course of the stream, 2; at the middle course, 3; at the upper course.

*Table 1. Outline of the moss and lichen vegetation in the quadrats for long-term monitoring. In descending scale, the quadrat numbers are arranged from the month of the Yukidori Valley to the polar ice-cap. * All* Usnea sphacelata *in the quadrat No. 25 has been harvested to study recolonization of the denuded surface. – no record.*

a. Lichen vegetation

Quadrat number	Predominant species	Substrates	Colony size (cm)	Slope aspect	Slope degree (°)
4	*Lecidea andersonii*	gravel	45×76	N30W	14
	Rinodina olivaceobrunnea				
5	*Candellariella antarctica*	gravel	45×50	N55W	18
	Lecidea andersonii				
7	*Buellia frigida*	boulder	15×20	–	0
6	*Buellia frigida*	boulder	25×35	–	0
	Umbilicaria aprina				
23	*Lecidella siplei*	gravel	25×30	S85W	18
26	*Pseudephebe pubescens*	boulder	24×15	S50W	30
	Usnea sphacelata				
8	*Buellia frigida*	gravel	28×25	S80W	12
	Usnea sphacelata				
9	*Physcia caesia*	boulder	27×25	–	0
	Umbilicaria aprina				
*25	*Usnea sphacelata*	bed rock	221×13	S50W	30
12	*Buellia frigida*	bed rock	26×25	S82W	51
	Umbilicaria aprina				
24	*Pseudephebe pubescens*	boulder	23×22	S50W	30
	Usnea sphacelata				
10	*Umbilicaria aprina*	bed rock	25×23	S77W	22
	Xanthoria elegans				
11	*Xanthoria elegans*	bed rock	251 long	S77W	22
22	*Physcia caesia*	boulder	15×18	S61W	24
	Rhizoplaca melanophthalma				
21	*Buellia frigida*	bed rock	17×18	S43W	12
20	*Pseudephebe pubescens*	gravel	46×15	S87E	5
17	*Buellia frigida*	bed rock	45×30	N85W	17
18	*Buellia subfrigida*	bed rock	25×47	S80W	17
	Rhizocarpon flavum				
19	*Umbilicaria decussata*	bed rock	30×24	S75W	20
16	*Buellia frigida*	boulder	20×35	–	0
15	*Umbilicaria decussata*	bed rock	40×150	N89W	46
	Usnea sphacelata				
14	*Buellia subfrigida*	boulder	25×28	N75W	20
	Rhizocarpon flavum				
13	*Buellia subfrigida*	boulder	15×18	–	0
	Rhizocarpon flavum				
A	*Physcia caesia*	bed rock	–	–	–
B	*Pseudephebe minuscula*	bed rock	–	–	–
	Buellia frigida				
	Umbilicaria decussata				

Table 1. (Continued).

b. Moss vegetation

Quadrat number	Predominant species	Yearly mean water content (%)	Maximum turf depth (cm)
1	*Bryum pseudotriquetrum*	99.8	1.2
21	*Bruym pseudotriquetrum*	155.6	2.1
	Ceratodon purpureus		
3	*Bryum argenteum*	12.3	1.3
	Bryum pseudotriquetrum		
2	*Grimmia lawiana*	27.2	1.4
22	*Bryum pseudotriquetrum*	289.9	3.2
	Ceratodon purpureus		
4	*Ceratodon purpureus*	13.2	1.3
23	*Bryum pseudotriquetrum*	111.3	2.4
	Ceratodon purpureus		
28	*Ceratodon purpureus*	32.6	2.6
5	*Bryum pseudotriquetrum*	50.1	3.4
	Ceratodon purpureus		
6	*Ceratodon purpureus*	3.6	1.8
7	*Bryum pseudotriquetrum*	83.0	2.6
8	*Bryum amblyodon*	138.4	1.9
9	*Bryum amblyodon*		
10	*Bryum amblyodon*	73.5	1.6
24	*Bryum amblyodon*	80.4	3.0
15	*Bryum pseudotriquetrum*	25.3	1.4
	Pottia austrogeorgica		
16	*Bryum argenteum*	10.3	1.0
	Bryum pseudotriquetrum		
17	*Bryum amblyodon*	276.8	2.2
	Bryum pseudotriquetrum		
27	*Ceratodon purpureus*	41.7	1.5
	Grimmia lawiana		
18	*Ceratodon purpureus*	99.3	2.0
19	*Bryum amblyodon*	462.5	3.7
25	*Bryum pseudotriquetrum*	133.6	1.5
20	*Bryum pseudotriquetrum*	138.7	2.0
26	*Grimmia lawiana*	31.6	1.2
	Pottia austrogeorgica		

the valley in the summer season of 1988 (Fig. 2, Table 1:b). The vegetational and environmental changes of pure stands of moss communities such as *Bryum amblyodon, B. argenteum, B. pseudotriquetrum, Ceratodon purpureus, Grimmia lawiana, Pottia austrogeorgica* and *P. heimii* and of mixed communities were analyzed by photographs taken after three years since the establishment of these quadrats. Besides community size, growth rate, species composition, coverage on vegetation and epiphytic organisms, some environmental factors such as degree of water contents and accumulation of snow drifts were measured at each fixed point. Water content of mosses was seasonally measured and calculated as a

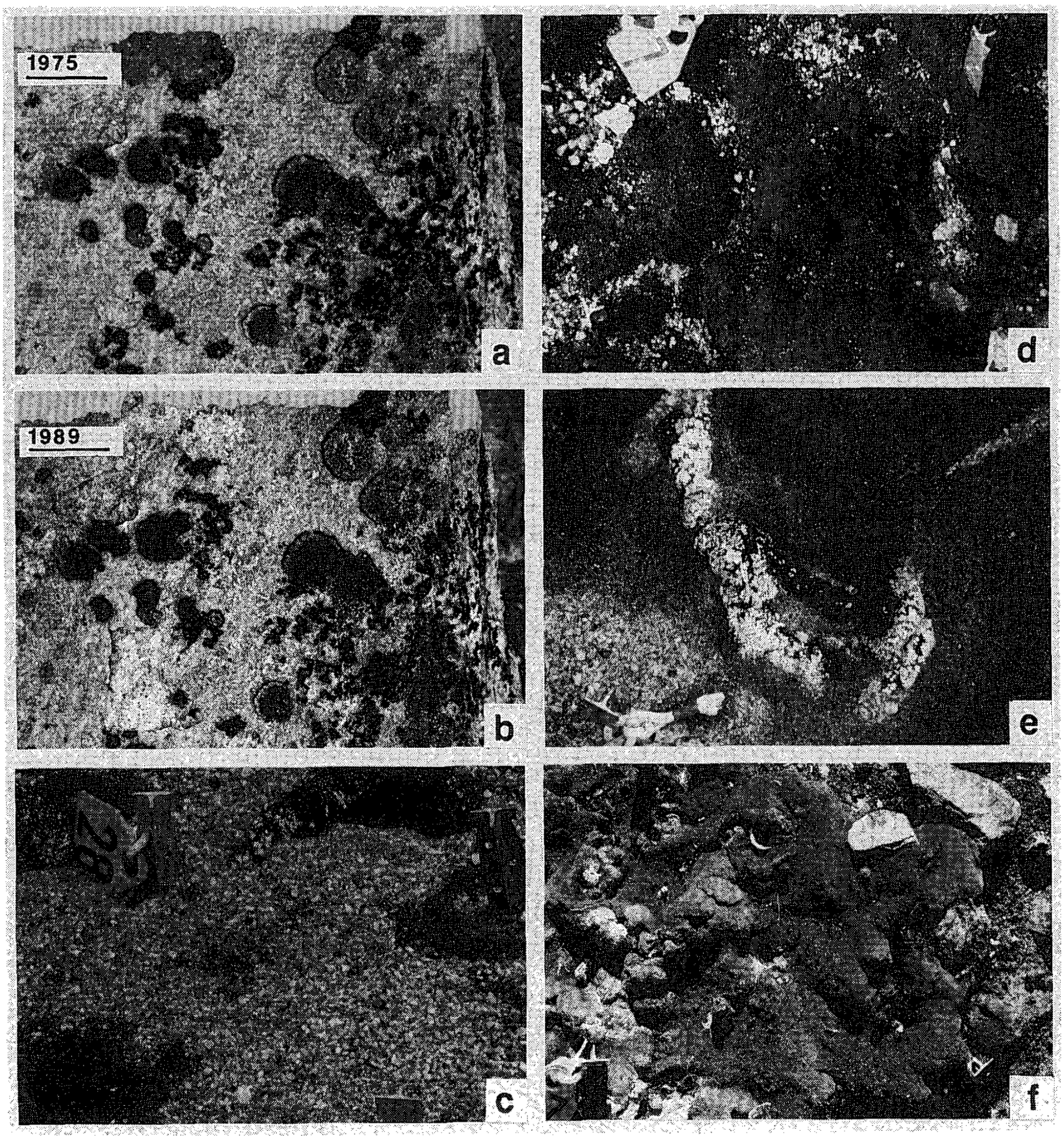

Fig. 3. Vegetational changes in the Yukidori Valley, Langhovde. a, b: change of the mixed colonies of Buellia frigida, Pseudephebe minuscula *and* Umbilicaria decussata *over 14 years; In each photograph, the bar shows 40 mm; c: sand cover on the vegetation surface of* Ceratodon purpureus*; d: cyanobacteria on the vegetation of* Bryum pseudotriquetrum*; e: imperfect lichen growing on the exposed moss surface free from sand cover; f: rapid change on the vegetation of* B. pseudotriquetrum *from disturbance by seabirds.*

percentage of the dry weight.

The moss and lichen distribution in the Langhovde region was shown using a grid of 500×500 m (Fig. 4). Furthermore, the SSSI area of appropriately 3 km along the Yukidori Valley was sectioned into 50×50 m areas and points where mosses were located were confirmed for every species.

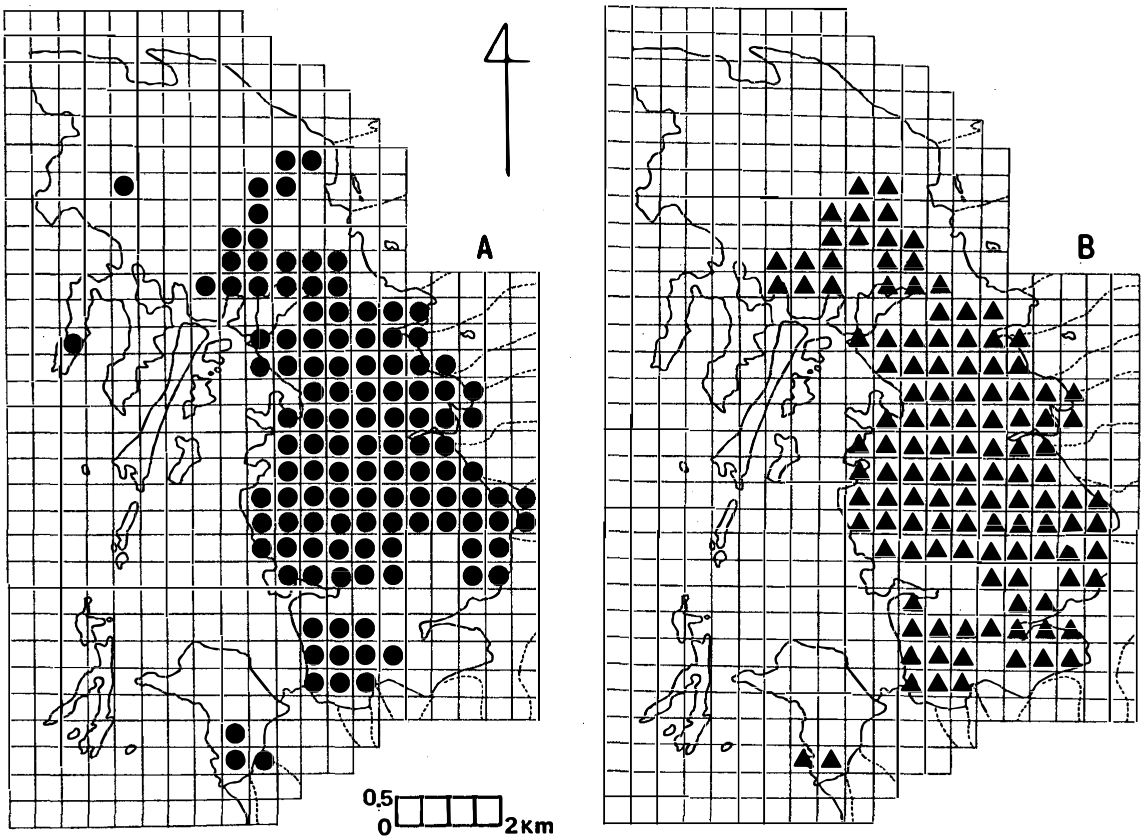

Fig. 4. Distribution map of the vegetation in 500 m grid squares across the Langhovde region. A. mosses; B. lichens.

3. Results and Discussion

No increase of the dimensional growth of crustose and foliose lichen communities in the Yukidori Valley has been detected at all by photographs taken after five years. Similarly, no growth of lichen colonies composed of the mixed colonies with *Pseudephebe minuscula, Umbilicaria decussata* and *Buellia frigida* has been detected even after fourteen years (Fig. 3: a, b). In the Vestfold Hills, continental Antarctica, individual thalli of *Buellia frigida* at the permanent photo point show no detectable radial growth after two years (PICKARD, 1986). Measurements of radial increase of *Buellia frigida* on Mt. Falconer, lower Taylor Valley in the McMurdo Dry Valley (78°S) show a growth rate of approximately 1 mm per 100 years (personal communication with Dr. R. SEPPELT). On Signy Island, maritime Antarctica, growth of lichen colonies may proceed rapidly when the substrate conditions are more favorable. SMITH (1990) indicated percentage growth increment 41% per year in colonizing thalli of *Umbilicaria antarctica* (over 15 years); 23% in mature circular thalli of *Buellia latemarginata* (over 14 years); 13–17% in mature irregular thalli of *Caloplaca* spp. (over 11 years) and *Xanthoria elegans* (over 4 years) and 0.5-0.8% in *Rhizocarpon geographicum* (over 13 years). This seems to show that the change in size and abundance of lichen thalli is considerably different in climatically diverse zones, and also varies very much according to species, thallus age and habitat characteristics. In this study, we determined all lichen specimens occurring in the quadrats (Table 1: a). These data together with photographs of selected thalli will become significant for the long-term monitoring studies.

Changes in the moss vegetation is hardly detectable after three years. It is not easy to assess the changes of moss colonies composed of a bundle of shoots which are different from lichen thalli with two dimensional growth. However, the degree of coverage by sand and epiphytic organisms like cyanobacteria and imperfect lichens on the moss surface frequently changed throughout the year and they will have significant effects on ecological processes. The moss quadrats No. 6 and 28 were selected as the long-term monitoring sites for dry habitats. The vegetation surface in depressions is frequently covered by sand and silty soil brought by local wind (Fig. 3: c). The growth on the vegetation covered by sand will be accelerated due to good water preservation. In contrast, the exposed vegetation is subject to potential damage by wind borne abrasives as well as desiccation during the summer season.

During the development of moss vegetation, it is important to monitor invasive organisms and physical conditions such as water content, sand cover, wind, etc. Especially, as to the water content, RUSSELL (1987) suggested that bryophyte production in Marion Island was positively correlated with field water content and GIMINGHAM and SMITH (1971) interpreted the relationships between growth form of moss and water balance in Signy Island. In continental Antarctica, KANDA (1986) reported the seasonal changes in the water content in moss communities and SMITH (1988) indicated the relationships between growth form and the water loss and uptake of mosses and lichens.

At the Yukidori Valley area, the vegetation growing at wet sites along the stream is closely associated with cyanobacteria and other mosses. The moss quadrats No. 7 and 19 are of more luxuriant vegatation within the fixed quadrats, and have deeper turf of about 2.6 cm and 3.7 cm and an adjacent water source is derived from streams, so that yearly mean water content was 83.0 % and 462.5 %, respectively (Table 1). With more favorable water conditions, colonies of cyanobacteria, mainly *Nostoc* sp. and *Phormidium* sp., appear on the moss vegetation. Growth of cyanobacteria (Fig. 3: d) is considered to proceed more rapidly than that of lichens and mosses. Imperfect lichens growing on the exposed moss surface free from sand cover will considerably affect the future growth of the moss vegetation (the moss quadrats No. 5, Fig. 3: c and No. 20). Water content of the moss is also an important factor in dertermining surface microtopography and the distribution and growth of epiphytic algae and crustose lichens.

Sea birds making nests on the ice-free areas may also have considerable influence on the vegetation. At the moss quadrat No. 17, which was beside a lake where Antarctic skuas (*Catharacta maccormicki*) had made nests and spread bones and feathers of snow petrels (*Pagodroma nivea*), there is a rich nutrient resource from bird droppings and also favorable water conditions. Here the vegetation was better than at other sites, with 267.8 % in yearly mean water content and 2.2 cm in turf depth. However, the process of vegetational change couldn't be followed owing to rapid change from disturbance by seabirds, such as droppings, trampling and pecking (Fig. 3: f). It is also important to know when, how and why the changes in vegetational or environmental factors occur. Therefore, it should be observed with for intervals than five years in mosses and ten years in lichens. Yearly measurement of environmental and vegetation factors over shorter intervals than five years allow us to predict when and why the vegetation changed. We determined all moss specimens occurring in the quadrats and measured the yearly mean water contents and the turf depth (Table 1: b).

Temperature and photosynthetically active radiation significantly affect the development of moss vegetation. Year-round records of environmental parameters such as air and moss temperature, wind speed and direction, relative humidity, light intensity from appropriate sites are needed in order to predict changes attributable to micro and macroclimatic alterations. The results of the microclimate study at the Yukidori Valley have been reported elsewhere (Ohtani *et al.*, 1990, 1991a, b, 1992; Ino, 1990, 1992). It is widely acknowlegded that geographical distribution of mosses and lichens is governed by the water requirements of individual species in relation to their community structures. The water contents of moss vegetation along the stream increased towards the upper end of the course and decreased towards the lower end of the course, though the species and topographic features of moss vegetation varied. The water content increases in summer and gradually decreases towards autumn, and is at its minimum in the winter season. But water content fluctuations depend on annual climatic conditions, and possible regional climate change in Antarctica.

The distributional pattern of mosses and lichens in the Langhovde region were shown in Fig. 4. Mosses and lichens were rare or absent in northern and northern-east part of the ice-free area and the western part with seaward peninsulas and small islands. This is probably caused by sparse accumulation of soil and sea salt deposition. Inoue (1991) suggested that one of the main environmental factors affecting the lichen distribution was the wind-blown salt spray accumulated in the snow cover. Similarly, in the Vestfold Hills, the moss and lichen vegetation were distributed sparsely over the easterly inland regions, but the western section, strongly influenced by salt spray, was virtually barren of moss and lichen (Pickard, 1986; Seppelt, 1986a, b).

Moss and lichen floras in the Antarctic environment, although belonging to different systematic groups and with few physiological similarities, show important ecological similarities (Bates and Farmer, 1992). In this context, the distribution of moss and lichen vegetation is largely affected by: nutrient and substrate conditions, available sheltered sites in valleys or depressions, surface hydrology such as streams, ponds and lakes, and glacier or snow drift dymanics. Distribution of species within the community is affected by species composition, cover, and growth rate of moss shoot or lichen thalli during the growing season. This may be caused by microclimatic and microtopographic features.

It is important to investigate the current abundance and spatial distribution of key species and their associated environmental factors in long-term monitoring. This study has established the essential baseline data for such monitoring of local and global climatic perturbations.

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