SEASONAL CHANGES OF SOME ENVIRONMENTAL FACTORS AROUND THE MOSS VEGETATION NEAR SYOWA STATION, EAST ANTARCTICA

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Abstract: Seasonal changes of environmental factors around the moss vegetation such as snow drift, water supply and temperature were investigated in the vicinity of Syowa Station from February 1983 to January 1984.

Topographical features around the vegetation are basically concerned in the formation of snow drift. After late September the depth of snow cover gradually decreased and in October the vegetation was partially exposed from snow. In early December water traces were recognized beneath the snow. In contrast with a decay of the snow drift, the water content of moss turves increased and reached a maximum value of 125.8% during the period from late December to early January. Each small moss colony composing the vegetation had its own pattern of water supply which was considered to be related with small streams from the drift. Referring to the water supply, temperature profile and moss growth were also discussed.

1. Introduction

The mosses are predominating in the flora in the ice-free areas throughout Antarctica. In the Continental Antarctic, only ten species of mosses are known in contrast with over 80 species in the Maritime Antarctic. The terrestrial biological elements in the Continental Antarctic are limited to those which live or possibly exist by uniquely adaptating themselves to environmental extremes. In particular, the moss vegetation occurring in the polar regions is liable to accept disruptive factors for the life cycle owing to the strictly slow growth rate. Therefore, it is necessary to study the relationship between the environmental factors and the growth of moss vegetation. However, little is known about the Antarctic environmental factors controlling the moss growth.

In the Continental Antarctic, MATSUDA (1963, 1968) was the first to carry out the ecological studies of the moss community and microorganisms in the Syowa Station area, and he suggested that the temperature at the moss level would not harm the microorganisms living in the community. Furthermore, he pointed out that the moss habitat was directly dependent on a snow drift, and indirectly on topographic features and wind direction. In addition to the environmental factors mentioned by MATSUDA (1968), the most fundamental or major limiting factor for the moss growth is considered to be a water content absorbed by moss turf.

The author undertook some field works of terrestrial biology, which were carried out from February 1983 to January 1984 as part of the winter program of the 24th

Japanese Antarctic Research Expedition (JARE-24). Among them, the present study was undertaken to clarify a process of water supply caused by the snow drift as possible utilization for the moss growth, measuring seasonal changes of the snow drift, the water content and the temperature.

2. Materials and Methods

The study area is located in the vicinity of the Naka-no-seto Strait, 1 km southwest of Syowa Station (69°00′S, 39°35′E), East Ongul Island and is about 25 m above sea level. The moss vegetation studied is spreading approximately 8 m in area and is dominated by the community of *Ceratodon purpureus* (HEDW.) BRID., which was partially covered by epiphytic lichens and algae. *Bryum pseudotriquetrum* (HEDW.) GAERTN., MAYER et SCHERB. was merely mixed in the community. The study area is shown in Fig. 1.

Seasonal changes of snow drift were observed for a year from February 1983 to

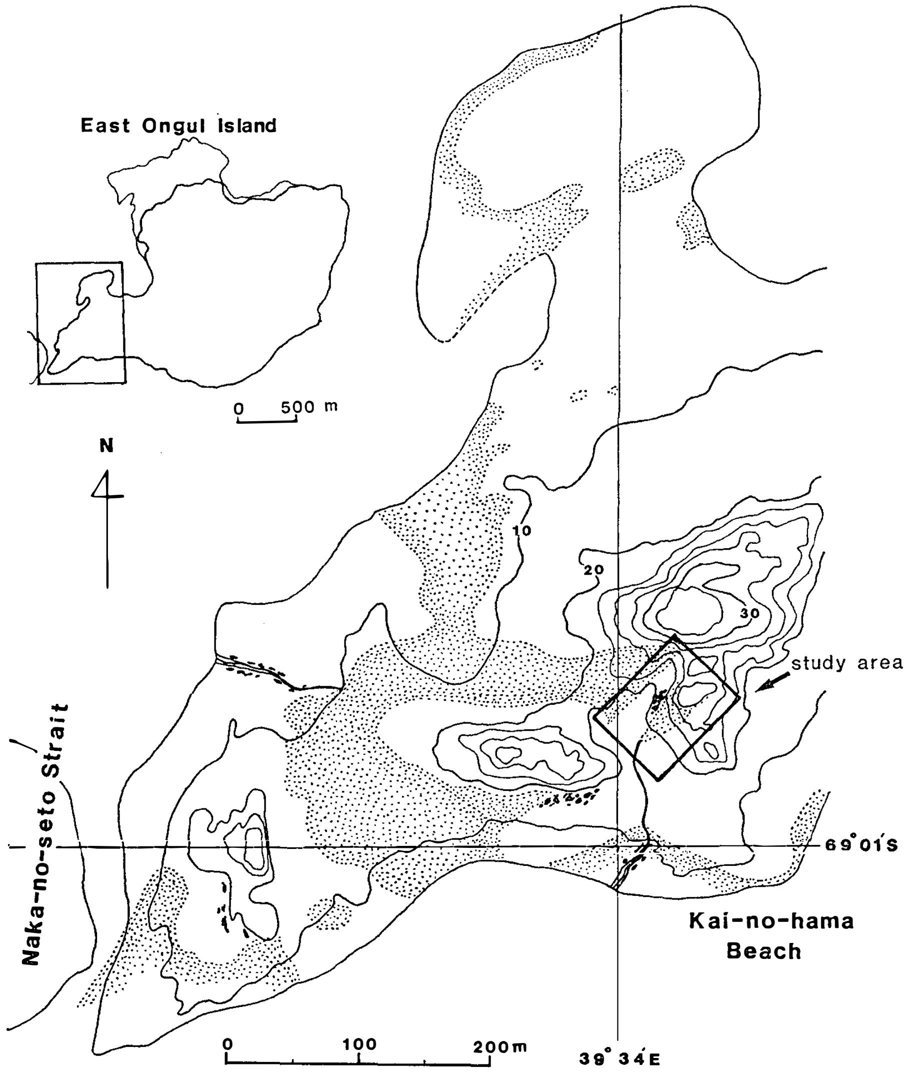

Fig. 1. Location map of the Naka-no-seto Strait, East Ongul Island and the study area.

January 1984 at intervals of once or twice per month.

The water content of moss turf was measured from early September 1983 to middle January 1984. The following method was used to estimate the water content from collected samples: fresh weight was calculated by subtracting the moss dry weight and the weight of the bottle from the weight of the unopened bottle containing fresh material. The mean water content was calculated as percentages of the dry weight.

Temperatures in air and at moss level were occasionally measured with a portable thermistor thermometer (Takara A-700) in the field. For the comparison, the routine meteorological data at Syowa Station were referred.

3. Results and Discussions

3.1. Topography (Figs. 1, 2 and Plate 1: 1)

In the winter season, a large snow drift (drift-I) was formed on the leeward of a small hill, which consists of weathering exposed-rocks, in the northeast to southwest direction. This drift of about 300 m^2 in area was formed by a prevailing wind from the continental ice sheet in the northeast to southwest direction. There are some moss turves on the northwest side of the snow drift.

In parallel with drift-I, there is another snow drift (drift-II) spreading to the southwest side. The western part of this snow drift continued to the snow cover on the slopes facing the seashore near the Naka-no-seto Strait. In the summer, a relatively large stream of 1 m in width made of melt snow ran from the west margin of the snow drift to the seashore, and some moss colonies were observed along the stream. The east margin of the snow drift forms an ice-cliff and there was no vegetation near the drift. Whereas around the tail of drift-I in the next summer, a small stream occurred beneath the drift and ran to the Kai-no-hama Beach opposite to the Naka-no-seto Strait. There were some moss colonies scattered on the stream banks.

The relationship between wind direction and snow drift was first mentioned at East Ongul Island by MATSUDA (1963, 1968), who indicated that the west and south slopes of snow drift were the best places for the growth of plant, because the slope received enough sunlight in the afternoon, and that the sands beneath the snow drift were exposed fast and the water from melt snow would infiltrate. SHIMIZU (1977) showed that the southwest slope direction of moss community at West Ongul Island, Sôya Coast was the most frequent and indicated that the occurrence of plant communities is related to the slope direction and to the solar radiation. According to SHIMIZU's classification, the moss habitat at the Naka-no-seto Strait is of the type occurring at the side of snow drift which is the most common habitat in West Ongul Island. While, YAMANAKA and SATO (1977) also analyzed the distribution of moss communities in Prince Olav Coast, and they suggested that there is no significant correlation between the slope direction and the plant community in isolated islands or in small-scaled ice-free areas. The moss communities occurred most frequently on slopes facing the northeast or northwest.

3.2. Microclimate

3.2.1. Snow drift

The flat ground with the moss vegetation lies between drifts-I and -II. Seasonal

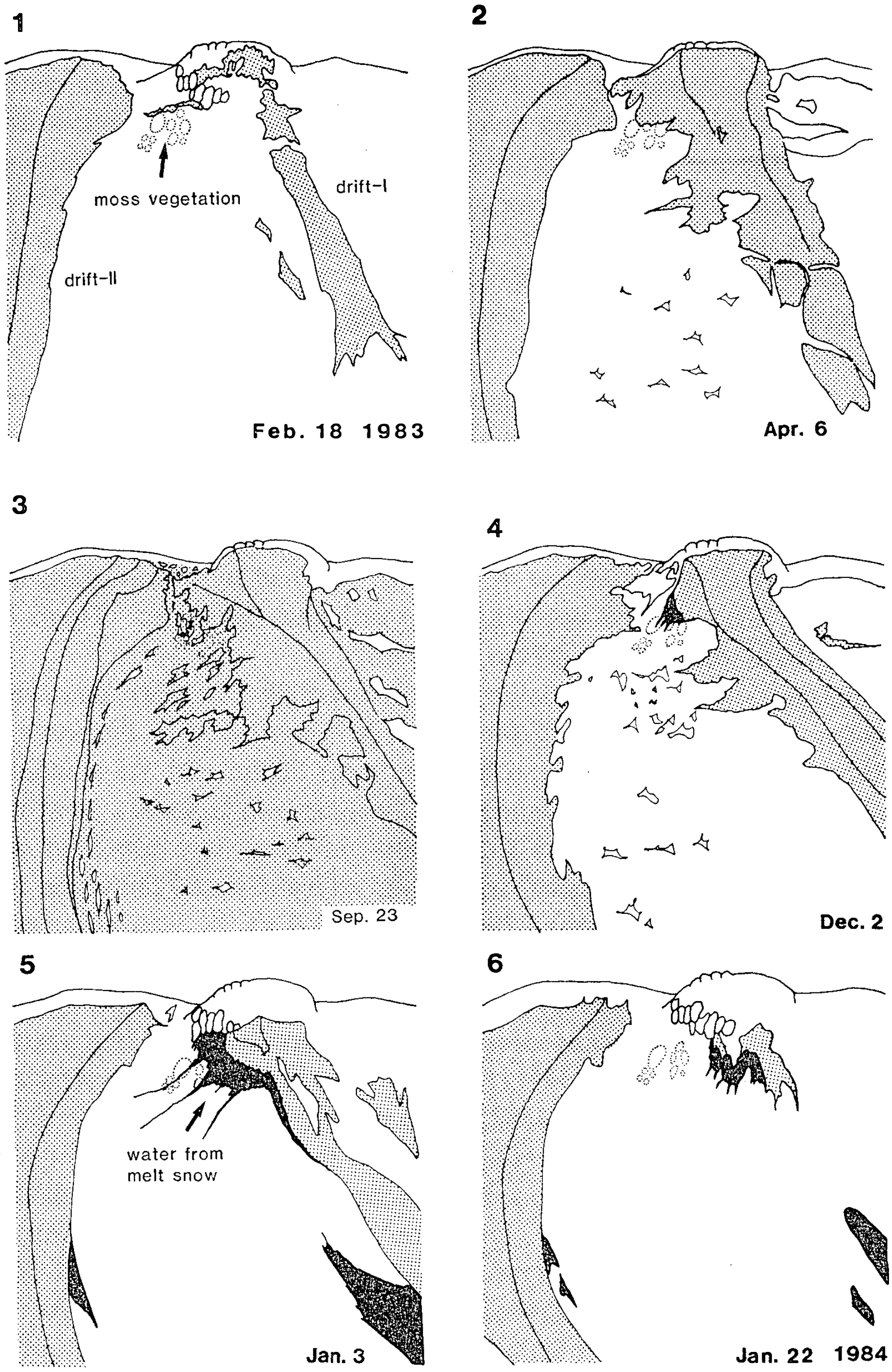

Fig. 2. The seasonal change of snow drift in the study area.

change of snow drift is shown in Fig. 2: 1–6, Plate 1: 1–3. The moss vegetation was covered by thin snow of 15 cm in maximum depth in the winter season (July to September), and at the same time the snow drifts were extended leeward (Fig. 2: 2, Plate 1: 1). The mosses in the winter season seem to be protected from desiccation and extreme cold temperature by snow cover as stated by MATSUDA (1963, 1968) and GREENE and LONGTON (1970).

After late September, the depth of snow cover gradually decreased, and in October the moss vegetation was partially exposed from snow. The snow cover in this season seems not enough for water supply for the moss growth. It was to be decreased as just sublimation because the air temperature was below −10°C and the water content of moss turf was below 3%. In early December, about a half of the moss vegetation was exposed, and a water trace from melt snow runs on the sloped bedrock facing the northwest. Furthermore, in late December, the water content of moss turf increased abruptly and the ground occurring moss vegetation was much moistened and looked blackish with a water (Fig. 2: 5). In early January, the snow drift became smaller, and rocks were partially dried, and in late January the mosses were also dried up or frozen (Fig. 2: 1, 6 and Plate 1: 3, 6). Under such condition, the moss growth may cease completely (Fig. 2: 1, 6). On the other hand, there had been scarcely any seasonal changes throughout a year on the east side of drift-II. A part of the snow drift that was out of solar radiation will never be melted, and not useful for water supply for moss growth.

The seasonal changes of the snow drift and snow cover in the study area are related to the air temperature and solar radiation. It is assumed that the snow drift as a source of water supply is a decisive factor for the growth and distribution of mosses in this area.

3.2.2. Water content of mosses

The seasonal change of water content of mosses in this area is shown in Table 1 and Fig. 3. Compared with the seasonal change of the snow drift, the water content of mosses showed a striking contrast as it increased after the decay of the snow drift. Before the moss vegetation was exposed from snow cover (September to November), the water content was 0.3–2.4%. In early December, however, the water content increased to 24.4–46.0%. Judging from the air temperature and the solar radiation, the water content of mosses might begin to rise in late November. The soil near the terminal of the snow drift became moistened on 2nd December when the air temperature and solar radiation were about −5°C and 100 h/10 days, respectively (Fig. 2: 4). The mean water content of mosses has a more significant correlation with the solar

Table 1. Seasonal change of water contents (%) of mosses in each colony composing the vegetation.

Date	Colony									
	A	B	C	D	E	F	G	H	I	Mean
1 Sep.	2.4	1.8	—	—	—	—	—	—	—	2.1
23	0.9	0.9	—	—	—	—	—	—	—	0.9
10 Oct.	2.4	0.3	—	—	—	—	—	—	—	1.4
2 Dec.	46.0	26.5	—	—	—	—	—	—	—	36.3
11	54.1	51.3	29.9	97.8	42.7	96.1	—	—	—	62.0
15	34.4	49.6	25.0	55.9	61.8	39.0	71.6	75.7	—	51.6
21	43.6	73.4	16.8	93.2	32.5	34.9	38.0	105.8	—	54.8
26	40.8	44.2	124.3	73.0	45.8	35.2	35.6	34.2	50.8	53.8
3 Jan.	62.4	53.2	41.9	85.7	26.8	125.8	62.0	43.3	54.1	61.7
19	21.3	33.3	42.6	63.9	52.4	43.7	31.3	42.5	18.3	38.8
Mean	30.8	33.5	46.8	78.3	43.7	62.5	47.7	60.3	41.1	

—: Water contents of mosses covered by snow are not measured.

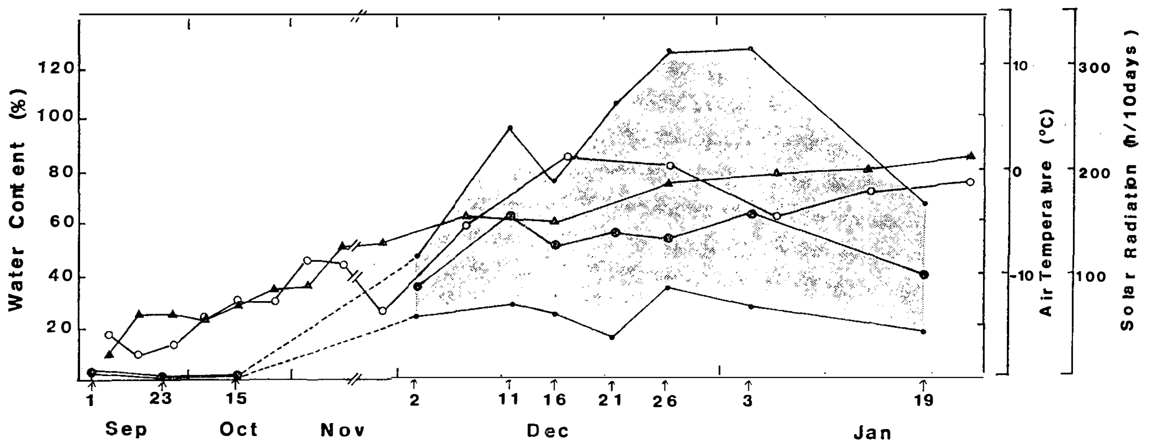

Fig. 3. The seasonal change of water content of mosses. • indicates the maximum (upper) and minimum (under) water contents. ◉ mean water content; ▲ air temperature (Syowa Station); ○ solar radiation (Syowa Station).

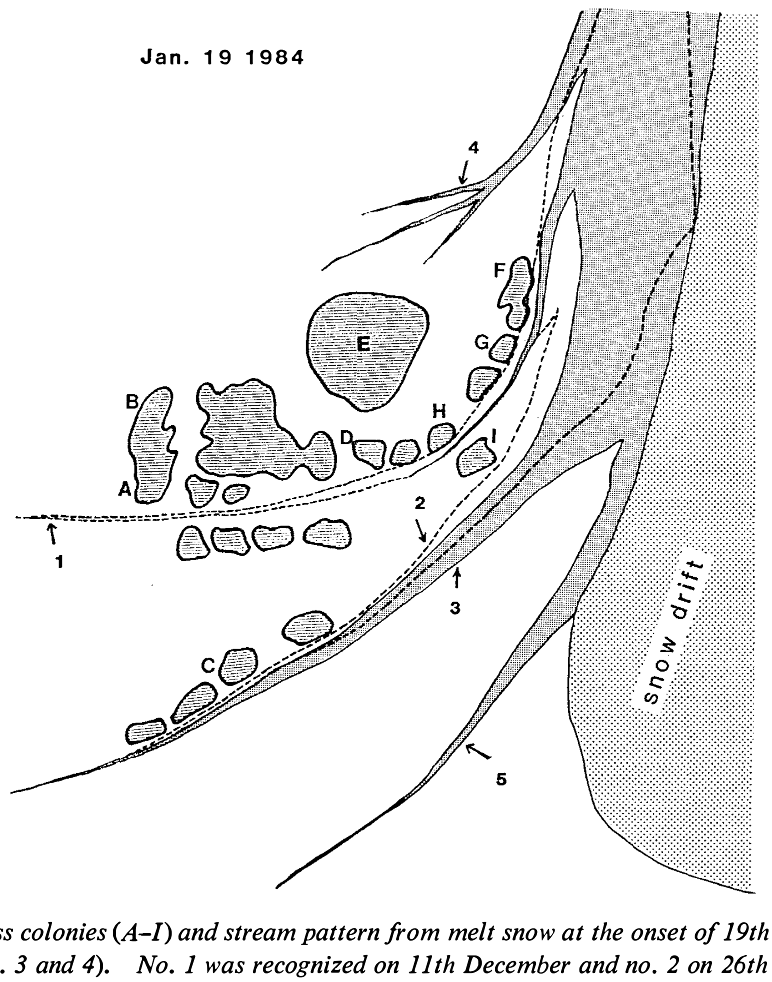

Fig. 4. Moss colonies (A–I) and stream pattern from melt snow at the onset of 19th January 1984 (nos. 3 and 4). No. 1 was recognized on 11th December and no. 2 on 26th December.

radiation than with the air temperature (Fig. 3). From late December to early January, the water content of mosses reached in a maximum value of 125.8%.

The moss vegetation in the study area is composed of about 20 clonies. Small flags with alphabet (A–I) were set prior to this observation to examine the pattern of water content of mosses of each colony (Fig. 4). Figure 5 shows moss colonies B, C, D, E and F having independent water content patterns. The water content of colony B gradually increased and reached 73.4% in maximum value on 21st December and decreased to 33.3% on 19th January. Water contents of colonies C and F varied in the range of 16.8–124.3% during all seasons. In contract, water contents of colonies D and E were relatively stable in the ranges of 55.9–97.8% and 26.8–61.8%, respectively. Furthermore, colonies C and F, and D and E were related inversely to each other in the pattern of water content of mosses. It is assumed that the water content of these moss colonies is dependent on an access of streams or time lag of water absorption by each moss colony. Figure 4 and Plate 1: 4, 5 show the visible seasonal change of streams on 11th December to 19th January. The first stream (no. 1) started to run on 11th December and the second stream (no. 2) on 26th December toward colony C. On 19th January, other streams (nos. 3, 4 and 5) newly appeared and at the same time the first stream disappeared. Despite colony E had been covered with sandy soil and always looked free from streams, it reserved the water in a relatively suitable condition. This is probably due to the cover of sandy soil which is

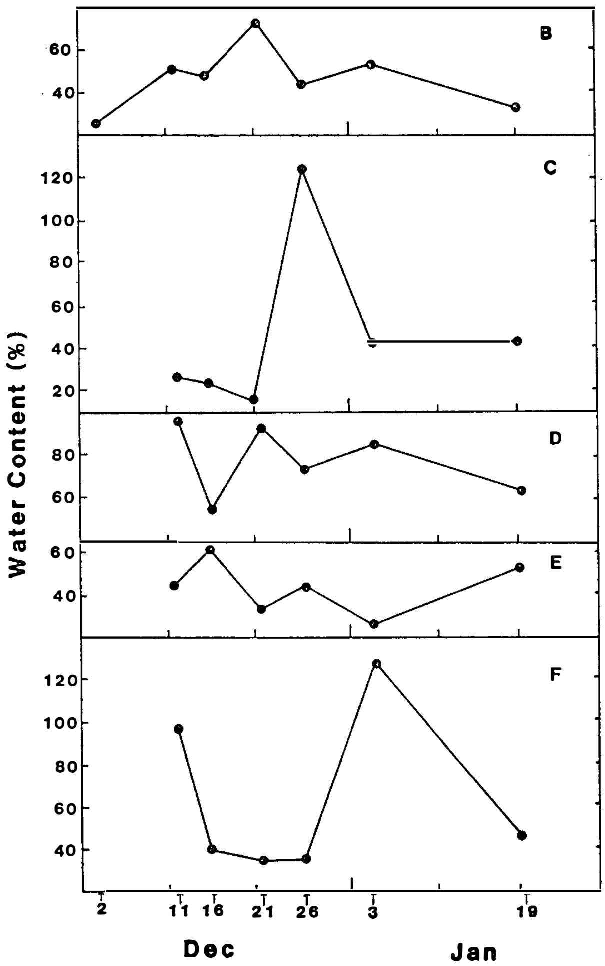

Fig. 5. Water content patterns of selected colonies B, C, D, E and F.

useful to restrain the strong radiation or cold temperature. Plate 1: 5 and 6 show the water condition of colony C observed on 19th and 30th January, respectively. No streams are seen along colony C on 30th January.

NAKANISHI (1977) classified moss habitats into six types by the pattern of water supply. SHIMIZU (1977) classified them into four types. Among them, the moss habitat getting water from a small-scaled snow drift is the most common in the Syowa Station area.

3.2.3. Temperature

Temperatures at the moss level were occasionally measured when other micro-climatic factors were surveyed at the Naka-no-seto Strait. Figure 6 shows the temperature profile. The temperature at the surface of moss turf was approximately −10°C at around two o'clock on 15th October. On 11th December, however, it rose up to 10°C in contrast with −5°C of air temperature. The temperature inside 3 cm from the surface in moss turf is variable but it is close to the air temperature at 1.5 m height from the ground. The temperature at the moss surface was usually 2–7°C higher than the air temperature during 11th December to 3rd January.

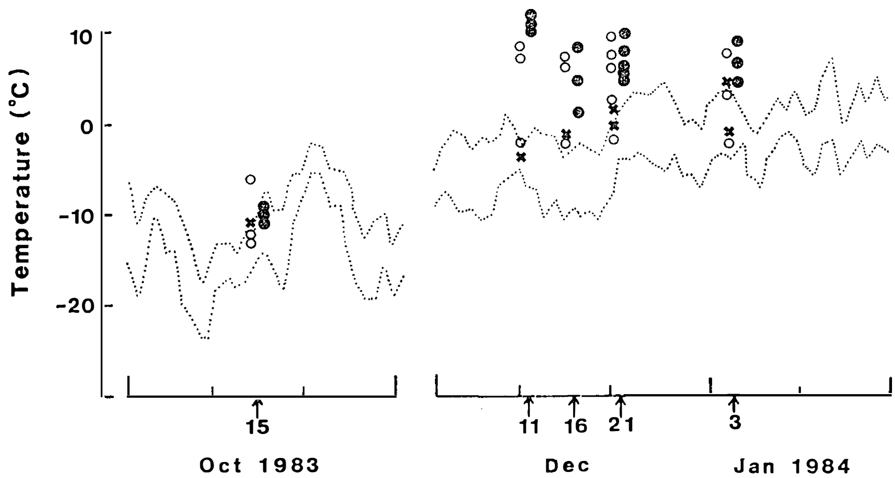

Fig. 6. Temperature profiles at the surface of moss turf (⊛) and the inside of 3 cm in moss turf (○), showing the air temperature at 1.5 m height from ground measured in the study area (×). Broken lines indicate the maximum (upper) and minimum (under) air temperatures measured routinely at Syowa Station.

On the windward side of the snow drift, small moss colonies sometimes occurs on wet soil at the foot of cliffs or the edge of boulder itself (SHIMIZU, 1977). It is also conceivable that indispensable water for mosses was preserved at the site shaded by rocks. In the study area, the author observed that strong radiant heat on the rocks exposed in the summer sun shine melted the marginal snow, and the resultant melt water worked to melt other parts of the drift.

3. Concluding Remarks

In the study area near the Naka-no-seto Strait, no visible growth of the moss during a year was recognized. However, an exact measurement of the growth rate is expected in future. The growth of mosses begin in combination with suitable conditions of water content in moss turf, solar radiation and temperature at the moss level. A period climatically reasonable for the growth of mosses in the study area was expected to be approximately 40 days from early December to middle January, judging from the microclimatical data at the moss level. However, it is a necessary approach to study how survival strategy exists during a long winter in the Continental Antarctic. In temperate regions which lack prolonged frost and snow cover, growth of some mosses occurred largely during winter (LONGTON, 1980), and initiation of growth prior to snow melt in spring was reported in a species of *Calliergidium* on Signy in the Maritime Antarctic (COLLINS *et al.*, 1975).

INO *et al.* (1980, 1981) indicated that there was a good correlation between the soil respiration rate and the water content of soil, but temperature was not a strong stimulus to a biotic activity. Furthermore, INO (1983) estimated that the mean net production rate of moss community for 17 years was 3.7 g dw/m^2·y. Such strictly slow growth rate and slight production of mosses in the Continental Antarctic are considered to be caused by severe environmental factors.

Further intensive investigations on the interrelation among the microclimatic factors and the moss growth will clarify the life history of mosses surviving in the Antarctic regions.

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References

COLLINS, N. J., BAKER, J. H. and TILBROOK, P. J. (1975): Signy Island, Maritime Antarctic. Structure and Function of Tundra Ecosystems, ed. by T. ROSSWALL and O. W. HEAL. Stockholm, Swedish Natl Sci. Res. Council, 345–374 (Ecol. Bull., No. 20).

GREENE, S. W. and LONGTON, R. E. (1970): The effects of climate on Antarctic plants. Antarctic Ecology, Vol. 2, ed. by M. W. HOLDGATE. London, Academic Press, 786–800.

INO, Y. (1983): Estimation of primary production in moss community on East Ongul Island, Antarctica. Nankyoku Shiryô (Antarct. Rec.), **80**, 30–38.

INO, Y., OSHIMA, Y., KANDA, H. and MATSUDA, T. (1980): Soil respiration in the vicinity of Syowa Station, Antarctica. 1. Relationships between soil respiration rate and water content or nitrogen content. Nankyoku Shiryô (Antacrt. Rec.), **70**, 31–39.

INO, Y., OSHIMA, Y., OHYAMA, Y., KANDA, H. and MATSUDA, T. (1981): Soil respiration in the vicinity of Syowa Station, Antarctica. 2. Estimation of carbon dioxide amount evolved from the naked part of West Ongul Island. Nankyoku Shiryô (Antarct. Rec.), **73**, 124–133.

LONGTON, R. E. (1980): Physiological ecology of mosses. The Mosses of North America, ed. by R. T. TAYLOR and A. E. LEVITON. Washington, D.C., Am. Assoc. Adv. Sci., 77–113.

MATSUDA, T. (1963): Nankyoku Higashi Onguru Tô ni okeru senrui bunpu ni tsuite (The distribution of mosses on East Ongul Island, Antarctica). Hikobia, **3**, 254–265.

MATSUDA, T. (1968): Ecological study of the moss community and microorganisms in the vicinity of Syowa Station, Antarctica. JARE Sci. Rep., Ser. E (Biol.), **29**, 58 p.

Nakanishi, S. (1977): Ecological studies of the moss and lichen communities in the ice-free areas near Syowa Station, Antarctica. Nankyoku Shiryô (Antarct. Rec.), **59**, 68–96.

Shimizu, H. (1977): Nishi Onguru Tô oyobi Teoiya Tô no shokusei bunpu to kankyô yôin (Vegetational distribution and habitats on West Ongul and Teöya Islands, Antarctica). Nankyoku Shiryô (Antarct. Rec.), **59**, 97–107.

Yamanaka, M. and Sato, K. (1977): Syowa Kiti fukin no rikujô shokubutsu gunraku no bunpu to suibun oyobi yôbun tono kankei (Distribution of terrestrial plant communities near Syowa Station in Antarctica, with special reference to water supply and soil property). Nankyoku Shiryô (Antarct. Rec.), **59**, 54–67.

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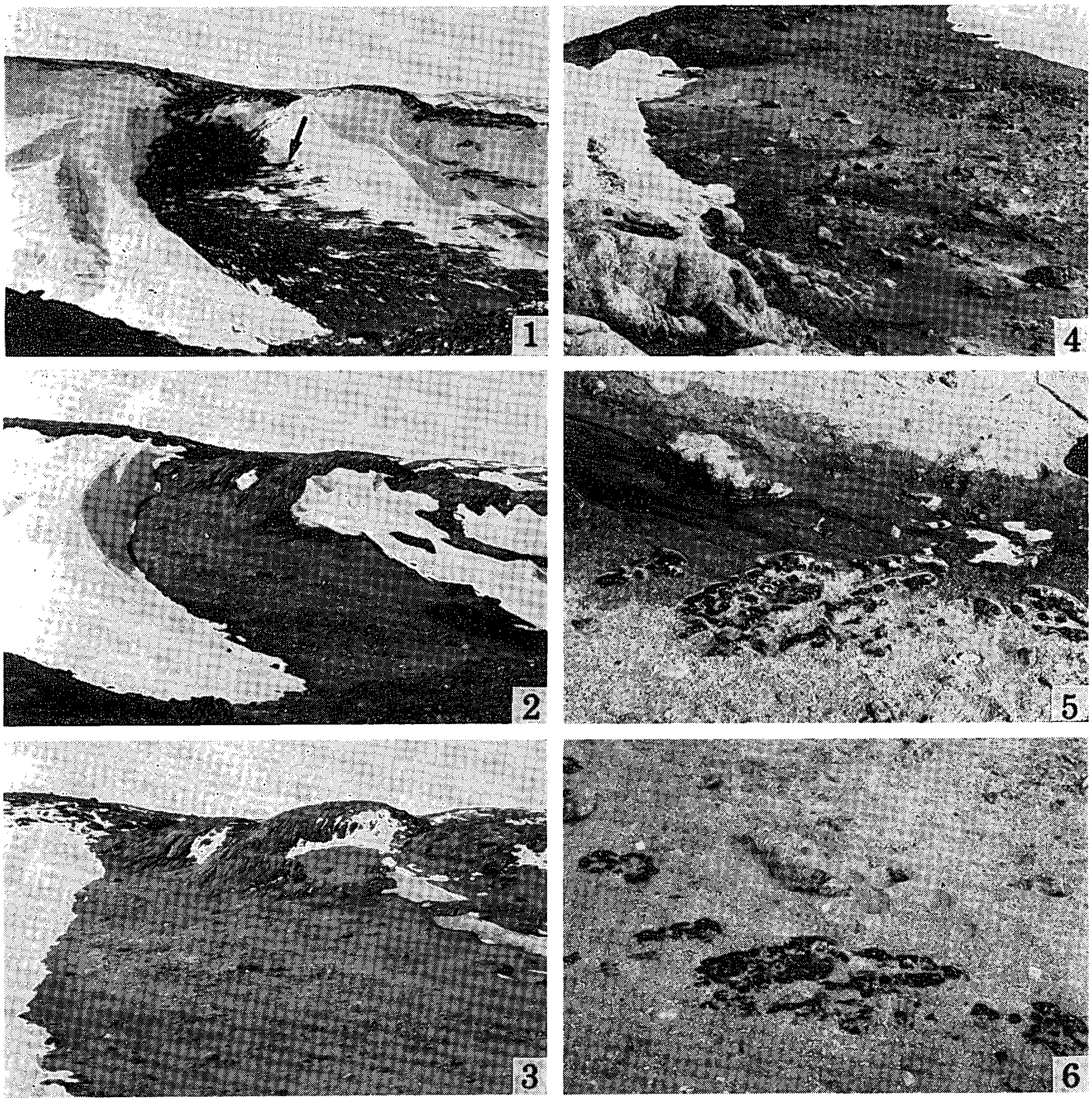
Plate 1



1. *Topography and snow drifts in the study area near the Naka-no-seto Strait. The arrow shows the moss vegetation on 1st September 1983.*

2, 3. *Decreasing snow drift and moist soil in the study area on 26th December 1983 and 30th January 1984.*

4. *The stream pattern around the moss vegetation on 19th January 1984.*

5, 6. *The water condition at colony C on 19th and 30th January 1984.*