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THE RELATIONSHIP BETWEEN DISTRIBUTION OF BRYOPHYTES AND SOIL CONDITIONS ON DEGLACIATED ARCTIC TERRAIN IN NY-ÅLESUND

Yoshinori MINAMI[1], Hiroshi KANDA[2] and Takehiro MASUZAWA[3]

[1]*Hiraoka Environmental Science Laboratory, 8–8, Hosoyama, Asao-ku, Kawasaki 215*
[2]*National Institute of Polar Research, 9–10, Kaga 1-chome, Itabashi-ku, Tokyo 173*
[3]*Department of Biology, Faculty of Science, Shizuoka University, 836, Ohya, Shizuoka 422*

Abstract: The relationship between distribution of bryophytes and soil conditions on deglaciated arctic terrain in front of East Brøgger glacier in Ny-Ålesund, Spitsbergen, Svalbard was studied. Vegetation was divided into four community types, *i.e.* 1) moraine community, 2) *Saxifraga* community (dominated by *Saxifraga oppositifolia*), 3) *Dryas* community (dominated by *Dryas octopetala*), and 4) wetland community, based on the vegetation map by I. BRATTBAKK (Vegetation Map 1:10000, Museet, Bot. avd., Trondheim, 1981). We established study sites randomly in each community (18, 27, 26 and 23 sites respectively), carried out vegetation analysis and sampled soil. Six patterns were observed in the frequency of major species in the four communities. In soil chemistry, total nitrogen concentration was low, and soil pH and EC were high, with soil pH approximated neutral, in the moraine community. Mg and Zn content were also high in the moraine community. Conversely, Al content was highest in the *Dryas* community and lowest in the moraine community. It was considered that the soil conditions on the moraine were distinctive, and greatly influence the bryophytes growing there.

1. Introduction

On the land north of forest limit in the Northern hemisphere, the extensive arctic meadows, rivers and lakes have a very important ecological function at a global level through influencing the cycling of nutrients between marine and terrestrial situations (MATTHEWS, 1992). The ecosystems under severe environmental conditions in the arctic region is easily modified by climatic change caused by global atmospheric warming originated in increasing human activities (OECHEL and VOURLITIS, 1994). Glacial retreat is particularly remarkable, and the influence may produce a serious change in the vegetation along the glacier (MATTHEWS, 1992). However, little knowledge is available about the direct or indirect influence of changes in environment on Arctic life. To clarify these concerns, it is necessary to establish the influence of environmental change of ecological dynamics, as early as possible. Accordingly, we examined the relationship between the growth of bryophytes and environmental factors, *i.e.* stability of moraine due to the retreat of glacier and so on, as fundamental data. In this study, the relationship between soil conditions (chemistry and certain elements) and the distribution of bryophytes was studied. Arctic soils are well-known to be nutrient deficient (KLOKK and RØNNIG, 1987).

2. Study Site

Ny-Ålesund (79°N) is located in the north-west part of Spitsbergen, Svalbard, faced Kingsfjord. We studied mainly within an area of 3 km^2 in front of East Brøgger glacier. The distance from Kingsfjord to East Brøgger glacier is approximately 2 km. The topography is undulating with the highest altitude 55 m (Kolhaugen). Most area of ground is covered by cryptogams, especially bryophytes and lichens.

3. Methods

3.1. Vegetation analysis

Vegetation was divided into four community types, *i.e.* 1) moraine community, 2) *Saxifraga* community (dominated by *Saxifraga oppositifolia*), 3) *Dryas* community (dominated by *Dryas octopetala*) and 4) wetland community, based on the vegetation map by BRATTBAKK (1981). We established study sites randomly within the community types, excepting moraine community (27 in *Saxifraga,* 26 in *Dryas* and 23 in wetland community). For the moraine community, 18 study sites were established on a line transect established from glacier edge to downstream on ground moraine. Five to ten quadrats ($30\times30\sim50\times50$ cm^2) were investigated for vegetation analysis to record number, cover and frequency of each species. Frequency (%) of each species was calculated by the expression as follows;

$$F=A/B\times100,$$

where F is frequency (%), A is number of sites at each community in which a given species was recorded and B is total number of sites at that community.

3.2. Sampling of soil

Soil samples were collected from soil surface under the vegetation removed litter at sites adjacent to those area for vegetation analysis in four community types as mentioned above. The number of soil samples was 17 at moraine community, 16 at *Saxifraga* community, 25 at *Dryas* community and 10 at wetland community. We analysed soil chemistry (total nitrogen, NO_3^-, P_2O_5, pH and EC) and element contents (Na, Mg, Fe, Zn and Al) by using soil screened through 1 mm sieve after air-drying. Total nitrogen and P_2O_5 were analysed by the Kjeldahl method and the Truog method respectively, and NO_3^-, pH and EC were measured by Horiba Compact Meter (C-141 "CARDY", B-212 "twin pH" and B-173 "twin Cond", respectively). Element contents were analysed by using atomic absorption spectrometer "NIPPON Jarrell Ash AA-835".

We used the Kruskal-Wallis test (KWtest) to establish the significance of differences between the four communities.

4. Results

4.1. Major bryophytes in communities

Major species recorded in the four communities are shown in Table 1. In this study,

Table 1. Six patterns of major moss species appearance in four communities divided on the basis of BRATTBAKK *(1981), i.e. moraine community,* Saxifraga *community dominated by* Saxifraga oppositifolia, Dryas *community dominated by* Dryas octopetala *and wetland community.*

Species	Moraine	*Saxifraga*	*Dryas*	Wetland
Type 1)				
Sanionia uncinata	IV	V	V	III
Tortula ruralis	II	II	II	II
Type 2)				
Dicranoweisia crispura		IV	IV	IV
Aulacomnium turgidum		I	II	I
Type 3)				
Loeskypnum badium		II		II
Type 4)				
Bryum cryophilum	IV	I		
Pottia heimii	III		I	
Type 5)				
Racomitrium lanuginosum			IV	
Hylocomium splendens		I	III	
Type 6)				
Philonotis tomentella				I
Calliergon sarmentosum				III
Vegetation cover (%)	28.5	62.7	67.3	74.6

Arabic numerals of each species indicate grade values of frequency in each community ($I<20$, $20<II\leqq40$, $40<III\leqq60$, $60<IV\leqq80$, $80<V\leqq100$).

we found six patterns as follows; 1) species observed in all communities (*e.g. Sanionia uncinata* and *Tortula ruralis*), 2) species observed in all communities except the moraine community (*e.g. Dicranoweisia crispula* and *Aulacomnium turgidum*), 3) species observed in *Saxifraga* and wetland communities (*e.g. Loeskypnum badium*), 4) species observed mainly in the moraine community (*e.g. Bryum cryophilum* and *Pottia heimii*), 5) species observed mainly in the *Dryas* community (*e.g. Racomitrium lanuginosum* and *Hylocomium splendens*), and 6) species observed mainly in the wetland community (*e.g. Philonotis tomentella* and *Calliergon sarmentosum*). Vegetation cover (%) in each community are 28.5, 62.7, 67.3 and 74.6 respectively. Vegetation cover in the moraine community is very low, but species composition is not exiguous compared with the other communities, especially number of species in bryophytes.

4.2. Soil chemistry

Chemistry of the soil collected from each community is shown Table 2. Total nitrogen concentration was lower in the moraine community than in other communities (KWtest, <0.1% compared to *Saxifraga* community and *Dryas* community, and 2.1% compared to wetland community). The highest value of total nitrogen concentration was in the *Dryas* community, but there was no significant difference between the *Dryas* community and other communities except the moraine community. Conversely, NO_3^- concentration was lowest in the *Dryas* community, where it was significantly different to the moraine and wetland communities (KWtest, 1.4 and <0.1%). P_2O_5 concentration was low in all communities with no significant difference. pH value in the *Dryas* community was significantly lower in the moraine and the wetland communities

Table 2. Soil chemistry in each community. Each figure is shown as a median (range).

	Total nitrogen (%)	NO_3^- (ppm)	P_2O_5 (ppm)	pH	EC (μS/cm)
Moraine	0.011	52.5	0.14	6.7	112
	(0.002–0.039)[1]	(30.0– 75.0)	(0.13–0.18)	(6.6–6.9)	(64–149)[4]
Saxifraga	0.207	51.3	0.13	6.1	44
	(0.016–0.365)	(20.0– 85.0)	(0.11–0.16)	(5.6–6.5)	(4– 91)
Dryas	0.273	27.5	0.13	5.7	56
	(0.062–1.249)	(15.0– 75.0)[2]	(0.09–0.19)	(4.9–6.1)[3]	(18–197)
Wetland	0.120	77.5	0.13	6.2	67
	(0.048–0.483)	(42.5–115.0)	(0.12–0.18)	(5.9–6.5)	(44–113)

[1] KWtest, < 0.1% to *Saxifraga* and *Dryas* community, and 2.1% to wetland community.
[2] KWtest, 1.4% to moraine community and < 0.1% to wetland community.
[3] KWtest, < 0.1% to moraine community and 0.7% to wetland community.
[4] KWtest, < 0.1% to *Saxifraga* community and 0.2% to *Dryas* community.

Table 3. Element contents (ppm) in soil sampled from in each community. Each figure is shown as a median (range).

	Na	Fe	Mg	Zn	Al
Moraine	0.013	0.115	0.072	0.090	0.144
	(0.007–0.021)	(0.044–0.166)	(0.050–0.118)[1]	(0.044–0.166)[2]	(0.051–0.291)[3]
Saxifraga	0.014	0.102	0.044	0.024	0.151
	(0.007–0.022)	(0.040–0.180)	(0.019–0.132)	(0.011–0.117)	(0.075–0.252)
Dryas	0.015	0.144	0.024	0.040	0.252
	(0.007–0.024)	(0.055–0.172)	(0.027–0.130)	(0.022–0.142)	(0.137–0.323)
Wetland	0.017	0.161	0.060	0.040	0.242
	(0.010–0.022)	(0.055–0.286)	(0.022–0.170)	(0.018–0.164)	(0.086–0.395)

[1] KWtest, 1.3% to *Saxifraga* community and < 0.1% to *Dryas* community.
[2] KWtest, 0.4% to *Saxifraga* community and 0.1% to *Dryas* community.
[3] KWtest, 1.6% to *Dryas* community.

(KWtest, < 0.1 and 0.7%). pH value of the moraine community is approximately neutral. EC value in moraine community was fairly high, and significantly greater than in the *Saxifraga* community and the *Dryas* community can be found (KWtest, < 0.1 and 0.2%).

4.3. *Metal contents*

Element contents in soil in each community are shown in Table 3. No significant difference between communities in Na and Fe concentration was found. Mg and Zn concentration in the moraine community are high, and are significantly greater than in the *Saxifraga* community and the *Dryas* community (KWtest, 1.3 and < 0.1% in Mg, and 0.4 and < 0.1% in Zn, respectively). Conversely, Al is high in the *Dryas* community and low in the moraine community (KWtest, 1.6%).

5. Discussion

Decomposition organic matter in polar region is very slow due to the severely cold climate, so that limited nutrients for plants are available (FENTON, 1980). In such a peculiar circumstance microclimate affects the growth of bryophytes, and species composition and quantity of vegetation differ between habitats because of differences of desiccation or frost tolerance. In this study, we found obvious differences in the distribution of bryophytes between the moraine community and the other communities. LONGTON (1988) describe that important physiological features influencing the polar mosses are the broad response of net photosynthesis to temperature, the lower irradiance required for compensation and saturation, interactions between irradiation and temperature and the seasonal variation in response pattern shown by many plants. Species observed in the moraine community are of two types; *i.e.* 1) those largely restricted to the moraine community, and 2) those occurring also in other communities. Some species, *i.e.* *Bryum cryophilum* and *Pottia heimii,* observed mainly in the moraine community are adapted to the habitat of such moraine, with its peculiar environmental conditions. These species may simultaneously perhaps be weak in ecological competition in the other community. On the contrary, some other species, which were observed in all communities, are highly adapted to arctic environments.

Soil chemistry in the moraine community differs from that in other communities, especially the *Dryas* community and the *Saxifraga* community. Total nitrogen concentration is the lowest, and pH and EC value are the highest, in the moraine community. Furthermore, NO_3^- which is indispensable to plant growth, is high in the moraine community compared with the *Dryas* community. Mg and Zn, for which passive cation exchange process are important (WOJTUN, 1994), were also high concentration in the moraine community. It is difficult to understand why soil condition in the moraine community is disadvantageous for the growth of plants. However, it is possible that the relatively sparse bryophyte vegetation on the moraine explain the higher concentrations of Mg and Zn.

On the basis of the above, some of the differences in soil chemistry could be the results of, rather than the cause of, the different types of bryophyte present. The distribution of bryophytes in the study area is likely to be influenced by factors other than soil chemistry, notably water availability, and it is known that snow plays a dominant role in the annual behaviour of high arctic geoecosystem (REMPFLER, 1989).

Because nitrogen availability is low in arctic soil, nitrogen fixation by cyanobacteria is important for plants (NAKATSUBO and INO, 1987; LONGTON, 1988). The supply of nitrogen fixed by cyanobacteria or bacteria epiphytic on bryophytes in the moraine community is not low compared with other habitats in this area. LONGTON (1984) points out that bryophytes have important ecological role in increasing rates of weathering of rocks or soil particles at early stages in primary succession, and that associated microorganisms contribute to biological nitrogen fixation. Conversely storage in living and dead moss may lower nutrient availability to other plants. Results from this study suggest that bryophytes growing on the moraine habitat, where other plants can not invade, are important organisms in nutrients cycling at early stages in primary succession. More detailed studies, *i.e.* water availability, snow condition and so on, to bryophytes on the moraine habitat in deglaciated region.

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