Note on the Structure of Moss Colonies Composed of Two Species on King George Island, the South Shetland Islands

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キングジョージ島の2種より成る蘚類コロニーの構造について

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要旨: キングジョージ島の長城基地周辺において，蘚類 *Sanionia uncinata* と *Bryum pseudotriquetrum* で構成されるコロニーの縦断面を観察し，コロニー内における2種の関係と，そのコロニーの構造に及ぼす影響を調べた．その結果，*B. pseudotriquetrum* のシュートから成る層が *S. uncinata* のシュートで部分的に被われている場合，逆に *S. uncinata* のシュートの層が *B. pseudotriquetrum* のシュートで部分的に被われている場合，両種が互いに被いあうことなく共存している場合の3パターンが認められた．コロニーの成長にともない，2種の割合は徐々に変化するが，その変化の方向は生育地の中でも一定ではないことが明らかになった．

Abstract: Moss colonies composed of two species *Sanionia uncinata* and *Bryum pseudotriquetrum* are abundant in the vicinity of Great Wall Station on King George Island. Vertical cross-sections of these colonies were examined to know the colony structure indicating the interaction between the two species. In several colonies, a layer composed of *B. pseudotriquetrum* was partially covered with shoots of *S. uncinata* (pattern 1). In some other colonies, a layer composed of *S. uncinata* was partially covered with shoots of *B. pseudotriquetrum* (pattern 2). For the rest of the colonies, both species coexisted without covering each other (pattern 3). It is concluded that the proportion of the two species in a colony has changed through the colony growth, but the direction of the change varies among the colonies at each site.

1. Introduction

The Antarctic region presents an extremely harsh condition for mosses with low temperature, short growing period, strong wind and immature soil. It is considered that the structure of Antarctic moss communities is largely determined by these abiotic factors. The importance of snow cover, wind-direction, moisture and nutrient availability in determining the structure of Antarctic moss communities was shown by many authors (*e. g.* MATSUDA, 1968; SMITH, 1972; NAKANISHI, 1977).

In addition to these abiotic factors, species interactions may play an important role in determining the structure of Antarctic moss communities. It has been suggested that species interactions affected the structure of some moss communities on

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Signy Island (COLLINS, 1976) and on Candlemas Island (LONGTON and HOLDGATE, 1979). However, only a few studies about these interactions have been reported for other places in the Antarctic region.

During the 1990/91 austral summer, the authors were able to join the 7th Chinese National Antarctic Research Expedition and stay at Great Wall Station on King George Island in the maritime Antarctic. In the vicinity of Great Wall Station, moss colonies composed of two species *Sanionia uncinata* and *Bryum pseudotriquetrum* are abundant in moist habitats. It was expected that the interaction between the two species had affected the structure of these colonies especially at the portions where these species grew side by side. Therefore, as part of the study of the interaction between the two species, we examined vertical cross-sections of these portions of the colonies. Shoot elongation rates of the two species were also compared.

2. Study Sites

Great Wall Station is situated on the Fildes Peninsula of King George Island, the South Shetland Islands in the maritime Antarctic (58°57′W, 62°12′S; Fig. 1). Monthly mean air temperature, measured in the meteorological field at Great Wall Station, of November, December 1990 and January 1991 was −1.3, 0.1 and 2.0°C, respectively. Days of precipitation of each month were 25, 22 and 24 days, respectively (Chinese National Antarctic Research Expedition, unpublished data). Most of the precipitation occurred as rain from the end of December to the middle of February.

Vegetation of King George Island was described by LINDSAY (1971). *Sanionia uncinata* (HEDW.) LOESKE [=*Drepanocladus uncinatus* (HEDW.) WARNST.] covers extensive area of the ground in moist habitats along the coast, but it also occurs in mesic

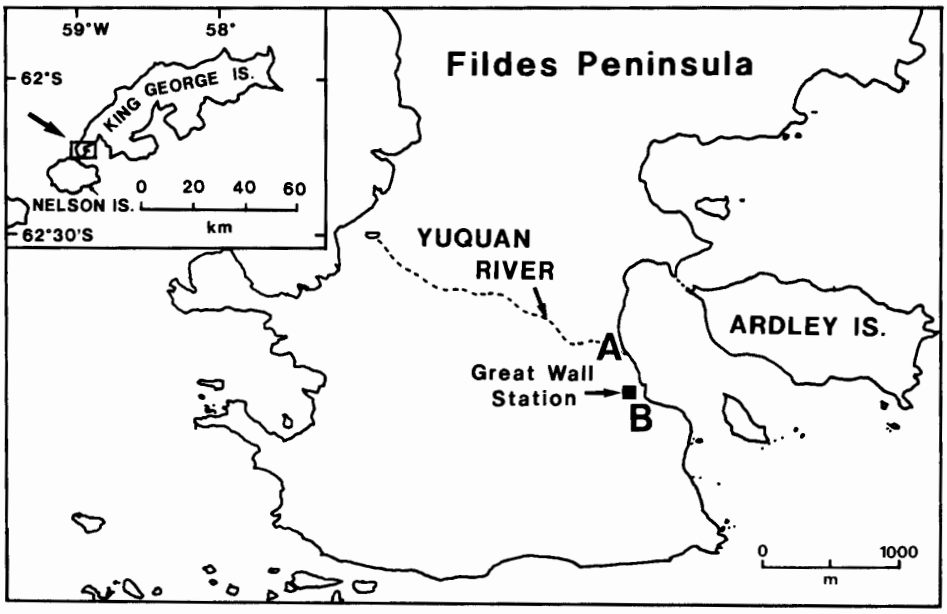

Fig. 1. Map showing the study sites.

habitats on exposed rocks. *Bryum pseudotriquetrum* (HEDW.) GAERTN., MEYER et SCHERB. often grows among or close to the carpet of *S. uncinata*. Growth-forms of *S. uncinata* and *B. pseudotriquetrum* are carpet and large cushion, respectively (after LONGTON, 1988). In the following text, each species is expressed by its generic name.

Sample collections were carried out at the following two study sites where colonies composed of *Sanionia* and *Bryum* were abundant (Fig. 1). Both of these sites were lower than 5 m above sea level.

Site A: A flat area around the mouth of a river, Yuquan River. *Sanionia* and

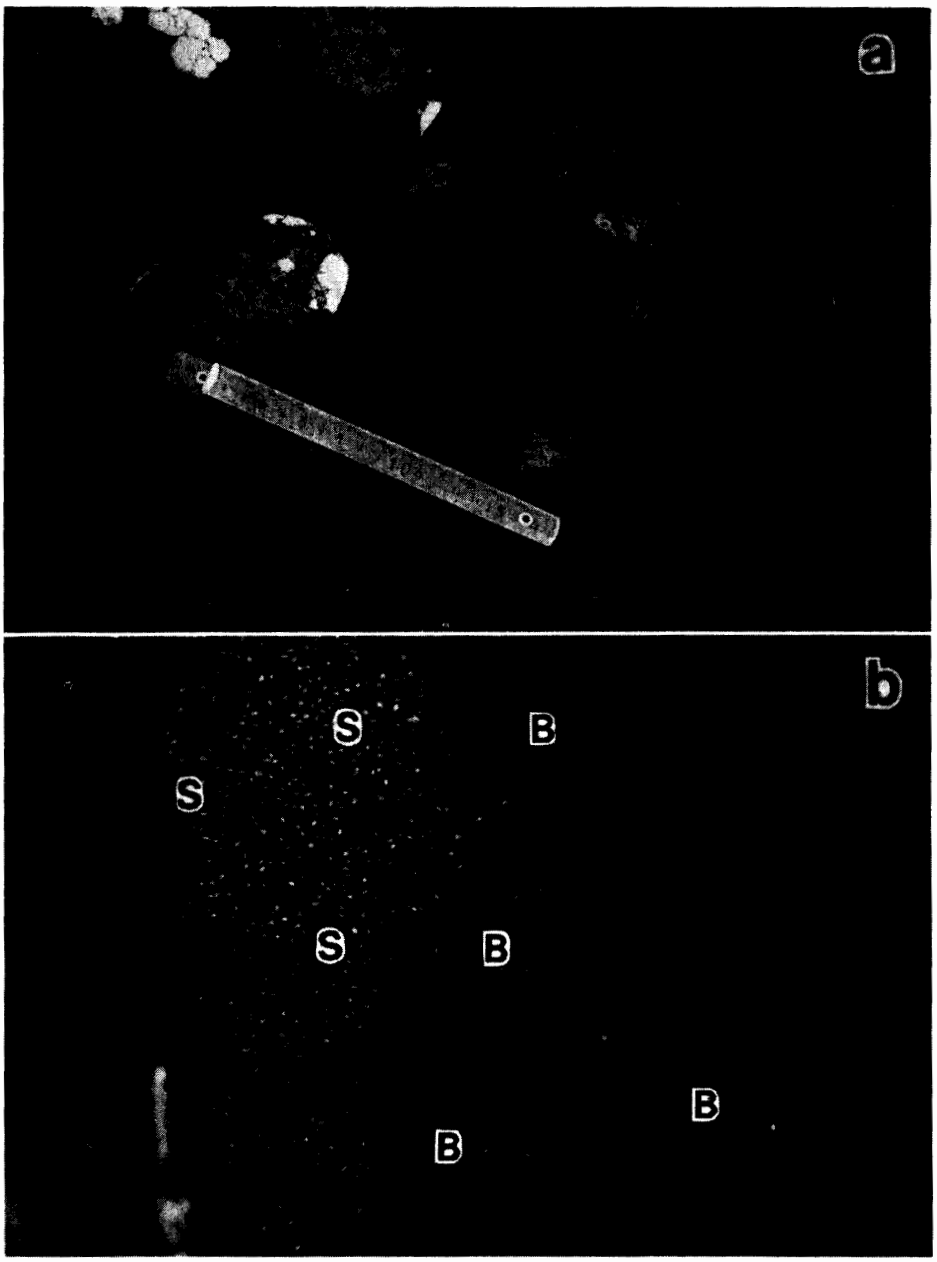

Fig. 2. Photographs of a moss colony (cushion) composed of S. uncinata *and* B. pseudotriquetrum. *(a) Habitat. (b) Close-up. S:* S. uncinata, *B:* B. pseudotriquetrum.

another carpet-forming moss *Calliergon sarmentosum* (WAHLENB.) KINDB. covered extensive area along the streams. *Bryum* were found among or close to the carpet-forming mosses and abundant at waterlogged sites. The substrata were gravel and sand. The moss colonies were covered with snow until early January. They were supplied with water by both the stream and rain during the snow-free season.

Site B: A rock (15 m × 10 m) by the seashore near Great Wall Station. *Sanionia* covered the upper horizontal surface of the rock. *Bryum* grew among or close to *Sanionia*. Most of these colonies were not covered with snow from the middle of December to the end of February. During the snow-free season, rain was the only source of water to moss colonies at this site.

The colonies composed of the two species were classified into three forms; carpet, cushion and hummock. These colony-forms were largely determined by the growth form of the dominant species. Large and flat colonies dominated by *Sanionia* are carpets. *Bryum* was rarely abundant in these carpets. On the other hand, isolated colonies dominated by *Bryum* forms dome-shaped cushions (Fig. 2a). In moist habitats near streams, these moss species form continuous hummocky colonies (hummock). *Bryum* was usually abundant in these colonies. Carpet was the dominant colony-form at the two study sites. Cushion and hummock were abundant in moist areas at site A, but they were not observed at site B.

Two types of mixing of the two species in a colony were recognized, 'mosaic type' and 'mix type'. In mosaic type, the colony consisted of almost pure stands of each species, *i. e.* some part of the colony was composed mainly of *Sanionia* and the other part was of *Bryum* (Fig. 2b). In mix type, on the other hand, shoots of the two species mixed with each other in a colony

3. Methods

Twenty-three moss colonies (17 at site A, 6 at site B) were selected so as to include various colony-forms and mixing-types. Part of each colony, either center or margin, was cut vertically from the green surface layer across the brown layer to the bottom of the colonies. For each colony, a piece of the colony showing the cut surface, 5 to 9 cm in length and *ca.* 1 cm in width, was collected. Sampling site, colony-form, type of mixing and sampled part of the colony are shown in Table 1. These samples were brought to the laboratory, and the thickness, shoot arrangement and the proportion of the two species were recorded.

Shoot elongation rates in the field were measured using the stain technique (RUSSELL, 1988). One colony of mix type was selected at site B. In this colony, main shoots of both species were almost erect and parallel except in the bottom part of the colony. The thickness of the colony was *ca.* 4 cm. In order to mark the tips of the shoots of both species, part of the surface of this colony was painted with water-soluble paint (Point Color, orange, Washin Chemical Industry Co., Ltd.) at the beginning of the summer season, December 7. After two months, these shoots were collected and the shoot length above the marking point was measured under a binocular. Some of the marked shoots showed new branching at or just below the marking point. These shoots with new branching were eliminated since the branching might be the effect of

Table 1. Samples of moss colonies composed of Sanionia uncinata *and* Bryum pseudotriquetrum *examined in the present study.*

Sample No.	Site	Colony form	Type of mixing	Sampling part	Thickness (mm)	* Profile of the sample	Note
1	A	cushion	mosaic	center	40	pattern 1	
2	A	hummock	mosaic	margin	50	pattern 1	
3	A	carpet	mosaic	center	35	pattern 2	Surface of *Sanionia* was brown.
4	A	hummock	mosaic	margin	35	pattern 1	
5	A	carpet	mosaic	center	30	pattern 2	Surface of *Sanionia* was brown.
6	A	carpet	mosaic	margin	36	pattern 1	
7	A	carpet	mix	center	30	pattern 3	The sample contained *Calliergon*.
8	A	carpet	mosaic	margin	30	pattern 1	Fig. 3
9	A	carpet	mix	center	20	pattern 3	The sample contained *Calliergon*.
10	A	cushion	mosaic	margin	30	pattern 2	Fig. 5
11	A	hummock	mosaic	margin	32	pattern 3	
12	A	hummock	mosaic	margin	30	pattern 1	
13	A	hummock	mosaic	margin	45	pattern 1	The sample contained *Calliergon*.
14	A	carpet	mix	margin	25	pattern 3	
15	A	cushion	mosaic	margin	37	pattern 3	
16	A	carpet	mix	center	40	pattern 3	
17	A	hummock	mosaic	center	28	pattern 2	*Sanionia* was partially brown.
18	B	carpet	mix	center	43	pattern 3	
19	B	carpet	mosaic	center	30	pattern 1	
20	B	carpet	mosaic	margin	28	pattern 1	Fig. 4
21	B	carpet	mix	center	38	pattern 3	
22	B	carpet	mosaic	center	40	pattern 1	
23	B	carpet	mosaic	center	28	pattern 3	

* Pattern 1: *Bryum* was partially covered with *Sanionia*.
Pattern 2: *Sanionia* was partially covered with *Bryum*.
Pattern 3: Both species coexisted without covering each other.

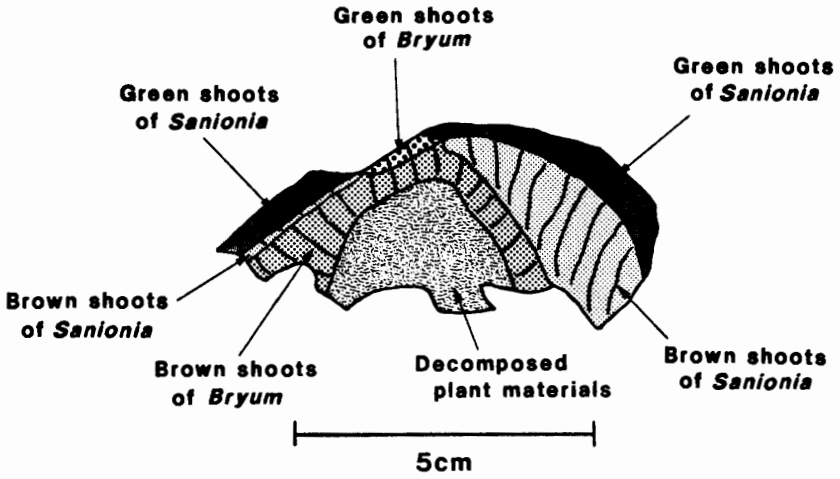

Fig. 3. Vertical cross-section of a moss colony in which B. pseudotriquetrum *was partially covered with* S. uncinata.

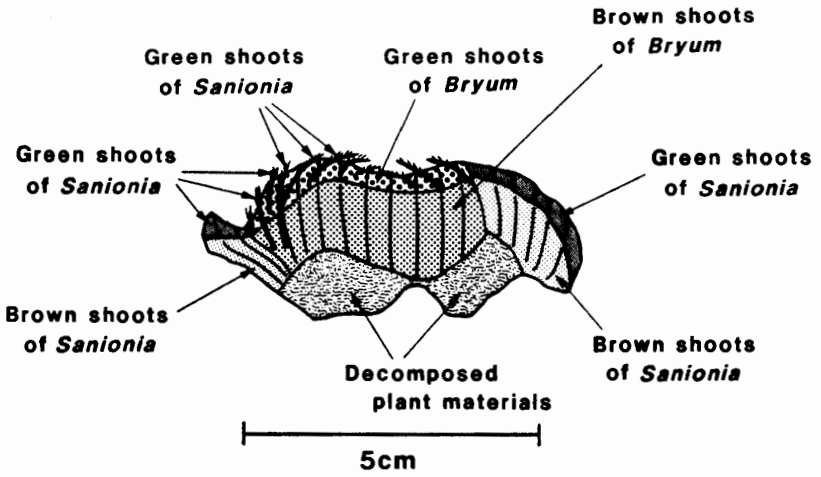

Fig. 4. Same as Fig. 3. except for green shoots of S. uncinata *lay on the green surface layer of* B. pseudotriquetrum.

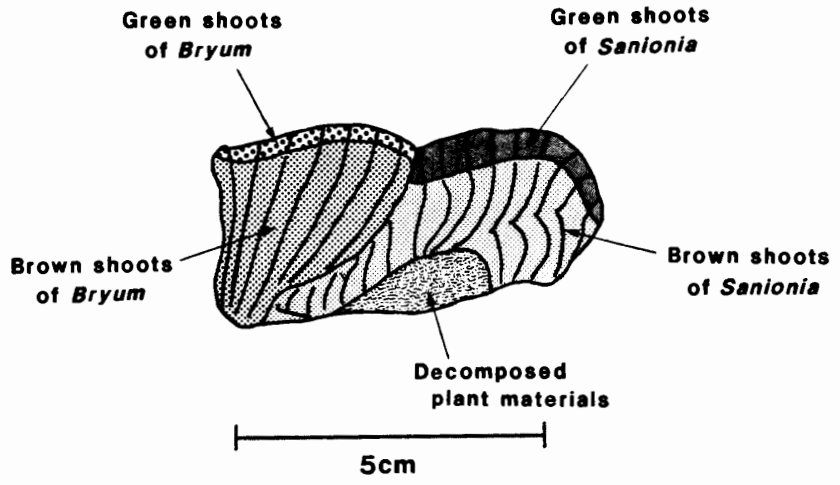

Fig. 5. Vertical cross-section of a moss colony in which S. uncinata *was partially covered with* B. pseudotriquetrum.

the marking. For the other shoots of the colony, it was assumed that the effect of the marking on the shoot elongation rate was negligible because no difference was detected between the surface level of the marked part and that of the nonmarked part in the same colony on the sampling date. Growth measurement could not be carried out at site A because of the prolonged snow cover.

4. Results and Discussion

The moss colonies at the study sites were composed of densely packed shoots. Although *Sanionia* is a pleurocarpous species, its main shoots were usually parallel and erect or ascending like those of *Bryum*. Radial shoot arrangement was observed only for colonies of cushion form. Total thickness of the colonies observed in the present study ranged from 2 to 5 cm. The surface green layer was thinner than 1 cm. Under the green layer, there was a brown layer composed of old moss shoots where individual shoots can be recognized. In most of the colonies, the bottom part was composed of compressed and decomposed plant materials. In the vicinity of Great Wall Station, brown skua (*Catharacta antarctica*) often disturbed and upset moss colonies. However, upside-down of moss shoots was not observed for all of the moss colonies examined in the present study.

Vertical change in the proportion of the two species was not detected for some of the samples. However, in the majority of the samples, the brown layer composed mainly of one species was partially covered with shoots of another species. The relations between the two species were classified into the following three patterns. The pattern of each sample is shown in Table 1.

Pattern 1: The layer composed of *Bryum* shoots was partially covered with *Sanionia* shoots. Seven samples collected at site A and three samples at site B showed this pattern. Figure 3 shows a sample showing this pattern. Surface layer of this sample is occupied mainly by *Sanionia*. *Bryum* occupied a small portion of the surface layer (*ca.* 1 cm in length). A brown layer composed of *Bryum* shoots was observed below the surface layer of *Sanionia*. A number of shoots apices of *Bryum* were found in the brown layer, which suggests that growth of these shoots had stopped.

Sanionia just covering *Bryum* was observed in a colony at site B (Fig. 4). In this sample, green *Sanionia* shoots lay on the green surface layer of *Bryum*. Some of these shoots originated from the edge of the surface layer of *Sanionia*. Prostrate growth form of *Sanionia* seems to be suitable for covering other species. This sample may represent the early stage of pattern 1.

Pattern 2: The layer composed of *Sanionia* shoots was partially covered with *Bryum*. Four samples collected at site A showed this pattern. In the sample shown in Fig. 5, surface green layer was composed of *Bryum* and *Sanionia*, but brown partly decomposed shoots of *Sanionia* with apices were observed at *ca.* 3 cm below the surface layer occupied by *Bryum*. In other three samples showing pattern 2, the surface layer of *Sanionia* was brown while that of *Bryum* was green. Since new shoots of *Sanionia* are usually green or yellowish green, the brown surface layer of *Sanionia* might be photosynthetically inactive.

Pattern 3: Vertical change in the proportion of the two species was not observed.

This applied to all of the samples of mix type and three samples of mosaic type.

These patterns had no relation to the colony-forms nor the sampling part in the colony.

The colony selected for the measurement of shoot elongation showed pattern 3. Shoot elongation in this colony from December 7 to February 7 was 3.7 ± 0.2 mm for *Bryum* and 3.3 ± 0.2 mm for *Sanionia* ($\bar{x}\pm$S. E.; $n=25$) Maximum shoot elongation was *ca.* 5 mm for both species. The difference between the two species was statistically not significant (t-test; $P>0.1$). Since the growing season might be longer than two months, these values may be smaller than the annual shoot elongation rate. However, this result suggests that undecomposed moss layer as thick as 3 cm could be formed within ten years at this site.

LONGTON and HOLDGATE (1979) studied replacement of moss species which appeared in the vertical cross-sections of moss colonies and concluded that cyclic succession took place in Candlemas Island, the South Sandwich Islands. The results of the present study suggests that partial replacement of species took place at these study sites. However, the direction of change was not constant; the proportion of *Sanionia* increased in some colonies (pattern 1), while it decreased in some other colonies (pattern 2) although colonies showing pattern 2 were fewer. This forms a contrast to moss banks in Signy Island where carpet-forming species were replaced by turf-forming species (COLLINS, 1976). The results show that interaction between *Sanionia* and *Bryum* results in variation of the colony structure rather than a directional change.

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