Polar Biosci., **17**, 128–138, 2004

Scientific note

On the structures of moss colony in the Yukidori Valley, Langhovde, East Antarctica

Hiroshi Kanda[1]*, Satoshi Imura[1] and Takeshi Ueno[2]†

[1] *National Institute of Polar Research, Kaga 1-chome, Itabashi-ku, Tokyo 173-8515 (*hkanda@nipr.ac.jp)*
[2] *Department of Polar Science, The Graduate University for Advanced Studies, Kaga 1-chome, Itabashi-ku, Tokyo 173-8515*

(Received August 21, 2003; Accepted September 19, 2003)

Abstract: The moss vegetation developing in the Yukidori Valley, Langhovde, East Antarctica, was investigated as based on the samples in the vertical cross-section housed as the herbarium specimens to categorize the structure of the moss colony and to determine the specific composition. The vegetation consists of pure colonies of one species, and mixed colonies composed of two or rarely three moss species. Each colony was classified by species composition and degree of unevenness. The active zone, decomposed zone which were seen in the vertical cross-section, and epiphytic condition on the surface such as cyanobacteria and imperfect lichens, and rhizoidal layers in the inside of colony were determined and measured. Furthermore, the relationship between epiphytic condition and the thickness of the pure and mixed colonies was discussed taking account of ecological significances of these structural features.

key words: moss, rhizoids, cyanobacteria, Yukidori Valley, herbarium specimens

Introduction

The moss vegetation growing in harsh environments in the Antarctic is known to have growth-form such as turf, cushion, carpet and hummock (Gimingham and Birse, 1957; Gimingham and Smith, 1970; Longton, 1967). Longton (1967) and Gimingham and Smith (1970) classified moss vegetation in Antarctic peninsula into four sub-formations including cushion (*Andreaea*), turf (*Dicranum*, *Polytrichum*), carpet (*Calliergon*, *Sanionia*), hummock (*Brachytheciumm*, *Bryum*, *Pohlia*, *Tortula*). Longton (1973) classified the vegetation at coastal sites near McMurdo Station into four subformation and established short moss turf and cushion subformation for moss vegetation. Nakanishi (1977) and Kanda (1986a, b) included moss vegetation in the Syowa Station area into the short moss turf and cushion subformation (nine sociations). Kanda (1987) described phytosociological aspects of the moss vegetation recognizing seven sociations in the Yukidori Valley, Langhovde.

However, almost of ecological works concerning with the growth-form or the classification of vegetation such as mentioned above have been carried out by external appearance of the colony. Furthermore, the concept of the growth-form of mosses in the

†Present address: National Institute of Polar Research, Kaga 1-chome, Itabashi-ku, Tokyo 173-8515.

Antarctica is unclear. We consider that it is necessary to know how the structure in the vertical cross-section of moss colony affects to the growth-form, how the growth-form is affected to the vegetation type, and how the relationships between species and the growth-form is.

The aim of this study is to know the structures of moss colony such as the specific composition, the gross thickness, the active zone and the decomposed zone, and the interaction with epiphytic organisms as cyanobacteria or imperfect lichen, colony type, etc. in the vertical cross-section of moss colony. In the present study, we used the herbarium specimens which were collected in the Yukidori Valley (Fig. 1, Fig. 2), Langhovde near Syowa Station, East Antarctica. It is one of the aims of this study whether the ecological data collected from the herbarium specimens will available or not for subsequent vegetation studies and field work of the Antarctic.

Study area and methods

The study area is approximately 3 km^2 of the Yukidori Valley (69°15′S, 39°46′E) where has been designed as a Site of Special Scientific Interest (SSSI) in 1986 and managed as Antarctic Special Protected Area (ASPA) in 2000 based upon the regulation of the Antarctic Treaty. One of the aim of the designation is to assess the changes to the structure and composition of the terrestrial vegetation, in particular the moss and lichen banks (Kanda and Inoue, 1994). We have collected randomly samples from moss vegetation at the upper (120–170 m in asl), the middle (50–120 m in asl) and the lower (0–50 m in asl) part of stream along the Yukidori Valley in 1989 (Table 1). All samples used here are collected in condition of the vertical cross-section. About one hundred moss samples were collected in the valley, which have been housed as a model case of the structure of moss colony in the herbarium (NIPR) of the National Institute of Polar Research, Tokyo. These specimens were determined structural features such as specific composition, thickness of colony, and differentiation of green, brown and decomposed parts, and were categorized into some colony types (Table 1). As shown in Fig. 3, the moss colony is generally composed of two parts, namely active green zone and decomposed zone. The physiologically active zone includes the surface green shoot and the brown shoot at the lower part (the main part consisted of a bundle of stems and branches and leaves or rhizoids attached with shoots), and the decomposed zone (crumbling stems, branches, leaves, rhizoids mixed in sandy soil, or humus-rich soil) occupied the basal part. The thickness of each zone was measured in the maximum and minimum part in the cross-section of moss colony.

Results

The structure pattern of the moss colony in the Yukidori Valley was shown in Fig. 4. The samples were categorized into two groups, namely pure colony and mixed colony. *Ceratodon purpureus* and *Bryum pseudotriquetrum* form themselves readily pure colony, and *Pottia heimii* and *Grimmia lawiana* also do it. The mixed colony was also divided into two-species and three-species ones. Two-species mixed colony composing of *Bryum pseudotriquetrum* and *Ceratodon purpureus* is the most popular case, but *Pottia heimii*,

Fig. 1. The moss vegetation in Yukidori Valley, Langhovde, East Antarctica.

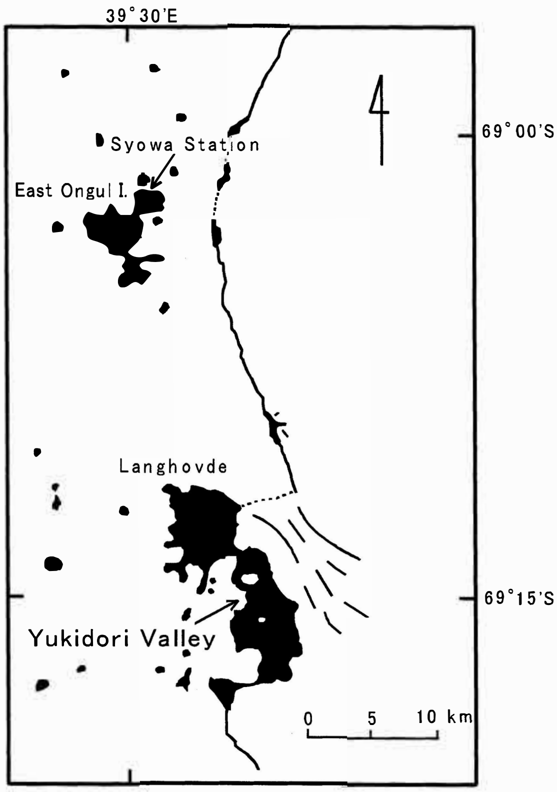

Fig. 2. The vicinity of Syowa Station and Yukidori Valley, Langhovde.

Table 1. Synthetic data related to moss colonies in the Yukidori Valley, Langhovde.

No.	Sample No.	Lo	A.Z.(mm)		D.Z.(mm)		G.T.(mm)		R.L.	Epiphytic Organisms			Species	Colony
			MA	MI	MA	MI	MA	MI	No.	C.	I.L.	L.		Type
1	A-1.1	U	7	2	12	10	19	12	8	#	#		B.p., C.p.	III
2	A-1.2	U	10	7	20	4	30	11	7	#	#		B.p., C.p.	III
3	A-2.1	U	7	5	6	6	13	11	8	#	#		B.p., C.p.	III
4	A-3.1	U	11	7	13	8	24	15	10	#	#		B.p., C.p.	III
5	A-3.2	U	11	10	12	11	23	21	10	#	#		B.p., C.p.	III
6	B-1	U	5	4	10	6	15	10	0	#	#		C.p.	I
7	B-2	U	5	5	20	17	25	22	0		#		C.p.	I
8	C-1	U	10	10	3	2	13	12	0	#			B.p.	II
9	C-2	U	8	6	8	6	16	12	8	#	#		B.p.	II
10	C-3	U	4	2	15	5	19	7	2	#			B.p.	II
11	C-4	U	8	6	5	2	13	8	0	#			B.a., C.p.	II
12	D-1	U	2	2	12	7	14	9	15				B.p.	III
13	D-2	U	35	30	20	10	55	40	15	#			B.p.	I
14	D-2.1	U	40	30	20	15	60	45	15	#			B.p.	II
15	D-2.2	U	40	30	20	15	60	45	15	#			B.p.	I
16	D-2.3	U	6	2	10	8	16	10	15	#			B.p.	II
17	D-3.1	U	33	21	27	15	60	36	15	#			B.p.	III
18	D-3.2	U	45	28	23	0	68	28	15				B.p.	III
19	D-4.1	U	19	9	4	3	23	12	7	#			B.p.	III
20	D-4.2	U	20	17	33	22	53	39	5				B.p.	III
21	D-4.3	U	11	4	66	15	77	19	6	#			B.p.	III
22	D-4.4	U	1	1	24	12	25	13	0				C.p.	I
23	D-4.5	U	9	4	14	9	23	13	0	#		#	B.p.	I
24	D-5.1	U	28	24	34	7	62	31	7	#			B.p., C.p.	III
25	D-5.2	U	30	16	41	22	71	38	10	#			B.p.	III
26	15.1	U	2	2	24	6	26	8	0				C.p., G.l.	II
27	15.2	U	40	30	22	7	62	37	0				B.p., C.p.	II
28	15.3	U	3	2	11	11	14	13	0				B.p.	I
29	15.4	U	2	2	28	6	30	8	0				C.p., G.l.	II
30	15.5	U	2	2	10	5	12	7	0				G.l.	II
31	16.1	U	10	2	12	6	22	8	8	#			B.p.	II
32	16.2	U	2	2	4	3	6	5	0				B.p.	III
33	16.3	U	2	2	8	4	10	6	0	#			C.p.	III
34	16.4	U	10	2	24	10	34	12	0				C.p.	III
35	21	U	4	3	13	5	17	8	0				B.p.	I
36	22	U	10	7	41	22	51	29	4				B.p.	II
37	24	U	23	10	34	19	57	29	10				B.p.	I
38	25.1	U	12	10	14	12	26	22	5				B.p.	I
39	25.2	U	9	8	12	8	21	16	7				B.p.	I
40	26.1	U	16	1	25	15	41	16	0	#			C.p.	III
41	26.2	U	23	17	29	21	52	38	0	#			C.p.	III
42	E-1	M	3	2	14	6	17	8	0	#	#		C.p.	I
43	E-2.1	M	25	9	25	22	50	31	10				C.p.	II
44	E-2.2	M	32	7	20	12	52	19	10				C.p.	II
45	F1	M	1	1	13	12	14	13	10				B.p.	III
46	F2	M	15	1	35	14	50	15	10				B.p.	III
47	F-1.1	M	5	0	17	11	22	11	3	#			B.p.	I
48	F-1.2	M	4	2	10	8	14	10	2	#			B.p.	I
49	F-1.3	M	5	3	25	13	30	16	3	#	#		B.p.	I
50	G1	M	6	3	18	9	24	12	3	#			B.p.	I

Lo.: Locality (U: Upper stream, M: Middle stream, L: Lower stream), A.Z. = Active Zone, D.Z. = Decomposed Zone, G.T. = Gross thickness (the sum A.Z. and D.Z), MA = in the maximum part of the vertical cross-section of the colony, MI = in the minimum, R.L. = Rhizoidal Layers, Epiphytic Organisms: C.; Cyanobacteria (mainly *Nostoc* spp.), I.L.; Imperfect Lichen (*Lepraria* spp.), L.: Lichen, Species: B.p.; *Bryum pseudotriquetrum*, B.a.; *Bryum argenteum*, C.p.; *Ceratodon purpureus*, P.h.; *Pottia heimii*, G.l.; *Grimmia lawiana*, Colony type: see Fig. 4.

Table 1. (Continued).

No.	Sample No.	Lo	A.Z.(mm)		D.Z.(mm)		G.T.(mm)		R.L. No.	Epiphytic Organisms			Species	Colony Type
			MA	MI	MA	MI	MA	MI		C.	I.L.	L		
51	Auf.3	M	8	4	10	5	18	9	4	#		#	B.p.	II
52	Auf.4	M	19	5	10	6	29	11	4	#		#	B.p., P.h.	II
53	Auf.6	M	6	5	22	5	28	10	5			#	P.h.	I
54	Auf.7	M	7	4	5	4	12	8	5	#			B.p.	II
55	Auf.7.1	M	21	17	4	4	25	21	4			#	B.p.	II
56	Auf.10	M	6	3	37	16	43	19	7	#	#	#	B.p.	II
57	Auf.11.1	M	12	3	13	4	25	7	3				B.p.	II
58	Auf.11.2	M	4	2	9	4	13	6	3				B.p., C.p.	II
59	Auf.14	M	12	9	8	12	20	21	2		#	#	B.p., C.p.	II
60	Auf.18.1	M	7	4	9	8	16	12	0	#			B.p., C.p.	II
61	Auf.18.2	M	9	6	6	6	15	12	0	#			B.a, B.p, C.p.	II
62	Auf.20	M	6	6	15	9	21	15	0				B.a., B.p.	II
63	Auf.24.1	M	16	4	8	7	24	11	5				B.a.,B.p.	II
64	Auf.24.2	M	17	7	11	9	29	16	0				B.a.,B.p.	II
65	Auf.25	M	7	5	23	15	30	20	0				B.a., B.p.	II
66	Auf.29	M	14	10	15	7	29	17	0				B.a., B.p.	II
67	0.1	M	7	2	32	11	39	13	3		#	#	C.p.	II
68	0.2	M	20	20	17	10	37	30	5	#			B.a., B.p.	II
69	0.3	M	5	1	17	7	22	8	0	#			B.a., B.p.	II
70	8.1	M	20	15	20	5	40	20	0				B.p.	II
71	8.2	M	25	5	20	2	45	7	0		#		B.p.	II
72	9	M	20	12	17	5	37	17	0	#			B.p.	II
73	10.1	M	1	1	2	1	3	2	0				B.p.	I
74	10.2	M	2	1	7	7	9	8	0		#		B.p., C.p.	II
75	10.3	M	18	4	13	10	31	14	6				C.p.	II
76	10.4	M	20	5	15	10	35	15	0				C.p.	II
77	10.5	M	15	4	17	10	32	14	5				B.p., C.p.	II
78	11.1	M	2	1	4	2	6	3	0	#			B.p.	I
79	11.2	M	5	0	7	5	12	5	0	#			C.p.	II
80	11.3	M	10	7	10	4	20	11	6				B.p.	I
81	12.1	M	16	2	22	6	38	8	0				C.p.	II
82	12.2	M	1	1	12	7	13	8	0				B.p.	I
83	12.3	M	30	0	10	10	40	10	0		#		B.p., C.p.	III
84	12.4	M	5	5	45	35	50	40	10				B.p., C.p.	I
85	12.5	M	6	4	10	8	16	12	10	#			B.p.	II
86	13	M	15	5	15	5	30	10	0	#			B.p., C.p.	II
87	14.1	M	4	2	7	6	11	8	5	#	#		B.p.	I
88	14.2	M	1	1	1	0	2	1	0			#	C.p.	I
89	1	L	20	10	8	0	28	10	0	#			B.p.	I
90	2	L	10	5	7	3	17	8	5	#			B.p.	II
91	3.1	L	42	3	10	5	52	8	0	#			B.p.	II
92	3.2	L	40	30	10	6	50	36	0	#			B.p.	I
93	4.1	L	5	1	10	8	15	9	0	#	#		C.p.	II
94	4.2	L	58	30	10	8	68	38	0				C.p.	III
95	4.3	L	50	28	10	5	60	33	0				C.p.	III
96	4.4	L	40	40	15	5	55	45	0	#			C.p.	II
97	5.1	L	20	20	28	2	48	22	0	#			B.p.	I
98	5.2	L	32	30	12	2	44	32	5				B.p., C.p.	II
99	5.3	L	20	15	10	5	30	20	0	#			B.p., C.p.	II
100	5.4	L	25	10	7	4	32	14	0				B.p., C.p.	II
101	6.1	L	14	10	16	6	30	16	7				B.p.	I
102	6.2	L	25	10	10	5	35	15	8	#			B.p.	I
103	6.3	L	25	18	7	4	32	22	8	#			B.p.	II
104	6.4	L	3	1	22	15	25	16	0				B.p.	II
105	7	L	20	17	5	2	25	19	0	#			B.p.	III
	Mean		14.7	8.4	16	8.3	30.7	16.7	3.8					

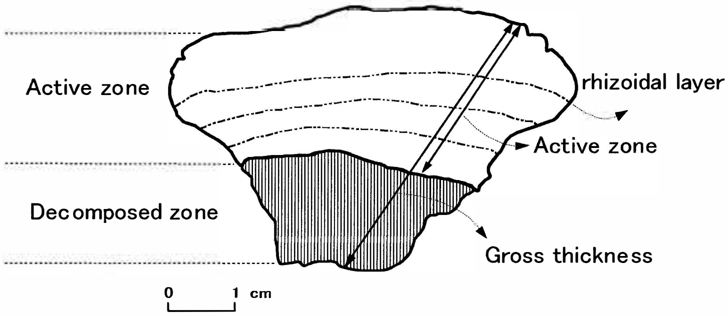

Fig. 3. The structure of moss colony in vertical cross-section.
The physiologically active zone includes the surface green shoot and brown shoot at the lower part, and the decomposed zone occupies the basal part. The rhizoidal layers are recognized at the active zone. The gross thickness is treated as the sum of the active zone and decomposed zone.

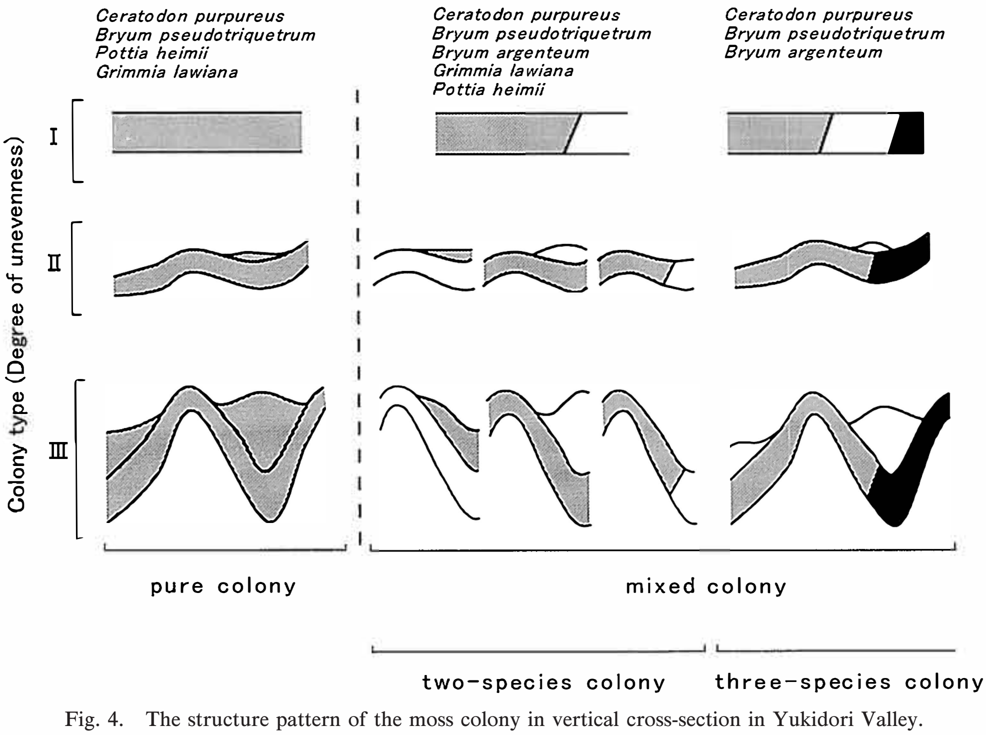

Fig. 4. The structure pattern of the moss colony in vertical cross-section in Yukidori Valley.
Colony type I: flat, II: wave, III: strongly uneven.

Bryum argenteum and *Grimmia lawiana* sometimes exist together with *Ceratodon purpureus* or *Bryum pseudotriquetrum*. As a result, the moss colony in the Yukidori Valley was categorized into three patterns of species composition and three patterns of the roughness; flat (colony type I), wave (colony type II) and strongly uneven (colony type III) and were totally categorized into six colony types. Figure 5(A) shows the pure

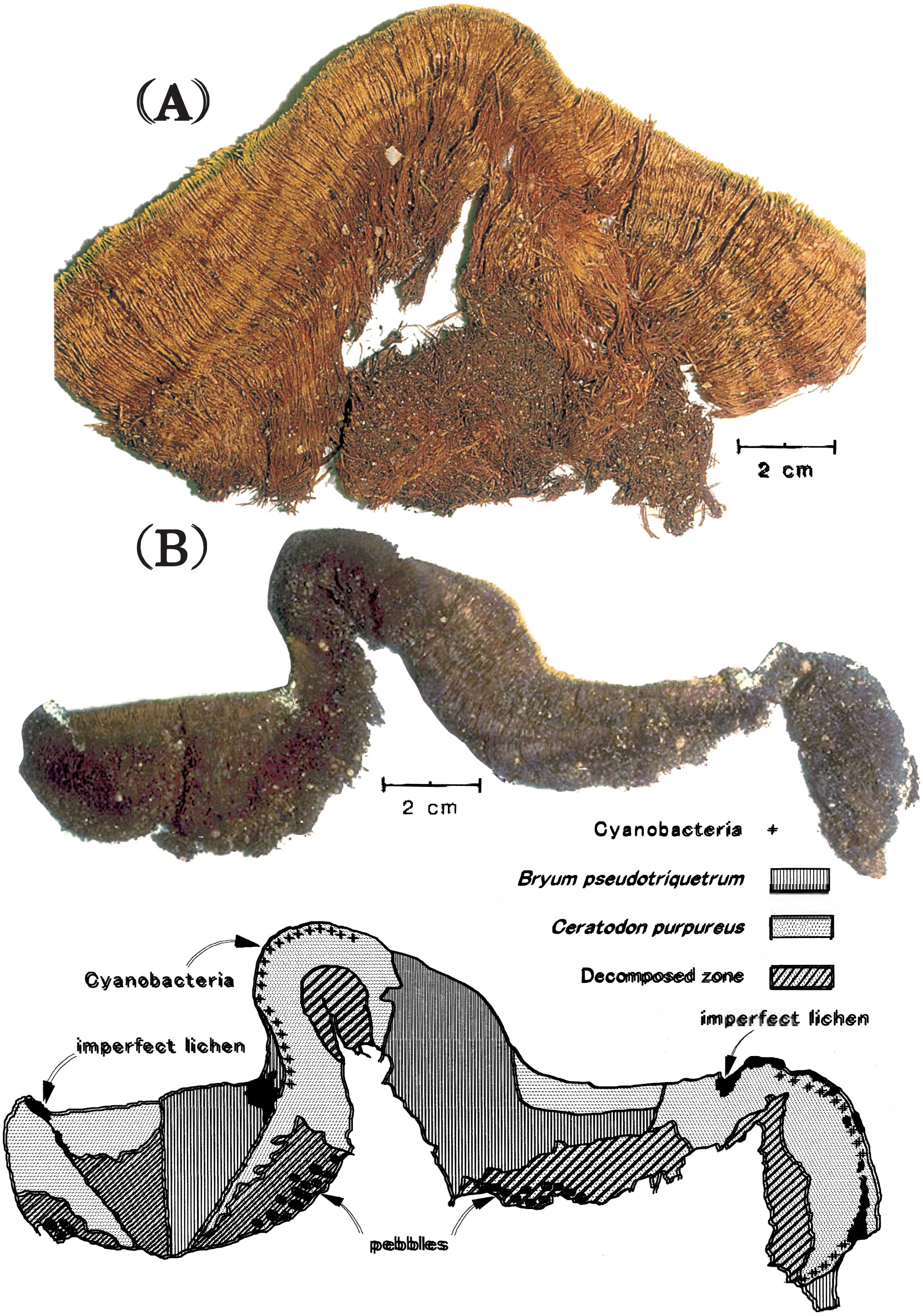

Fig. 5. (A) Pure colony of *Bryum pseudotriquetrum*.
(based on the specimens, D-3)
(B) Mixed colony of *Ceratodon purpureus* and *Bryum pseudotriquetrum*.
(based on the specimens, A-2.1)

colony of *Bryum pseudotriquetrum* (colony type III) which has approximately 15 clear rhizoidal layers. According to the rhizoidal layers and shoot arrangement, both flanks of this colony are considered to have developed after the growth of the central part in the moist condition at the hollow part. Figure 5(B) shows the sample (colony type III) of the two-species mixed colony of *Ceratodon purpureus* and *Bryum pseudotriquetrum*. This colony is composed of *Ceratodon purpureus* at both parts of the foot and at the half of the convex part. While *Bryum pseudotriquetrum* occupied at the other half of the convex part. Parts suffering from algae (mainly cyanobacteria) and imperfect lichens (*Lepraria* spp.) are limited to the surface and inside of the colony of *Ceratodon purpureus*. Along the development of the colony, the extent of the unevenness of the surface seems to vary owing to the different microclimate conditions on/in the colony. It is likely that *Bryum pseudotriquetrum* recovers at the hollow and moist part of the *Ceratodon purpureus* surface, or of the surface with a weak activity after any fungal or algal infection, though *Bryum pseudotriquetrum* was rarely found inside of the *Ceratodon purpureus* colony. In the same way, *Bryum argenteum* is introduced on the *Bryum pseudotriquetum* colony and *Ceratodon purpureus* on the *Grimmia lawiana* colony. The extent of unevenness of the colony surface becomes stronger in thicker colony. The growth rates of constituent mosses are probably different according to microclimates such as temperature, water content, or light, so on caused by degree of roughness of the surface. Three-species mixed colony was rarely found in only one sample composed of *Ceratodon purpureus*, *Bryum pseudotriquetrum* and *B. argenteum* in the Yukidori Valley.

Table 1 shows the synthetic data related to the moss colony. Mean thicknesses of active zone (A.Z.), decomposed zone (D.Z.) and gross thickness (G.T.) were 14.7 mm, 16.0 mm, 30.7 mm in the maximum part (MA) of the cross-section, respectively. Similarly, they were 8.4 mm, 8.3 mm and 16.7 mm in the minimum part (MI), respectively. Figure 6 shows the relationships between gross thickness and thickness of active zone with special reference to epiphytic condition of colony surface. The mean gross thickness is 33.8 mm, 31.2 mm and 28.5 mm in *Ceratodon purpureus*, *Bryum pseudotriquetrum* and mixed colony, respectively. In the pure colony of *Ceratodon purpureus*, 'no epiphyte' is increasing with the increase of the thickness (Fig. 6, A). While the pure colony of *Bryum pseudotriquetrum* have partially epiphytes (shown as 'partial' in the figure) and the epiphytes were found even in the thick colony over 70 mm (Fig. 6, B). The thickest colony of 77 mm was covered by epiphytes throughout the surface (shown as 'all' in the figure), but the thickness in active zone was only 11 mm. The thickness of mixed colony was various and the mean value is not high showing 28.5 mm (Fig. 6, C). In conclusion, none epiphytes occurred in thicker *Ceratodon purpureus* colony, but partial epiphytes in the pure colony of *Bryum pseudotriquetrum* and the mixed colony were recognized in various ranges of thickness.

The occurrence of the rhizoidal layers was recognized in 28% of pure colonies of *Ceratodon purpureus* and in 64% of pure colonies of *Bryum pseudotriquetrum*. The bulk of the occurrence of rhizoidal layers seems to be different in specific level and sites collected dsamples. The relationships between the number of rhizoidal layers and the gross thickness were shown in Table 1 and Fig. 7. In *Ceratodon purpureus* it shows that the number of rhizoidal layers is comparatively large (maximum 10) despite thinner

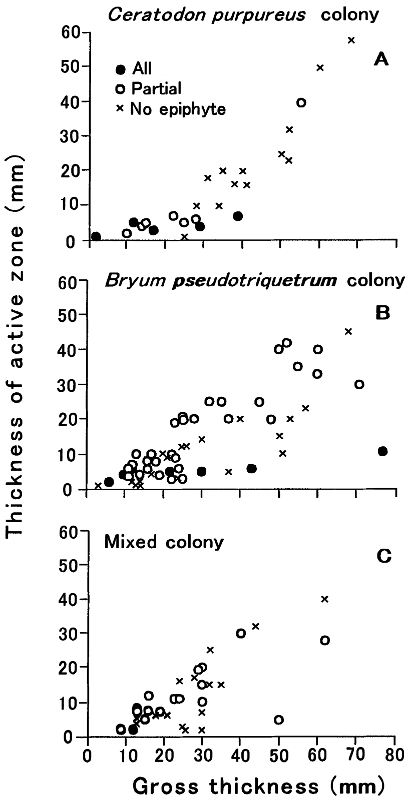

Fig. 6. Relationships between the gross thickness and the active zone in thickness with special reference to epiphytic condition on colony surface.

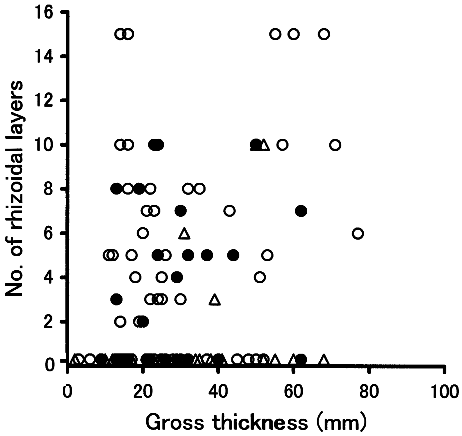

Fig. 7. Relationship between the number of rhizoidal layers and the thickness of gross thickness.
○ *Bryum pseudotriquetrum* colony;
△ *Ceratodon purpureus* colony;
● Mixed colony.

colony. In case of *Bryum pseudotriquetrum*, the number increases along increasing gross thickness (maximum 15).

Discussion

The structure of the moss colony in vertical cross-section was analyzed and some morphological factors were measured using the herbarium specimens. In conclusion, the moss vegetation in the Yukidori Valley was categorized into six patterns and discussed on the relationships among the gross thickness, degree of epiphytic organisms on the moss surface and rhizoid layers. These morphological factors of the moss colony were not paid attention to the field survey. In particular, they will become significant characters in respect of the categonization of growth-form and vegetation ecology. Gimingham (1967) insisted it particularly important in mosses to take account into not only the properties of the individual shoots in respect of water uptake and loss, but effect of the way in which the shoots are grouped in together in the colony: that is the growth-form of the moss. Therefore, it is also important to know the structure of colony, and the relationships between the growth-form of mosses and environmental factors (Gimingham and Smith, 1971; Smith, 1972; Longton and Holdgate, 1979).

There is a little study on the colony structure in vertical cross section. Imura *et al*. (1994) investigated the morphological structure of the colony of *Bryum argenteum* and *B. pseudotriquetrum* in the Syowa Station area and they classified the moss colonies into three structural patterns by the arrangement of the two species as follows: 1) *B. argenteum* colony occurs on the top of the *B. pseudotriquetrum* colony, 2) the former species colony overgrows throughout the latter species colony, and 3) the former species colony grows partially burring under the hollow surface of the latter species colony. Nakatsubo and Ohtani (1992) examined the moss colonies in vertical cross-section in King George Island, South Shetland Islands, and examined the interaction between two species, *Sanionia uncinata* and *Bryum pseudotriquetrum*. They categorized the moss colony into three patterns, that is *Bryum pseudotriquetrum* covered with *Sanionia uncinata*, *Sanionia uncinata* covered with *Bryum pseudotriquetrum*, and both species coexisted without covering each other. The interaction results in variation of the colony structure rater than a directional change in the successional process shown in Longton and Holdgate (1979).

Okitsu *et al*. (2003) set up an interesting hypothesis on the relationship between the micro-relief and the moss vegetation in the Syowa Station area. The authors consider that the mixed colony composed of *Ceratodon purpureus* and *Bryum pseudotriquetrum* is established by not only mutual interaction of both species, but also by covering with sand and epiphytes such as cyanobacteria. They also suggested that the epiphytes are more abundant in the *Ceratodon purpureus* colony than in the *Bryum pseudotriquetrum* colony, and that *Bryum pseudotriquetrum* colonizes first at a moist site covered with sand, and afterward *Ceratodon purpureus* invades to *Bryum pseudotriquetrum* colony. Finally *Ceratodon purpureus* with physiological characteristic of dry tolerance is infected with cyanobacteria and the colony breaks down by strong wind or snowing in winter season. They concluded that both colonies are considered to maintain each niche by a cyclic succession. However, there is no reliable evidence that *Ceratodon purpureus* invaded and established on the *Bryum pseudotriquetrum* colony subsequently. In the present study, the hollow part of *Ceratodon purpureus* is mostly covered with *Bryum pseudotriquetrum* and the surface epiphyte on the thicker colony of *Ceratodon purpureus* is rather fewer than *Bryum pseudotriquetrum*. This problem should be discussed based upon more detail data. The relationship in the mixed colony was similar to pure colony in *Ceratodon purpureus.*

Regarding the rhizoidal layers in moss colony, Matsuda (1968) observed some layers composed of rhizoids or cyanobacteria in vertical cross-section of the moss colony and indicated the rhizoidal layers to suggest yearly growth as tree rings. Then he reported a moss colony with over 100 years old. Similarly, Seppelt and Ashton (1978) counted 40–50 years old in the samples from Mawson Station area, Mac. Robertson Coast. However, in the present study whether the rhizoidal layer plays the roll of tree rings was not able to clear significantly yet.

References

Gimingham, C.H. (1967): Quantitative community analysis and bryophyte ecology on Signy Island. Philos. Trans. R. Soc., London, Ser. B, Biol. Sci., **252**, 251–259.

Gimingham, C.H. and Birse, E.M. (1957): Ecological studies on growth-form in bryophytes: I. Correlations between growth-form and habitat. J. Ecol., **45**, 533–545.

Gimingham, C.H. and Smith, R.I.L. (1970): Bryophyte and lichen communities in the maritime Antarctic. Antarctic Ecology, Vol. 2, ed. by M.W. Holdgate. New York, Academic Press, 752–785.

Gimingham, C.H. and Smith, R.I.L. (1971): Growth form and water relations of mosses in the maritime Antarctic. Br. Antarct. Surv. Bull., **25**, 1–21.

Imura, S., Higuchi, M., Kanda, H. and Iwatsuki, Z. (1994): Structure of moss colonies in the Syowa Station area, Antarctica. Proc. NIPR Symp. Polar Biol., **7**, 232–236.

Kanda, H. (1986a): Seasonal change of some environmental factors around the moss vegetation near Syowa Station, East Antarctica. Mem. Natl Inst. Polar Res., Ser. E, **37**, 17–16.

Kanda, H. (1986b): Moss communities in some ice-free areas along Sôya Coast, East Antarctica. Mem. Natl Inst. Polar Res., Spec. Issue, **44**, 229–240.

Kanda, H. (1987): Moss vegetation in the Yukidori valley, langhovde, East Anytarctica. Papers on Plant Ecology and Taxonomy to the Memory of Dr. Satoshi Nakanishi, Kobe Geobotanical Society,198–204.

Kanda, H. and Inoue, M. (1994): Ecological monitoring of moss and lichen vegetation in the Syowa Station area, Antarctica. Proc. NIPR Symp. Polar Biol., **7**, 221–231.

Longton, R.E. (1967): Vegetation in the maritime Antarctic. Philos. Trans. R. Soc., London, Ser. B, Biol. Sci., **252**, 213–235.

Longton, R.E. (1973): Classification of terrestrial vegetation near McMurdo Sound, continental Antarctica. Can. J. Bot., **51**, 2339–2346.

Longton, R.E. and Holdgate, M.W. (1979): The South Sandwich Islands: IV. Botany. Br. Antarct. Surv. Sci. Rep., **94**, 1–53.

Matsuda, T. (1968): Ecological study of the moss community and microorganisms in the vicinity of Syowa Station, Antarctica. Jap. Antarct. Res. Exp., Sci. Rep., Ser. E, **29**, 1–58.

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

Nakatsubo, T. and Ohtani, S. (1992): Notes on the structure of moss colonies composed of two species on King George Island, the South Shetland Islands. Nankyoku Shiryô (Antarct. Rec.), **36**, 285–293.

Okitsu, S., Imura, S. and Ayukawa, E. (2003): Structure and dynamics of the *Ceratodon purpureus-Bryum pseudotriquetrum* community in the Yukidori Valley, Langhovde, continental Antarctica. Polar Biosci., **16**, 49–60.

Seppelt, R.D. and Ashton, D.E. (1978): Studies on the ecology of vegetation at Mawson Station, Antarctica. Aust. J. Ecol., **3**, 373–388.

Smith, R.I.L. (1972): Vegetation of the South Orkney Islands with particular reference to Signy Island. Br. Antarct. Surv. Sci. Rep., **68**, 1–124.