Mem. Natl Inst. Polar Res., Spec. Issue, 44, 209-219, 1986

EPIPHYTIC ALGAE ON MOSSES IN THE VICINITY OF SYOWA STATION, ANTARCTICA

Shuji OHTANI

National Institute of Polar Research, 9-10, Kaga 1-chome, Itabashi-ku, Tokyo 173

Abstract: Species composition and abundance of epiphytic algae on mosses growing in the vicinity of Syowa Station were investigated. Moss samples were collected from three localities, East Ongul Island, Mukai Rocks and Langhovde. The epiphytic algae identified in these samples were 23 species in total, 16 of blue-green algae, 4 of diatoms, 3 of green algae. Blue-green algae were more frequently found among these epiphytic algae on mosses in each locality. Among the three localities, Langhovde was the most favorable habitat for the epiphytic algae, as well as the moss vegetation. The epiphytic algal flora on mosses turned out to be poorer than submerged algal flora in the same or similar localities in the Antarctic.

1. Introduction

Mosses predominate in the Antarctic vegetation and some species of algae on moss colonies are reported from various localities of the maritime and continental Antarctic. BROADY (1977, 1979a, 1979b) reported extensive ecological studies of the algae on mosses at Signy Island, the maritime Antarctic. HICKMAN and VITT (1973) studied the diatom flora on mosses at Campbell Island, the sub-Antarctic. In the continental Antarctic, FUKUSHIMA (1959) and AKIYAMA (1974) briefly described the algal flora on mosses in the vicinity of Syowa Station and BROADY (1982a) studied the ecology of algae on mosses at Mawson Rock. However, little information has been accumulated concerning the algae on mosses from other localities of the continental Antarctic. In the present study, the algae on mosses in the vicinity of Syowa Station were investigated.

2. Materials and Methods

The moss samples used in this study were collected by Dr. H. KANDA who was one of the wintering members of the 24th Japanese Antarctic Research Expedition, 1983–1984 from Naka-no-seto Strait in East Ongul Island, Mukai Rocks and Yukidori Valley in Langhovde. The localities of sampling sites are shown in Fig. 1. Seven moss samples from East Ongul Island, five from Mukai Rocks and nineteen from Langhovde were used for this study (Table 1). All of these samples were stored at −20°C in a refrigerator for about one year. For making a microscopic preparation, a small chip (about 10 mm^2) of a moss sample was taken after defreezing, and algae, if present, were scraped off from the chip by a needle under the binocular. Preparations were observed in living condition. When a moss sample was not homogeneous in color or in the composition of moss species, a preparation was made each for different color parts or different species. The number of preparation is shown in Table 1. Microscopic illustrations

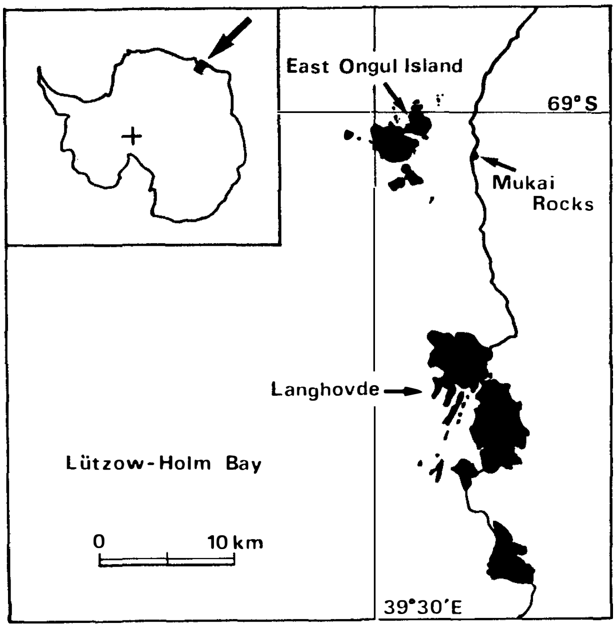

Fig. 1. Map showing the sampling sites of mosses.

were prepared using a camera lucida attachment.

3. Localities and Moss Vegetation

Naka-no-seto Strait is located on East Ongul Island in Lützow-Holm Bay in Antarctica (Lat. 69°S, Long. 39°35′E). Only two moss species, *Ceratodon purpureus* (HEDW.) BRID. and *Bryum pseudotriquetrum* (HEDW.) GAERTN., MEYER et SCHERB. grew on this Island. Most of the moss vegetations were small, and usually brown or blackish brown in color. Snow drift formed by the prevailing wind had supplied these vegetations with water.

Mukai Rocks is located in the north of the Sôya Coast. Moss and lichen vegetations which were often mixed with each other occurred on the rock surface or on soil at the foot of boulder in the moraine zone. Moss species were *Ceratodon purpureus* (HEDW.) BRID., *Bryum pseudotriquetrum* (HEDW.) GAERTN., MEYER et SCHERB. and *Grimmia lawiana* J. H. WILLIS. The last one was the dominant species in this region. The water available for the vegetation was supplied from only snow drift as at Naka-no-seto Strait.

The Yukidori Valley is located in the southern part of Langhovde, which is about 30 km south of Syowa Station. The valley is approximately 3 km in length, embracing the ponds and the streams which supply much water available for the vegetation along the valley during the summer season. A number of snow petrels (*Pagodroma nivea*) nest at the upper part of this valley. Moss and lichen vegetations developed well near the streams, the ponds and the bird nests. The large-scaled moss vegetation extended along the valley and the thickness of moss colony sometimes attained to 9 cm (MATSUDA, 1964; KANDA, 1981). *Ceratodon purpureus* (HEDW.) BRID., *Bryum argenteum* HEDW., *B. pseudotriquetrum* (HEDW.) GAERTN., MEYER et SCHERB., *Grimmia lawiana* J.H. WILLIS, *Pottia heimii* (HEDW.) HAMPE. and *P. austrogeorgica* CARD. were distributed in this region. Well-grown greenish mosses were often mixed with brown-color mosses.

Table 1. The moss samples studied.

Sample No.	Collection date	Locality	Moss species
192	Sep. 24, 1983	Mukai Rocks	GL (1)[1]
193	Oct. 15, 1983	Naka-no-seto Strait, East Ongul Island	CP (1)
577	Sep. 23, 1983	Mukai Rocks	GL (1)
887	Jan. 19, 1984	Naka-no-seto Strait, East Ongul Island	CP (1)
890	Jan. 19, 1984	Naka-no-seto Strait, East Ongul Island	CP (1)
893	Jan. 19, 1984	Naka-no-seto Strait, East Ongul Island	CP (1)
896	Jan. 19, 1984	Naka-no-seto Strait, East Ongul Island	CP (1)
898	Jan. 19, 1984	Naka-no-seto Strait, East Ongul Island	CP (2)
899	Jan. 19, 1984	Naka-no-seto Strait, East Ongul Island	BP (1)
966	Aug. 23, 1983	Yukidori Valley, Langhovde	BA, BP, CP (1)
967	Aug. 23, 1983	Yukidori Valley, Langhovde	BA, BP (2)
970	Aug. 24, 1983	Yukidori Valley, Langhovde	BP, CP (1)
971	Aug. 24, 1983	Yukidori Valley, Langhovde	CP (2); BP, CP (1)
975	Aug. 23, 1983	Yukidori Valley, Langhovde	CP (1); BP, CP (1)
978	Aug. 24, 1983	Yukidori Valley, Langhovde	CP (1); BP, CP (1)
979	Aug. 24, 1983	Yukidori Valley, Langhovde	BP, CP (2)
980	Aug. 24, 1983	Yukidori Valley, Langhovde	BP, CP (1)
984	Aug. 24, 1983	Yukidori Valley, Langhovde	GL (2)
989	Sep. 23, 1983	Mukai Rocks	GL (2)
990	Sep. 23, 1983	Mukai Rocks	GL (2)
991	Sep. 23, 1983	Mukai Rocks	GL (1)
994	Oct. 1, 1983	Yukidori Valley, Langhovde	BP (1); CP (2); BP, CP (1)
1002	Oct. 2, 1983	Lake Yukidori, Langhovde	BP (1); CP (2)
1003	Oct. 2, 1983	Yukidori Valley, Langhovde	CP (1); BP, CP (2)
1007	Oct. 2, 1983	Yukidori Valley, Langhovde	PH (2)
1019	Oct. 2, 1983	Yukidori Valley, Langhovde	GL (2)
1021	Oct. 2, 1983	Yukidori Valley, Langhovde	BP (1)
1149	Dec. 4, 1983	Yukidori Valley, Langhovde	BP (2)
1150	Dec. 4, 1983	Yukidori Valley, Langhovde	BP (1); BP, CP (1)
1152	Dec. 4, 1983	Yukidori Valley, Langhovde	GL (2)
1153	Dec. 4, 1983	Yukidori Valley, Langhovde	BP (1); CP (1)

[1] Parentheses show the number of preparation. BA: *Bryum argenteum* HEDW.; BP: *Bryum pseudotriquetrum* (HEDW.) GAERTN., MEYER et SCHERB.; CP: *Ceratodon purpureus* (HEDW.) BRID.; GL: *Grimmia lawiana* J. H. WILLIS; PH: *Pottia heimii* (HEDW.) HAMPE.

4. Results and Discussion

Twenty-three species of epiphytic algae excluding unidentified ones were recognized in the moss samples examined. These algae were sixteen species of blue-green algae, four species of diatoms, three species of green algae (Table 2). The richness in the species composition of a preparation was compared among the localities and among the moss species (Table 3). Algae were predominantly observed among leaves and stems near the surface of moss turfs (Fig. 2a, b) and were more abundant on moribund than greenish mosses as stated by BROADY (1977, 1982a). The surface of moss turf was often completely covered with algae and new moss shoots appeared from a few millimeters below such an algae-covered top (Fig. 2c). The production of new moss shoots below algal crust has been observed also by MATSUDA (1964) and BROADY (1977, 1982a).

Table 2. The algal species on mosses in the vicinity of Syowa Station.

Species	East Ongul Isl. Naka-no-seto Strait (8)[1]	Langhovde Yukidori Valley (39)	Mukai Rocks (7)
Cyanophyceae			
Gloeocapsa magma		3	3
Gl. ralfsiana		8	
Gl. sp.		13	
Synechococcus aeruginosus	1[2]	17	2
S. maior	2	11	
Stigonema sp.		1	3
Calothrix parietina		7	
Tolypothrix sp. 1	2		
T. sp. 2		1	
Petalonema velutinum		10	1
Nostoc commune		10	
N. sp.	7	23	2
Anabaena sp.	1		
Lyngbya perelegans	1	24	
L. purpurea		10	
L. spp.		8	1
Unidentified coccoid algae		10	1
Unidentified filamentous algae	2	13	1
Chlorophyceae			
Actionotaenium cucurbita	2	18	
[3]*Cosmarium clepsydra*		1	
[3]*Oedogonium* sp.		1	
Unidentified coccoid algae	8	20	3
Unidentified filamentous algae	1	2	
Bacillariophyceae			
Hantzschia amphioxys		12	
Navicula muticopsis		16	
N. sp.		4	
Pinnularia borealis	6	27	
Unidentified alga		3	

[1] Number of preparation. [2] Frequency of occurrence in each locality.
[3] A few dead specimens were observed.

Table 3. Comparison of richness in species composition of a preparation among the three localities and among moss species.

Number of species per preparation	East Ongul Isl. Naka-no-seto Strait		Langhovde Yukidori Valley							Mukai Rocks
	BP[1]	CP	BP	CP	GL	PH	BP CP	BA BP	BA BP CP	GL
4>		6	2	1	5	2	2	1		5
4–7	1	1	3	3	1		3			2
8–11			2	5			3		1	
11<				1			3	1		

[1] Abbreviation same as Table 1.

4.1. The epiphytic algal flora in each locality

At Naka-no-seto Strait, the epiphytic algae on mosses were generally poor in quantity and number of species. The number of species was less than seven in total for the samples. *Nostoc* sp. and unidentified green algae (*cf. Chlorella* and *cf. Stichococcus*) were observed in most of the samples and were occasionally rich in quantity. While the occurrence of diatoms was rather rare and several specimens of *Pinnularia borealis* EHR. were confirmed in five moss samples.

The epiphytic algal flora on mosses at Mukai Rocks were the poorest of the three regions. The number of species was less than six and the abundance of each species was usually poor. Diatoms were never observed in any samples. Such an algal flora is similar to that found on the moss cushion (*Andreaea* sp.) in Signy Island which was subjected to the severe desiccation (BROADY, 1979b). All of the moss samples examined in this region were composed of only *Grimmia lawiana* growing on dry sandy soils. KANDA (1981) reported that habitats supporting the *Grimmia lawiana* sociation at Cape Ryûgû, the Prince Olav Coast were exposed to the strong sunshine and had scarcely received water supply. At Mukai Rocks, it is probable that much less water supply for the moss vegetation restricted the growth of epiphytic algae as well.

In the Yukidori Valley, on the contrary to the former two regions, the epiphytic algae on mosses were rather abundant. *Nostoc commune* VAUCH., *Nostoc* sp. and *Lyngbya perelegans* LEMM. became rather common in most of the moss samples. The number of species and abundance tended to be rich in the moss samples of *Bryum pseudotriquetrum* and/or *Ceratodon purpureus* which were often associated with *Bryum argenteum* and these mosses were collected along the streams, on the sides of rocks and near the sea bird nests (Table 3). On the other hand, the number of species was small in the moss samples of *Grimmia lawiana* growing on the dry sandy soils. This showed that the availability of water supply for the moss habitat seemed to largely influence the growth of the epiphytic algae as well. In addition to this, the richness of algal flora in this region may be caused by the droppings of the sea bird, topographic variation and rather rich moss vegetation.

4.2. Characteristic features of the epiphytic algal flora on mosses

In the present study, twenty-three species of algae were recognized by the examination of the moss samples in the vicinity of Syowa Station. This algal flora is poor in comparison with those of submerged or aquatic habitats. HIRANO (1979, 1983) listed 65 and 134 taxa of algae from the streams and/or the ponds in Langhovde and Skarvsnes, respectively. In addition, the scarcity of diatoms shown in the present study is remarkable. For example, only a single diatom species from Naka-no-seto Strait and five from the Yukidori Valley was identified and no diatoms were found at Mukai Rocks. The paucity of diatom species on mosses has been reported from Signy Island, the maritime Antarctic (BROADY, 1977, 1979b) and at Mawson Rock, the continental Antarctic (BROADY, 1982a). On the other hand, FUKUSHIMA (1962a, b) reported thirty-four and forty-six taxa of diatoms from ponds of Shinnan Rock and Kasumi Rock, respectively, both of which are located in the Prince Olav Coast. Furthermore, FUKUSHIMA *et al.* (1973) listed eighteen taxa of diatoms from ponds on East Ongul Island. These results may show that most diatoms are probably not resistant to the aerial or arid habitats.

In the present study, it was confirmed that blue-green algae predominated in all the samples as in the previous studies on the algal flora of the Antarctic region (HIRANO, 1979, 1983; BROADY, 1981, 1982b). However, the proportion of oscillatoriacean blue-green algae was much less than that of the aquatic habitats (HIRANO, 1979, 1983; BROADY, 1982b), while the heterocystous blue-green algae, *Nostoc commune* and *Nostoc* sp., were more common on mosses in the studied area. YAMANAKA and SATO (1977) reported that carbon and nitrogen sources in soils were scarce in the vicinity of Syowa Station.

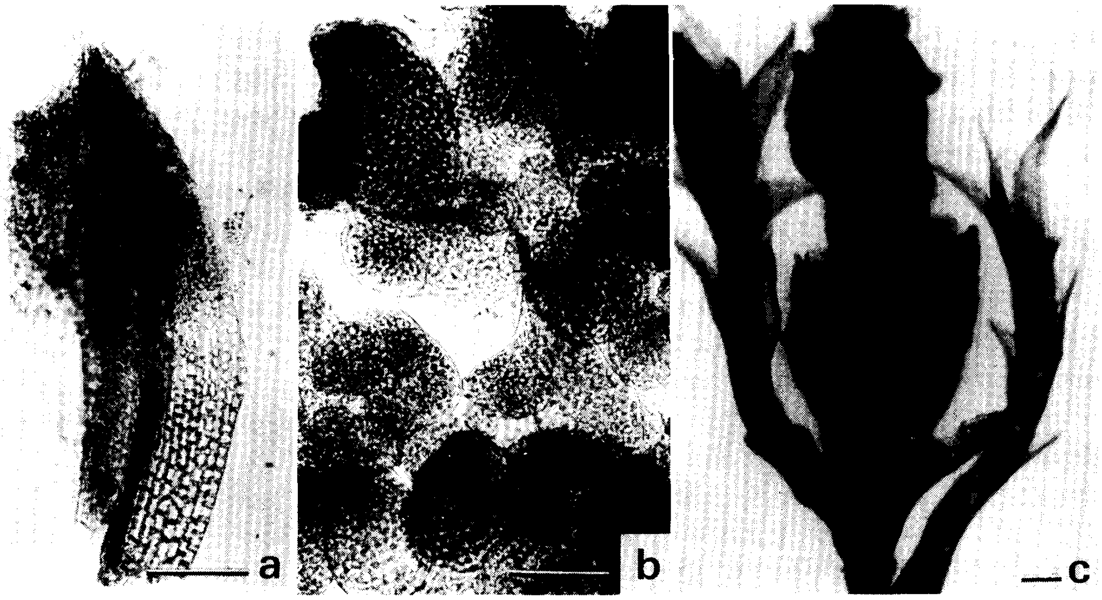

Fig. 2. a: Algae on the leaf of Grimmia lawiana. *b: Colonies of* Nostoc *sp. c: A moribound main apex with covering algal colonies and new side shoots of* Ceratodon purpureus. *Scale bar, 100 μm.*

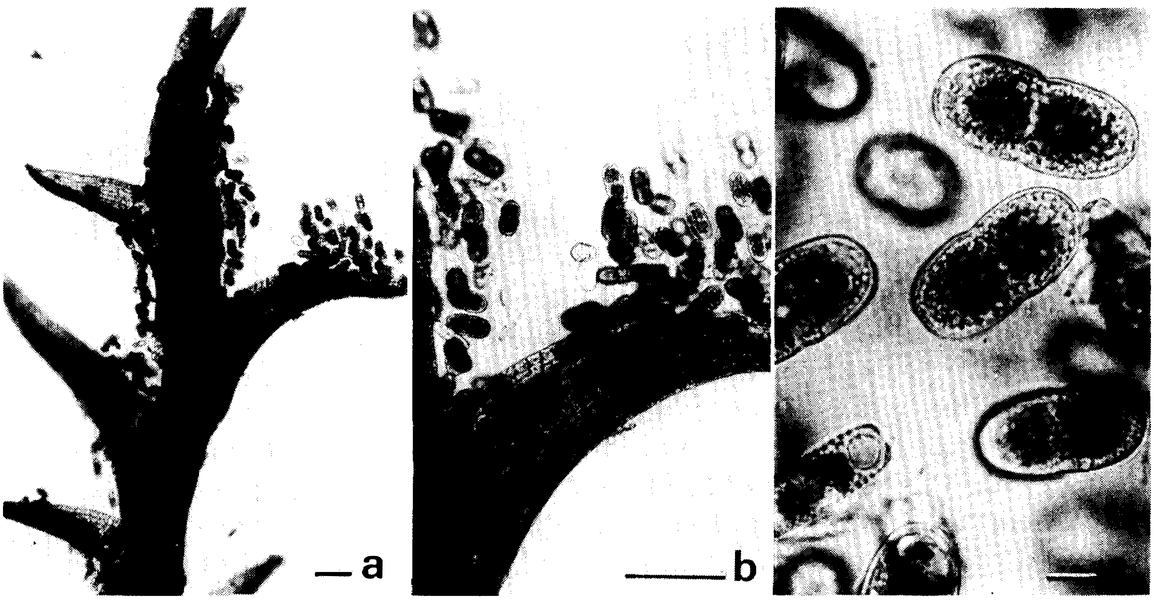

Fig. 3. a–c: Colonies of Actinotaenium cucurbita *on the stem and leaves of* Ceratodon purpureus. *Scale bar: a, b. 100 μm; c. 10 μm.*

The species of *Nostoc* could colonize favorably in such nutrient-deficient habitats by the ability to fix atmospheric nitrogen and these algae might play an important role in providing moss vegetation with nitrogen source.

HIRANO (1979) reported eleven taxa of desmids from the ponds and the streams in the Yukidori Valley, Langhovde. While in the present study, only two species, *Actinotaenium cucurbita* (BRÉB.) TEIL. (*Cosmarium cucurbita* BRÉB.) and *Cosmarium clepsydra* NORDST. were found on mosses near Syowa Station. These algae were widely distributed in the streams of the Yukidori Valley (HIRANO, 1979). *Actinotaenium cucurbita* was predominant on green parts of mosses and attached with its mucilage to the moss leaves or stems. Probably the mucilage served as a useful means to protect the alga from the arid condition (Fig. 3). *Cosmarium clepsydra*, however, rarely occurred on mosses. Only three dead specimens of *C. clepsydra* were found, that were probably carried there from a stream. From these results, *A. cucurbita* is considered to be only one desmid, so far, which can grow on the moss habitat in the vicinity of Syowa Station.

5. Enumeration of the Species

Gloeocapsa magma (BRÉB.) HOLLERBACH

Cells spherical or elliptical in shape, 4–8μm in diameter with thin non-stratified sheath, reddish-brown in color, makes irregularly shaped mass. Found in sample Nos. 970, 975, 989, 990 (Fig. 4a).

Gloeocapsa ralfsiana (HARV.) KÜTZ.

Cells spherical or elliptical in shape, 6–8μm in diameter with red-brown walls, and enclosed in a stratified thick sheath which consists of an inner pale reddish part and an outer colorless part. Colony spherical in form, 16–50μm in size. Found in sample Nos. 966, 967, 971, 994, 1002 (Fig. 4b, c).

Gloeocapsa sp.

Cells spherical or elliptical in shape, 3–7μm in diameter, with thick purple-black walls which appear to be penetrated by numerous pores. Found in sample Nos. 966, 967, 970, 971, 975, 978, 994, 1002, 1003, 1149, 1150 (Fig. 4d–f).

Synechococcus aeruginosus NÄG.

Cells blue-green, elliptical or cylindrical, 11–16μm wide, 17–41μm long. Found in sample Nos. 899, 970, 971, 978, 984, 989, 994, 1002, 1021, 1150 (Fig. 4g, h).

Synechococcus maior SCHROETER

Cells blue-green, elliptical, 17–30μm wide, 22–52μm long. Found in sample Nos. 898, 899, 967, 970, 975, 994, 1002, 1003, 1021, 1150, 1153 (Fig. 4i, j).

Calothrix parietina THURET

Filaments 8–10μm wide at base, gradually attenuate to the hairy part, trichome 6μm wide at base, 2μm at apex, slightly constricted at transverse walls, sheath yellowish brown and stratified. Cells attaining about 1/2–1 times the width. Found in sample Nos. 967, 970, 971, 975, 978, 1002, 1003 (Fig. 4m).

Petalonema velutinum (RABENH.) MIGULA

Sheath thick, stratified, yellowish brown in the old sheath, trichomes 7–9μm wide, cells 3–5μm long, filaments 23–28μm wide with irregular false branches. Found in sample Nos. 966, 967, 970, 971, 978, 980, 990, 994, 1002 (Fig. 4n).

Tolypothrix sp. 1

Trichomes blue-green 4–5μm wide, slightly constricted at transvers walls. Cells attaining about 1–2 times the width. Filaments with false branches. Found in sample Nos. 896, 898.

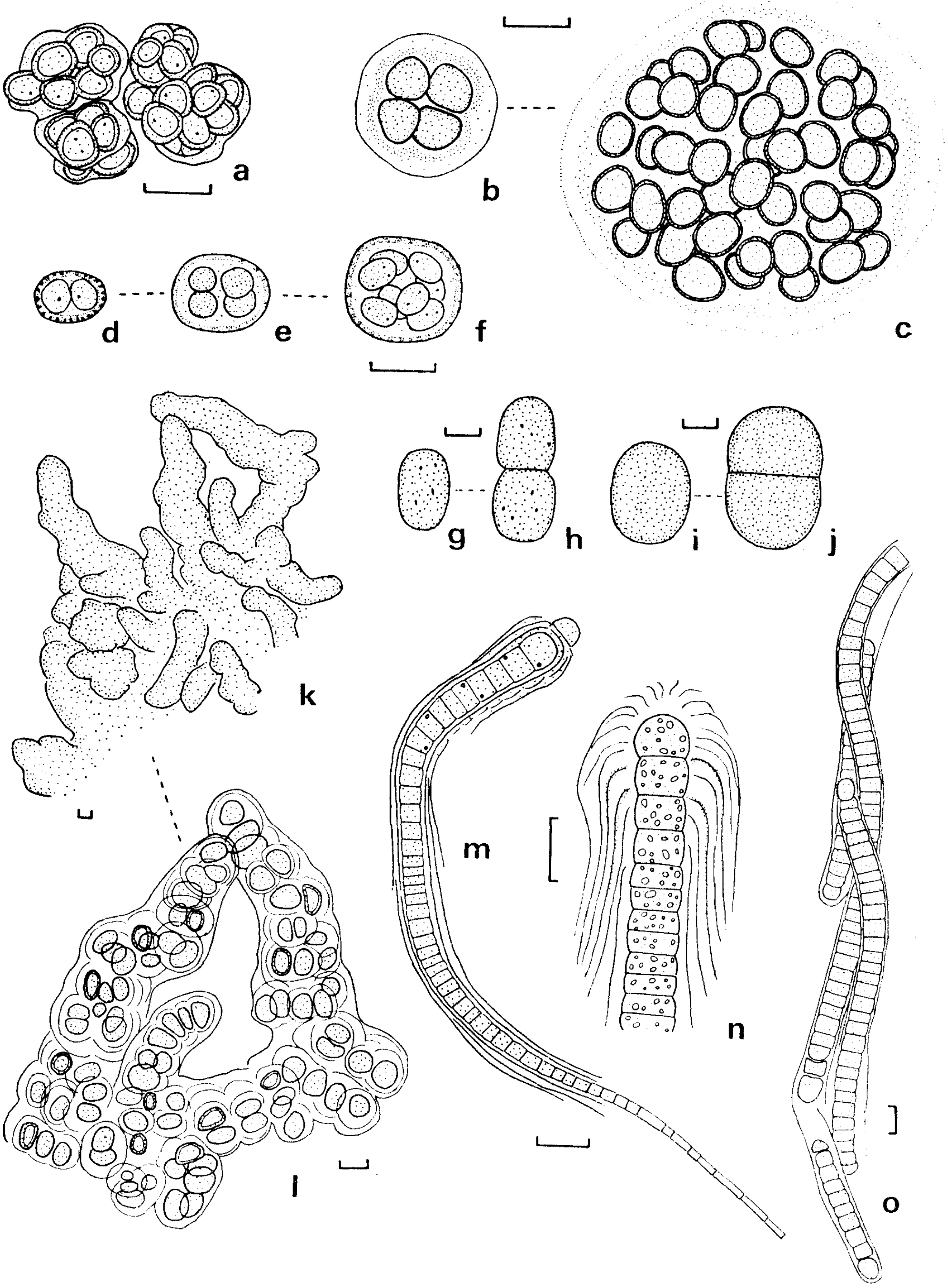

Fig. 4. *a:* Gloeocapsa magma; *b, c:* Gloeocapsa ralfsiana; *d–f:* Gloeocapsa sp.; *g, h:* Synechococcus aeruginosus; *i, j:* Synechococcus maior; *k, l:* Stigonema *sp.; m:* Calothrix parietina; *n:* Petalonema velutinum; *o:* Tolypothrix *sp. 2. Scale, 10 μm.*

Tolypothrix sp. 2

Trichomes blue-green 8–9μm wide, slightly constricted at transvers walls. Cells short, 4–7μm long. Filaments with false branches. Heterocysts spherical or elliptic 8–9μm in diameter. Found in sample No. 970 (Fig. 4o).

Stigonema sp.

Filaments 27–40μm in width, cells arranged in one row or several rows in the sheath, cells spherical or elliptic in shape, 5–10μm wide, each having an individual sheath within the common sheath.

This alga occurred only on moss species, *Grimmia lawiana.*

Found in sample Nos. 984, 989, 990 (Fig. 4k, l).

Nostoc commune VAUCH.

Thalli blue-green to yellowish brown, up to about 10 mm in size. Trichomes highly entangled, cells barrel-shaped or spherical, 3–5μm in diameter, heterocysts spherical or elliptic, 5–7μm in diameter, with an individual sheath.

This alga was widely distributed in the Yukidori Valley, Langhovde, and often covered the surface of moss turfs.

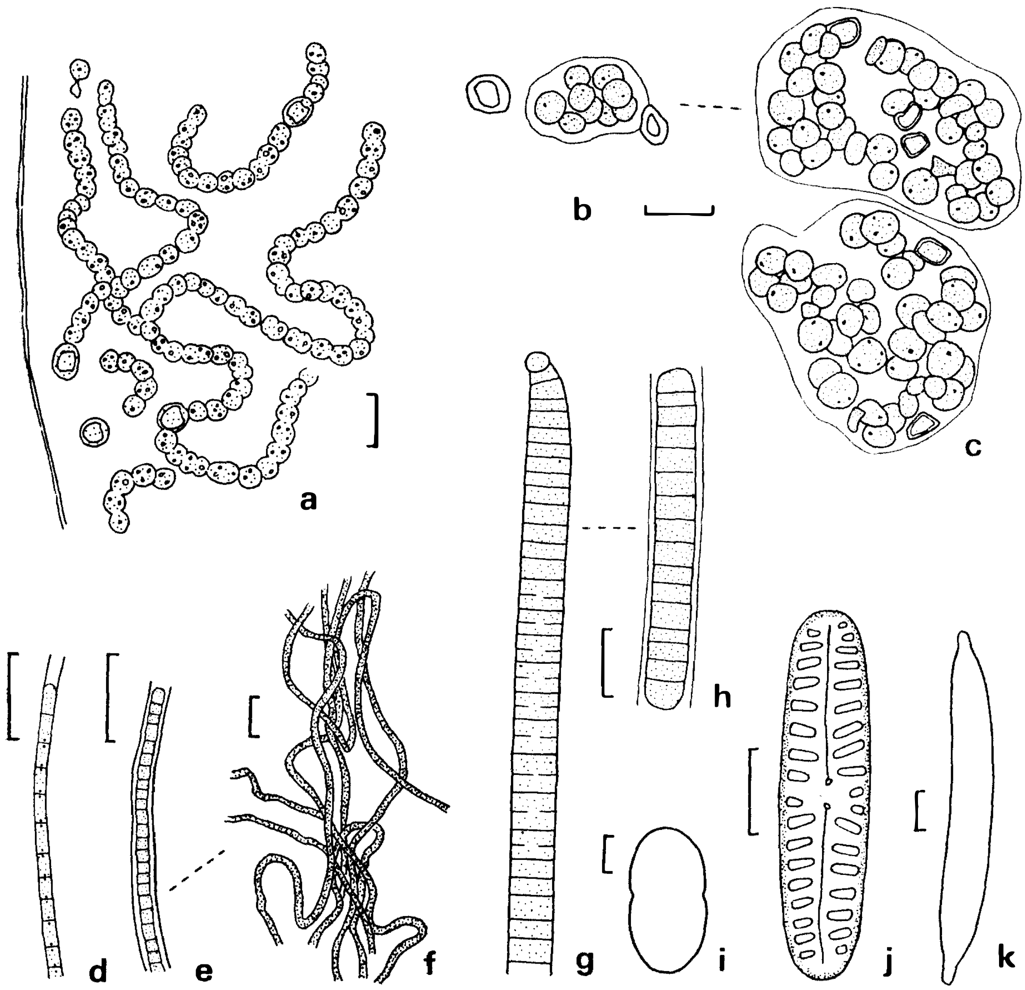

Fig. 5. *a:* Nostoc commune; *b, c:* Nostoc *sp.*; *d:* Lyngbya perelegans; *e, f:* Lyngbya purpurea; *g, h:* Lyngbya *sp.*; *i:* Actinotaenium cucurbita; *j:* Pinnuralia borealis; *k:* Hantzschia amphioxys. *Scale, 10 μm.*

Found in sample Nos. 966, 967, 970, 971, 994, 1002, 1003, 1021, 1150 (Fig. 5a).

Nostoc sp.

Colony microscopic, punctiform, bright blue-green to yellowish brown, up to about 200μm in diameter.

The present species is distinguished from *N. commune* by the microscopic size, but other characters are the same as those of *N. commune*. This alga was widely distributed in the vicinity of Syowa Station.

Found in sample Nos. 193, 577, 887, 890, 893, 896, 898, 899, 966, 967, 970, 971, 975, 978, 979, 980, 984, 987, 990, 994, 1002, 1003, 1021, 1149, 1150 (Fig. 5b, c).

Lyngbya perelegans LEMM.

Trichomes pale blue-green, entwined densely with each other, 1.0–1.5μm wide, in thin hyaline sheath, with a granule present at both apices. Cells 2–4μm long.

This alga was widely distributed in the region, and often attached to the species of genus *Nostoc* and many other algae.

Found in sample Nos. 887, 896, 899, 966, 967, 970, 971, 975, 978, 979, 980, 994, 1002, 1003, 1021, 1149, 1150, 1152 (Fig. 5d).

Lyngbya purpurea (HOOK. et HARV.) GOM.

Filaments violet and entwined densely with each other, 2–3μm wide. Trichome 1–1.5μm wide, usually not visible. Cells nearly quadrate or attaining about 1.5 times the width. Found in sample Nos. 966, 967, 970, 971, 975, 978, 994, 1002 (Fig. 5e, f).

Lyngbya sp.

Trichomes straight, pale blue-green, 6–7μm wide, without constriction, gradually attenuated to the apex, the terminal cell forms a circular calyptra, cells 3–4μm long. Found in sample Nos. 984, 1002, 1153 (Fig. 5g, h).

Actinotaenium cucurbita (BRÉB.) TEIL.

Cells subcylindrical with shallow median constriction, 35–40μm long, 19μm wide, in apical view circular.

This alga sometimes formed a large colony on mosses in the Yukidori Valley, Langhovde.

Found in sample Nos. 898, 899, 966, 970, 971, 975, 978, 1002, 1003, 1021, 1150, 1153 (Fig. 5i).

Navicula muticopsis VAN HEURCK

Valves elliptic with short rostrate and slightly capitate ends, 8–10μm wide, 16–28μm long, striations 13–15 in 10μm. Found in sample Nos. 978, 980, 994, 1002, 1003, 1019, 1021, 1150.

Pinnularia borealis EHR.

Valves sublinear, lateral margin slightly convex, with broadly rounded apices, 9–11 μm wide, 27–46μm long, striations 5–6 in 10μm.

This alga was the most common species of diatoms.

Found in sample Nos. 887, 893, 896, 898, 899, 966, 967, 970, 971, 975, 978, 980, 984, 994, 1002, 1003, 1019, 1021, 1150, 1152, 1153 (Fig. 5j).

Hantzschia amphioxys (EHR.) GRUN.

Valves 10–11μm wide, 85–94μm long, ventral margin straight or slightly concave, dorsal margin slightly convex. Found in sample Nos. 970, 971, 975, 980, 994, 1002, 1003, 1021, 1150 (Fig. 5k).

Acknowledgments

I wish to express my deep gratitude to Prof. M. AKIYAMA of Shimane University, and Dr. T. ICHIMURA of Institute of Applied Microbiology, University of Tokyo for their constructive criticism of the manuscript. I am much indebted to Dr. H. KANDA of National Institute of Polar Research who gave me much pertinent advice and the moss samples collected by him in the Antarctic for this study.

References

AKIYAMA, M. (1974): Nankyoku Ryutsuo-Horumu Wan engan rogan-tai no sôrui shokusei (yohô) (A preliminary note on some algae found in the ice-free area of the coastal region of Lützow-Holm Bay, Antarctica). Shimane Daigaku Kyôiku Gakubu Kiyô (Mem. Fac. Educ. Shimane Univ.), **1**, 36–56.

BROADY, P. A. (1977): The Signy Island terrestrial reference sites; VII. The ecology of the algae of site 1, a moss turf. Br. Antarct. Surv. Bull., **45**, 47–62.

BROADY, P. A. (1979a): The Signy Island terrestrial reference sites; IX. The ecology of the algae of site 2, a moss carpet. Br. Antarct. Surv. Bull., **47**, 13–29.

BROADY, P. A. (1979b): Quantitative studies on the terrestrial algae of Signy Island, South Orkney Islands. Br. Antarct. Surv. Bull., **47**, 31–41.

BROADY, P. A. (1981): Ecological and taxonomic observations on subaerial epilithic algae from Princess Elizabeth Land and Mac. Robertson Land, Antarctica. Br. Phycol. J., **16**, 257–266.

BROADY, P. A. (1982a): Ecology of non-marine algae at Mawson Rock, Antarctica. Nova Hedwigia, **36**, 209–229.

BROADY, P. A. (1982b): Taxonomy and ecology of algae in a freshwater stream in Taylor Valley, Victoria Land, Antarctica. Arch. Hydrobiol., Suppl., **63**, 331–349.

FUKUSHIMA, H. (1959): Onguru Tô no seibutsu gaihô. Tokuni tansui sôrui ni tsuite (General report on fauna and flora of the Ongul Islands, Antarctica, especially on freshwater algae). Yokohama Shiritsu Daigaku Kiyô (J. Yokohama Muni. Univ. Ser. C), **31**, 1–10.

FUKUSHIMA, H. (1962a): Nankyoku Purinsu Orafu Kaigan Shinnan Iwa rogan chitai no keisô (Diatoms from the Shin-nan Rock ice-free area, Prince Olav Coast, the Antarctic Continent). Nankyoku Shiryô (Antarct. Rec.), **14**, 80–91.

FUKUSHIMA, H. (1962b): Nankyoku Tairiku Kasumi Iwa rogan chitai no keisô (Notes on diatom vegetation of the Kasumi Rock ice-free area, Prince Olav Coast, Antarctica). Nankyoku Shiryô (Antarct. Rec.), **15**, 39–52.

FUKUSHIMA, H., WATANUKI, T. and KO-BAYASHI, T. (1973): Higashi Onguru Tô yori eta keisô (yohô) (A preliminary report on the diatom from East Ongul Island). Nankyoku Shiryô (Antarct. Rec.), **46**, 125–132.

HICKMAN, M. and VITT, D. H. (1973): The aerial epiphytic diatom flora of moss species from Sub-antarctic Campbell Island. Nova Hedwigia, **24**, 443–458.

HIRANO, M. (1979): Freshwater algae from Yukidori Zawa, near Syowa Station, Antarctica. Mem. Natl Inst. Polar Res., Spec. Issue, **11**, 1–25.

HIRANO, M. (1983): Freshwater algae from Skarvsnes, near Syowa Station, Antarctica. Mem. Natl Inst. Polar Res., Ser. E, **35**, 1–31.

KANDA, H. (1981): Flora and vegetation of mosses in ice-free areas of Sôya Coast and Prince Olav Coast, East Antarctica. Hikobia, Suppl., **1**, 91–100.

MATSUDA, T. (1964): Nankyoku Ranguhobude chiku ni okeru senrui gunraku no seitaigaku-teki kenkyû (Ecological studies on the community of mosses at Langhovde region, Antarctica). Nankyoku Shiryô (Antarct. Rec.), **21**, 25–38.

YAMANAKA, M. and SATO, K. (1977): Syôwa Kichi 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.

(Received June 26, 1986; Revised manuscript received August 5, 1986)