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MORPHOLOGY OF THE AQUATIC MOSSES COLLECTED IN LAKE YUKIDORI, LANGHOVDE, ANTARCTICA

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Abstract: Participating in the 29th Japanese Antarctic Research Expedition (JARE-29, 1987–1989), the authors collected aquatic mosses growing in Lake Yukidori, Langhovde near Syowa Station, East Antarctica. The moss specimens examined are mostly submerged forms of *Bryum pseudotriquetrum* (HEDW.) GAERTN., MEYER et SCHERB. which is usually characterized by elongate stems, loose foliation and short-obtuse leaf-apices. The moss specimens occasionally included a submerged form of *Pottia heimii* (HEDW.) HAMPE and were usually associated with some epiphytic algae. *Ceratodon purpureus* (HEDW.) BRID. which is one of the most abundant terrestrial moss species on the surrounding land, together with *B. pseudotriquetrum*, was not found in the lake. Ecological aspects of the lake in which aquatic mosses occurred were surveyed and discussed.

1. Introduction

Deep-water mosses in lakes of the Continental Antarctic were first recorded when Russian biologists carried out Antarctic studies in the International Geophysical Year (IGY), 1957–1958. SAVICH-LYUBITSKAYA and SMIRNOVA (1959) studied the aquatic mosses collected at a depth of 33–36 m in lakes of the Bunger Hills, Queen Mary Land, and the mosses were described as a new species, *Bryum korotkevicziae*, and its variety, *B. korotkevicziae* var. *hollerbachii*. The same authors (1964) also described another new species, *Plagiothecium simonovii*, from a depth of 32.3 m in Lake Glubokoye, Schirmachervatna, Queen Maud Land. SEPPELT (1983) and PICKARD and SEPPELT (1984) reported *Bryum algens* CARD. in lakes of the Vestfold Hills, Prince Elizabeth Land. Furthermore KASPER *et al.* (1982) also found *B. algens* at 31 m depth in Lake Vanda, Dry Valleys, South Victoria Land.

In the Syowa Station area, East Antarctica, an aquatic moss with peculiar globose gemmae was collected from lake bottoms at 3–5 m depth in the Skarvsnes regions (NAKANISHI, 1977). IMURA and KANDA (1986) tentatively treated it as a *Bryum* sp. and they described its smooth rhizoids with spherical gemmae. KANDA and IWATSUKI (1989) restudied the same moss and considered it a species closely related to *Dicranella palustris* (DICKS.) CRUNDW. ex WARB., which had probably never been found in the Antarctic, based upon characteristics such as thin-walled cortical cells of stem and squarrose leaves with sheathing bases.

It is well known that the morphological features of mosses are likely to vary when submerged, as LODGE (1959) and SONESSON (1966) showed with the amphibious moss *Drepanocladus*, and PRIDDLE (1979) with *Calliergon* and *Drepanocladus* in their experimental studies.

We participated in the 29th Japanese Antarctic Research Expedition (JARE-29) during the period of 1988–1989 and were in charge of botanical studies in the vicinity of the Syowa Station area (KANDA *et al.*, 1990). The aim of this short report is to describe the morphological features of the aquatic mosses collected in Lake Yukidori and to discuss their ecological significance.

2. Study Site

Lake Yukidori is located in the central part of the Langhovde region near Syowa Station at an altitude of 120 m above sea level about one kilometer east of the mouth of the Yukidori Valley (Fig. 1). The lake is approximately 600 square meters. The Yukidori Valley is an ice-free area supporting the most prominent vegetation in the Syowa Station area (KANDA, 1987). The stream at the upper course of the valley gathers melt water from the continental ice sheet and enters the lake from the east side. The lake water flows out from the west side of the lake. A persisting snow drift covers the northeastern slope of the lake, but the prominent moss and lichen vegetation occurs on the southern shore of the lake. Nests of skua, *Catharacta maccormicki* SAUNDERS, are scattered on the shore, and lots of rookeries of snow petrel, *Pagodroma nivea* (FORSTER), are distributed on cliffs of the upper and middle courses of the valley. Profiles of the lake depth and water temperature are as follows (Fig. 2): at 10 m from the shore the water is shallow, 1–1.5 m, at 20 m it becomes deeper to 4.5 m, and from 20 m to 100 m the depth remains 4.5–7 m. The water temperature was 2.0°C at one meter depth when the air temperature was −4°C during 1500 to 1700 on 18th February

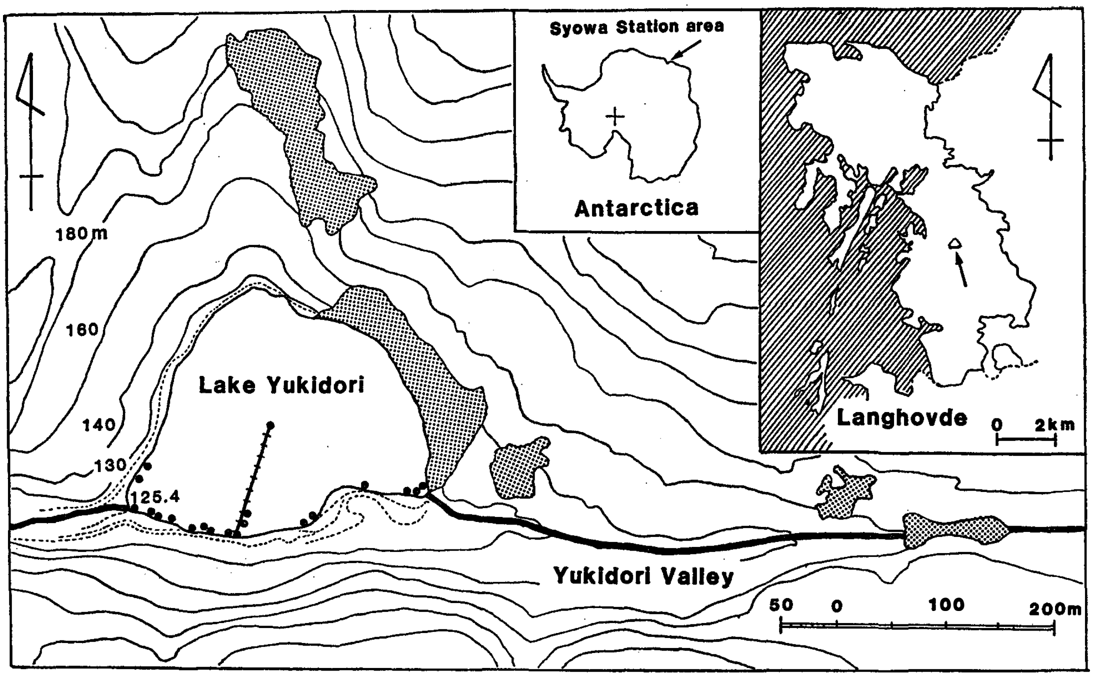

Fig. 1. Location of Lake Yukidori in the Langhovde region. ●: Localities where mosses were collected, ▒: persisting snow drift, +++++: a course of a rubber boat, ——: stream, ▨: sea water.

1988. The temperature range was 2.0–2.5°C at 1–4 m depth and attained to the maximum of 4.0°C at 4–7 m depth. The physico-chemical analysis of the lake water showed that the electric conductivity was in the range from 26–40 μΩ/cm and the pH value was about 7 (HIRANO, 1979).

3. Materials and Methods

About one hundred moss specimens were collected from the water and banks along the shore of Lake Yukidori during the two summer seasons of 1988 and 1989, and during the winter season of 1988. Algal mats covering the lake bed at 4.5–7 m depth, 100 m from the shore, were collected from a rubber boat (Achilles type). Floating algal felts mixed with aquatic mosses were also gathered. Simultaneously the surface water was taken by a water sampler (Kitahara type) and the water depth and water temperature were measured every 10 m over a distance of 100 m from the lake edge toward the central part of lake. In the winter season from March to November 1988, we collected pieces of algal mats scattered within the ice cover of 1.5–2 m thickness. It seems that the algae were moving upward through the ice cover from the lake bottom by means related to solar energy and physiological activity (WILSON, 1965). The moss and algal samples were brought back to Japan in both dry and frozen conditions. All specimens examined are housed in the herbarium of the National Institute of Polar Research (NIPR).

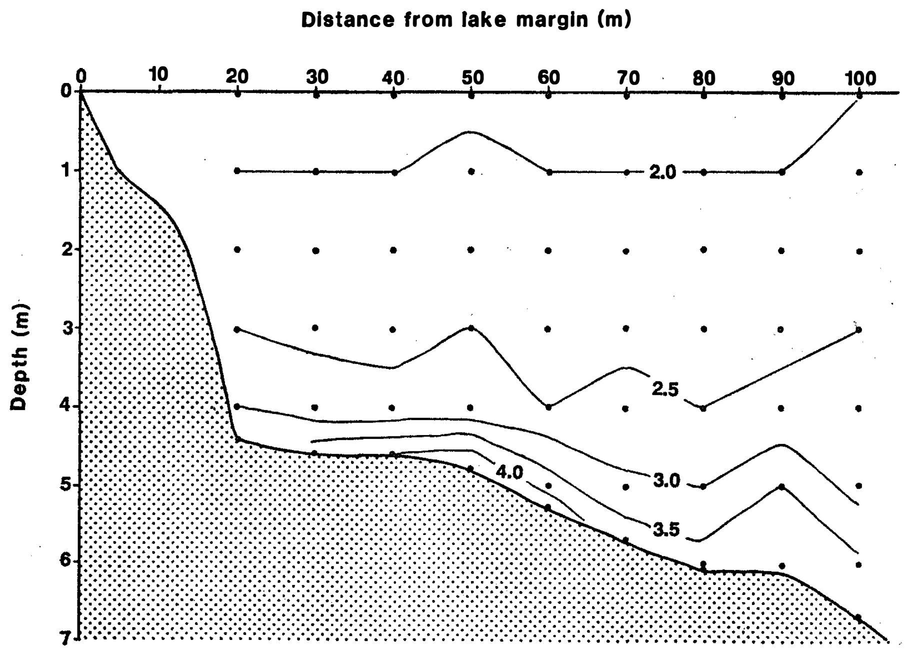

Fig. 2. Isotherms (°C) in Lake Yukidori on 18th February 1988.

4. Results and Discussion

4.1. Morphological variation of aquatic mosses

a) *Bryum psuedotriquetrum* (HEDW.) GAERTN., MEYER et SCHERB.

We examined and determined a hundred specimens of aquatic mosses growing on lake beds, floating on water surfaces, or drifting at lake margins. The specimens examined vary greatly with regard to morphological features of stem length and leaves. Stems are usually longer and more sparsely foliated than in terrestrial plants. In particular, the leaves mostly have indistinct serrulation at the upper margins and obtuse apices, and the costa is not percurrent, rarely ceasing shortly below half the length of the leaf. Based upon several significant features such as the cell shape, areolation of leaf cells, features of alar cells, certain serrulation at the upper margins and width of costa, we concluded that the mosses were *Bryum pseudotriquetrum* and they grew predominantly in the lake water. However, we found some puzzling cases in determining them. Description and discussion are given with consideration to the relationships between their morphological features and habitats.

Plants (Nos. 181–183, Fig. 3) are slender, 2–5 cm long, sometimes making a bundle of elongate stems, dirty-green to brown. Stems sparsely branched, attached to algal felts at the basal part, or fragmentarily mixed in algal assemblages. Leaves sparsely foliated, weakly spreading, small, ovate-lanceolate to oblong, 1.2–1.8 mm long, 0.6–0.8 mm wide, gradually narrowed to short obtuse apices; at the upper margins, slightly

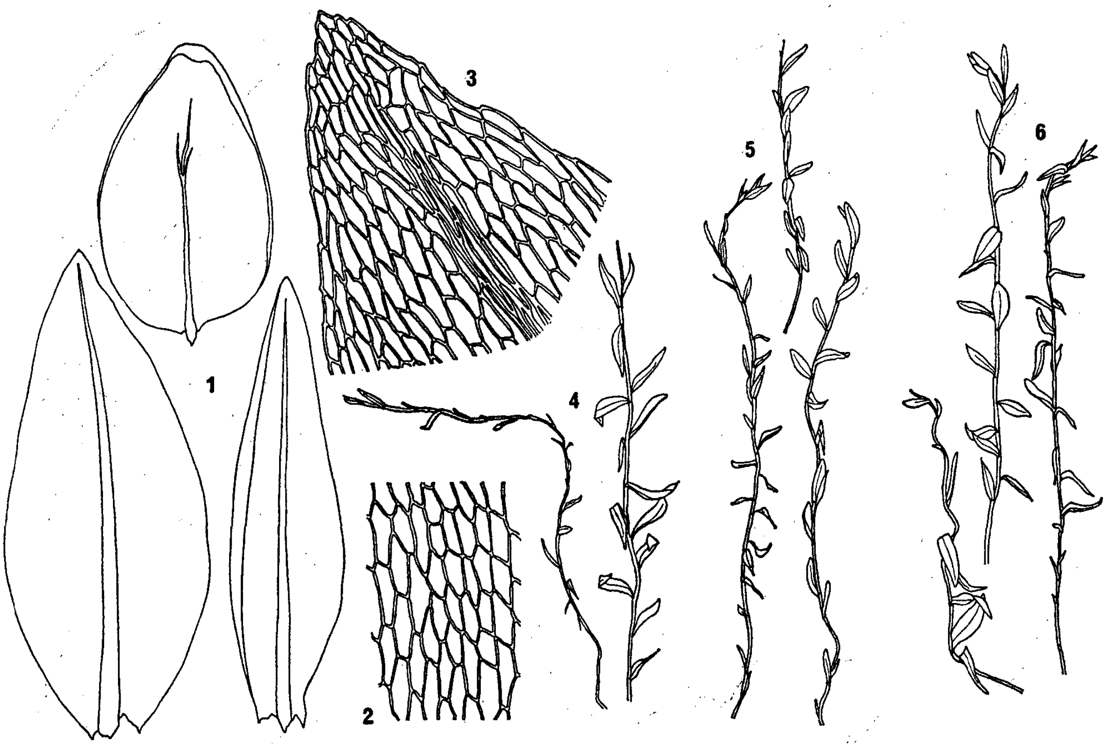

Fig. 3. Bryum psuedotriquetrum (*HEDW.*) *GAERTN., MEYER et SCHERB. 1: Stem leaves, 2: Median laminal cells, 3: Apical part of leaf, 4–6: Plants. 1: ×30, 2, 3: ×180, 4–6: ×4. 1–4: Drawn from Kanda 181, 5: Kanda 182, 6: Kanda 183.*

serrulate with 8–10 teeth; at the lower part, narrowed to insertion, not decurrent; costa is single, reaching near the leaf apex, occasionally forked near the apex.

The submerged forms of *Bryum pseudotriquetrum* having elongate stems and short obtuse leaf-apices are predominant in Lake Yukidori, mixed with the algal mats on the lake beds at 4.5–7 m depth (Fig. 3: 1–3). Stems are slender, somewhat etiolated and sparsely foliated with small leaves (Fig. 3: 4–6). These features resemble the plants of *Bryum pseudotriquetrum* reported from lakes of the Skarvsnes near Syowa Station (KANDA and IWATSUKI, 1989). The leaf shapes also resemble those of the species of *Calliergon* or *Calliergidium* in having short obtuse apices. PRIDDLE (1979) studied unusual forms of *Calliergon sarmentosum* (WAHLENB.) KINDB. with large leaves and long internodes growing in lakes on Signy Island. The *Calliergon* produced such aquatic form when it grows either submerged or under damp condition. The plants from Lake Yukidori, however, are easily distinguished from mosses of these genera by the undifferentiated alar cells and shorter laminal cells of leaves.

The obtuse leaves may be a leaf character derived after a long process of adaptation to the cold aquatic habitats. As to the aquatic obtuse leaves of Bryaceae, SEPPELT and SELKIRK (1984) studied the growth of deciduous shoot tips of *Bryum argenteum* HEDW. from subantarctic Macquarie Island grown in the laboratory at 21°C and 4°C. The plants showed quite contrasting patterns of regrowth Narrower leaves with more acute to acuminate apices were produced at the higher temperature, 21°C, while at 4°C in the culture, the leaves showed obtuse to round apices and lacked a costa.

Fig. 4. Bryum pseudotriquetrum (*HEDW.*) *GAERTN., MEYER et SCHERB. 1–3: Leaves at the upper stems (1), at the middle stems (2) and at the lower dense-foliated stems (3), 4–5: Plants. 1–3: ×30, 4, 5: ×4. 1–4: Drawn from Kanda 187, 5: Kanda 189.*

In the plants of No. 187 (Fig. 4), the leaves on the lower stem are densely foliated, very small, sometimes broken at the apex; costa is strong, reaching the apex; margins are serrulate on the upper parts and recurved almost throughout the leaf. However, the upper leaves are loosely foliated, 2–3 times longer and 1.5 times wider than the lower, reaching about 2.5 mm long and 1.2 mm wide (Fig. 4: 1–4). Similarly the leaves on the upper stem of the plants of No. 189 are large, sometimes shrunken, narrowed to short-acute to obtues apices, making elongated internodes. On the lower stem, leaves are brownish, densely foliated, but small, sometimes broken at the tip, with narrowed to long acute apices (Fig. 4: 5). In contrast, the leaves on the lower stem of the plants of No. 184 (Fig. 5) are large, long-lanceolate, narrowed to acute apices; margins are entire with indistinct serrulation at the upper part. On the upper stems, however, leaves are short, about half the length of leaves on the lower stems (Fig. 5: 1–3).

Two different leaf features on the same stems as shown in the plants Nos. 187 (Fig. 4: 4, 5) and 184 (Fig. 5: 3) are probably caused by the change from the terrestrial habitats to aquatic ones. The plants grown in terrestrial habitats were conveyed to the lake water by wind or water flows and innovated leaves on the upper part of the stem were developed and altered to the submerged form under the more favorable environmental condition than the surrounding land. It seems that the leaf features on the lower stem are derived from terrestrial habitats, judging from the serrulation of the upper leaf margins, narrowly recurved leaf margins and the dense foliation.

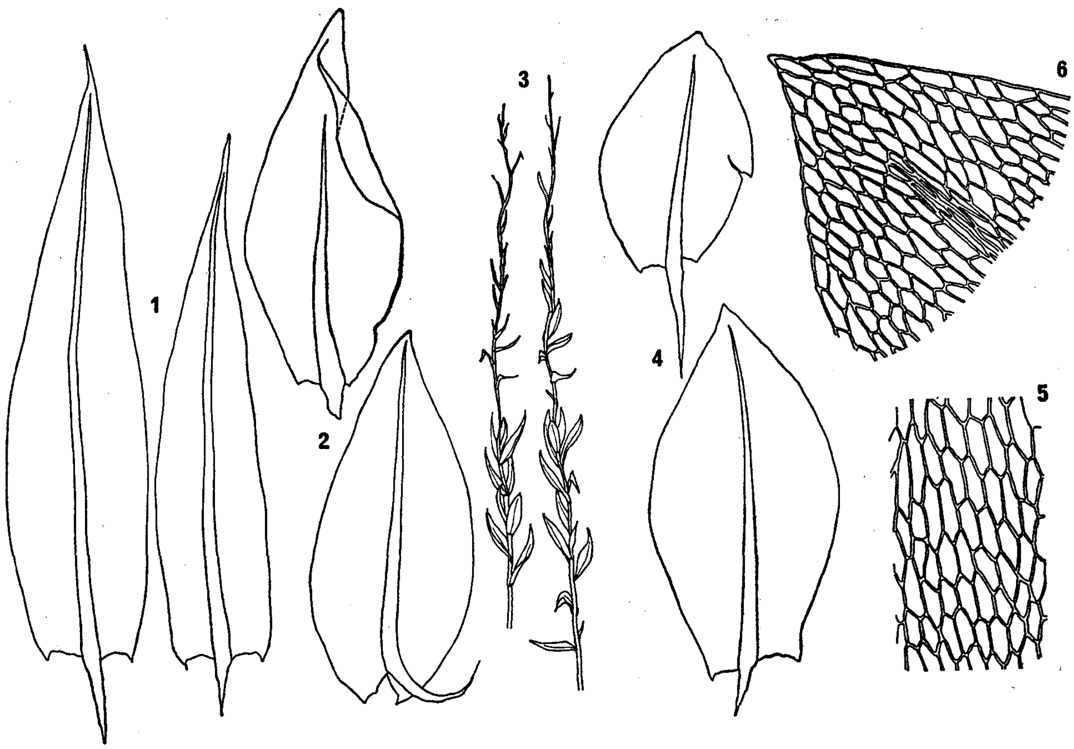

Fig. 5. Bryum pseudotriquetrum (*HEDW.*) *GAERTN., MEYER et SCHERB. (1–3) and* Pottia heimii (*HEDW.*) *HAMPE (4–6). 1, 2: Leaves at the lower stems (1) and at the upper stems (2), 3: plants, 4: Stem leaves, 5: Median laminal cells, 6: Apical part of leaf. 1, 2, 4: ×30, 3: ×4, 5, 6: ×180. 1–3: Drawn from Kanda 184, 4–6: Kanda 185.*

In the aquatic mosses previously recorded in the Continental Antarctic, the leaves of *B. pseudotriquetrum* are not always larger than those in terrestrial habitats. PRIDDLE and DARTNALL (1978) showed that *Calliergon* was variable, ranging from robust shoots to microphyllous or even leafless stems in submerged habitats. As for elongate stems, it may be partially attributable to the very low decomposition rates in these cold, oligotrophic lakes resulting in the persistence of dead stem material. The findings of PRIDDLE and DARTNALL (1978) and PRIDDLE (1979) were also confirmed in the similar experiment by KASPER *et al.* (1982).

b) *Pottia heimii* (HEDW.) HAMPE

We found a submerged form of *Pottia heimii* in the lake. All leaves of the plant also had short obtuse apices and indistinct serrulation on the upper margins (Fig. 5:4–6). Although the distinction between this species and *Bryum pseudotriquetrum* is not easy, the former is always broadest at the upper to middle part of the leaf with short rhomboidal cells, and never has a reddish tint in the basal part of the leaf.

c) Other aquatic mosses

Aquatic forms of *Ceratodon purpureus* (HEDW.) BRID. have never been found in lakes near Syowa Station. This species prefers a drier habitat in terrestrial vegetation and may not survive in aquatic habitats. KASPER *et al.* (1982) observed experimentally that several xerophytic taxa (*e.g. Andreaea gainii* CARD., *A. regularis* CARD., *Dicranoweisia grimmiacea* (C. MUELL.) PAR., *Grimmia antarctici* CARD., and *Tortula fuscoviridis* CARD.) cultivated in water did not adapt to submerged conditions and at last died. PRIDDLE (1979) also stated that most aquatic mosses on Signy Island, including *Calliergon*, appear to be derived from terrestrial populations of the same species. According to him, small clumps of various terrestrial mosses were found during diving surveys of many lakes on the island, indicating that a large amount of moss may be introduced into the lakes even though some lakes are too turbid to be suitable for moss growth. On the other hand, it is quite significant that terrestrial mosses such as *Dicranella*, *Plagiothecium* and *Bryum* were certainly found on lake beds in deep water and their morphological features were altered by adaptation to the aquatic habitats. Some of them were described as endemic new species to Antarctica. They are considered to be a kind of relic having persisted from ancient times and now their mother species are never seen on the surrounding land.

4.2. *Relationships with epiphytic algae*

Algal mats mixed with aquatic mosses obtained from the lake bottom were examined, and the structure and species composition were preliminarily studied. Our survey using a rubber boat failed to get any samples that provided the natural structure of algal mats growing on the bed at 6–7 m depth. Judging from pieces of the algal mat floating on the surface water near the lake shore, the mats mixed with mosses in the deepest parts consisted of three layers, *i.e.* moss, algal and crust layers. Aquatic mosses in the moss layer become 1 to 4 cm in length. The basal stems are attached to the crust layer. Some colonies of moss rhizoids appeared on the undersurface of the mat. Sometimes the aquatic mosses are free from the crust and exist in algal assemblages. Epiphytic algae in the moss layer were composed of the following species: *Cosmarium clepsydra* NORDST., *Gonatozygon* sp., *Oedogonium* sp., and *Phormidium* sp. In the algal layer, *Phormidium* sp. is predominant and *Lyngbya purpurea* (HOOKER and HARVEY) GOM., *Nostoc* sp., *Cosmarium subcrenatum* HANTZSCH and *Kentrosphaera* sp. are added to the species in the moss layer. In the crust layer, there were only three species, *Phormidium* sp., *Cosmarium clepsydra* and *Kentrosphaera* sp. As this layer is attached to the substrata of lake bottom such as rocks, sands or other kinds of sediments, it has probably been decomposed by bacteria.

The fresh water algae in Lake Yukidori were studied by HIRANO (1979), who, however, did not mention the epiphytic algae on the aquatic mosses. PRIDDLE and DARTNALL (1978) recorded 38 species as epiphytic algae and mentioned that none of these appeared to be wholly restricted to the mosses. Furthermore, they grouped them into two epiphytic types: habitual and casual epiphytes. To know the influence of epiphytic algae on the morphology of aquatic mosses is one of our purposes of this study, but the specimens so far examined are too insufficient to discuss it in the present study.

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