# AN ANNOTATED LIST OF BENTHIC ALGAE (EXCLUDING DIATOMS) FROM FRESHWATER LAKES ON SIGNY ISLAND

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ABSTRACT. A list of benthic algae, excluding Bacillariophyta, from the 17 freshwater lakes on Signy Island, South Orkney Islands, is presented. The majority of taxa belongs to the Chlorophyta (34 taxa) although many of these species are poorly represented in the benthos. The other major group, the Cyanophyta, is represented by 13 taxa and one species of Xanthophyta is present. The distributions of 45 taxa are recorded, and analysed using Reciprocal Averaging and Group Average Clustering. Both techniques indicate similar trends in the variation of the lakes which can be interpreted in terms of natural nutrient-enrichment and of morphometry.

## INTRODUCTION

The seventeen small lakes of Signy Island, South Orkney Islands, present a variety of freshwater environments (Heywood and others, 1979, 1980). Benthic algae are abundant in most lakes and may be divided into two communities. The shallow sublacustrine shelf region freezes solid during the winter and the algae present are similar in all lakes (Priddle, 1980). The characteristic vegetation of this part of the lake consists of an epilithic 'felt' of filamentous blue-green algae which may become overgrown by patches of filamentous conjugate green algae during summer. The epilithic felt is typically brownish orange and this is related to the high ratio of carotenoid : chlorophyll pigments in the blue-green algae (Priddle and Belcher, 1981).

The algae of the deeper lake trough exhibit greater diversity both within and between lakes. A subjective classification of benthic algal communities has been used to characterize lakes of differing nutrient status on Signy Island (Heywood and others, 1980). The lakes are typically nutrient-poor, receiving inflow from catchments dominated by permanent snow and ice, and bare scree. Such lakes have a rich benthos comprising perennial algal felts, often dominated by Cyanophyta, and stands of aquatic moss (Light and Heywood, 1973; Priddle and Dartnall, 1978; Priddle, 1979, 1980). Some lakes have become enriched by contamination of inflow water by effluent from seal wallows, by input of ions from sea-spray and by leaching of ions from lowland cryptogamic vegetation. These lakes are dominated by phytoplankton growth in summer and have poorly developed benthic vegetation (Light and others, 1981).

The taxonomy of the algae in the Signy Island lakes is incomplete. Light (1977) and Light and others (1981) noted the phytoplankton species present in one lake and Weller (1977) listed the main species of phytoplankton and benthic algae from a second lake. Priddle and Dartnall (1978) described epiphytic algae found on mosses in a number of Signy Island lakes. Five other publications are relevant to the taxonomy of the freshwater algae of Signy Island. Fritsch (1912*a*, *b*) described freshwater and terrestrial algae collected from other islands in the South Orkney group by the Scottish National Antarctic Expedition (1902–4). Broady (1979) gives a thorough account of the terrestrial algae of Signy Island, and Fogg (1967) and Kol (1972) both described algae from samples of coloured snow from the South Orkney Islands.

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## Methods

The majority of collecting was carried out by one of us (J. P.) by scuba diving. The lakes were sufficiently small for the entire lake trough to be inspected and a subjective assessment of the important communities in the benthos to be made. A large proportion of the bottom of most lakes was covered with fine glacial sediment and this was overgrown by various algal 'felts', each usually dominated by a few species of filamentous algae and recognizable by its colour and texture. Epilithic algal crusts colonized exposed rock surfaces. Samples were removed by hand from each of these communities. Some lakes, especially those on the east coast of the island, were visited on several occasions whilst others were seldom sampled or inaccessible for scuba sampling. Further samples were collected from the surface using boats in summer or through holes cut in the ice in winter. Samples were preserved in Lugol's iodine and examined as water mounts soon after collection. Initial taxonomic work was carried out on samples collected between 1963 and 1972 by Drs R. B. Heywood and J. J. Light, British Antarctic Survey. All samples are now kept at the British Antarctic Survey headquarters at Cambridge.

Distribution data were examined by two classification methods, both using presence-or-absence (qualitative) data. Ordinations of both lakes and species were carried out using Reciprocal Averaging (RA), a symmetrical ordination technique (Hill, 1973). Cluster analysis of the lakes was executed by Group Average Clustering (Lance and Williams, 1967), an agglomerative technique. The similarity matrix on which the latter analysis was based used the coefficient of Jaccard (1908), $S_J$. The coefficient represents the ratio of shared and unique taxa in site pairs and is calculated as:

$$S_J = \frac{N_{ab}}{(N_{ab} + N_a + N_b)}$$

where $N_{ab}$ is the number of taxa shared by two sites, A and B;
$N_a$ and $N_b$ are the numbers of taxa restricted to sites A and B respectively.

Values of $S_J$ vary from 1 (all taxa shared) to 0 (no taxa shared) (Sneath and Sokal, 1973, p. 131).

Both the ordinations and cluster analysis were carried out using library programs on the University College of North Wales DEC-10 computer.

## Results

### *Taxonomic list*

The following list of benthic algae from Signy Island lakes is necessarily incomplete. Some taxa present taxonomic problems which could not be solved using the available (preserved) material. Certain algal species may be identified with certainty only by the use of reproductive material or by the morphology of the species in culture. Identifications were often complicated by great morphological plasticity in some taxa.

The designation of major taxonomic groups follows Whitton and others (1978) except for the classification of the Zygnemaphyceae which is taken from Brook (1981). Diatoms (Bacillariophyta), which form the most taxonomically diverse group of algae in the benthos (although rarely ecologically important), are omitted from this list as they are being covered more exhaustively by Belcher, Carter and Priddle (in preparation). Table I gives the approximate number of taxa in the four phyla noted in the benthos of the Signy Island lakes.

Table I. Numbers of taxa in each algal phylum present in all the lakes of Signy Island.

| *Phylum* | *Number of taxa in all lakes* | *Maximum in any one lake* |
|---|---|---|
| Cyanophyta | 13 | 8 |
| Chlorophyta | 34 | 14 |
| Xanthophyta | 1 | 1 |
| Bacillariophyta* | *c.* 70 | Not known |

* Belcher, Carter and Priddle (in preparation)—distribution data are not available for this group.

## 1 CYANOPHYTA (= CYANOBACTERIA) (blue-green algae)

Examination of blue-green algae in culture has cast doubt on the 'classical' taxonomic status of many (in some orders, most!) of the morphologically defined species of some groups (Drouet and Daily, 1956; Drouet, 1968; Jeeji-Bai, 1977). In the following list, a purely morphological description will be given, with reference to classical species where appropriate.

### 1.1 Chroococcales

*Aphanocapsa* spp. Colonial Cyanophyta comprising spherical cells in mucilaginous colonies, common in some benthic communities and found as epiphytes on aquatic moss (Priddle and Dartnall, 1978). Cell diameters varied from 2 to 7 μm.

*Gomphosphaeria* sp. (Fig. 1a). Coenobium, *c.* 80 μm diameter, consisting of pairs of pear-shaped cells, *c.* 10 × 6 μm, embedded in clear mucilage. Compares with *G. aponina* Kütz. found by Fritsch (1912*a, b*) on Saddle Island. Rare on Signy Island, usually epiphytic on mosses (Priddle and Dartnall, 1978).

*Merismopedia* sp. (Fig. 1b). Coenobium small, comprising tetrads of cells, each 2 × 1 μm, bright green in living specimens, embedded in an indistinct mucilage sheath. Rare.

### 1.2 Chamaesiphonales

*Chamaesiphon* sp. (Fig. 1c). A common epiphyte on some filamentous Cyanophyta. Differs from *C. subglobosus* found growing terrestrially on Signy Island by Broady (1979).

### 1.3 Oscillatoriales

#### 1.3.1 Nostocinales

*Lyngbya* sp. (Fig. 1d). Trichomes simple, with cells much broader than long. Trichome thickness (including sheath) 5.5–6.5 μm, orange-brown in colour. Terminal cell rounded. Characteristic of shallow water and pools.

*Microcoleus* sp. (Fig. 1e). Individual trichomes *c.* 3 μm thick, cell walls indistinct. A thick, hyaline sheath surrounds the bundle of trichomes. Probably *M. vaginatus* (Vaucher) Gomont, which Broady (1979) recorded from the terrestrial algal flora of Signy Island.

Most of the Nostocinales encountered in this study have been referred to the genus *Phormidium*. Many taxa formed dense aggregations of trichomes and epilithic crusts often produced conical growths resembling *Symploca* spp.

*Phormidium* sp. A (Fig. 1f). Trichomes less than 1.5 μm thick (including sheath in this and following taxa). Colour bright green. Cells up to to eight times as long as broad, cross-walls indistinct but with granules sometimes visible. Compares with *P. angustissimum* W. and G. S. West although the description in Desikachary (1959) differs in some details, e.g. the granules.

*Phormidium* sp. B (Fig. 1g). Trichomes thin, *c.* 1 μm, sheath and cell cross-walls indistinct. Common in all Signy Island lakes. Compares with *P. antarcticum* W. and G. S. West.

*Phormidium* sp. C (Fig. 1h). Trichomes 2–3 μm thick with cell walls just visible. Cells *c.* 3 μm long, contents granular. Common in shallow water and pools. Variable.

*Phormidium* sp. D (Fig. 1i). Trichomes *c.* 1.5 μm thick, with thick sheath and distinct cells. Compares with *P. frigidum* Fritsch, which also occurs terrestrially on Signy Island (Broady, 1979).

*Phormidium* sp. E (Fig. 1j). Trichomes 5–6 μm thick, sheath prominent. Cells *c.* 3 μm long with conspicuous cross-walls. Compares with *P. uncinatum* (Ag.) Gomont.

*Plectonema* sp. (Fig. 1k). Trichomes *c.* 15 μm thick with thick yellowish, stratified sheath enclosing cells which are dark blue-green in fresh specimens but pale in preserved material. A common component of some deep-water benthic communities. Two species in this genus were recorded by Broady (1979) as growing terrestrially on Signy Island but neither apparently agrees with the present taxon.

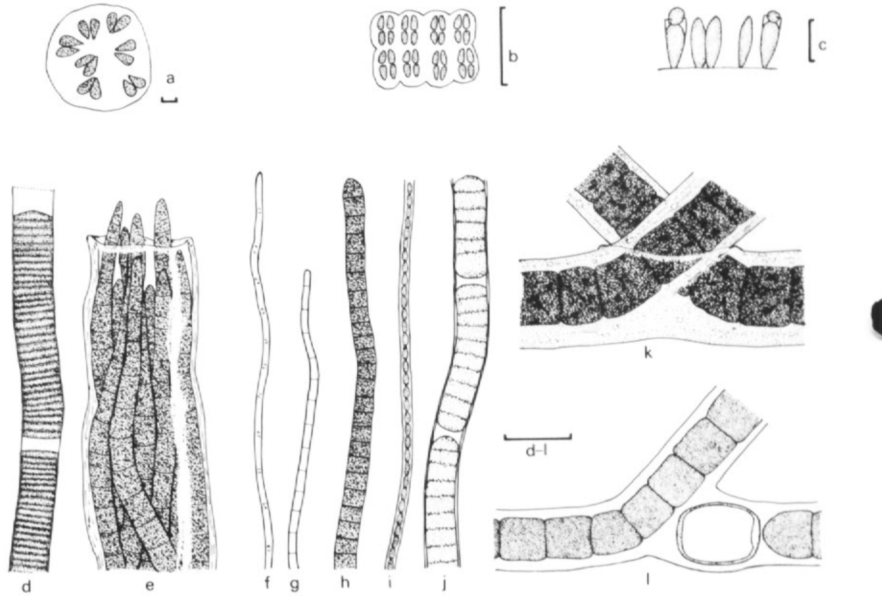


Fig. 1. Cyanophyta from Signy Island lakes, illustrations based on several preserved specimens. a, *Gomphosphaeria* sp.; b, *Merismopedia* sp.; c, *Chamaesiphon* sp.; d, *Lyngbya* sp.; e, *Microcoleus* sp.; f, *Phormidium* sp. A; g, *Phormidium* sp. B; h, *Phormidium* sp. C; i, *Phormidium* sp. D; j, *Phormidium* sp. E; k, pseudobranch of *Plectonema* sp.; l, pseudobranch of *Tolypothrix* sp. All scale bars 10 μm.

*Tolypothrix* sp. (Fig. 11). Trichomes *c.* 10 μm thick with colourless sheath. Cells brown-green but heterocysts paler. Cells vary from short to quadrate, *c.* 3–6 μm long and 6 μm broad. Common, usually associated with *Plectonema* sp. in a dense perennial felt. This taxon is probably *T. tenuis* (Kütz.) J. Schmidt (see Desikachary, 1959). This species was found growing terrestrially on Signy Island (Broady, 1979) and has been recorded in freshwater habitats on South Georgia (Carlson, 1913) and on the Îles Kerguelen (Hirano, 1965).

2 CHLOROPHYTA (green algae)

2.1 Chlorophyceae

2.1.1 Volvocales

*Asterococcus superbus* (Cienk.) Scherf. Single cells of this species were encountered occasionally.

*Chlamydomonas* spp. Unidentified species from this genus were found in littoral sediment. Weller (1977) found a *Chlamydomonas* sp. in the phytoplankton of Sombre Lake, and Light and others (1981) noted that some *Chlamydomonas* spp. were very common in the plankton of Heywood Lake. The genus is also common in inland pools and occurs in the snow algae on Signy Island (Fogg, 1967; Kol, 1972).

2.1.2 Chlorococcales

*Characium* cf. *C. pringsheimii* A. Braun. A common epiphyte on *Tribonema* sp. and *Zygnema* sp.

*Oocystis* sp. (spp. ?). Two-celled colonies referable to this genus were sometimes encountered in the benthos.

*Pediastrum* cf. *P. boryanum* (Turp.) Menegh. This colonial alga was common during summer in the benthos of some moderately enriched lakes, e.g. Light Lake. Colonies were often misshapen.

*Scenedesmus* sp. A cf. *S. bijuga* (Turp.) Lagerh. Four-celled colony of rounded, un-ornamented cells. Rare.

*Scenedesmus* sp. B cf. *S. obliquus* (Turp.) Kütz. Colony of four spindle-shaped cells with no obvious ornament. Rare, usually found in the outflows of lakes.

'*Scotiella*' sp. A conspicuous ovoid alga, *c.* 30 μm long and with the cell-wall bearing characteristic longitudinal flanges. Seldom found in this study and then usually near inflows, suggesting that it may have been washed into the lakes. Occurs terrestrially (Broady, 1979) and is found in coloured snow on Signy Island (*Scotiella antarctica* recorded by Fogg, 1967, whilst Kol, 1972, found *S. nivalis*). Fritsch (1912*a, b*) gave the original description of the genus based on material from Saddle Island (South Orkney Islands) and identified three species. Hoham and Mullet (1978) have now suggested that cryophilic species of *Scotiella* (including *S. antarctica* and *S. nivalis*) are zygotes of the snow alga *Chloromonas nivalis* (Chod.) Hoh. et Mull.

*Tetraedron minimum* (A. Braun) Hansg. A small species, *c.* 10 μm, found occasionally in the benthos.

2.1.3 Ulotrichales

*Ulothrix* spp. Three species of this genus were tentatively separated on the basis of cell size and form of the chloroplast. None has been identified with known species. All were uncommon and usually found in the outflow area of lakes, as well as in streams and inland pools.

2.1.4 Chaetophorales

*Chaetosphaeridium* sp. (Fig. 2a). A common epiphyte, especially on aquatic

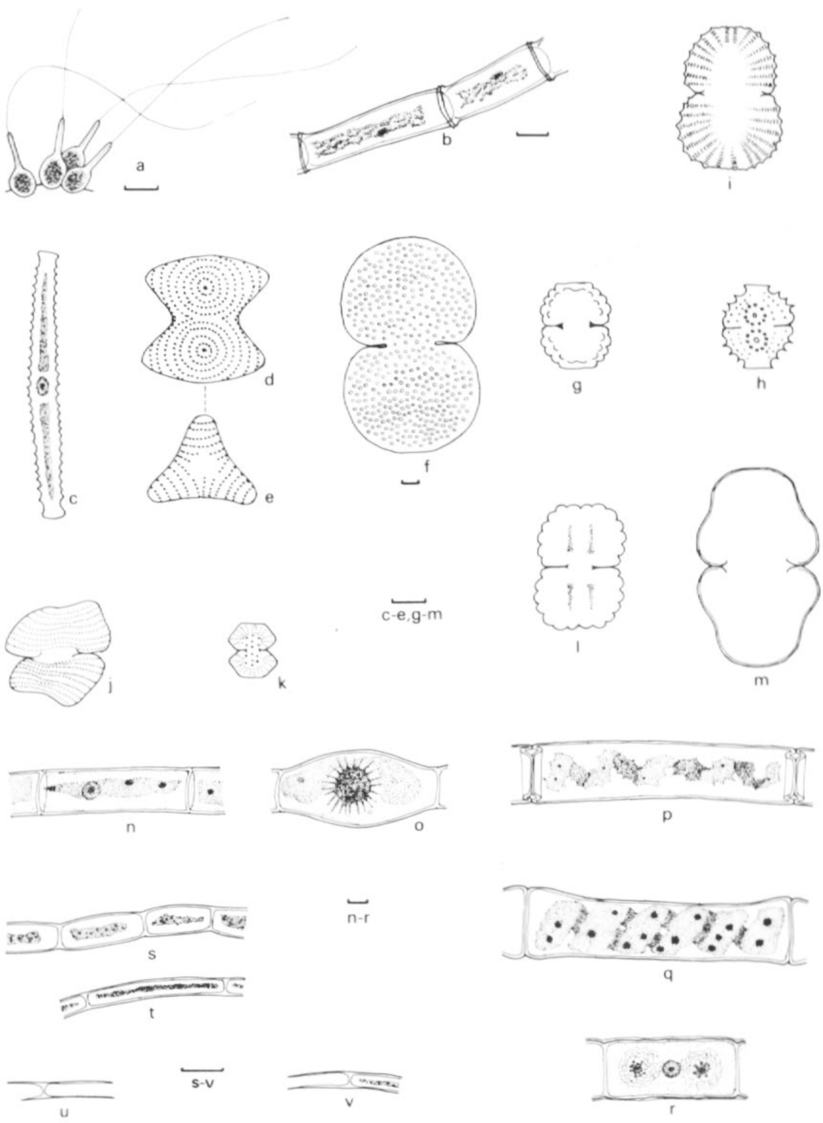


Fig. 2. Chlorophyta and Xanthophyta from Signy Island lakes, illustrations based on examination and photomicrographs of several preserved specimens. a, *Chaetosphaeridium* sp.; b, *Oedogonium* sp.; c, *Gonatozygon* sp.; d, side and e, apical views of *Staurastrum* sp. cf. *S. punctulatum*; f, *Cosmarium* sp. C; g, *Cosmarium* sp. G; h, *Cosmarium* sp. F; i, *Cosmarium* sp. A; j, *Cosmarium* sp. B; k, *Cosmarium* sp. D; l, *Cosmarium* sp. E; m, *Cosmarium* sp. H; n, normal and o, chytrid-parasitized cells of *Mougeotia* sp.; p, *Spirogyra* sp. A; q, *Spirogyra* sp. B; r, *Zygnema* sp.; s–v, *Tribonema* sp., with characteristic 'H-breakage' of cell wall (u, v). All scale bars 10 μm; note that all desmids are to the same scale except for f.

mosses (Priddle and Dartnall, 1978). Aggregations usually of *c.* 10 cells. Cell 10 μm in diameter, seta up to 300 μm with basal sheath 15–20 μm.

*Stigeoclonium* sp. Unidentified species present as attached alga and occasionally epiphytic. Cells *c.* 15 μm wide.

2.2 Oedogoniophyceae

2.2.1 Oedogoniales

*Oedogonium* sp. (Fig. 2b). A common species growing epiphytically or epilithically. Zoospore formation and germination were observed but no sexual stages were seen. Filament *c.* 15 μm thick.

2.3 Zygenamaphyceae

2.3.1 Zygnematales (Saccodermae)

2.3.1.1 Mesotaeniaceae

*Cylindrocystis brebissonii* Menegh.

*Cylindrocystis crassa* de Bary

Broady (1979) describes these two species of *Cylindrocystis* from soils on Signy Island.

2.3.1.2 Zygnemataceae

*Mougeotia* sp. (Fig. 2n, o). Filaments with cells 25–35 μm wide, 100–150 (rarely up to 200) μm long. Single longitudinal chloroplast with five to eight pyrenoids. Commonly found growing in dense masses, many filaments attached to the substrate. Swollen cells in some populations, containing one or more spiny bodies, were probably caused by a chytrid infection (Fig. 2o). No reproductive structures were noted.

*Spirogyra* sp. A (Fig. 2p). Filaments with cells 25–35 μm wide, 120–150 μm long. Single chloroplast of variable shape ranging from a simple ribbon (resembling *Mougeotia* spp.) to a tightly coiled, ornate spiral. These two extremes could sometimes be found in adjacent cells in the same filament. End walls of cells were infolded (Type 2 of Bourrelly, 1972, p. 386). No reproductive structures were found. A very common benthic alga in some moderately enriched lakes in summer.

*Spirogyra* sp. B (Fig. 2q). Filaments with cells *c.* 30 μm wide and 130 μm long. Two chloroplasts. Uncommon.

*Zygnema* sp. (Fig. 2r). Filaments with cells of varying proportions, 20–30 μm wide and 50–90 μm long. Cell walls thick with continuous mucilage layer up to 1.5 μm thick. Chloroplasts each with a conspicuous pyrenoid. Cytoplasm very granular. A common alga in the shallows and outflows of smaller lakes, and the principal filamentous green alga in streams (in summer only). Many actively dividing cells were seen in filaments collected in late December. No reproductive stages were found.

2.3.1 Desmidiales (Placodermae)

2.3.2.1 Archidesmidiinae

2.3.2.1.1 Gonatozygaceae

*Gonatozygon* sp. (Fig. 2c). Spinose, *c.* 85 × 10 μm. Common in the benthos of Lake 17. Probably *G. aculeatum* Hast.

2.3.2.1.2 Peniaceae

*Penium* spp. Two species are probably present, one approaches *P. cucurbitinum*, the second *P. curtum*.

2.3.2.1.3 Closteriaceae

*Closterium* sp. 70–100 μm. Approaches *C. leibleinii*.

2.3.2.2 Desmidiinae

*Cosmarium laeve* Rab. Often found as a secondary epiphyte.

*Cosmarium regnellii* Wille. A small species, occurring in secondary epiphytic community on aquatic mosses (Priddle and Dartnall, 1978) and found in the gut of a browsing ostracod, *Cypridopsis frigogena* H. Graf.

*Cosmarium subspeciosum* var. *validus* Nordst.

*Cosmarium* sp. A (Fig. 2i). 25 × 30 μm, semicells rounded with coarse peripheral sculpture but central area clear. Found in epilithic algal felt in shallow water. Probably a form of *C. speciosum* Lumdell.

*Cosmarium* sp. B (Fig. 2j). 40 × 30 μm. A distinctive species with the finely ornamented angular semicells twisted with respect to each other.

*Cosmarium* sp. C (Fig. 2f). 110 × 80 μm, the largest species of this genus recorded from Signy Island lakes. Rare, in deeper sites in clear lakes. Similar to *C. tuddalense* var. *americanum* Krieger and Gerloff, previously recorded only from Newfoundland (Professor A. J. Brook, personal communication).

*Cosmarium* sp. D (Fig. 2k). 15 × 12 μm, very small, semicells subangular.

*Cosmarium* sp. E (Fig. 2l). 35 × 30 μm. This species was noted in earlier collections examined by J.H.B. but not found in the latest survey.

*Cosmarium* sp. F (Fig. 2h). 25 × 22 μm. A distinctive species with a central boss on the face of each semicell and a spiny margin. Found in earlier collections but not in the present study.

*Cosmarium* sp. G (Fig. 2g). 25 × 20 μm. Semicells coarsely sculptured, subangular in outline.

*Cosmarium* sp. H (Fig. 2m). 60 × 35 μm. A large species with large smooth semicells with distinctive outline reminiscent of *C. hammieri* var. *hamalodermum* (Nordst.) West and West. Found in earlier collections but not in the present study.

*Staurastrum* sp. cf. *S. punctulatum* Bréb. (Fig. 2d, e). Differs from the *Staurastrum* sp. found by Broady (1979) in Signy Island soils.

3 XANTHOPHYTA (yellow algae)

3.1 Xanthophyceae

3.1.1 Heterotrichales

*Tribonema* sp. (Fig. 2s–v). A very variable species with cells varying from 6 μm broad × 10 μm long to 4 μm broad × 15 μm long, the latter approaching *T. elegans* Pasch. Different cell proportions were commonly present in the same filament. *Tribonema* sp. dominated the phytobenthos in the well-lit parts of moderately enriched lakes. The 'H-breakage' of the two parts of the cell wall, characteristic of the genus, was usually obvious (Fig. 2u, v) and often provided evidence of the feeding of various invertebrates on *Tribonema* patches. Two species of Crustacea were found to feed on the alga – *Branchinecta gaini* (Daday) (Anostraca) and *Macrothrix hirsuticornis* Norman & Brady (Cladocera). Broady (1979) recorded *T. vulgare* from terrestrial habitats on Signy Island. The present species does not agree with *T. vulgare*.

*Algal distribution*

The distributions of 45 taxa of benthic algae in the 17 lakes of Signy Island are shown in Fig. 3. It should be noticed that all lakes were not sampled with equal intensity of effort, and that in lakes where direct observation (by diving) of the benthos was not possible it was difficult to assess the ecological importance of the specimens collected.

The distribution of the algal taxa between lakes was used to examine the relationship between lakes. Presence-or-absence (qualitative) data for all taxa except three desmids not found in the latest study were used in an RA ordination of all lakes (Fig. 4a). The ordination was dominated by three lakes – Lakes 11 and 17 and Heywood Lake. The first two appear to be unusual lakes in the Signy Island system

| TAXON | L16 | ML | EL | L9 | SL | LL | CL | L11 | L17 | PL | TL | L13 | L8 | KL | L15 | AL | HL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Nutrient-poor | | | | | | | | LAKE | | | | | | | | Nutrient-rich |
| *Aphanocapsa* spp. | | • | • | • | • | • | | | | • | | | | | | | |
| *Gomphosphaeria* sp. | | X | | | | | | | | | | | | | | | |
| *Merismopedia* sp. | | | X | | | | | | | | | | | X | | | |
| *Chamaesiphon* sp. | | | | | | | | X | | | | | | | | | X |
| *Lyngbya* sp. | | | | • | | | • | • | • | | | | | • | • | • | • |
| *Microcoleus* sp. | | | | | • | | • | | | | | | | | | | |
| *Phormidium* sp. A | | | | X | | | | | | | | | X | | | | |
| *Phormidium* sp. B | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O |
| *Phormidium* sp. C | O | O | | O | O | | O | ● | O | • | O | | O | O | O | O | O |
| *Phormidium* sp. D | | • | | | • | • | ● | | | | | | | • | | | • |
| *Phormidium* sp. E | | | | | X | X | | | | | | | | | | | X |
| *Plectonema* sp. | | ● | ● | ● | ● | ● | • | | | | | | | | | | X |
| *Tolypothrix* sp. | | ● | ● | ● | ● | ● | • | | | ● | • | | | | | | |
| *Asterococcus superbus* | | X | | | | X | | | | | | | | | | | |
| *Chlamydomonas* spp. | | | | | | | | | | | | | | | | | X |
| *Characium* sp. | | | | | | • | • | | | | | | | | | | |
| *Oocystis* sp. | | | | X | | X | X | | X | | | | | | | | |
| *Pediastrum* sp. | | | | • | | • | • | | | X | • | | | • | | | |
| *Scenedesmus* sp. A | | | | X | | X | | | | | | | | X | | | |
| *Scenedesmus* sp. B | | X | | | | | | | | | | | | | | | |
| *Scotiella* sp. | | | | X | | | | | | | | | | | | | |
| *Tetraedron minimum* | | | | X | | X | | X | | | | | | | | | |
| *Ulothrix* spp. | | O | | | | | | | | | O | | | | O | | |
| *Chaetosphaeridium* sp. | | ● | | ● | | | | | | | | | | | | | |
| *Stigeoclonium* sp. | | | | | | | | | | | | | | X | X | | X |
| *Oedogonium* sp. | X | ● | ● | ● | ● | | • | | | ● | • | | | | | | |
| *Cylindrocystis brebissonii* | | | | | | | | | X | | | | | | | | |
| *C. crassa* | | | | X | X | | | | | | | | | | | | |
| *Mougeotia* sp. | | O | O | O | O | | O | | O | O | O | O | O | O | O | | |
| *Spirogyra* sp. A | | | | | | ● | | | | • | ● | | ● | ● | ● | X | X |
| *Spirogyra* sp. B | | | | | | | ● | | | | | | | | | | |
| *Zygnema* sp. | | O | O | O | | | O | | O | | O | | O | | O | | |
| *Gonatozygon* sp. | | | | | | | | | • | | | | | | | | |
| *Penium* spp. | | | | X | | | | | X | | X | | | | | | |
| *Closterium* sp. | | • | X | X | | • | | | | | | | | | | | |
| *Cosmarium laeve* | | X | X | X | X | | X | | | | X | | | | | | |
| *C. regnellii* | | X | X | | | | | | | | | | | | | | |
| *C. subspeciosum* v. *validus* | | X | | X | | X | | | | | | | | X | | | |
| *Cosmarium* sp. A | | | | | | X | | | | | | | | | | | |
| *Cosmarium* sp. B | | X | | | | X | X | | | | | | | | | X | |
| *Cosmarium* sp. C | | | X | | X | | | | | X | | | | | | | |
| *Cosmarium* sp. D | | | | | | | | | | | X | | | | | | |
| *Cosmarium* sp. G | | | | | | | | | | | X | | | | | | |
| *Staurastrum* sp. | | | X | | X | | | | | | | | | | | | |
| *Tribonema* sp. | • | | • | ● | ● | ● | • | | | ● | ● | | • | | • | | |
| Total number of taxa | 4 | 20 | 14 | 22 | 15 | 18 | 18 | 5 | 9 | 10 | 14 | 2 | 7 | 12 | 9 | 6 | 10 |
| Number of samples | 1 | 9 | 6 | 14 | 7 | 7 | 9 | 6 | 5 | 4 | 3 | 1 | 4 | 6 | 4 | 4 | 7 |

KEY TO SYMBOLS:

O: taxon important constituent of sublacustrine shelf community

●: taxon dominant constituent of an ecologically important community in lake trough

•: taxon common but not as above

X: taxon present

Fig. 3. The distributions of 45 taxa of benthic algae in the freshwater lakes of Signy Island. Three desmid taxa (all *Cosmarium* spp.), not found in the latest study, are omitted. The ordering of the lakes corresponds to the classification scheme of Heywood and others (1980). Abbreviations for lake names are: ML, Moss Lake; EL, Emerald Lake; SL, Sombre Lake; LL, Light Lake; CL, Changing Lake; PL, Pumphouse Lake; TL, Twisted Lake; KL, Knob Lake; AL, Amos Lake; HL, Heywood Lake. Other lakes are referred to by their original numbers, e.g. L16 is Lake 16 (see Heywood and others, 1980).

Table II. Algal taxa that contribute significantly to the axes of the RA ordinations described in the text. Axis scores were standardized to 0–100 and significant high scores were taken as 90–100 and significant low scores as 0–10

(a) Significant taxa from Axes 1–3 of ordination of all lakes data (Fig. 4a)

| | *Axis 1* | *Axis 2* | *Axis 3* |
|---|---|---|---|
| High scores: | *Chamaesiphon* sp.<br>*Chlamydomonas* spp. | *Gonatozygon* sp.<br>*Cylindrocystis brebissonii* | *Gonatozygon* sp. |
| Low scores: | *Gomphosphaeria* sp.<br>*Scenedesmus* sp. B<br>*Cosmarium regnellii*<br>*Cosmarium* sp. C<br>*Staurastrum* sp. | *Chamaesiphon* sp.<br>*Chlamydomonas* spp. | *Cosmarium* sp. D<br>*Cosmarium* sp. G |

(b) Significant taxa from Axes 1–3 of ordination of lakes excluding three outliers (Fig. 4b)

| | *Axis 1* | *Axis 2* | *Axis 3* |
|---|---|---|---|
| High scores: | *Stigeoclonium* sp.<br>*Cosmarium* sp. D<br>*Cosmarium* sp. G | *Cosmarium* sp. A | *Cosmarium* sp. D<br>*Cosmarium* sp. G |
| Low scores: | *Phormidium* sp. E<br>*Cosmarium* sp. A | *Cosmarium* sp. C<br>*Staurastrum* sp. | *Merismopedia* sp.<br>*Microcoleus* sp.<br>*Stigeoclonium* sp.<br>*Cosmarium* sp. C<br>*Staurastrum* sp. |

(Heywood and others, 1979, 1980) whilst Heywood Lake represents the extreme of the main cline amongst the lakes (Heywood and others, 1980). Taxa with significant scores on the first three axes of this ordination are given in Table IIa.

The strong individuality of the three outliers of the previous ordination results in the clustering of the remaining 14 lakes near the centre of the ordination. A second RA ordination, excluding the three outliers and four taxa restricted to them (data for 14 lakes, 41 taxa), was executed to elucidate the relationships within this cluster. Four natural groups of lakes and three outliers appear in this ordination (Fig. 4b). The clusters are:

i. Sombre Lake and Emerald Lake – both are deep, shaded cirque lakes with aquatic moss and *Tolypothrix–Plectonema* felt (Priddle, 1980) dominating the trough vegetation;
ii. Moss Lake and Lake 9 – both have diverse benthic communities and are nutrient-poor. Moss predominates in the benthos;
iii. Amos Lake, Knob Lake, Lakes 8 and 15 – all are nutrient-rich without perennial benthic communities and have high phytoplankton biomass in summer;
iv. Pumphouse Lake and Lakes 13 and 16 – there appears to be little ecological relevance in this group, although their similarity may arise from the large proportion of ubiquitous taxa found in each.

The outliers in this ordination are Light Lake, Twisted Lake and Changing Lake. Algal taxa dominating the axes of this ordination are given in Table IIb.

Group Average Clustering (for all lakes and the taxa in Fig. 3) gives similar groupings of lakes (Fig. 4c) to those suggested by the second RA ordination. Two

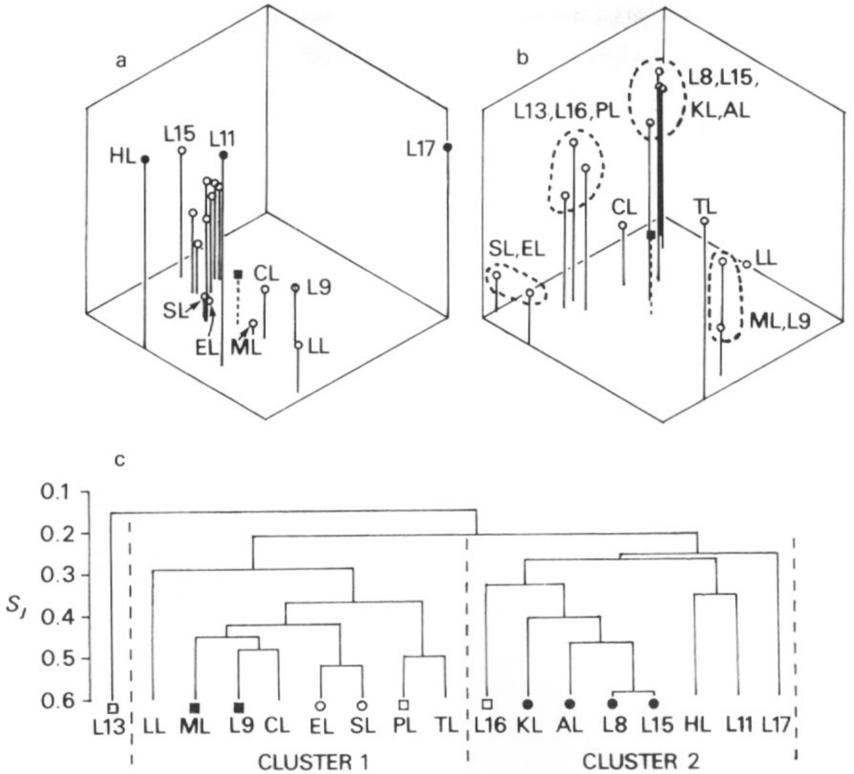


Fig. 4 Ordinations of Signy Island lakes based on the presence-or-absence data for algal distributions given in Fig. 3. (a) Reciprocal Averaging (RA) ordination of all 17 lakes. Three outliers (●) are separated from the remaining lakes (○), and the centre of the cluster is indicated (■); (b) RA ordination of 14 lakes, excluding the outliers in (a). Centre of the cluster is indicated (■); (c) Cluster Analysis of all the lakes. Symbols indicate the lake groups identified in (b). Lake name abbreviations as Fig. 3.

major clusters include all lakes except Lake 13. One cluster comprises the species-rich but nutrient-poor lakes (Cluster 1 = Light Lake, Moss Lake, Lake 9, Changing Lake, Emerald Lake, Sombre Lake, Pumphouse Lake and Twisted Lake). Numbers of taxa recorded from these lakes ranged from 10 to 22. The second cluster contains a wider variety of lake types with the most nutrient-rich and nutrient-poor lakes being represented. None of this group had more than ten algal taxa.

## Conclusion

The list presented here is necessarily incomplete, partly through the difficulty of separation of some taxa and also because of the omission of the Bacillariophyta, which will be covered in detail elsewhere (Belcher, Carter and Priddle, in preparation). This deficiency makes it difficult to compare the algal flora of the Signy Island lakes with other Antarctic collections, especially where some other published material may have similar failings. Hirano (1965) reviewed records of collections of freshwater algae from the Antarctic Continent, offlying and sub-Antarctic islands and noted the preponderance of Cyanophyta at higher latitudes, with corresponding decreases in the numbers of taxa of Zygnemaphyceae. Although it appears that blue-green algae are important constituents of the freshwater algal flora in Antarctica, much of the trend observed by Hirano may be attributed to the wide variety of habitats sampled, with the majority of higher latitude water-bodies comprising seasonal pools. Comprehensive surveys of algae in freshwater habitats (Anvers Island: Parker and others, 1972; Alexander Island: Heywood, 1977; South Victoria Land: Seaburg and others, 1979) and a terrestrial collection (Broady, 1979) indicate that high species diversity of non-marine algae may exist in Antarctica. The collection assessed in this paper has a diversity comparable to that of these later studies and this is attributable largely to the number of taxa of conjugate Chlorophyta.

Heywood and others (1980) classified the lakes on Signy Island on the basis of physico-chemical variables and correlated this with a subjective description of algal communities. Their scheme has been used in the ordering of lakes in Fig. 3. It emphasizes the impact of natural nutrient-enrichment, especially from seal-wallows, imposed on the typically nutrient-poor environment of glacial lakes. The responses of individual lakes to this effect were related to their morphometry and their proximity to the sea. Classification of the lakes using qualitative data for benthic algal species distributions corresponds well with the results obtained by Heywood and his co-workers and identifies natural groups of lakes.

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