BENTHIC PROTOZOA FROM MARITIME ANTARCTIC FRESHWATER LAKES AND POOLS

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Abstract. Eighty-two species of benthic Protozoa (33 flagellates, 15 rhizopods, 4 heliozoans and 30 ciliates) have been isolated from a variety of Maritime Antarctic freshwater lakes and pools. Of these, 43 species were new records from Antarctica. All the Protozoa were cosmopolitan and, with few exceptions, of small size ($<150\,\mu$m). Flagellates and ciliates showed the greatest species diversity but flagellates and amoebae dominated numerically. Cluster analysis identified differences in species composition between lake populations and pool populations. However, despite the wide range of trophic status evident within the two groups of systems, population composition was remarkably similar within each group.

Seasonal fluctuations, both in major groups (flagellates and rhizopod amoebae) and individual species, were linked with fluctuations in numbers and activity of algae and bacteria. A large proportion of the rhizopod population was always encysted whereas flagellate cysts normally constituted less than 5% of the total population. It is concluded that flagellates are the most important protozoan group in these polar freshwater systems and constitute a potentially substantial grazing component.

Introduction

First reports of free-living Protozoa in Antarctica emerged from a series of European scientific expeditions undertaken at the beginning of this century (Richter, 1907; Murray, 1910; Penard, 1911). Almost fifty years elapsed before serious studies of Protozoa were resumed in continental Antarctica. These have been largely concerned with terrestrial forms (e.g. Flint and Stout, 1960; Decloitre, 1960; Sudzuki, 1964), but a few studies have also made of lake Protozoa, particularly in the Dry Valleys of southern Victoria Land (Hada, 1967; Dillon and others, 1968; Bierle, 1969 and Cathey and others, 1981). Studies of terrestrial Protozoa from the Maritime Antarctic have been comprehensively reported by Smith (1978). Information on the protozoan fauna of lakes and pools in this area of the Antarctic (which is comparatively rich, biologically) is restricted to papers by Thompson (1972) and Thompson and Croome (1976) which were concerned exclusively with the ciliate forms. As part of a larger programme of research into the ecology of Antarctic lake micro-fauna, a detailed investigation of Protozoa in lakes and pools at Signy Island, South Orkney Islands was undertaken during the period 1978–81. This paper is concerned with the benthic Protozoa.

Environmental Setting

Over thirty distinct water bodies are present on Signy Island, virtually all of which occur in the coastal lowland region bordering the permanent ice cap of this small island. Sixteen lakes are recognized. These permanent bodies of water are distinguished from pools by the fact that they never freeze solid (i.e. they are more than 2 m deep). The locations and names of lakes and pools which were studied are given in Fig. 1. Only the lake names are officially recognized. The pools are ice-free

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*All communications.

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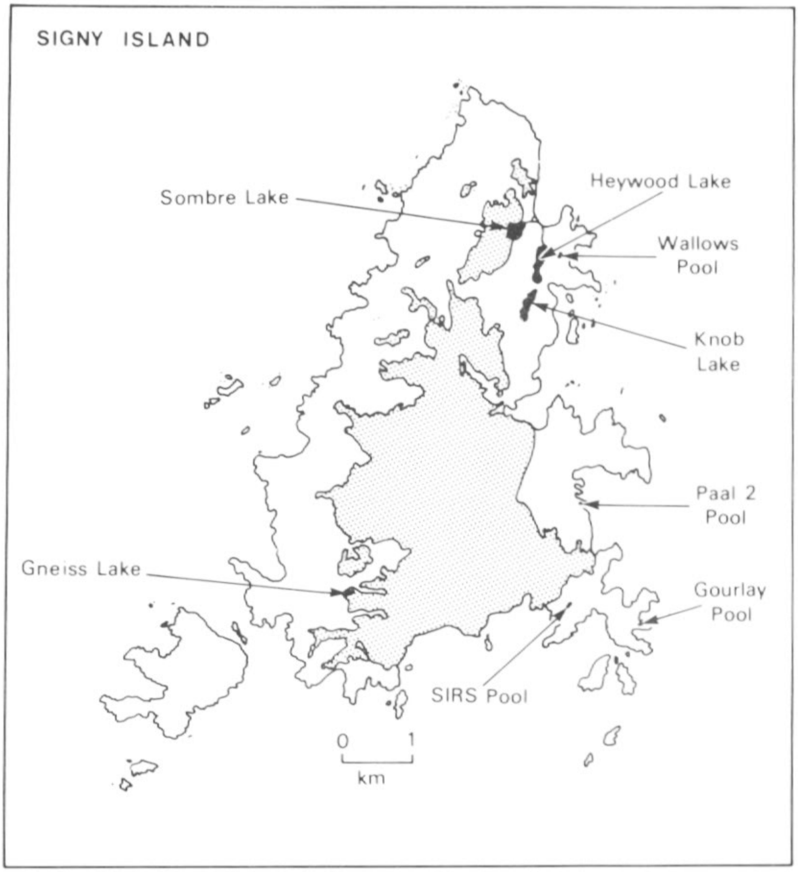

Fig. 1. Location of lakes and pools studied. Stippled area indicates permanent ice-cover.

for two to three months each year and the lakes for up to four months. All the lakes are ice-covered to a depth of 1.0–1.5 m in winter and Gneiss Lake is permanently ice-covered. The data presented in Table I indicate the wide range of nutrient status occurring amongst the freshwater bodies on Signy Island.

Lakes

1. Sombre Lake. A clear, oligotrophic system (maximum depth 11.2 m) with an extensive benthic plant community. Under winter ice cover the sump (9.0–11.2 m) becomes strongly anoxic. The catchment is largely ice and scree and the inflows are essentially meltwater. Moss carpet covers about 4% of the total catchment area.

2. Heywood Lake. A turbid, mesotrophic system (maximum depth 6 m) surrounded by a moss-carpeted catchment enriched by seals and birds. Phytoplankton dominate the flora and substantial sedimentation occurs each year.

3. Knob Lake. A shallow, (maximum depth 4 m, average depth 1 m) fairly clear lake surrounded by a catchment of lichen-covered rock/scree and moss carpet. Large amounts of mineral debris are washed into the lake burying plant assemblages, so plant development is largely restricted to filamentous green algae which proliferate each summer.

Table I. Chemical and chlorophyll-*a* data to illustrate the variation in nutrient status present in freshwater systems studied at Signy Island.

		Variables					
		*Chlorophyll-*a $\mu g\ l^{-1}$	*Alkalinity* *meq* l^{-1}	o-*Phosphate* $\mu g\ l^{-1}$	$NO_2 + NO_3$ $\mu g\ l^{-1}$	*Ammonia* $\mu g\ l^{-1}$	*Chloride* $\mu g\ l^{-1}$
Lakes							
Gneiss Lake	s	1.7	0.05	1.2	235.0	10	42
	w	2.5	0.08	0.5	180.0	62	48
Sombre Lake	s	3.0	0.23	tr	179.0	13	35
	w	1.8	0.30	3.4	938.0	64	47
Knob Lake	s	6.8	0.16	tr	203.0	33	45
	w	2.9	0.32	13.8	115.0	388	71
Heywood Lake	s	9.9	0.18	47.0	79.0	38	56
	w	5.4	0.25	86.0	1674.0	144	68
Pools							
SIRS Pool	s	5.8	0.05	168.0	tr	ND	86
Paal Pool	s	2.8	0.05	76	0.3	ND	968
Gourlay Pool	s	25.2	1.25	2580	333.0	ND	92
Wallows Pool	s	1460.0	ND	714	733.0	1649	ND

ND – No data; s – summer; tr – trace; w – winter.

4. Gneiss Lake. Located in a remote upland area, this lake is permanently ice-covered and melts out only around its perimeter. The catchment is almost entirely ice, and the lake ultra-oligotrophic with a sparse benthic development, except in summer when large amounts of filamentous green algae can develop in the shallow areas. Maximum depth 8.2 m.

Pools

1. Wallows Pool. A shallow (<1 m) hyper-eutrophic pool, often frequented by elephant seals and draining a rocky catchment which is a site of considerable seal activity. Dense populations of green algal unicells develop (see Table I, chlorophyll-*a* data) at times turning the pool water bright green. Sediment is virtually absent.

2. Paal Two Pool. A shallow (about 40 cm deep) pool, situated on a small rocky peninsula in Paal Harbour and therefore subject to fluctuating ion input from sea spray. Substantial development of filamentous green algae occurs in summer.

3. Gourlay Pool. Situated in a small rocky basin and enriched by seals and penguins due to its proximity to a large rookery. A shallow system (30 cm deep) with a fairly anaerobic sediment. Bright red patches are often observed due to large aggregations of the Antarctic rotifer *Philodina gregaria*.

4. SIRS Pool. A body of standing water on the wet moss part of the Signy Island Reference Site – an area of moss banks and carpets (see Tilbrook, 1973). The maximum depth of the pool is 25 cm.

METHODS

Samples of sediment, detritus and plant material obtained from the littoral zones of the lakes and pools were quickly returned to the laboratory and stored at 2°C. Sediment samples were obtained from the lakes with the corer described by

Ellis-Evans (1982) or, using a hand corer, by SCUBA diving. Samples from the pools were obtained in summer with a sterile plastic container and in winter by cutting samples out of the ice and slowly thawing benthic material in the laboratory.

All material was subjected to direct microscopic examination but also subsampled and inoculated into several different culture media:

(a) 0.05% Oxoid liver infusion.
(b) Barley grain in 5 ml sterile filtered lake water.
(c) Soil expressate.
(d) 10% seawater plus 0.05% liver infusion.
(e) 10% seawater plus a barley grain.

All the above were made up in sterile filtered lake water and autoclaved at 15 lb/in^2 for 15 min. Each sample was incubated in a 5-cm Petri dish under both dark and light conditions at 4°C and examined after 2–3 weeks. Preliminary examination of cultures was with a Prior inverted microscope. More detailed observations were made under bright field and phase contrast illumination. Ciliate movement was slowed when necessary by the addition of 25% methyl cellulose and nuclei stained with 1% methyl green. Identifications were made with reference to Cash and others (1921), Sandon (1927), Kahl (1935), Decloitre (1960), Kudo (1960), Curds (1969), Page (1974), Corliss (1979), Ogden and Headley (1980). Cluster analysis of the data employing a group average clustering technique (Lance and Williams, 1967) was kindly undertaken by Dr J. Priddle (BAS).

Regular sampling to study seasonal fluctuations in numbers was undertaken in Sombre Lake and Heywood Lake. Counting of Protozoa followed the Singh (1955) ring culture method as modified by Smith (1973*a*). For each lake sample, two parallel series of dilution cultures were initiated, one untreated whilst the other was acid treated. The latter procedure killed the trophozoites, so any subsequent growth could be attributed to development from cysts which remain unaffected. Subtraction of the latter dilution series counts from those of the untreated dilution series gave the number of trophozoites.

RESULTS

Species composition

The numbers of protozoan species found in the three lakes during this study were similar: 41 species in Sombre Lake, 37 in Heywood Lake and 33 in Knob Lake. The total for Knob Lake is probably an underestimate (see Fig. 2) as the lake was sampled less frequently than the others. In general, the flagellates in a sample were found fairly quickly because the method employed is particularly effective for isolating this group. Ciliates proved more difficult to obtain in culture, but ultimately 30 spp. were found in the lakes and pools (Table II). No major protozoan group was found exclusively in the pools, but the converse was true of the lakes. Heliozoans were only isolated from the three study lakes (total 4 spp.) and rhizopods were also almost completely absent from pools. The latter group (mainly Amoebodida) only revealed diversity of form in Sombre Lake (9 spp.) and Heywood Lake (10 spp.) but were found in quantity whereas ciliates were often only encountered as solitary specimens. Certain genera of Protozoa were found in all three lakes, but few were found to occur also in the full range of pools. Flagellates, such as *Heterochromonas* sp., *Bodo saltans* Ehrenberg and *Heteromita globosa* Stein, and the ciliates *Cinetochilum margaritaceum* Perty and *Aspidisca costata* Dujardin are examples of ubiquitous species, but invariably these were not present in sufficient numbers to indicate any recognizable pattern.

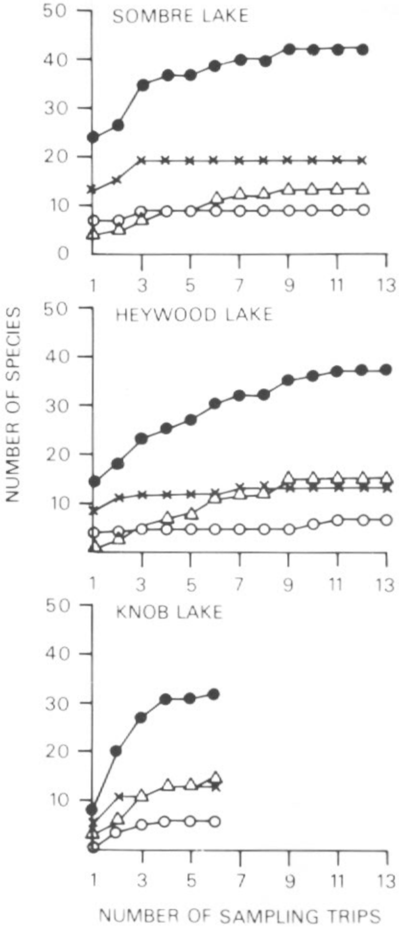

Fig. 2. Cumulative species totals for protozoan isolates obtained from three lakes versus number of sampling occasions. ●, total protozoan isolates, ×, total flagellates, △, total ciliates, ○, total rhizopods.

The majority of Protozoa isolated in this study (Table II) could be identified to species level and all to genus. This indicates the cosmopolitan nature of these organisms and the absence of endemic Antarctic species. A large proportion of the species (43 spp. in a total of 83) reported here are new records for the Antarctic region.

The majority of the Protozoa listed in Table II are small (< 150 μm) with obvious exceptions being certain of the rhizopods. Larger forms (> 150 μm) occur, but these appear to be restricted to the water column of eutrophic systems such as Heywood Lake and the Wallows Pool. Most of these larger Protozoa were ciliates (which graze the phyto-flagellates of the water column) and are the subject of a separate study. The benthic grazers are probably most correctly termed detritivores, but their small size suggest that bacteria form the bulk of their food. Direct examination of material showed few large Protozoa in samples, so the preponderance of small forms was not a result of the enrichment technique.

Table II. Observed occurrence of protozoan taxa in freshwater habitats

Protozoa	*Sombre Lake*	*Heywood Lake*	*Heywood Shelf*	*Heywood Shelf (F)*	*Knob Lake*	*Gneiss Lake*	***Wallows Pool***	*Paal 2 Pool*	*Gourlay Pool*	*Gourlay Pool (F)*	***SIRS Pool***
Sarcomastigophora											
Mastigophorea											
Phytomastigia											
(a) Cryptomonadida											
Chilomonas sp. Ehrenberg*						●					
(b) Chrysomonadida											
Heterochromonas sp.*	●	●	●	●	●	●	●	●	●	●	●
Oikomonas mutabilis Kent	●	●									
Polypseudomodius bacteriodes Puschkarew	●										
(c) Euglenoidida											
Distigma proteus Ehrenberg*	●	●						●			●
Peranema granulifera Penard*	●	●									
Petalomonas angusta Klebs							●			●	
Zoomastigia											
(a) Rhizomastigidia											
Actinomonas mirabilis Kent						●					
Mastigella simplex Kent*		●									
(b) Protomonadida											
Allantion tachyploon Sandon	●			●			●	●			
Amastigomonas debruynei de Saedeleer*	●										
Amphimonas globosa Kent*								●			●
Apusomonas proboscoidea Alexeiff		●						●	●	●	
Bicosoeca exilis Penard*	●	●			●						
Bodo caudatus Dujardin*											●
Bodo celer Klebs	●										
Bodo elax Klebs							●	●		●	
Bodo saltans Ehrenberg	●	●	●	●	●		●	●	●	●	●
Cercobodo sp. Krassilstchik					●						
Cercomonas crassicauda Alexeiff	●	●			●	●	●	●	●		●
Cercomonas longicauda Stein	●	●			●	●		●	●		●
Clautravia parva Massart*	●										
Desmarella moniliformis Kent*		●									
Helkesimatix faecicola Woodcock and Lapage*	●										
Heteromita globosa Stein	●	●		●	●	●		●	●	●	●
Heteromita sp. Dujardin						●	●		●		●
Monosigna ovata Kent*	●	●	●	●	●			●	●		
Parabodo attenuatus Skuja*									●		
Rhyncomonas nasutum Klebs*	●	●			●				●		●
Sainouron mikroteron Sandon	●				●						
Spiromonas angusta Dujardin*					●						
Spongomonas minima Dangeard*					●			●		●	●
(c) Polymastigida											
Tetramitus rostratus Perty		●			●				●	●	
Total taxa:	18	14	3	5	13	7	7	12	11	8	11

Table II. – *continued*

Protozoa	*Sombre Lake*	*Heywood Lake*	*Heywood Shelf*	*Heywood Shelf (F)*	*Knob Lake*	*Gneiss Lake*	*Wallows Pool*	*Paal 2 Pool*	*Gourlay Pool*	*Gourlay Pool (F)*	*SIRS Pool*
Sarcodinea											
Rhizopodia											
(a) Amoebida											
Acanthamoeba castellani Douglas*	●		●								
Amoeba diminutiva Bovee*	●										
Cochliopodium minus Page*		●									
Echinamoeba exudans Page*	●										
Hartmanella sp. Alexieff*		●									
Naegleria gruberi Schardinger		●	●				●				
Pelomyxa schiedti Schaeffer*		●									
Valkampfia magna Jollos*										●	
Vanella sp. Bovee		●									
Vanella platypodia Glaser*	●										
Vanella simplex Wohlfarth-Botterman*						●					
(b) *Testacida*											
Arcella vulgaris Ehrenberg		●					●				
Euglypha tuberculata Dujardin						●					
Microgramia socialis (Archer) Hertwig and Lesser	●										
Trinema lineare Penard	●	●									
Actinopodia											
(a) Heliozoida											
Astrodisculous araneiformis Schewiakoff*					●						
Ciliophrys infusionum Chienkowski*	●				●						
Raphidiophrys sp.	●	●									
Actinophrys sol Ehrenberg	●				●						
Total taxa:	9	8	2	0	3	2	2	0	0	1	0
Ciliophora											
Ciliatea											
Holotrichia											
(a) Gymnostomatida											
Chilodonella uncinata Ehrenberg						●	●	●			
Lacrymaria olor Müller*	●	●		●							
Trachelophylum tachyblastum Stokes*					●						
Urotricha agilis Stokes	●	●			●						
(b) Hymenostomatida											
Cinetochilum margaritaceum Perty	●	●	●		●	●		●	●	●	●
Cryptochilum nigricans (Müller) Maupas						●					
Cyclidium glaucoma Müller	●	●	●		●			●	●		●
Cyrtolophosis mucicola Stokes*	●	●			●				●		
Glaucoma scintillans Ehrenberg*				●						●	
Pseudoglaucoma muscorum Kahl	●	●			●						
Sathrophilus putrinus Kahl*		●									
Tetrahymena rostrata Kahl	●										
Uronema marinum Dujardin					●			●			
(c) Trichostomatida											
Plagiopyla nasuta Stein*	●										

Table II. – *continued*

Protozoa	*Sombre Lake*	*Heywood Lake*	*Heywood Shelf*	*Heywood Shelf (F)*	*Knob Lake*	*Gneiss Lake*	*Wallows Pool*	*Paal 2 Pool*	*Gourlay Pool*	*Gourlay Pool (F)*	*SIRS Pool*
Peritrichia											
(a) Peritrichida											
Platycola longicollis Kent	●										
Vorticella convallaria Linnaeus		●				●					
Vorticella microstoma Ehrenberg				●			●				
Vorticella sp. Linnaeus	●	●	●					●	●		
Suctoria											
(a) Suctorida											
Tokophrya infusionum Stein*								●	●		
Spirotrichia											
(a) Heterotrichida											
*Blepharisma elongatum**	●	●			●	●		●	●	●	
Bursaria sp. Müller△	●										
Bursaridium sp. Lauterborn*					●						
(b) Oligotrichida											
Halteria grandiella Müller		●		●			●	●	●	●	●
(c) Hypotrichida											
Aspidisca costata (Dujardin)*	●	●	●		●	●		●	●	●	●
Aspidisca lynceus Ehrenberg*					●						
Euplotes sp. Ehrenberg					●						
Oxytrichia sp. Bory				●		●		●	●		
Tachysoma parvistyla Stokes*	●										
Uroleptus caudatus Clapard-Lachman*	●	●		●	●						
Urostyla gracilis Entz*		●		●	●	●					
Total taxa:	15	14	4	7	14	8	3	10	9	5	4

● Presence of organism.

* First report from Antarctica

△ Not observed by authors, but identified from drawing and description in BAS internal report N12/1975/H, Priddle and Dartnall.

(F) Sample taken when site frozen.

Visual examination of the data (Table II) suggests that the species composition of lake populations is different from that of pools. The results of the cluster analysis are illustrated in Fig. 3. These indicate that there are differences between lakes and pools and that the trough populations of the three main study lakes can be separated from the other lake and pool site populations. There is a high degree of similarity between the three main lake sites despite markedly different nutrient status. Of the remainder, several small 'sub-clusters' may be identified, e.g. the frozen samples (Heywood Lake shelf and Gourlay Pool) and three of the pools (Paal, Gourlay and SIRS), but it was not felt that the data or technique were rigorous enough to justify such separation. An exception was the Wallows Pool, which was obviously separable from all the other systems. The pool has very active zoo- and phyto-plankton populations, but virtually no sediment accumulation. On a saprobity scale, it would register high (Table I), so perhaps the differences can in part be traced to lower species diversity due to gross enrichment. It is interesting that Gneiss Lake

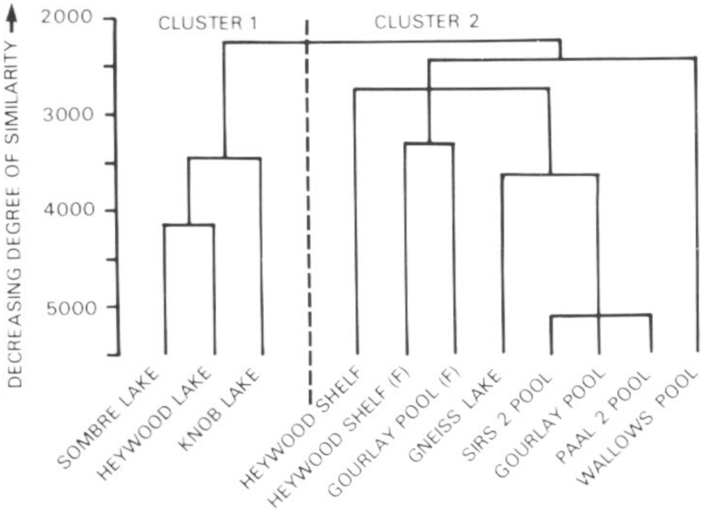

Fig. 3. Results of cluster analysis to indicate the degree of similarity between protozoan populations of the eight study sites.

population composition was comparable to the pools, possibly reflecting its immaturity and instability. Also, the two frozen material samples were comparable and yet summer samples from the same sites showed considerable disparity.

Protozoan numbers

Sediment profiles indicate that the Protozoa are restricted to the top few millimetres of sediment and as attempts to culture them under anaerobic conditions failed the populations are clearly aerobes. All the sampling stations in this study were located in areas of the lakes where the surface sediments remain relatively oxic throughout the year. Recent work has examined Sombre Lake sediments from the anoxic sump region in summer and winter. Few trophozoites were recovered from anoxic winter sediment samples and the population largely comprised encysted forms, which emerged when the sediment samples were gently aerated before culturing. In general, flagellate cysts from both Sombre Lake and Heywood Lake represented less than 5% of the total flagellate populations (Fig. 4), the two exceptions being indicated in the Figure. In contrast, encysted forms were usually a substantial component (7–85%) of total rhizopod numbers for both lakes, as illustrated in Fig. 4. Although sampling was not sufficiently detailed to support any definitive statements regarding seasonal changes in species composition, the data do indicate certain trends. Both total and trophozoite counts for rhizopods in Sombre Lake were highest between May and December, when the lake was ice-covered, and declined during the open water period (January–April) (Fig. 4). The Heywood Lake data indicated generally lower rhizopod numbers and seasonal trends were less apparent. The flagellate data from both lakes (Fig. 4a) showed that this group was present in highest numbers during late winter when plant production had begun, microbial numbers were increasing and the inflow streams running. It is also clear that flagellate numbers were low during the open water period and through much of the winter. The errors on flagellate counts were considerable, but the late winter peaks are significantly different from counts at other periods of the year.

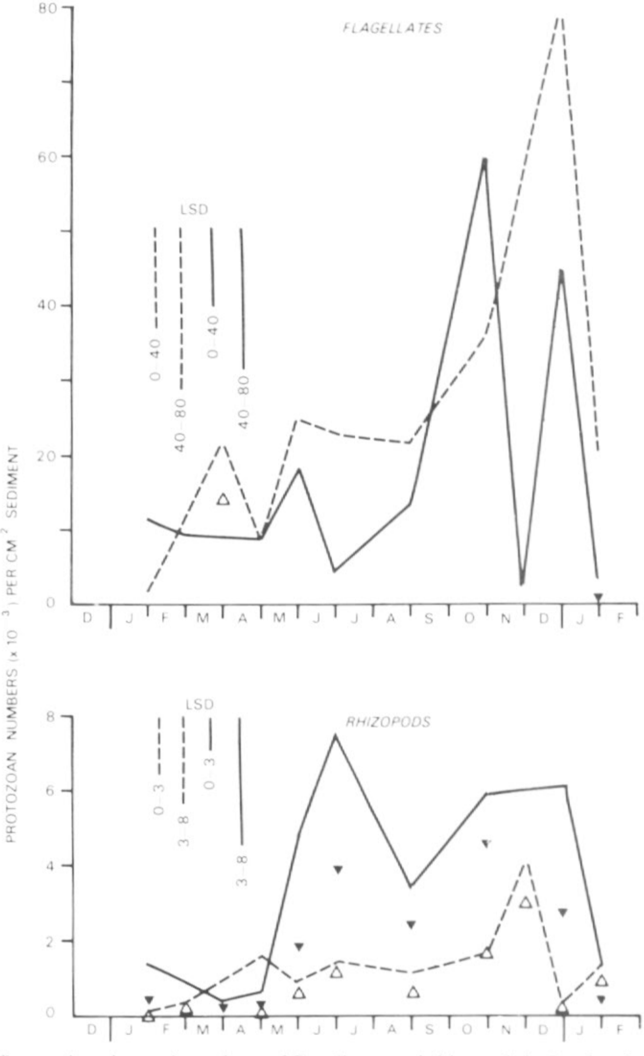

Fig. 4. Seasonal fluctuations in total numbers of flagellates and rhizopods in Sombre Lake (– – – –) and Heywood Lake (————). The significance may be assessed from the vertical bars indicating Least Significant Difference. Two values of LSD are given for each data set and each value applies to a specific range of population sizes (0–40 and 40–80 flagellates (× 10^3) cm^{-2} and 0–3 and 3–8 rhizopods (× 10^3) cm^{-2}). Numbers of cysts in each sample are indicated by △ (Sombre Lake) and ▼ (Heywood Lake). Only two such points are shown for the flagellates as all other flagellate cyst counts were $<5\%$ of the total.

Although it proved impracticable to count individuals of particular genera on a regular basis, counts were made of five genera on three occasions during the important late winter/early spring period and results are presented in Fig. 5. The ciliate that was consistently found in any significant numbers was *Cinetochilum margaritaceum* Perty. Its occurrence in September, November and February samples from Sombre Lake and Heywood Lake was monitored together with the

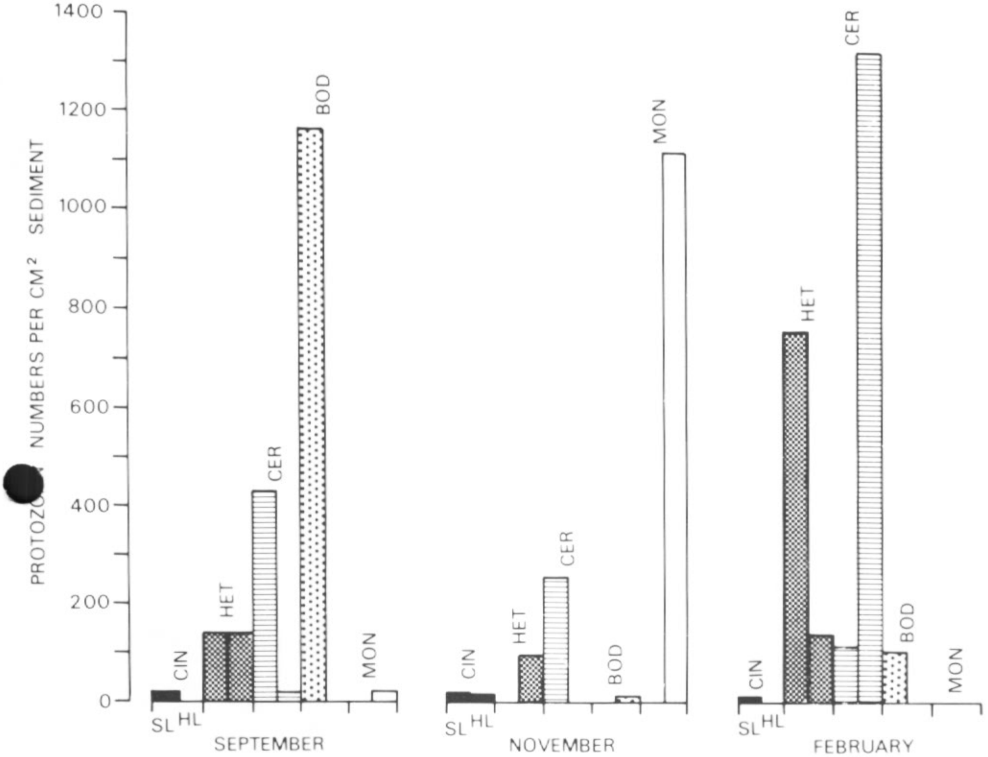

Fig. 5. Fluctuations in numbers of five protozoan genera during the spring/summer period in sediment samples from Sombre Lake (SL) and Heywood Lake (HL). CIN – *Cinetochilum margaritaceum*, HET – *Heterochromonas* sp., CER – *Cercomonas longicauda*, BOD – *Bodo celer* and MON – *Monosigna ovata*.

chrysomonad, *Heterochromonas* sp. and three numerically common protomonads (*Bodo celer, Cercomonas longicauda* Stein and *Monosigna ovata* Kent). *C. margaritaceum* was present only in very low numbers in each of the three samples (range 0–17 individuals per cm^2) from both lakes, so no pattern was discernible. Further work has indicated that it only occurs in detectable numbers (>5 individuals per cm^2) in Heywood Lake during the spring period whereas it occurs year-round in Sombre Lake. In contrast, substantial changes in counts of the other four protozoan types were observed between sampling dates. In Sombre Lake, September samples were dominated by *Bodo* spp. but subsequent samples revealed low counts compared to *Cercomonas*. In February, *Heterochromonas*, which had previously been observed in very low numbers, became dominant. *Bodo celer* was only found in the oligotrophic lake, whereas *Monosigna ovata* was rarely found there, but was frequently observed in Heywood Lake, Though only a very small component of the protozoan population in September and February, *Monosigna* constituted almost 45% of the November flagellate population in Heywood Lake. None of the genera studied were present in Heywood Lake samples in any substantial numbers during September, but *Cercomonas* was estimated to represent almost 30% of the total flagellate count for this lake during the open water conditions of February.

DISCUSSION

Biogeographical significance

These results represent the first year-round study of Protozoa in Antarctic aquatic environments. From their review of the literature, Sudzuki and Shimoizumi (1967) concluded that the protozoan fauna of Antarctica is relatively species-poor and almost entirely composed of cosmopolitan forms. This conclusion was based on summer-only data sets, but, from data presented here and in Smith (1978), it seems nevertheless to be essentially correct. It appears that the isolated position and hostile environment of Antarctica has not generally resulted in the evolution of new forms but rather the elimination of those less adaptable and the establishment of more cosmopolitan organisms. This is well illustrated by the data on bipolar bigeography of the ciliate genus *Colpoda* presented by Smith (1973*b*).

If populations are essentially cosmopolitan one might anticipate that similar environments in different areas of Antarctica would have some overlap of species occurrence. However, from a review of the literature, this would not appear to be the case. This may be in part due to the haphazard nature of the main transpor[illegible] mechanisms utilized by potential colonizers, namely wind and birds. But the fact that some overlap is invariably found between diverse ecosystems within the same study and yet not between similar systems in separate studies implies that sampling methods and sampling intensity also influence the form of these data sets. (See for example, Dillon and others, 1968; Bierle, 1969; Smith, 1978; Thompson and Croome, 1976; and Cathey and others, 1981.) The influence of sampling intensity is clearly demonstrated by the data in Fig. 2. However, Signy Island is more deglaciated and better vegetated than most other study sites in Antarctica and Smith (1974) found that data from Signy Island could not be fitted into either of the two groups of Protozoa recognized for the other islands of the South Orkney group. The fact that a large proportion of the taxa reported here and in Cathey and others (1981) are new records for Antarctica is an indication of how much work remains to be done in establishing the range of Protozoa occurring in various Antarctic environments. For these reasons it was not considered valid to compare directly the present data with those reported from other Antarctic investigations.

Lake vs pool populations

It is perhaps significant that only 35 species of Protozoa were recorded from the four Signy Island pools, whereas the four lakes yielded 75 species. This in par[illegible] reflects differences in sampling frequency, but the lakes offer a greater range of ecological niches (Priddle and Dartnall, 1978). The results may reflect the instability inherent in pool systems due to their small volume and the brevity of the ice-free period when biological activity is possible. The four pools are markedly different in terms of physico-chemistry yet cluster analysis indicated that, with the exception of the Wallows Pool, they had a similar benthic protozoan fauna. The virtual absence of sediment from the Wallows Pool readily explains its exclusion, but the high degree of similarity apparent in the remaining pools is more difficult to explain. A general lack of variation was also noted in the fauna of the lakes which are, in terms of trophic status, markedly different from each other (Heywood and others, 1980). Cathey and others (1981) found significant differences between lakes in their study but this may reflect a relatively low sampling intensity, bearing in mind the data presented in Fig. 2.

On an individual species basis there are clearly differences between water bodies as evidenced by the data (Table II and Fig. 5). In some cases, such differences can readily be explained. For example, the absence of *Cinetochilum margaritaceum* Perty from the Wallows Pool samples can be attributed to the well-documented sensitivity of this organism to free ammonia, which is particularly abundant in seal wallows (Lindeboom, 1979). Nitrogen is present in relatively small amounts, usually as nitrate, in the other systems where the ciliate has proved to be ubiquitous. Other popular poly-saprobity indicator species such as *Vorticella microstoma* and *Tetramitus rostratus* Perty occurred in an apparently random distribution which defied interpretation. However, most such indicator species are in fact of euryecious character (Bick, 1973), so only occurrence in high abundance constitutes a valid indication of any given saprobic condition. As none of the above indicator species occurred in high numbers, differences in species composition were not necessarily significant in the present data set.

Seasonality of Protozoa

Seasonal fluctuations in numbers for protozoan groups were more readily identified than for individual species. In both Sombre Lake and Heywood Lake, total flagellate numbers were highest during the period October–January when bacterial populations were increasing in both numbers and activity (Ellis-Evans, 1982). The curious double peak of flagellate numbers observed in Heywood Lake is very similar to that reported by Ellis-Evans (1981) for bacterioplankton of this lake but the cause of this phenomenon is yet to be found. In contrast to the flagellate data, counts of amoebae indicated that highest numbers were associated with the period of ice cover. It is perhaps of relevance than when numbers were high, cyst numbers were also high and, in Sombre Lake, virtually the entire population of amoebae appeared to be encysted. It may be concluded from such data that rhizopods are not particularly important components of lake protozoan populations in terms of grazing activity. Cysts reprsented a small proportion of total flagellate counts so the seasonality apparent in this group was probably a real change. The decrease in flagellate numbers during the summer open water may be linked to predation by other zoobenthos, which increase in numbers during this period (Weller, 1977). Although protozoan numbers do not appear to be particularly high during the summer, their occurrence in substantial numbers in spring coinciding with the increase in population size of aerobic bacteria indicate a potentially significant grazing impact in Antarctic freshwater lakes.

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