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ABSTRACT

A SURVEY was made of the terrestrial protozoan fauna of 97 sites located in eight sub-Antarctic and maritime Antarctic island groups, extending from lat. 51° to 68° S. The habitats investigated included glacial and volcanic mineral materials, guano of marine birds and mammals, moss peats, and soils and litters with herbaceous, grass, dwarf-shrub or woodland vegetation. 124 species of Protozoa were recorded from the samples: 31 flagellates, ten naked amoebae, 35 testate amoebae and 48 ciliates. 83 of the species are considered to be definitely established members of the sub-Antarctic and maritime Antarctic fauna, the other 41 species being insufficiently observed. The ecology and geographical distribution of these 83 species are reviewed, and direct and inverse association analyses of the distributional data are given. The results of these analyses are combined to form a matrix showing the tendencies of eight communities of Protozoa to occur in six habitat classes, the habitat classes being distinguished by their geographical zone, pH and organic matter content, and by the presence or absence of vegetation or enrichment by marine animals. An artificial key to the genera and a glossary are provided.

RÉSUMÉ

ON a procédé à un examen des protozoaires terricoles de 97 stations situeés dans huit groupes d'îles sub-antarctiques et antarctiques oceaniques, qui s'étendent de la latitude 51° jusqu'à 68° S. Les biotopes examinés ont compris des matières minerales glaciaires et volcaniques, le guano des animaux marins, des tourbes de mousse, et des sols et litières à végétation herbacée, graminée, de l'arbrisseau nabougrie ou boisée. 124 espèces de protozoaires ont été observées dans les échantillions: 31 flagellaires, 10 amibes, 35 thécamoebiens et 48 ciliés. Il semble que 83 des espèces sont établies d'une manière bien determinée parmi la faune sub-antarctique ou antarctique oceanique; les 41 autres espèces ont été insuffisamment observées. Un compte rendu est fait de l'écologie et de la répartition géographique de ces 83 espèces, et des analyses d'association directe et inverse sont réalisées sur les données de la répartition géographique. Les resultats des analyses sont combinées sous la forme d'une matrice montrant les dispositions de huit communautés d'espèces de protozoiares qui se présentent dans six catégories de biotopes; les biotopes sont distingués par leur zone géographique, pH, et la teneur en matières organiques, et par la présence ou l'absence de végétation ou par l'amandement par les animaux marins. Une clé artificielle des genres et une glossaire sont fournis.

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I. INTRODUCTION

THIS report is a comprehensive account of the distribution and ecology of the terrestrial Protozoa observed in samples taken from 97 sites on a number of islands in the Southern Hemisphere during a programme of protozoological research undertaken between 1968 and 1973. The islands from which the samples were taken fall into eight discrete island groups:

	lat.	long.
Tierra del Fuego	54° 48′ S.,	68° 19′ W.
Falkland Islands	51° 42′ S.,	57° 52′ W.
Iles Crozet	45° 26′ S.,	51° 45′ E.
South Georgia	54° 20′ S.,	36° 40′ W.
South Orkney Islands	60° 40′ S.,	45° 40′ W.
South Shetland Islands	61°–63° S.,	55°–60° W.
Argentine Islands	65° 15′ S.,	64° 17′ W.
Islands in Marguerite Bay	67°–68° S.,	67°–69° W.

Whilst these islands show considerable differences in their geological origin and present-day geomorphology, climatically they represent a continuous cline from the southern fringes of the southern cool-temperate region, through the sub-Antarctic to the southern end of the maritime Antarctic. The island groups are therefore listed above in order of increasing climatic severity. Tierra del Fuego and the Falkland Islands are situated north of the Antarctic Convergence, Iles Crozet lie on the Convergence and the other islands are south of it (Fig. 1). Although any sub-division of a continuous variable into discrete

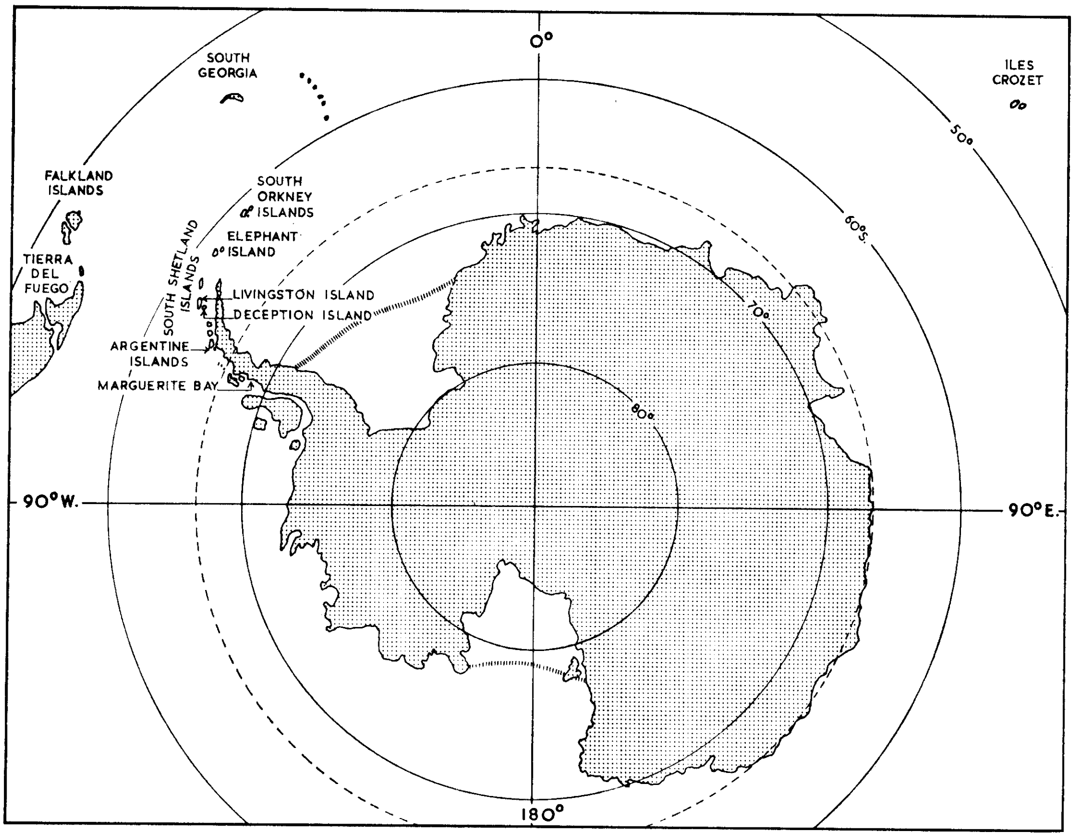


FIGURE 1
Sketch map of the Antarctic zone showing the island groups included in the present study.

categories is necessarily arbitrary, it is convenient to designate the climate of the islands north of lat. 60° S. as sub-Antarctic and the climate of those south of lat. 60° S. as maritime Antarctic. Correlated with the cline of increasingly cold climates are gradients of decreasing vegetation cover and decreasing diversity of vegetation and soil types. In view of the range of environmental conditions experienced by these islands, a survey was undertaken of the terrestrial Protozoa, encompassing all the island groups, in order to provide data from which the composition of the protozoan fauna could be related to environmental variables, both in regard to local ecological factors and at the regional geographical scale.

II. ENVIRONMENT OF THE AREAS INVESTIGATED

A. GEOLOGY AND TOPOGRAPHY

With the exception of the Falkland Islands and Iles Crozet, all of the island groups are geographically a continuation of the Andean cordillera. The Antarctic Peninsula forms the Antarctandes which are linked to Tierra del Fuego by the Scotia Ridge, on which are situated South Georgia and the South Sandwich, South Orkney and South Shetland Islands. The geology of the Antarctic Peninsula and the islands off the west coast is dominated by the igneous rocks of the Andean Intrusive Suite with associated volcanic rocks (Elliot, 1964; Hobbs, 1968; Dewar, 1970; personal communications from T. G. Davies and A. C. Skinner). The South Orkney and eastern South Shetland Islands are dominated by a petrographically distinct sequence of quartz-mica-schists (Matthews and Maling, 1967; West, 1968; Thomson, 1968, 1971, 1973, 1974; Dalziel, 1971). Deception Island, near the southern end of the South Shetland Islands, is a volcanic caldera composed of pyroclastic rocks and their alteration products (Baker and others, 1975). South Georgia, the largest island of the Scotia Ridge, is composed mainly of slightly metamorphosed sedimentary rocks—greywackes and tuffs—with a small igneous complex at the south-eastern end (Trendall, 1953, 1959; Skidmore, 1972). The Falkland Islands are composed almost entirely of Palaeozoic and Mesozoic sedimentary rocks. They are considered to be an isolated fragment of the former Gondwanaland continent; they have been stratigraphically correlated with eastern South Africa (Maling, 1960) but recent work by Greenway (1972) suggests that they are related to the Deseado Massif of southern Argentina. Iles Crozet, situated in the southern Indian Ocean, are Tertiary volcanic islands composed mainly of plagioclase-basalt (Philippi, 1908; Dreux and Rémy, 1963).

All of the islands, except the smallest, are mountainous with highly indented coastlines; the Falkland Islands alone lack steep impressive montane scenery. All exhibit the topographic features of previous glaciation: cirques, troughs and patterned ground. Many possess raised beaches, though the Falkland Islands appear to have a submerged coastline (Hobbs, 1968; Clapperton, 1971; Greenway, 1972; Thomson, 1974). The Falkland Islands and Iles Crozet have no permanent snow cover and their lowland areas have a more or less continuous vegetation cover of a rough moorland type. Above 100 m. altitude on Iles Crozet and 180 m. on the Falkland Islands the terrain is of the fell-field type, stony with sparse vegetation (King and others, 1969; Davies, 1973). Tierra del Fuego is the only island with forest, small trees of *Nothofagus* spp., which reaches to an altitude of 400 m. Above 1,000 m. there is permanent snow.

All the islands south of the Antarctic Convergence have high ground extensively covered with snow and ice which extends to the coast as glaciers. The cover of permanent snow is interrupted by rocky peninsulas and cliffs around the coast and inland by nunataks which are free of snow each summer. In some areas there are extensive coastal lowlands with inland valleys bounded by scree slopes which are also clear of snow in summer.

B. CLIMATE

The islands of the sub-Antarctic and maritime Antarctic experience an oceanic climatic regime, dominated by the prevailing westerly air flow which circulates across the southern Pacific, Atlantic and Indian Oceans. Seasonal variations in temperature are small compared with those in continental areas; the annual range of monthly mean temperatures never exceeds 20° C and in the lower latitudes may be as low as 6° C. A summary of meteorological observations on these islands is given in Table I.

The islands north of the Antarctic Convergence have monthly mean temperatures above zero all year and most of the precipitation falls as rain, evenly spread throughout the year, though snow may fall at

TABLE I

SUMMARY OF DATA FROM METEOROLOGICAL STATIONS ON SUB-ANTARCTIC AND MARITIME ANTARCTIC ISLANDS

Meteorological station	*Tierra del Fuego Ushuaia*	*Falkland Islands Stanley*	*Iles Crozet Ile de la Possession*	*South Georgia Grytviken*	*South Orkney Islands Signy Island*	*South Shetland Islands*		*Argentine Islands Galindez Island*	*Islands in Marguerite Bay Stonington Island*
						Elephant Island	*Deception Island*		
Period of observations	1931–60	1951–64	1965–73	1951–64	1948–71	December 1970—March 1971	1951–64	1951–64	1946–49
Temperature (°C)									
Monthly means:									
January	+9·2	+ 8·7	+ 7·9	+ 4·4	+ 0·8	− 0·2	+ 1·6	+ 0·5	+ 0·7
July	+1·6	+ 2·2	+ 3·0	− 1·5	− 9·9	—	− 9·4	−13·8	−16·4
Overall mean	+ 5·5	+ 5·5	+ 4·8	+ 2·0	− 3·6	—	− 3·2	− 5·4	− 7·6
Extremes									
Mean highest summer maximum	—	+20·0	+19·9	+18·4	+ 8·6	—	+ 7·8	+ 6·3	+ 6·7
Mean lowest winter minimum	—	− 5·0	− 4·4	− 9·8	−29·7	—	−19·7	−30·3	−37·5
Overall highest summer maximum	—	+25·0	+22·0	+22·8	+13·9	+15·0	+11·1	+11·7	+ 7·8
Overall lowest winter maximum	—	− 7·8	− 7·0	−13·3	−34·4	—	−27·8	−43·3	−39·4
Wind speed (m./sec.), mean	—	8·9	11·0	4·3	7·4	5·7	7·0	4·0	4·3
Prevailing wind directions	—	NW; SW	W	NW; SE	W/NW; SE	W	ENE; W	N/NE; S	E/SE
Sunshine (hr.), mean/day	—	4·5	3·4	4·4	1·5	—	1·7	2·1	—
Cloud cover (octas), mean	—	5·8	—	5·6	6·9	7·0	6·7	6·4	6·1

any time except mid-summer. The seas are always ice-free. Very strong winds are continually experienced by these islands, particularly by Iles Crozet.

The islands south of lat. 60° S. have a maritime Antarctic climate with sub-zero mean temperatures, though at least 1 month each summer has a mean air temperature above 0° C (Holdgate, 1964). However, ground temperatures may rise to +17° C or more (Longton and Holdgate, 1967). Soil-temperature records on Signy Island (Smith, 1973*b*) show that during one summer the top few centimetres of soil experienced mean temperatures greater than +2° C, between 09.00 and 16.00, for at least 4 months. Most precipitation throughout the year falls as snow; there is some rain in summer. The coldest months of the year are June–September when monthly means below −10° C are common. The seas are usually ice-free in summer but in some years they are blocked by heavy pack ice. Icebergs are always present. Sea ice is often present between May and October but it may be broken up by gales.

C. TERRESTRIAL HABITATS—SOILS AND VEGETATION

Ground which is free of snow, in summer at least, is potentially available for colonization by living organisms. Exposed surfaces vary considerably and include bare rock faces, scree slopes, glacial deposits, open and closed stands of vegetation, and areas habitually occupied by marine birds or mammals.

A classification of vegetation types in the maritime Antarctic has been proposed by Longton (1967). Following a survey of the soils on Signy Island in 1962 (Holdgate and others, 1967), a classification of soil types was proposed by Allen and Heal (1970). Consideration of the data in these publications, together with the author's original observations, led to the construction of a classification of terrestrial habitats in the sub-Antarctic and maritime Antarctic as a framework for subsequent studies on the protozoan fauna of terrestrial habitats. This classification is given below with brief descriptions of each habitat type.

1. *Non-vegetated habitats*

These are areas which are potentially available for colonization by plant life; they are without vegetation either because they have been released from permanent snow cover for too short a time, or because the exposure of the areas causes them to have too unfavourable a micro-climate, or because the substrate is too unstable owing to continual weathering and erosion, or to periodic agitation by marine birds or mammals.

i. *Glacial moraines and mineral debris* (*Min*). Raw mineral material occurs as glacial moraines or as debris from weathered rock outcrops. Particle sizes vary from coarse gravel to fine clay. These materials constitute primitive "soils", in which little leaching has so far occurred, and they are frequently base rich having a pH greater than 5·0. Where the parent material is quartz-mica-schist, as in the South Orkney Islands and Elephant Island (Thomson, 1968, 1971, 1973, 1974; Roxburgh and Burkitt, 1971), they have a pH between 6·5 and 7·5. Mineral materials do contain some organic matter but this may be barely detectable and is almost always less than 2 per cent. In the Falkland Islands and Iles Crozet, mineral material covers large areas of the fell-field which occurs at altitudes above 150 m.

ii. *Volcanic ash* (*VA*). Recent volcanic ash occurs on Deception Island, South Shetland Islands (Fig. 11), where there have been three pyroclastic eruptions since 1967 (Baker and others, 1969, 1971, 1975). The pyroclastic materials vary from large bombs, through cinders and lapilli, to fine ash and dust, and consist largely of dark scoriaceous rocks. Recently deposited ash has a barely detectable organic content (0·04 per cent or less) but this increases slowly with time at the rate of approximately 0·3 per cent per year in the absence of colonization by mosses (Smith, 1974*b*). Its pH varies between 4·8 and 7·2. In areas influenced by fumaroles, some colonization of the ash by a moss species of the family Funariaceae has occurred (Collins, 1969).

iii. *Marine bird guano* (*ChPG, APG, GPG, KPG, ShG*). Three penguin species of the genus *Pygoscelis*—*P. antarctica* (chinstrap) *P. adeliae* (Adélie) and *P. papua* (gentoo)—and *Aptenodytes patagonica* (king penguin) breed in the sub-Antarctic or maritime Antarctic in colonies numbering tens of thousands, so that large areas of coastal land are covered with extensive guano deposits. This is a brown or black reducing mud, alkaline (pH 6·5–8·2), containing nitrogen, phosphorus and potassium in high concentrations (Holdgate and others, 1967). The trampling and nest-building activities of the penguins results in the guano becoming mixed with the underlying mineral matter; it thus has a low organic content (30–40 per cent). Similar accumulations of guano are found around the nesting colonies of *Phalacrocorax atriceps* (blue-eyed shag).

iv. *Elephant seal wallow grounds* (*ESW*). Elephant seals (*Mirounga leonina*) moult ashore in wallow grounds wherein compacted hair, excrement and faeces form a black reducing mud with physical and chemical properties similar to those of penguin guano, though being less agitated it has a higher organic content, about 70 per cent. The concentration of ammonium-nitrogen is particularly high (Holdgate and others, 1967).

2. *Vegetated habitats*

These are areas where vegetation in macroscopic quantities has become established, providing habitats for a diverse terrestrial fauna. Two major formations are recognized in the Antarctic zone (Longton, 1967): the phanerogam formation, in which herbaceous or woody angiosperm vegetation occurs, and the cryptogam formation in which only thallophytes or bryophytes occur. Within each of these, several sub-formattions can be readily identified. It was therefore found convenient to classify vegetated habitats according to the vegetation they bear at the formation and sub-formation level.

a. *Cryptogam sub-formations*

i. *Thallose alga* (*Pras*). Penguin guano deposits and elephant seal wallows (when not physically agitated) and other areas, which are subject to heavy contamination by sea birds, become colonized by the green alga *Prasiola crispa* which forms extensive thallose mats (up to 70 per cent cover over several hundred m.^{2}). The material under the *Prasiola* has a pH of 5·5–6·0, distinctly lower than that of uncolonized penguin guano. It also has a higher organic content (50–60 per cent). The degree of ground cover by *Prasiola* in such areas appears to be closely correlated with the moisture content of the substratum, *Prasiola* being susceptible to die-back during dry weather in summer (Smith, 1973*c*).

ii. *Moss cushions* (*MCu*). Certain moss species can grow directly on glacial moraines, scree slopes and bare rock surfaces in the form of small cushions or mats. Most of these belong to the genera *Andreaea* and *Grimmia* in the maritime Antarctic and the genus *Rhacomitrium* in the sub-Antarctic. The cushions accumulate little organic matter beneath them (usually less than 7 per cent), so that the cushion material is almost as basic as the uncolonized mineral matter with a relatively high pH in the range 5·0–7·0.

iii. *Moss-turf peat* (*MTP*). *Polytrichum alpestre* and *Chorisodontium aciphyllum* are tall turf-forming mosses. Stands of these species, either separately or mixed, sometimes with *Rhacomitrium* spp., may cover large areas up to several thousand m.^{2}. The moss shoots are erect, densely packed and sparingly branched. They overlie compact fibrous peat which builds up into banks (exceptionally up to 3 m. deep) with little compression. The fibres do not degenerate into the amorphous peats which are common in temperate blanket bogs. The peat is acid (pH 3·0–4·5), almost entirely organic (90–98 per cent) and usually holds 500–800 per cent dry weight of moisture. During dry weather in mid-summer the moisture may drop as low as 200 per cent (Smith, 1973*b*).

iv. *Moss-carpet peat* (*MCP*). The pleurocarpous mosses *Brachythecium* sp., *Calliergon* sp. and *Drepanocladus uncinatus* form spongy carpets, usually in wetter and less stable areas than the turf-forming species, which overlie a layer of peat a few centimetres thick. Carpets may be formed of any one, two, or all three species and, like the turf-forming species, may cover large areas. Carpet peat is less acid than turf peat, having a pH 4·0–5·5, and it has a very variable organic content (50–90 per cent). It is frequently very wet with moisture in the range 500–2,000 per cent dry weight, though moss carpet consisting of *Drepanocladus* only may occur in dry exposed situations with the moisture content as low as 50 per cent (Smith, 1974*a*).

b. *Phanerogam sub-formations*

i. *Fuegian meadowland soil* (*MS*). On the north side of the Beagle Channel, Tierra del Fuego (Fig. 2), east of the town of Ushuaia, the *Nothofagus* woodland is flanked by small knolls (up to 20 m. high) covered by mixed herbaceous vegetation. This contains several composite species, including

Erigeron sp., as well as the genera *Cerastium, Phleum* and *Acaena* (personal communication from R. I. L. Smith). The soil is black, compact and peaty; it has a pH between 5·2 and 5·6 and an organic content of 75 per cent.

ii. *Nothofagus litter* (*NL*). Woodland consisting of the southern beech species *Nothofagus antarctica* and *Nothofagus pumilio* occurs on Tierra del Fuego, but on none of the other islands. The litter of the woodland floor consists of dead and decaying leaves aggregated with mineral material from the underlying soil; it has a pH which varies from 4·8 to 6·2 and an organic content of about 50 per cent.

iii. *Lowland bog peat* (*LBP*). Much of the lowland ground in the northern part of East Falkland is covered by bog formed under conditions of impeded drainage. The dominant vegetation is the association *Astelia pumila* and *Rostkovia magellanica* (King and others, 1969). The soil is wet, black acid peat, having a high organic content (87 per cent) and a low pH of 4·2.

iv. *Dwarf-shrub peat* (*DSP*). Peat formed under the dwarf-shrub formation is common on the sub-Antarctic islands. It usually occurs as a shallow layer about 20 cm. deep in moist but well-drained locations such as the foot of scree slopes. In the Falkland Islands, *Empetrum rubrum* (Diddle-dee) is the commonest component of the vegetation in association with *Blechnum penna-marina* and *Gunnera magellanica*. On Iles Crozet and South Georgia, *Acaena* is the dominant genus, sometimes in association with the moss *Tortula*. *Empetrum* peat is the more acid, having a pH of 4·0–4·5 and a higher organic content, about 90 per cent, whilst *Acaena* peat is relatively basic, having a pH of 5·0–6·0, and well mixed with mineral material, having an organic content of 60–70 per cent.

v. *Tussock peat* (*TP*). Tussock peat is formed from the accumulated litter and root stocks of the tall-growing grass *Poa flabellata*. This species occurs as a coastal fringe around the sub-Antarctic islands. It has a high nitrogen requirement and derives nutrient income from sea spray and the excreta of marine animals (King and others, 1969). The peat is moderately acid, having a pH in the range 4·2–5·6. Its organic content is usually very high, about 90 per cent, but where there has been contamination by marine birds or mammals the organic content may be much lower.

vi. *Grass-marsh peat* (*GMP*). Grass-marsh peat accumulates up to 30 cm. deep in areas of impeded drainage under vegetation dominated by graminae species: *Cortaderia pilosa* (white grass) in the Falkland Islands and *Deschampsia antarctica* in South Georgia. The vegetation and the physical nature of the peat represents a transition between the hydromorphic lowland bog and the drier grass heath. The peat is acid, commonly having a pH of 4·0 but varying between 3·6 and 5·6. It has a high organic content, about 80 per cent. Unlike many peaty soils, it contains a small but detectable amount of exchangeable calcium—about 0·5 m.e./100 g. (King and others, 1969).

vii. *Grass-heath peat* (*GHP*). Grass-heath peat occurs as a shallow layer, about 20 cm. deep, in the inland areas of the sub-Antarctic islands where there is good drainage. *Festuca erecta* is the dominant grass; it occurs either in almost pure stands or in association with *Cortaderia* in the Falkland Islands and with *Acaena* in South Georgia. There is more aggregation of the peat with mineral matter than occurs with marsh peat; it thus has a higher pH, between 4·5 and 6·0, and a lower organic content, between 50 and 60 per cent.

viii. *Pringlea litter* (*PL*). *Pringlea antiscorbutica* is a large cruciferous plant which grows on the sub-Antarctic islands in the southern Indian Ocean, including Iles Crozet. At the stem bases accumulate dead and decaying leaves, still attached to the main stems. These decompose into a rich, moist mucilaginous litter which has a high organic content, 85 per cent, and it is also alkaline or only slightly acid, the pH ranging from 5·4 to 7·8.

ix. *Azorella cushion* (*AzCu*). *Azorella selago* is an umbelliferous plant in the form of wind-resistant cushions in the exposed fell-field of Iles Crozet (personal communication from L. Davies). The cushion material is dry and intimately mixed with the underlying mineral material. It thus has a low organic content (10–16 per cent) and at pH 5·0 it is only slightly more acid than uncolonized mineral matter.

x. *Grass soil* (*GS*). The grass *Deschampsia antarctica*, either in pure stands or in association with the small herb *Colobanthus crassifolius*, is the only form of angiosperm vegetation in the Antarctic south of lat. 60° S. It grows in small patches (usually less than 10 m. across) on sheltered north-facing slopes. The sites are usually flushed and enriched by sea birds. A dark loam-like soil is developed below the grass sward which shows a much greater degree of microbial cellulolytic activity than the

Antarctic moss peats. Its structure is similar to that of temperate brown earths with an intimate mixture of organic and mineral material. It has a variable organic content (20–75 per cent) and is acid with pH 4·5–5·5.

III. REVIEW OF THE LITERATURE

THE earliest records of terrestrial Protozoa from sub-Antarctic islands occur in the publications of Richters (1907, 1908), who examined mosses collected by the German and Swedish South Polar Expeditions (1901–03) from Iles Kerguelen, Iles Crozet, Heard Island, South Georgia, the Falkland Islands and Tierra del Fuego. Richter's records were confined almost entirely to testate amoebae, particularly the genera *Arcella*, *Difflugia*, *Euglypha*, *Nebela* and *Trinema*; he also recorded a single naked amoeba species, *Amoeba terricola*, and the colonial ciliate *Epistylis* sp.

Following the British Antarctic Expedition (1907–09), Murray and Penard published the first records of Protozoa from continental Antarctica. Murray's (1910) report mentioned the ciliate genera *Vorticella* and *Nassula* but it is otherwise in the form of drawings of unidentified flagellates, Rhizopoda and ciliates. Penard recorded testate species observed in mosses from both Cape Royds (Ross Island) and Macquarie Island. He listed genera previously observed by Richters (1907, 1908) and also *Assulina*, *Centropyxis*, *Heleopera* and *Phryganella*. Further records of these testate genera were made by Penard (1913) from moss samples collected from the South Shetland Islands and the Antarctic Peninsula by the *Nimrod* and *Pourquoi Pas?* expeditions (1908–10).

The first positive identifications of flagellates from the Antarctic were made by Sandon and Cutler (1924), who recorded five flagellate species from a sample of glacial moraine collected from Elephant Island, South Shetland Islands, by the *Quest* expedition (1921–22). Their list included the three common flagellates *Oikomonas termo*, *Cercomonas crassicauda* and *Spongomonas* sp. From South Georgia they recorded the testate genera *Gromia* and *Microgromia* as well as 14 testate species belonging to the genera already mentioned.

There were no further records of Protozoa from the Antarctic for 36 years. However, in the period since 1960 there have been a large number of studies on the different protozoan groups in fresh water, semi-aquatic and truly terrestrial habitats. Earliest of the modern observations were those made by Flint and Stout (1960), who recorded the chloromonad flagellate *Chlamydomonas*, some unspecified naked and testate amoebae, and four ciliates including *Colpoda cucullus* from moss, algae and soil around McMurdo Sound. *C. cucullus* is a very common soil protozoan (Sandon, 1927) but it is extremely rare in the Antarctic (Smith, 1973*d*).

American and Japanese scientists have given detailed attention to the Protozoa of lakes, melt-water pools and moss water (Armitage and House, 1962; Hada, 1964; Sudzuki, 1964; Dillon, 1967; Dillon and others, 1968; Bierle, 1969; Thompson, 1972). Ciliates were given special attention by Bierle (1969), who listed 48 species from a fresh-water lake in Victoria Land, and by Thompson, who made exact taxonomic descriptions of 24 marine and fresh-water species and recorded four species new to science.

Testates have been given detailed study by the European scientists Decloitre, Heal and Grospietsch. Decloitre (1960*c*, 1964) recorded seven testate species from a variety of terrestrial habitats in Terre Adélie following the 8th and 12th French Antarctic Expeditions. Heal (1965) recorded 18 testate species from grass soil on Signy Island, seven of which were also found in moss peats. Following the South African expedition to Marion and Prince Edward Islands (1965–66), Grospietsch (1971) recorded a total of 53 testate species from a wide variety of habitats on Marion Island. He compiled a most valuable comparative table of all records of Testacida from the Antarctic and sub-Antarctic.

A wide diversity of flagellates, naked and testate amoebae, and ciliates has been recorded by Smith (1972, 1973*a*, 1974*a*, 1975) from Elephant Island (following the Combined Services Expedition, 1970–71), the South Orkney Islands and Iles Crozet. Flagellates and ciliates have also been observed in the volcanic tephra of Deception Island (Smith, 1974*b*). The results of these recent observations are incorporated in the present report.

As a result of observations made during the last 15 years, the species diversity and range of habitats of Antarctic Protozoa are now considerably better known. Present records are still very incomplete as a description of the total fauna. Frequently, samples were examined for only one group of Protozoa; only rarely were attempts made to sample all possible habitats in a locality or to relate the distribution of species to environmental conditions. The use of different sampling and laboratory methods by different workers renders valid comparisons difficult. However, the records are ample evidence that the Antarctic is far from devoid of Protozoa and, as has been pointed out by Penard (1913), Heal (1965) and Smith (1973*a*), the diversity of species in the richest habitats is only slightly less than in temperate moorland soils.

A summary of the principal published records is given in Tables II and III.

IV. METHODS

THE present study was initiated as a comprehensive survey of the protozoan fauna of Signy Island during the summer 1968–69; it was subsequently extended to the rest of the South Orkney Islands and other island groups in the sub-Antarctic and maritime Antarctic, as opportunity permitted, during the years 1970–73.

To sample the total snow-free ground on even a small island like Signy Island (7·2 km. by 5·0 km.), and then analyse the samples for Protozoa, was quite impossible. Therefore, in order to achieve as comprehensive a survey as possible in the time available, it was decided to concentrate effort on 13 sites widely distributed through the island, selected so as to encompass the complete range of major terrestrial habitats. A series of samples was thus obtained which, it was hoped, were representative of the whole island. Samples taken from these sites were analysed for Protozoa in the laboratory at the Signy Island station, Factory Cove (Fig. 7), to obtain species lists for the sites. Measurements of the physical properties of the samples were also made. It was hoped that the results would show some pattern whereby species distribution could be related to habitat factors.

Samples from islands other than Signy Island were collected as opportunities arose. On some occasions it was impossible for the author to take samples himself; in these cases, instructions were lodged with the Captains of the British Antarctic Survey's research vessels, and personnel on board were requested to collect samples when practicable. Inevitably, these collections were less comprehensive than those made on Signy Island but they were sufficient to demonstrate the variety of habitat types and species composition of the terrestrial protozoan fauna throughout the sub-Antarctic and maritime Antarctic.

A. FIELD METHODS

At each of the sites selected for study, material was taken from the 0–5 cm. horizon, there being six randomly selected sub-sampling points within each site. Each sample was labelled with the date and precise location. Vegetated soils and peats were sampled using a steel corer (2·5 cm. diameter) with a toothed cutting edge. Other materials like penguin guano, screes and moraine clays were sampled with a trowel. Sampling instruments were sterilized before each period of field work and extracted samples were transported to the laboratory either in sterilized Kilner jars or in new unused polythene containers to minimize contamination of the samples. Samples collected outside Signy Island were stored at 4° C during transport to either the Signy Island station or the United Kingdom for analysis.

B. LABORATORY METHODS

1. *Analysis of samples for Protozoa*

Information on the protozoan fauna of each set of six sub-samples was obtained by two laboratory procedures: culturing, using Singh's (1955) method for flagellates, naked amoebae and ciliates, and direct examination, using Couteaux' (1967) method for testate amoebae.

a. *Culturing*. Sterile petri dishes with 15 ml. of soil-extract agar poured into each were used. The soil extract was prepared by soaking 250 g. of grass soil in 1 l. of cold tap water and immediately steaming for 2 hr. After cooling, the supernatant was filtered and the filtrate gelled with 3 per cent agar after adding 0·5 per cent NaCl. Soil extract instead of nutrient agar was used so that the growth of bacteria, possibly toxic to Protozoa, was not unduly favoured, while the growth of Protozoa was encouraged. *Aerobacter aerogenes*

Table II

SUMMARY OF PUBLISHED RECORDS OF TERRESTRIAL PROTOZOA IN SUB-ANTARCTIC AND ANTARCTIC REGIONS

Authority	*Location*	*Latitude*	*Longitude*	*Habitat*	*Protozoan group studied*	*Number of species recorded*
ichters (1907)	Iles Kerguelen	49° 46′S.	69° 03′E.	Mosses	Amoebida	1
					Testacida	7
					Ciliata	1
	Iles Crozet	45° 25′S.	51° 45′E.	Mosses	Testacida	8
					Ciliata	1
	Heard Island	53° 04′S.	73° 24′E.	Mosses	Testacida	6
ichters (1908)	Tierra del Fuego	54° 48′S.	68° 19′W.	Mosses	Amoebida	1
					Testacida	5
	Falkland Islands	51° 42′S.	57° 52′W.	Mosses	Amoebida	1
					Testacida	8
	South Georgia	54° 16′S.	36° 30′W.	Mosses	Testicida	5
urray (1910)	Ross Island	77° 33′S.	166° 09′E.	Lake moss	Mastigophora	3
					Rhizopoda	3
					Ciliata	9
enard (1911)	Ross Island	77° 33′S.	166° 09′E.	Mosses, moraine	Testacida	13
	Macquarie Island	54° 33′S.	159° 00′E.	Compacted moss	Testacida	22
enard (1913)	Antarctic Peninsula	63–70° S.	60–70°W.	Mosses	Testacida	21
andon and Cutler (1924)	South Georgia	54° 16′S.	36° 30′W.	Organic soil	Mastigophora	3
					Testacida	3
				Grass soil	Mastigophora	5
				Organic soil	Mastigophora	6
					Amoebida	1
					Testacida	12
					Ciliata	1
	Elephant Island	61° 10′S.	55° 14′W.	Glacial moraine	Mastigophora	5
					Amoebida	3
ecloitre (1960*c*)	Terre Adélie	66° 44′S.	140° 00′E.	Mosses	Testacida	1
rmitage and House (1962)	Ross Island	77° 33′S.	166° 09′E.	Melt-water pools	Ciliata	7
ecloitre (1964)	Archipel de Pointe Géologie	66° 40′S.	140° 01′E.	*Prasiola*	Testacida	3
	Ile Lamarck	66° 40′S.	140° 02′E.	*Prasiola*	Testacida	1
	Rochers Mathieu	66° 20′S.	136° 49′E.	*Prasiola*	Testacida	3
	Nunatak du Bon Docteur	66° 40′S.	140° 02′E.	Pool near an Adélie penguin colony	Testacida	3
udzuki (1964)	Langhovde	69°13′S.	39° 45′E.	Moss water	Mastigophora	9 (all uncertain)
					Amoebida	5 (3 uncertain)
					Testacida	30 (6 uncertain)
					Ciliata	24 (17 uncertain)
ada (1964)	Syowa station	69° 08′S.	39° 48′E.	Fresh water	Ciliata	9
eal (1965)	Signy Island	60° 43′S.	45° 36′W.	Grass soil	Testacida	18
				Mosses	Testacida	7
				Marble debris	Testacida	4
illon (1967)	Ross Island	77° 33′S.	166° 09′E.	Soil and melt water	Mastigophora	3
illon and others (1968)					Amoebida	6
					Ciliata	16
ierle (1969)	Victoria Land	72° 20′S.	170° 26′E.	Lake	Ciliata	48
rospietsch (1971)	Marion Island	46° 53′S.	37° 52′W.	Fresh-water algae	Testacida	15
				Humus with lichens	Testacida	17
				Liverwort humus	Testacida	13
				Moss peat	Testacida	33
				Peat with flowering plants	Testacida	13
				Elephant-seal wallows	Testacida	6
hompson (1972)	Anvers Island	64° 35′S.	63° 30′W.	Fresh-water pool	Ciliata	12
	Humble Island	64° 46′S.	64° 06′W.	Melt-water pool	Ciliata	3
	Litchfield Island	64° 46′S.	64° 06′W.	Melt-water pool	Ciliata	2
	Torgersen Island	64° 46′S.	64° 05′W.	Melt water pool	Ciliata	1

TABLE III

SUMMARY OF PUBLISHED RECORDS OF TERRESTRIAL PROTOZOA INCORPORATED IN THIS REP

Authority	*Location*	*Latitude*	*Longitude*	*Habitat*	*Protozoan group studied*	*Number species rec*
Smith (1972)	Elephant Island	61° 13′S.	55° 09′W.	Moss peat	Mastigophora	15
					Amoebida	4
					Testacida	12
					Ciliata	14
				Grass soil	Mastigophora	7
					Testacida	9
					Ciliata	9
				Glacial moraines	Mastigophora	7
					Ciliata	3
				Chinstrap penguin guano	Mastigophora	6
					Ciliata	1
Smith (1973*a*)	Signy Island	60° 43′S.	45° 36′W.	Moss peat	Mastigophora	16
					Testacida	17
					Ciliata	17
Smith (1974*a*)	South Orkney Islands	60° 40′S.	45° 40′W.	Moss peat	Mastigophora	11
					Amoebida	14
					Testacida	9
					Ciliata	16
Smith (1974*b*)	Deception Island	62° 59′S.	60° 43′W.	Volcanic tephra	Mastigophora	6
					Ciliata	7
Smith (1975)	Ile de la Possession	45° 25′S.	51° 45′E.	Moss peat	Mastigophora	4
					Testacida	6
					Ciliata	11
				Tussock peat	Mastigophora	4
					Amoebida	1
					Testacida	5
					Ciliata	8
				Acaena peat	Mastigophora	4
					Testacida	6
					Ciliata	5
				Azorella peat	Mastigophora	3
					Testacida	4
					Ciliata	3
				Pringlea litter	Mastigophora	2
					Amoebida	1
					Testacida	6
					Ciliata	10
				Mineral soil	Mastigophora	2
					Ciliata	2

(NCIB strain 418) was supplied as food for the Protozoa because it is known to be an organism on which many Protozoa species thrive (Singh, 1955). *Aerobacter* was cultured separately on a rich nutrient agar:

Beef extract	10 g.	NaCl	5 g.
Bacteriological peptone	6 g.	Agar	15 g.
Yeast extract	2 g.	Distilled water	1 l.

After 3 days' incubation at 25° C, the bacterial culture was harvested with a glass spatula and spread over the surface of the soil-extract agar. 2 g. of each field sample were immediately inoculated on to the agar, moistened with sterile 0·5 per cent NaCl and incubated at 12° C, a suitable temperature for both mesophilic and psychrophilic organisms. The petri-dish cultures were examined for Protozoa species after being incubated for 1, 3, 7, 15 and 30 days; a final examination was made between the fiftieth and sixtieth days. Cultures were examined by placing drops (about 0·05 ml.) of the culture fluid on glass slides and observing under the microscope by transmitted light and by phase contrast. Observations were normally made on fresh material. To aid recognition, the movement of highly motile cells was slowed down either physically, by adding a drop of 2 per cent methyl cellulose, or chemically by adding a drop of 0·1 per cent $NiSO_4$. In addition, preparations were stained with Noland's stain fixative (Noland, 1928) in order to make cilia and flagella more conspicuous. Species observed were identified morphologically and a species list was built up for each field site.

b. *Direct examination.* A small sub-sample of field material, about 0·25 g., was placed in Bouin's fixative for 24 hr. The fixative was removed by centrifugation (5 min. at 1,500 r.p.m.). The residue was then rinsed, suspended in distilled water and made up to 250 ml., thus diluting the original material by a factor of 1,000. After being stirred for 2 hr., 20 ml. aliquots of the suspension were passed through 0·45 grade membrane filters. The filters, bearing the residue, were air dried at room temperature. Sections of the filters were placed on slides, cleared in xylene and mounted in Canada balsam. Six replicate slides were made for each site. This treatment destroyed cytoplasmic structures but the siliceous or chitinous tests of testate amoebae remained intact, allowing microscopic identification.

2. *Physical properties of samples*

The pH of each field sample was measured as soon as possible after collection (with minimum wetting with distilled water when necessary) using a glass electrode and a pH meter.

The loss on ignition (per cent dry weight), an estimate of organic content, was assessed by ashing oven-dry material in a muffle furnace at 450° C. Samples collected early in the course of the field work were ignited to constant weight; later a period of 10 hr. ignition was adopted as the standard time.

C. IDENTIFICATION OF PROTOZOA

The earliest phase of the present study was undertaken as a preliminary to intensive ecological studies on the terrestrial Protozoa of Signy Island. While it was hoped that the results would provide valuable biogeographical and distributional information about terrestrial Protozoa, it was important that collecting the data should not occupy too much time. It was recognized that many of the taxonomic problems which inevitably arose in the course of the survey would require almost unlimited time for their definitive solution. It was therefore decided that identifications of the Protozoa observed would proceed as far as possible in the limited time available, but that no attempt would be made to solve outstanding taxonomic problems. Accordingly, many identifications had to be left at the genus level.

There is no single scheme of taxonomy for the phylum Protozoa which is universally recognized and therefore the acceptance of a particular one for any given group involved value judgements. In particular, there are considerable differences of opinion regarding the classification of the naked amoebae. The identifications here are intended to be a means of recording observations made, using names for which there is independent authority. They are not intended to be taxonomically definitive. Observations were made on fresh preparations as often as possible, since behavioural characteristics were frequently as useful as morphological features for identification. Protozoa belonging to four groups are commonly found in terrestrial habitats: Mastigophora, Amoebida, Testacida and Ciliata. The problems involved in identification are different for each group. The means whereby these problems were tackled for each group are explained below.

1. *Mastigophora*

The main difficulty in identifying flagellates is their small size; many are under 20 μm., some are as small as 4 μm. Also, morphological differences between congeneric species are often very slight. Fortunately, the identification manual for soil Protozoa by Sandon (1927) is particularly comprehensive for this group, so that with experience flagellates could be identified to the species level with this book and with occasional reference to Kudo's (1966) manual.

2. *Amoebida*

The naked amoebae which occur in terrestrial habitats are small species (usually less than 50 μm.) and are very difficult to identify. The taxonomic literature on this group is extremely confusing. The life histories of many species are unknown; Protozoa belonging to other groups sometimes possess an amoeboid stage;

individual specimens of amoebae can show considerable changes in morphology from one minute to another. The manuals by Sandon (1927) and Kudo (1966) were found to be inadequate for the identification of this group. It was decided to adopt the taxonomic scheme of Schaeffer (1926) which is based on observations of the larger free-living amoebae. The advantage of this scheme is that it uses morphological patterns of the amoebae as they appear in "normal" existence. Schaeffer did not provide for the identification of small amoebae, such as occur in terrestrial habitats, but studies by Bovee (1953), using phase-contrast microscopy, showed that the scheme could also be used for small species. Using this scheme, it was found that amoebae observed could be identified to genus level, though very few to species. The book by Jahn and Jahn (1949) was occasionally consulted. More recently, papers by Page (1967, 1968, 1972, 1974) have made a considerable contribution to clarifying and defining the taxonomic criteria for naked amoebae.

3. *Testacida*

Testate amoebae are probably the best described group of Protozoa in the published literature because the species-specific features of their tests are more easily recognizable than the cytoplasmic features which characterize non-testate groups. The manuals by Sandon (1927), Deflandre (1959) and Kudo (1966) were used extensively for identification. When more detail was required, reference was made to monographs on particular genera (Deflandre, 1928, 1936; Gauthier-Lièvre, 1958; Decloitre, 1960*a*, 1962, 1969*a*) or to published lists of species where full species descriptions are given (Jung, 1942; Hoogenraad and Groot, 1948; van Oye, 1956; Chardez, 1969*b*; Delhez and Chardez, 1970). The Penard Slide Collection at the British Museum (Nat. Hist.) was also consulted and this was a considerable aid to the identification of species.

4. *Ciliata*

Ciliates are usually large enough (30–120 μm.) for morphological features to be distinguished relatively easily. However, they are difficult to observe because of the very high motility of most ciliate species; killing them with a fixative often distorts cytoplasmic features so as to make them unrecognizable; also, there is frequently considerable individual variation within species. Cautious use of physical or chemical "slowing-down" agents usually enabled sufficient detail of ciliary arrangements to be observed to identify ciliates to genus level, but in many instances it was not possible to identify species. Sandon (1927) was of limited value for identifying ciliates; Kudo's (1966) manual and the large monograph by Kahl (1935) were used extensively. The illustrated key by Curds (1969) was useful for some species. The genus *Vorticella* was speciated following the work of Noland and Finley (1931).

D. ASSOCIATION ANALYSIS

The results obtained from analysing all the samples for Protozoa constituted a raw data presence–absence matrix with the axes species against sites. In this raw form it was difficult to draw conclusions from so large a quantity of data about the distribution of the fauna in relation to their environment. In order to reduce the information content of the results to a more compact and comprehensible form, the data were subject to direct and inverse association analyses. This involved grouping sites together on the basis of their tending to have similar fauna, and grouping species together on the basis of their tending to occur together or be absent together in sites. In direct analysis, the sites were divided into groups on a hierarchical system. At each stage in the hierarchy the sites were divided dichotomously into those with and those without a certain selected "divider" species, the "divider" being the species carrying the highest total χ^2 calculated by the method of Williams and Lambert (1959). In inverse analysis, species were divided dichotomously into those which did and those which did not occur in a "divider" site selected by the same calculation procedure. The calculation of highest total χ^2 was performed on the Edinburgh Regional Computing Centre's IBM computer using the programme written in IMP language (see p. 15).

The results of the direct and inverse analyses were plotted as dendrograms and combined to form a matrix showing the tendency of groups of species to occur in particular groups of sites by the following procedure:

Each group of sites in the direct analysis dendrogram, containing two or more sites, was assigned a number; each group of species in the inverse analysis dendrogram, containing two or more species,

```
   //EBFR14AA JOB (R=192K),'SMITH,ANTARCTIC'
   //        EXEC IMP
   //C.SYSIN DD*

   %COMMENT SINGLE STAGE OF ASSOCIATION ANALYSIS PRINTS DIVIDER
   %BEGIN
   %INTEGER
    READ(P);READ(Q)
         %BEGIN
         %INTEGER I,J,K,A,B,C,D,DIVIDER
         %INTEGERARRAY  E(1:Q, 1:P)
         %REAL MAXCHISQ
         %REALARRAY CHISQ(1:Q,1:Q),TOTCHISQ(1:Q)
         %CYCLE I=1,1,Q; CHISQ(I,I)=0
               %CYCLE J=1,1,P
                READ (E(I,J))
               %REPEAT
         %REPEAT
         %CYCLE I=1,1,Q-1
               %CYCLE J=I+1,1,Q
                A=0;B=0;C=0;D=0
                     %CYCLE K=1,1,P
                     %IF E(I,K)=E(J,K) %THEN GO TO 1
                     %IF E(I,K)=1 %THEN B=B+1
                     %IF E(I,K)=2 %THEN C=C+1
                      GO TO 2
                  1: %IF E(I,K)=1 %THEN A=A+1
                     %IF E(I,K)=2 %THEN D=D=1
                  2: %REPEAT
          CHISQ(I,J)=(.00001+(A*D-B*D)**2*P)/(.000011+(A+B)*(A+C)*(B+D)*(C+D))
          CHISQ(J,I)=CHISQ(I,J)
         %REPEAT
   %REPEAT
   %PRINTTEXT 'CHISQ' 'TOTALS'
    MAXCHISQ=0
   %CYCLE
    TOTCHISQ(I)=0
         %CYCLE J=1,1,Q
          TOTCHISQ(I)=TOTCHISQ(I)+CHISQ(I,J)
         %REPEAT
    PRINT(I,3,0);PRINT(TOTCHISQ(I),6,4)  NEWLINE
   %IF TOTCHISQ(I)=MAXCHISQ %THEN GO TO 3; GO TO 4
3:   MAXCHISQ=TOTCHISQ(I)
    DIVIDER=I
4: %REPEAT
   %PRINTTEXT'DIVIDER' 'IS'
    PRINT(DIVIDER,4,0)
   %END
   %ENDOFPROGRAM
```

was assigned a letter. Each group containing only one site or species was then allocated to the numbered or lettered group which it most closely resembled. The species list for each site in turn was inspected in order to determine which groups of species occurred in it. Where half or more of the species in a given group of species was found to occur in half or more of the sites in a given group of sites, that group of species was said to "tend to occur" in that group of sites. A presence–absence matrix of groups of species in groups of sites was then drawn up. By inspection, the groups of species were aggregated into "communities" and the groups of sites into "habitat classes". The matrix could then be plotted so as to show the tendencies of each community of protozoan species to be positively or negatively associated with each habitat class.

V. DESCRIPTION OF SITES SAMPLED

Samples were collected from 97 sites distributed as follows:

Tierra del Fuego (Fig. 2)	2 sites
Falkland Islands (Fig. 3)	5 sites
Iles Crozet	
Ile de la Possession (Fig. 4)	7 sites
South Georgia (Figs. 5 and 6)	15 sites
South Orkney Islands	
Signy Island (Fig. 8)	13 sites
Coronation Island and associated islands (Fig. 7)	7 sites
Laurie Island and the eastern islands (Fig. 7)	9 sites
South Shetland Islands	
Elephant Island (Fig. 9)	23 sites
Livingston Island (Fig. 10)	1 site
Deception Island (Fig. 11)	5 sites
Argentine Islands	
Galindez Island (Fig. 12)	4 sites
Islands in Marguerite Bay	
Avian Island (Fig. 13)	1 site
Cone Island (Fig. 13)	2 sites
Pourquoi Pas Island (Fig. 13)	3 sites

These sites, with details of sample-collection dates, the nature of the materials sampled and the physical properties of the samples are listed in Tables IV–VIII. Each site is prefixed by a code containing two blocks of letters; the first block denotes the island or island group on which the site was located; the second group denotes the nature of the sample as indicated in the classified list of terrestrial habitats (p. 6–9).

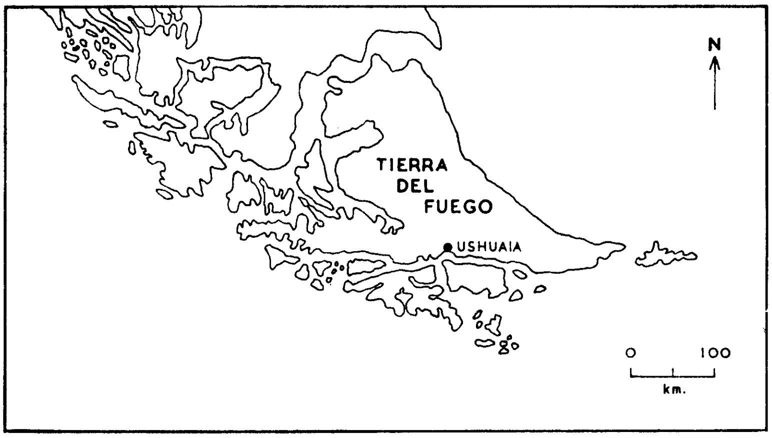


FIGURE 2

Sketch map of Tierra del Fuego.

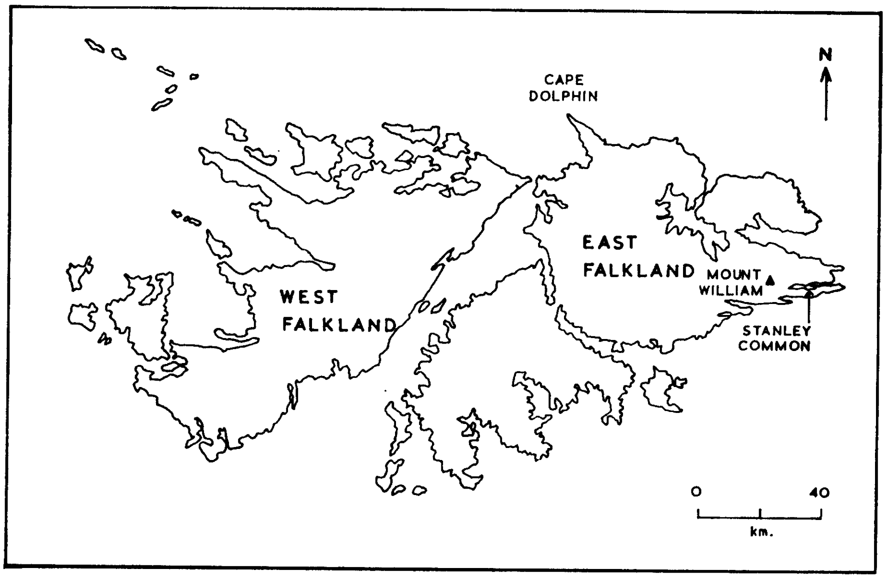


FIGURE 3
Sketch map of the Falkland Islands.

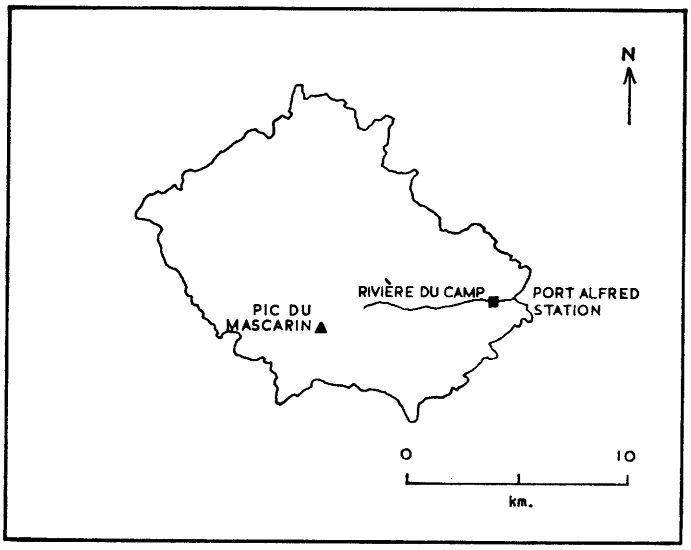


FIGURE 4
Sketch map of Ile de la Possession, Iles Crozet.

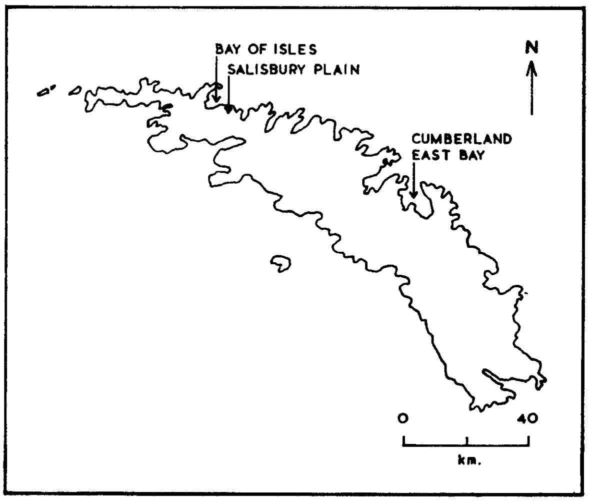


FIGURE 5
Sketch map of South Georgia.

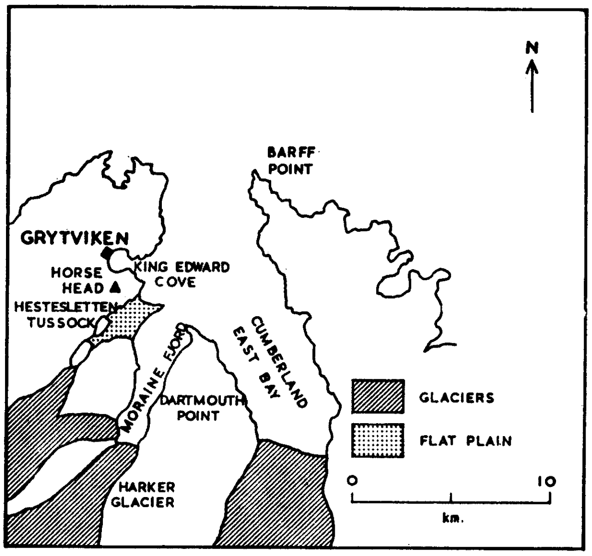


FIGURE 6
Sketch map of the Cumberland East Bay area of South Georgia.

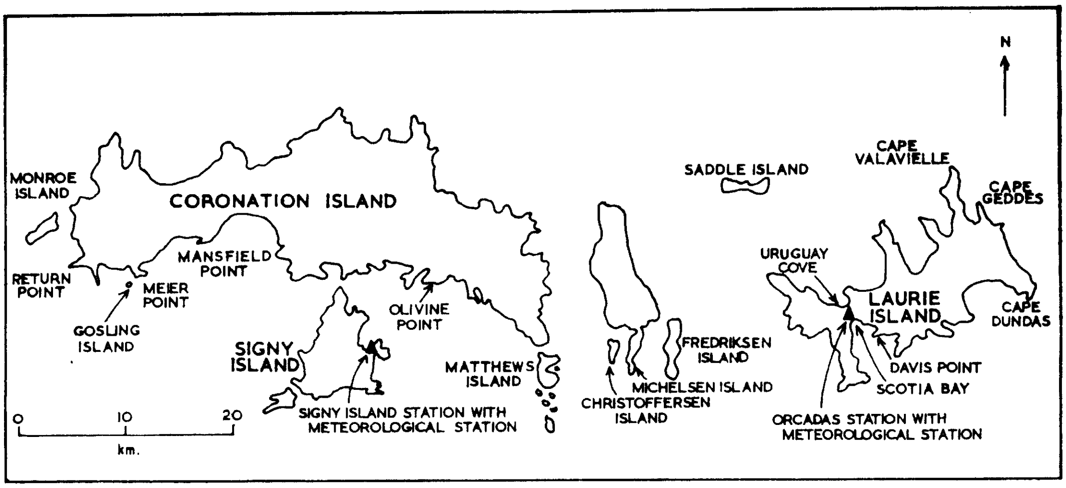


FIGURE 7

Sketch map of the South Orkney Islands.

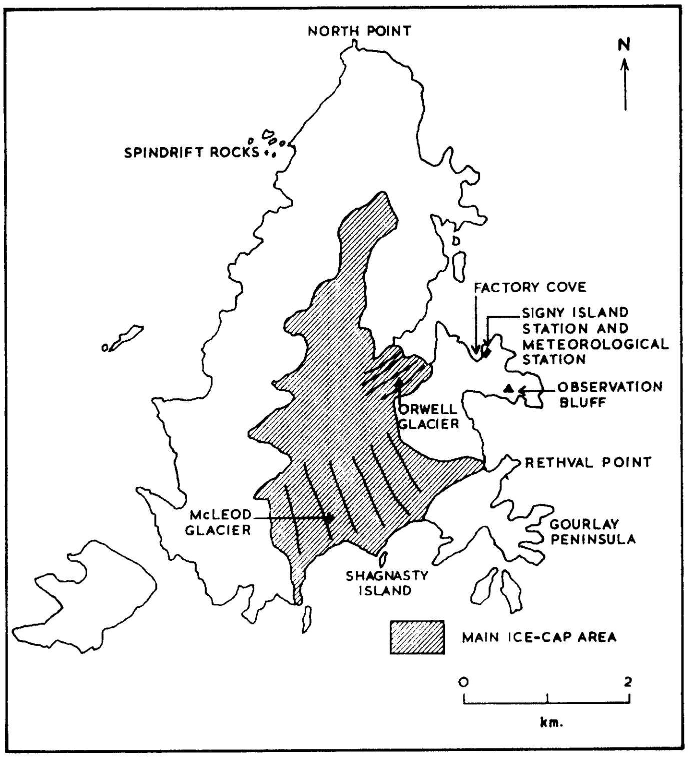


FIGURE 8

Sketch map of Signy Island, South Orkney Islands.

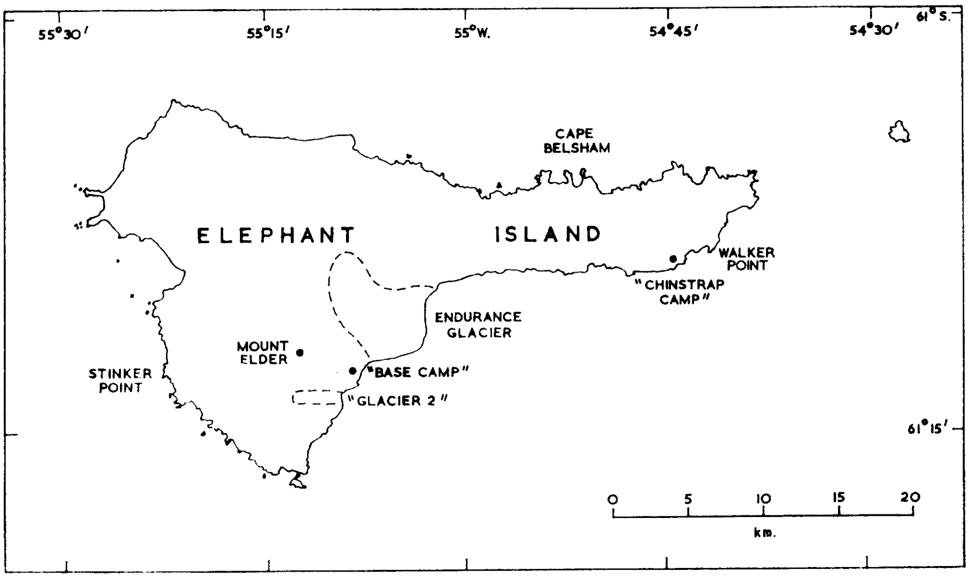


FIGURE 9

Sketch map of Elephant Island, South Shetland Islands.

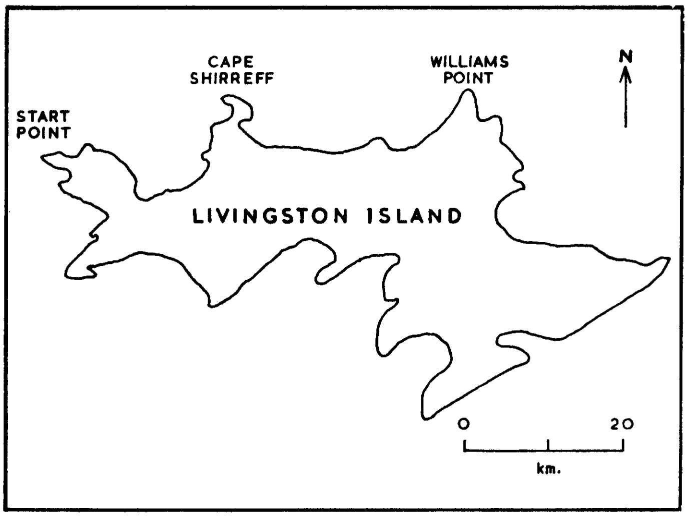


FIGURE 10
Sketch map of Livingston Island, South Shetland Islands.

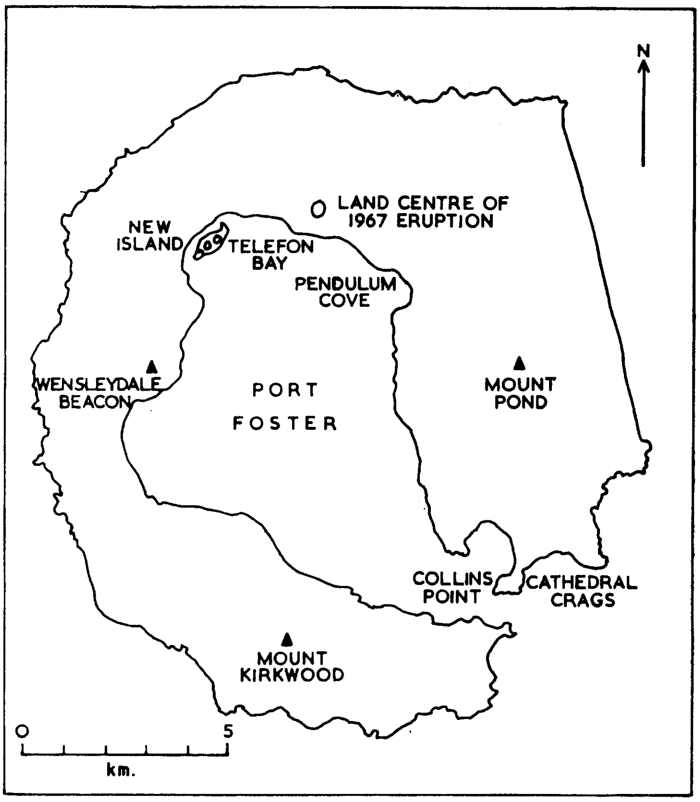


FIGURE 11
Sketch map of Deception Island, South Shetland Islands.

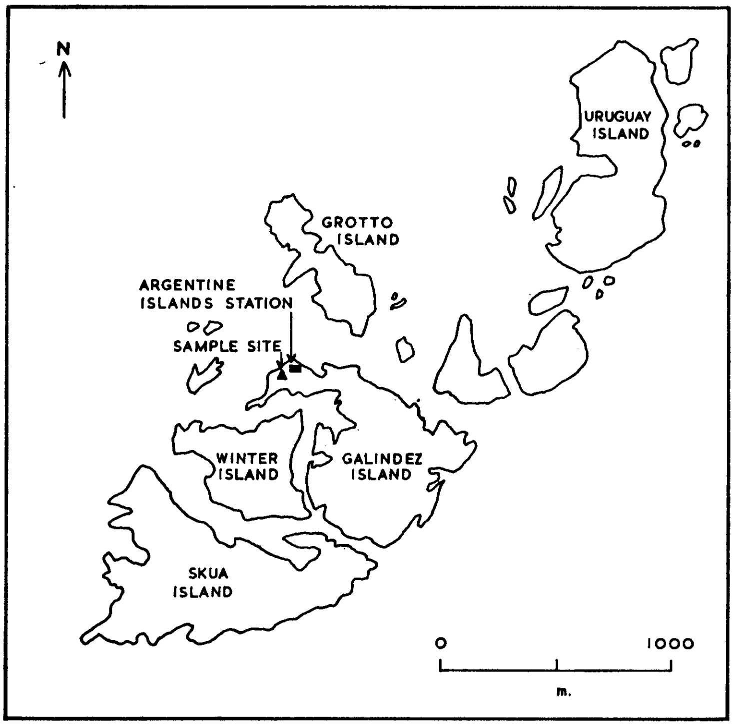


FIGURE 12
Sketch map of the Argentine Islands, Antarctic Peninsula.

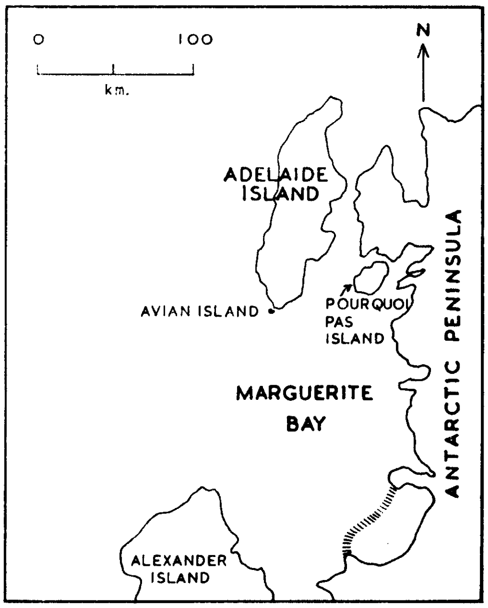


FIGURE 13
Sketch map of Marguerite Bay, Antarctic Peninsula. Cone Island is a small islet off the southern tip of Adelaide Island.

TABLE IV

LISTS OF SITES SAMPLED IN TIERRA DEL FUEGO, FALKLAND ISLANDS AND ILES CROZET

Code	*Location of site*	*Date of collection*	*Nature of samples*	*pH of samples**	*Loss on ignition of samples** (per cent dry weight)
TF-MS-1	Tierra del Fuego, meadowland, east of Ushuaia	24 April 1971	Peat soil below meadow vegetation	5·4±0·2	75±11
TF-NL-1	Tierra del Fuego, woodland scrub east of Ushuaia	24 April 1971	Litter of *Nothofagus* spp.	5·3±0·6	49±23
FI-LBP-1	Falkland Islands, east end of Stanley Common	21 April 1971	Lowland bog peat (*Rostkovia–Astelia*)	4·2±0·1	87±1
FI-DSP-1	Falkland Islands, west coast of Cape Dolphin	13 November 1969	Dwarf-shrub peat (*Empetrum*)	4·1±0·3	—
FI-DSP-2	Falkland Islands, east end of Stanley Common	21 April 1971	Dwarf-shrub peat (*Empetrum*)	3·9±0·2	90±1
FI-GMP-1	Falkland Islands, east slope of Mount William	30 October 1969	Grass-marsh peat (*Cortaderia–Festuca*)	4·0±0·2	—
FI-GMP-2	Falkland Islands, west coast of Cape Dolphin	13 November 1969	Grass-marsh peat (*Cortaderia*)	5·6±1·4	—
IC-Min-1	Iles Crozet, Ile de la Possession, fellfield	7 April 1973	Mineral soil, uncolonized scree	5·8±0·2	6·2±0·8
IC-MCu-1	Iles Crozet, Ile de la Possession, fellfield	7 April 1973	Moss cushion (*Rhacomitrium*)	5·0±0·3	12±3
IC-AzCu-1	Iles Crozet, Ile de la Possession, fellfield	7 April 1973	*Azorella* cushions	5·1±0·2	13±2
IC-MTP-1	Iles Crozet, Ile de la Possession, south of Rivière du Camp	7 April 1973	Moss-turf peat (*Rhacomitrium–Chorisodontium*)	4·9±0·2	88±1
IC-TP-1	Iles Crozet, Ile de la Possession, south of Rivière du Camp	7 April 1973	Tussock peat (*Poa*)	5·6±0·9	90±5
IC-DSP-1	Iles Crozet, Ile de la Possession, south of Rivière du Camp	7 April 1973	Dwarf-shrub peat (*Acaena*)	5·1±0·3	55±8
IC-PL-1	Iles Crozet, Ile de la Possession, south of Rivière du Camp	7 April 1973	Litter of Kerguelen cabbage (*Pringlea*)	6·7±0·9	85±2

*Figures are means ± 95 per cent confidence limits (six replicates).

TABLE V

LISTS OF SITES SAMPLED ON SOUTH GEORGIA

Code	*Location of site*	*Date of collection of samples*	*Nature of samples*	*pH of samples**	*Loss on ignition of samples** (per cent dry weight)
SG-Min-1	Moraine at snout of Harker Glacier	15 April 1971	Glacial moraine clay	6·5±0·4	1·0±0·2
SG-Min-2	Scree slopes above Dartmouth Point	9 April 1969	Clay, sand and gravel	*c.* 5·3	—
SG-Min-3	Scree slopes, south side of Horse Head	15 April 1971	Clay, sand and gravel	5·3±0·2	2·0±0·4
SG-MCu-1	Scree slopes, south side of Horse Head	15 April 1971	Moss cushion (*Rhacomitrium*)	4·7±0·3	64±10
SG-MTP-1	North side of King Edward Cove	17 November 1968	Moss-turf peat (*Polytrichum*)	*c.* 3·9	—
SG-MTP-2	Hestesletten	15 April 1971	Moss-turf peat (*Polytrichum*)	4·3±0·5	94±3
SG-DSP-1	South side of Horse Head	15 April 1971	Dwarf-shrub peat (*Tortula–Acaena*)	6·2±0·2	73±9
SG-TP-1	North side of King Edward Cove	17 November 1968	Tussock peat (*Poa*)	3·5±0·2	—
SG-TP-2	Hestesletten	15 April 1971	Tussock peat (*Poa*)	4·7±0·3	25±5
SG-GM-1	North side of King Edward Cove	17 November 1968	Grass-marsh peat (*Deschampsia*)	3·6±0·1	—
SG-GM-2	East end of Horse Head	15 April 1971	Grass-marsh peat (*Deschampsia*)	4·9±0·2	86±3
SG-GH-1	North side of King Edward Cove	17 November 1968	Grass-heath soil (*Festuca*)	4·5±0·2	—
SG-GH-2	South side of Horse Head	15 April 1971	Grass-heath soil (*Festuca*)	5·2±0·2	50±16
SG-GPG-1	Bay of Isles, Prion Island	10 April 1969	Gentoo penguin guano	*c.* 7·9	—
SG-KPG-1	Bay of Isles, Salisbury Plain	16 April 1971	King penguin guano	7·3±0·5	6·6±3·3

*Figures are means ± 95 per cent confidence limits (six replicates).

TABLE VI
LISTS OF SITES SAMPLED IN THE SOUTH ORKNEY ISLANDS

Code	*Location of site*	*Date of collection of samples*	*Nature of samples*	*pH of samples**	*Loss on igni of sample* (per cent d weight)
SO-Min-1	Signy Island, new moraine of Orwell Glacier	7 January 1969	Moraine clay	6·8±0·4	*c.*1·0
SO-Min-2	Signy Island, Marble Knolls	17 February 1969	Marble debris	6·9±0·2	*c.* 2·0
SO-ChPG-1	Signy Island, North Point	11 December 1968	Chinstrap penguin guano	7·4±0·2	39±5
SO-APG-1	Signy Island, Spindrift Rocks	26 March 1971	Adélie penguin guano	7·6±0·3	48±5
SO-GPG-1	Signy Island, North Point	4 April 1971	Gentoo penguin guano	6·7±0·2	30±3
SO-ShG-1	Signy Island, Shagnasty Island	1 February 1970	Shag guano	*c.* 8·2	—
SO-ESW-1	Signy Island, Gourlay Peninsula	17 January 1969	Elephant-seal wallows	7·0±0·2	*c.* 70
SO-Pras-1	Signy Island, Gourlay Peninsula	17 January 1969	*Prasiola* alga	5·6±0·7	*c.* 25
SO-Pras-2	Fredriksen Island	29 March 1970	*Prasiola* alga	5·7±0·4	57±8
SO-MCu-1	Signy Island, old moraine of Orwell Glacier	7 January 1969	Moss cushion (*Andreaea*)	6·4±0·2	*c.* 2·0
SO-MCu-2	Signy Island, Marble Knolls	17 February 1969	Moss cushion (*Grimmia*)	6·8±0·3	*c.* 8·0
SO-MTP-1	Signy Island, Rethval Point	11 January 1970	Moss-turf peat	3·6±0·3	97±1
SO-MCP-1	Coronation Island, Mansfield Point	9 February 1971	Moss-carpet peat	5·5±0·2	78±4
SO-MCP-2	Coronation Island, Meier Point	9 February 1971	Moss-carpet peat	5·5±0·2	83±6
SO-MCP-3	Gosling Island	9 February 1971	Moss carpet peat	5·1±0·3	84±2
SO-MCP-4	Coronation Island, Return Point	10 February 1971	Moss-carpet peat	4·5±0·3	56±6
SO-MCP-5	Monroe Island	10 February 1971	Moss-carpet peat	4·9±0·2	86±6
SO-MCP-6	Matthews Island	11 February 1971	Moss-carpet peat	5·1±0·4	81±18
SO-MCP-7	Christoffersen Island	11 February 1971	Moss-carpet peat	4·3±0·2	81±9
SO-MCP-8	Michelsen Island	11 February 1971	Moss-carpet peat	4·0±0·5	72±7
SO-MCP-9	Laurie Island, Davis Point	12 February 1971	Moss-carpet peat	4·5±0·2	87±2
SO-MCP-10	Laurie Island, Valavielle Point	13 February 1971	Moss-carpet peat	4·6±0·4	90±1
SO-MCP-11	Laurie Island, Cape Geddes	13 February 1971	Moss-carpet peat	4·4±0·3	87±2
SO-MCP-12	Saddle Island, eastern end	14 February 1971	Moss-carpet peat	6·0±0·4	85±4
SO-MCP-13	Laurie Island, Cape Dundas	15 February 1971	Moss-carpet peat	5·2±0·2	87±4
SO-MCP-14	Coronation Island, Olivine Point	16 February 1971	Moss-carpet peat	4·4±0·2	54±6
SO-MCP-15	Fredriksen Island	29 March 1970	Moss-carpet peat	4·5±0·1	84±4
SO-MCP-16	Signy Island, Clowes Moor	16 March 1971	Moss-carpet peat	4·6±0·1	93±4
SO-GS-1	Signy Island, slope below Observation Bluff	27 January 1969	Grass soil	4·6±0·2	77±6

*Figures are means ± 95 per cent confidence limits (six replicates).

TABLE VII

LISTS OF SITES SAMPLED ON ELEPHANT ISLAND, SOUTH SHETLAND ISLANDS

Code	*Location of sites*	*Date of collection of samples*	*Nature of samples*	*pH of samples**	*Loss on ignition of samples** **(per cent dry weight)**
E-Min-1	Moraine of Endurance Glacier (chinstrap penguin moulting site)	13 March 1971	Moraine clay	8·0±0·1	4·1±1·6
E-Min-2	Northern moraine, "Glacier 2"	16 March 1971	Moraine clay	7·1±0·1	1·5±0·2
E-Min-3	Northern moraine, "Glacier 2"	16 March 1971	Moraine clay	7·5±0·2	0·9±0·3
E-Min-4	Southern moraine, Endurance Glacier	16 March 1971	Moraine clay	7·0±0·6	1·6±0·6
E-Min-5	Southern moraine, Endurance Glacier	16 March 1971	Moraine clay	7·3±0·3	1·2±0·3
E-ChPG-1	Chinstrap penguin colony north of "Glacier 2"	13 March 1971	Chinstrap penguin guano	6·8±0·1	49±2
E-ChPG-2	Chinstrap penguin colony, headland between Endurance Glacier and "Glacier 2"	13 March 1971	Chinstrap penguin guano	8·1±0·1	21±5
E-ChPG-3	Chinstrap penguin colony, southern moraine of Endurance Glacier	13 March 1971	Chinstrap penguin guano	8·2±0·1	23±2
E-ChPG-4	Chinstrap penguin colony north of "Glacier 2"	16 March 1971	Chinstrap penguin guano	7·1±0·1	53±4
E-ChPG-5	Chinstrap penguin colony, southern moraine of Endurance Glacier	16 March 1971	Chinstrap penguin guano	8·2±0·1	39±2
E-MTP-1	"Chinstrap Camp"	25 February 1971	Moss-turf peat	4·5±0·3	58±11
E-MTP-2	Southern flank of "Glacier 2"	18 March 1971	Moss-turf peat	5·9±0·2	47±8
E-MTP-3	Southern flank of "Glacier 2"	18 March 1971	Moss-turf peat	5·4±0·1	42±5
E-MTP-4	Bluff above "Base Camp"	23 March 1971	Moss-turf peat	5·6±0·1	62±4
E-MCP-1	"Chinstrap Camp"	25 February 1971	Moss-carpet peat	5·0±0·2	68±4
E-MCP-2	Point Belsham	4 March 1971	Moss-carpet peat	4·9±0·1	36±5
E-MCP-3	South of Endurance Glacier	13 March 1971	Moss-carpet peat	3·9±0·1	40±5
E-MCP-4	Stinker Point	21 March 1971	Moss-carpet peat	4·7±0·3	5·6±1·2
E-MCP-5	Bluff above "Base Camp"	23 March 1971	Moss-carpet peat	4·7±0·1	44±13
E-GS-1	South of Endurance Glacier	13 March 1971	Grass soil	4·4±0·4	6·5±1·3
E-GS-2	Southern flank of "Glacier 2"	18 March 1971	Grass soil	4·8±0·2	30±8
E-GS-3	Southern flank of "Glacier 2"	18 March 1971	Grass soil	4·6±0·2	30±4
E-GS-4	Stinker Point	21 March 1971	Grass soil	4·7±0·1	28±5

*Figures are means ± 95 per cent confidence limits (six replicates).
"Chinstrap Camp". Joint Services Expedition (1970–71) camp site west of Walker Point.
"Base Camp". Joint Services Expedition camp site below Mount Elder.
"Glacier 2". The small east-flowing glacier 5 km. south of Endurance Glacier.

TABLE VIII

LIST OF SITES SAMPLED ON LIVINGSTON ISLAND, DECEPTION ISLAND, ARGENTINE ISLANDS AND ISLANDS IN MARGUERITE BAY

Code	*Location of site*	*Date of collection*	*Nature of samples*	*pH of samples**	*Loss on ignition of samples** (per cent dry weight)
Liv-MCP-1	Livingston Island, Cape Shirreff	19 February 1971	Moss-carpet peat	4·7±0·1	12±4
D-VA-1	Deception Island, new island in Telefon Bay, north-east end	11 December 1969	Volcanic tephra, 2 yr. old	6·8±0·1	0·3±0·1
D-VA-2	Deception Island, new island in Telefon Bay, south-west end	11 December 1969	Volcanic tephra, 2 yr. old	6·5±0·2	0·3±0·1
D-VA-3	Deception Island, land centre of 1967 eruption	11 December 1969	Volcanic tephra, 2 yr. old with moss	5·5±0·5	2·1±0·5
D-VA-4	Deception Island, Cathedral Crags	27 November 1969	Volcanic tephra, 10 months old	6·3±0·2	0·04±0·01
D-VA-5	Deception Island, Collins Point	11 December 1969	Volcanic tephra, 10 months old	*c.* 6·4	0·15±0·06
A-MTP-1	Argentine Islands, Galindez Island	21 January 1970	Moss-turf peat	3·7±0·1	99±1
A-MTP-2	Argentine Islands, Galindez Island	21 January 1970	Moss-turf peat	4·0±0·2	98±1
A-MCP-1	Argentine Islands, Galindez Island	21 January 1970	Moss-turf peat	4·3±0·1	94±1
A-MCP-2	Argentine Islands, Galindez Island	21 January 1970	Moss-turf peat	3·9±0·1	88±2
MB-Min-1	Marguerite Bay, Pourquoi Pas Island	21 February 1970	Moraine clay	4·9±0·2	0·8±0·1
MB-APG-1	Marguerite Bay, Cone Island	23 February 1970	Adélie penguin guano	8·2±0·1	36±2
MB-MTP-1	Marguerite Bay, Pourquoi Pas Island	21 February 1970	Moss-turf peat	4·6±0·1	51±15
MB-MCP-1	Marguerite Bay, Pourquoi Pas Island	21 February 1970	Moss-carpet peat	4·7±0·2	50±6
MB-MCP-2	Marguerite Bay, Avian Island	9 February 1970	Moss-carpet peat	5·0±0·5	90±2
MB-MCP-3	Marguerite, Cone Island	23 February 1970	Moss-carpet peat	4·4±0·2	89±4

*Figures are means ± 95 per cent confidence limits (six replicates).

VI. COMPOSITION OF THE PROTOZOAN FAUNA

A. LIST OF SPECIES OBSERVED

124 species of Protozoa were recorded from the samples:

Mastigophora	31
Rhizopoda, Amoebida	10
Rhizopoda, Testacida	35
Ciliata	48

MASTIGOPHORA	
PHYTOMASTIGIA	
CHRYSOMONADIDA	*Cephalothamnium cyclopum* Stein*
	Chrysamoeba radians Klebs*
	Oikomonas mutabilis Kent
	Oikomonas termo Ehrenberg
	Polypseudopodius bacterioides Puschkarew
PHYTOMONADIDA	*Chlamydomonas* sp. Ehrenberg
EUGLENOIDIDA	*Petalomonas augusta* (Klebs) Lemmermann
	Petalomonas mediocanellata Stein
	Polytoma uvella Ehrenberg
ZOOMASTIGIA	
PROMONADIDA	*Allantion tachyploon* Sandon
	Bodo caudatus Dujardin*
	Bodo edax Klebs
	Bodo saltans Ehrenberg
	Bodo terricolus Martin*
	Cercobodo agilis Martin
	Cercobodo vibrans Sandon
	Cercomonas crassicauda Alexeieff
	Cercomonas longicauda Stein
	Heteromita globosa Stein*
	Heteromita lens Muller*
	Heteromita obovata Lemmermann*
	Phalansterium solitarium Sandon*
	Pleuromonas jaculans Perty*
	Sainouron mikroteron Sandon
	Spiromonas angusta Dujardin*
	Spongomonas uvella Stein
POLYMASTIGIDA	*Hexamita* sp. Dujardin*
	Spironema multiciliata Klebs*
	Tetramitus pyriformis Klebs*
	Tetramitus spiralis Goodey*
	Tetramitus rostratus Perty
RHIZOPODA	
AMOEBIDA	*Astramoeba radiosa* Ehrenberg
	Dinamoeba sp. Leidy
	Flabellula sp. Schaeffer
	Hyalodiscus guttula Dujardin

Mayorella sp. Schaeffer
Metachaos sp. Schaeffer
Naegleria gruberi (Schardinger) Wilson
Thecamoeba verrucosa Ehrenberg*
Valkampfia limax Dujardin
Vexillifera sp. Schaeffer

TESTACIDA

Arcella discoides Ehrenberg
Arcella vulgaris Ehrenberg
Assulina muscora Greef
Centropyxis spp. Stein*
Clypeolina sp. Penard*
Corythion dubium Taranek
Difflugia arcula Leidy
Difflugia constricta Ehrenberg
Difflugia lucida Penard
Difflugia oblonga Ehrenberg
Difflugia penardi Wailes
Difflugiella sp. Cash
Diplophrys archeri Barker*
Euglypha bryophila Brown*
Euglypha ciliata (Ehrenberg) Leidy*
Euglypha laevis (Ehrenberg) Perty
Euglypha rotunda Wailes and Penard
Euglypha strigosa (Ehrenberg) Leidy
Heleopera sp. Leidy*
Hyalosphenia elegans Leidy*
Hyalosphenia minuta Cash*
Lecythium hyalinum (Ehrenberg) Hertwig and Lesser*
Microgromia socialis (Archer) Hertwig and Lesser*
Nebela certesi Penard
Nebela dentistoma Penard
Nebela martiali Certes
Nebela minor Penard
Nebela penardiana Deflandre
Nebela vas Certes
Nebela wailesi Deflandre
Parmulina cyathus Penard*
Phryganella acropodia (Hertwig and Lesser) Hopkinson
Pseudodifflugia sp. Schlumberger
Trinema enchelys (Ehrenberg) Leidy
Trinema lineare Penard

CILIATA
HOLOTRICHA
GYMONSTOMATIDA

Chilodonella sp. Strand*
Chilophrya sp. Kahl
Chaenea sp. Quennerstedt
Dileptus sp. Dujardin
Enchelys sp. Hill
Holophyra sp. Ehrenberg
Lacrymaria sp. Ehrenberg*
Lagynophrya sp. Kahl
Litonotus sp. Wresniowski

	Loxophyllum sp. Dujardin
	Nassula elegans Ehrenberg*
	Spathidium sp. Dujardin
	Urotricha agilis Stokes
SUCTORIDA	*Hallezia* sp. Sand*
	Podophyra sp. Ehrenberg*
TRICHOSTOMATIDA	*Colpoda cucullus* Muller
	Colpoda maupasi Enriques
	Colpoda steini Maupas
	Leptopharynx sphagnetorum (Levander) Mermod
	Microthorax simulans (Kahl) Engelmann*
HYMENOSTOMATIDA	*Colpidium colpoda* (Ehrenberg) Stein
	Cryptochilium nigricans (Muller) Maupas
	Cyclidium glaucoma Muller
	Dichilium cuneiforme Schewiakoff
	Glaucoma pyriformis Ehrenberg
	Paramecium aurelia Muller*
	Paramecium polycaryum Ehrenberg*
	Philaster sp. Fabre-Domergue
PERITRICHIDA	*Vorticella microstoma* Ehrenberg
	Vorticella striata Dujardin var. *octava* Stokes
SPIROTRICHA	
HETEROTRICHIDA	*Spirostomum* sp. Ehrenberg*
OLIGOTRICHIDA	*Halteria grandinella* Muller
HYPOTRICHIDA	*Aspidisca* sp. Ehrenberg
	Epiclintes sp. Stein*
	Euplotes sp. Ehrenberg
	Gastrosyla sp. Engelmann*
	Gonostomum affine Stein
	Holosticha sp. Wresniowski
	Hypotrichidium sp. Ilowaisky*
	Keronopsis sp.*
	Onychodromus sp. Stein*
	Oxytricha fallax Stein
	Oxytricha pellionella (Muller) Ehrenberg
	Oxytricha setigera Stokes
	Pleurotricha lanceolata (Ehrenberg) Stein
	Uroleptus sp. Ehrenberg
	Urostyla sp. Ehrenberg
	Urostrongylum contortum Kahl*

The 41 species marked with an asterisk (*) were insufficiently observed for them to be considered as definitely established members of the Antarctic protozoan fauna. Accordingly, only the 83 definitely established species are included in the following review of protozoan ecology, maps of geographical distribution and the association analysis. However, all genera observed are included in the artificial key to genera.

B. ECOLOGY AND GEOGRAPHICAL DISTRIBUTION OF THE SPECIES

Oikomonas Kent

Figs. 14, 15 and 18, Nos. 1 and 2

Oikomonads are spherical flagellates with a single flagellum. *Oikomonas termo* is one of the commonest of all soil Protozoa (Sandon, 1927) and was observed in almost every sample examined. Its widespread occurrence in nature is correlated with its ability to grow in laboratory culture at a wide range of pH and salinity; it feeds either saprozoically in many types of axenic culture or holozoically on many strains of bacteria (Hardin, 1942, 1944). It has been classified by Kolkwitz (1950) as an α-mesosaprobe. *Oikomonas mutabilis*, a larger polysaprobic species, was also common in the Antarctic, but it was restricted to acid habitats. No species of the related genus *Monas* (Ehrenberg) Stein, which has a short accessory flagellum, has been recorded from the Antarctic, although this genus is fairly common in temperate and tropical soils (Sandon, 1927).

Polypseudopodius Puschkarew

Figs. 16 and 18, No. 3

Polypseudopodius bacterioides is a very small organism with two unequal flagella. It was originally described by Puschkarew (1913) and is one of the species which Martin and Lewin (1914) stated can be found in the soil. No other records of the flagellate are known. However, it was observed, though rarely, in samples from all the island groups from South Georgia south to Marguerite Bay.

Chlamydomonas Ehrenberg

Figs. 17 and 18, No. 4

Chlamydomonas spp. are green phytomonads and are very common organisms in fresh-water habitats. They are relatively rare in terrestrial habitats though they have been recorded from several temperate soils in America and Europe (Fellers and Allison, 1920; Waksman, 1931). This genus was recorded only rarely in the Antarctic, being restricted to the more nutrient-rich mineral and moss habitats on South Georgia and Signy Island.

Petalomonas Stein

Fig. 18, Nos. 5 and 6; Figs. 19 and 20

Petalomonas spp. are flattened leaf-like flagellates with a longitudinal furrow on one or both surfaces. Many fresh-water species are known (Pascher and Lemmermann, 1913; Shawhan and Jahn, 1947) but only two of them have previously been recorded from soils: *Petalomonas angusta* in Tristan da Cunha (Sandon and Cutler, 1924) and Spitsbergen (Sandon, 1924), and *Petalomonas mediocanellata* in Greenland (Sandon, 1927). Both of these species were observed rarely in moss-peat habitats in the maritime Antarctic.

Polytoma Ehrenberg

Fig. 18, No. 7; Fig. 21

Polytoma uvella is a bi-flagellate and very similar to *Chlamydomonas* except that it contains no chloroplasts. The presence of non-green plastids has been reported by Jirovec (1926) and the fine structure of these has been studied by electron microscopy by Lang (1963). The nucleus and process of mitosis has been described by Entz (1918). *Polytoma uvella* has been recorded in several temperate and tropical soils (Wolff, 1912; Sandon, 1927), though its most usual habitat is stagnant water or sewage (Kudo, 1966). Fatty acid oxidases have been induced in this species (Cirillo, 1956) and over several generations such induction produced long-term adaptation to fatty acid media and faster growth (Cirillo, 1957). This species was observed in the meadow and grass soils of Tierra del Fuego and the Falkland Islands but not in the maritime Antarctic.

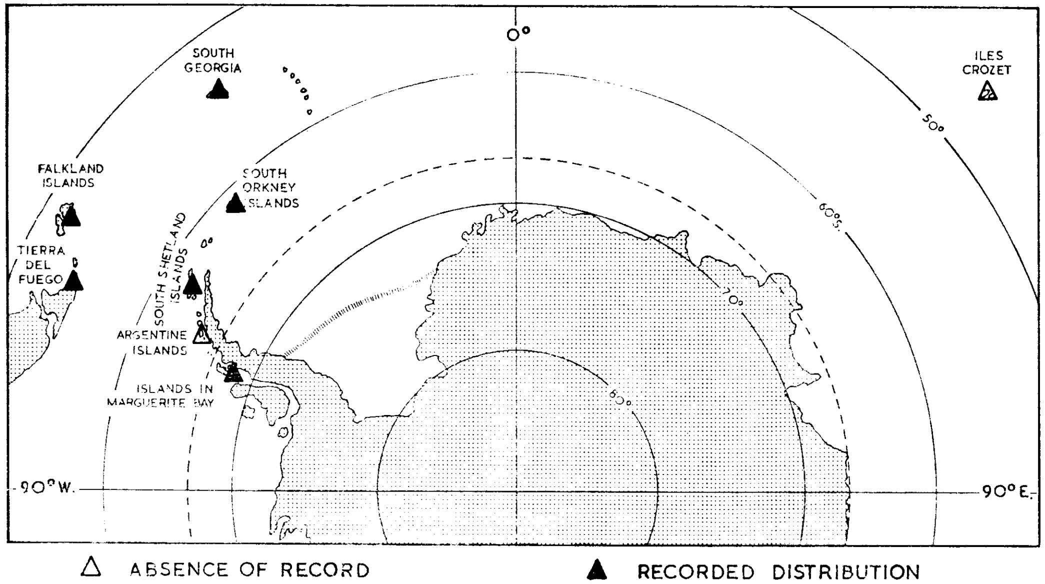


FIGURE 14

The distribution of *Oikomonas mutabilis*.

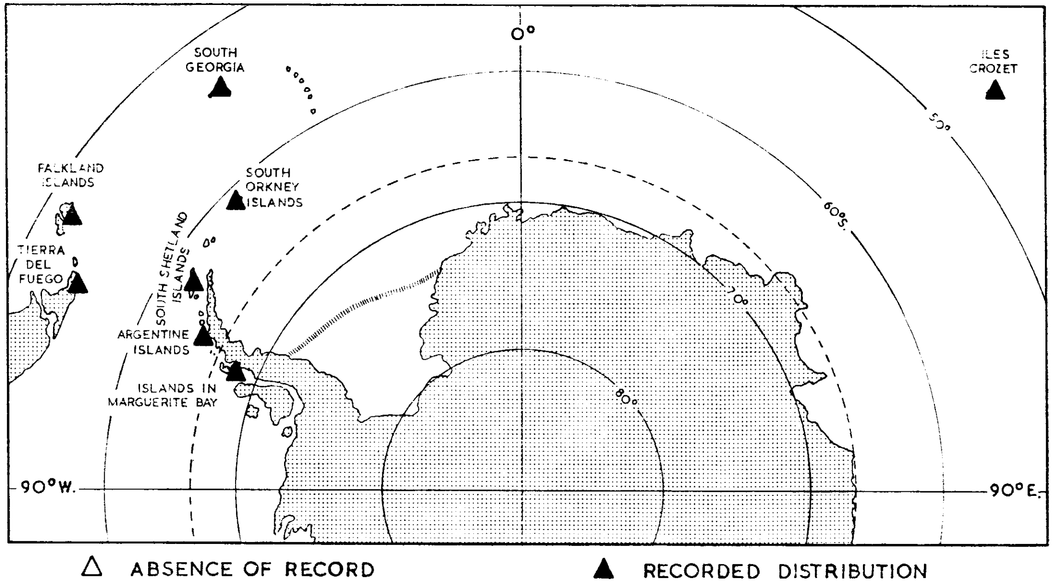


FIGURE 15

The distribution of *Oikomonas termo*.

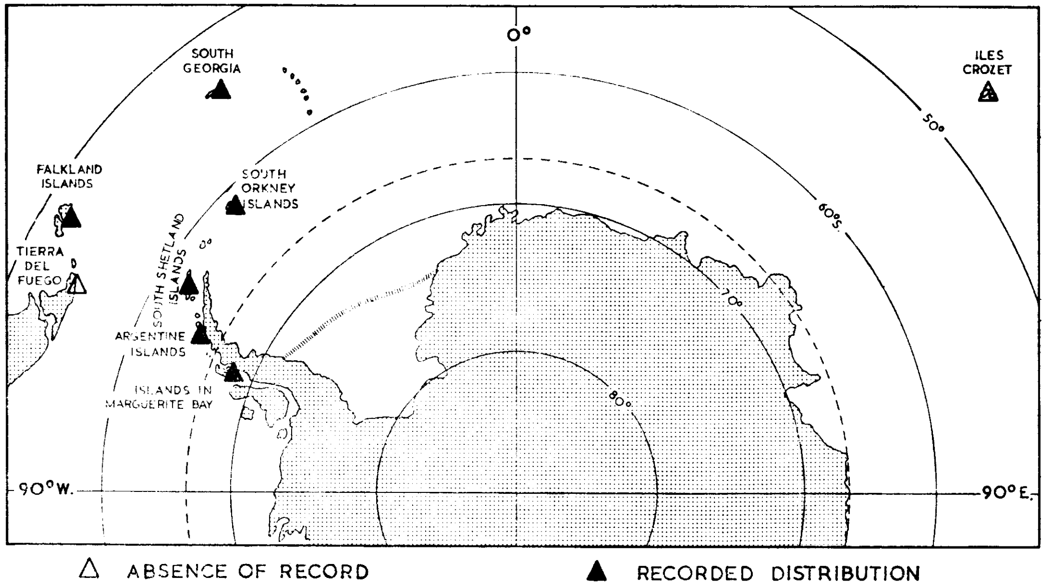


FIGURE 16

The distribution of *Polypseudopodius bacterioides*.

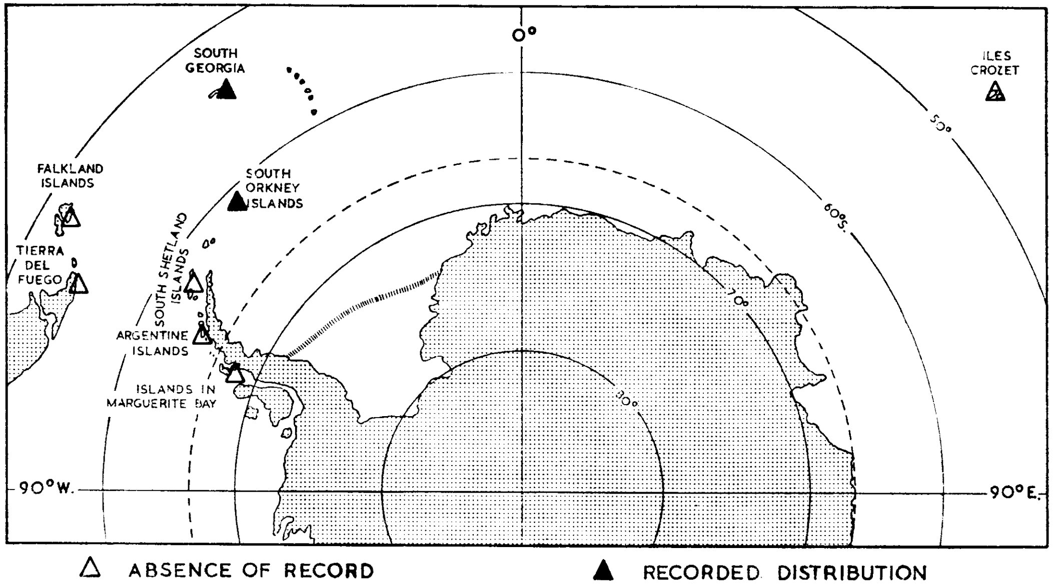


FIGURE 17

The distribution of *Chlamydomonas* sp.

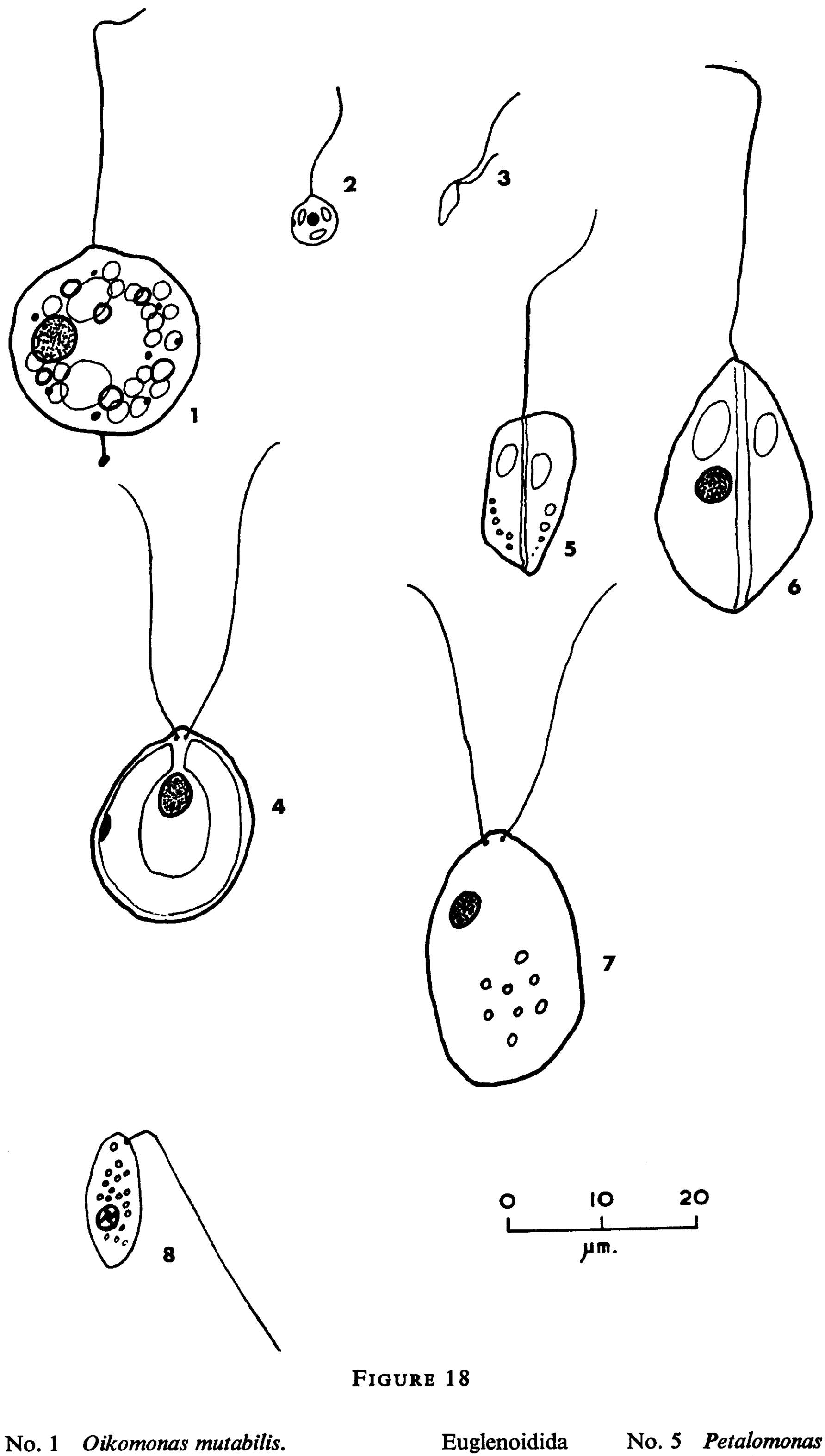


FIGURE 18

Mastigophora.

Chrysomonadida	No. 1	*Oikomonas mutabilis.*	Euglenoidida	No. 5	*Petalomonas angusta.*
	No. 2	*Oikomonas termo.*		No. 6	*Petalomonas mediocanellata.*
	No. 3	*Polypseudopodius bacteriodes.*		No. 7	*Polytoma uvella.*
Phytomonadida	No. 4	*Chlamydomonas* sp.	Protomonadida	No. 8	*Allantion tachyploon.*

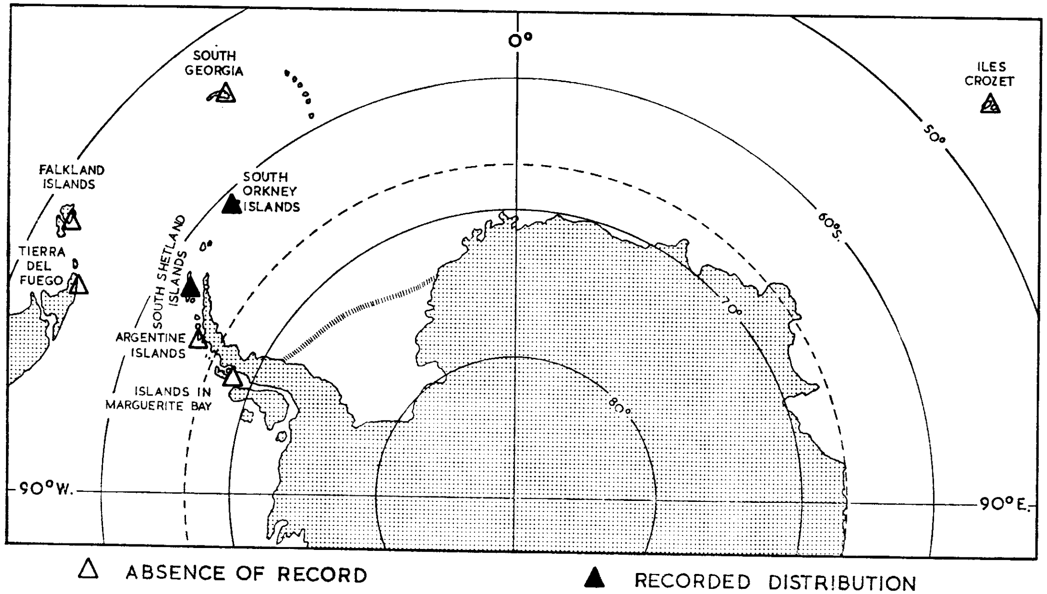


FIGURE 19

The distribution of *Petalomonas angusta*.

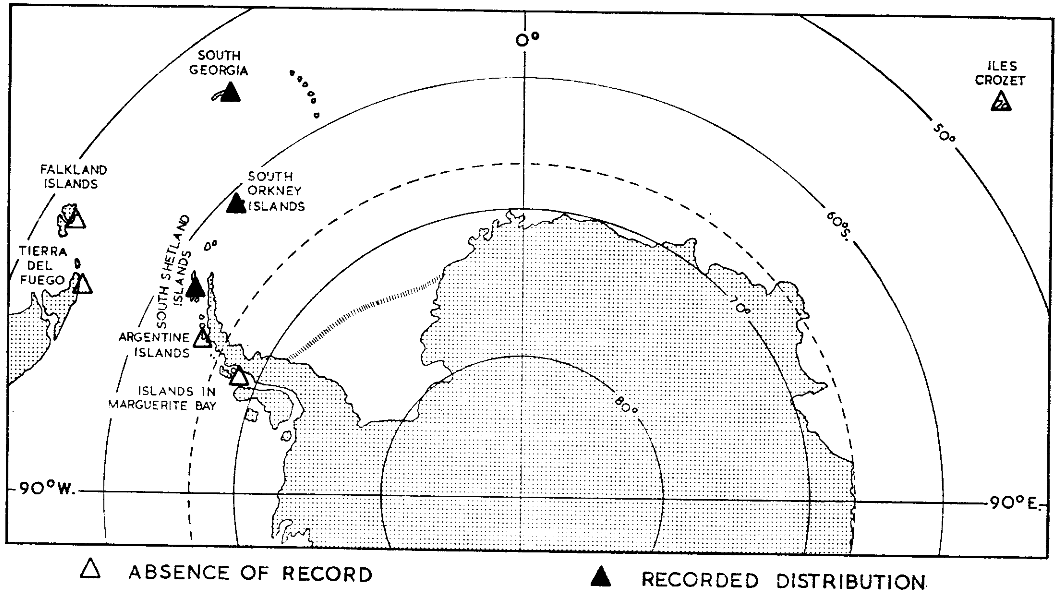


FIGURE 20

The distribution of *Petalomonas mediocanellata*.

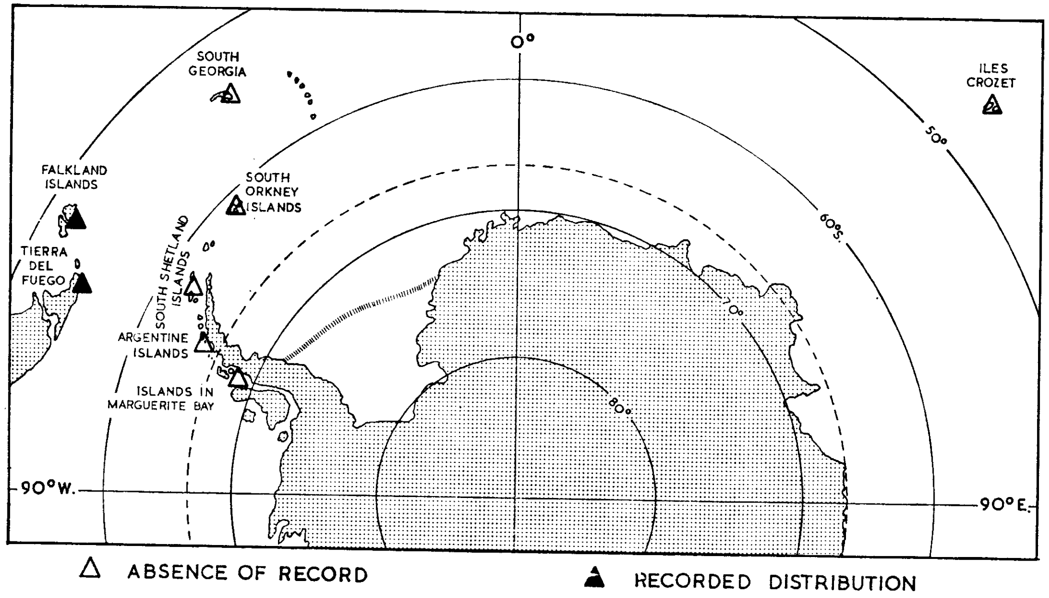


FIGURE 21

The distribution of *Polytoma uvella*.

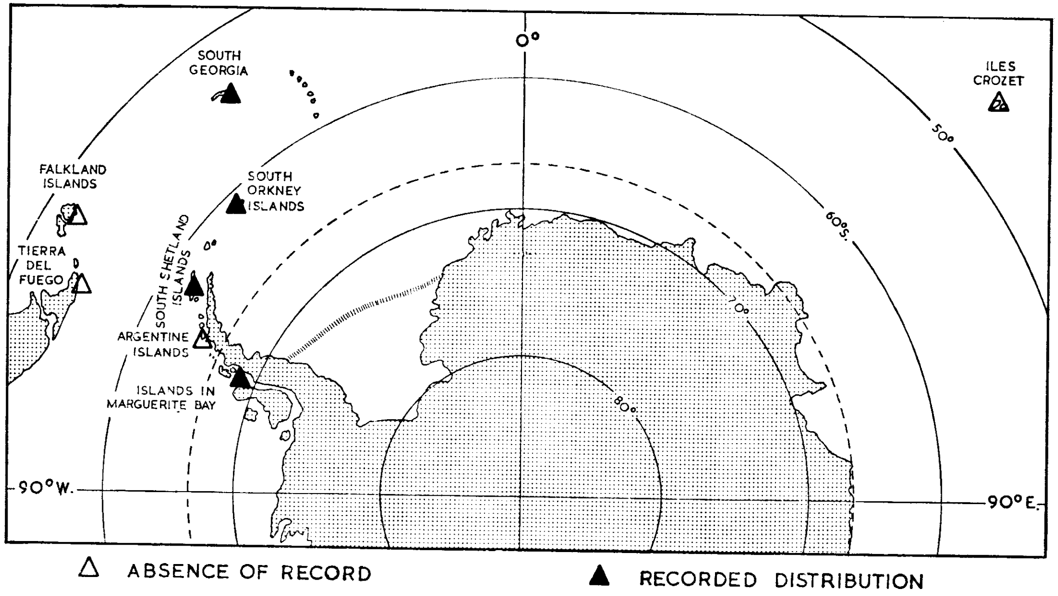


FIGURE 22

The distribution of *Allantion tachyploon*.

Allantion Sandon

Fig. 18, No. 8; Fig. 22

Allantion tachyploon was originally described by Sandon (1924) from moss material obtained by the Oxford University Expedition to Spitsbergen in 1922 and named by him [from Greek: "a swiftly sailing little sausage"]. It was later recorded as common in Arctic, temperate and tropical soils (Allison, 1924; Sandon, 1927; Dixon, 1939). It was an uncommon species in the Antarctic but its rare occurrences covered a wide range of habitat types—moraines, moss peats, grass soil and penguin guano—and its range extended from South Georgia south to Marguerite Bay.

Bodo Ehrenberg

Figs. 23, 24 and 27, Nos. 9 and 10

Many species of *Bodo* are known from the observations of nineteenth century microscopists on the fauna of "infusions". They are small very active protomonads with two flagella, one of which is long and trails posteriorly, and an anterior cytostome. A comparative study of the ultrastructure of three species of *Bodo* including *Bodo saltans* has been made by Burzell (1973). Their nutrition is holozoic, saprozoic or rarely parasitic. Some species have been classified as polysaprobic, α- or β-mesosaprobic (Kolkwitz, 1950), and are typically coprozoic or found in stagnant water. *Bodo* spp. are rare in soils, though Sandon's (1927) review suggests that up to seven species may occur infrequently. *Bodo* was considered by Detcheva (1973) to be one of the genera typical of agricultural soils in Bulgaria. *Bodo edax* has been recorded only rarely from temperate soils but was found frequently in Greenland soils by Dixon (1939). It was observed in mineral, moss and grass-soil habitats in the Falkland Islands and South Georgia, and in the richer habitats on Signy Island but it was otherwise absent from the Antarctic. *Bodo saltans* has been recorded more frequently from temperate soils (Fellers and Allison, 1920; Sandon, 1927, 1928), from Gough Island (Sandon and Cutler, 1924) and from Greenland (Dixon, 1939). *Bodo saltans* was observed to be very common in the Antarctic and was most frequently recorded from animal-guano habitats. In the South Orkney Islands, its occurrence in *Drepanocladus* moss peat appeared to be correlated with the presence of Weddell and fur seals (Smith, 1974*a*).

Cercobodo Krassilstchik

Figs. 25, 26 and 27, Nos. 11 and 12

Cercobodo spp. are a heterogenous group of bi-flagellate protomonads distinguished from the genus *Bodo* by the absence of a cytostome. Nutrition is therefore probably entirely saprozoic but, since pseudopodia have been observed at the posterior (Sandon, 1927), holozoic ingestion of bacteria may occur. *Cercobodo agilis* is apparently rare in soils but it has been recorded from tropical soils in Burma and the Sudan (Sandon, 1927), from agricultural soil in Bulgaria (Detcheva, 1973), and from soils rich in organic matter in East Greenland (Dixon, 1939). It was uncommon but widespread in the maritime Antarctic and South Georgia, occurring in mineral and moss-peat habitats. It was also observed in sub-Antarctic organic litters: *Aceana* soil on Iles Crozet and *Nothofagus* litter on Tierra del Fuego. *Cercobodo vibrans* was originally isolated from soil on Spitsbergen by Sandon (1924) as "species δ" and later fully described and given its specific name (Sandon, 1927). Sandon referred to it being very common in northern temperate and tropical soils, but in the Antarctic it was more restricted in distribution than *C. agilis*, being confined to moss and grass-soil habitats in the maritime Antarctic, Falkland Islands and South Georgia.

Cercomonas Dujardin

Fig. 27, Nos. 13 and 14; Figs. 28 and 29

Cercomonads are bi-flagellate protomonads in which the proximal part of the posterior flagellum is attached to the body. They are amongst the most abundant of soil Protozoa and have a universal distribution (Allison, 1924; Sandon, 1927, 1928). They have been recorded from Spitsbergen (Sandon, 1924) and

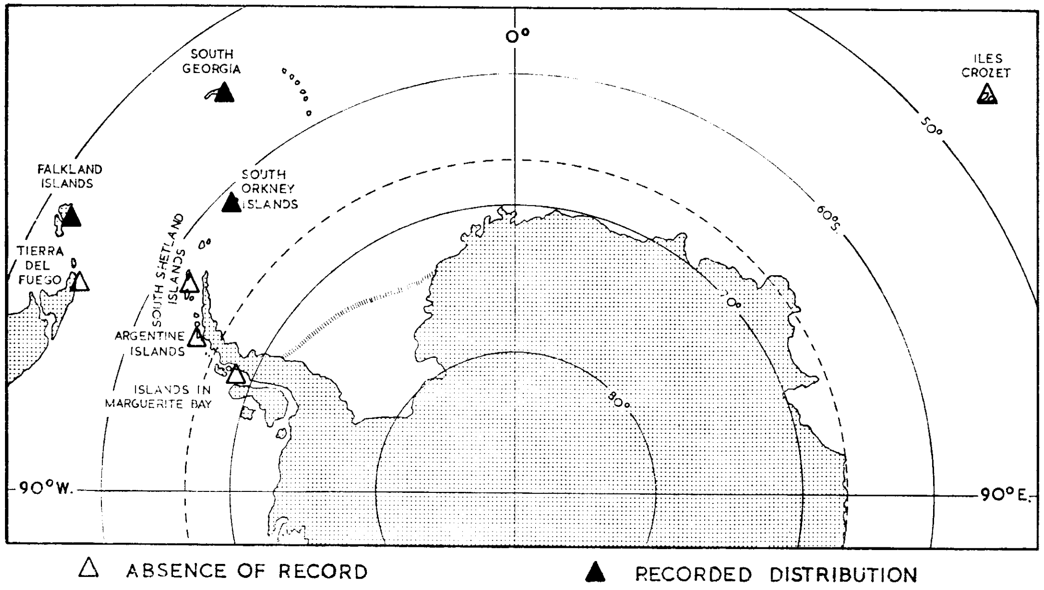


Figure 23

The distribution of *Bodo edax.*

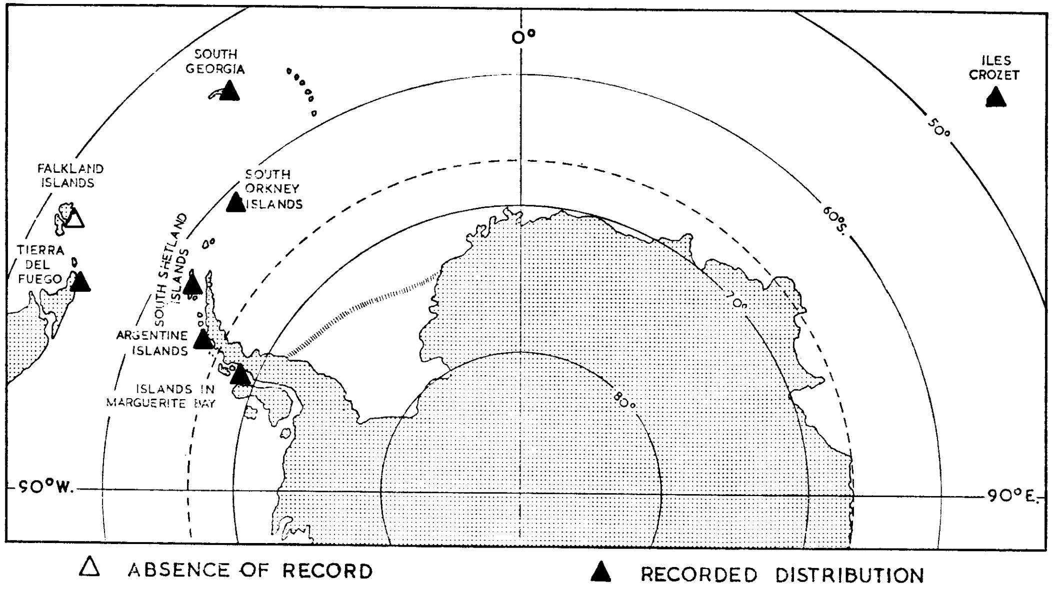


Figure 24

The distribution of *Bodo saltans.*

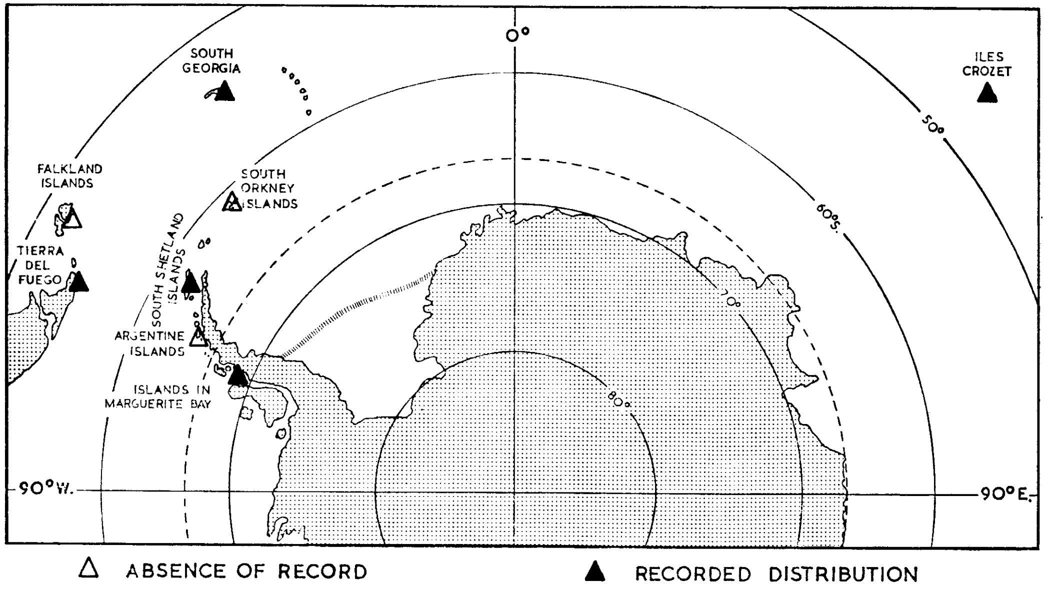


Figure 25

The distribution of *Cercobodo agilis.*

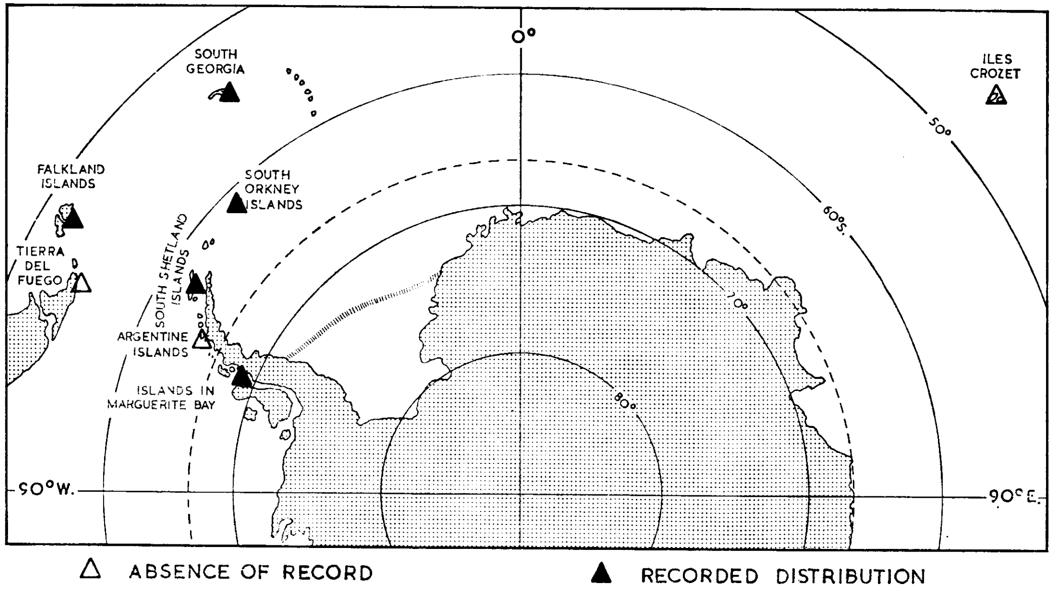


Figure 26

The distribution of *Cercobodo vibrans.*

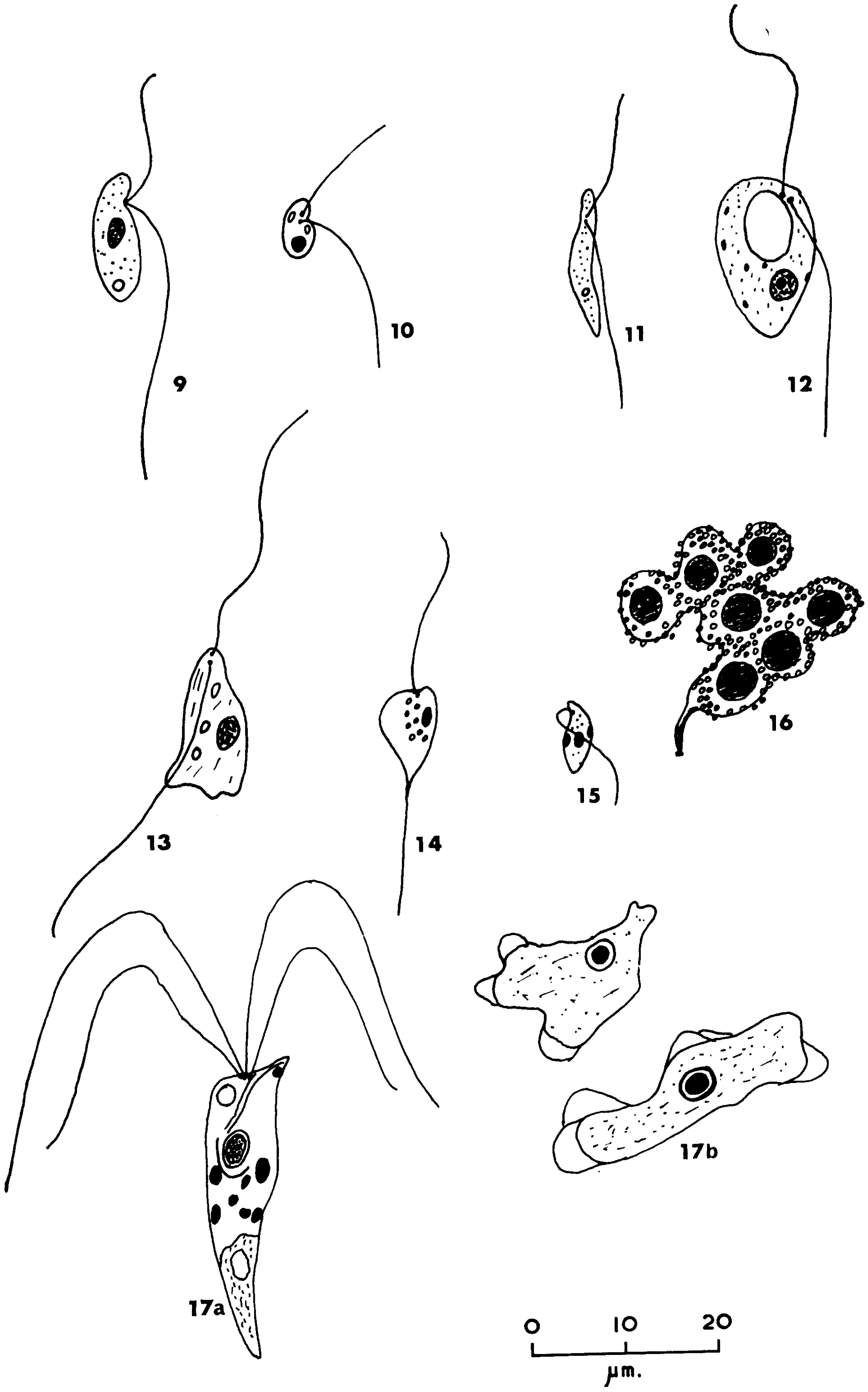


FIGURE 27

Mastigophora.
Protomonadida No. 9 *Bodo edax.*
No. 10 *Bodo saltans.*
No. 11 *Cercobodo agilis.*
No. 12 *Cercobodo vibrans.*
No. 13 *Cercomonas crassicauda.*
No. 14 *Cercomonas longicauda.*
No. 15 *Sainouron mikroteron.*
No. 16 *Spongomonas uvella* (sedentary form).
No. 17 *Tetramitus rostratus.*
a. Flagellate form.
b. Amoeboid form.

Greenland (Dixon, 1939). They have been classified by Kolkwitz (1950) as polysaprobic. Singh (1942) cultured *Cercomonas crassicauda* on a wide variety of soil bacteria, including plant pathogenic strains which were inedible to soil amoebae. *Cercomonas crassicauda* was regarded as extremely common by Sandon (1927) but in the Antarctic it was observed only rarely, being restricted to a few of the most species-rich organic habitats. It was also present in the bog peat of the Falkland Islands and the *Nothofagus* litter on Tierra del Fuego. By contrast, *Cercomonas longicauda* was rare in the sub-Antarctic but it was ubiquitous in the maritime Antarctic, occurring in almost every sample studied except alkaline animal guano.

Sainouron Sandon

Fig. 27, No. 15; Fig. 30

Sainouron mikroteron is a very small flagellate with a single trailing flagellum originally described by Sandon (1924) from moss on Spitsbergen; he also regarded it as common in temperate and tropical soils. It has been recorded from soils in many parts of America (Allison, 1924; Sandon, 1928) and from all the tropical and temperate islands visited by the *Quest* expedition, 1921–22 (Sandon and Cutler, 1924). Dixon (1939) recorded it as ubiquitous in East Greenland. In the Antarctic it was observed only in the volcanic tephra on Deception Island, where it occurred in four of the five sites investigated and in a glacial moraine on Pourquoi Pas Island. A possible preference for a volcanic tephra habitat is supported by the occurrence of *S. mikroteron* as one of four pioneer colonizing flagellates observed in the tephra of the island of Surtsey, Iceland (Smith, 1970).

Spongomonas Stein

Fig. 27, No. 16; Fig. 31

Spongomonas uvella is a colonial amphimonad flagellate having two equal anterior flagella, the cells comprising a colony being embedded in a granular gelatinous matrix. The detailed morphology of the colony has been described by Cholodny (1923). From its distribution in Czechoslovakian reservoirs, it has been regarded by Sladeckova and Sladecek (1960) as an indicator of oligo- or β-mesosaprobic conditions. It is a common soil species; Sandon (1927, 1928) and Sandon and Cutler (1924) recorded it from the South Atlantic islands: St. Helena, Tristan da Cunha, Gough Island, South Georgia and Elephant Island. The present observations confirm the occurrence of *Spongomonas* on South Georgia and Elephant Island: it was also observed, though rarely, in moss peats from the South Orkney Islands, Argentine Islands and Pourquoi Pas Island. In view of these and Sandon and Cutler's (1924) observations, the apparent absence of *Spongomonas* from Tierra del Fuego, the Falkland Islands and the Iles Crozet is surprising.

Tetramitus Perty

Fig. 27, No. 17; Fig. 32

Tetramitus rostratus is a polymastigid flagellate with four, sometimes unequal, flagella; it also exists as an amoeboid morph similar to *Naegleria gruberi*. Its life cycle has been described in detail by Bunting (1926) and the population dynamics of the amoeba-to-flagellate transformation in laboratory culture have been investigated by Outka (1965). In nature it is a strict coprozoic species but, in the laboratory, it can be cultured aerobically in a yeast–peptone–liver extract medium to which autoclaved bacteria have been added (Brent, 1954), or in a chemically defined medium containing 18 amino acids, glucose acetate and certain vitamins (Balamuth and Outka, 1962). *Tetramitus* is closely related taxonomically to symbiotic/parasitic polymastigid species which inhabit the digestive tracts of animals. However, there appears to be no conclusive evidence, despite Bunting's (1926) implication to the contrary, that it exists in the intestine of any animal, though it can be readily isolated from faecal material (Hollande, 1942; Rafalko, 1951). *Tetramitus rostratus* showed a very clearly defined habitat preference in the Antarctic, being ubiquitous in, and entirely restricted to, animal-guano habitats. Its seasonal fluctuations in numbers in chinstrap penguin guano have been described by Smith (1973*c*).

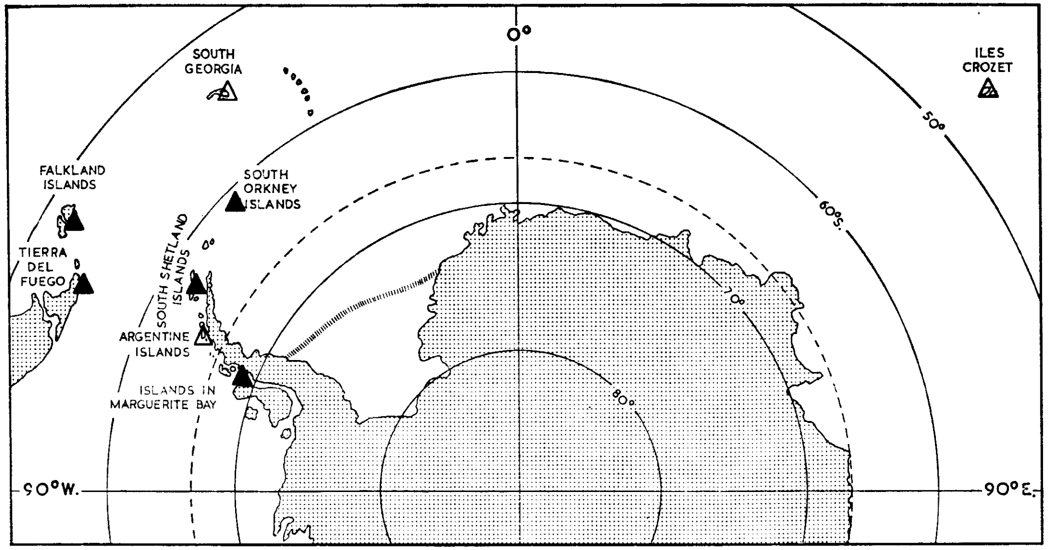


FIGURE 28
The distribution of *Cercomonas crassicauda*.

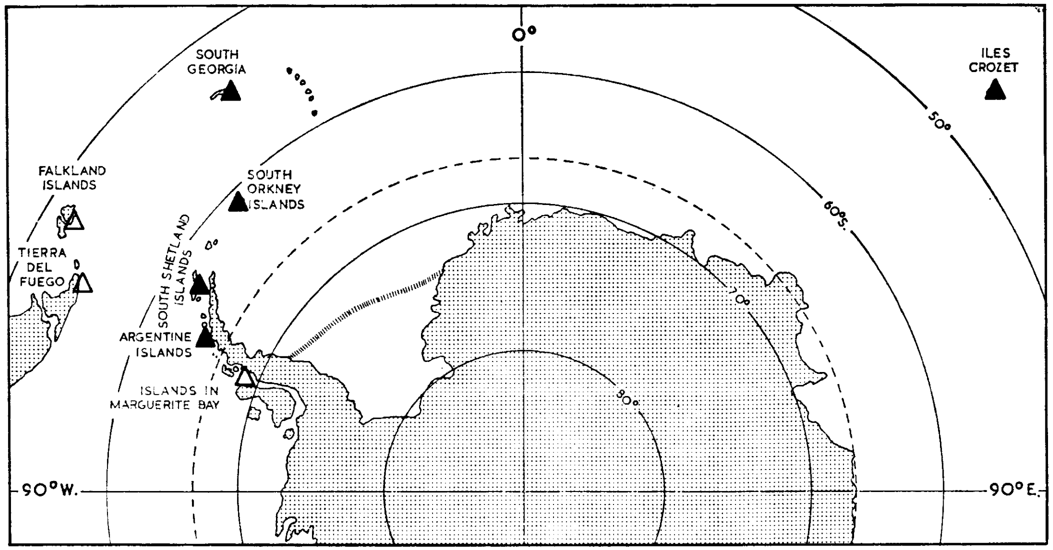


FIGURE 29
The distribution of *Cercomonas longicauda*.

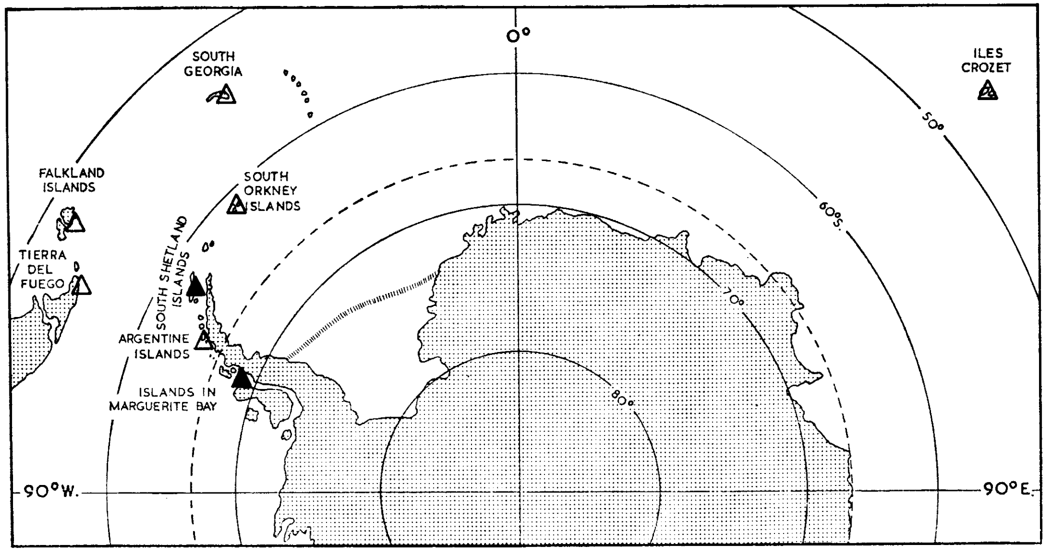


FIGURE 30
The distribution of *Sainouron mikroteron*.

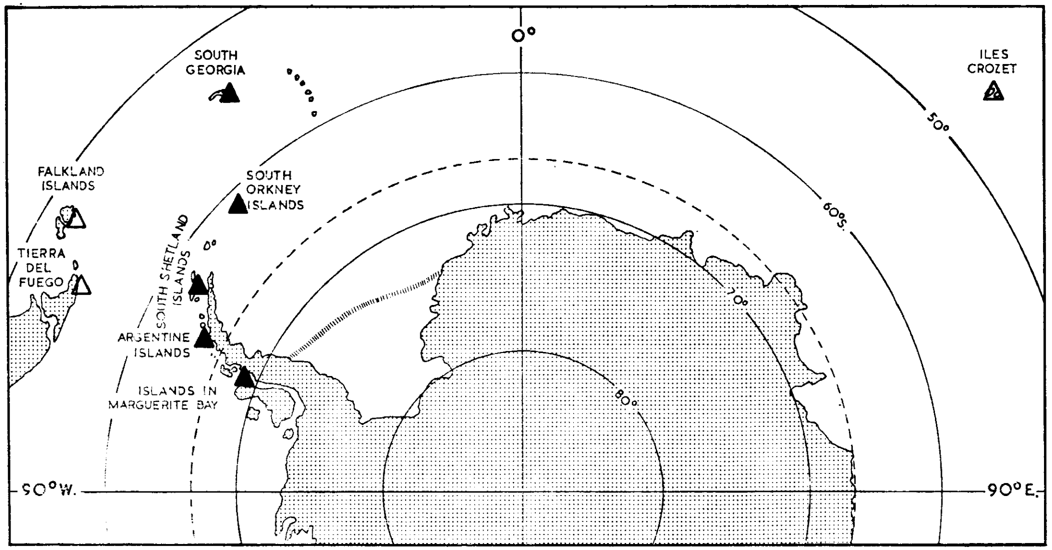


FIGURE 31
The distribution of *Spongomonas uvella*.

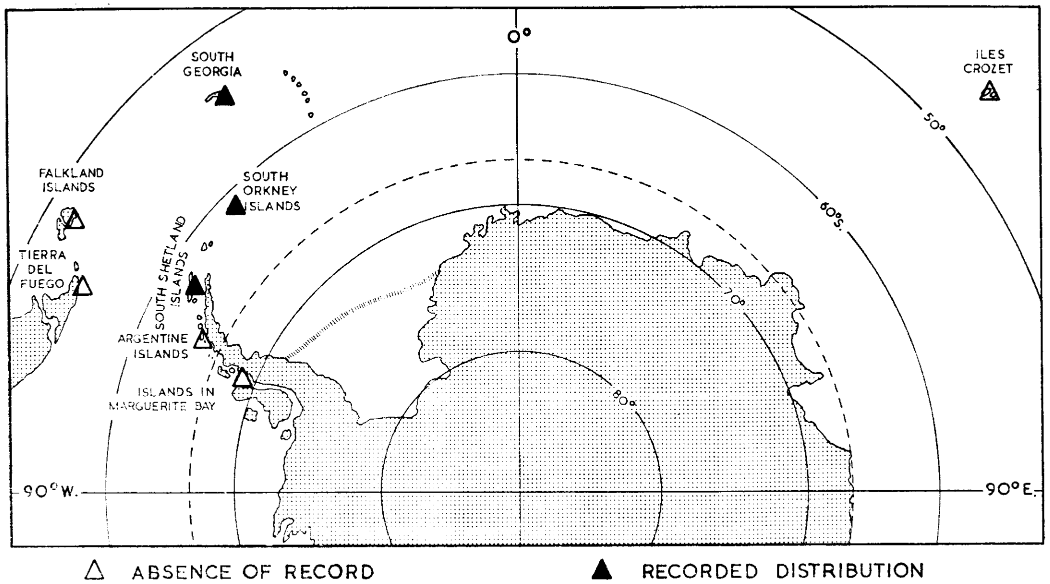


FIGURE 32

The distribution of *Tetramitus rostratus*.

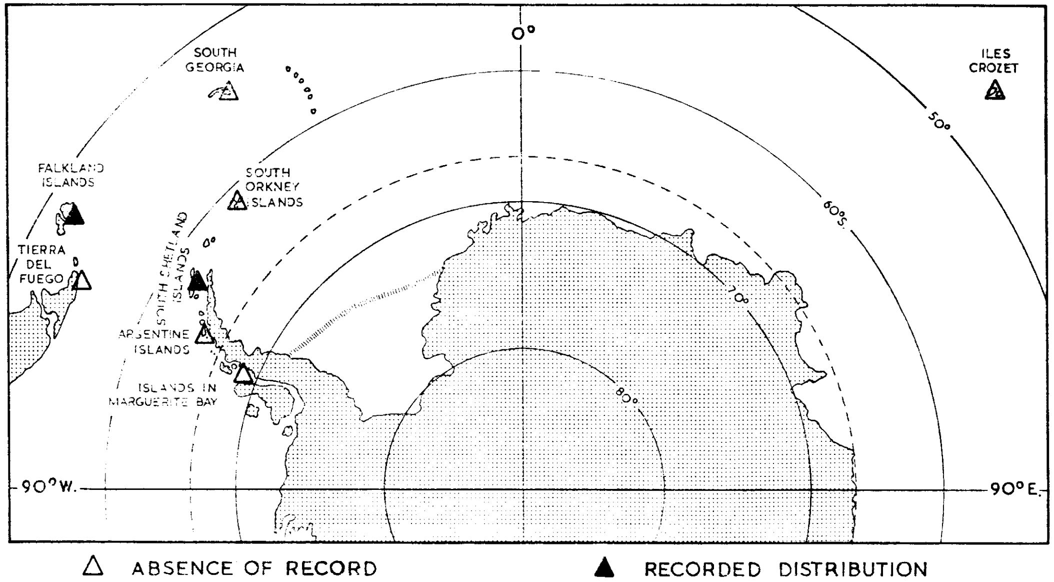


FIGURE 33

The distribution of *Astramoeba radiosa*.

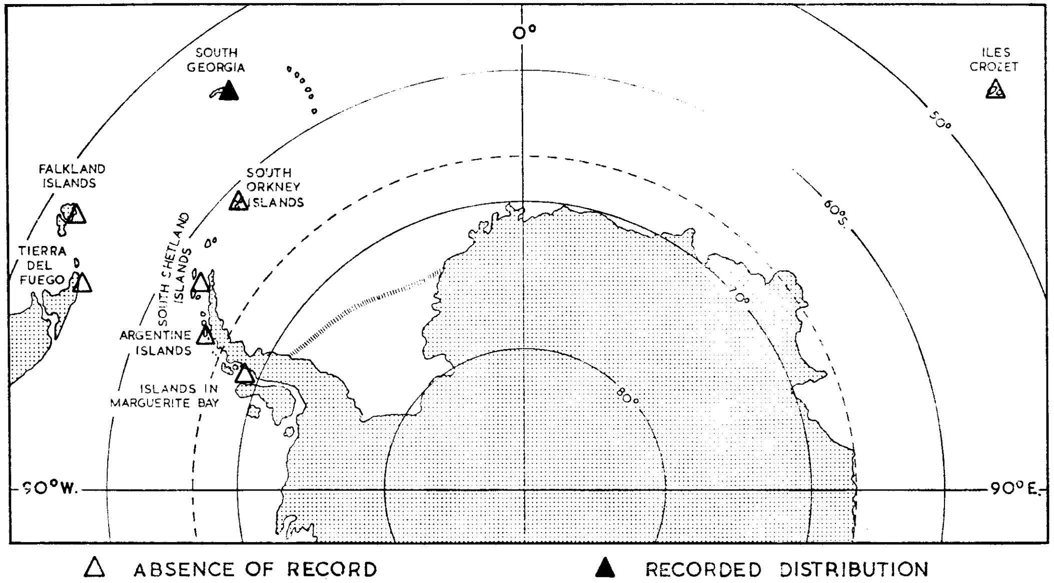


FIGURE 34

The distribution of *Dinamoeba* sp.

Astramoeba Vejdovsky

Figs. 33 and 35, No. 18

Astramoeba radiosa is a small transparent amoeba, typically exhibiting long slender tapering pseudopodial rays. This species, or forms closely resembling it, have been reported by Sandon (1927) as being frequently found in soils. It has been recorded from agricultural soils in America (Sandon, 1928; Dillon and Stoeckmann, 1968) and from tropical and temperate Atlantic islands (Sandon and Cutler, 1924). It appears to be particularly frequent in polar soils, having been recorded from Spitsbergen (Sandon, 1924), Elephant Island (Sandon and Cutler, 1924), East Greenland (Dixon, 1939), Enderby Land (Sudzuki, 1964), Cape Royds, Ross Island (Dillon and others, 1968) and Surtsey, Iceland (Holmberg and Pejler, 1972, 1974). Present observations confirm the occurrence of *Astramoeba radiosa* on Elephant Island but otherwise it was observed only once—in grass-marsh peat from the Falkland Islands.

Dinamoeba Leidy

Figs. 34 and 35, No. 19

Dinamoeba differs from other genera of amoebae in having a large number of small, conical determinate pseudopodia, which may be branched. It has been considered by Schaeffer (1926) as a voracious feeder. The type species of this genus, *Dinamoeba mirabilis* Leidy, is an inhabitant of sphagnous swamp (Kudo, 1966); its morphology, mode of feeding and cyst formation have been described by Groot (1936). The *Dinamoeba* sp. recorded from grass and *Acaena* soils on South Georgia and from *Acaena–Cerastium–Phleum* meadow soil on Tierra del Fuego is smaller than either of the two described species (Leidy, 1879; Schaeffer, 1926) and it may be a new species.

Flabellula Schaeffer

Fig. 35, No. 20; Fig. 36

Flabellula is a mayorellid amoeba moving by means of a broad anterior ectoplasmic wave, which gives the body, during locomotion, a triangular fan-shaped appearance. Experiments by Rice (1935) on the bacterial feeding of *Flabellula mira* showed that it could be cultured monoxenically on a wide variety of Gram-negative bacilli and also on the Gram-positive cocci *Sarcina* and *Staphylococcus* if the bacteria were live. *Flabellula* spp. are rare in soils, being most frequently recorded from marine habitats (Schaeffer, 1926; Page, 1968), although they can often be maintained in laboratory cultures, with reduced salinity, which contain algae and decomposing organic matter. Dillon and Stoeckmann (1968) recorded *Flabellula mira* and *Flabellula symmetrica* from agricultural soils in South Dakota. An undetermined species of *Flabellula* was observed in grass soils from South Georgia and in moss-turf peat from Iles Crozet and Elephant Island.

Hyalodiscus Hertwig and Lesser

Fig. 35, No. 21; Fig. 37

Hyalodiscus is characterized in locomotion by a central or posterior hemispherical hump of granular endoplasm which is apparently dragged along without streaming by the action of the anterior ectoplasmic wave; thin spine-like pseudopodia radiate from the central hump. The means whereby the cell membrane retains its surface integrity (as a protective barrier to the external medium) whilst in locomotion has been studied by micro-cinematography by Hulsman and Haberey (1973). Like *Flabellula*, *Hyalodiscus* is principally a marine genus (Schaeffer, 1926) but some species occur in fresh water among vegetation (Kudo, 1966); Hoogenraad (1907) described the feeding of *Hyalodiscus rubicundus* on the algae *Spirogyra* and *Oedogonium*. *Hyalodiscus limax* and *Hyalodiscus guttula* have been classified by Kolkwitz and Marsson (1909) as polysaprobic indicators. *H. guttula* is the species most frequently recorded from soils in Europe and America (Wolff, 1912; Fellers and Allison, 1920; Yakimoff and Zeren, 1924). *Hyalodiscus* sp. has also been recorded from moss by Sandon and Cutler (1924) on Gough Island and by Stout (1970) from East Greenland. In the present study, *H. guttula* was observed in the sub-Antarctic in a variety of soils with

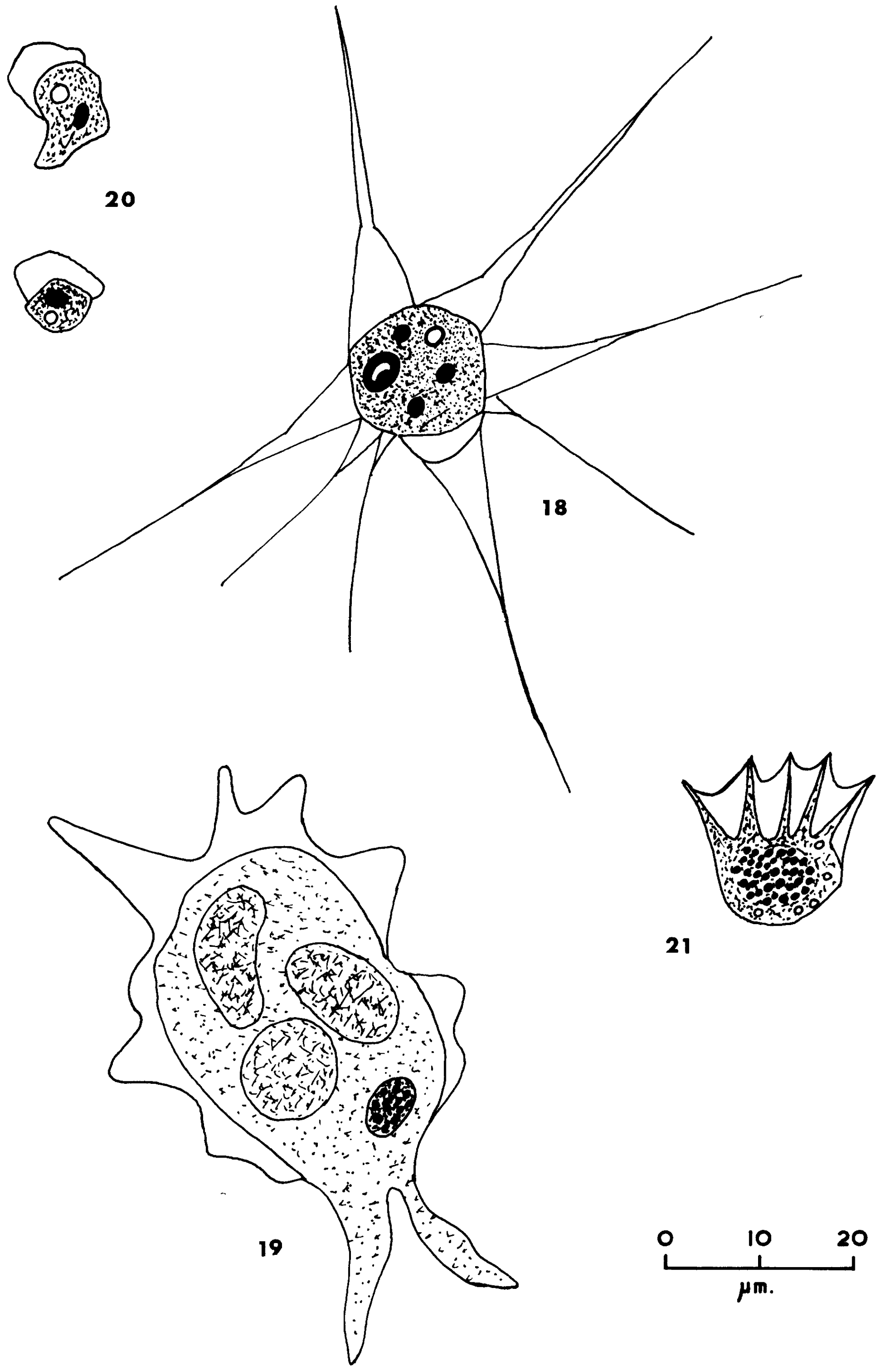


FIGURE 35

Rhizopoda.
Amoebida

No. 18 *Astramoeba radiosa.*
No. 19 *Dinamoeba* sp.
No. 20 *Flabellula* sp.
No. 21 *Hyalodiscus guttula.*

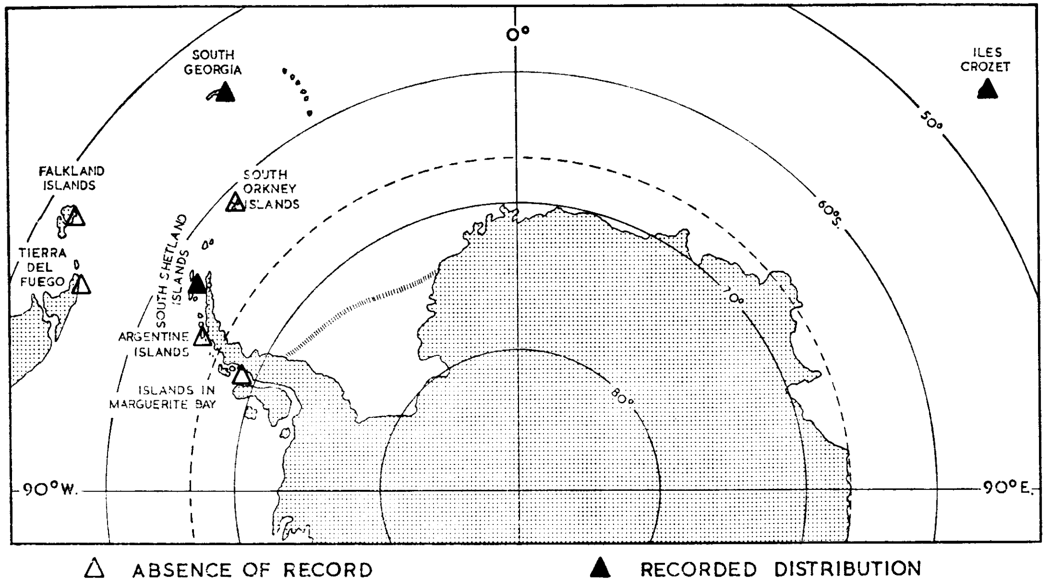


FIGURE 36
The distribution of *Flabellula* sp.

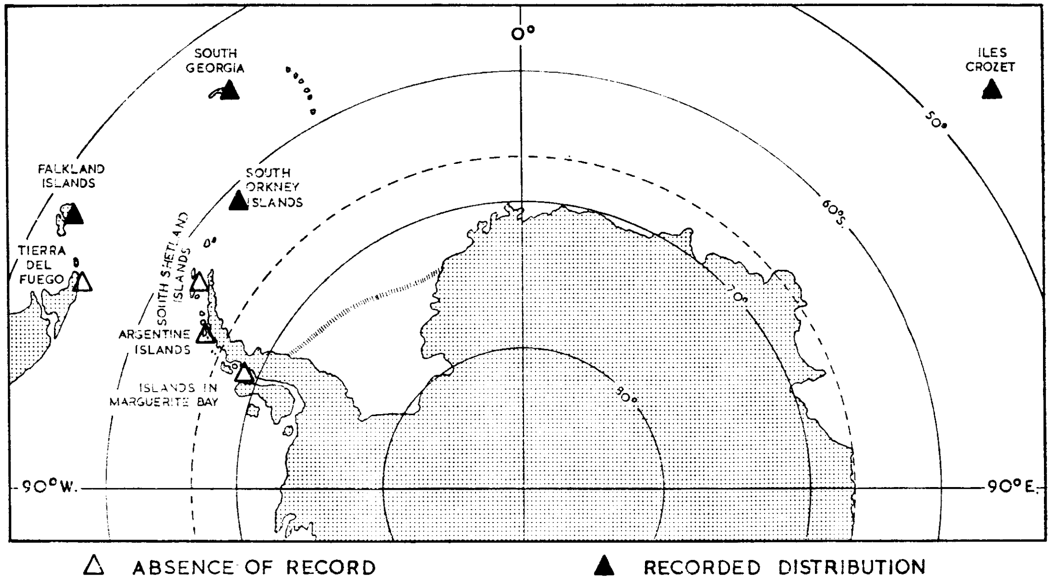


FIGURE 37
The distribution of *Hyalodiscus guttula.*

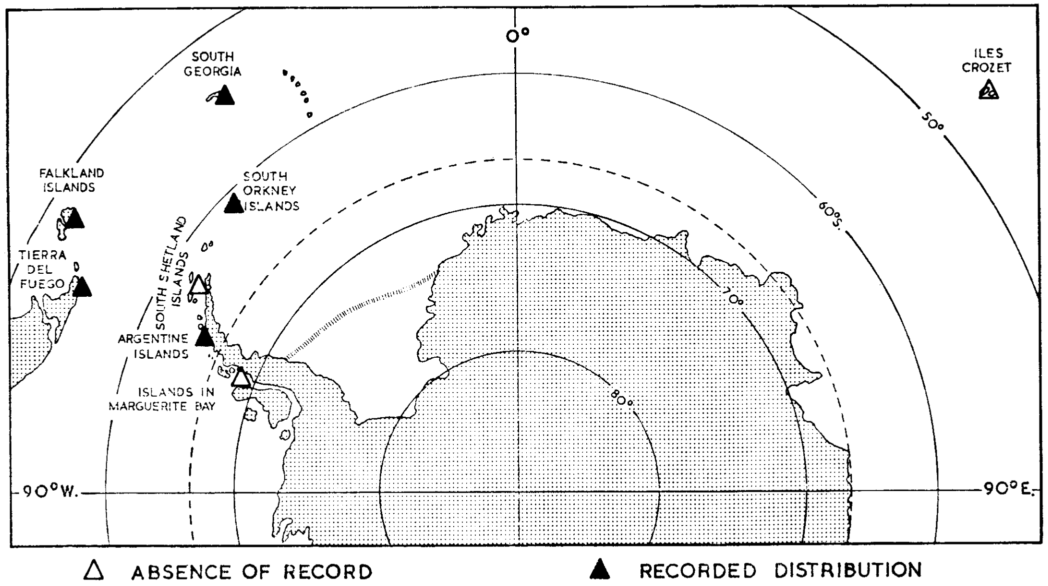


FIGURE 38
The distribution of *Mayorella* sp.

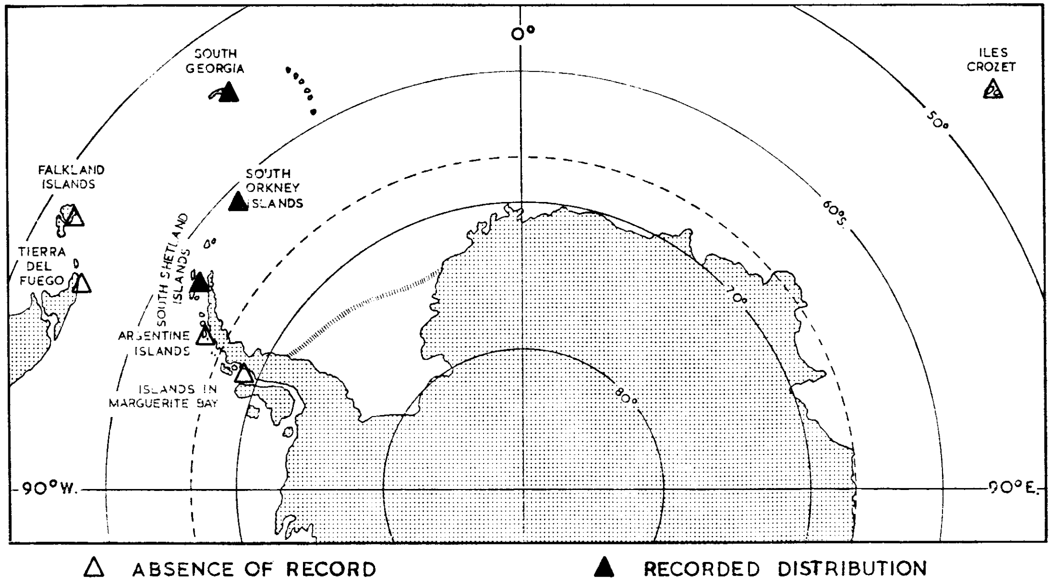


FIGURE 39
The distribution of *Metachaos* sp.

angiosperm vegetation from the Falkland Islands, Iles Crozet and South Georgia, and in one Antarctic moss peat from the South Orkney Islands.

Mayorella Schaeffer

Figs. 38 and 40, No. 22

Mayorella is characterized by numerous small conical pseudopodia which are being continuously formed and retracted. There are several marine and fresh-water species (Schaeffer, 1926; Bovee, 1970). *Mayorella palastinensis* has been cultured axenically by Band and Mohrlock (1969), and Lasman and Reich (1965) have demonstrated that this species can metabolize carbohydrates anaerobically producing lactic acid. The commonest fresh-water species of *Mayorella—M. clavabellans*, *M. spumosa* and *M. vespertilio*—have also been recorded from soils (Dillon and Stoeckmann, 1968) and in this case of *M. vespertilio* from several polar localities: Spitsbergen (Sandon, 1924), East Greenland (Dixon, 1939), Cape Royds and Cape Evans, Ross Island (Dillon and others, 1968), Scoresby Land, Greenland (Stout, 1970) and Surtsey, Iceland (Holmberg and Pejler, 1972, 1974). In the present study, a small *Mayorella* sp. was observed in moss peat from South Georgia, the South Orkney Islands and Argentine Islands, and in soils with angiosperm vegetation from Tierra del Fuego, the Falkland Islands and South Georgia.

Metachaos Schaeffer

Figs. 39 and 40, No. 23

The genus *Metachaos* comprises a group of amoeba species which move by means of cylindrical blunt indeterminate pseudopodia, the endoplasm filling the cell except the extreme tips of advancing pseudopodia. Endoplasmic granules are evenly distributed and the whole amoeba is constantly streaming into its primary pseudopodium. The large *Metachaos* spp. described by Schaeffer (1926) are all fresh-water, or very tolerant of dilution if marine, and feed on diatoms and algae. A very small species of *Metachaos*, *M diminutrium*, has been described by Bovee (1953) and has been recorded from agricultural soil in South Dakota (Dillon and Stoeckmann, 1968). A small *Metachaos* sp. (about 30 μm.) was observed in moss peat and grass soil from South Georgia, the South Orkney Islands and Elephant Island. While considerably smaller than the large forms described by Schaeffer, this species was significantly larger than *M. diminutrium*.

Naegleria Alexeieff

Fig. 40, No. 24; Fig. 41

Naegleria gruberi is the most frequently recorded species of amoeba from soils. It is dimorphic, existing as a limax amoeba with a single indeterminate pseudopodium and also as an ovoid to pyriform flagellate with two equal forward-directed flagella. Rafalko (1947) described in detail the morphology of the nucleus and the process of mitosis. Willmer (1956, 1961) investigated the factors influencing the amoeba-to-flagellate transformation, concluding that low cation concentrations and the presence of deoxycorticosterone favoured the flagellate form and that the transformation could be suppressed with Li^{+}, Mg^{++} and sulphate ions. Napolitano and others (1967) and Preston (1973) have studied the comparative physiology of the amoeboid and flagellate phases. The electron-microscopic structure of the amoeboid, flagellate and cyst phases have been described by Schuster (1963*a*, *b*), who also recorded (Schuster, 1969) the presence of intranuclear virus-like particles. Recent observations by Dunnebacke and Schuster (1974) suggested that the cytopathogenic agent is not viral but may possibly be related to the scrapie agent: it is genus-specific to *Naegleria*. O'Dell and Brent (1974) have shown that different strains of *Naegleria gruberi* differ in morphological detail, nutrition requirements and optimum growth temperature. Willmer's (1956) drawings suggest that the strain of *N. gruberi* he used had considerable affinities with *Tetramitus rostratus* in both the amoeboid and flagellate stages; it is possible that these two species are more closely related than their traditional taxonomic positions would suggest. *Naegleria gruberi* has been recorded from many temperate soils (Fellers and Allison, 1920; Allison, 1924; Sandon, 1928; Detcheva, 1973), from East Greenland (Dixon, 1939; Stout, 1970) and from many Atlantic islands stretching from the Azores to South Georgia (Cutler and Sandon, 1924). Its occurrence on South Georgia is confirmed by present observations and it was also observed in grass soil and in marble debris on Signy Island.

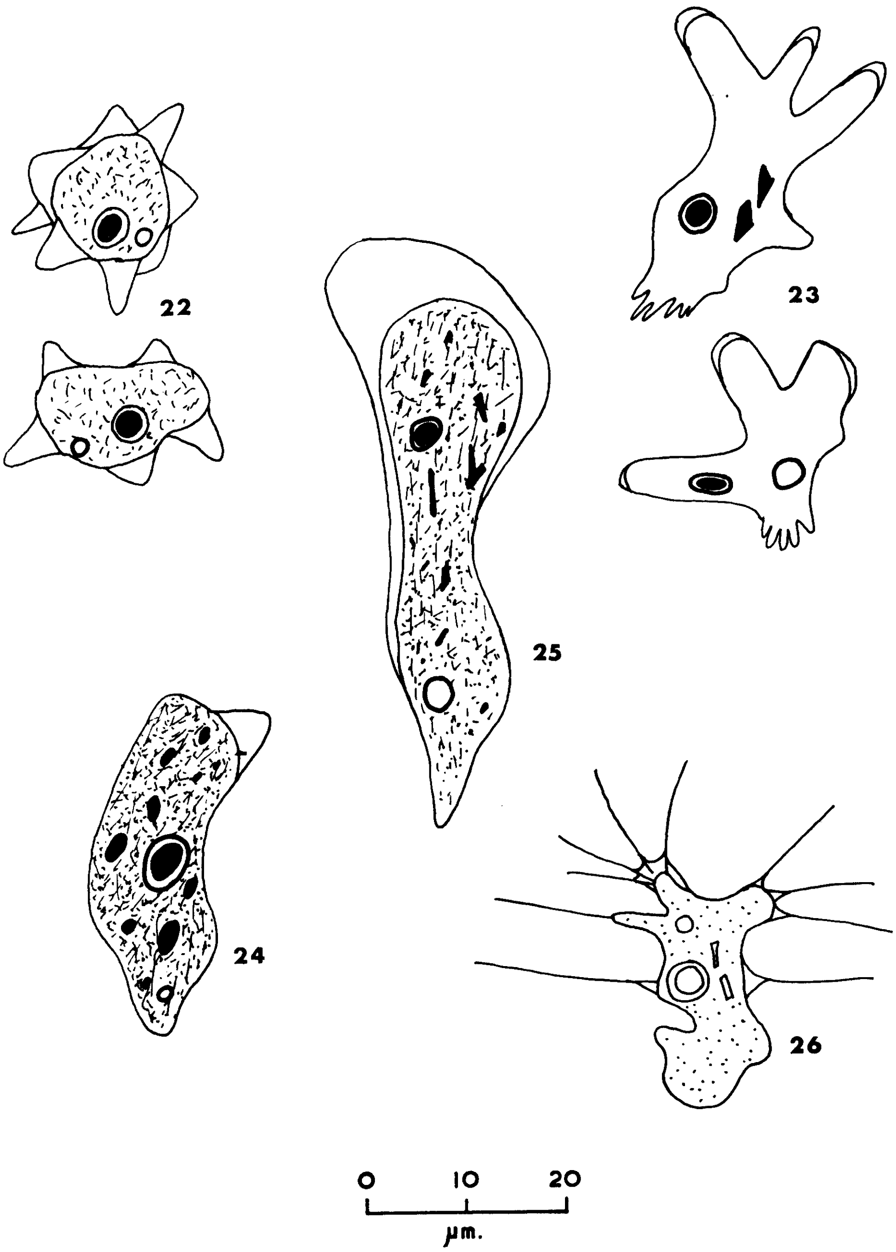


FIGURE 40

Rhizopoda.				
Amoebida	No. 22	*Mayorella* sp.	No. 25	*Valkampfia* sp.
	No. 23	*Metachaos* sp.	No. 26	*Vexillifera* sp.
	No. 24	*Naegleria gruberi.*		

Valkampfia Chatton and Lalung-Bonnaire

Fig. 40, No. 25; Fig. 42

Valkampfia is a limax amoeba in which rapid movement is effected by a broad anterior ectoplasmic wave but, unlike *Flabellula*, it maintains a long narrow form during locomotion. An early account of this genus was given by Wherry (1913), who cultured it on ovomucoid medium and described endogenous budding and symbiosis with *Bacillus* sp. Kathe (1929) reported the existence of a flagellate form of *Valkampfia tachypodia*. *Valkampfia* has normally been considered to be a fresh-water genus (Jahn and Jahn, 1949; Kudo, 1966) but a parasitic species, *V. calkensi*, from the intestine of oysters has been described by Hogue

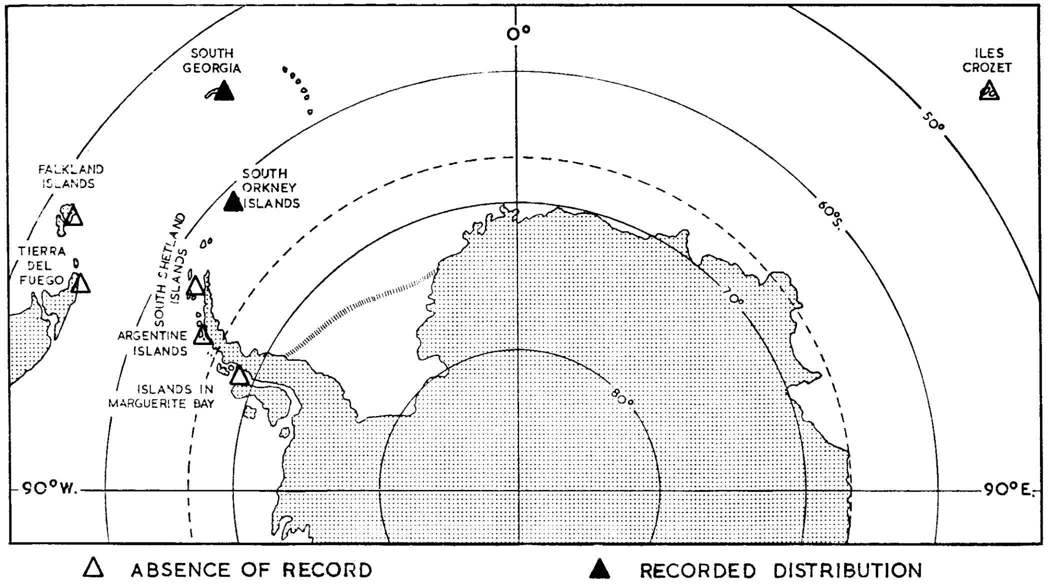


FIGURE 41

The distribution of *Naegleria gruberi.*

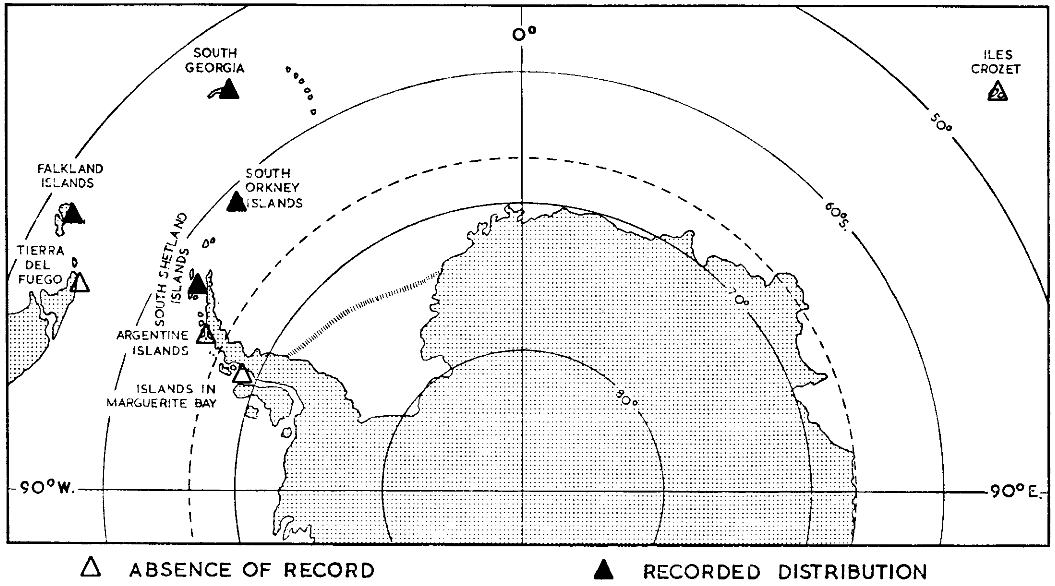


FIGURE 42

The distribution of *Valkampfia* sp.

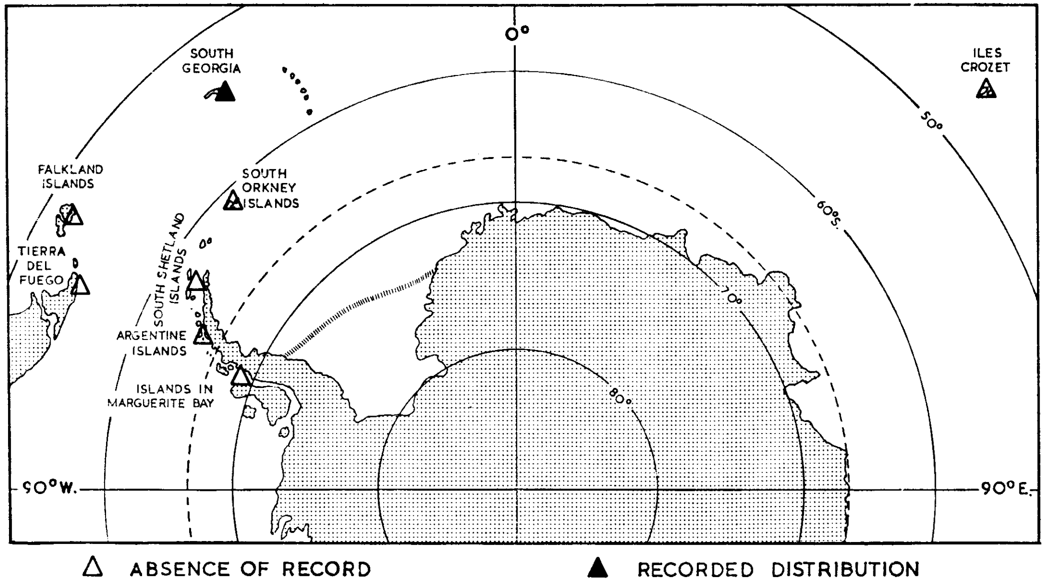


FIGURE 43

The distribution of *Vexillifera* sp.

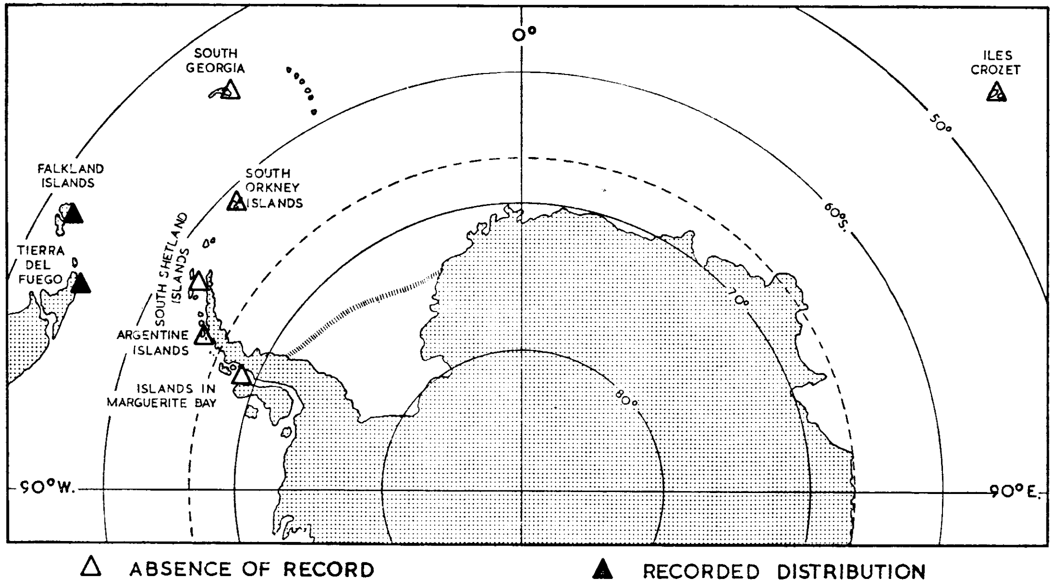


FIGURE 44

The distribution of *Arcella discoides.*

(1914). *Valkampfia limax* has been recorded from American soils (Stoeckmann and Dillon, 1968) and from several polar sites: Cape Royds, Ross Island (Dillon and others, 1968) and Surtsey, Iceland (Holmberg and Pejler, 1972, 1974). Sudzuki (1964) has recorded "*Valkampfia* sp." as occurring in moss water at Langhovde, Enderby Land; from his drawing it is clear that this organism is not *Valkampfia* but probably *Trichamoeba* sp. *Valkampfia* sp. was observed in grass-marsh soil from the Falkland Islands and South Georgia, and in moss peats from South Georgia, the South Orkney Islands and Elephant Island.

Vexillifera Schaeffer

Fig. 40, No. 26; Fig. 43

Vexillifera is characterized by long slender pseudopodia which can move about in the manner of tentacles. These do not direct locomotion and indeterminate pseudopodia are not formed. *Vexillifera aurea*, described by Schaeffer (1926), is a marine species which is not tolerant of reduced salinity. The type species, *Vexillifera ambulacris* Penard, has been recorded by Stoeckmann and Dillon (1968) from agricultural soil. A *Vexillifera* sp. intermediate in size between *ambulacris* and *aurea* was observed in the tussock peat and *Aceana* soil from South Georgia.

Arcella Ehrenberg

Figs. 44, 45 and 48, Nos. 27 and 28

Arcella spp. have a transparent yellow to brown dome-shaped test. *Arcella vulgaris* is the most intensively studied species of this genus. Early descriptions of its morphology and life cycle were made by Elpatiewsky (1907), Swarczewsk (1908), Khainsky (1911) and Schirch (1914). Jollos (1924) described intra-specific variants. Recent studies by micro-cinematography and electron microscopy have been made by Netzel and Heunert (1971). Moraczwesk (1971), in studies on the chemical composition of the test, has detected nine amino acids and considered the test to be composed of keratin not chitin as is commonly assumed. *Arcella vulgaris* has been recorded from many tropical and temperate terrestrial habitats, particularly peaty soils and mosses (Fellers and Allison, 1920; Hoogenraad, 1935; Hofker, 1940; Bonnet, 1966; Golemansky, 1968; Boltovsky and Lena, 1974). Heal (1964) considered it to be a eurytope species of fens and bogs in Britain, and it has been classified by Kolkwitz (1950) as a β-mesosaprobic indicator. In the Arctic it has been recorded from a peat bog in Greenland (Dixon, 1939) and from aquatic vegetation and moss in Iceland (Chardez, 1969*b*). There are several previous records from Antarctic and sub-Antarctic peats: Iles Kerguelen, Iles Crozet and Iles Amsterdam (Richters, 1907), the Falkland Islands and South Georgia (Richters, 1909), Macquarie Island (Penard, 1911) and Gough Island (Sandon and Cutler, 1924). Present observations suggest that *A. vulgaris* is restricted to acid grass soils and moss peats in the Antarctic. *Arcella discoides* is a more uncommon species but it occurs in habitats similar to those of *A. vulgaris* (Heal, 1964). However, it has not been recorded from Arctic or montane soils and does not reach such high latitudes in the Antarctic, having been observed only in Tierra del Fuego and the Falkland Islands apart from a single doubtful record from moss water in Enderby Land at lat. 69° S. (Sudzuki, 1964).

Assulina Ehrenberg

Figs. 46 and 48, No. 29

Assulina muscora is a euglyphid testate with a thick brown chitinous test, imbricated scales and a dentate aperture. It is a very frequently observed species in mosses and acid soils (particularly in *Sphagnum* bog) in tropical and temperate regions (Sandon, 1928; Hoogenraad, 1935; Hoogenraad and Groot, 1948; van Oye, 1956; Heal, 1961, 1964; Bonnet, 1966; Golemansky, 1968; Couteaux, 1969; Delhez and Chardez, 1970; Rosa and Lhotsky, 1971). Heal (1964) observed that *Assulina muscora* was restricted to the top 6 cm. of *Sphagnum* bog, while Golemansky's (1968) observations suggested that it is a species common in all types of moss habitats but absent from aquatic vegetation. There are also numerous records of *Assulina muscora* inhabitating mosses, particularly *Sphagnum*, in polar regions: Spitsbergen (Penard, 1903; Sandon, 1924), Iceland (Chardez, 1969*b*), East Greenland (Stout, 1970); Ross Island and Macquarie Island (Penard, 1911), the South Shetland Islands (Penard, 1913), South Georgia (Sandon and Cutler, 1924),

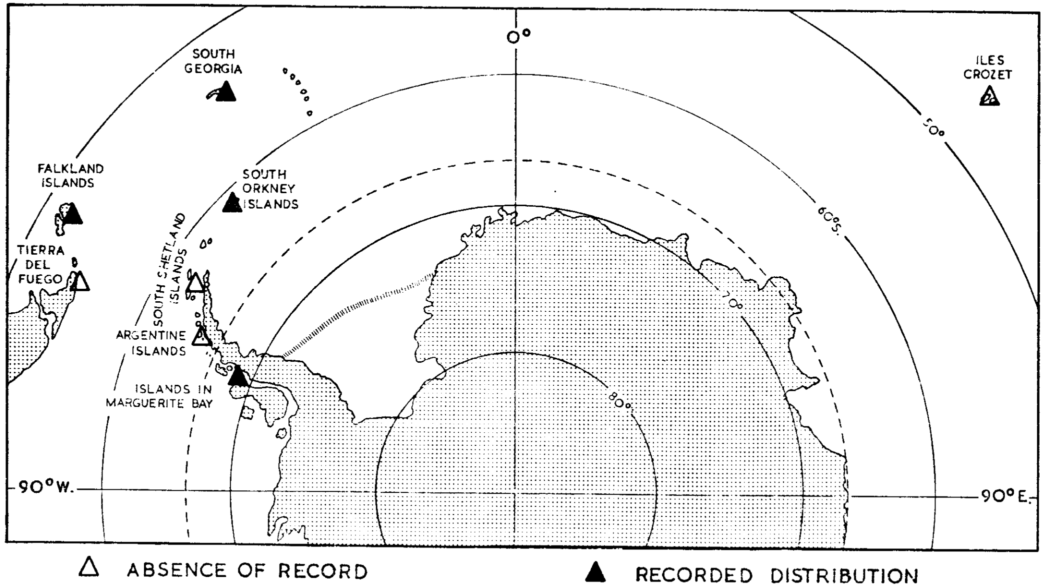


FIGURE 45

The distribution of *Arcella vulgaris.*

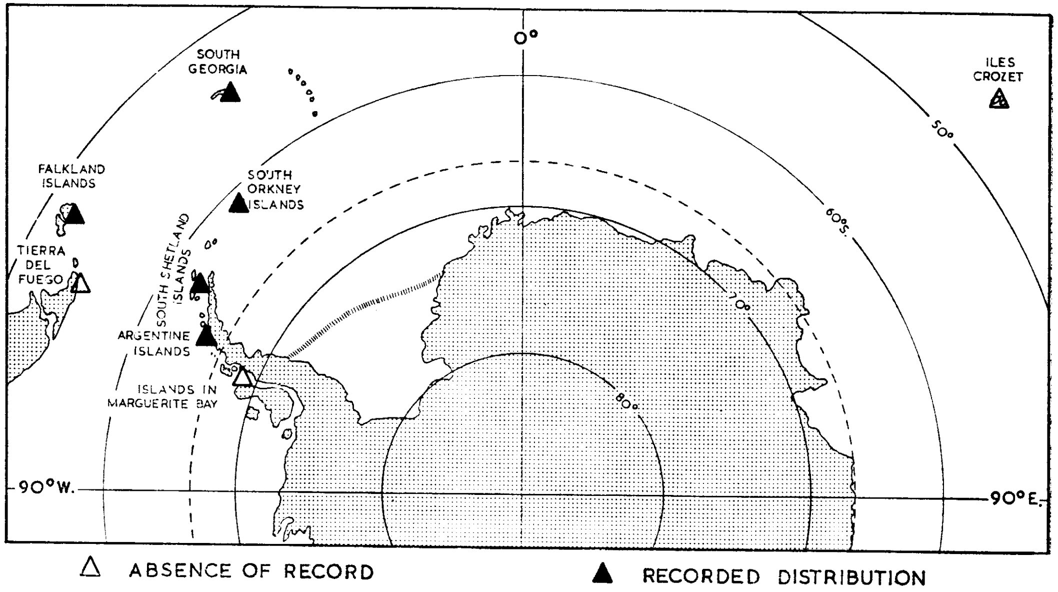


FIGURE 46

The distribution of *Assulina muscora.*

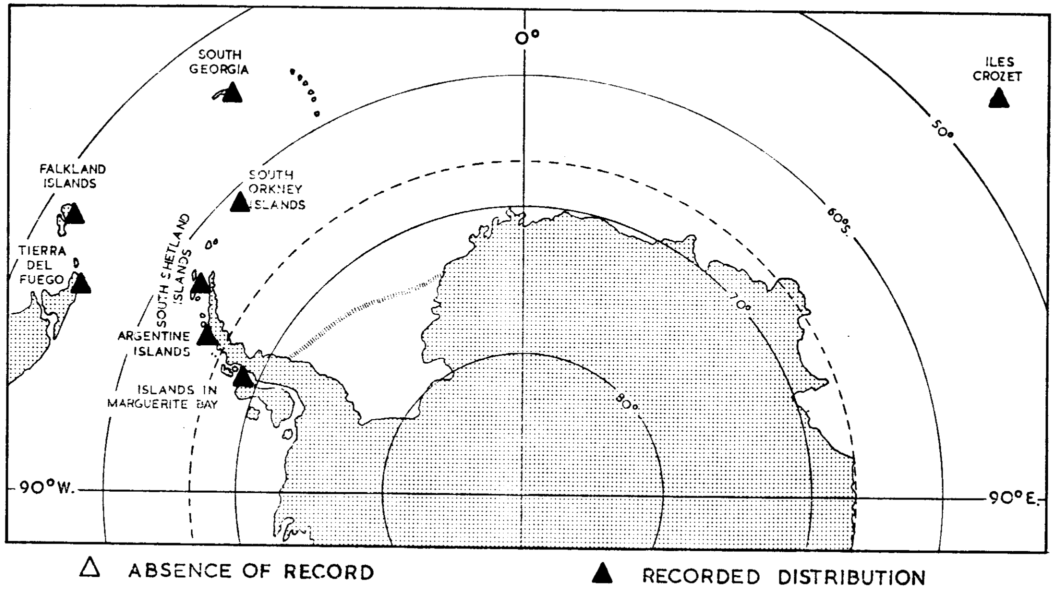


FIGURE 47

The distribution of *Corythion dubium.*

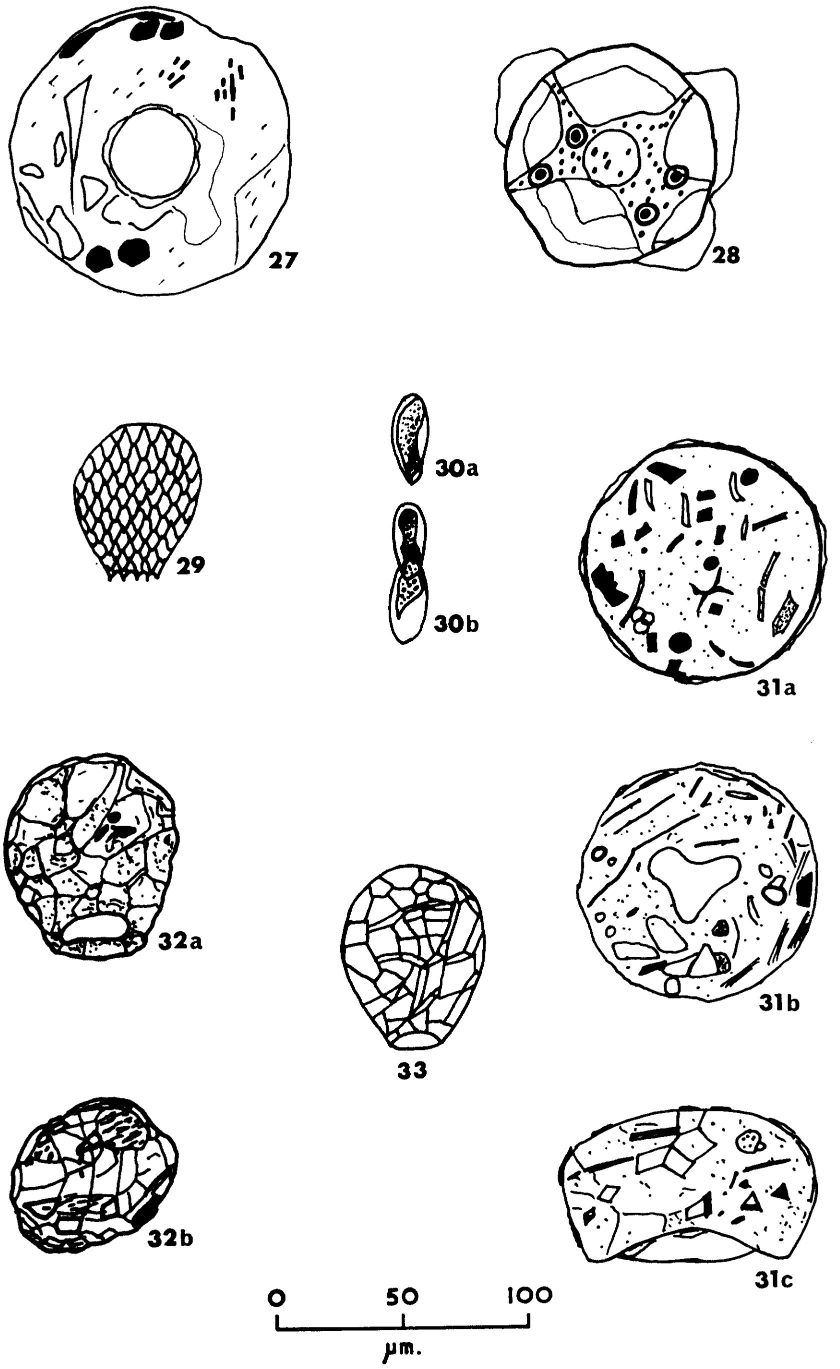


FIGURE 48

Rhizopoda.
Testacida

No. 27 *Arcella discoides* (oral view).
No. 28 *Arcella vulgaris* (aboral view).
No. 29 *Assulina muscora.*
No. 30 *Corythion dubium.*
a. Individual cell.
b. Asexual reproduction; cytoplasmic fission.

No. 31 *Difflugia arcula.*
a. Aboral view.
b. Oral view.
c. Lateral view.
No. 32 *Difflugia constricta.*
a. Lateral view.
b. Aboral view.
No. 33 *Difflugia lucida.*

Enderby Land (Sudzuki, 1964), the South Orkney Islands (Heal, 1965) and Marion Island (Grospietsch, 1971). Present observations confirm this ubiquity, *A. muscora* being found to occur in almost every island group in which moss habitats were examined.

Corythion Taranek

Figs. 47 and 48, No. 30a and b

Corythion dubium is a small euglyphid with a test composed of small siliceous plates, which are normally very difficult to distinguish, but they have been observed by Decloitre (1960*b*) with phase-contrast microscopy to have the usual euglyphid imbricated arrangement. It is a very frequently recorded species of soils and mosses (Heal, 1961, 1964; Bonnet, 1966; Golemansky, 1968; Couteaux, 1969; Rosa and Lhotsky, 1971). There are several records of *C. dubium* from the Arctic (Penard, 1903; Dixon, 1939; Chardez, 1969*b*; Stout, 1970; Holmberg, and Pejler, 1974) and from the southern cool-temperate zone (Penard, 1911; Sandon and Cutler, 1924; Hoogenraad and Groot, 1935; Grospietsch, 1971), starting from the early years of this century. However, there were no records from the Antarctic until 1964, when it was recorded by Sudzuki from Enderby Land and by Decloitre from Terre Adélie. Heal (1965) observed *C. dubium* in large numbers on Signy Island. Detailed studies of the population ecology of *C. dubium* on Signy Island have been made by Smith (1973*b*) which confirmed and extended Heal's observations and indicated that the numbers of *C. dubium*, constituting on average 40 per cent of the total testate fauna of moss-turf peat, were related to the temperature and moisture content of the peat. Present observations confirm the ubiquity of *C. dubium* in moss peats throughout the maritime Antarctic and sub-Antarctic, though it is not everywhere so dominant a member of the testate community as it is on Signy Island.

Difflugia Leclerc

Fig. 48, Nos. 31–33; Figs. 49–53 and 55, Nos. 34 and 35

Difflugids have a test with a circular terminal aperture which is covered with sand grains or other extraneous particles. This genus contains many species and at least one species has been recorded from every terrestrial and fresh-water site examined for Testacida. *Difflugia oblonga* is the commonest species and has a wide ecological amplitude. It has been recorded from high montane forest soils (Rosa and Lhotsky, 1971) as well as from lowland temperate soils (Heal, 1962; Bonnet, 1966; Couteaux, 1969) and there are early records of *D. oblogna* from the Falkland Islands, Iles Kerguelen, Iles Crozet and Heard Island (Richters, 1907, 1908). It was observed in the present survey in peat soils from the Falkland Islands and South Georgia but it appeared to be entirely absent from the maritime Antarctic. Similarly, *Difflugia arcula* and *Difflugia constricta* were observed to be common in the sub-Antarctic (thus confirming Sandon and Cutler's (1924) observations on soils from South Georgia) but they were not observed farther south, apart from rare occurrences of *D. constricta* in the South Shetland Islands. These species have, however, been recorded from Greenland and Spitsbergen (Penard, 1903; Sandon, 1924; Dixon, 1939). *Difflugia lucida* has also been recorded from Greenland (Stout, 1970) and was frequently observed in moss peats on Elephant Island as well as in moss peat and grass soil from South Georgia, Iles Crozet, the Falkland Islands and Tierra del Fuego. It was recorded from Signy Island by Heal (1965) but this was not confirmed. *Difflugia penardi* is a very rare species in soils, though it has been commonly observed in fresh-water habitats (Golemansky, 1968; Chardez, 1969); however, it has been observed in moss from Greenland (Stout, 1970) and in the present survey was observed in the moss peats and *Prasiola* soils on Signy Island.

Difflugiella Cash

Figs. 54 and 55, No. 36

Difflugiella is a small arcellid testate distinguished by the dimorphism of its pseudopodia. It appears to be a very rare genus of testate but it was observed in soils from the Falkland Islands and South Georgia and in moss peats from Marguerite Bay, and the South Shetland and South Orkney Islands. The only other record of *Difflugiella* from terrestrial habitats in the Southern Hemisphere is of *D. oviformis* var. *fusca* in *Nothofagus* forest soil in Chile (Bonnet, 1966).

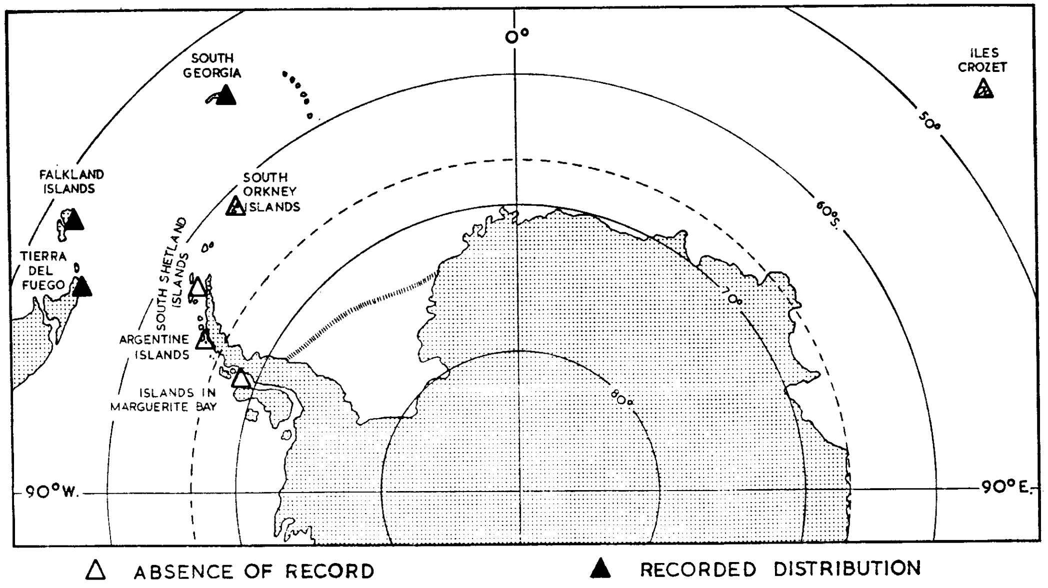


FIGURE 49

The distribution of *Difflugia arcula.*

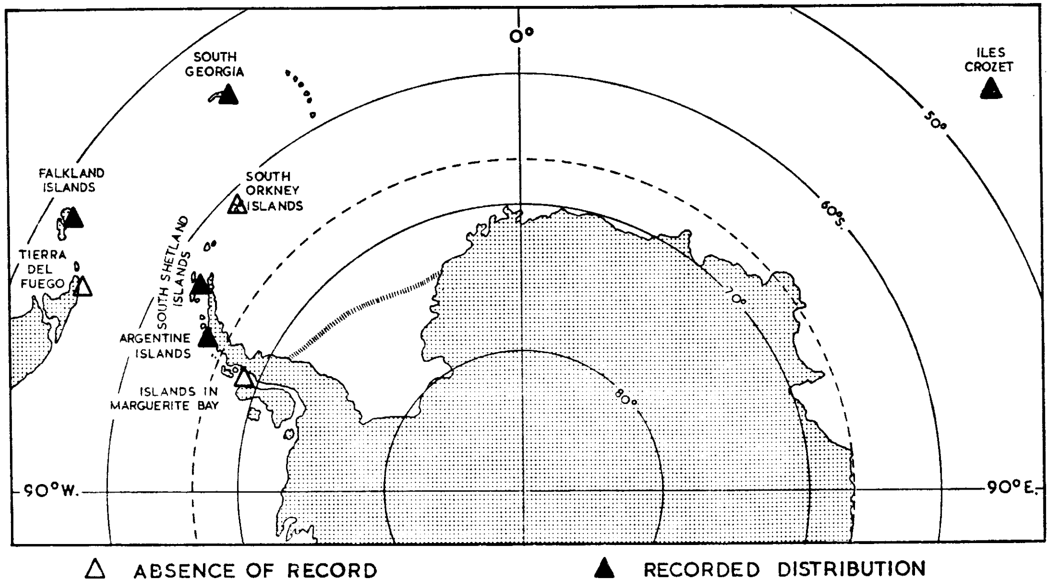


FIGURE 50

The distribution of *Difflugia constricta.*

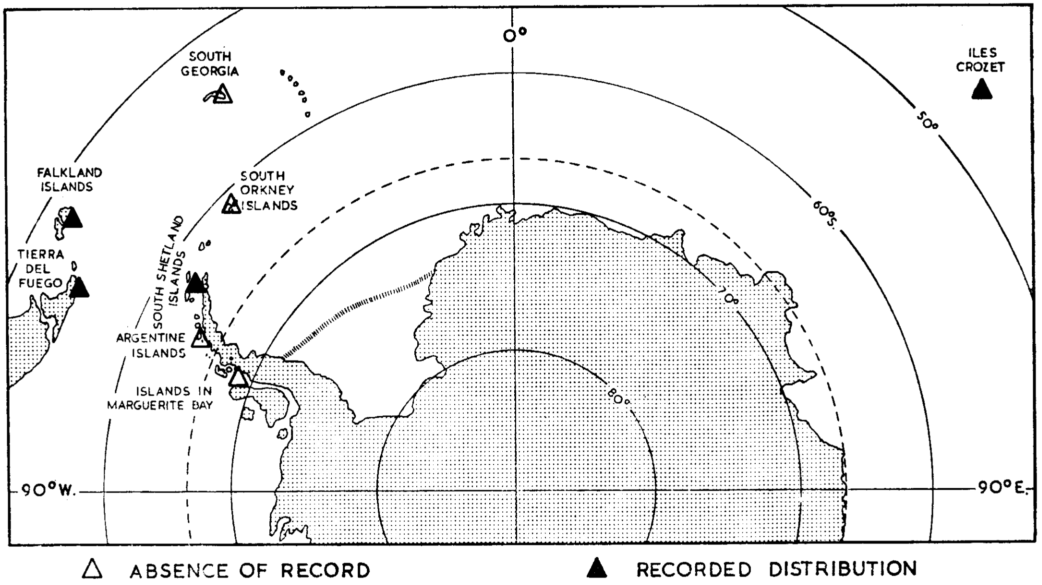


FIGURE 51

The distribution of *Difflugia lucida.*

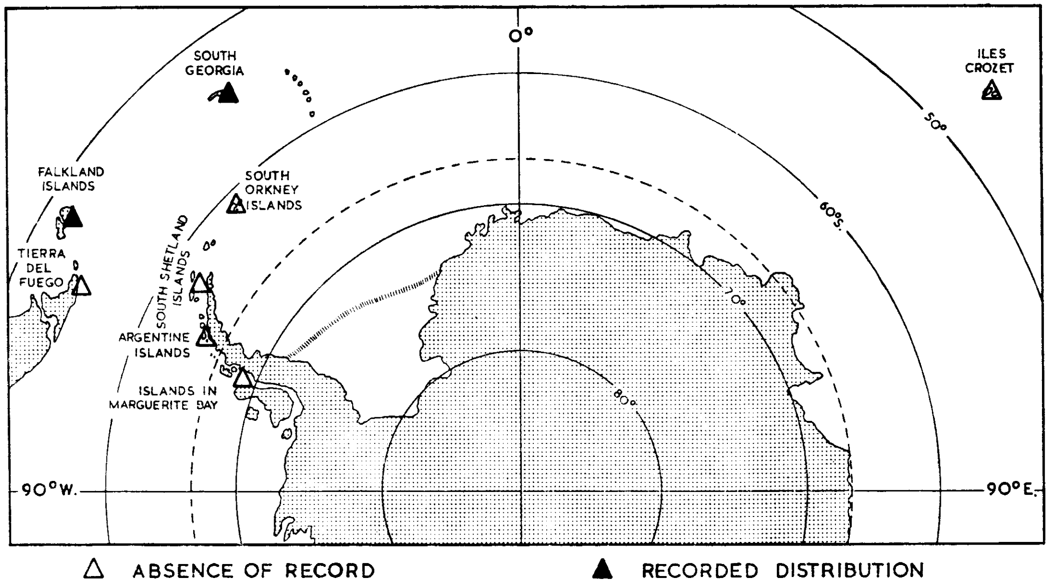


FIGURE 52

The distribution of *Difflugia oblonga.*

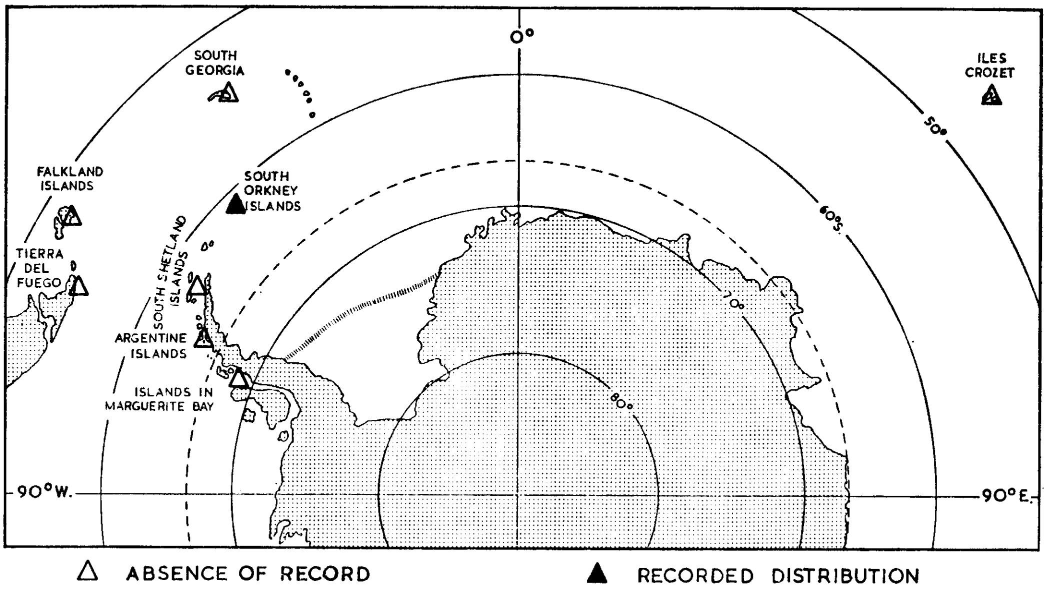


FIGURE 53

The distribution of *Difflugia penardi.*

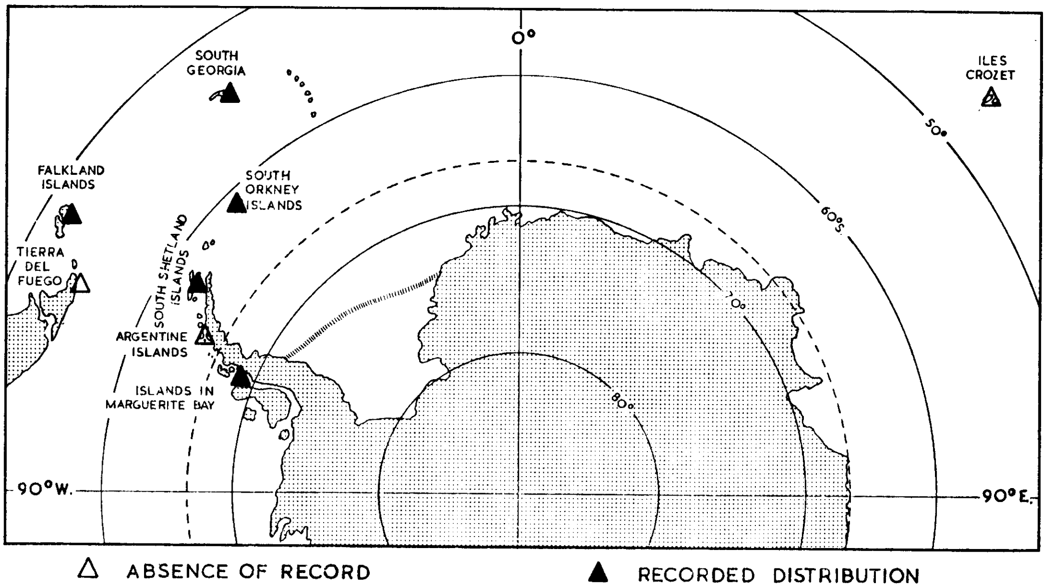


FIGURE 54

The distribution of *Difflugiella* sp.

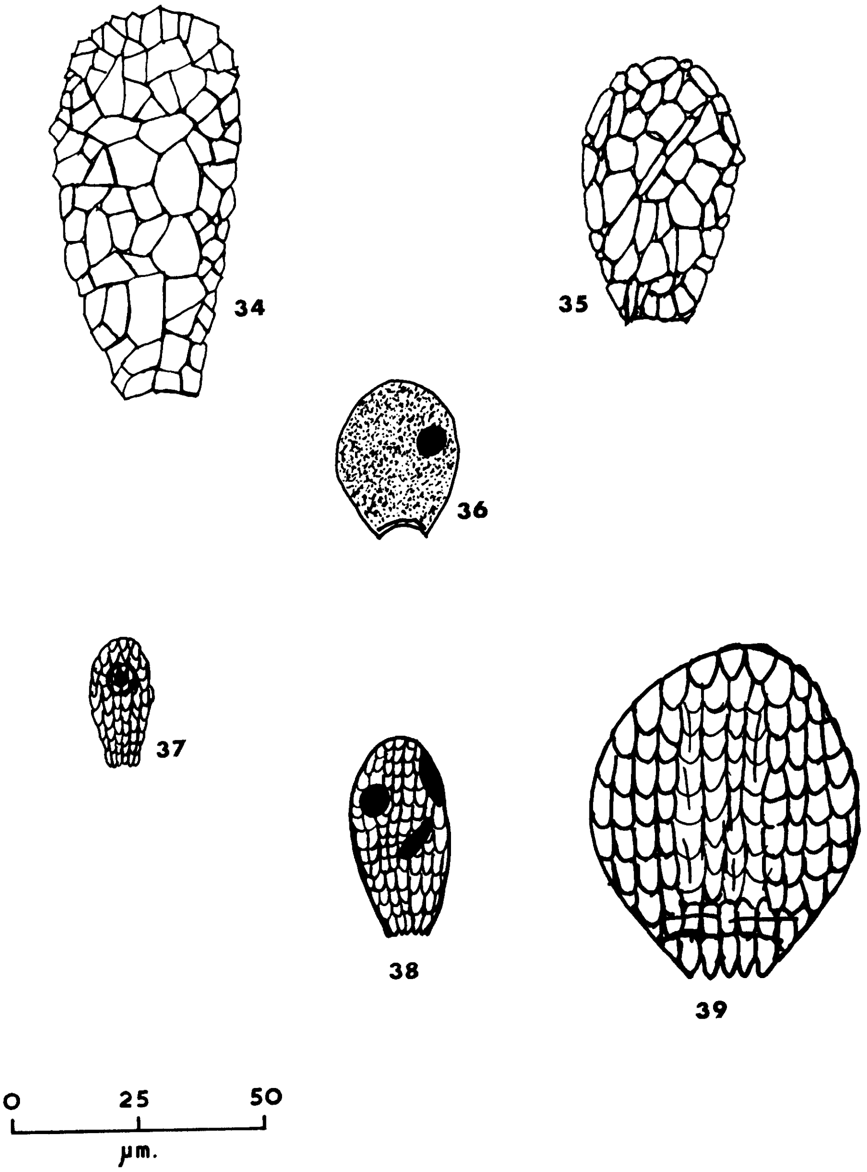


FIGURE 55

Rhizopoda.
Testacida

No. 34 *Difflugia oblonga.*
No. 35 *Difflugia penardi.*
No. 36 *Difflugiella* sp.
No. 37 *Euglypha laevis.*
No. 38 *Euglypha rotunda.*
No. 39 *Euglypha strigosa.*

Euglypha Dujardin

Fig. 55, Nos. 37–39; Figs. 56–58

Euglyphid testates are characterized by a test composed of regularly arranged scales. The genus *Euglypha* has a cosmopolitan distribution in fresh water and soils; it contains numerous species. Many species have spines but soil forms are almost invariably glabrous. The three species *E. laevis*, *E. rotunda* and *E. strigosa* all occur in both temperate and polar regions. *Euglypha strigosa* is the most frequently recorded of the three in temperate soils in both hemispheres (Sandon, 1928; Hoogenraad, 1935; van Oye, 1956; Bonnet, 1966; Golemansky, 1968; Couteaux, 1969; Delhez and Chardez, 1970; Rosa and Lhotsky, 1971), but *Euglypha laevis* is the most frequent in both the Arctic and the Antarctic, having been recorded from

Iceland, Greenland and Spitsbergen and from many Antarctic islands, the Antarctic Peninsula and continental Antarctica (Penard, 1903, 1911, 1913; Sandon, 1924; Sandon and Cutler, 1924; Dixon, 1939; Sudzuki, 1964; Heal, 1965; Chardez, 1969*b*; Stout, 1970; Grospietsch, 1971; Holmberg and Pejler, 1972). This distributional trend is confirmed by the present observations; *E. strigosa* was frequently observed in soils and moss peats from the Falkland Islands and South Georgia but rarely from the maritime Antarctic, whereas *E. laevis* was most frequently observed in moss peat from the Argentine Islands.

Nebela Leidy

Fig. 59, Nos. 40–46; Figs. 60–66

Nebela is a testate genus containing at least 60 species. They have thin, flattened flask-shaped tests with small platelets which may be regular or irregular in size and arrangement. Four of the seven species recorded in the present study (*N. dentistoma*, *N. minor*, *N. penardiana* and *N. wailesi*) are cosmopolitan species and are common in northern temperate regions. *Nebela dentistoma* was observed in the peat and litter of angiosperm species from Iles Crozet; it is a common species in the Arctic (Dixon, 1939; Chardez, 1969*b*; Stout, 1970) and has also been recorded from Macquarie Island (Penard, 1911) and Marion Island (Grospietsch, 1971). *Nebela minor* was observed in two moss peats from Pourquoi Pas Island, Marguerite Bay, a surprising result as this species has not been previously recorded from polar regions. *Nebela penardiana*, observed in dwarf-shrub peat in the Falkland Islands, has been recorded previously from East Greenland (Stout, 1970) but not from the Antarctic. *Nebela wailesi* appeared to be the most frequent species in the present study, being observed in mineral habitats, moss peat and grass soil from Iles Crozet, South Georgia and Signy Island; it is also known from Marion Island (Grospietsch, 1971).

The other three species of *Nebela* observed (*N. certesi*, *N. martiali* and *N. vas*) have distributions restricted to the Southern Hemisphere. *Nebela certesi* has a circum-polar distribution in the tropical and temperate regions of southern Asia, South America and Australasia (Deflandre, 1936; Bonnet, 1966); it was observed in grass-marsh peat from the Falkland Islands and in moss peats from the Argentine Islands and Cone Island; it has been recorded from Marion Island (Grospietsch, 1971) but it has not previously been observed farther south. *Nebela martiali* has a distribution very similar to that of *N. certesi* and was also observed in peat from the Falkland Islands; it has also been recorded from Macquarie Island (Penard, 1911). *Nebela vas* is the most frequent and widespread of the specifically Southern Hemisphere species of *Nebela*. It has been recorded from tropical and temperate regions of all the southern continents except Africa (Deflandre, 1926) and from many Antarctic and sub-Antarctic islands (Richters, 1907, 1908; Penard, 1911, 1913; Grospietsch, 1971), extending as far south as Ross Island. It was observed in two grass soils from South Georgia in the present study.

Phryganella Penard

Figs. 67 and 69, No. 47a and b

Phryganella acropodia (sometimes called *Phryganella hemispherica*) is a difflugid testate and is covered with small sand grains and platelets; it is distinguished particularly by possessing pointed radiating pseudopodia. It is a cosmopolitan species and is ubiquitous in moss habitats. There are many records from tropical and temperate regions (Hoogenraad, 1935; Hoogenraad and Groot, 1948; Heal, 1962, 1964; Decloitre, 1964; Bonnet, 1966; Golemansky, 1968; Couteaux, 1969; Delhez and Chardez, 1970). It has been frequently recorded from the Arctic (Sandon, 1924; Chardez, 1969; Stout, 1970) and, in the maritime Antarctic, from the South Shetland Islands (Penard, 1913), Macquarie Island (Decloitre, 1960*c*) and Signy Island (Heal, 1965). Observations in the present study showed it to be present in moss-peat and grass soils in all the island groups investigated except the Argentine Islands. It was observed in particularly high numbers in moss peats, grass soil and *Prasiola* from Signy Island during the summer 1968–69 (Table IX). In the Signy Island terrestrial reference site 1 (Smith, 1973*a*) the numbers of *Phryganella acropodia* were measured at monthly intervals from January 1970 to March 1971 (Fig. 68). The size of the population was much smaller than that of the co-existing *Corythion dubium* (Smith, 1973*b*) but otherwise it was greater than that of any other testate species. Like *C. dubium*, *Phryganella acropodia* showed initially high numbers in January 1970 followed by progressive mortality during the autumn and winter months of 1970 reaching a minimum

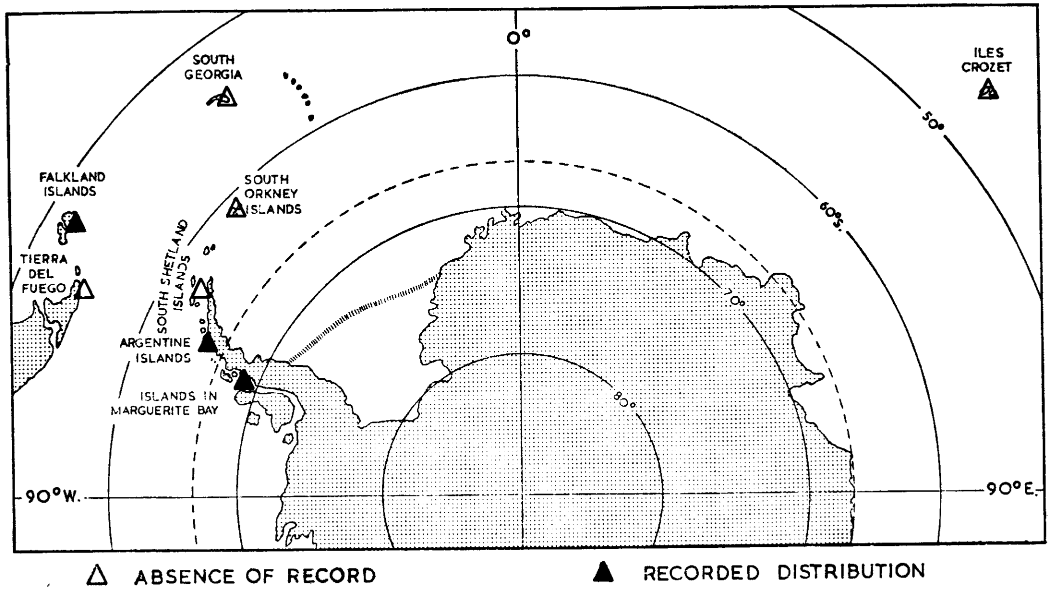


Figure 56
The distribution of *Euglypha laevis*.

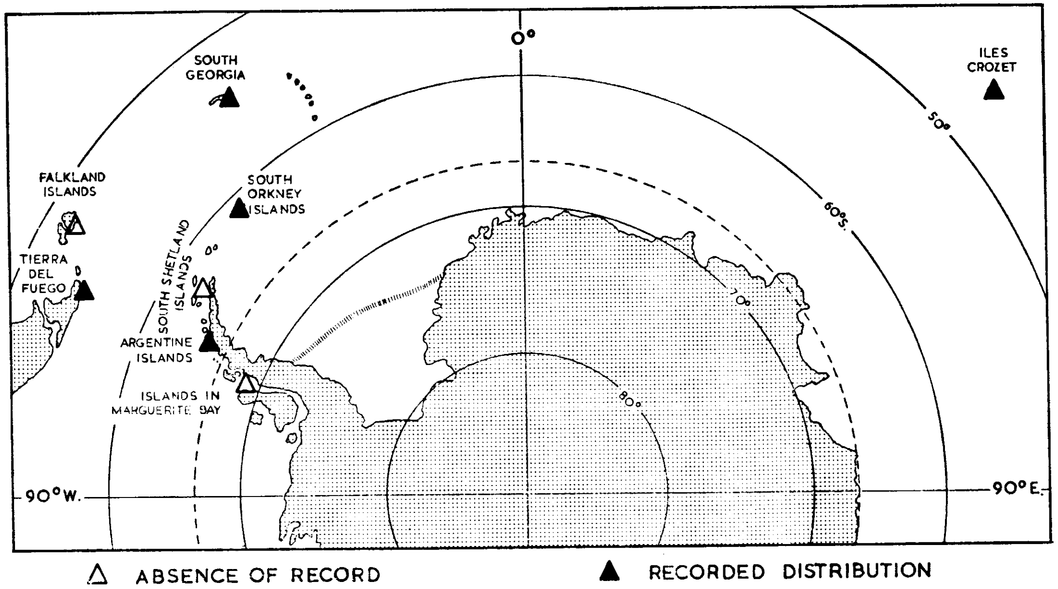


Figure 57
The distribution of *Euglypha rotunda*.

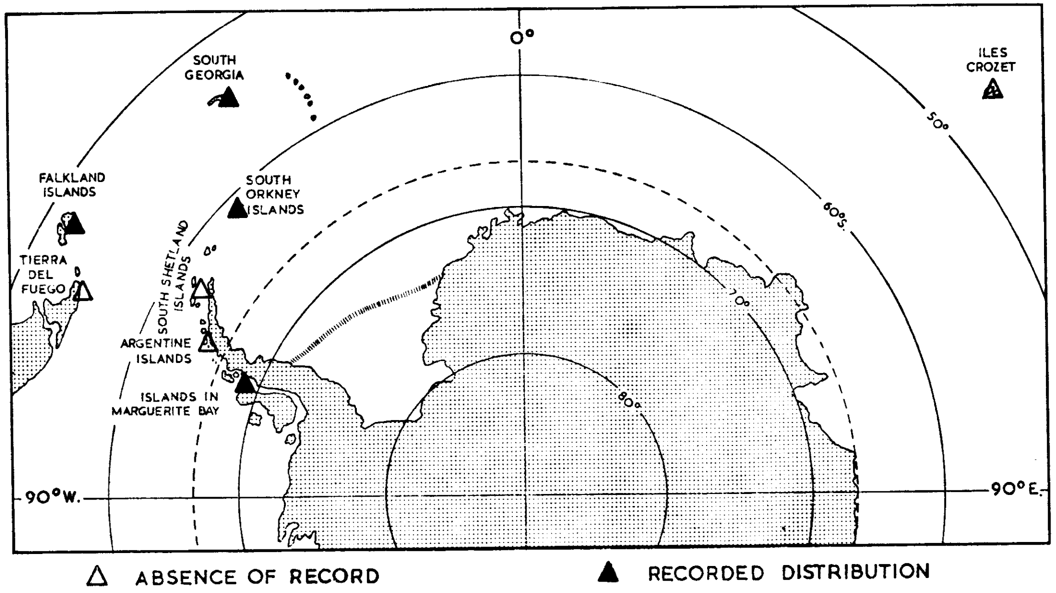


Figure 58
The distribution of *Euglypha strigosa*.

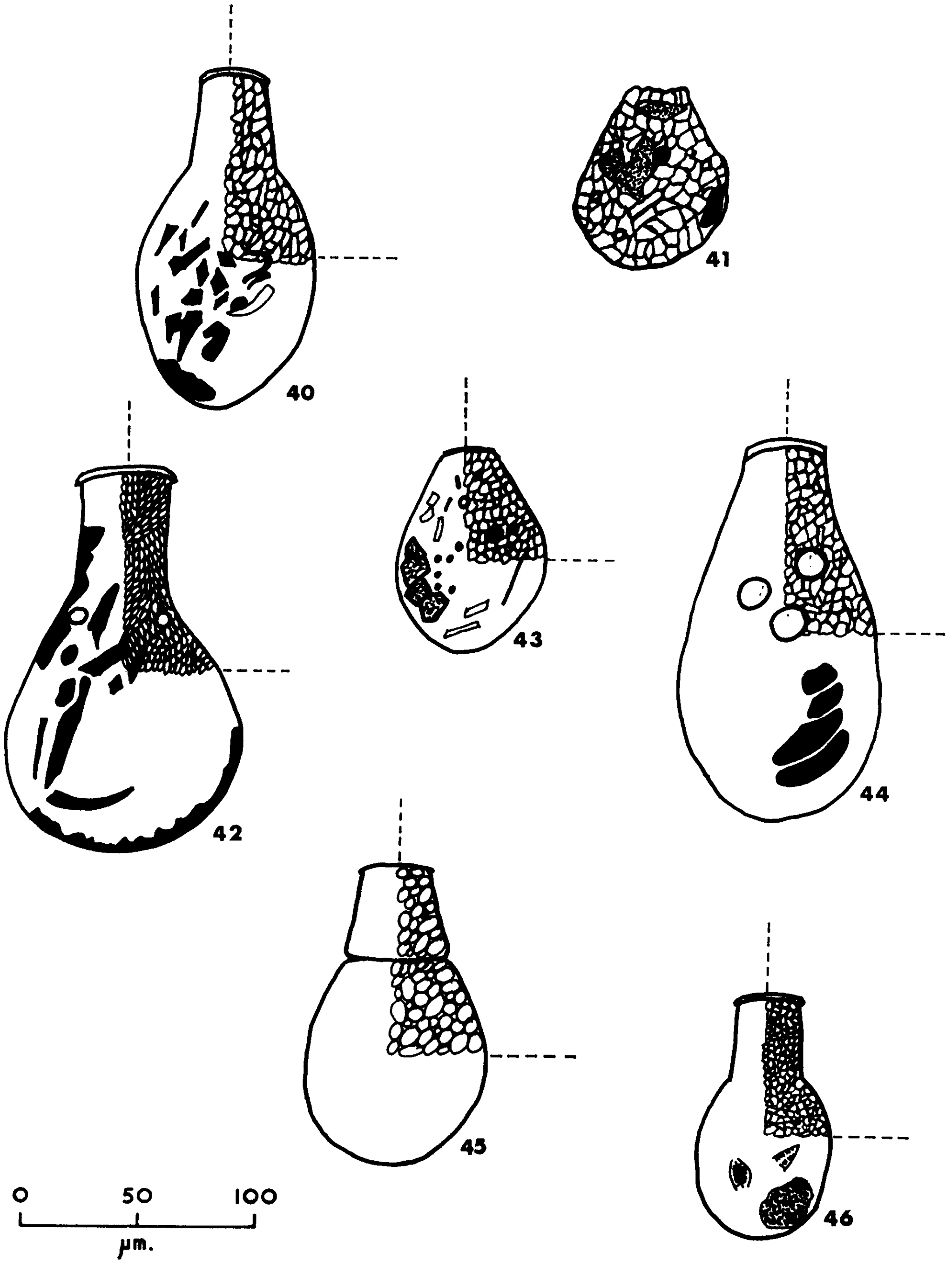


FIGURE 59

Rhizopoda.
Testacida

No. 40 *Nebela certesi.*
No. 41 *Nebela dentistoma.*
No. 42 *Nebela martiali.*
No. 43 *Nebela minor.*
No. 44 *Nebela penardiana.*
No. 45 *Nebela vas.*
No. 46 *Nebela wailesi.*

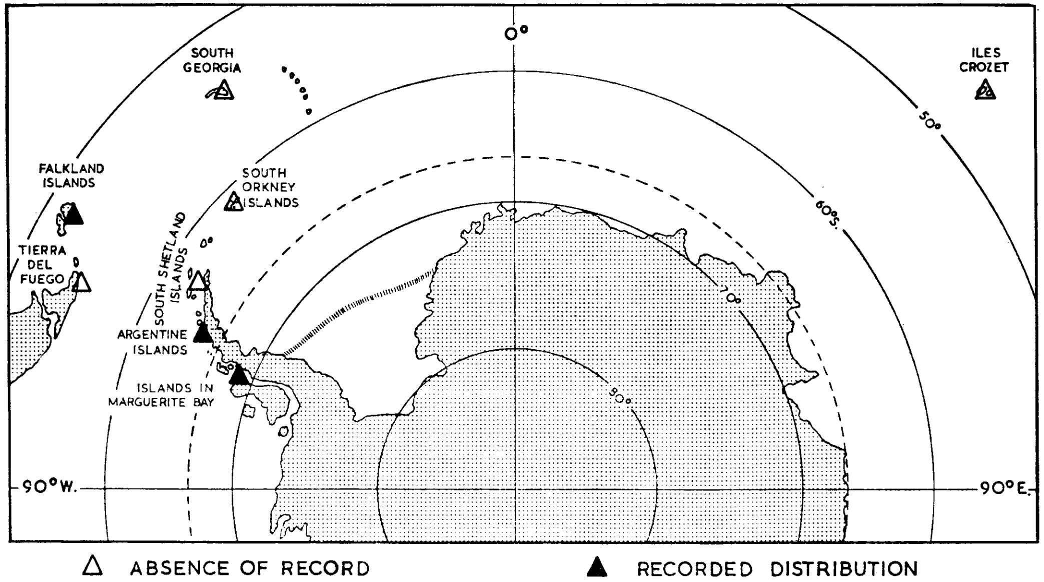


FIGURE 60
The distribution of *Nebela certesi.*

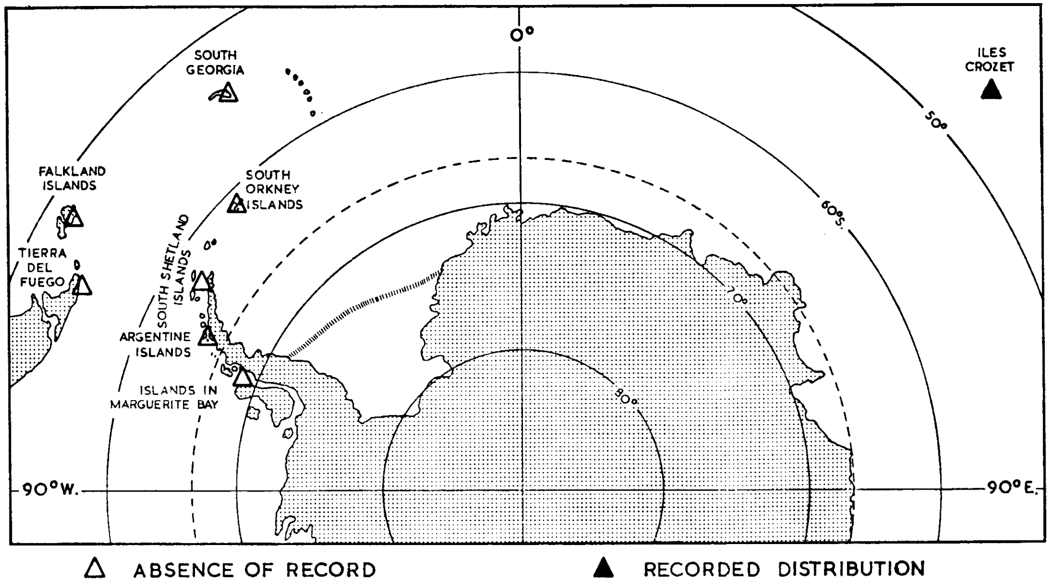


FIGURE 61
The distribution of *Nebela dentistoma.*

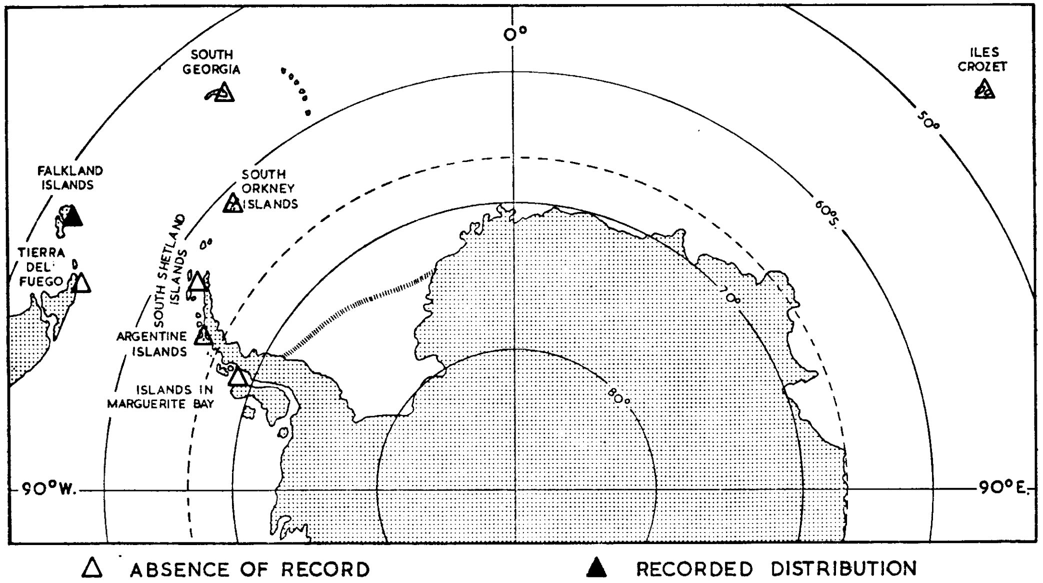


FIGURE 62
The distribution of *Nebela martiali.*

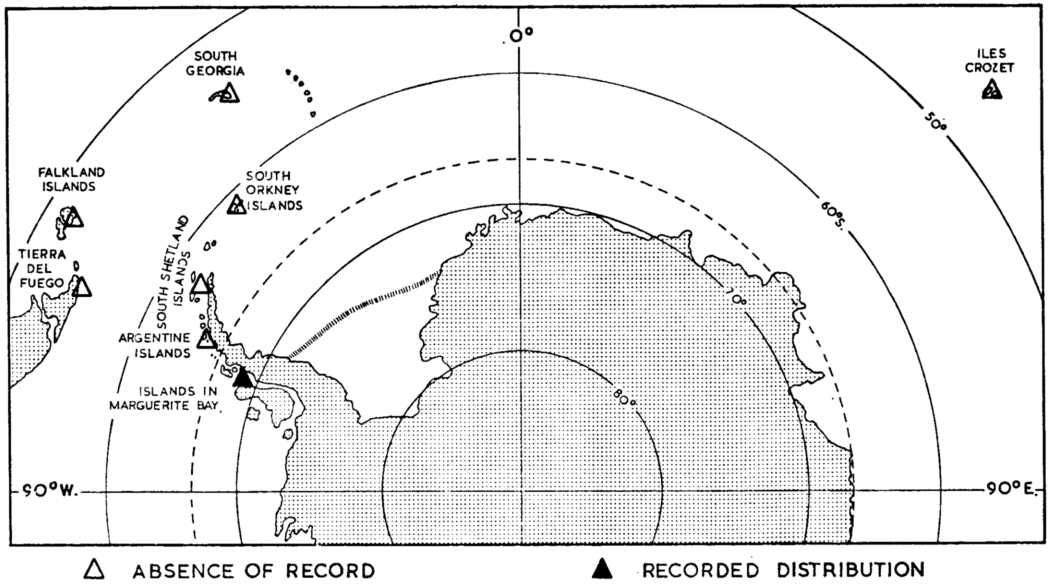


FIGURE 63
The distribution of *Nebela minor.*

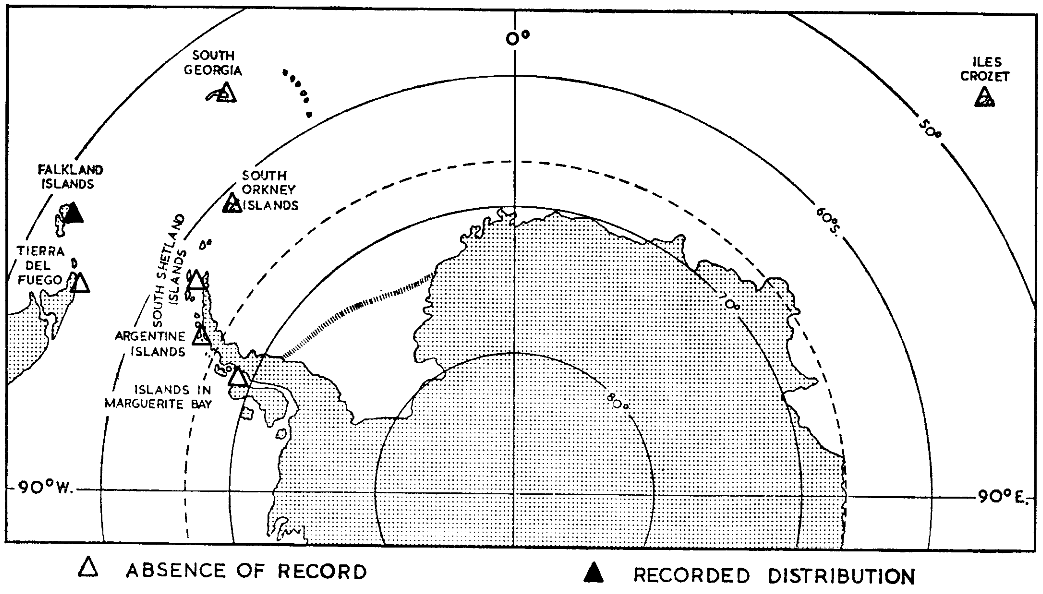


FIGURE 64
The distribution of *Nebela penardiana*.

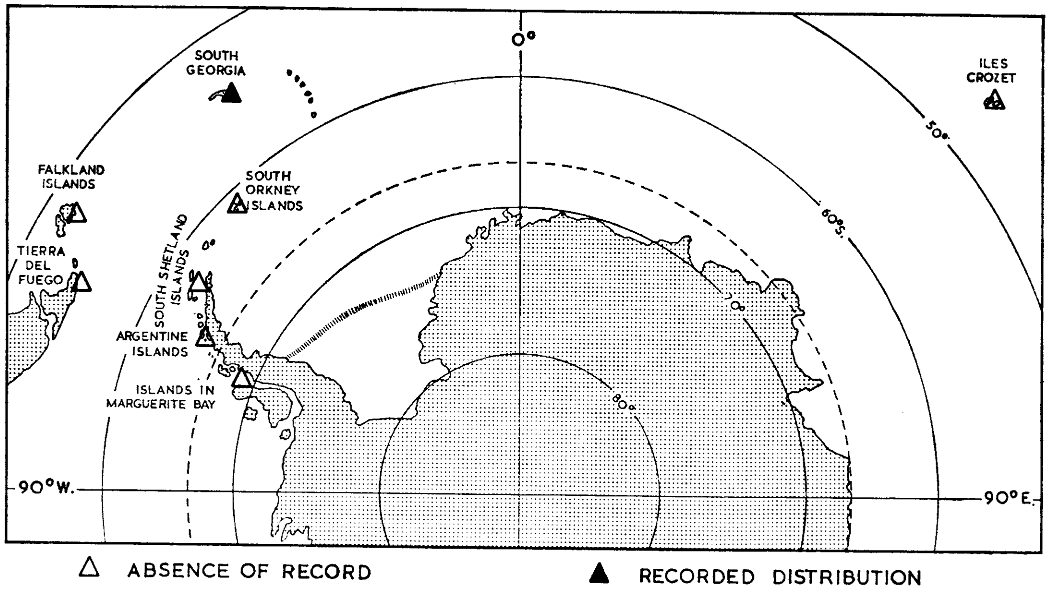


FIGURE 65
The distribution of *Nebela vas*.

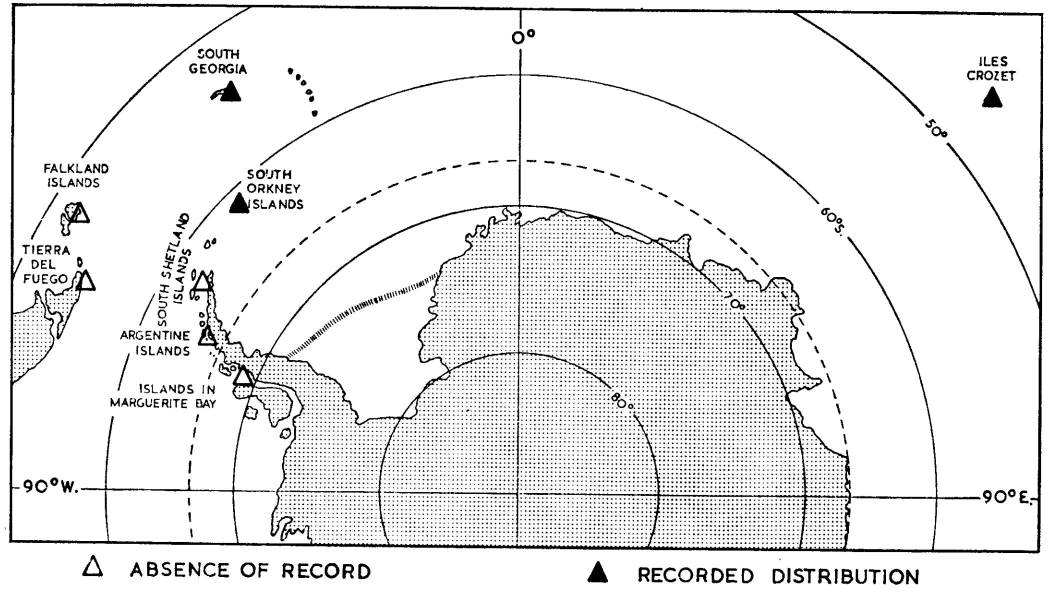


FIGURE 66
The distribution of *Nebela wailesi*.

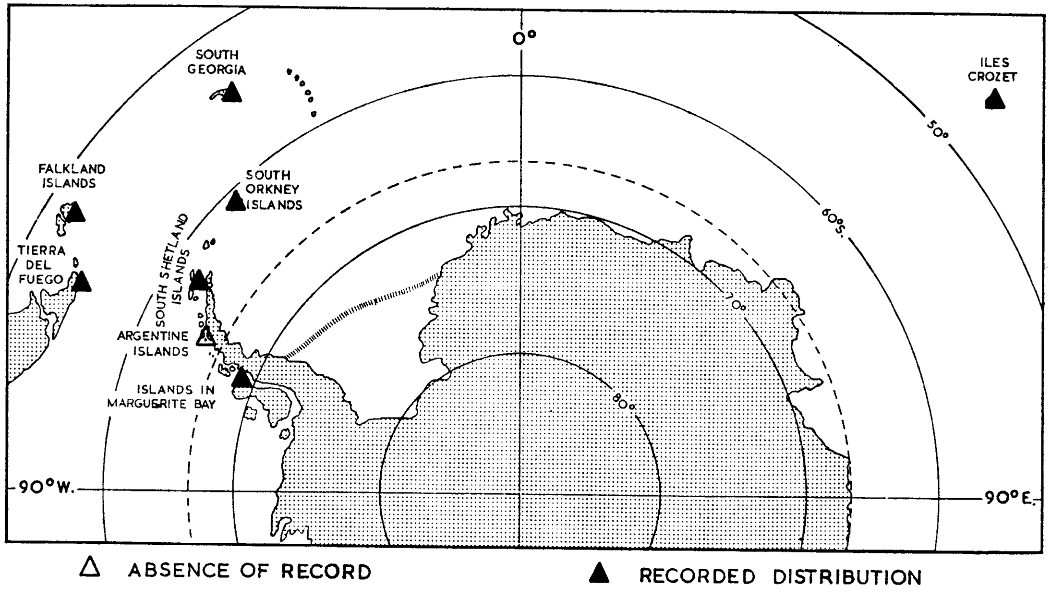


FIGURE 67
The distribution of *Phryganella acropodia*.

TABLE IX

NUMBERS OF *Phryganella acropodia* OBSERVED IN SAMPLES COLLECTED FROM SIGNY ISLAND DURING THE SUMMER 1968–69

Site	*Date of collection*	*Nature of sample*	*pH of sample*	*Numbers of Phryganella per g. fresh weight ±standard error*
Factory Cove	29 December 1968	Moss-turf peat (*Polytrichum–Chorisodontium*)	3·5	500± 210
Gourlay Peninsula	17 January 1969	*Prasiola*	5·6	2,700± 770
Observation Bluff	29 January 1969	Grass soil (*Deschampsia antarctica*)	4·6	27,200±3,650
Factory Cove	9 February 1969	Moss-carpet peat (*Drepanocladus*)	4·2	8,900± 530
Marble Knolls	17 February 1969	Moss cushion (*Grimmia*)	6·8	450± 140

in August. A spectacular bloom occurred during September and October, associated with the spring melt, followed by mid-summer mortality when the peat was very dry and a smaller autumnal bloom when wetter conditions returned in February 1971.

Pseudodifflugia Schlumberger

Fig. 69, No. 48; Fig. 70

Pseudodifflugia is a testate genus which is sometimes classified as a difflugid (Kudo, 1966), since the test is often covered with mineral particles, and sometimes as a gromiid on account of the pseudopodia taking the form of finely branched filopodia. It is a widespread and frequent genus but rarely abundant in temperate peats, mosses and forest soils (Heal, 1962; Bonnet, 1966; Couteaux, 1969; Rosa and Lhotsky, 1971), and has also been recorded from East Greenland (Dixon, 1939; Stout, 1970). There are no previous records from the Antarctic but in the present study *Pseudodifflugia* sp. was observed in moss peats and grass soils in all the island groups except Iles Crozet. It was always a rare species except at one site of *Drepanocladus* moss carpet in the Argentine Islands, in which *Pseudodifflugia* had an abundance of 4,000/g. fresh weight in January 1970 and constituted 60 per cent of the total testate fauna. The Argentine Islands were the one location from which *Phryganella acropodia* seemed to be absent; these observations on *Pseudodifflugia* suggest that, in the Argentine Islands, this species may be occupying the ecological niche elsewhere occupied by *Phryganella.*

Trinema Dujardin

Fig. 69, Nos. 49 and 50; Figs. 71 and 72

Trinema is a euglyphid testate genus with a sub-terminal aperture. Two species are particularly common in terrestrial habitats: *Trinema enchelys* and *Trinema lineare;* the two frequently co-exist in mosses and peaty soils (Sandon, 1928; Hoogenraad, 1935; Heal, 1964; Bonnet, 1966; Couteaux, 1969; Rosa and Lhotsky, 1971). These two species have been observed to be the dominant organisms in the testate fauna of 105 species inhabiting organic habitats in the Austrian Alps (Laminger, 1972, 1973, 1975). Some records indicate that *T. lineare* is the more widespread species in tropical, temperate and particularly Arctic regions (Sandon, 1924; Dixon, 1939; Hoogenraad and Groot, 1948; Chardez, 1969; Delhez and Chardez, 1970; Stout, 1970). However, *T. enchelys* may possibly be the more widespread species in the Antarctic, from the observations of Richters (1907), Penard (1911, 1913) and Decloitre (1960*c*). *Trinema*

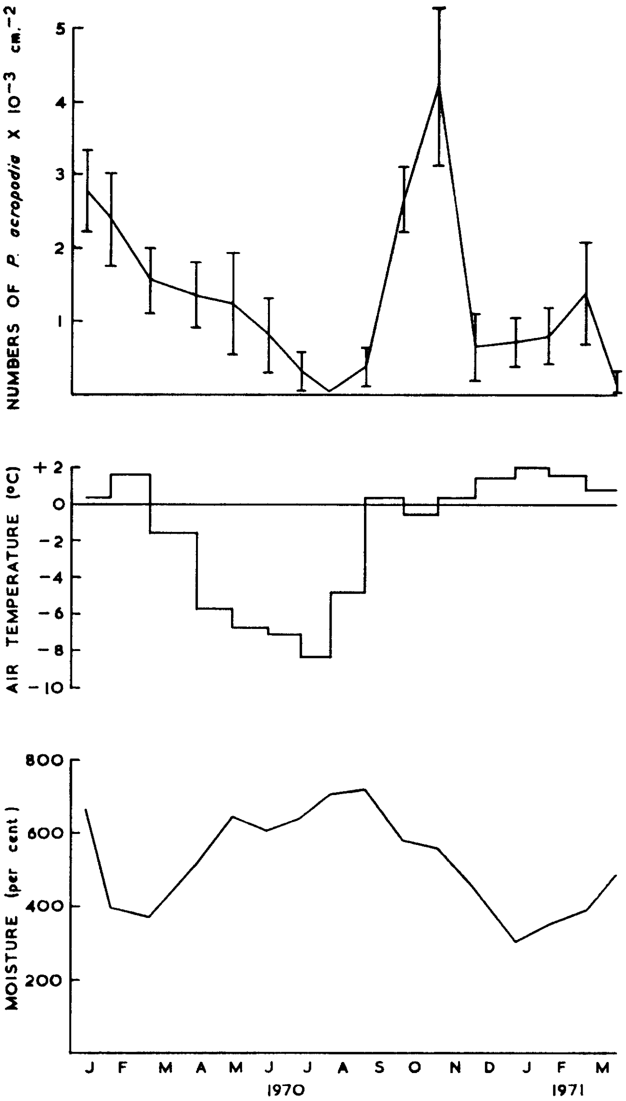


FIGURE 68

Fluctuations in the numbers of *Phryganella acropodia* in the 0–9 cm. horizon of moss-turf peat at the Signy Island terrestrial reference site 1 during the period January 1970–March 1971. The figures plotted are means ± standard errors.

enchelys has been classified as an α-mesosaprobic indicator species by Kolkwitz (1950). The present observations and those of Sandon and Cutler (1924), Heal (1965) and Grospietsch (1971) indicate that the two species are both very common and equally widespread on sub-Antarctic and maritime Antarctic islands, and that they have the same preference for moss and peaty soil habitats.

Chilophyra Kahl

Figs. 73 and 77, No. 51

Chilophyra is a gymnostomatid holotrich with a cytostome at the anterior pole surrounded by protrusible rods and overhung by an ectoplasmic lip. Fresh-water and marine species are known (Kahl, 1935) but it is rare in terrestrial habitats. It is possible that a species of this genus is particularly adapted as a pioneer colonizer of mineral habitats, since it was observed to be a prominent member of the fauna of glacial moraine clay and moss cushions on Signy Island and of volcanic ash on Deception Island, but it was otherwise almost entirely absent from the sites examined.

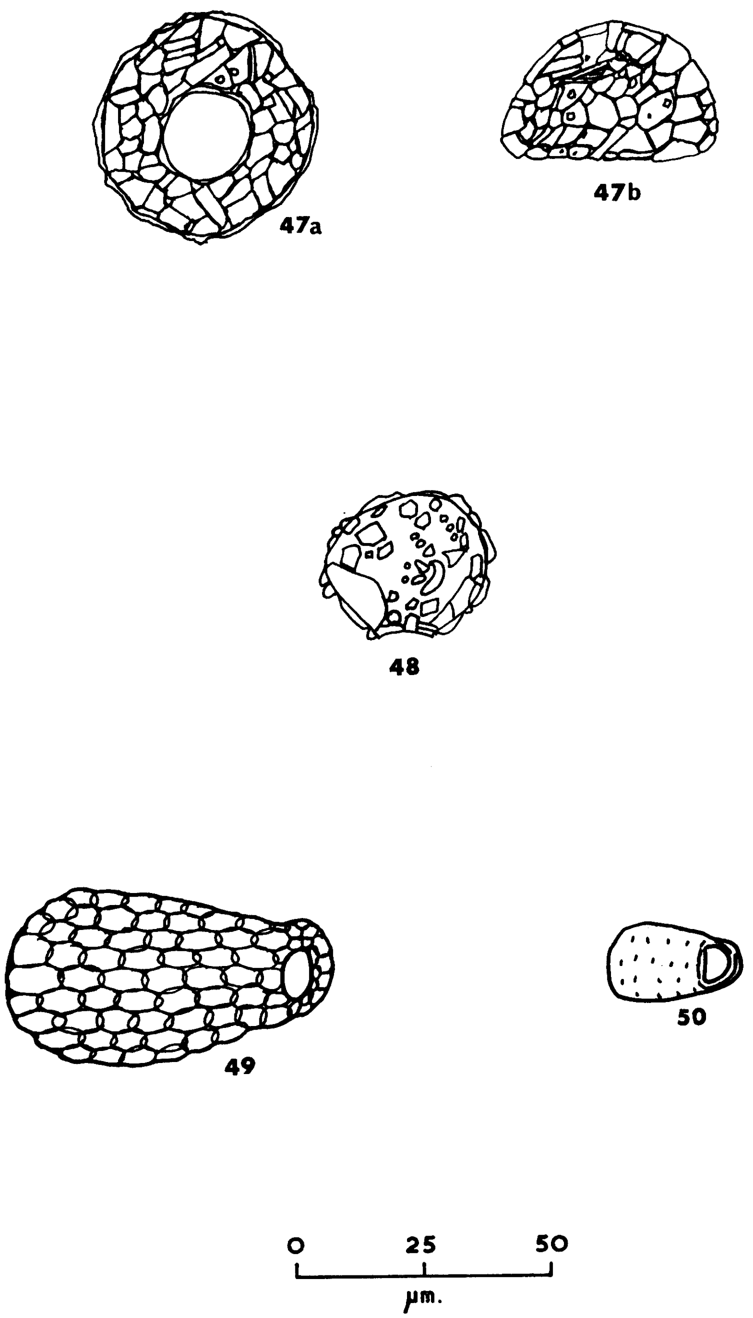


FIGURE 69

Rhizopoda.
Testacida No. 47 *Phryganella acropodia*
a. Oral view.
b. Lateral view.
No. 48 *Pseudodifflugia* sp.
No. 49 *Trinema enchelys.*
No. 50 *Trinema lineare.*

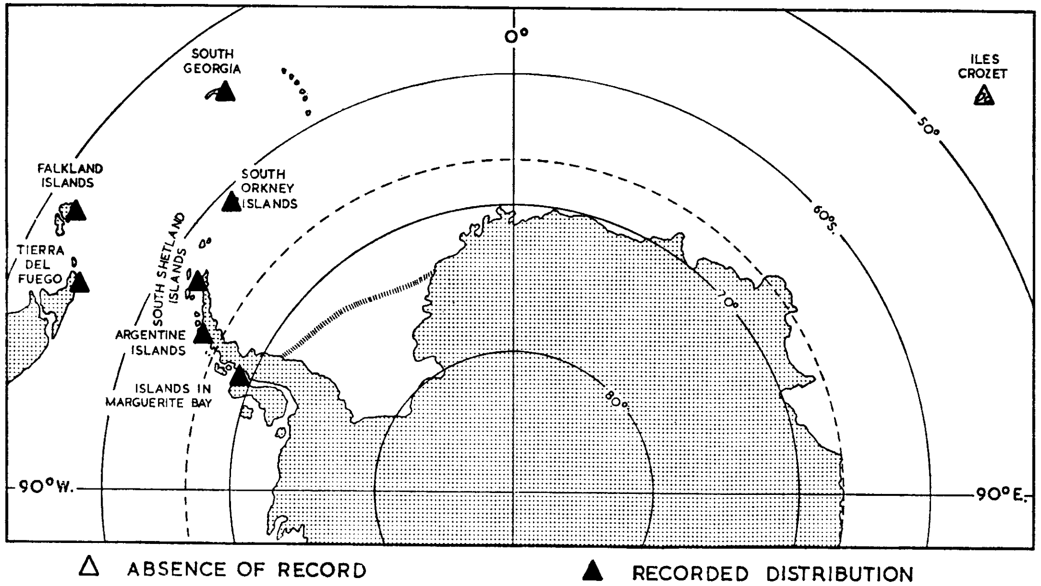


FIGURE 70
The distribution of *Pseudodifflugia* sp.

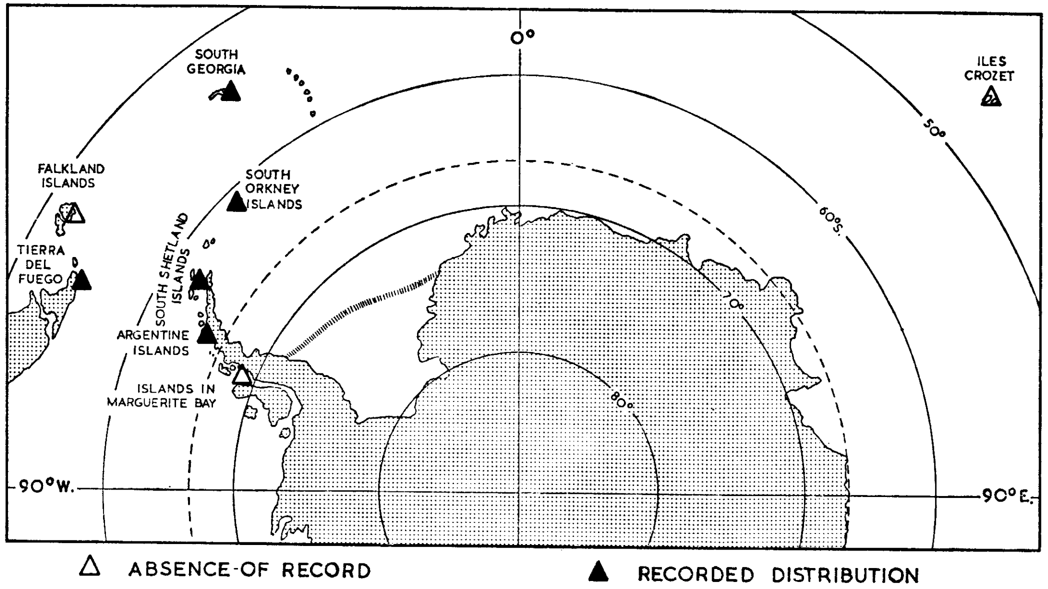


FIGURE 71
The distribution of *Trinema enchelys*.

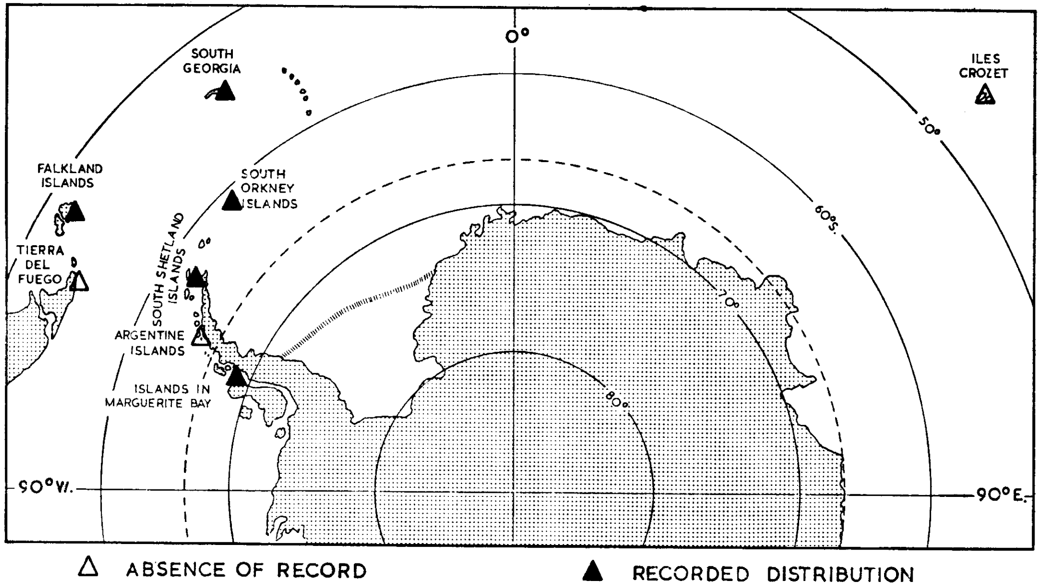


FIGURE 72
The distribution of *Trinema lineare*.

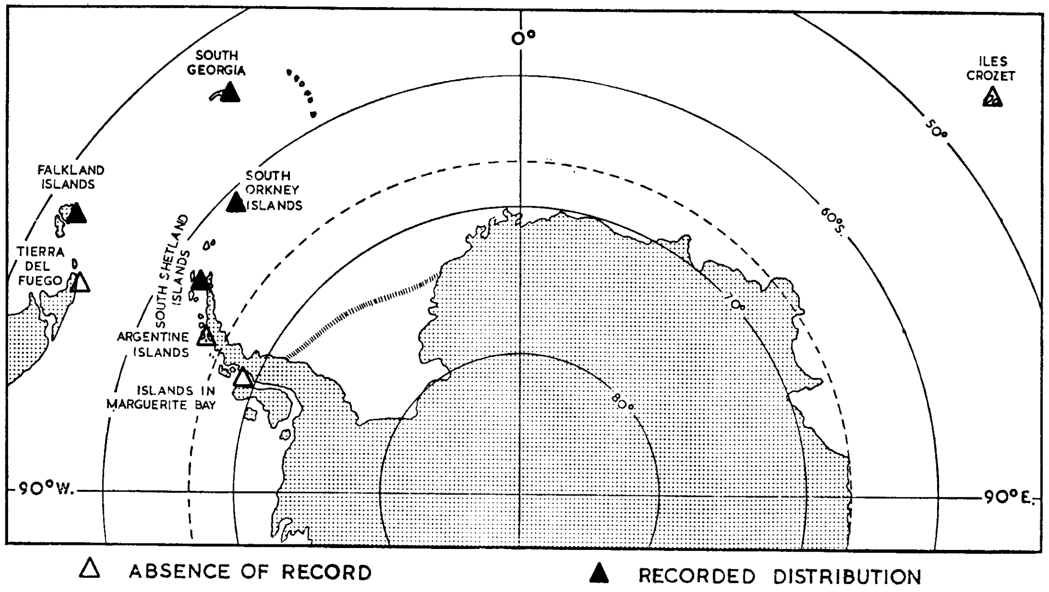


FIGURE 73
The distribution of *Chilophyra* sp.

Chaenea Quennerstedt

Figs. 74 and 77, No. 52

Chaenea is a gymnostomatid holotrich with an elongated tapering body terminating in a short furrowed "head". Like *Chilophyra*, *Chaenea* is primarily an aquatic genus but it is also frequent in terrestrial habitats. In sewage, *Chaenea teres* has been classified as a mesosaprobic indicator (Hausman, 1923). It has been recorded from soils in Egypt, Mauritius, Ocean Island and Tristan da Cunha (Sandon, 1927), and in the Arctic from Spitsbergen (Sandon, 1927) and East Greenland (Stout, 1970). There are no previous records of *Chaenea* from the Antarctic; the present observations indicate that this species is rare but widespread in peaty soils in the sub-Antarctic and maritime Antarctic.

Dileptus Dujardin

Figs. 75 and 77, No. 53

Dileptus is an elongated holotrich having a flask-shaped body with a dorsally curved neck-like anterior prolongation. It is a predatory organism feeding continuously during daylight hours. *Dileptus anser* can be cultured with *Colpidium campylum* as food (Miller, 1968). It appears to have protein-sensitive chemoreceptors; chick-liver homogenate fractions will induce a phagocytic reaction (Seravin and Orloskaya, 1973). Intensive investigations of the ciliary activity and responses to external mechanical stimuli by Dorozewski (1970) have shown that stimulation of the anterior of the body promotes a "withdrawal" reaction, while stimulation of the posterior promotes forward movement. *Dileptus anser* has been classified as a β-mesosaprobic indicator (Sladecek, 1969).

Dileptus is a common cilate genus in soils as well as fresh water and is capable of forming a cyst (Prowazek, 1904). It has been recorded from soil, mosses and fresh-water bodies in many European countries (Yakimoff and Zeren, 1924; Gellert, 1955*a*, *b*; Dingfelder, 1962; Stout, 1963; Chardez, 1967; Nielsen, 1968). Dingfelder (1962) reported that *Dileptus* spp. have a preference for acidic fresh-water habitats—as low as pH 5·8. There are very few previous records of *Dileptus* from polar regions; it has been observed in moss water from Enderby Land (Sudzuki, 1964). In the present study, *Dileptus* sp. was observed in all the island groups, except Iles Crozet, to as far south as Deception Island. It appeared able to tolerate mineral habitats as well as peats, which most ciliates are unable to do.

Enchelys sp. Hill

Figs. 76 and 77, No. 54

Enchelys is a flask-shaped gymnostomatid holotrich with a rounded posterior and an obliquely truncated anterior which bears a slit-like cytostome. Most species of *Enchelys* appear to be strictly fresh water (Kahl, 1935; Dingfelder, 1962). It seems likely that there is just one species inhabiting soils, though it has never been given an exact description or a specific name. It has been mentioned by Sandon (1927) as being an organism 25–30 μm. long. It is common in many types of soil in temperate and tropical regions (Yakimoff and Zeren, 1924; Sandon, 1927, 1928; Stout, 1963) and also in the Arctic (Sandon, 1924; Dixon, 1939; Chardez, 1967; Stout, 1970). There are no previous records from the Antarctic but in the present study *Enchelys* sp. was very frequently observed in all the island groups and appeared to have a wide ecological amplitude, being found in both acid and alkaline, and also mineral and organic habitats.

Holophrya Ehrenberg

Fig. 77, No. 55; Fig. 78

Holophrya is a symmetrical globose-ellipsoidal gymnostomatid holotrich. There are numerous aquatic species (Dingfelder, 1962) but *Holophrya* is rare in soils. Outside the polar regions, it appears to be confined to organic acid soils (Yakimoff and Zeren, 1924; Sandon, 1927, 1928; Horvath, 1949; Gellert, 1955*a*, *b*). The few records of *Holophrya* from the Arctic (Dixon, 1939) and from the Antarctic (the present study) suggest that it can exist in dry soils as well as peats. It was a widespread species in the sub-Antarctic and

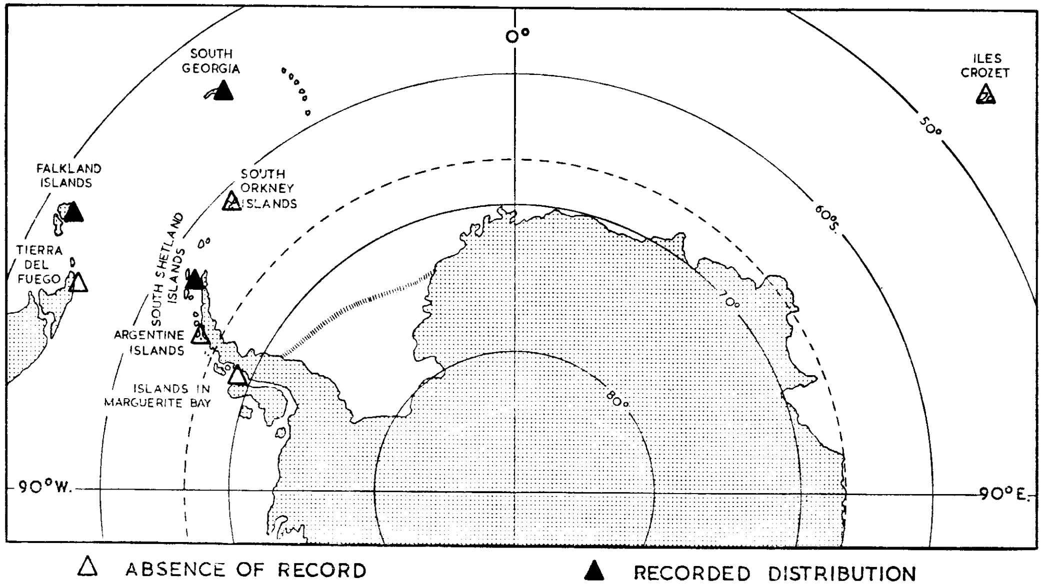


FIGURE 74

The distribution of *Chaenea* sp.

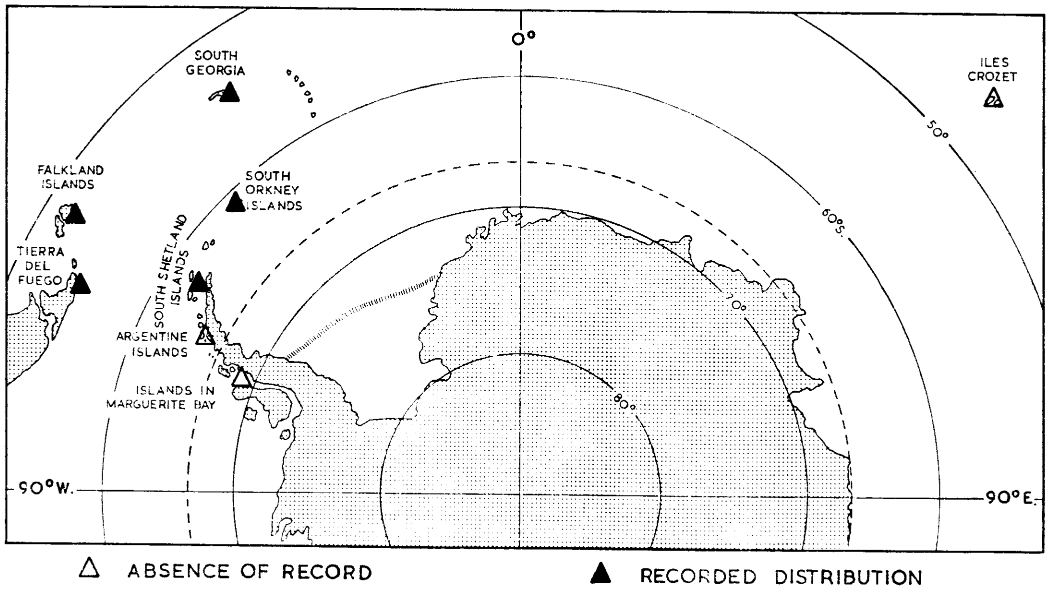


FIGURE 75

The distribution of *Dileptus* sp.

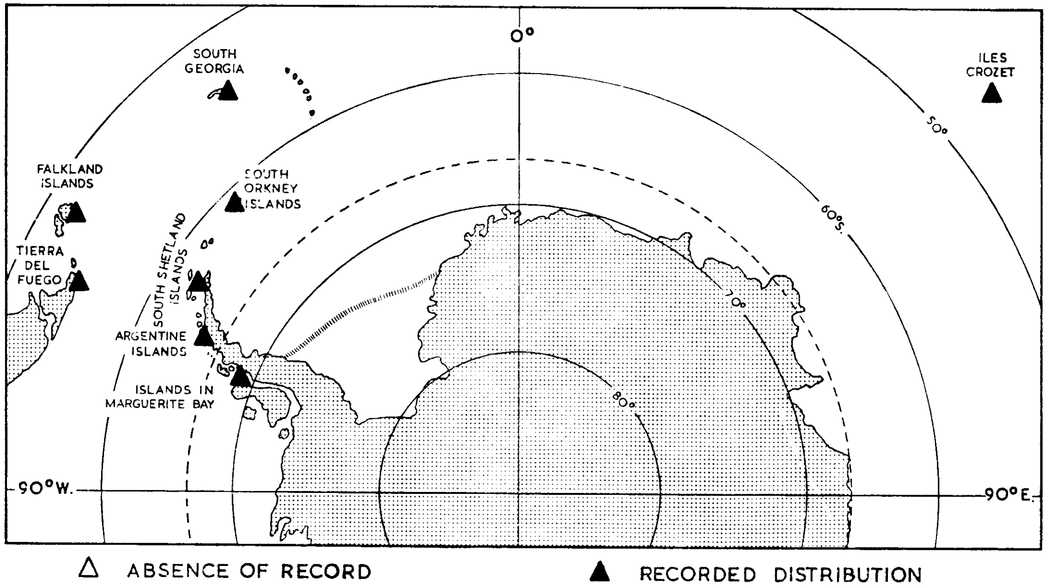


FIGURE 76

The distribution of *Enchelys* sp.

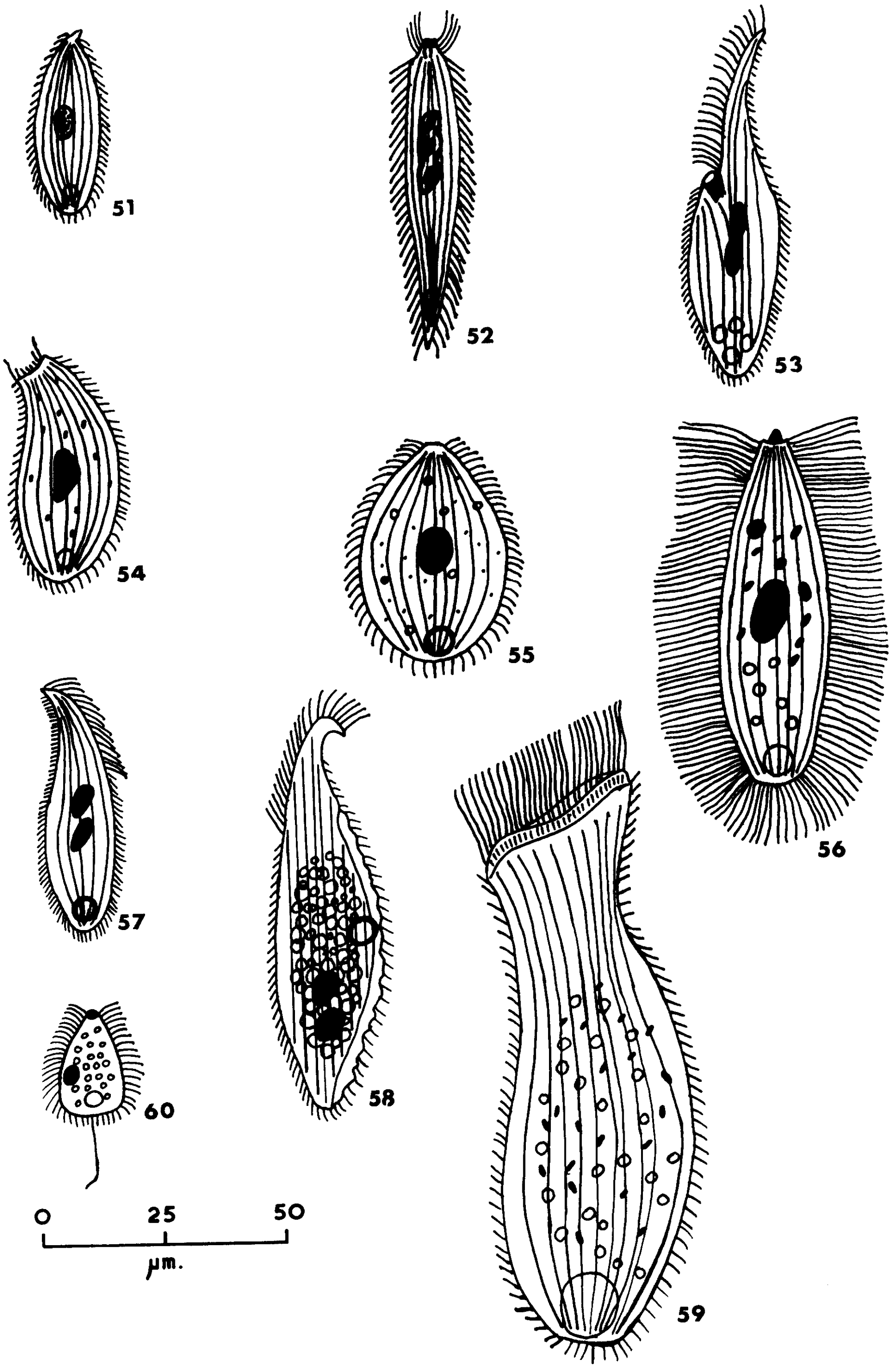


FIGURE 77

Ciliata.

Gymnostomatida	No. 51	*Chilophrya* sp.	No. 56	*Lagynophrya* sp.
	No. 52	*Chaenea* sp.	No. 57	*Litonotus* sp.
	No. 53	*Dileptus* sp.	No. 58	*Loxophyllum* sp.
	No. 54	*Enchelys* sp.	No. 59	*Spathidium* sp.
	No. 55	*Holophrya* sp.	No. 60	*Urotricha agilis.*

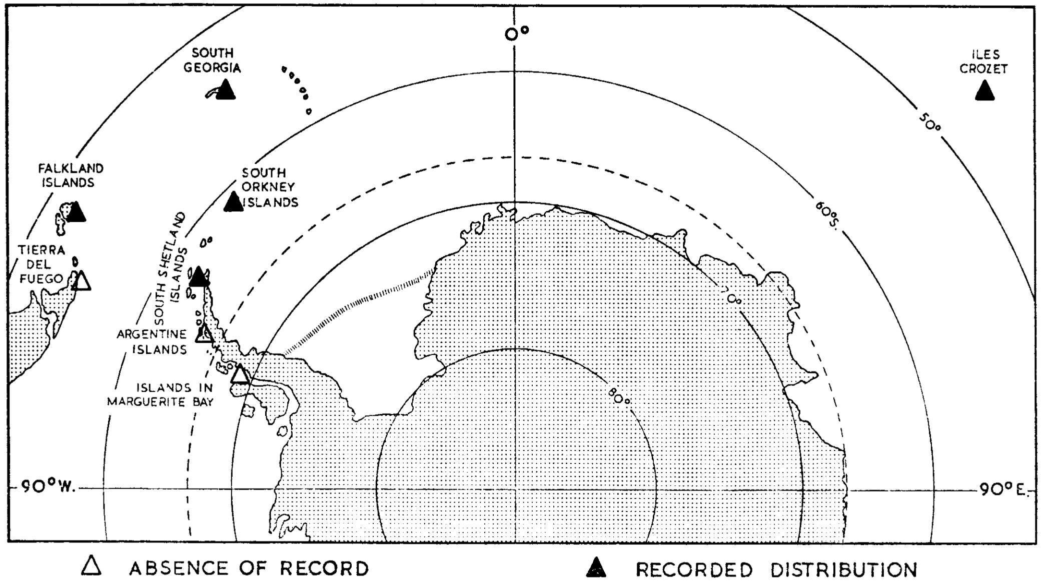


FIGURE 78
The distribution of *Holophrya* sp.

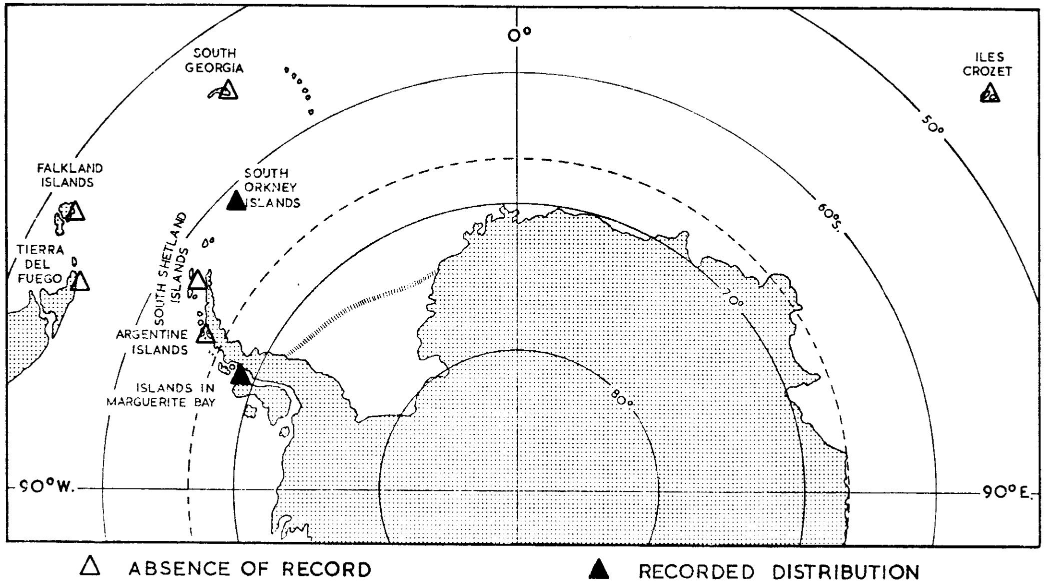


FIGURE 79
The distribution of *Lagynophrya* sp.

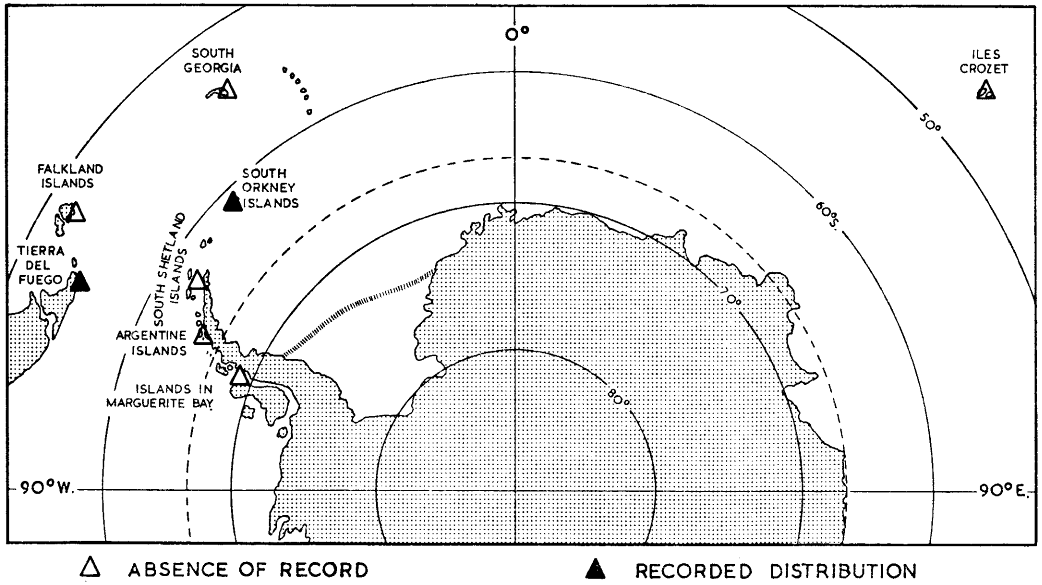


FIGURE 80
The distribution of *Litonotus* sp.

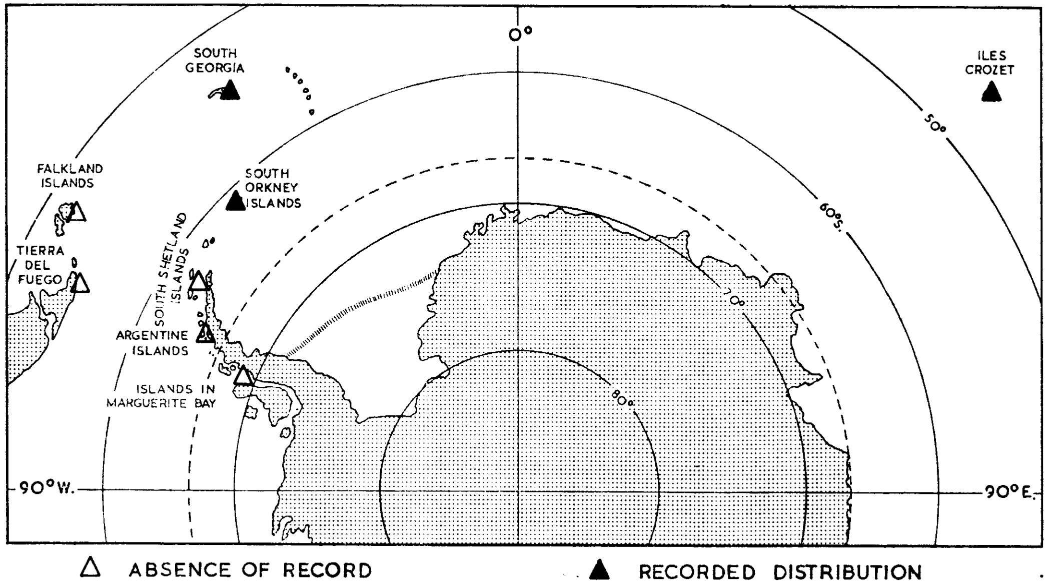


FIGURE 81
The distribution of *Loxophyllum* sp.

maritime Antarctic, extending as far south as Deception Island. The species observed in East Greenland (Dixon, 1939) was identified as *Holophrya ovum* which as been classified by Kolkwitz (1950) as an oligosaprobic indicator.

Lagynophrya Kahl

Fig. 77, No. 56; Fig. 79

Lagynophrya is a gymnostomatid holotrich showing many morphological similarities to *Holophrya;* however, it is more elongated and is distinguished by numerous long cilia. There are several fresh-water species (Kahl, 1935; Dingfelder, 1962) but it is a very rare genus in soils. In the present study it was observed only in the richest moss peats and grass soil in the South Orkney Islands and Avian Island.

Litonotus Wresniowski

Fig. 77, No. 57; Fig. 80

Litonotus is an elongated flask-shaped gymnostomatid holotrich tapering to a point at both the anterior and posterior ends; long cilia border the cytostome. The species occurring in sewage are considered to be mesosaprobic indicators (Hausman, 1923; Kolkwitz, 1950; Curds, 1966). Aquatic species show a preference for a medium with a pH near 7 (Dingfelder, 1962). *Litonotus* is rare in soils (Chardez, 1967; Delhez and Chardez, 1970) but its distribution extends to high alpine forest soils (Rosa and Lhotsky, 1971) and to the Arctic (Dixon, 1939; Stout, 1970). In the present study, it was observed in three sites in the South Orkney Islands: two moss peats and an elephant seal wallow and in meadow soil from Tierra del Fuego.

Loxophyllum Dujardin

Fig. 77, No. 58; Fig. 81

Loxophyllum is a gymnostomatid holotrich distinguished by an extreme degree of lateral flattening so that it has a leaf-like appearance with a hyaline border along the ventral edge. This genus has been observed only rarely in soils. There are a few records from temperate regions but none previously from polar regions. In the present study, it appeared to be restricted to a few moss peats, grass soil and *Prasiola* from Iles Crozet, South Georgia and Signy Island; its distribution suggested that *Lagynophrya* has a specific requirement for a habitat rich in organic matter but only slightly acid.

Spathidium Dujardin

Fig. 77, No. 59; Fig. 82

Spathidium is a sack-shaped gymnostomatid holotrich with a wide cytostome occupying the whole of the anterior end and a very large posterior contractile vacuole. It is a predatory organism feeding on other ciliates (Jahn and Jahn, 1949; Kudo, 1966). Most species of *Spathidium* exceed 100 μm. in length; nevertheless, there are many records of soil-inhabiting species and it is one of the most frequently recorded genera of holotrichous ciliates in terrestrial habitats (Yakimoff and Zeren, 1924; Horvath, 1949; Gellert, 1955*a*, *b*; Stout, 1963; Chardez, 1967; Nielsen, 1968; Detcheva, 1973). Previous records from polar regions were from Enderby Land (Sudzuki, 1964), East Greenland (Stout, 1970) and the Antarctic Peninsula (Thompson, 1972). In the present study *Spathidium* spp. were observed most frequently in animal guano habitats and more rarely in grass soils and peats in both the sub-Antarctic and maritime Antarctic.

Urotricha Claparede and Lachmann

Fig. 77, No. 60; Fig. 83

Two species of *Urotricha* (*U. agilis* and *U. farcta*) have been recorded by Sandon (1927) as occurring in terrestrial habitats. In the present study, only *Urotricha agilis* was definitely established as a member of the Antarctic terrestrial fauna. *U. agilis* is a very small gymnostomatid holotrich (up to 20 μm. long) with an ellipsoid body. It is a common species in fresh water and *Sphagnum* bog (Kudo, 1966). Observations by

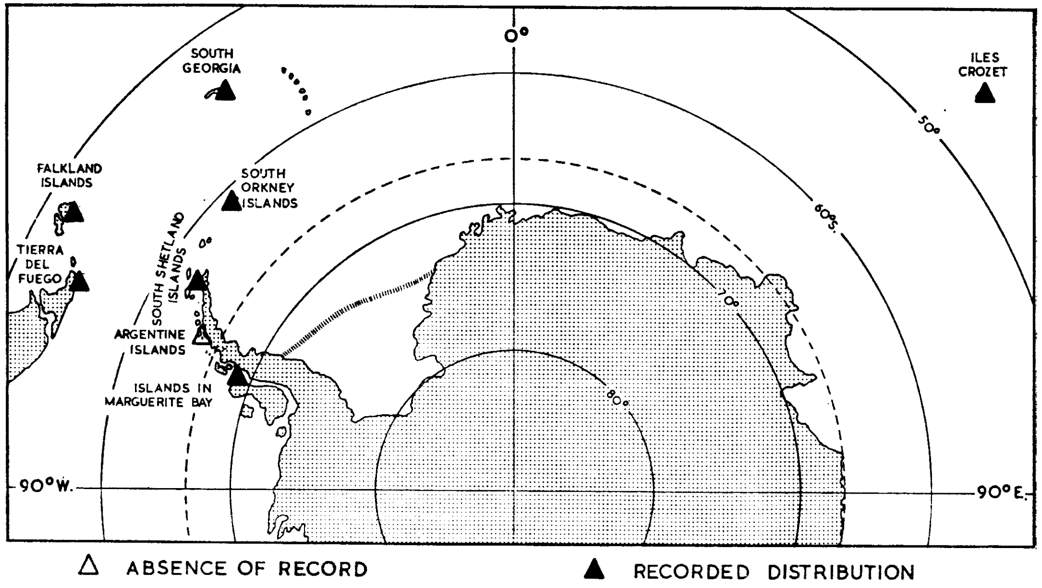


FIGURE 82
The distribution of *Spathidium* sp.

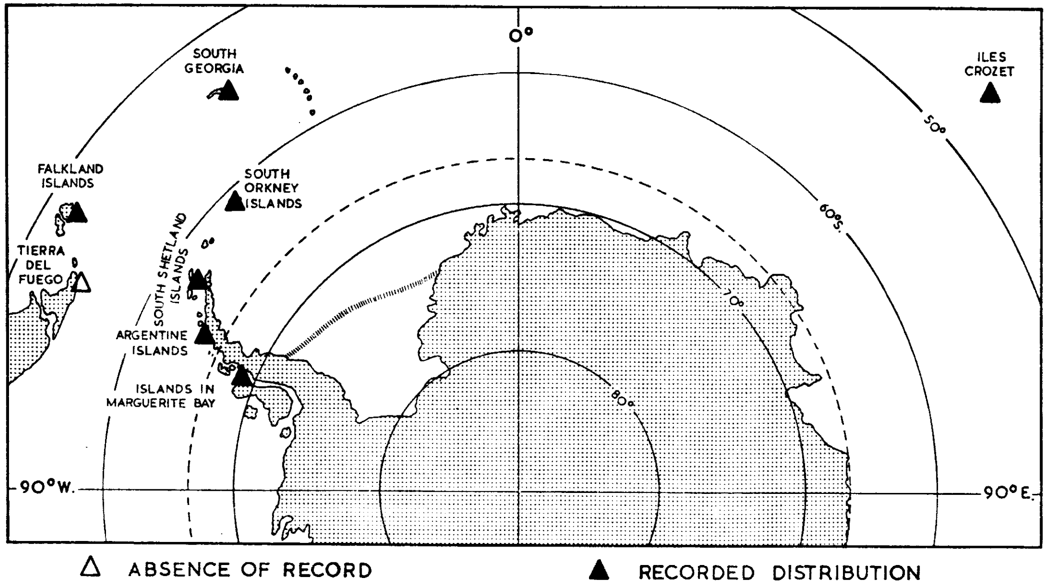


FIGURE 83
The distribution of *Urotricha agilis*.

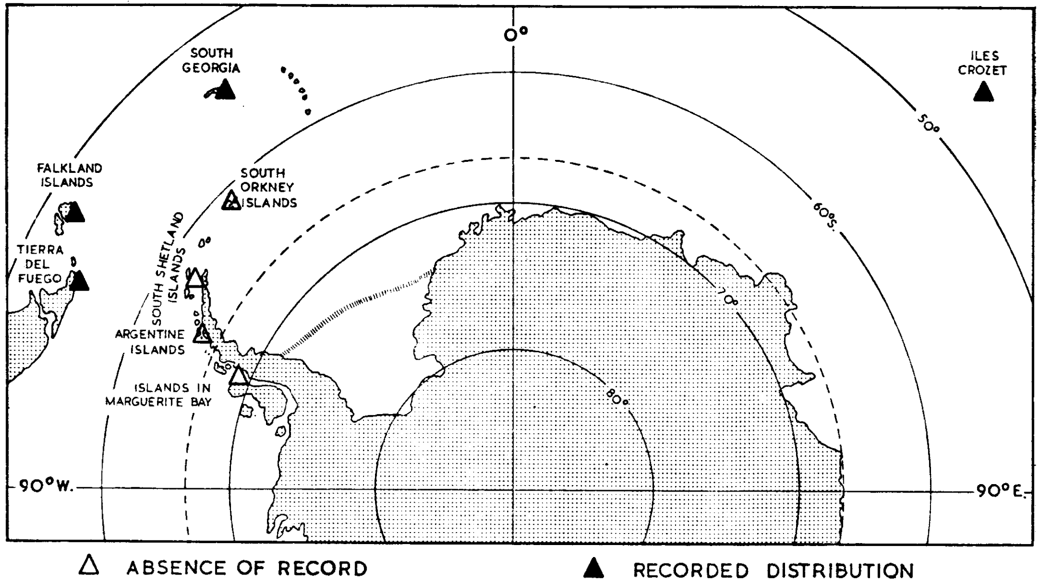


FIGURE 84
The distribution of *Colpoda cucullus*.

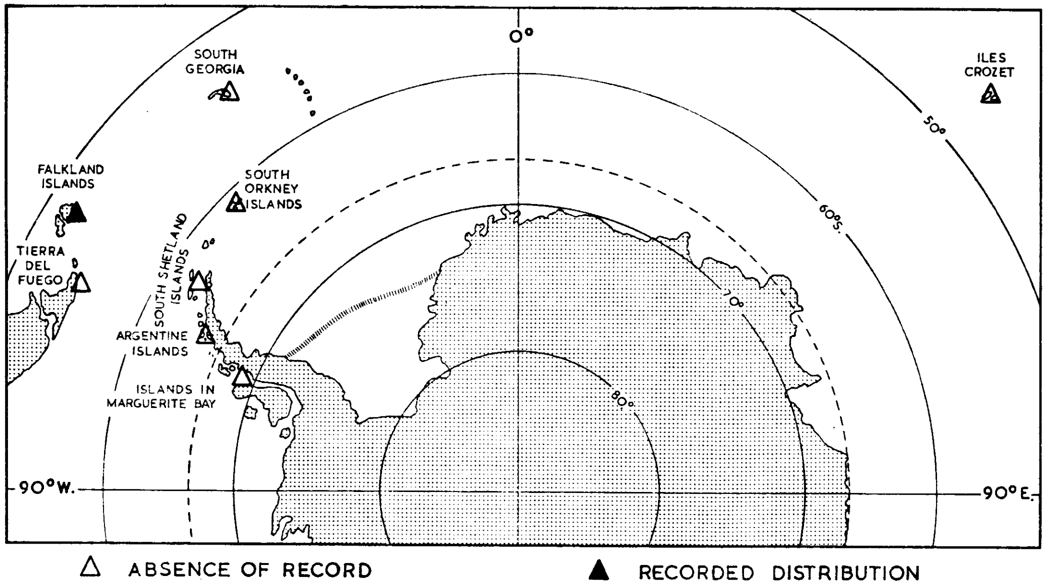


FIGURE 85
The distribution of *Colpoda maupasi*.

Yongue and others (1973) suggested that *U. agilis* has a preference for alkaline water bodies with a high concentration of dissolved minerals. It has been observed only rarely in soils but has been recorded from the Antarctic Peninsula (Thompson, 1972); in the present study it was frequently observed in nutrient-rich grass soils and moss peats in both the sub-Antarctic and maritime Antarctic, extending as far south as Pourquoi Pas Island, Marguerite Bay.

Colpoda Muller

Figs. 84–86 and 88, Nos. 61–63

Colpoda is the most widespread and most abundant of all genera of Protozoa in terrestrial habitats. It is a trichostomatid holotrich, kidney-shaped with an oral funnel situated in the flattened ventral side. Detailed morphological studies have been made by Gonder (1910), Oehler (1919), Taylor and Strickland (1937), Taylor and Ferguson (1938), Padnos and others (1954), and Tibbs (1968). It is exceptionally well adapted to soil habitats, being small, able to multiply rapidly under favourable conditions and also to encyst rapidly in response to adverse conditions (Stout, 1955). The cysts can withstand desiccation, ultra-violet radiation, low oxygen tension, and extremes of temperature, pressure and pH; they remain viable for years or even decades (Goodey, 1915; Dawson and Mitchell, 1929; Taylor and Strickland, 1935, 1936; Lozina-Lozinsky and Uspenskaja, 1968). *Colpoda* spp. are bacterial feeders (Singh, 1941); their presence in *Azotobacter* cultures can enhance the rate of nitrogen fixation by *Azobacter* at sub-optimal temperatures (Nasir, 1923; Darbyshire, 1972*a*, *b*). Other aspects of the physiology of *Colpoda* which have been studied are respiration (Pigon, 1959), antigenicity (Padnos, 1962*a*) and protein synthesis (Tibbs and Marshall, 1970).

Numerous records suggest that *Colpoda cucullus* and *Colpoda steini* have a ubiquitous and cosmopolitan distribution throughout all tropical, temperate and Arctic regions, and occupy an extreme range of habitats from hot desiccating deserts to Arctic *Sphagnum* bog (Allison, 1924; Sandon, 1924, 1927; Sandon and Cutler, 1924; Yakimoff and Zeren, 1924; Dixon, 1939; Horvath, 1949; Gellert, 1955*a*, *b*; Stout, 1963, 1970; Chardez, 1967; Nielsen, 1968; Bamforth, 1969; Delhez and Chardez, 1970; Mueller and Mueller, 1970; Rosa and Lhotsky, 1971; Detcheva, 1973; Dietz-Elbraechter, 1973). *Colpoda cucullus* has also been recorded from aquatic habitats (Dingfelder, 1962). It occurs infrequently in activated sludge (Curds, 1969), where it has been considered a poly- or α-mesosaprobic indicator (Kolkwitz and Marsson, 1909). From the present study, it appears that *Colpoda* spp. are completely absent from maritime Antarctic terrestrial habitats, though frequent observations of *Colpoda* in soils from Tierra del Fuego, the Falkland Islands, Iles Crozet and South Georgia confirm the observations of Sandon and Cutler (1924) that it is common on southern temperate and sub-Antarctic islands. Comparative experiments on the temperature relations of soil Protozoa (Smith, 1973*d*) suggest that the explanation for this absence is not the coldness of the maritime Antarctic winters (through which encysted *Colpoda* spp. could certainly survive) but the coolness of Antarctic summers, which do not permit *Colpoda* to multiply sufficiently to become established in the terrestrial fauna.

Leptopharynx Mermod

Figs. 87 and 88, No. 64

Leptopharynx sphagnetorum is a trichostomatid holotrich with a rigid body and a pellicle with longitudinal furrows; it is laterally flattened and has two small but conspicuous contractile vacuoles; the ciliature is greatly reduced. It is rare in temperate and alpine soils, and appears to be confined to woodland soils (Stout, 1963; Nielsen, 1968; Rosa and Lhotsky, 1971). However, this species is common in non-wooded peat soils in the Arctic and Antarctic (Stout, 1970; Thompson, 1972). In the present study, *L. sphagnetorum* was observed in peaty soils from all the island groups, except Tierra del Fuego, and showed a preference for moss-peat habitats.

Colpidium Stein

Fig. 88, No. 65; Fig. 89

Colpidium colpoda is a hymenostomatid ciliate with an elongated reniform body; the cytostome is situated near the anterior end and is bordered by a small undulating membrane. The morphology of

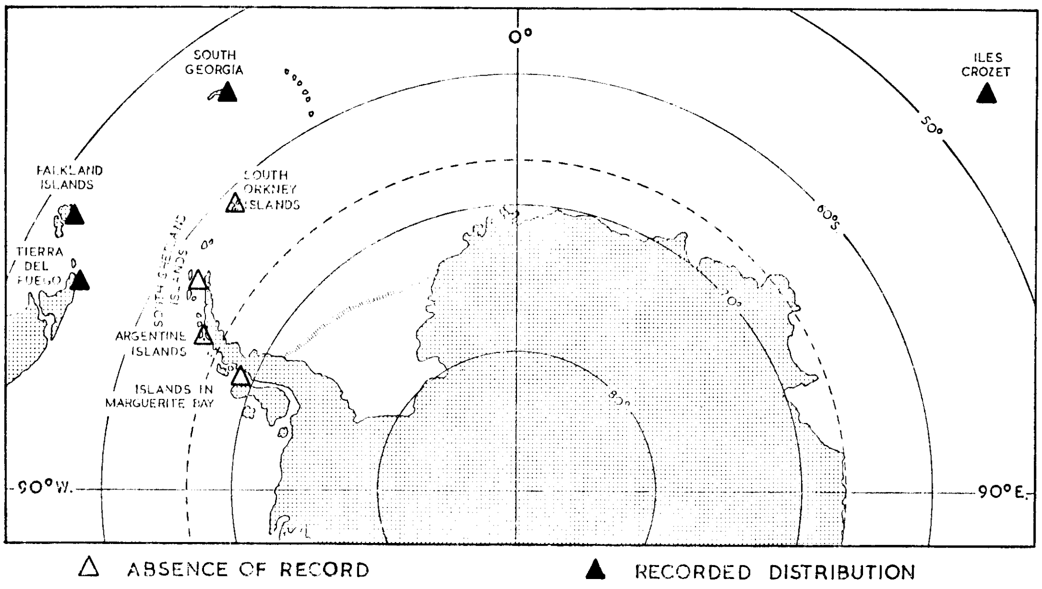


FIGURE 86
The distribution of *Colpoda steini.*

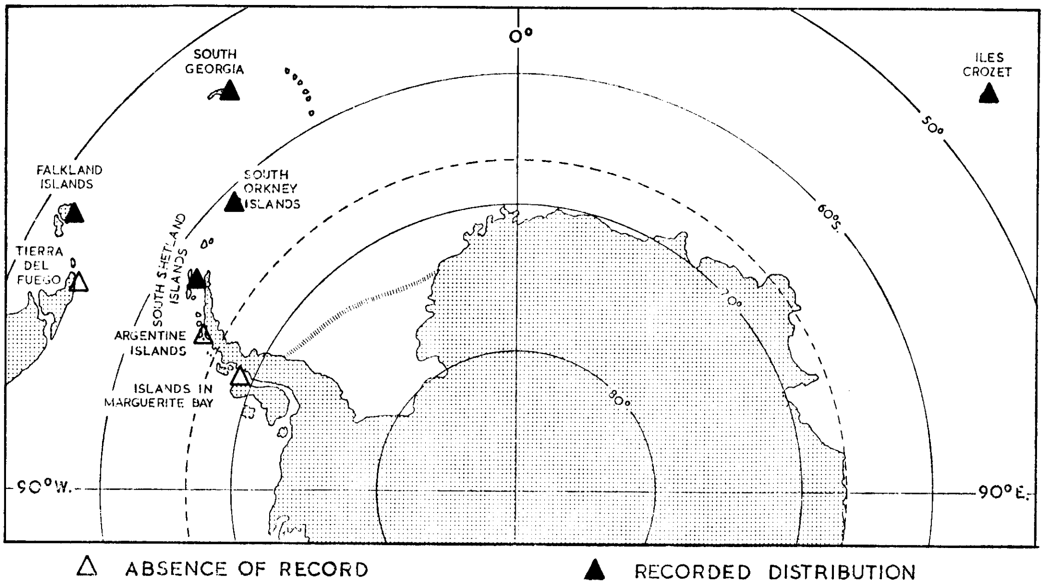


FIGURE 87
The distribution of *Leptopharynx sphagnetorum.*

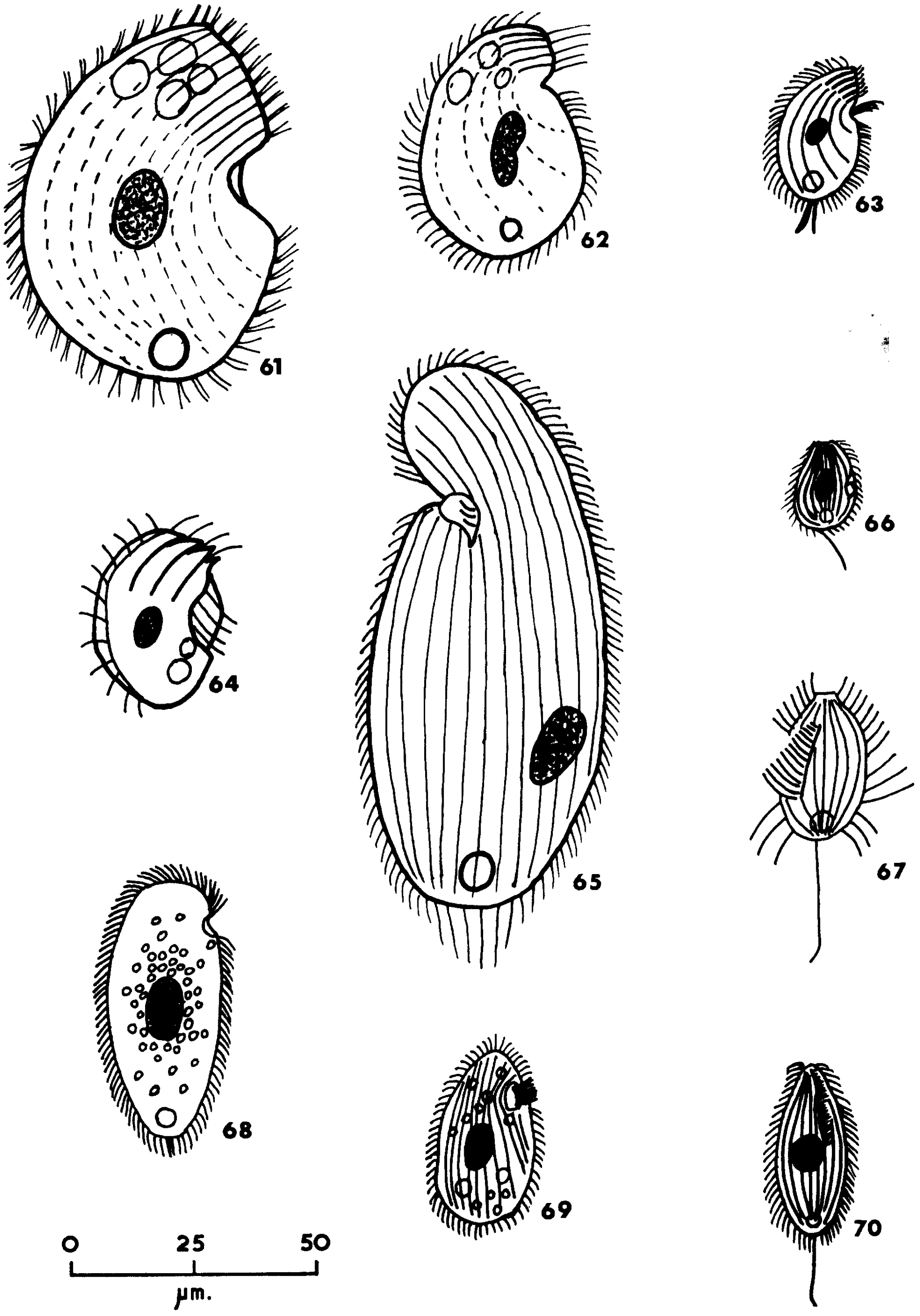


FIGURE 88

Ciliata.

Trichostomatida	No. 61	*Colpoda cucullus.*	No. 66	*Cryptochilium nigricans.*
	No. 62	*Colpoda maupasi.*	No. 67	*Cyclidium glaucoma.*
	No. 63	*Colpoda steini.*	No. 68	*Dichilium cuneiforme.*
	No. 64	*Leptopharynx sphagnetorum.*	No. 69	*Glaucoma pyriformis.*
Hymenostomatida	No. 65	*Colpidium colpoda.*	No. 70	*Philaster* sp.

Colpidium colpoda has been described by Prowazek (1915). An electron-microscope study by Cheissin and Mosevich (1962) showed that *C. colpoda* discharges mucus on to its surface through secretory ampules; this action may have a protective function. Studies by Hall (1935, 1939) and by Hall and Loefer (1936) showed that growth of *Colpidium* spp. is stimulated by pimelic acid, amino acids and asparagin, but inhibited by ethyl alcohol and tryptophane. The reproduction rate of *C. colpoda* in laboratory culture seemc to be closely correlated with amount of bacterial food available (Cutler and Crump, 1924). In aquatis habitats, it is considered to be an α-mesosaprobic indicator (Kolkwitz and Marsson, 1909). *Colpidium colpoda* is recorded infrequently from temperate terrestrial habitats (Yakimoff and Zeren, 1924; Sandon, 1927, 1928; Chardez, 1967). The only previous record from polar regions is that of Stout (1970) from algae in East Greenland. It appears that *Colpidium* does not occur in the Antarctic south of lat 60° S., since it was observed only in moss peats and grass soil from the Falkland Islands and South Georgia.

Cryptochilium Maupas

Fig. 88, No. 66; Fig. 90

Cryptochilium nigricans (*Uronema nigricans* Florentin) is a very small hymenostomatid ciliate (often as little as 15 μm. long) with a tapering ellipsoidal body, a long caudal cilium and small cytostome situated in a longitudinal furrow. It is principally an aquatic species (Hoare, 1927) and is considered to be a poly- or α-mesosaprobic indicator (Kolkwitz and Marsson, 1909; Curds, 1966). It has been very rarely recorded from terrestrial habitats (Sandon, 1927) and never previously from polar regions. However, it was observed frequently in acid peats from all the island groups in the present study, except Tierra del Fuego and the Argentine Islands. In view of its small size, it is possible that this species, in the maritime Antarctic, is opportunistically occupying the niche normally filled by *Colpoda steini*.

Cyclidium Muller

Fig. 88, No. 67; Fig. 91

Cyclidium glaucoma is a small ellipsoid hymenostomatid ciliate with a long caudal cilium and is distinguished by a large peristomal membrane situated laterally. Its morphology has been given detailed study by Parducz (1939), Hoare (1927) and Berger and Thompson (1960). It is a frequently recorded species from temperate soils (Yakimoff and Zeren, 1924; Sandon, 1927, 1928; Horvath, 1949; Stout, 1963; Chardez, 1967; Nielsen, 1968) and also from alpine and polar soils, peats and fresh water (Sandon, 1924, 1927; Sandon and Cutler, 1924; Rosa and Lhotsky, 1971; Thompson, 1972). Sudzuki (1964) has recorded *Cyclidium* sp. from Enderby Land and Stout (1970) observed *Cyclidium muscicola* in *Salix* litter from East Greenland. Present observations indicate that *C. glaucoma* has a widespread but infrequent distribution, being confined to moss peats and grass soil throughout the maritime Antarctic.

Dichilium Schewiakoff

Fig. 88, No. 68; Fig. 92

Dichilium cuneiforme is a hymenostomatid ciliate, ellipsoid in shape, with a small cytostome near the anterior end. It is a very rare species and previously unrecorded from terrestrial habitats, though it is known from fresh water (Kahl, 1935). It was observed in all the grass soils examined from Elephant Island and in the moss peat and *Acaena* soil from Iles Crozet.

Glaucoma Ehrenberg

Fig. 88, No. 69; Fig. 93

Glaucoma pyriformis is an ovoid-ellipsoid, slightly flattened hymenostomatid ciliate with a small cytostome near the anterior end; the cytostome is inserted obliquely as in *Colpidium* but, unlike *Colpidium*, the body is not at all reniform. *Glaucoma pyriformis* is distinguished from the common aquatic species, *Glaucoma scintillans*, by its smaller size, more pointed anterior and larger undulating membrane. It is

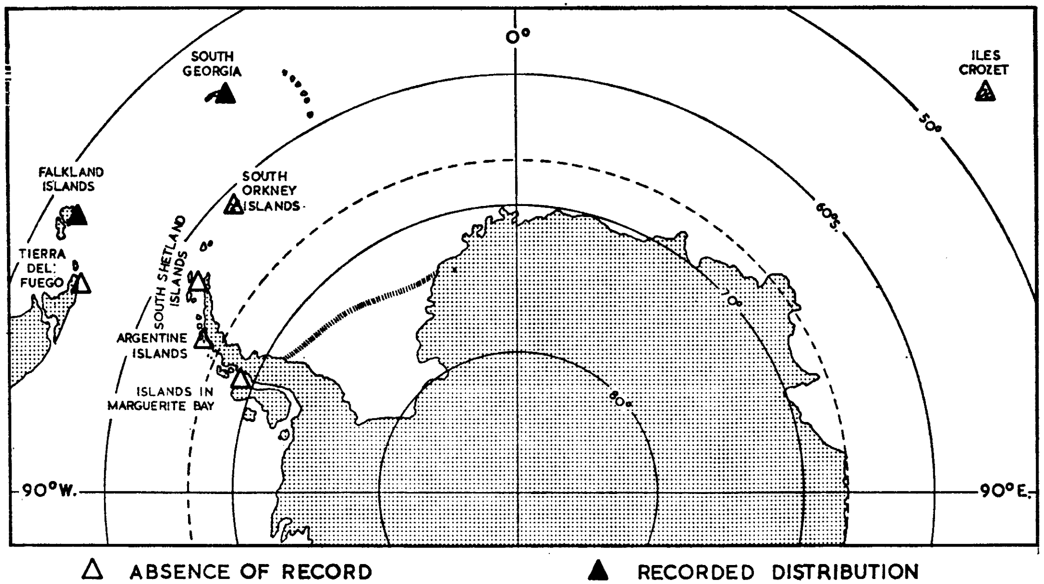


FIGURE 89

The distribution of *Colpidium colpoda.*

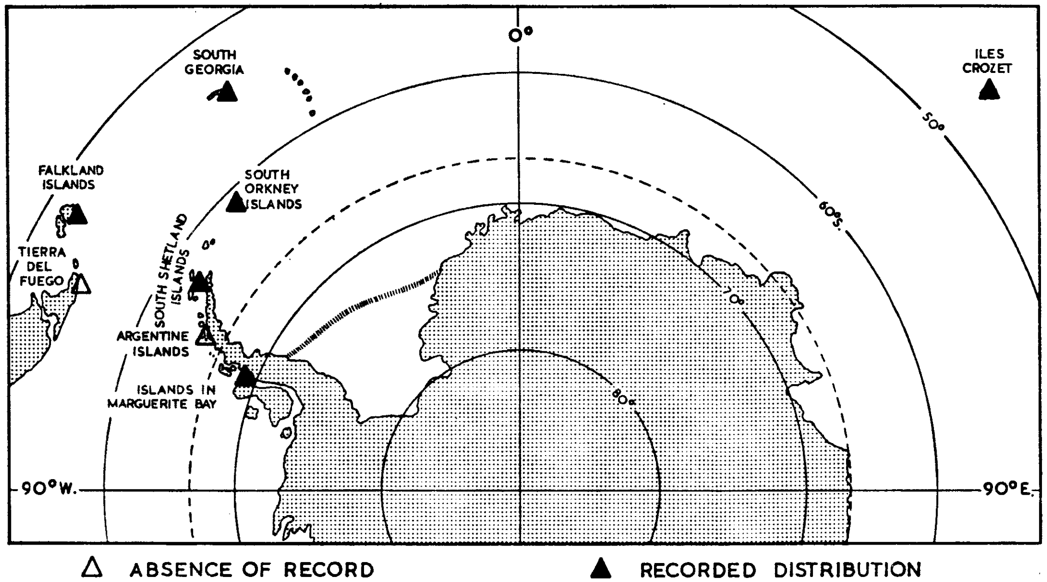


FIGURE 90

The distribution of *Cryptochilium nigricans.*

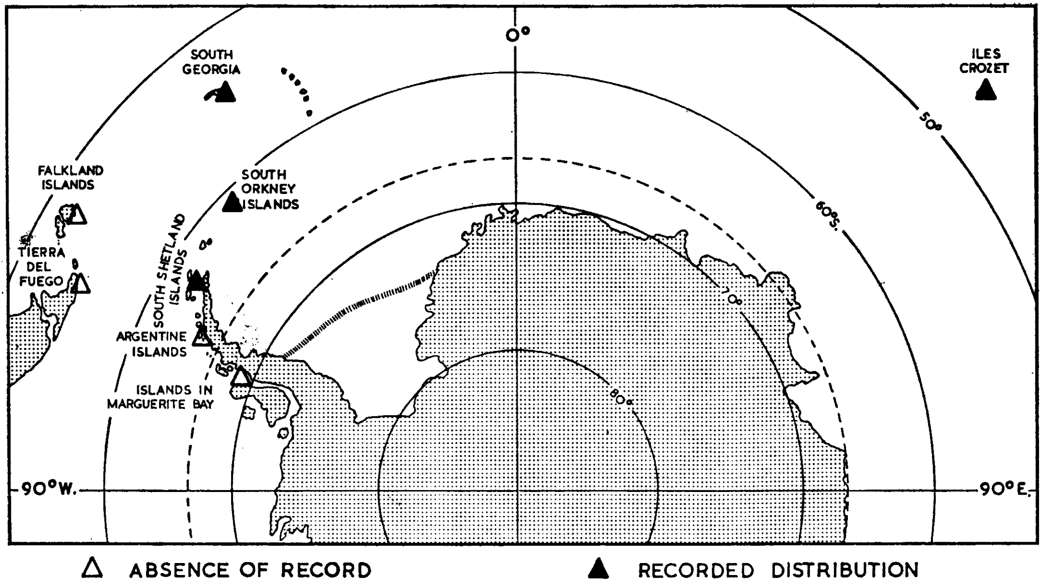


FIGURE 91

The distribution of *Cyclidium glaucoma.*

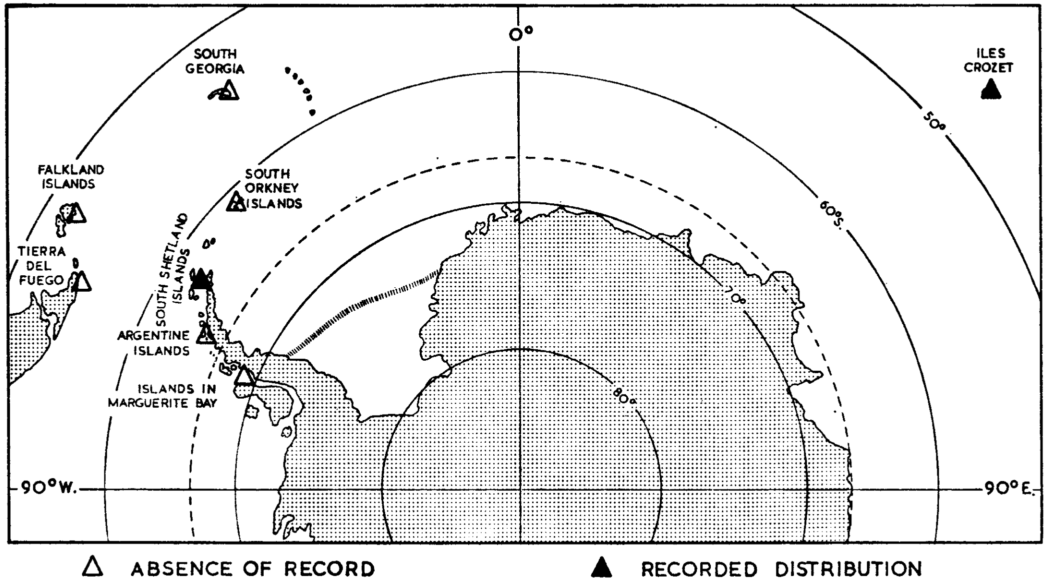


FIGURE 92

The distribution of *Dichilium cuneiforme.*

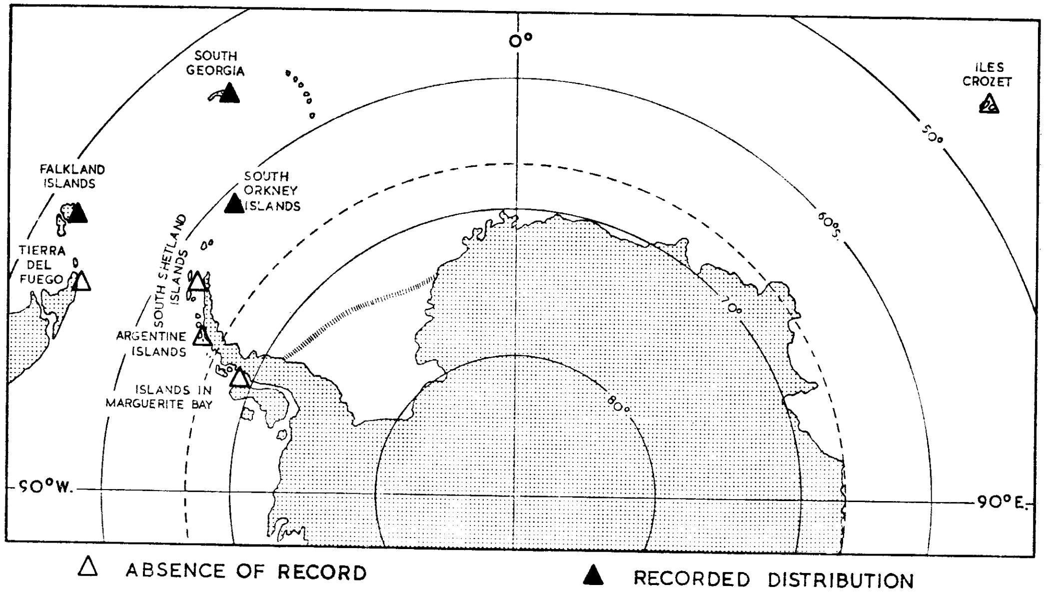


FIGURE 93
The distribution of *Glaucoma pyriformis*.

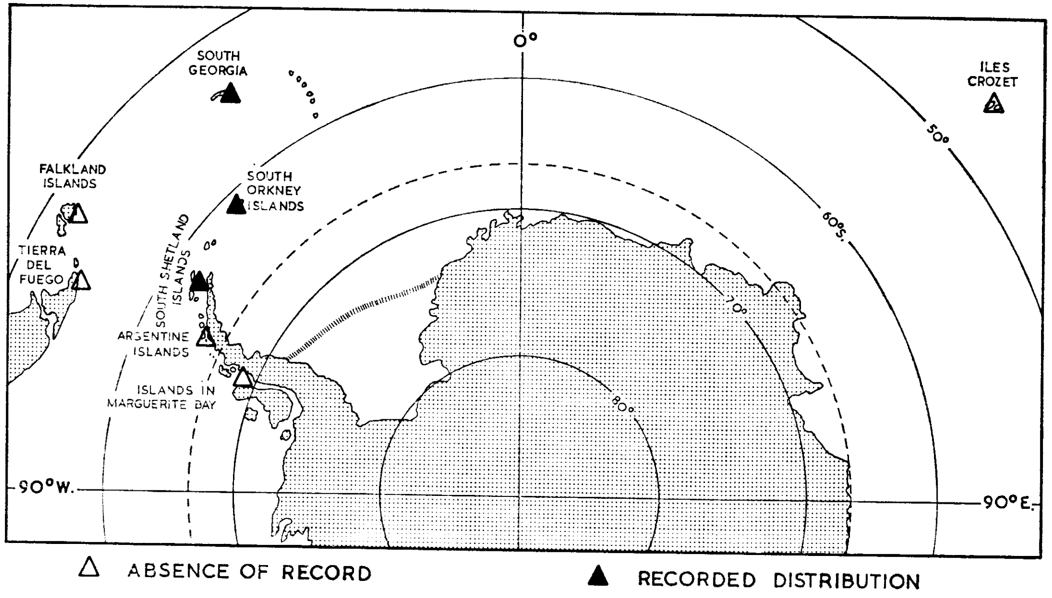


FIGURE 94
The distribution of *Philaster* sp.

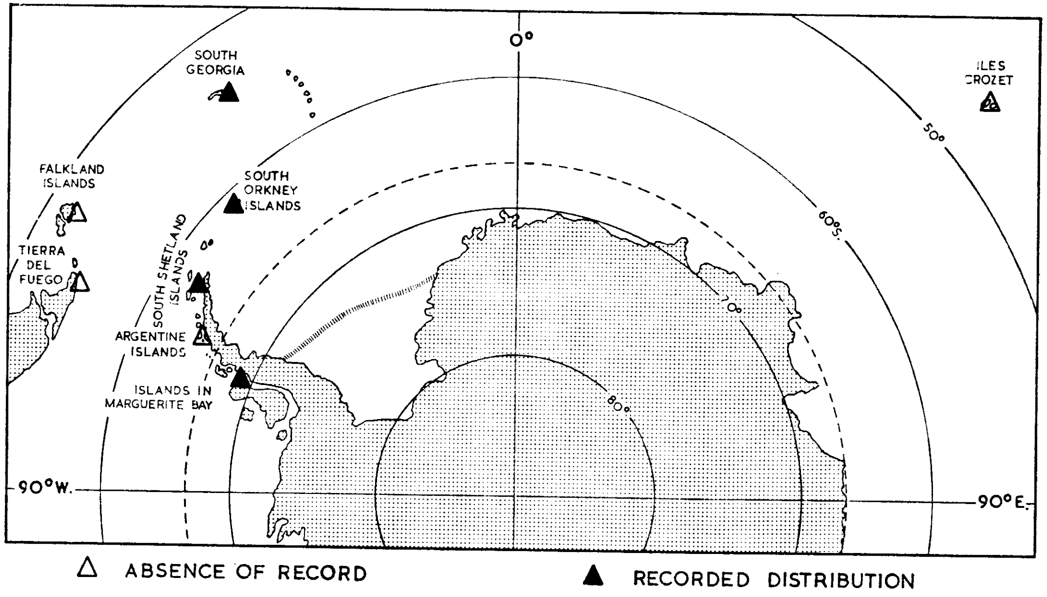


FIGURE 95
The distribution of *Vorticella microstoma*.

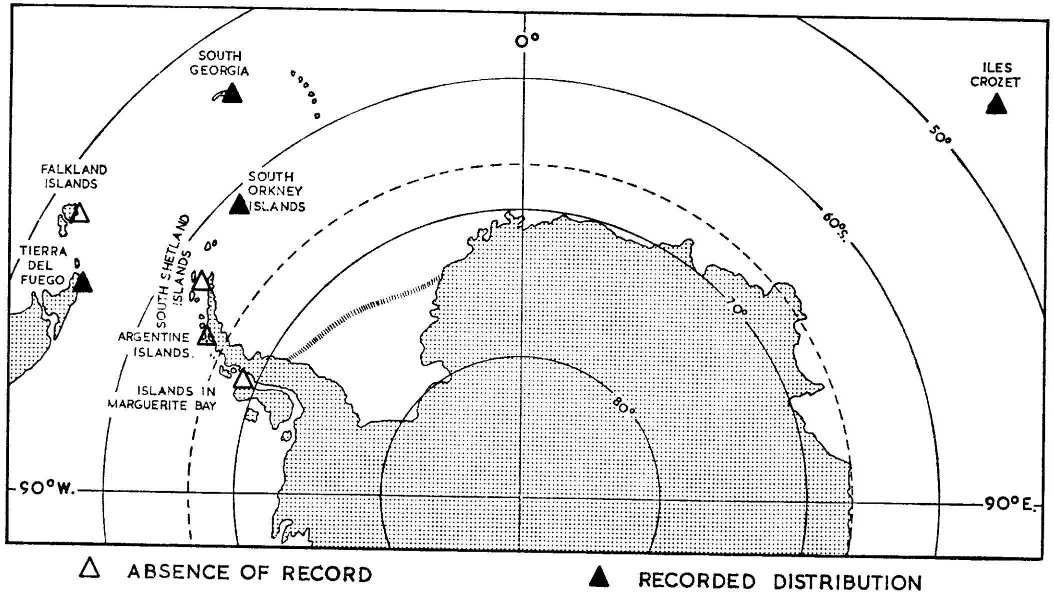


FIGURE 96
The distribution of *Vorticella striata* var. *octava*.

tolerant of a wide range of pH (4.0–8.9) but it has a preference for acid conditions (pH 4.8–5.3) (Johnson, 1935). It can easily be cultured in axenic conditions (Hetherington, 1936). It has been frequently recorded from temperate soils (Sandon, 1928; Horvath, 1949; Chardez, 1967; Delhez and Chardez, 1970). Its distribution extends to alpine forest soils (Rosa and Lhotsky, 1971) but it has not previously been recorded from polar regions. It was observed rarely in moss peat and grass soil from South Georgia and the South Orkney Islands.

Philaster Fabre-Domergue

Fig. 88, No. 70; Fig. 94

Philaster is a hymenostomatid ciliate: the body is ovoid but pointed at the anterior end; the cytostome lies at the bottom of an elongate-triangular oral groove which runs laterally from the anterior tip. This genus has not previously been recorded from terrestrial habitats. The species observed in the present study was restricted to alkaline animal guano. It proved impossible to identify it with any previously described species; it most closely resembled *Philasterides armata* Kahl (Kahl, 1935) but it is much smaller. A detailed study of the population ecology of this species, inhabiting chinstrap penguin guano on Signy Island, has been made by Smith (1973*c*). Culture experiments (Smith, 1973*d*) indicated that this species may be an obligate psychrophile.

Vorticella Ehrenberg

Figs. 95, 96 and 97, Nos. 71, 72a and b

Vorticella is a sessile peritrichous ciliate, solitary and with a bell-shaped body and a contractile stalk. *V. microstoma* and *V. striata* var. *octava* are the two smallest species and the two most commonly recorded from terrestrial habitats. They are distinguished by *V. striata* possessing distinctive transverse striations. Both species are common in soils, though the two species do not co-exist (Sandon and Cutler, 1924; Yakimoff and Zeren, 1924; Sandon, 1927, 1928; Horvath, 1949; Stout, 1963; Nielsen, 1968; Rosa and Lhotsky, 1971). The two species have distinct habitat preferences. *V. microstoma* is polysaprobic, whereas *V. striata* is meso- or oligosaprobic (Curds, 1966, 1969; Sladeckova and Sladecek, 1966; Sladecek, 1969). *V. microstoma* can be cultured either axenically or with bacterial food (Finley and others, 1959). Bacteria favouring the growth of *Vorticella* include Gram-positive strains of *Bacillus* and *Streptococcus*, Gram-negative enterobacteria being unfavourable (Curds and Vandyke, 1966). The process of encystment has been described by Brand (1923). There are several records of both species from Spitsbergen and Greenland (Sandon, 1924; Dixon, 1939; Stout, 1970) but none previously from the Antarctic. However, *V. microstoma* was observed to occur very frequently and abundantly in alkaline animal guano habitats, while *V. striata* was occasionally observed in moss peat and grass soil. The population ecology of *V. microstoma* in chinstrap penguin guano on Signy Island has been described by Smith (1973*c*).

Halteria Dujardin

Fig. 97, No. 73; Fig. 98

Halteria grandinella is an oligotrichid ciliate with a spherical body. It has a large peristomal membrane but is otherwise without cilia except for an equatorial girdle of stiff cirri. It is characterized by springing erratic movements which may be of survival value as an anti-predator device (Tamar, 1968). *Halteria grandinella* has been reported feeding on bacteria and algae (Szabo, 1935), and shows a preference for a near neutral pH and temperatures above 20° C, being unable to tolerate acidity or cold conditions (Dingfelder, 1962; Tamar, 1965, 1967). It has been frequently recorded from temperate soils (Sandon and Cutler, 1924; Yakimoff and Zeren, 1924; Sandon, 1927, 1928; Horvath, 1949; Stout, 1963; Chardez, 1967; Nielsen, 1968; Delhez and Chardez, 1970), but very rarely from polar regions; the geographical distribution thus reflects Tamar's (1965) observations on temperature and pH preferences. It has been recorded from Greenland (Stout, 1970) and in the present study was observed in moss peat and grass soil from Signy Island (Smith, 1973*a*).

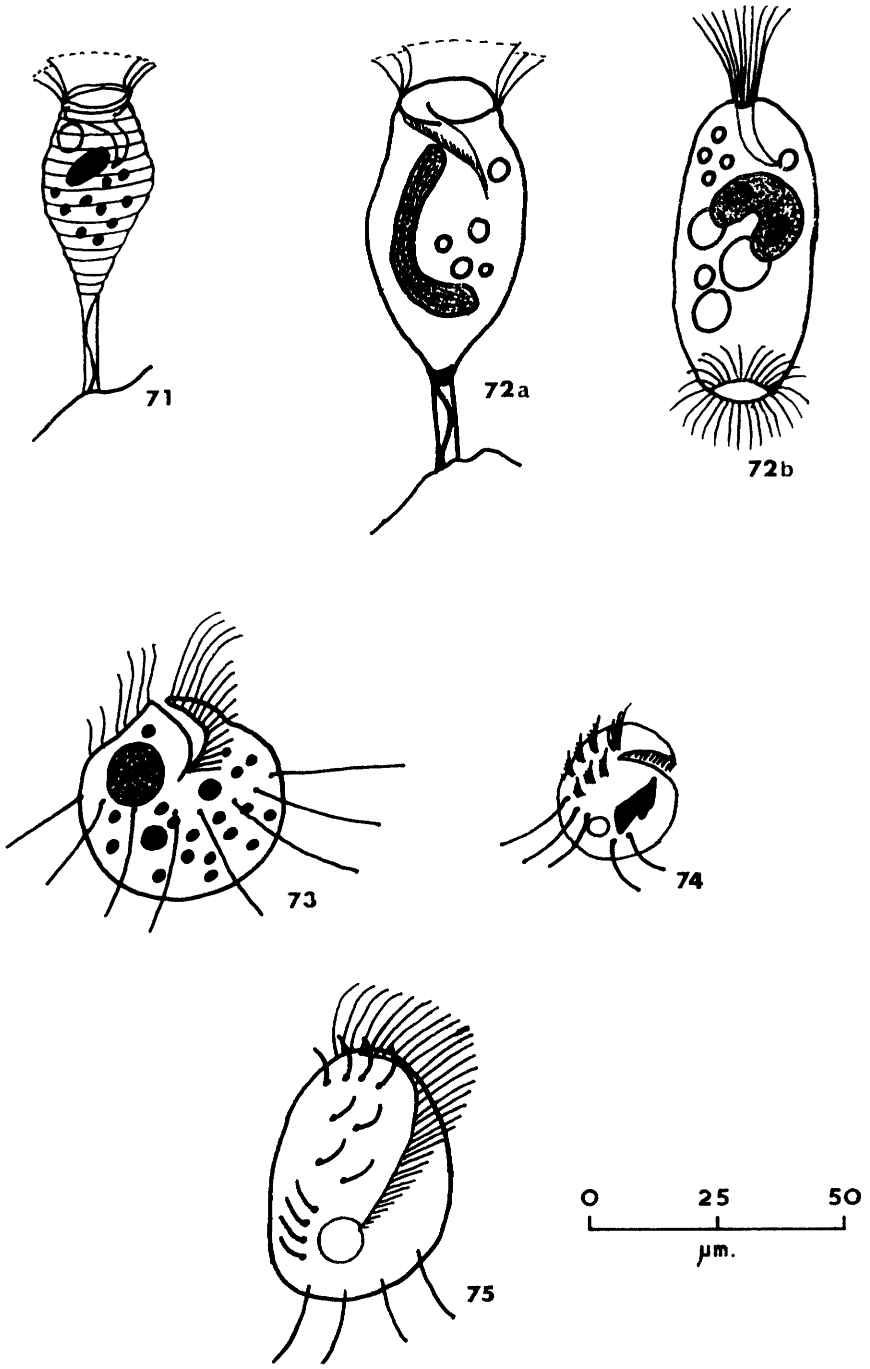


FIGURE 97

Ciliata.

Peritrichida	No. 71	*Vorticella striata* var. *octava* polyp.
	No. 72	*Vorticella microstoma.* a. Polyp. b. Telotroch.
Oligotrichida	No. 73	*Halteria grandinella.*
Hypotrichida	No. 74	*Aspidisca* sp.
	No. 75	*Euplotes* sp.

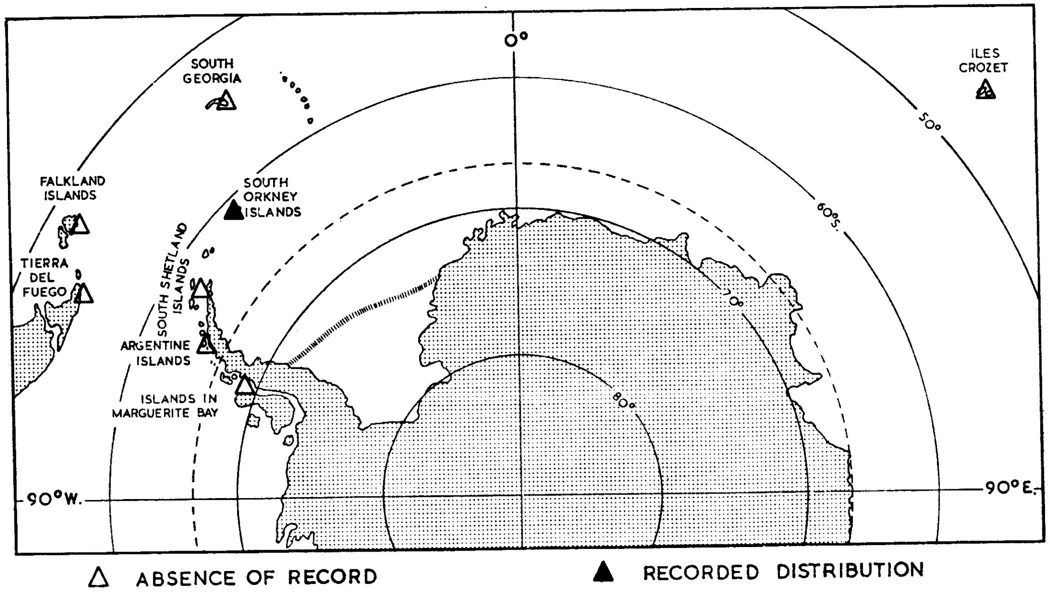


FIGURE 98
The distribution of *Halteria grandinella*.

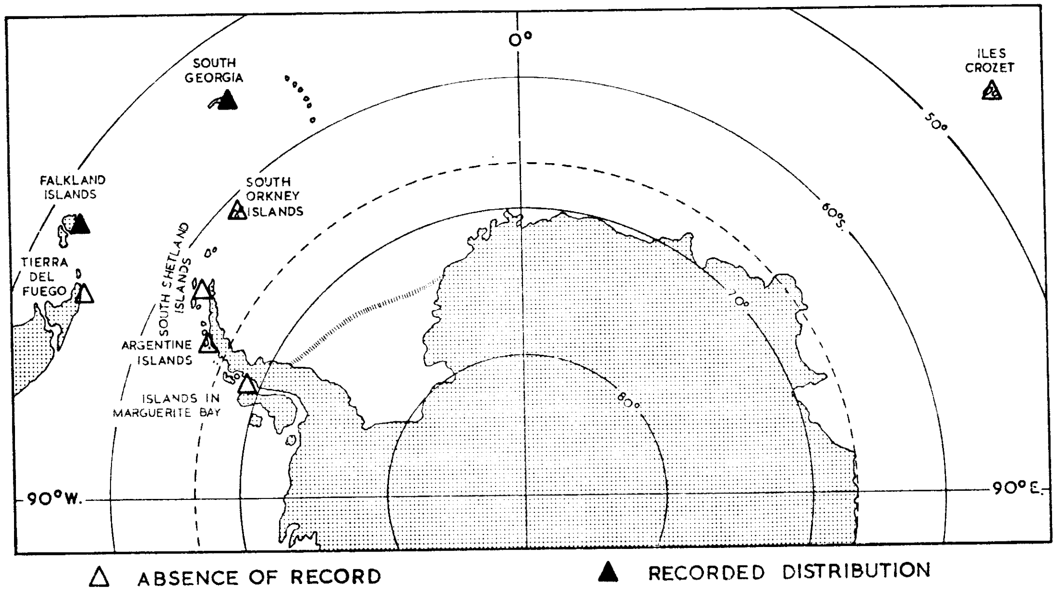


FIGURE 99
The distribution of *Aspidisca* sp.

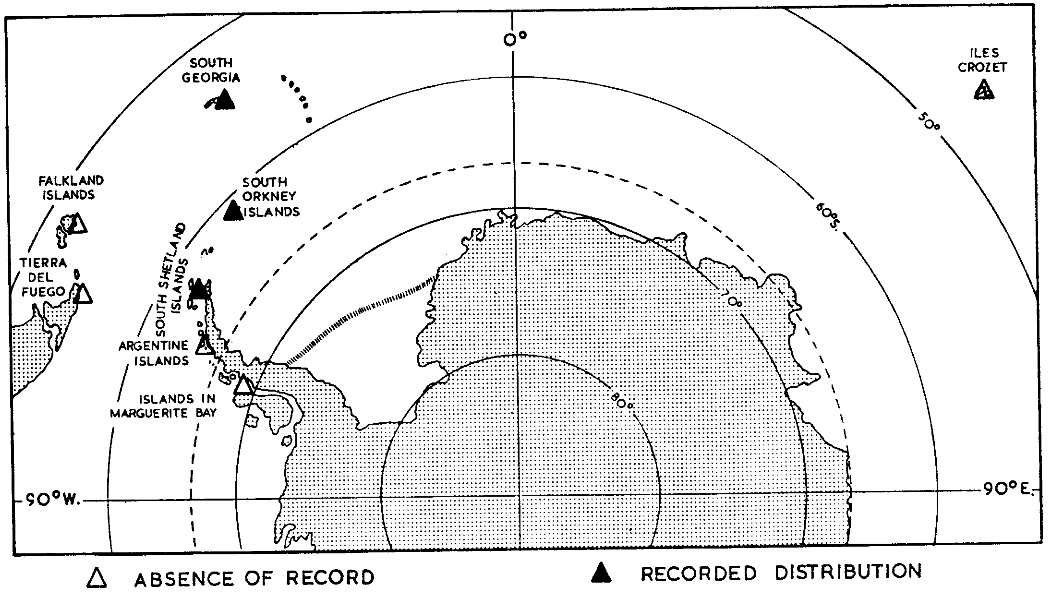


FIGURE 100
The distribution of *Euplotes* sp.

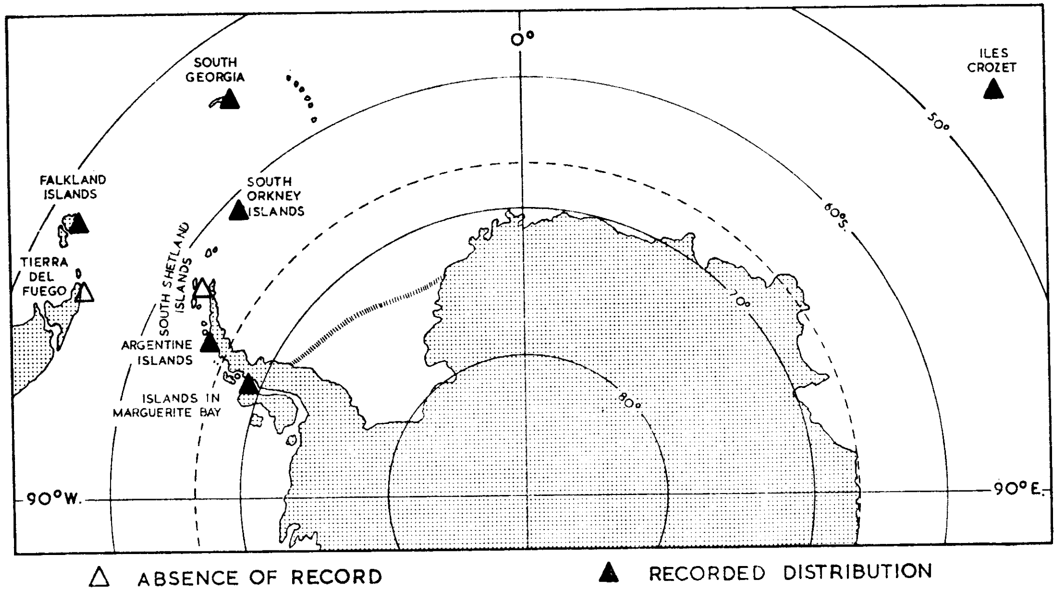


FIGURE 101
The distribution of *Gonostomum affine*.

Aspidisca sp. Ehrenberg

Fig. 97, No. 74; Fig. 99

Aspidisca is a hypotrichous ciliate in which the ciliature is reduced to a small group of frontal and anal cirri. The body is a small flattened disc, the ventral side flat and the dorsal side convex and ridged. *Aspidisca* is rare in soils (Yakimoff and Zeren, 1924; Sandon, 1927; Chardez, 1967); the only previous records from polar regions are those of Stout (1970), who observed it in moss and *Salix* soil from East Greenland. It was observed in the present study in grass soils from the Falkland Islands and South Georgia.

Euplotes Ehrenberg

Fig. 97, No. 75; Fig. 100

Euplotes is a hypotrich with a large peristome and a variable number of frontal, five anal and four caudal cirri. The body is ovoid and flattened. It is primarily an aquatic genus with many fresh-water and marine species (Tuffrau, 1960; Borror, 1968; Carter, 1972). An obligate psychrophilic species, *Euplotes antarctica*, has been isolated from Antarctic sea-ice slush; it showed a temperate tolerance range of —3° to +10° C (Fenchel and Lee, 1972*a*, *b*). *Euplotes* spp. have been recorded infrequently from terrestrial habitats but the records indicate a widespread distribution in many soil types through the temperate and tropical zones (Sandon, 1927; Horvath, 1949; Gellert, 1955*b*; Stout, 1963; Nielsen, 1968). *Euplotes* has not previously been recorded from polar regions. In the present study it was observed in moss peats and grass soil in South Georgia, Signy Island and Elephant Island.

Gonostomum Sterki

Figs. 101 and 104, No. 76

Gonostomum affine is a hypotrichous ciliate with an elongate-ellipsoid flexible body and a peristome which runs from the anterior parallel to the body axis then makes a sharp bend at the middle of the body. It is a frequently occurring species in all types of soils (Sandon and Cutler, 1924; Yakimoff and Zeren, 1924; Sandon, 1927, 1928; Horvath, 1949; Gellert, 1955*b*; Stout, 1963; Chardez, 1967; Nielsen, 1968; Rosa and Lhotsky, 1971). There are also several records from Greenland and Spitsbergen (Sandon, 1924; Dixon, 1939; Stout, 1970) but none previously from the Antarctic. Observations in the present study reflected its distribution in temperate regions; it was found to occur in both acid and alkaline, and also both mineral and organic habitats in all the island groups investigated except Tierra del Fuego.

Holosticha Wresniowski

Figs. 102 and 104, No. 77

Holosticha is a hypotrichous ciliate with an oval body distinguished by long rows of ventral and marginal cirri. It is an almost entirely aquatic genus (Peschkowsk, 1926) and it has been reported to occur in Antarctic sea-ice slush (Fenchel and Lee, 1972*a*). There are a few records of *Holosticha* from organic soils in temperate Europe (Gellert, 1955*a*, *b*; Nielsen, 1968). The few observations of *Holosticha* during the present study do not reveal any consistent pattern in habitat preference or geographical distribution.

Oxytricha (Bary) Ehrenberg

Figs. 103 and 104, Nos. 78–80; Figs. 105 and 106

Oxytricha is a hypotrichous ciliate with an ovoid flexible body, a flattened ventral surface and a convex dorsal surface. The differentiation of the ciliature and cytoplasmic cortex of *Oxytricha fallax* during reproduction and excystment have been described in detail by Hashimoto (1963) and by Grimes (1972, 1973). There are many fresh-water species (Horvath, 1933) but three also occur in terrestrial habitats: *O. fallax*, *O. pellionella* and *O. setigera*. *Oxytricha pellionella* has been recorded very much more frequently than the other two species but it may co-exist with either or both of them. All three occur frequently in organic

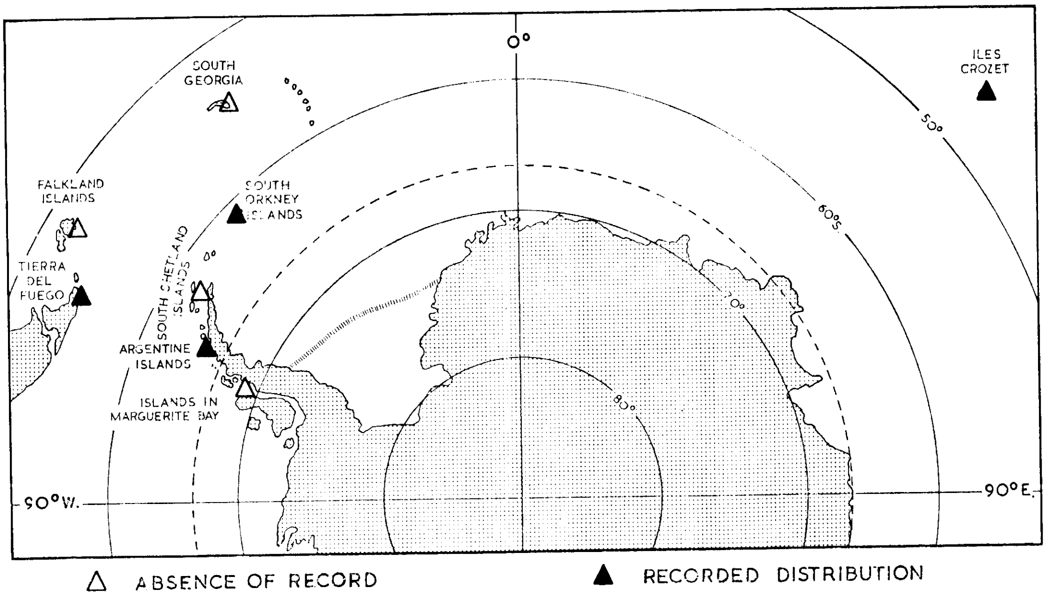


FIGURE 102
The distribution of *Holosticha* sp.

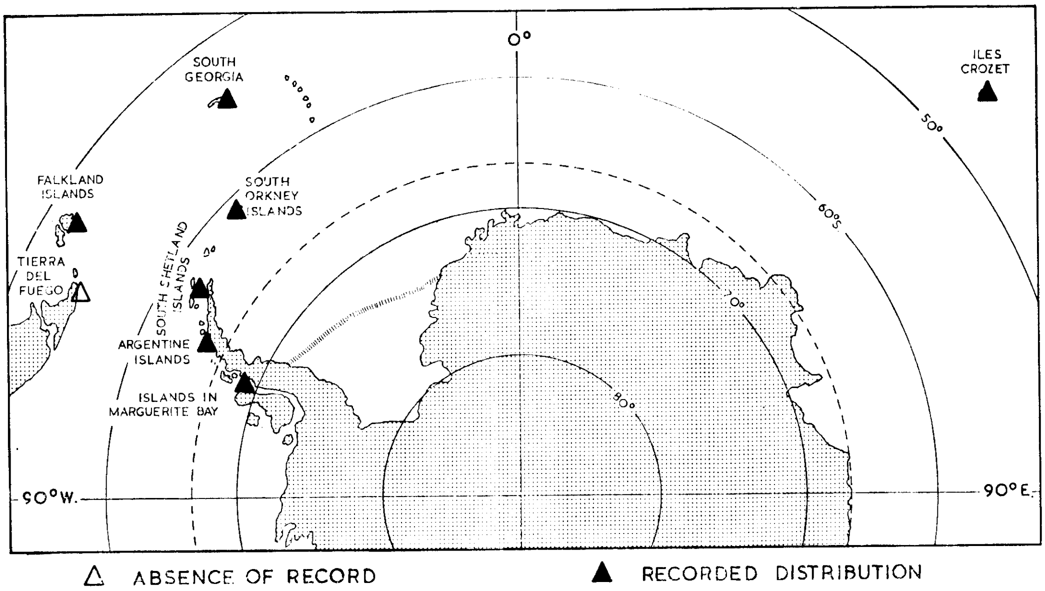


FIGURE 103
The distribution of *Oxytricha fallax*.

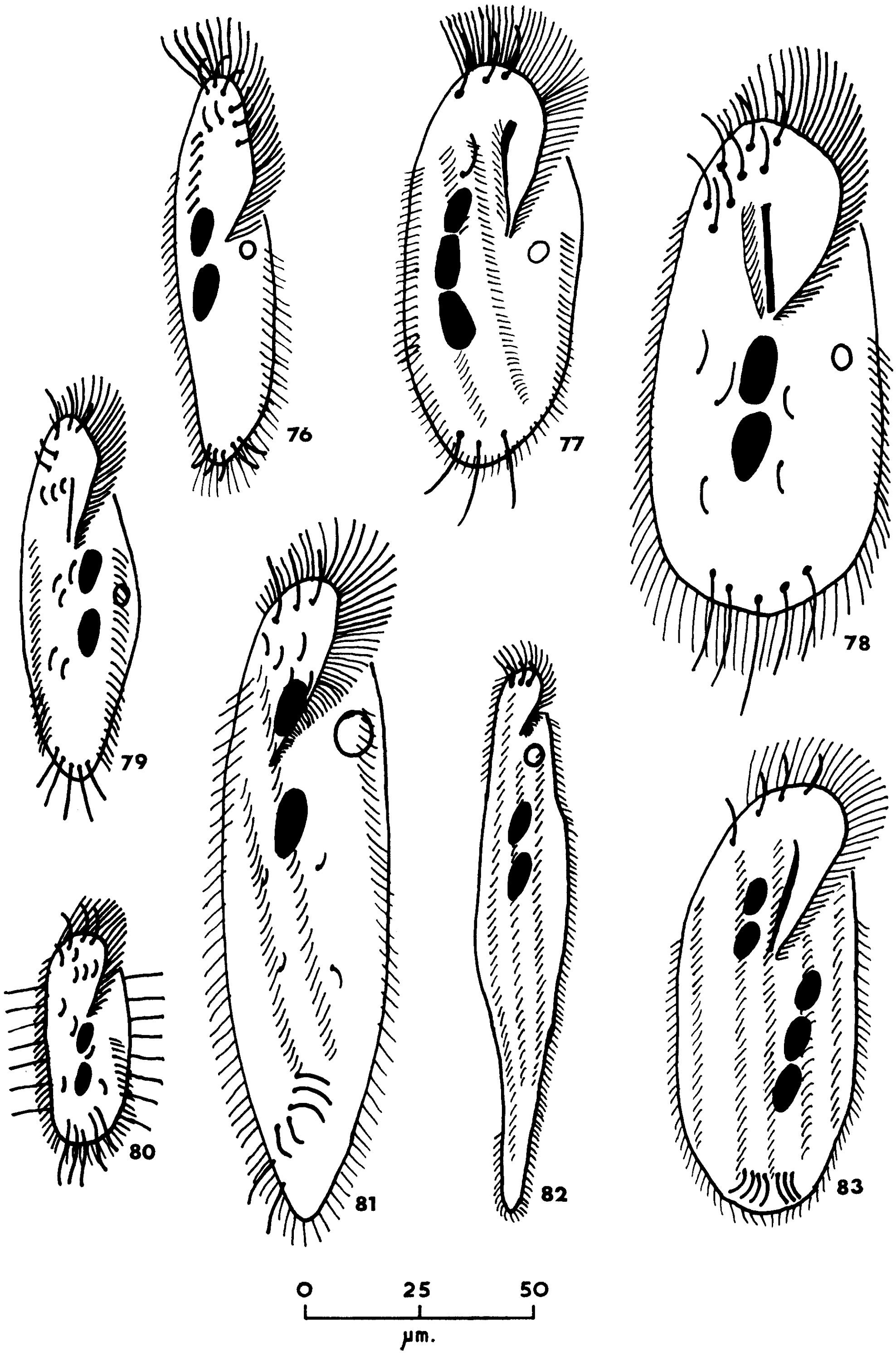


FIGURE 104

Ciliata.
Hypotrichida
No. 76 *Gonostomum affine.*
No. 77 *Holosticha* sp.
No. 78 *Oxytricha fallax.*
No. 79 *Oxytricha pellionella.*
No. 80 *Oxytricha setigera.*
No. 81 *Pleurotricha lanceolata.*
No. 82 *Uroleptus* sp.
No. 83 *Urostyla* sp.

peaty soils (Sandon and Cutler, 1924; Sandon, 1927, 1928; Stout, 1963; Chardez, 1967; Rosa and Lhotsky, 1971). All three species have been recorded from the Arctic and Antarctic, *O. pellionella* being the most frequent (Sandon, 1924, 1927; Dixon, 1939; Stout, 1970; Thompson, 1972). Observations in the present study indicate that *Oxytricha* spp. have wide ecological tolerances; all three species occurred predominantly in acid peats but *Oxytricha fallax* also occurred in alkaline guano and *Oxytricha pellionella* appeared to be well adapted to mineral habitats; among the ciliates it was a pioneer colonizer of volcanic tephra on Deception Island (Smith, 1974*b*). This distinction is reflected in the saprobic classification. Both species have been considered α-mesosaprobic by Kolkwitz and Marsson (1909) but Curds' (1969) observations indicated that *O. fallax* is poly- or α-mesosaprobic, while *O. pellionella* is β-mesosaprobic.

Pleurotricha Stein

Fig. 104, No. 81; Fig. 107

Pleurotricha lanceolata is a hypotrichous ciliate with a large ellipsoid body and a large spectacular peristome. It has a characteristic cyst bearing short stout spines. Studies of the processes of encystment and excystment have been made by Manwell (1928), Penn (1935) and Jeffries (1956, 1962); these indicate that amino acids and nucleic acids induce excystment, whilst carbohydrates and vitamins do not. It occurs in many temperate and tropical soils (Sandon and Cutler, 1924; Sandon, 1927, 1928) and has also been recorded from Greenland, Spitsbergen and the Antarctic Peninsula (Sandon, 1924; Dixon, 1939; Thompson, 1972). In the present study, it was observed in moss peats, grass soil and *Aceana* soil in South Georgia, the South Orkney Islands and Elephant Island.

Uroleptus Ehrenberg

Fig. 104, No. 82; Fig. 108

Uroleptus is a hypotrichous ciliate with a greatly elongated body, the posterior being drawn out into a tail. *Uroleptus* spp. have been recorded from many temperate and tropical soils (Sandon and Cutler, 1924; Yakimoff and Zeren, 1924; Sandon, 1927, 1928; Gellert, 1955*b*; Stout, 1970; Thompson, 1972). Observations in the present study showed *Uroleptus* as a frequently occurring genus in all the island groups investigated as far south as Livingston Island. It showed a habitat preference for acid peats but also occurred in mineral habitats and in alkaline guano, particularly when this had been colonized by *Prasiola*.

Urostyla Ehrenberg

Fig. 104, No. 83; Fig. 109

Urostyla is a hypotrichous ciliate with an oblong body, the ventral surface being covered by at least four long rows of short ventral cirri. *Urostyla* is a fresh-water genus and is rare in terrestrial habitats. It has been recorded from temperate soils (Yakimoff and Zeren, 1924; Sandon, 1927; Stout, 1963). Observations made in the present study suggested that it is confined to moss peat and grass soil on South Georgia and Iles Crozet; it was not observed farther south. However, it has been recorded from the Antarctic Peninsula (Thompson, 1972).

C. Artificial Key to the Genera

This key can be used to identify the genera of Protozoa occurring in terrestrial habitats in the sub-Antarctic and maritime Antarctic. It utilizes the characters of Protozoa as they appear during active life in fresh microscopic preparation. Identifications of the species within the genera can be made by referring to the particular works indicated for each genus. The abbreviation "BM" indicates that permanent preparations of specimens of the genus concerned are held in slide collections in the British Museum (Nat. Hist.) and they were deposited by Brady, Carlier, Murray, Penard or Wallich. The numbers given refer to the individual slides of the genus; the slides in the Perkins Collection do not have individual numbers.

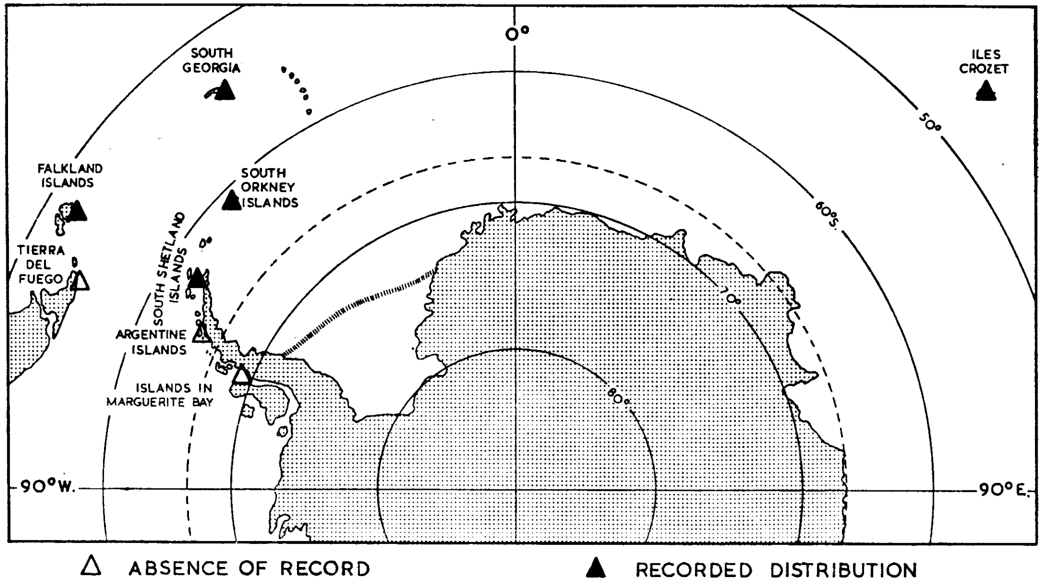


Figure 105

The distribution of *Oxytricha pellionella.*

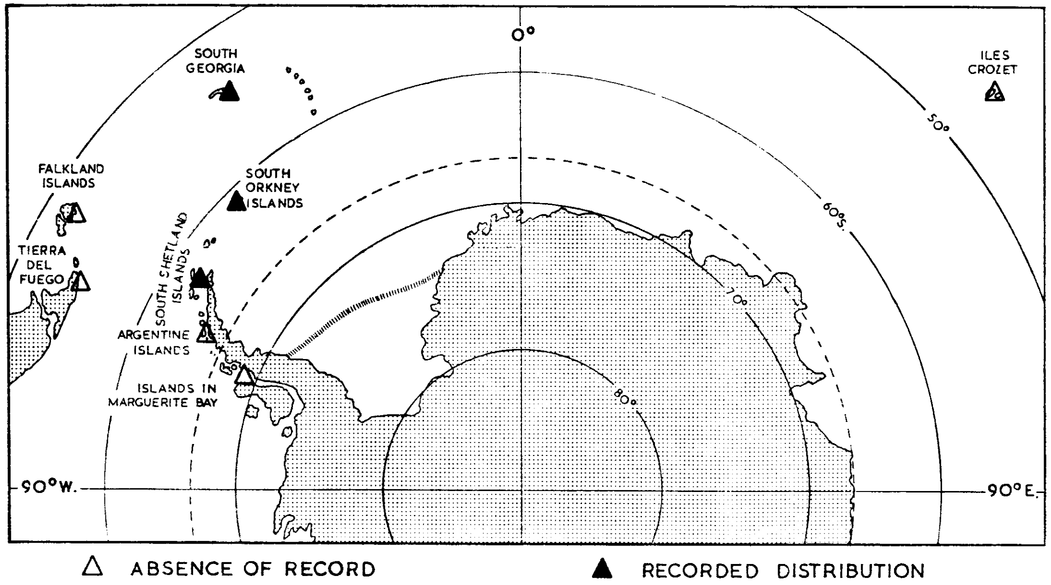


Figure 106

The distribution of *Oxytricha setigera.*

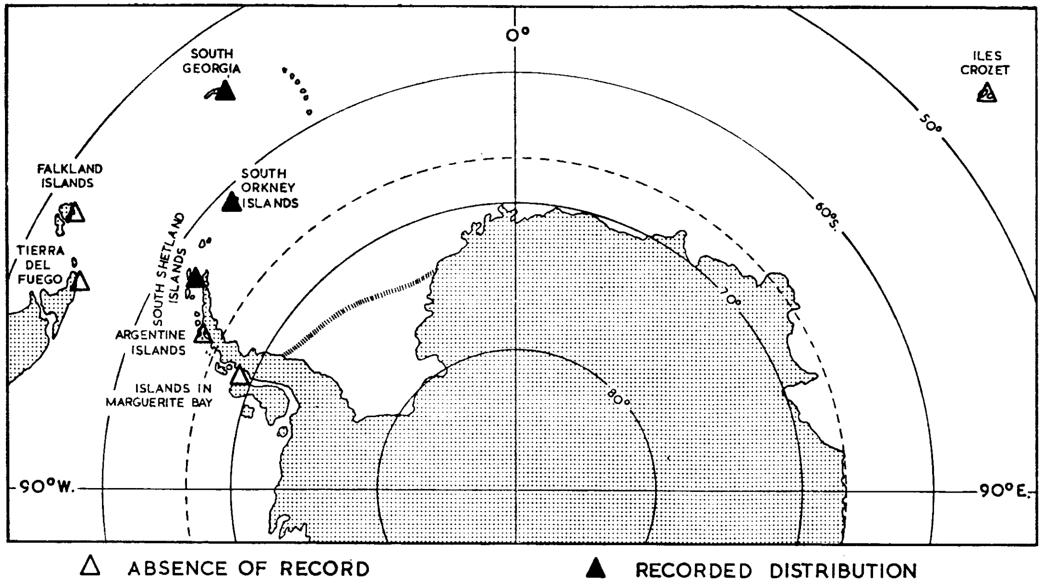


Figure 107

The distribution of *Pleurotricha lanceolata.*

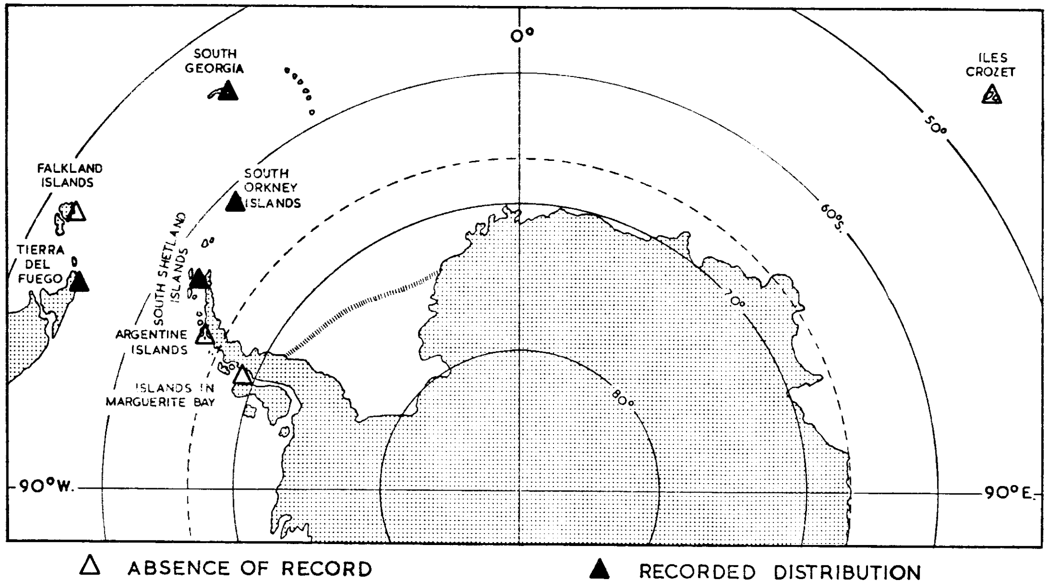


Figure 108

The distribution of *Uroleptus* sp.

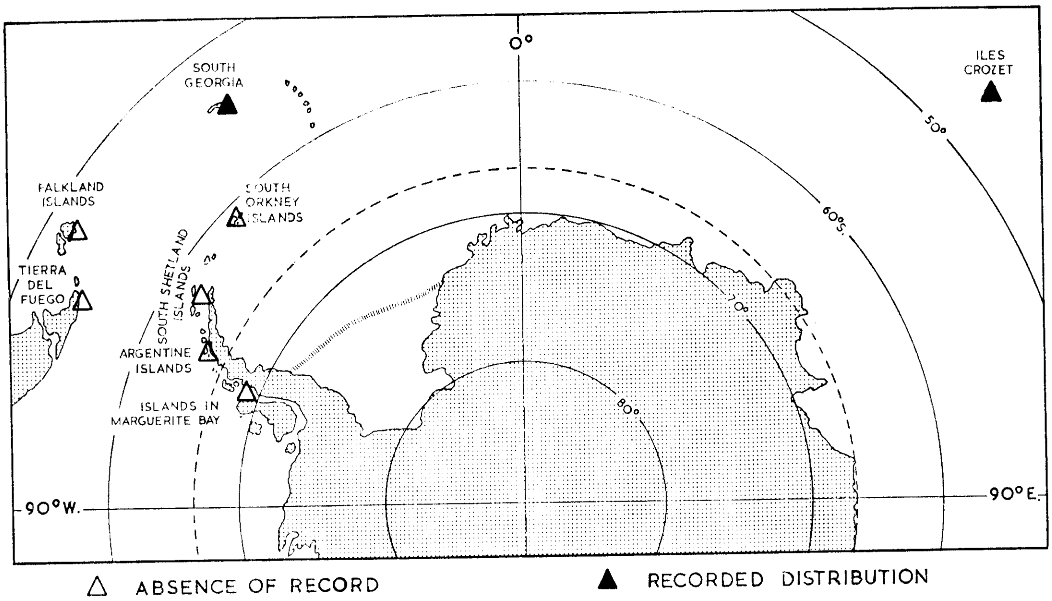


FIGURE 109
The distribution of *Urostyla* sp.

1. PROTOZOA: animals composed of a single cell or having an acellular body
a. Organism sessile, with or without a stalk 2
b. Organism motile 5

2. Sedentary organisms
a. With suctorial tentacles . . . . Order SUCTORIDA 3
b. With a whorl of adoral cilia on an anterior disc . . Order PERITRICHIDA 4
c. Colony of spherical cells (about 6 μm. diameter), each with two flagella (not easily visible), embedded in a gelatinous matrix . . . . Genus ***Spongomonas*** (p. 35) (Fig. 27, No. 16)
[Species of *Spongomonas*: Kudo, 1966, 426–27.]
d. Colony of elongated cells (10–15 μm. diameter), each with one flagellum, embedded in a gelatinous matrix . Genus ***Phalansterium***
[Species of *Phalansterium*: Sandon, 1927, 78–79; Kudo, 1966, 405–06.]

3. SUCTORIDA
a. With a rigid stalk; tentacles distributed over the body surface . . . . Genus ***Podophyra***
[Species of *Podophrya*: Kahl, 1931, 462–64; Kudo, 1966, 1048–49; Curds, 1969, 78–80; BM–Perkins.]
b. Stalk short or absent; tentacles in clusters . . . Genus ***Hallezia***
[Species of *Hallezia*: Kudo, 1966, 1038.]

4. PERITRICHIDA
a. Solitary; stalk contractile; may be attached to inanimate substratum . . . . Genus ***Vorticella*** (p. 72) (Fig. 97, Nos. 71 and 72a)
[Species of *Vorticella*: Noland and Finley, 1931, 81–123; Kahl, 1935; 713–34; Curds, 1969, 38–50.]
b. Colonial; stalk rigid; epizoic . . . . . Genus ***Epistylis***
[Species of *Epistylis*: Curds, 1969, 51–54; BM–Pennard (20.12.8:662–63).]

5. Motile organisms
   a. Movement by 1 to 4 flagella (rarely 8 or more) 6
   b. Movement by cytoplasmic flow (not always occurring); cell occupies a rigid shell . . . . . Order TESTACIDA 24
   c. Movement by cytoplasmic flow; cytoplasm naked 7
   d. Movement by cilia . . . . . Class CILIATA 38

6. Movement by flagella
   a. Cell ellipsoid, 15–20 μm. long; two equal flagella, forward directed; nucleus anterior, vesicular; 3–4 μm. diameter Genus ***Naegleria*** (p. 41) (flagellate form)
      [Species of *Naegleria*: Kudo, 1966, 519–20.]
   b. Cell not as in (a) . . . . . Class MASTIGOPHORA 8

7. Movement by cytoplasmic flow; cytoplasm naked
   a. Cell 20 μm. long (extremes 14–40 μm.); one or more indeterminate pseudopodia; nucleus vesicular, 5–6 μm. diameter, uroid absent . . . . . Genus ***Tetramitus*** (p. 35) (amoeboid form) (Fig. 27, No. 17b)
      [Species of *Tetramitus*: Pritchard, 1961, 501; Sandon, 1927, 93–95; Klug, 1936, 107–12.]
   b. Cell not as in (a) . . . . . Order AMOEBIDA 19

8. MASTIGOPHORA
   a. With 1 flagellum 9
   b. With 2 flagella 12
   c. With 4 flagella . . . . . Genus ***Tetramitus*** (p. 35) (Fig. 27, No. 17a)
      [Species of *Tetramitus*: Pritchard, 1961, 501; Sandon, 1927, 93–95; Klug, 1936, 107–12.]
   d. With 8 or more flagella 18

9. With 1 flagellum
   a. Flagellum forward-directed 10
   b. Flagellum backward-directed 11

10. Flagellum forward-directed
    a. Cell approximately spherical . . . . . Genus ***Oikomonas*** (p. 28) (Fig. 18, Nos. 1 and 2)
       [Species of *Oikomonas*: Sandon, 1927, 96–99; BM-Perkins.]
    b. Cell elongated; a collar round the base of the flagellum (not easily visible) . . . . . Genus ***Phalansterium***
       [Species of *Phalansterium*: Sandon, 1927, 78–79; Kudo, 1966, 405–06.]
    c. Cell flattened, leaf-like; a longitudinal groove on one or both surfaces . . . . . Genus ***Petalomonas*** (p. 28) (Fig. 18, Nos. 5 and 6)
       [Species of *Petalomonas*: Pascher and Lemmerman, 1913, 164–67; Sandon, 1927, 108–09; Schawhan and Jahn, 1947, 182–89.]

11. Flagellum backward-directed
    a. Cell more than 6 μm. long; movements smooth gliding Genus ***Allantion*** (p. 32) (Fig. 18, No. 8)
       [Species of *Allantion*: Sandon, 1924, 461–62.]

b. Cell less than 6 μm. long; movements rapid and vibratory — Genus ***Sainouron*** (p. 35) (Fig. 27, No. 15)

[Species of *Sainouron*: Sandon, 1924, 459–61.]

12. With 2 flagella
    a. Flagella both forward-directed, equal in length 13
    b. Flagella both forward-directed, one main flagellum and one short accessory 14
    c. One flagellum forward-directed, the other backward-directed 15

13. With 2 equal forward-directed flagella
    a. Cell less than 10 μm. long . . . . . . — Genus ***Spongomonas*** (p. 35) (motile form)

    [Species of *Spongomonas*: Kudo, 1966, 426–27.]

    b. Cell more than 10 μm. long; with chloroplasts . . — Genus ***Chlamydomonas*** (p. 28) (Fig. 18, No. 4)

    [Species of *Chlamydomonas*: Pascher, 1921, 120–32; 1925, 549–77; 1929, 426–64; Gerloff, 1940, 311–502; Ettl, 1965*b*, 271–430; Farooqui, 1974*a*, *b*, 185–200.]

    c. Cell more than 10 μm. long; without chloroplasts . — Genus ***Polytoma*** (p. 28) (Fig. 18, No. 7)

    [Species of *Polytoma*: Pritchard, 1861, 504–05; Ettl, 1965*a*, 47–54; Kudo, 1966, 335–36; BM–Perkins.]

14. With 1 main flagellum and 1 accessory, both forward-directed
    a. Cell less than 5 μm. long, spindle-shaped; always solitary — Genus ***Polypseudopodius*** (p. 28) (Fig. 18, No. 3)

    [Species of *Polypseudopodius*: Puschkarew, 1913, 358–62.]

    b. Cell more than 5 μm. long, wedge-shaped; sometimes colonial . . . . — Genus ***Cephalothamnium***

    [Species of *Cephalothamnium*: Kudo, 1966, 318; BM–Perkins.]

15. With 1 forward-directed flagellum and 1 backward-directed
    a. Cell less than 10 μm. diameter; posterior flagellum arises half-way down the body . . . . — Genus ***Pleuromonas***

    [Species of *Pleuromonas*: Pritchard, 1861, 502; Kudo, 1966, 428.]

    b. Cell longer than 10 μm.; both flagella arise at the anterior 16

16. Both flagella arise at the anterior
    a. Proximal parts of the backward-directed flagellum attached to the body . . . . — Genus ***Cercomonas*** (p. 32) (Fig. 27, Nos. 13 and 14)

    [Species of *Cercomonas*: Pritchard, 1861, 497–98; Sandon, 1927, 71–72; BM–Perkins.]

    b. Both flagella completely free of the body 17

17. Both flagella completely free of the body
    a. Cell kidney-shaped or elongate-crescentic . . . — Genus ***Bodo*** (p. 32) (Fig. 27, Nos. 9 and 10)

    [Species of *Bodo*: Pritchard, 1861, 496–97; Sandon, 1927, 79–82.]

    b. Cell posterior tapers to a point . . . . . — Genus ***Cercobodo*** (p. 32) (Fig. 27, Nos. 11 and 12)

    [Species of *Cercobodo*: Sandon, 1927, 72–76; Hollande, 1942, 198–205.]

c. Cell ovoid-ellipsoid . . . . Genus ***Heteromita***

[Species of *Heteromita*: Pritchard, 1861, 499–500; Sandon, 1927, 83–86; BM–Perkins.]

d. Cell elongated and twisted . . . . . . Genus ***Spiromonas***

[Species of *Spiromonas*: Pritchard, 1861, 502; Sandon, 1927, 88.]

18. With 8 or more flagella

a. With 8 flagella always, 6 anterior and 2 posterior . Genus ***Hexamita***

[Species of *Hexamita:* Pritchard, 1861, 499; Kudo, 1966, 449–50.]

b. With 8 to 18 flagella, all anterior . . . . . Genus ***Spironema***

[Species of *Spironema*: Sandon, 1927, 95–96.]

19. AMOEBIDA

a. Pseudopodia indeterminate; movement by cytoplasmic flow into the main pseudopodium 20

b. Pseudopodia determinate or absent; movement by eruptive advance of anterior cytoplasmic wave 21

20. Pseudopodia indeterminate

a. Cell shape antler-like; many pseudopodia (commonly four or five); uroid present . . . . . . Genus ***Metachaos*** (p. 41) (Fig. 40, No. 23)

[Species of *Metachaos*: Schaeffer, 1926, 34–41; Bovee, 1953, 602.]

b. Cell shape an irregular oval; a single anterior pseudopodium; uroid absent or not easily visible . . . . . Genus ***Naegleria*** (p. 41) (Fig. 40, No. 24)

[Species of *Naegleria*: Sandon, 1927, 132–33; Kudo, 1966, 519–20.]

21. Pseudopodia determinate or absent

a. Cell consistently star-shaped; pseudopodia many, very long and thin . . . . Genus ***Astramoeba*** (p. 38) (Fig. 35, No. 18)

[Species of *Astramoeba*: Schaeffer, 1926, 71–76.]

b. Cell shape irregular; pseudopodia many, short and conical Genus ***Mayorella*** (p. 41) (Fig. 40, No. 22)

[Species of *Mayorella*: Schaeffer, 1926, 56–63; Bovee, 1953, 606; 1970, 184–223; Page, 1972, 404–20.]

c. Cell shape irregular oval; longer than broad 22

d. Cell shape irregular oval; broader than long 23

22. Cell longer than broad

a. Pseudopodia many, short, sometimes branching . . Genus ***Dinamoeba*** (p. 38) (Fig. 35, No. 19)

[Species of *Dinamoeba*: Leidy, 1897, 80–93; Schaeffer, 1926, 77–78; Bovee, 1953, 606.]

b. Pseudopodia many, long and slender, no branching . Genus ***Vexillifera*** (p. 44) (Fig. 40, No. 26)

[Species of *Vexillifera*: Schaeffer, 1926, 64–65; Bovee, 1953, 606.]

c. Pseudopodia none; pellicle thick with folds and ridges . Genus ***Thecamoeba***

[Species of *Thecamoeba*: Schaeffer, 1926, 88–94; Bovee, 1953, 612.]

d. Pseudopodia none; pellicle thin and clear, no folds or ridges . . . . Genus ***Valkampfia*** (p. 42) (Fig. 40, No. 25)

[Species of *Valkampfia*: Kudo, 1966, 525–27; Page, 1967, 499–520; 1974, 149–84.]

23. Cell broader than long

a. Cell shape triangular or fan-shaped; pseudopodia (rarely present) long thin rays . . . . Genus ***Flabellula*** (p. 38) (Fig. 35, No. 20)

[Species of *Flabellula*: Schaeffer, 1926, 103–04; Bovee, 1953, 609; Page, 1968, 9–25.]

b. Cell shape irregular; pseudopodia thin spines radiating from the centre; endoplasm thick and granular forming a hemispherical hump at the centre or posterior . Genus ***Hyalodiscus*** (p. 38) (Fig. 35, No. 21)

[Species of *Hyalodiscus*: Schaeffer, 1926, 97–100; Bovee, 1953, 612; Kudo, 1966, 501–03; Page, 1968, 9–25.]

24. TESTACIDA

a. Test homogenous, membranous 25

b. Test covered with extraneous particles 30

c. Test composed of plates or scales 33

25. Test homogenous, membranous

a. Test flattened, saucer-shaped . . . . . . Genus ***Corycia***

[Species of *Corycia*: Sandon, 1927, 151; Kudo, 1966, 573; BM–Penard (04.5.9:51,52), (20.12.8:112–24); BM–Carlier (48.112:261–64).]

b. Test tall, elongated . . . . Genus ***Hyalosphenia***

[Species of *Hyalosphenia*: Leidy, 1879, 128–41; BM–Penard (04.5.9:179–81), (20.12.8:390–407); BM–Carlier (48.11.2:265–68).]

c. Test hemispherical 26

d. Test more or less spherical 27

26. Test hemispherical

a. Aperture circular, central . . . . Genus ***Arcella*** (p. 44) (Fig. 48, Nos. 27 and 28)

[Species of *Arcella*: Leidy, 1879, 165–79; Deflandre, 1928, 152–287; BM–Penard (04.5.9:25–38), (20.12.8:43–63); BM–Carlier (48.11.2:139–48); BM–Wallich (18–8.1:17, 20, 21, 32, 48, 52, 53).]

b. Aperture linear, able to be opened and closed . . Genus ***Parmulina***

[Species of *Parmulina*: Sandon, 1927, 151; Deflandre, 1959, 237; BM–Penard (20.12.8:526–27).]

27. Test more or less spherical

a. Pseudopodia of two kinds (medians short, digitate; laterals long, thin), no branching or anastomosing . . Genus ***Difflugiella*** (p. 47) (Fig. 55, No. 36)

[Species of *Difflugiella*: Deflandre, 1959, 251; Kudo, 1966, 572–73.]

b. Pseudopodia of one kind, branching and anastomosing 28

c. Pseudopodia of one kind, branching but not anastomosing 29

28. Pseudopodia branching and anastomosing

a. Test greater than 50 μm. diameter; never colonial . Genus ***Gromia***

[Species of *Gromia*: Hedley, 1958, 1391–92; Kudo, 1966, 572–73; BM–Penard (04.5.9:163–68), (20.12.8:346–67).]

b. Test less than 40 μm. diameter; sometimes colonial . Genus ***Microgromia***

[Species of *Microgromia*: Sandon, 1927, 165–66.]

29. Pseudopodia branching but not anastomosing
    a. Test with two apertures at opposite poles . . . Genus ***Diplophrys***
        [Species of *Diplophrys*: Leidy, 1879, 256–57; Kudo, 1966, 568.]
    b. Test with only one aperture . . . . . . Genus ***Lecythium***
        [Species of *Lecythium*: Sandon, 1927, 164; Deflandre, 1959, 257–58; BM–Carlier (48.11.2:79).]

30. Test covered with extraneous particles
    a. Test spherical or elongate 31
    b. Test more or less hemispherical 32

31. Test spherical or elongate
    a. Aperture central and circular; pseudopodia few and lobose . . . . Genus ***Difflugia*** (p. 47) (Fig. 55, Nos. 34 and 35)
        [Species of *Difflugia*: Leidy, 1879, 95–123; Jung, 1942, 275–78; Gauthier-Lievre and Thomas, 1958, 253–349; BM–Penard (04.5.9:70–154), (20.12.8:156–298); BM–Wallich (18.8.1:17–21, 32–38, 50–72, 563–66); BM–Murray (62.2.12:1–7, 26–63, 76–85, 96–133); BM–Brady (64.4.3:8–14).]
    b. Aperture central and circular; pseudopodia many, long and thin . . . . Genus ***Pseudodifflugia*** (p. 56) (Fig. 69, No. 48)
        [Species of *Pseudodifflugia*: Leidy, 1879, 197–200; Jung, 1942, 322–24; BM–Penard (04.5.9:219–20), (20.12.8:575–81); BM–Carlier (48.11.2:80–83).]
    c. Aperture long and narrow; elliptical notches in side view . . . . Genus ***Heleopera***
        [Species of *Heleopera*: Leidy, 1879, 162–64; Jung, 1942, 296–98; BM–Penard (04.5.9:169–75), (20.12.8:368–89); BM–Carlier (48.11.2:32–33, 54–56, 90–101, 348–89).]

32. Test more or less hemispherical
    a. Aperture central . . . . Genus ***Phryganella*** (p. 51) (Fig. 69, No. 47a and b)
        [Species of *Phryganella*: Chardez, 1969*a*, 315–22; BM–Penard (04.5.9:211), (20.12.8:535–40); BM–Carlier (48.11.2:258–60); BM–Murray (62.2.12:64–68, 134–36).]
    b. Aperture eccentric . . . . Genus ***Centropyxis***
        [Species of *Centropyxis*: Leidy, 1879, 180–83; Jung, 1942, 286–94; Deflandre, 1959, 241–43; BM–Penard (04.5.9:42–45), (20.12.8:87–107); BM–Carlier (48.11.2:90–101, 149–59); BM–Murray (62.2.12:8–15, 53–56, 86–89, 121).]

33. Test composed of plates or scales
    a. Test comprises a double envelope; outer envelope of two valves . . . . Genus ***Clypeolina***
        [Species of *Clypeolina*: Kudo, 1966, 582.]
    b. Test comprises a single envelope 34

34. a. Plates regular, imbricated 35
    b. Plates irregular, non-imbricated 36
    c. Plates small, apparently absent in bright-field microscopy, visible in phase-contrast illumination 37

35. Plates regular, imbricated

a. Test hyaline; plates siliceous, in longitudinal rows; aperture terminal . . . . Genus ***Euglypha*** (p. 50) (Fig. 55, Nos. 37–39)

[Species of *Euglypha*: Leidy, 1879, 206–20; Sandon, 1927, 163; Deflandre, 1959, 253–55; Decloitre, 1962, 51–100; BM-Penard (04.5.9:155–62), (20.12.8:305–45); BM-Wallich (18.8.1:21–22, 36–37, 67–69, 560); BM-Carlier (48.11.2:1–41, 73–74, 309–16, 338–42, 360–67).]

b. Test hyaline; plates siliceous, in longitudinal rows; aperture ventral . . . . Genus ***Trinema*** (p. 56) (Fig. 69, Nos, 49 and 50)

[Species of *Trinema*: Sandon, 1927, 163; BM-Penard (04.5.9:231), (20.12.8:599–604); BM-Carlier (48.11.2:67–74, 90–101).]

c. Test brown; plates chitinous, in diagonal rows; aperture terminal to oblique . . . . Genus ***Assulina*** (p. 44) (Fig. 48, No. 29)

[Species of *Assulina*: Leidy, 1879, 224–26; Deflandre, 1969, 256; BM-Penard (04.5.9:39–40, 193), (20. 12.8:64–74); BM-Carlier (48.11.2:48–53, 57–58, 90–101).]

36. Plates irregular, non-imbricated

a. Test slightly elongated or broadly ovoid, with some extraneous particles . . . . Genus ***Heleopera***

[Species of *Heleopera*: Leidy, 1879, 162–64; Jung, 1942, 296–98; Deflandre, 1959, 248–49; BM-Penard (04.5.9:196–75), (20.12.8:368–89); BM-Carlier (48.11.2:32–33, 54–56, 90–101, 348–89).]

b. Test flask-shaped, rarely with any extraneous particles . Genus ***Nebela*** (p. 51) (Fig. 59, Nos. 40–46)

[Species of *Nebela*: Leidy, 1879, 145–61; Deflandre, 1936, 201–86; BM-Penard (04.5.9:190–204), (20.12.8:429–520); BM-Carlier (48.11.2:90–101, 270–342).]

37. Plates small, visible in phase-contrast illumination

a. Plates oval, not very regular, aperture oblique to sub-terminal . . . . Genus ***Corythion*** (p. 47) (Fig. 48, No. 30a and b)

[Species of *Corythion*: Deflandre, 1959, 256; Kudo, 1966, 584; BM-Penard (20.12.8:84–85, 120–21), BM-Carlier (48.11.2:54–56, 75–78).]

b. Plates circular, regular; aperture ventral . . . Genus ***Trinema*** (p. 56) (Fig. 69, Nos. 49 and 50)

[Species of *Trinema*: Sandon, 1927, 163; BM-Penard (04.5.9:231), (20.12.8:599–604); BM-Carlier (48.11.2:67–74, 90–101).]

38. CILIATA

a. Peristomal and adoral ciliature absent or inconspicuous 39

b. Peristomal or adoral ciliature large and conspicuous 55

39. Peristomal and adoral ciliature absent or inconspicuous

a. Body ciliature simple, apparently covering more or less the whole body 40

b. Body ciliature much reduced 53

40. Body ciliature simple, apparently covering ± the whole body

a. Cell more or less spherical to ovoid-ellipsoid 41

b. Cell elongated 46

41. Cell ±spherical to ovoid-ellipsoid
    a. With a long caudal cilium 42
    b. Without a long caudal cilium 43

42. With a long caudal cilium
    a. Caudal cilium obliquely posterior; mouth situated in a furrow on the ventral surface . . . . . . Genus ***Cryptochilium*** (p. 69) (Fig. 88, No. 66)
       [Species of *Cryptochilium*: Hoare, 1927, 154–222; Sandon, 1927, 180–81; Kahl, 1935, 337–38; Thompson and Evans, 1968, 369–74.]
    b. Caudal cilium directly posterior; mouth situated at the anterior apex; no ventral furrow . . . . . Genus ***Urotricha*** (p. 64) (Fig. 77, No. 60)
       [Species of *Urotricha*: Kahl, 1926, 197–438; 1927, 34–129; 1935, 56–61; BM–Perkins.]

43. Without a long caudal cilium
    a. Cell reniform; an anterior notch in the ventral surface . Genus ***Colpoda*** (p. 66) (Fig. 88, Nos. 61–63)
       [Species of *Colpoda*: Kahl, 1935, 274–81; Burt, 1940, 414–32; Curds, 1969, 26–27.]
    b. Cell more or less axially symmetrical 44
    c. Cell flattened; dorsal surface convex, ventral surface flat 45

44. Cell more or less axially symmetrical
    a. Mouth at anterior apex; contractile vacuole large, posterior . . . . Genus ***Holophrya*** (p. 60) (Fig. 77, No. 55)
       [Species of *Holophrya*: Kahl, 1926, 197–438; 1927, 34–129; 1935, 47–53; Lepsi, 1959, 254–60.]
    b. Mouth 1/4 way down the ventral side; contractile vacuole large, posterior . . . . Genus ***Dichilium*** (p. 69) (Fig. 88, No. 68)
       [Species of *Dichilium*: Kahl, 1935, 324–25.]
    c. Mouth 1/4 way down the ventral side; contractile vacuole inconspicuous, not necessarily posterior . . . . Genus ***Glaucoma*** (p. 69) (Fig. 88. No. 69)
       [Species of *Glaucoma*: Kahl, 1935, 329–32; Curds, 1969, 29–32; BM–Perkins.]

45. Cell dorso-ventrally flattened
    a. With few to many contractile vacuoles scattered through the body . . . . Genus ***Chilodonella***
       [Species of *Chilodonella*: Kahl, 1935, 235–42; Curds, 1969, 24–25.]
    b. With one large contractile vacuole opening ventrally, with some accessory vacuoles. . . . . . . Genus ***Nassula***
       [Species of *Nassula*: Pritchard, 1861, 625–26; Kahl, 1935, 216–21.]

46. Cell elongated
    a. Mouth at the anterior apex 47
    b. Mouth not at the anterior apex 50

47. Mouth at the anterior apex
    a. Mouth slit-like on an anterior ridge 48
    b. Mouth circular. 49

48. Mouth slit-like on an anterior ridge
    a. Mouth as wide as the body . . . . . . Genus ***Spathidium*** (p. 64) (Fig. 77, No. 59)
        [Species of *Spathidium*: Kahl, 1926, 197–438; 1935, 150–65; Wenzel, 1955; 515–40; Curds, 1969, 16–17.]
    b. Mouth narrow on a truncated neck . . . . Genus ***Enchelys*** (p. 60) (Fig. 77, No. 54)
        [Species of *Enchelys*: Pritchard, 1861, 607–08; Kahl, 1935, 96–101.]

49. Mouth circular
    a. Mouth overhung by an ectoplasmic lip-like projection . Genus ***Chilophrya*** (p. 57) (Fig. 77, No. 51)
        [Species of *Chilophrya*: Kahl, 1926, 197–438; 1927, 34–129; 1935, 56–64.]
    b. Mouth at the end of a long contractile proboscis . . Genus ***Lacrymaria***
        [Species of *Lacrymaria*: Kahl, 1927, 34–129; 1935, 90–95.]
    c. Mouth on a non-ciliated cone-like anterior process . Genus ***Lagynophrya*** (p. 64) (Fig. 77, No. 56)
        [Species of *Lagynophrya*: Kahl, 1927, 34–129; 1935, 83–85.]
    d. Mouth on a narrow truncated "head" with longitudinal furrows . . . . Genus ***Chaenea*** (p. 60) (Fig. 77, No. 52)
        [Species of *Chaenea*: Kahl, 1927, 34–129; 1935, 103–07; Curds, 1969, 18–19.]

50. Mouth not at the anterior apex
    a. Body elongate-reniform, with a ventral notch . . Genus ***Colpidium*** (p. 66) (Fig. 88, No. 65)
        [Species of *Colpidium*: Kahl, 1935, 330–34; Curds, 1969, 32–33; Foissner, 1969, 17–25.]
    b. Body elongate-ellipsoid (cigar-shaped). . . . Genus ***Paramecium***
        [Species of *Paramecium*: Wenrich, 1928, 275–82; Kahl, 1935, 289–95; Kudo, 1966, 902–06; Curds, 1969, 34–36; BM–Perkins.]
    c. Body long and parallel-sided (vermiform) . . . Genus ***Spirostomum***
        [Species of *Spirostomum*: Kahl, 1926, 197–438; 1935, 437–40; BM–Perkins.]
    d. Anterior of the body tapers to a point. 51

51. Anterior of the body tapers to a point
    a. Mouth at the bottom of a ventral oral groove; with a caudal cilium . . . . Genus ***Philaster*** (p. 72) (Fig. 88, No. 70)
        [Species of *Philaster*: Kahl, 1935, 364–66.]
    b. Without an oral groove; without a caudal cilium 52

52. Without an oral groove or caudal cilium
    a. Mouth circular. . . . . Genus ***Dileptus*** (p. 60) (Fig. 77, No. 53)
        [Species of *Dileptus*: Kahl, 1935, 205–09; Golinska, 1971, 367–68.]
    b. Mouth slit-like; body very flat (leaf-like), with a ventral hyaline border . . . . Genus ***Loxophyllum*** (p. 64) (Fig. 77, No. 58)
        [Species of *Loxophyllum*: Kahl, 1935, 195–203; Vuksanovic, 1959, 165–78.]

c. Mouth slit-like; body flask-shaped, without a hyaline border . . . . Genus ***Litonotus*** (p. 64) (Fig. 77, No. 57)

[Species of *Litonotus*: Kahl, 1926, 197–438; 1935, 186–95.]

53. Body ciliature much reduced

a. Body dorso-ventrally compressed; ciliature (cirri) on the ventral surface only; a single contractile vacuole . Genus ***Aspidisca*** (p. 75) (Fig. 97, No. 74)

[Species of *Aspidisca*: Kahl, 1935, 642–50; Brown, 1968, 245–52; Curds, 1969, 63–65.]

b. Body laterally compressed; ciliature (cilia) on both surfaces; two contractile vacuoles . . . . Family MICROTHORACIDAE 54

54. MICROTHORACIDAE

a. Surface with distinct longitudinal furrows; mouth left side of ventral ridge, without stiff ectoplasmic lip . Genus ***Leptopharynx*** (***Trichopelma***) (p. 66) (Fig. 88, No. 64)

[Species of *Leptopharynx*: Kahl, 1935, 300–04.]

b. Surface without longitudinal furrows; mouth right side of ventral ridge, with stiff ectoplasmic lip . . Genus ***Microthorax***

[Species of *Microthorax*: Kahl, 1935, 306–09.]

55. Peristomal or adoral ciliature large and conspicuous

a. Body ciliature of ordinary cilia only 56

b. Body ciliature includes large bristle-like cirri 57

56. Body ciliature of ordinary cilia only

a. Cell long and cylindrical; mouth at the anterior apex (N.B. the cell swims backwards) . . . . Genus ***Vorticella*** (telotroch) (p. 72) (Fig. 97, No. 72b)

[Species of *Vorticella*: Noland and Finley, 1931, 81–132; Kahl, 1935, 713–34; Curds, 1969, 38–50; BM–Perkins.]

b. Cell ovoid; mouth at least half-way down the body . Genus ***Cyclidium*** (p. 69) (Fig. 88, No. 67)

[Species of *Cyclidium*: Hoare, 1927, 154–122; Kahl, 1935, 375–82; Curds, 1969, 37; Berger and Thompson, 1960, 256–62.]

57. Body ciliature includes cirri

a. Cell spherical; with an equatorial girdle of cirri . . Genus ***Halteria*** (p. 72) (Fig. 97, No. 73)

[Species of *Halteria*: Kahl, 1935, 504–07; Szabo, 1935, 307–17; Tamar, 1968; 177–83; BM–Perkins.]

b. Cell dorso-ventrally flattened; cirri on the ventral surface only . . . . Order HYPOTRICHIDA 58

[Classification of HYPOTRICHIDA: Borror, 1972, 1–22.]

58. HYPOTRICHIDA

a. Body long and spirally twisted; rows of cirri follow the twists . . . . Genus ***Urostrongylum***

[Species of *Urostrongylum*: Kahl, 1935, 556–62.]

b. Body outline oval (not twisted) with a pointed posterior; cirri in diagonal spiral rows . . . . . . Genus ***Hypotrichidium***

[Species of *Hypotrichidium*: Kahl, 1935, 542–43.]

c. Body outline more or less circular, without marginal cirri — Genus **Euplotes** (p. 75) (Fig. 97, No. 75)

[Species of *Euplotes*: Kahl, 1935, 621–43; Tuffrau, 1960, 1–77; Borror, 1968, 802–08; Curds, 1969, 70–73; Carter, 1972, 466–91.]

d. Body outline elongate-oval; marginal cirri in longitudinal rows present 59

59. With marginal cirri in longitudinal rows

a. Without differentiated frontal cirri; the rows of ventral cirri extend into the frontal field 60

b. With 3 to 8 (rarely many) differentiated frontal cirri 61

60. Without differentiated frontal cirri

a. Body ovoid/ellipsoid . . . . Genus **Keronopsis**

[Species of *Keronopsis*: Kahl, 1935, 571–78; Ruhmenkorf, 1935, 255–98.]

b. Body with thin head and tail, swollen in the middle . Genus **Epiclintes**

[Species of *Epiclintes*: Kahl, 1935, 562–70.]

61. With differentiated frontal cirri

a. 5 individual ventral cirri (none in rows); 8 frontal cirri, 5 anal cirri . . . . Genus **Oxytricha** (p. 75) (Fig. 104, Nos. 78–80)

[Species of *Oxytricha*: Kahl, 1935, 599–604; Curds, 1969, 66–68.]

b. 1 row of ventral cirri with a few scattered individuals; 5 or 6 frontal cirri; 5 anal cirri . . . . . Genus **Gastrostyla**

[Species of *Gastrostyla*: Kahl, 1935, 593–96.]

c. 1 or 2 *short* rows of ventral cirri (anterior to the mouth); 8 frontal cirri; 4 or 5 anal cirri . . . . . Genus **Gonostomum** (p. 75) (Fig. 104, No. 76)

[Species of *Gonostomum*: Kahl, 1935, 597–98.]

d. 2 or more complete rows of ventral cirri; 3 frontal cirri; without anal cirri . . . . Genus **Uroleptus** (p. 78) (Fig. 104, No. 82)

[Species of *Uroleptus*: Pritchard, 1861, 637; Kahl, 1935, 547–51.]

e. 2 or more complete rows of ventral cirri; 3 or more frontal cirri; 5 or more anal cirri 62

62. With 2 or more complete rows of ventral cirri; 5 or more anal cirri

a. With 3 frontal cirri 63

b. With more than 3 frontal cirri 64

63. With 3 frontal cirri

a. 2 rows of ventral cirri (often one or more individual ventral cirri also) . . . . Genus **Holosticha** (p. 75) (Fig. 104, No. 77)

[Species of *Holosticha*: Peschkowsk, 1926, 31–57; Kahl, 1935, 579–89.]

b. 3 rows of ventral cirri (no individual ventral cirri) . Genus **Onychodromus**

[Species of *Onychodromus*: Kahl, 1935, 620–21.]

64. With more than 3 frontal cirri

a. 2 rows of ventral cirri and 3 or 4 individual ventral cirri — Genus **Pleurotricha** (p. 78) (Fig. 104, No. 81)

[Species of *Pleurotricha*: Kahl, 1935, 593.]

b. 4 to 10 rows of ventral cirri but no individual ventral cirri — Genus **Urostyla** (p. 78) (Fig. 104, No. 83)

[Species of *Urostyla*: Pritchard, 1861, 643; Kahl, 1935, 562–68.]

VII. ASSOCIATION ANALYSIS

1. *Direct and inverse analyses*

The raw data results of this survey of terrestrial Protozoa constituted a presence–absence matrix of 83 species in 97 sites. These data were subjected to direct and inverse association analyses by the method described on p. 14–16.

The direct analysis of sites on the basis of species occurrence is shown as a dendrogram in Fig. 110. The analysis ran to 12 stages and showed considerable "chaining" throughout, indicating the considerable heterogeneity in the composition of the fauna observed in different sites. This was probably an inevitable result of the policy of the survey which was deliberately designed to include investigation of as wide a range of habitats as possible. The early stages of the analysis produced, as divider species, the ciliates *Colpoda cucullus* and *Colpoda steini* which occur almost exclusively in acid vegetated habitats and whose distributions are entirely north of lat. 60° S. As a result, vegetated sub-Antarctic sites are split off from all other sites and are concentrated on the left-hand side of the dendrogram (Fig. 110). The middle stages of the analysis produced, as divider species, the testate amoebae *Corythion dubium*, *Pseudodifflugia* sp. and *Difflugia lucida*, which showed a preference for Antarctic acid soils and peats bearing moss vegetation. Sites representing these habitats thus became concentrated in the centre of the dendrogram. The remaining sites represented mineral and alkaline guano habitats; these became concentrated on the right-hand side of the dendrogram and were segregated by *Vorticella microstoma* and *Bodo saltans*, as divider species, which were specific to guano-influenced habitats.

The dendrogram resulting from the inverse analysis is shown in Fig. 111. The analysis ran to 24 stages and showed an even stronger tendency to "chaining". The large number of stages was made necessary by the fact that eight of the stages segregated only one species. These were either rare species, such as *Valkampfia* sp. (stage 22) and *Nebela dentistoma* (stage 23), or more common species such as *Spongomonas uvella* (stage 13) and *Dileptus* sp. (stage 19), whose distributions were too poorly correlated with those of other species for them to be included in larger groups by the analysis technique. It proved possible, however, to allocate each of these species to the group, whose distribution it most closely resembled, by the inspection technique described on p. 14–16, except for the flagellate species *Sainouron mikroteron*, a pioneer colonizer of volcanic tephra on Deception Island, whose distribution was so dissimilar to that of any other species that it was left as a "community" of one species.

2. *Community–habitat matrix*

The results of the direct and inverse association analyses were combined to form a community–habitat matrix by the method described on p. 14–16. The resulting matrix is shown in Fig. 112. The black areas of the matrix indicate the tendencies of particular groups of species to occur in particular groups of sites, the groups of species and sites being aggregated into eight communities (labelled A to H) and six habitat classes (labelled I to VI). By inspection of the data on the physical properties and location of each site in each of the habitat classes, it was possible to characterize each habitat class according to its geographical zone, its pH and organic content, the nature of any vegetation cover and the presence or absence of enrichment by animal guano.

The species composition of each community was as follows:

COMMUNITY A. Protozoa specific to alkaline animal guano habitats; a community of a restricted number of specialized flagellates and ciliates.

Bodo saltans
Tetramitus rostratus
Spathidium spp.
Philaster sp.
Vorticella microstoma

COMMUNITY B. Protozoa specific to neutral mineral habitats; a single species, apparently a colonizer of mineral habitats, not occurring outside them.

Sainouron mikroteron

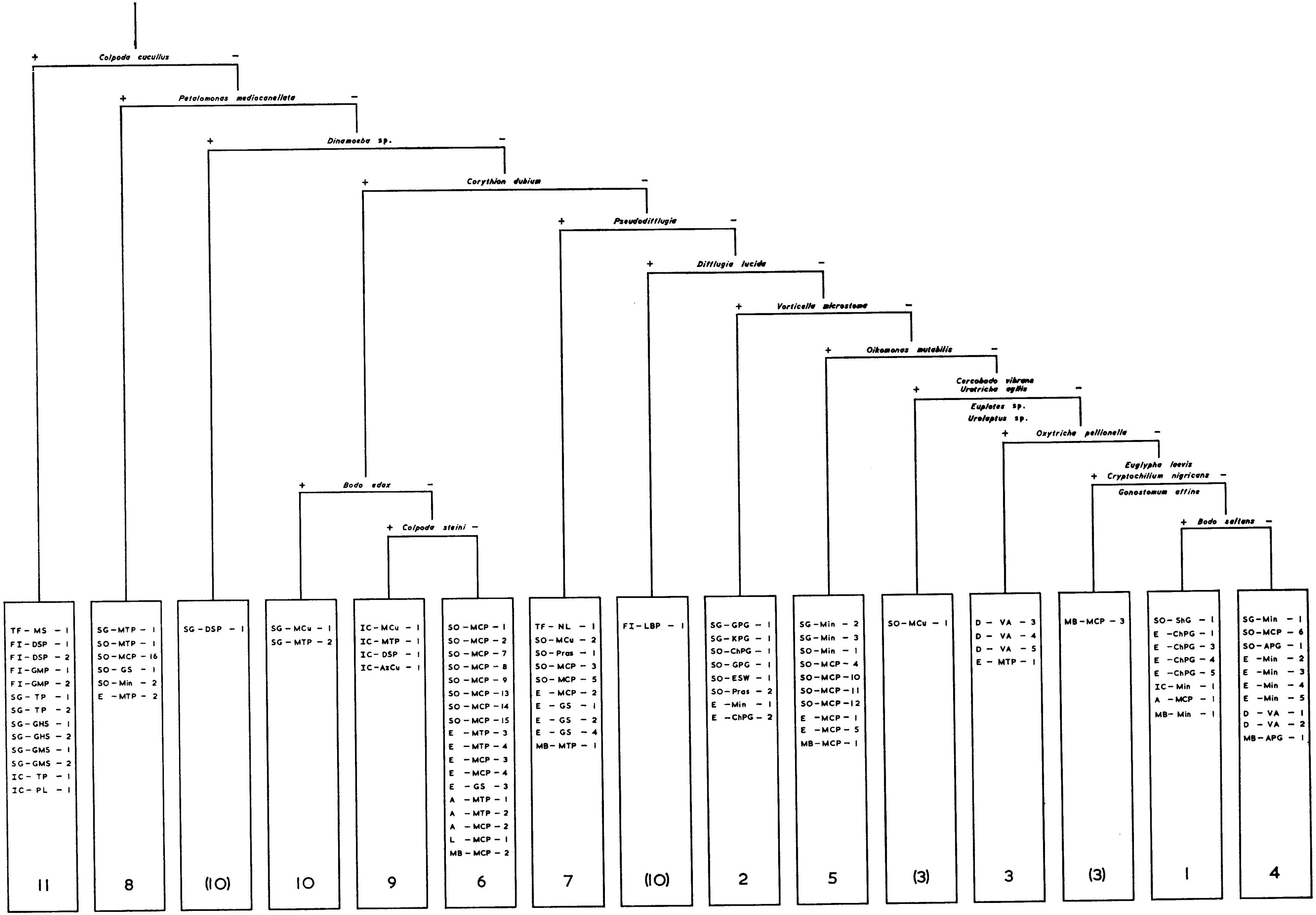


FIGURE 110

Dendrogram of an association analysis of 97 sites on the basis of their protozoan fauna.
]

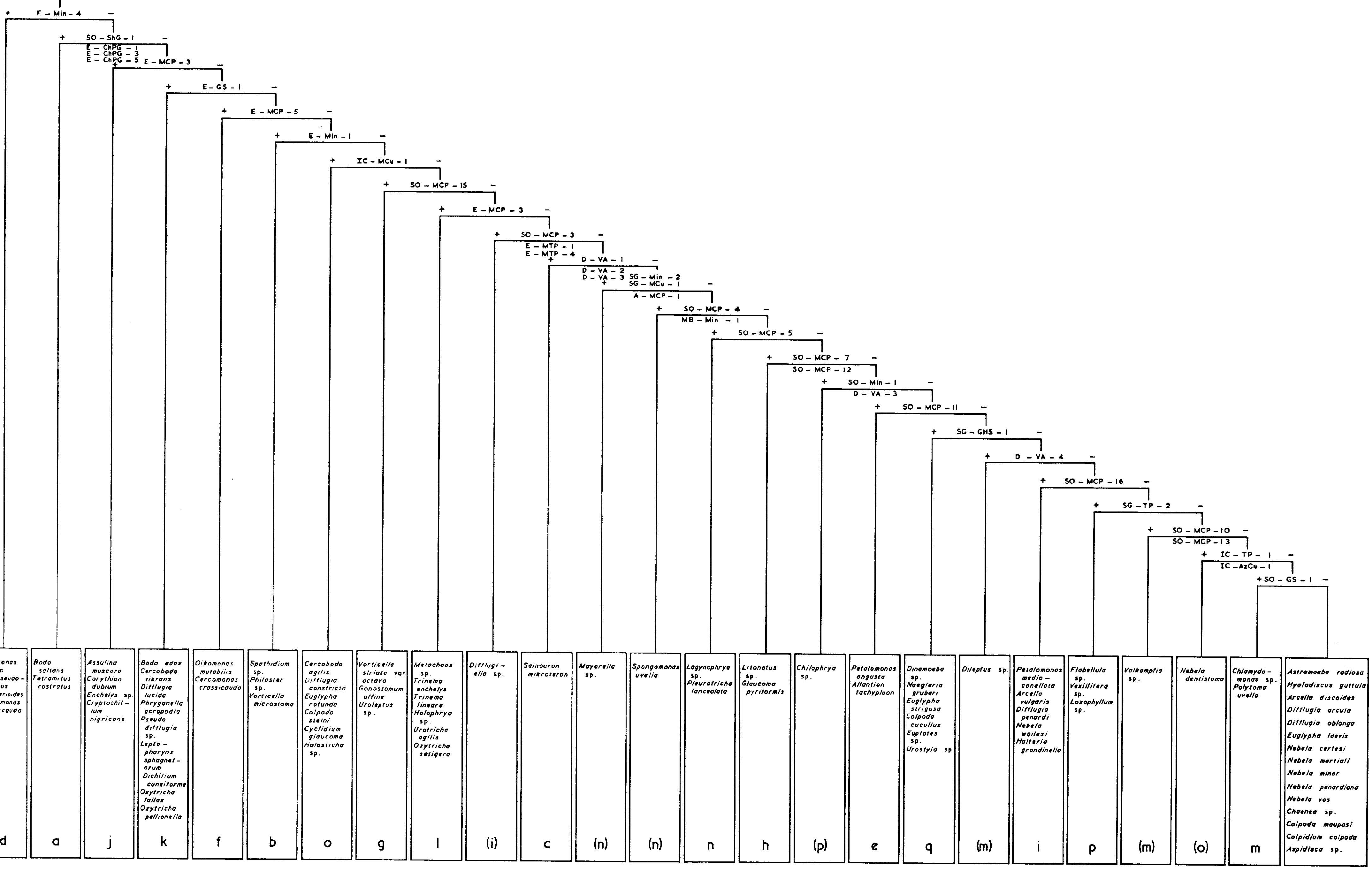
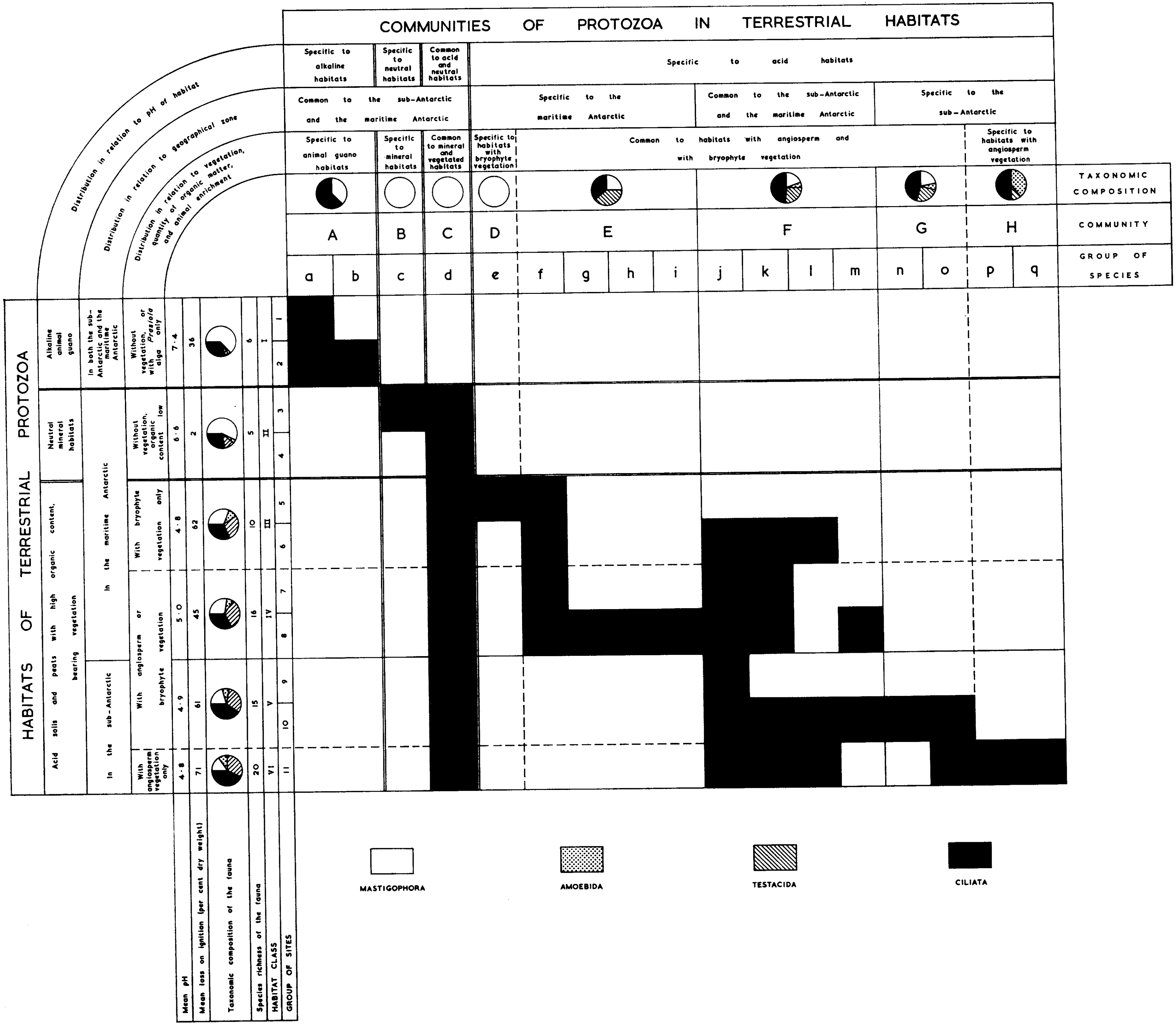


FIGURE 111

Dendrogram of an association analysis of 83 species of Protozoa on the basis of their occurrence in 97 sites.


COMMUNITIES OF PROTOZOA IN TERRESTRIAL HABITATS
Specific to alkaline habitats
Specific to neutral habitats
Common to acid and neutral habitats
Specific to acid habitats
Common to the sub-Antarctic and the maritime Antarctic
Specific to the maritime Antarctic
Common to the sub-Antarctic and the maritime Antarctic
Specific to the sub-Antarctic
Specific to animal guano habitats
Specific to mineral habitats
Common to mineral and vegetated habitats
Specific to habitats with bryophyte vegetation
Common to habitats with angiosperm and with bryophyte vegetation
Specific to habitats with angiosperm vegetation
TAXONOMIC COMPOSITION
COMMUNITY
A
B
C
D
E
F
G
H
GROUP OF SPECIES
a
b
c
d
e
f
g
h
i
j
k
l
m
n
o
p
q
Distribution in relation to pH of habitat
Distribution in relation to geographical zone
Distribution in relation to vegetation, quantity of organic matter, and animal enrichment
HABITATS OF TERRESTRIAL PROTOZOA
Alkaline animal guano
Neutral mineral habitats
Acid soils and peats with high organic content, bearing vegetation
In both the sub-Antarctic and the maritime Antarctic
In the maritime Antarctic
In the sub-Antarctic
Without vegetation, or with Prasiola alga only
Without vegetation, organic content low
With bryophyte vegetation only
With angiosperm or bryophyte vegetation
With angiosperm vegetation only
Mean pH
7·4
6·6
4·8
5·0
4·9
4·8
Mean loss on ignition (per cent dry weight)
36
2
62
45
61
71
Taxonomic composition of the fauna
Species richness of the fauna
6
5
10
16
15
20
HABITAT CLASS
I
II
III
IV
V
VI
GROUP OF SITES
1
2
3
4
5
6
7
8
9
10
11
MASTIGOPHORA
AMOEBIDA
TESTACIDA
CILIATA

Community C. Protozoa common to acid and neutral, vegetated and mineral habitats; a community of flagellate species with wide ecological amplitudes, occurring in all habitats except the most alkaline.

Oikomonas termo
Polypseudopodius bacterioides
Cercomonas longicauda

Community D. Protozoa specific to maritime Antarctic habitats with bryophyte vegetation; a community of muscicolous flagellates.

Petalomonas angusta
Allantion tachyploon

Community E. Protozoa specific to maritime Antarctic vegetated habitats; a community of flagellates, testates and ciliates occurring in both moss peats and grass soil.

Oikomonas mutabilis
Cercomonas longicauda
Petalomonas mediocannellata

Arcella vulgaris
Difflugia penardi
Difflugiella sp.
Nebela wailesi

Litonotus sp.
Glaucoma pyriformis
Vorticella striata
Halteria grandinella
Gonostomum affine
Uroleptus sp.

Community F. Protozoa common to sub-Antarctic and maritime Antarctic vegetated habitats; a large diverse community of flagellates, rhizopods and ciliates in all types of vegetated habitats.

Chlamydomonas sp.
Polytoma uvella
Bodo edax
Cercobodo vibrans
Metachaos sp.
Valkampfia sp.

Assulina muscora
Corythion dubium
Difflugia lucida
Phryganella acropodia
Pseudodifflugia sp.
Trinema enchelys
Trinema lineare

Dileptus sp.
Enchelys sp.
Holophyra sp.
Urotricha agilis
Leptopharynx sphagnetorum
Cryptochilium nigricans
Dichilium cuneiforme
Oxytricha fallax
Oxytricha pellionella
Oxytricha setigera

Community G. Protozoa specific to sub-Antarctic vegetated habitats; a community of flagellates, Rhizopoda and ciliates whose ranges do not extend south of lat. 60° S.

Cercobodo agilis
Spongomonas uvella
Mayorella sp.

Difflugia constricta
Euglypha rotunda
Nebela dentistoma

Lagynophrya sp.
Colpoda steini
Cyclidium glaucoma
Holosticha sp.
Pleurotricha lanceolata

Community H. Protozoa specific to sub-Antarctic habitats with angiosperm vegetation; a community of rhizopods and ciliates restricted to floristically rich habitats.

Dinamoeba sp.
Flabellula sp.
Naegleria gruberi
Vexillifera sp.

Euglypha strigosa

Chilophyra sp.
Loxophyllum sp.
Colpoda cucullus
Euplotes sp.
Urostyla sp.

The 15 species of Protozoa which were too rare or whose distributions were too iregular for inclusion in this classification into communities were:

Astramoeba radiosa
Hyalodiscus guttula
Arcella discoides

Nebela certesi
Nebela martiali
Nebela minor

Chaenea sp.
Colpoda maupasi
Colpidium colpoda

Difflugia arcula
Difflugia oblonga
Euglypha laevis
Nebela penardiana
Nebela vas
Aspidisca sp.

It seems likely that the failure to classify these according to habitat preference is not a reflection of any biological properties of the species but a consequence of insufficient data. Further and more intensive investigations would certainly enable conclusions to be reached on the ecological tolerances of these species.

3. *Conclusions*

It is clear from the results of the association analyses that, despite the immense heterogeneity of the terrestrial protozoan fauna of sub-Antarctic and maritime Antarctic islands, significant trends can be detected relating the distribution of species to habitat factors. Using pH and the nature of the substratum as critera, three types of habitat were detected, each having a substantially discrete fauna:

Animal guano, alkaline, intermediate organic content (habitat class I).
Mineral materials, neutral, low organic content (habitat class II).
Vegetated habitats, acid, high organic content (habitat classes III–VI).

Habitat classes I and II each appear to have a similar fauna whether they occur in the maritime Antarctic or the sub-Antarctic (the mineral habitat sites incidentally very nearly all occur in the maritime Antarctic), suggesting that the physical and chemical nature of the substratum is a more important factor determining the composition of the protozoan fauna than are climatic factors.

Guano habitats (class I) have a restricted fauna, the average species diversity being 6; these are coprozoic, polysaprobic species (community A), which are not found outside areas enriched by marine birds or mammals.

Mineral habitats appear not to have an exclusive fauna (except for *Sainouron mikroteron* as a pioneer colonizer); they are characterized by a restricted fauna (mean species diversity is 5), in which community C is the dominant constituent, this community also occurring in all classes of vegetated habitat.

The vegetated habitats (classes III, IV, V and VI) are differentiated by their geographical location and whether the vegetation is bryophyte or angiosperm. They all show considerably greater species diversity than mineral and guano habitats (10–20). In general, sub-Antarctic sites have a more diverse fauna than maritime Antarctic sites and sites with angiosperm vegetation a more diverse fauna than those with bryophytes.

Using the model that each protozoan species will have a certain southern limit of distribution and that this will vary among different species, depending on their specific environmental tolerances, it might reasonably be predicted that the ranges of some protozoan species will extend to include the sub-Antarctic but not farther south. Among the Protozoa occurring in vegetated habitats, this proves to be the case; communities G and H constitute a distinctive fauna of 21 species (mostly common temperate species), whose ranges do not appear to extend south of lat. 60° S. These include notably the ciliates *Colpoda cucullus* and *Colpoda steini* and 12 other testate and ciliate species. The occurrence of four species of naked amoeba in community H, in conjunction with their almost total absence from maritime Antarctic habitats, appears significant. Possibly the ranges of these species are limited by the occurrence of angiosperm vegetation, rather than climatic factors, to provide suitable habitats.

There also appears to be a fauna of vegetated habitats that is well established in the maritime Antarctic, comprising 15 species (communities D and E), which is absent from the sub-Antarctic. There are also common temperate species, so their absence from the sub-Antarctic sites is surprising; possibly they are competitively inhibited from becoming established there by the presence of the diverse fauna of communities G and H.

In addition, there is a large fauna of 23 species of flagellates, rhizopods and ciliates (community F), which have wide ecological amplitudes and occur in vegetated habitats, both bryophyte and angiosperm, in both the sub-Antarctic and maritime Antarctic. As might be expected, several of the commonest species in temperate regions belong to this community: *Assulina muscora*, *Corythion dubium*, *Phryganella acropodia* and *Trinema* spp.; *Dileptus* sp., *Leptopharynx sphagnetorum* and *Oxytricha* spp.

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APPENDIX

Glossary

aboral: in reference to testate amoebae; the portion of the test at the opposite pole to the aperture.

abundant: occurring in large numbers, but not necessarily with high frequency, in a given locality.

adoral: in reference to testate amoebae; the portion of the test immediately surrounding the aperture.

aperture: in reference to testate amoebae; the hole in the test through which pseudopodia protrude during feeding and locomotion.

axenic culture: culture in a totally sterile medium; a culture which contains no living organisms except the one being cultured.

Chrysomonadida: minute phytoflagellates which lack a definite cell wall, possess non-green chromatophores and only one or two flagella.

Ciliata: Protozoa which possess cilia or cirri at some stage of the life cycle; they are always multinucleate, with nuclear polymorphism, and reproduce asexually by transverse binary fission (rarely by budding).

cilium: a thread-like or bristle-like organelle, borne at the body surface, which is used in locomotion and feeding. The possession of cilia, frequently in very large numbers, is a characteristic (though not diagnostic) feature of Protozoa belonging to the class Ciliata.

cirri: compound cilia; they usually take the form of stiff bristle-like projections; they are possessed by Protozoa belonging to the ciliate orders Oligotrichida and Hypotrichida.

common: an imprecise term usually employed to describe the occurrence of an organism in a given locality in which it is both abundant and frequent.

cosmopolitan: in reference to the distribution of a species; occurring in all regions of the world, not necessarily in all types of habitat.

dentate: in reference to the apertures of certain testate amoebae; having a toothed jagged appearance.

determinate: in reference to the pseudopodia of naked amoebae; having a more or less fixed maximum size and shape to which the pseudopodia are extended then retracted. Determinate pseudopodia *do not* determine the shape of the amoeba body or control the direction of locomotion.

Euglenoidida: phytoflagellates possessing an elongated body and usually one flagellum; chromatophores, if present are green.

flagellate: protozoan belonging to the class Mastigophora.

flagellum: an extended thread-like organelle, borne at the body surface by Mastigophora, which is commonly used for locomotion and feeding. Flagella resemble cilia in fine structure but are distinguished by being longer, relative to body size, and are nearly always fewer in number.

frequent: referring to the occurrence of an organism in a given locality: having a high probability of being present in a sample taken at random.

glabrous: in reference to testate amoebae; having a test without spines. When a testate species which is normally spined occurs in soil, it almost always does so as a glabrous variety of that species.

Gymnostomatida: holotrichous ciliates in which the cytostome opens directly on the body surface, with no specialized oral cilia.

Holotricha: ciliates which show uniform ciliation over the body surface.

Hymenostomatida: holotrichous ciliates in which the cytostome is located in a buccal cavity associated with which is an undulating membrane and three adoral zone membranellae.

Hypotrichida: dorso-ventrally flattened ciliates in which cilia and cirri are restricted to the ventral surface and there is a large, well-developed peristomal membrane.

imbricated: in reference to the scales of testate amoebae; overlapping like tiles on a roof.

indeterminate: in reference to the pseudopodia of naked amoebae; not having a fixed maximum size or shape. Indeterminate pseudopodia can be formed indefinitely so controlling the direction of locomotion; they *do* determine the shape of the amoeba body.

Mastigophora: Protozoa which possess one or more flagella, are nearly always mononucleate and reproduce asexually by longitudinal binary fission.

monoxenic culture: culture in a medium which contains one species of living organism (as food supply) in addition to the species being cultured.

naked amoeba: a rhizopod in which the cytoplasm is not contained within any form of shell or test.

Oligotrichida: ciliates in which the body ciliation is reduced or absent, but the adoral zone membranellae are well developed.

oval: in reference to body shape; being parallel-sided with rounded ends (sausage-shaped).

ovoid: in reference to body shape; being rounded but having one end more pointed than the other (egg-shaped).

Peritrichida: ciliates, frequently sessile, which have an expanded anterior disc bearing prominent adoral cilia.

Phytomonadida: phytoflagellates which possess a cellulose cell wall and green chromatophores; they are sometimes colonial.

Polymastigida: zooflagellates possessing three to eight flagella.

Protomonadida: zooflagellates without a rigid pellicle, so they may occasionally assume an amoeboid form, with one or two flagella; they are sometimes colonial.

pseudopodium: a temporary projection of part of the cytoplasm of those Protozoa which do not possess a rigid pellicle. Pseudopodia are characteristic organelles of Rhizopoda but many Mastigophora are also able to form them.

Rhizopoda: Protozoa possessing pseudopodia which they use as the principal organelles for feeding and, in many species, also for locomotion. Non-marine species reproduce asexually by binary fission.

Suctorida: ciliates which possess tentacles but no cilia in the adult stage, but have a ciliated larval stage.

telotrich: the motile stage of a sessile peritrich.

test: the shell of testate amoebae. The basis of tests of all species is a chitinous or keratinous membranous envelope surrounding the cytoplasm; it usually has a single aperture through which pseudopodia protrude during locomotion and feeding.

Testacida: non-marine Rhizopoda in which the cytoplasm is enveloped by a single-chambered test.

Trichostomatida: holotrichous ciliates in which the cytostome is located in a non-ciliated buccal cavity.

ubiquitous: in reference to the distribution of a species; occurring in all types of habitat, not necessarily in all regions of the world.

uroid: a group of root-like cytoplasmic threads occurring at the posterior end of certain species of naked amoebae.