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The Freshwater Lakes of Signy Island and Their Fauna

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ANTARCTIC ECOSYSTEMS

The freshwater lakes of Signy Island and their fauna

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Introduction

Prior to 1962 work on freshwater within the British Sector of the Antarctic had been confined to the collection of specimens and their subsequent taxonomic evaluation. Collections were made by such expeditions as the Scottish National Antarctic Expedition 1902–04, the various *Discovery* Investigations in this region 1925–37, the British Graham Land Expedition 1934–37 and the Falkland Islands Dependencies Survey 1945–62. During the 1961/1962 summer season an ecological investigation of the freshwater lakes of Signy Island, South Orkney Islands, was started. This paper is an interim report on that work.

Signy Island and its drainage

Signy Island is one of the South Orkney Islands, a small group situated on the Scotia Arc in latitude 60° 43′ S, longitude 45° 38′ W. They lie within the Maritime Antarctic Region (Holdgate 1964). Signy Island is very small, being 19·94 km^2 in area. Although the land seldom rises above 240 m the lowland region is small (figure 65). The island is composed of regionally metamorphosed sediments, now largely garnetiferous quartz-mica-schists, with subordinate amphibolites and marbles (Matthews, Maling & Adie 1967). A more detailed account of the general topography and geology is given by Holdgate (this Discussion, p. 173).

The amount of precipitation falling on the island is small although the frequency of precipitation is high (Pepper 1954). Over ice-cap, glaciers and ice fields ablation is taking place at a far greater rate than deposition and the amount of water available during the summer is greater than the precipitation figures suggest.

The drainage over the lowland areas is poor. The glacial debris, overlying most of the region, is in various stages of weathering and the resulting substrate is very unstable and is constantly moving. Water running over most areas of the lower slopes and valley floors is of insufficient volume, force and frequency to form and maintain anything other than runnels in this unstable ground and where runnels are formed, excavation is limited by permanently frozen ground lying within perhaps 60 cm of the surface. (There are five areas on the island where the natural topography of the ground collects and confines the drainage water to a very narrow course, thereby forming a stream.) Over large areas of the lowland, frost shattering and solifluxion have reduced the substrate to a mineral soil or an aggregate of mineral soil and rock particles (Holdgate, Allen & Chambers 1967). The clay-like properties of the fine particles hinder horizontal drainage; the layer of permafrost prevents percolation into the subsoil. Water cascading down the steep upper slopes is not collected, therefore, into a stream drainage system. It must percolate through or run over ground already waterlogged. In the vicinity of ice fields and semipermanent snowbanks well defined seepage paths persist.

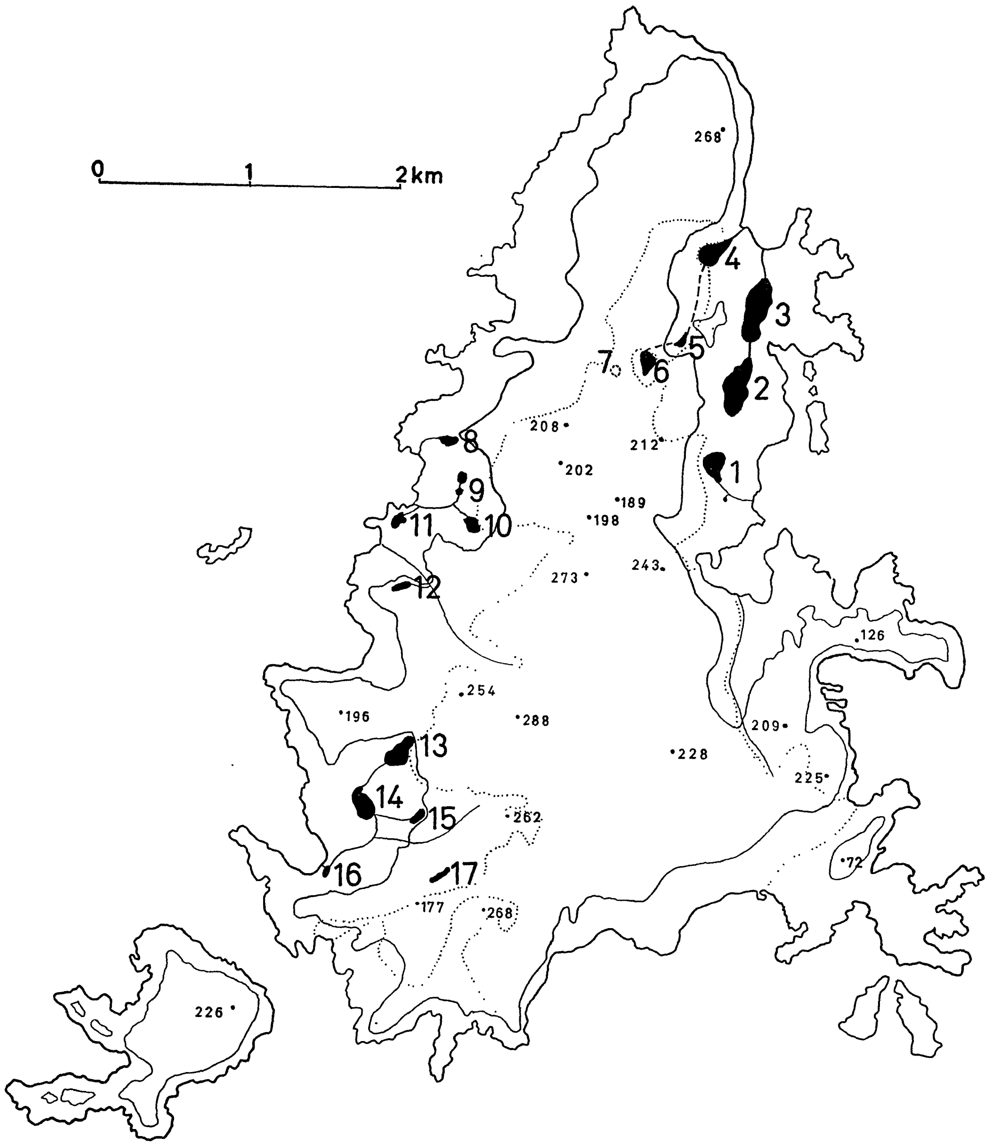

FIGURE 65. Signy Island, South Orkney Islands and its lake system. The lowland area is defined by the 60 m contour; the spot heights are in metres. The dotted line indicates the extent of permanent ice cover. For details of revised lake numbers see Appendix, p. 362.

The lakes

Small lakes occupy the lower areas of glacially overdeepened valleys. It is difficult to define the concepts of 'lake', 'pond' and 'puddle' for polar regions. The terminology of Røen (1962) is considered the most apposite. A lake is defined as a 'lentic, permanent, freshwater locality which never freezes solid'. There are 16 lakes on Signy Island, therefore, although the smallest has a surface area of only 500 m². The largest lake has a surface area of approximately 41 000 m². The lakes conform to a basic pattern; a steep-sided trough surrounded by a shelf of varying width. The trough is 3 to 6 m deep in the majority of the lakes and has a floor of gravel and silt broken by the occasional outjutting rock. The depth of the shelf area rarely exceeds 1 m and its substrate is a continuation of the surrounding scree and ground moraine—boulders, rocks and stones interspersed in some areas with patches of gravel and silt.

Detailed geological work is necessary before the exact origins of the various lakes can be described with certainty. General observation, however, suggests that at least four forms of glacial activity were involved in their formation. The body of water of one lake is held in its present position by the terminal wall of the Spindrift Col icefield (Lake 5, figure 65). The lake is, therefore, proglacial. (At the time of the 1947–50 survey of the island

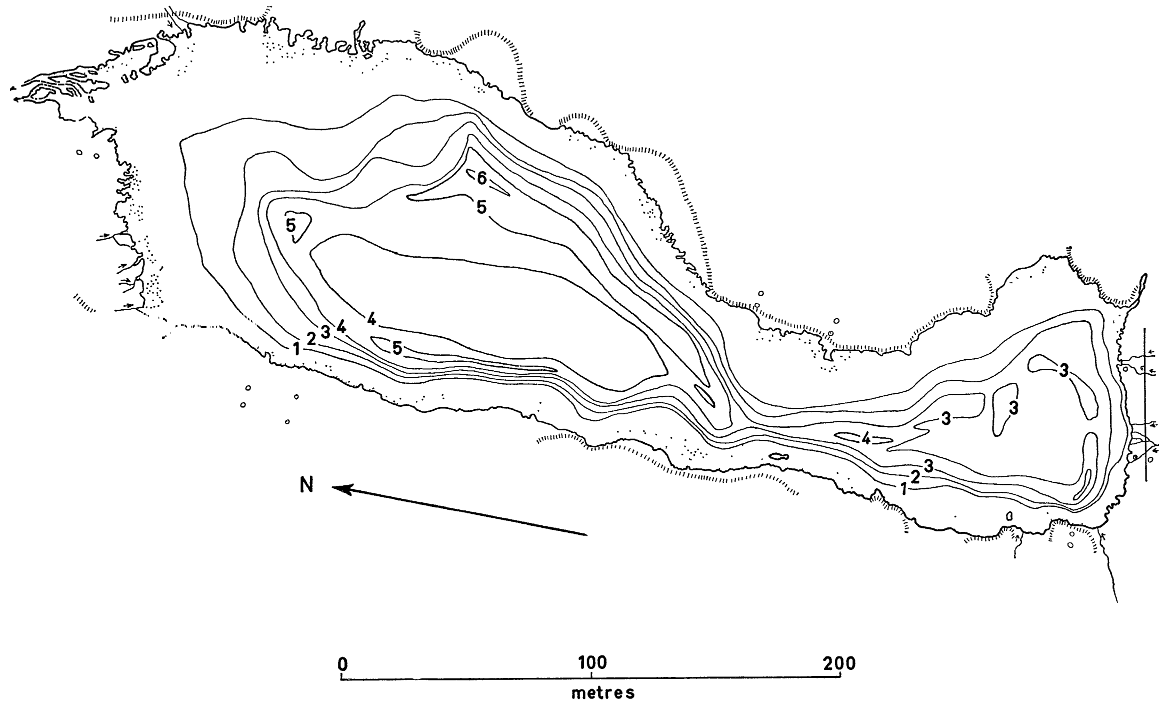

FIGURE 66. Lake 3, Signy Island. The depth contours recorded are given in metres.

(Matthews *et al.* 1967) a proglacial lake occupied a basin, consisting entirely of ice, on the north shoulder of Jane Peak (Lake 7). By 1962, the walls of the basin had been breached and the lake no longer existed.) Some lakes occupy small but well defined amphitheatres at the heads of glacial valleys (Lakes 6 and 13, figure 65). The entrances to the amphitheatres are blocked in part by rocky outcrops and there is evidence of moraines. They have the significant features of 'cirque' lakes. The majority of the remaining lakes appear to occupy depressions in ground moraine, and of these, many are 'kettle' lakes. A few may be 'ice-scour' lakes, however.

A hydrographic survey of Lake 3 revealed a series of irregular depressions bordering a small submerged plateau (figure 66). The topography suggests that this lake occupies a depression formed by the ice scour of fracture zones and shatter belts in a preglacial valley. Consideration of this lake is complicated by the fact that it lies only 5 m above mean sea level, 200 m from Stygian Cove. The greater part of the water may be held back by drift or ground moraine. The terminology used is after Hutchinson (1957).

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The shelf areas have arisen through the further deepening of the lakes by moraine damming, stone movement and solifluxion. In one lake (Lake 1) the overdeepening is caused by an artificial dam—a relic from the days when Signy Island supported a whaling factory.

The lakes are fed by the seepage of ground water, meltwater from ice lobes and semi-permanent snow banks and by precipitation falling over the surface of the water. All the lakes have an outflowing stream and receive sufficient water to maintain a constant and considerable outflow of water throughout the summer months. Some of the lakes are interconnected.

The flora of the drainage basins

Large areas of the drainage basins consist of ice cap and/or crags that border the inland plateau. Over these areas vegetation is absent or minimal.

The glacial debris and scree covering the lower slopes of the drainage basins present a gradation in particle size from large boulders to fine silt or mud. The finer material is usually bare of vegetation but where these areas are wet, near the lake, they have may a covering of blue/green algae, mainly *Phormidium* spp. Lichens, mainly *Usnea*, and a species of *Andreaea* colonize the stone stripes and scree. *Grimmia* mats replace this community on marble outcrops. There are banks of moss on the more consolidated ground. The dominant species is *Drepanocladus uncinatus* but considerable amounts of *Acrocladium* spp. are found in the wetter regions (Holdgate 1964). *Brachythecium* species are particularly common lining runnels where the water is running fast. *Pohlia* spp. and a *Bryum* are common associates of this community. In the wetter regions of the marble outcrops *Tortula* and *Mniobryum* are predominant lining the runnels. Where the soils are heavily contaminated by animals (seal wallows and bird colonies) the ground is bare of vegetation but *Prasciola crispa* is found where there is nitrogen-rich seepage water in the periphery of the contaminated zones.

The commoner physical and chemical factors of the lakes

The summer values for the commoner physical and chemical factors of several lakes have been recorded (table 31).

The temperatures given are indicative of the maximum temperatures attained by the main body of water in each lake during the 1962/63 and 1963/64 summers. The mean wind speed for the summer months is approximately 13 knots and there are few calm periods. The velocities of the horizontal currents produced in the surface waters by the wind may average 13 ft./min and frequently exceed 26 ft./min (Whipple 1927). In the shallow lakes of Signy Island currents of this magnitude are sufficient to maintain a constant circulation throughout the whole body of water. In consequence the main bodies of lake water remain homoiothermal during the summer. Horizontal thermal gradients are established between the waters over the shelf and trough during calm, relatively cloudless periods since the solar radiation quickly warms the water at the water/rock interface in the shallow areas. These periods are rare and invariably brief and the gradients recorded have not extended over more than 2 degC. The lakes of the more exposed west coast regions (figure 67) exhibit summer temperature regimes generally colder than those of the east coast lakes. The lakes are either cold monomictic or formally dimictic. The term 'formally' dimictic is used because, although the temperature of some lakes rises above 4 °C, inversion does not occur. The wind keeps the water homoiothermal throughout the period the lakes are open.

The prevailing high winds also serve to promote and maintain the oxygen concentrations at supersaturation point.

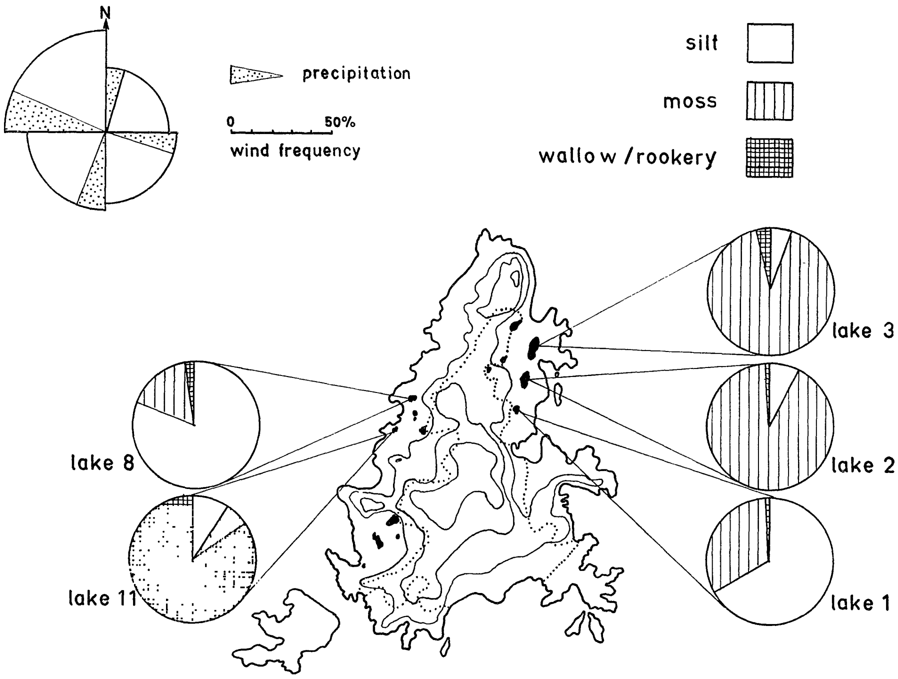

FIGURE 67. The extent to which the various lakes on Signy Island are protected from the prevailing winds. For certain lakes, the relative proportions of run-off water contaminated by moss stands and seal wallows/bird colonies are also shown.

The most important single factor influencing the chemical composition of the lake waters is contamination by wind-borne sea spray. Large amounts of chloride, sulphate and magnesium must be carried by the winds that sweep across Signy Island. The ratio of chloride to sulphate approached the oceanic value of 0·1396, during the summer, in all the lakes investigated. The amount of chloride carried by the wind and present in precipitation is known to decrease rapidly over even very short distances from the sea (Drischel 1940). This is presumably true for the other allied salts in an area free of industrial pollution, such as Signy Island. The salinity differences of the various lakes can be explained in part, therefore, by their respective distances from the sea, the direction of the prevailing wind and the degree to which the drainage basin of a lake is sheltered (figure 67). (The mass of Coronation Island, lying immediately to the north of Signy Island, promotes localized north-north-easterly winds that sweep down Three Lakes Valley, on the east coast. Lake 3 is particularly exposed to winds from this quarter.)

Several samples of run-off water were assayed (table 32). Although the concentrations of the major ions were reasonably high, inflowing water would have a diluting effect on the salinity of the lakes and the effect will be pronounced where ice or snow produce a plentiful supply of water throughout the summer months (e.g. Lake 1). The nutrient salt content of the run-off water appears to vary with the nature of the substrate. Water flowing

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Table 31. Summer values for some physical and chemical factors of five lakes on Signy Island

Lake	date	T (deg C)	η''†	O_2 (% sat.)	CO_2 (parts/10^6)	pH	alk. (m-equiv./l.)	Ca (parts/10^6)	Mg	Cl	SO_4	NO_3	PO_4
1	29. i. 64	5·7	0·39	102	1·5	7·1	0·14	2·1	1·3	17·5	1·6	0·03	0·002
2	29. i. 64	5·2	—	105	1·9	6·9	0·12	2·7	2·0	29·5	4·3	0·04	0·007
3	29. i. 64	4·2	0·80	104	1·9	6·7	0·12	3·6	3·1	44·0	6·0	0·07	0·013
8	27. ii. 64	2·9	0·50	110	2·1	6·9	0·18	4·8	3·9	48·0	5·5	0·04	tr.
11	28. ii. 64	3·8	1·65	94	3·1	7·1	0·30	12·5	5·4	61·0	15·0	9·03	0·160

† Vertical extinction coefficient.

Table 32. The chemical composition of several samples of run-off water

sample	date	description	pH	alkalinity (m-equiv./l.)	Ca (parts/10^6)	Mg	Cl	SO_4	NO_3	PO_4
A	15. xii. 63	inflow to Lake 1. Source—iceface. Runs 120 m at moderate speed over fine silt/scree	6·8	0·11	1·1	1·3	25·6	3·2	0·08	Tr.
B	28. i. 64	inflow to Lake 1. Source—iceface. Runs 120 m at moderate speed over fine silt/scree	7·2	0·19	1·7	0·6	7·6	0·8	0·08	0·001
C	28. i. 64	inflow to Lake 2. Source—snow bank. Runs at slow speed through mass stands	6·4	0·07	1·8	1·8	26·6	5·9	0·89	0·002
D	28. i. 64	inflow to Lake 3. Source—snow bank. Runs 50 m. at moderate speed through moss stands	6·8	0·16	3·6	2·0	32·8	8·7	1·13	0·003
E	5. iii. 64	inflow to Lake 8. Source—ice cap. Runs down 500 ft. cliff. Bird colony nearby	6·7	0·10	1·9	2·3	31·4	4·8	0·01	0·072
F	5. iii. 64	inflow to Lake 11. Source—general precipitation. Runs over seal wallow.	7·9	0·51	13·2	4·8	54·6	11·4	6·20	0·077
G	20. iii. 64	inflow to Lake 3. Source—snow bank. Runs 50 m at moderate speed through moss stands	—	—	—	—	—	—	3·26	0·025

over areas of scree and silt, bare of vegetation, had low concentrations of nitrate and phosphate (table 32, samples A and B) unless contaminated by bird droppings (sample E). If the water flowed through stands of moss it gained appreciable amounts of nutrient salts (samples C, D and G). The nitrates and phosphates may be leached out of the underlying peat or produced by the fungi, bacteria and fauna associated with the moss. They may even be extracted from the wind-borne sea spray by the moss stands (Allen, Grimshaw & Holdgate 1967). Water flowing over seal wallows is heavily contaminated and the assay revealed very high concentrations of nitrate and calcium (sample F). These salts are obviously produced by the decomposition of excretory products and moulted pelts. The concentration of nutrient salts in a lake is determined by the ratio of the various supplies of run-off water and the substrates over which they flow (table 31, figure 67).

It is impossible to estimate, even roughly, the volume of water percolating through the soil and, therefore, its effect on the chemical composition of the lake waters. The clay-like properties of the soil suggest that the volume is very small in comparison with the volume of run-off water. The chemical composition of the seepage water was not determined. The simple geology of the drainage basins suggests that the composition of this seepage water will vary only slightly from area to area and that it plays only a minor part in maintaining the observed differences between the chemical compositions of the various lakes. Water seeping from marble outcrops may serve to promote the slightly higher calcium to magnesium ratios presented by Lakes 1 and 8. The nature of the run-off water also influences the turbidity of a lake directly. Reduction in light penetration is caused mainly by suspended allochthonous matter—particularly organic matter, i.e. moss and lichen fragments. The mean vertical extinction coefficients range from 0·39 to 1·65 (table 31) (mean percentile transmissions per metre of 71·0 and 21·5 respectively). The amount of light reflected by the waves covering the surface of the lakes is commonly as high as 40 %.

The lake flora

Algae are the dominant primary producers in the lakes on Signy Island, for, with the exception of part of the phytoplankton and the rare submerged patch of *Acrocladium*, there are no other forms of vegetation. Within the littoral zone of the majority of lakes the benthic flora consists almost entirely of blue/green algae forming mats of varying luxuriance on the rocks and stones. The mats are nearly all a mixture of *Phormidium* species. Mingled with the blue/green algae are smaller amounts of green filamentous algae. The general stability of the stratum influences the vegetation cover considerably. Unstable ground prevents blue/green algal colonies from becoming firmly established, and, where the scree grades into fine silt the mats are very thin or lacking. In areas of instability and silting, green filamentous algae dominate the flora. Over certain areas of the shelf the growth of the blue/green algal mats is limited by the ice scour that occurs each year.

The organic detritus covering the floor of the troughs, although mainly allochthonous, contains numerous fragments of blue/green algal mat. These fragments presumably result from the ice scour of the shelf areas. Algal colonies of a globular form have been dredged from the bottom of the troughs and large amounts of green filamentous algae are known to exist on the floor of troughs in lakes where the mean percentile transmission per metre of light is high (e.g. Lake 1).

Samples of phytoplankton collected during the 1961/62 summer proved to be poor in quantity. For the summer months at least, the phytoplankton appears to play a very minor role in the productivity of the lakes.

The lake fauna

Protozoa, Rotifera, Tardigrada, Nematoda and Annelida (Enchytraeidae) are to be found in the periphyton and benthos. Although the phyla are represented by few species, each species is numerically strong in most lakes. Eight species of Crustacea complete the fauna.

The anostracan *Branchinecta gaini* dominates the nekton of many lakes during the summer. Numerically stronger, but of smaller biomass, the copepod *Pseudoboeckella silvestri* is present in the nekton of all lakes. The adult and late larval forms of these two species feed mainly off the blue/green algal mats and associated flora. Both species may prove to be omnivorous; it seems logical to assume that the diet is limited by particle size alone and that microscopic animals are ingested with the algae. The nauplii of *Branchinecta gaini* and *Pseudoboeckella silvestri* form a zooplankton. A larger copepod, *Parabroteas sarsi* preys on all life stages of *Pseudoboeckella silvestri* and the smaller larval forms of *Branchinecta gaini*. The population of *Parabroteas sarsi* is surprisingly small, even for a predator. The diet of this carnivore may also include the cladocerans *Macrothrix hirsuticornis* and *Alona rectangula* which are found swimming freely at all depths. These cladocera are particularly numerous in the benthos and periphyton, in association with a third cladoceran, *Ilyocryptus brevidentatus*. This cladoceran is found crawling within the blue/green algal mats and organic debris. In three of the lakes two ostracods, *Cypridopsis frigogena* and a *Eucypris* sp. complete the periphyton.

The reasons for the sporadic distribution of the anostracan and the ostracods are not known.

Seasonal changes in the physical and chemical factors of the lakes

Lake 3 was studied at intervals throughout the winter of 1963. Results are presented in graph form (figure 68).

After the heat budget of the lake became negative in early February the temperature of the lake water fell steadily. The winds continued to prevent thermal stratification and the lake remained homoiothermal even at temperatures below 1 °C. When the ice did form it was granular in texture. This type of ice is commonly formed when turbulent waters freeze slowly, being formed either from agglomeration of small freely floating ice crystals or from snow (Wilson, Zumberge & Marshall 1954). The ice cover attained its maximum, mid-lake thickness of 1 m in August. The increasing layers of insulating snow and ice cover were gradually reducing the heat flow from the lake and, after mid-August, the ice thickness was maintained but not increased. An inverse thermal gradient existed under the ice. Heat stored in the bottom deposits and rock of the trough maintained a temperature of 0·9 °C in the adjacent water.

The amount of light available under the ice was severely restricted for most of the winter. Light penetration gradually increased after August and, by mid-October, the light energy entering the lake was sufficient to warm up the main body of water remote from the ice.

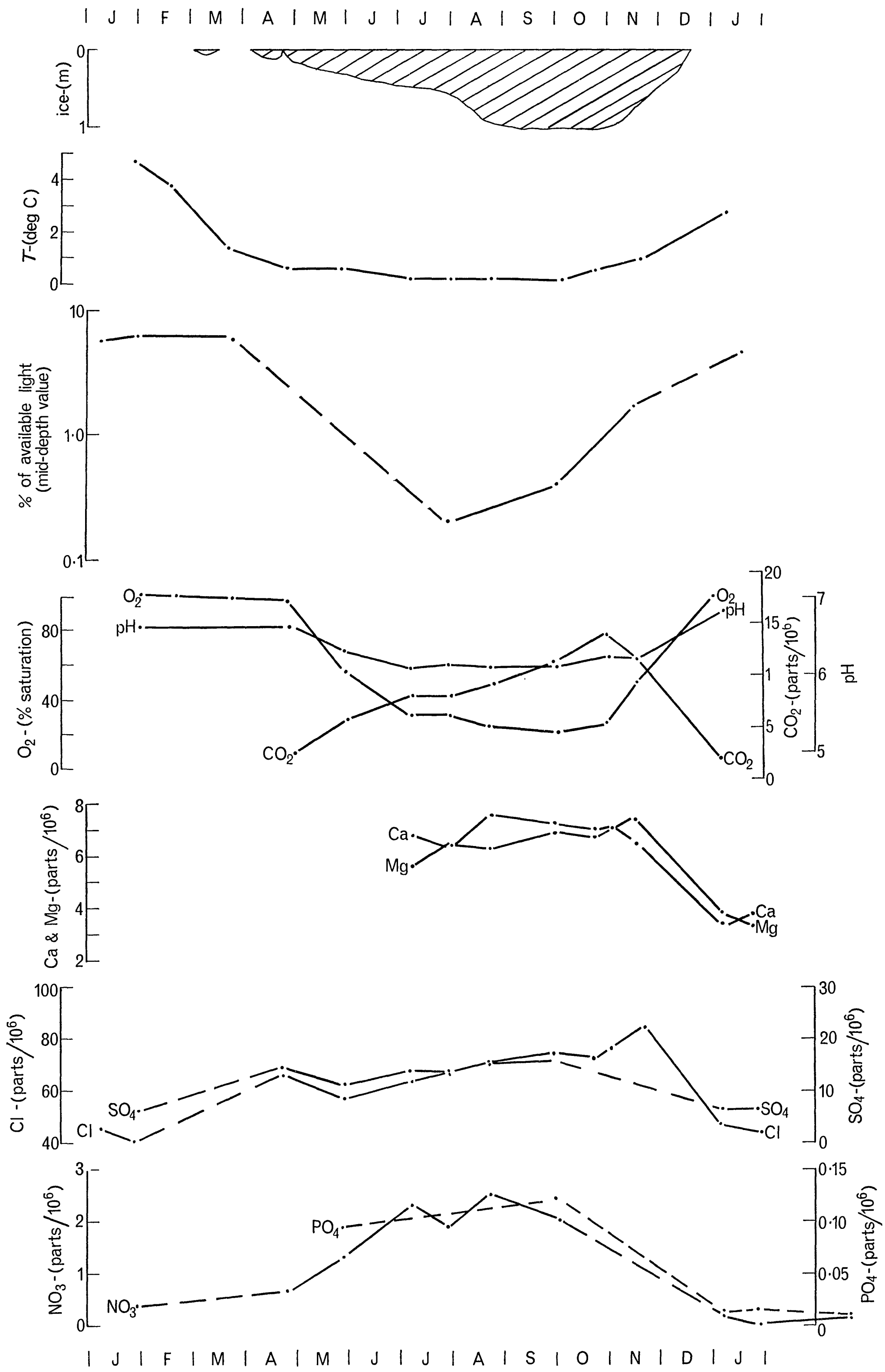

Figure 68. The seasonal variation in certain physical and chemical factors of Lake 3, Signy Island.

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Thawing became apparent at the edges of the lake in late November, and the lake opened in the second week of December.

The oxygen content of the lake fell rapidly after the surface had frozen over. The lowest values recorded were 39% saturation at the ice/water interface and 1% saturation at the silt/water interface—the conditions on 3 October. The decrease in oxygen was accompanied by an increase in the concentration of carbon dioxide and a fall in pH. The salt content of the lake also increased throughout the winter. When meltwater effected an entrance to the main body of lake water, in November, the chemical content quickly attained the summer level. As the snow producing the meltwater is contaminated with wind-borne sea spray, the meltwater does not bring about excessive dilution of the main salts below the normal summer levels. The nitrate and phosphate content may fall below the recorded levels.

Occasional work on three other lakes during the winter indicated that the pattern of events recorded in lake 3 occurred in all the lakes on Signy Island (table 33). Bacterial action in the heavily polluted waters of Lake 11 is presumably responsible for the reduction of the oxygen content to zero in that lake.

Changes occurring in the biota

The very low oxygen and high carbon dioxide values, recorded during the winter, suggest that photosynthesis ceases or is considerably reduced during the greater part of the period in which the vegetation is subject to very low light intensities. Most of the vegetation will be encased in ice during this period for the shelf area freezes solid. The algae appear to be undamaged by the actual freezing but all metabolic activity must be severely curtailed. The algal mats are damaged, however, by ice scour during the periods of ice formation and thaw. Ice scour obviously limits the growth of the algal mats and even colonization in certain areas.

Comment on the phytoplankton will be confined to the discussion.

As the algal mats become encased in ice the representatives of the lesser phyla in the periphyton must encyst or overwinter in the egg stage. *Branchinecta gaini* also overwinters in the egg stage.

The copepods, cladocerans and ostracods are not adversely affected by the general winter conditions; adult and larval forms are found at all depths throughout the winter. *Ilyocryptus brevidentatus* and the ostracods presumably migrate from the encroaching ice of the shelf areas. Ephippial females are found among the cladocerans and ephippia have been dredged from the troughs; certain individuals obviously overwinter in the egg stage. The copepods have the faculty to overwinter in the egg stage but they do not appear to do so in most lakes. In Lake 11, where the oxygen concentration falls almost to zero (and in the pools, which freeze solid), all the Crustacea overwinter in the egg stage.

Food supplies may present a problem to the Crustacea for the populations decrease considerably during the early winter period. With the exception of *Parabroteas sarsi*, the animals presumably rely on the small areas of algae still unfrozen and the organic detritus. The numerical strength of *Parabroteas sarsi* is obviously regulated by the winter populations of its prey. The Copepoda exhibit bimodality. Individuals which mature during the late

TABLE 33. WINTER VALUES FOR SOME PHYSICAL AND CHEMICAL FACTORS OF FOUR LAKES ON SIGNY ISLAND

							(parts/10^6)					
Lake	date	T (degC)	O_2 (% sat.)	Co_2 (parts/10^6)	pH	alkalinity (m-equiv./l.)	Ca	Mg	Cl	SO_4	NO_3	PO_4
1	11. ix. 63	0·70	12·7	16·4	6·2	0·31	7·3	4·5	47·0	7·8	0·26	0·012
3	3. x. 63	0·50	22·8	11·6	6·2	0·19	7·2	7·0	74·6	15·9	2·08	0·123
8	5. ix. 63	0·02	4·4	6·3	6·2	0·14	4·6	3·6	36·0	7·1	0·13	0·043
11	4. ix. 63	0·20	2·6	5·7	6·2	0·20	12·2	6·3	109·0	26·4	> 7·97	> 0·480

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summer and early winter are smaller than individuals which mature during the latter part of the winter and early summer. The bimodal forms are thought to reflect the amount of food available to the individuals during their periods of growth and maturation Heywood, in preparation).

Discussion

Experiments with a photoelectric cell buried beneath the ice cover on lake 3 have shown that the greater part of the available light is lost to the lake by reflexion within the snow cover and at the snow/air interface. (Removal of a 35 cm cover of snow, from ice above the photocell, for an area 3 m^2, increased the light intensity by 3000 %.) During the early part of the winter low-angled rays from the sun facilitate reflexion. After June the sun

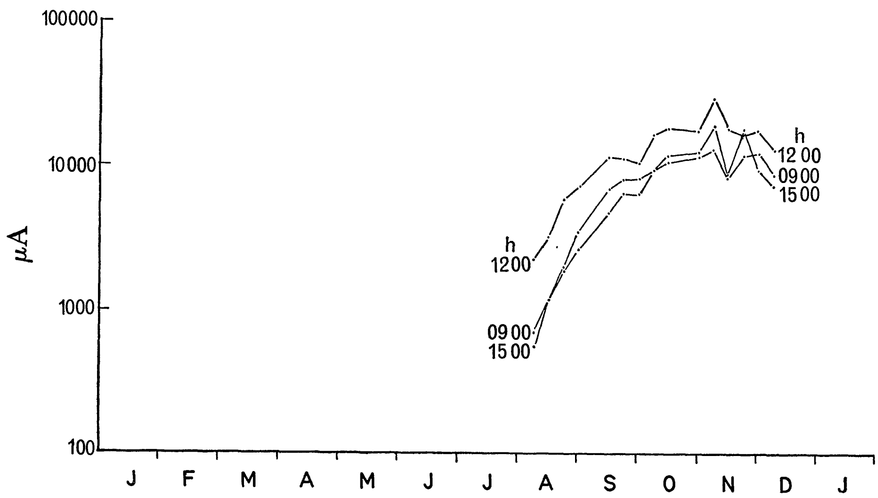

Figure 69. The increase in light, incident on the snow surface of Signy Island, as recorded from August to December, 1963. The values given are running means for 7-day periods.

regains altitude but the positive effects of this are reduced by the increasing thickness of the snow cover. The increase in day length, combined with the increasing elevation of the sun eventually ensures, however, that the total amount of light energy entering the lake does increase. The increase in available light energy, as recorded from August to December 1963 by a photoelectric cell at the snow/air interface, is shown in figure 69. High winds and periods of thaw thinned and occasionally removed the snow cover in late October and November 1963. This further facilitated light penetration.

Increase in the salt content of a lake, sealed from the external environment by ice cover, may be due to two factors: (*a*) the removal of water molecules in the formation of the ice; (*b*) the release of ions by decomposition of organic matter. Data from the hydrographic survey on Lake 3 were used to compute the volume of the lake and the volumes of increasing thicknesses of ice cover. The amount of water used in the formation of the ice cover and the effect of its removal on the concentration of various ions were then calculated. Some of the results are shown in figure 70. In spite of the obvious limits to the accuracy of this work certain conclusions are justified.

(*a*) The correlation between calculated and observed values reflects the extent to which a particular ion is 'bound up' in organic detritus, and therefore, subject to release by

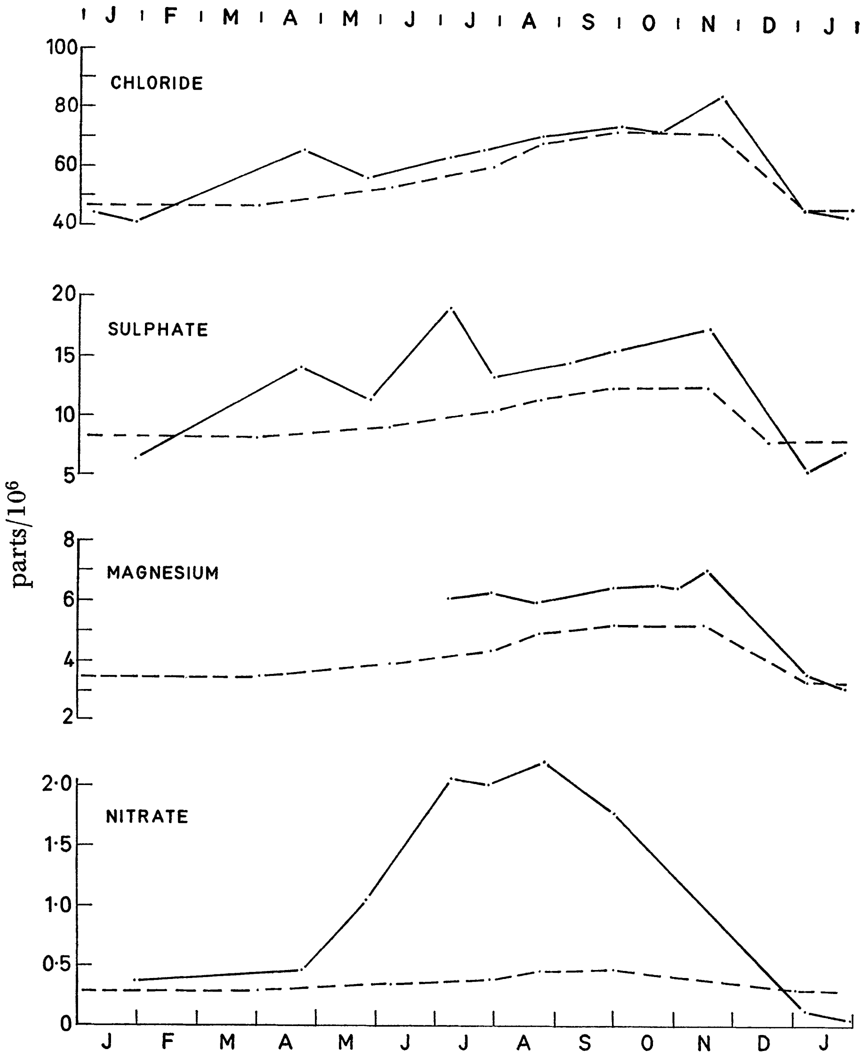

FIGURE 70. The concentration of salts by the removal of water in the formation of ice on Lake 3, Signy Island. The broken lines connect estimated values; the unbroken lines connect observed values.

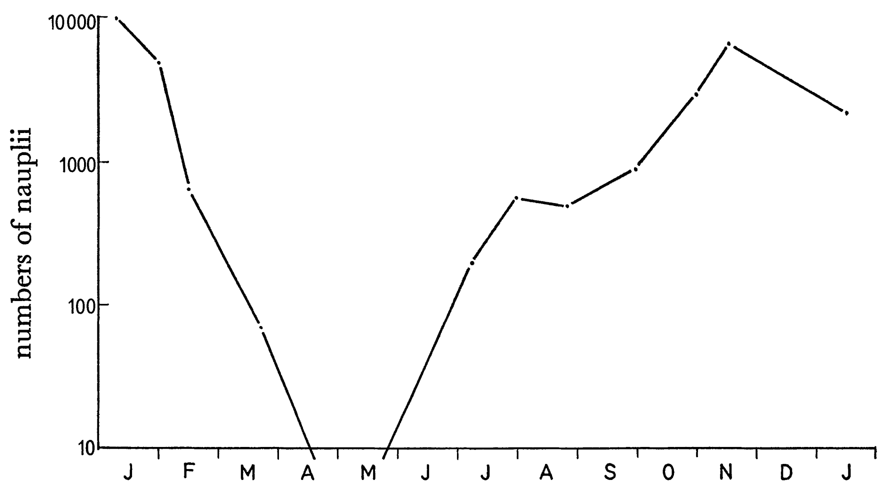

FIGURE 71. The seasonal variation in the numbers/m^3 of *Pseudoboeckella silvestri* nauplii, as recorded for the 2nd metre stratum, Lake 3.

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decomposition. Thus the increase in chloride is almost entirely due to the removal of water, whereas the increase in nitrate is due mainly to decomposition.

(*b*) The formation of ice cover on the shallow lakes of Signy Island is mainly responsible for the considerable increase in the salinity of the water observed during the winter months.

The zooplankton, as represented by the early larval forms of *Pseudoboeckella silvestri* and *Branchinecta gaini*, presumably feed on phytoplankton. The seasonal variation in the nauplii of *Pseudoboeckella silvestri*, as recorded from the second metre stratum, lake 3, is presented in figure 71. The rise in numbers during September/October coincides with the appearance of *Branchinecta gaini* larvae. A bloom in the zooplankton suggests, *ipso facto*, a bloom in the phytoplankton. Casual observations on euplankton present in general samples supports this suggestion but, until detailed studies are made on eu-, nanno- and μ-plankton, the evidence for a bloom at this time must be considered circumstantial. If a bloom in the phytoplankton does occur, the species will prove most active during a period when inorganic nutrients are high and available light energy very low. Certain species of Antarctic photo-autotrophic phytoplankton are known to be adapted to low light intensities and to be inhibited or injured at levels of higher illumination (Goldman, Mason & Wood 1963). The species present in the lakes of Signy Island may be similarly adapted. If this is so, it will explain the poor standing crop during the summer; the phytoplankton will be unable to attain a level of optimum light intensity in the continually circulating water. Heterotrophic phytoplankton may play a very important part in the productivity of the lakes during the winter period.

The productivity of the lakes appears to be limited more by physical factors than by the supply of inorganic nutrients. The dominant limiting factor is the prolonged presence of a thick ice cover. The effects of the ice cover are threefold. For long periods the available light energy is reduced to a level at which photosynthesis is severely curtailed. Metabolic activities are retarded or suspended in the main areas of vegetation for they are encased in ice. Ice scour damages the algal mats and restricts growth or colonization in many areas of the shelf region. During the summer, productivity may be reduced by the possible effects of high light intensities on the phytoplankton.

The wind, temperature and weather of Signy Island and the resulting snow cover vary considerably from year to year. The accumulation of snow, with its insulating properties, exerts a considerable effect on the ice cover. Precipitation during the early winter is frequently associated with high winds which prevent accumulation. Under these conditions heat flow from the lake is considerable and thickening of the ice cover is facilitated. Shallow troughs with accompanying light winds allow the rate of snow accumulation to increase as the winter proceeds. Heat flow from the lakes, and, consequently, increase in ice cover, is reduced and may cease. Although a thick cover of snow prevents the ice cover increasing it also serves to maintain the ice cover for the greater depth of snow prevents the warming of the water by light energy and protects the ice from minor periods of thaw. Thus the depth to which the water freezes and the duration of the ice cover vary from year to year (and from lake to lake) (Heywood, in preparation). Excessive depth and duration of ice cover may have an effect on the flora and fauna which the present investigation will not reveal.

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Summary

A description is given of the general drainage system of Signy Island, South Orkney Islands and of the commoner physical, chemical and biotic factors of several lakes. The lakes are cold monomictic or formally dimictic. The waters remain homoiothermal throughout the summer. The chemical compositions of the lakes are determined by the varying effect of contamination by wind-borne sea spray and the presence of moss stands, seal wallows and bird colonies. With the exception of the very rare patch of *Acrocladium*, algae form the aquatic vegetation. The fauna contains representatives of Protozoa, Rotifera, Tardigrada, Nematoda, Annelida (Enchytraeidae) and Arthropoda (Crustacea).

The lakes are ice covered for the greater part of the year (8 to 9 months on average). Snow, lying over the surface of the ice, reflects most of the light incident upon it and the light intensities available under the ice are very low. The oxygen content consequently falls and the lakes are almost anaerobic for part of the winter. The removal of water to form the ice cover increases the salinity of the underlying water considerably. Nutrient salts are released from organic detritus by decomposition. The productivity of the lakes falls as the main areas of vegetation become encased in ice but a phytoplankton bloom probably occurs under these conditions of very low light intensity. Certain animal species overwinter in the egg stage but others appear unaffected by the almost anaerobic conditions. The populations however, decrease in size, presumably affected by a limited food supply.

It is suggested that the prolonged period of ice cover is mainly responsible for the low degree of productivity in the lakes.

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Appendix (Heywood)

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A new map of Signy Island is in preparation and will be used in all future papers on the freshwater ecosystem of the island. The map uses a revised system of lake numbers and a key to the new numbers is given here:

old	new	old	new
1	6	9	8
2	5	10	9
3	2	11	10
4	1	12	11
5	3	13	12
6	4	14	14
7	omitted	15	13
8	7	16	15
		17	16

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