

CHARACTERISTICS OF THE FRESHWATER LAKES AT THE SCHIRMACHER OASIS IN ANTARCTICA

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Abstract

Schirmacher oasis which consists of a group of low lying hills interspersed by few glacial lakes is located between latitude $70^{\circ} 44' 33''$ S to $70^{\circ} 46' 30''$ S and longitude $11^{\circ} 22' 40''$ E to $11^{\circ} 54' 00''$ E. Ten different lakes situated around the Indian summer station Maitri were studied for their nutrient status, primary productivity and microfaunal characteristics of sediments during 18 to 24 January, 1985.

The water temperature of these lakes varied from 1.5 to 7°C ; the dissolved oxygen ranged from 4.3 to 6.02 ml l^{-1} and the pH from 7.6 to 8.8. The nutrient concentration showed wide range of fluctuation with some lakes showing very low levels of nitrate and phosphate. The maximum nitrate and phosphate values recorded were 3.1 and $1.1\ \mu\text{ mol l}^{-1}$ respectively. N : P concentration ratio ranged from 0 to 27.6. The concentrations of urea, ammonia and total nitrogen varied from 0 to $1.4\ \mu\text{ mol l}^{-1}$, 0.3 to $1.7\ \mu\text{ mol l}^{-1}$ and 0.8 to $17.9\ \mu\text{ mol l}^{-1}$ respectively. The high concentration of these nutrients may compensate the nitrate deficiencies in these waters. Silicate concentrations varied from 5.5 to $68.5\ \mu\text{ mol l}^{-1}$.

Chlorophyll *a* remained low (0.07 to 0.65 mg m^{-3}) but the primary productivity of the lake waters was quite high. Particulate organic carbon varied from 0.38 to 1.04 mg l^{-1} . Concentrations of dissolved and particulate carbohydrate indicate high organic matter content in these lakes. The faunal density in the upper 6 cm layer of sediment varied from 450 to 1920 numbers m^{-2} . The fauna was mainly dominated by nematods (22.1%). The distribution characteristics suggest that the particulate matter and the sediment microflora serves as a rich food source for the littoral benthic communities.

INTRODUCTION

The Antarctic continental margins are remarkably known for the diverse group of lakes, ponds and even rivers and streams. These water bodies may chemically range from distilled water of crystal clarity to salt laden brines (Heywood 1977, Heywood 1979, Burton 1981).

Extreme climatic conditions impose severe limitations on the number of plant and animal species inhabiting these waters. Freshwater lakes of Schirmacher Oasis and the organisms which inhabit them have received a little attention since 1981 when the Indian Expedition first landed in Antarctica. Preliminary reports have shown that some of these lakes are highly turbid with large populations of bacteria and low levels of nitrate and phosphate (Sengupta & Qasim 1983; Matondkar and Gomes 1983).

The knowledge of nutrient status and other chemical and physical factors is important in understanding the lake biology as well as the abiotic evolution of these lakes. Investigations were therefore undertaken on nutrients, primary productivity and microfaunal distribution in 10 different lakes in the Schirmacher oasis.

Description of the Study Area

Schirmacher hill is a typical desert oasis of Antarctica situated about 70 kms away from Prince Astric coast. It is a E-W tending low lying range with the maximum width of 2.7 km in the central part between latitude $70^{\circ} 44' 33''$ S to $70^{\circ} 46' 30''$ S and longitude $11^{\circ} 22' 40''$ E to $11^{\circ} 54' 00''$ E. Unlike main mountain range Schirmacher range forms a group of low lying hills of about 50 to 200 m high interspersed with a few glacial lakes ranging in size from 0.02 to 0.75 km² (Fig. 1).

Rocks at Schirmacher range show extensive glacial erosion with prominent U-shaped valleys, glacial striations on rock surface with thick morain cover in the lower altitudes.

Since the Schirmacher Oasis is away from the coast very few sea birds except snow petrels and skuas visit this region. Indian station Maitri is situated at the coast of one of the fresh water lakes named as Priyadarshini. This station is used as a camping site for the summer scientific party.

The extreme air temperature recorded at Schirmacher vary from minimum of -40°C in winter to a maximum of $+6^{\circ}\text{C}$ in summer. Precipitation in the form of snowfall is quite heavy but most of it is blown by strong katabatic winds from easterly direction. Several lakes are replenished annually by sporadic summer melting of adjoining glaciers and snow banks towards end of November up to beginning in early February. This water carries with it ions in low amounts. Most of the lakes have no surface outflow and it is unlikely that there is significant underground seepage. In some of the lakes the summer evaporation exceeds precipitation giving rise to the gradual reduction in water level and complete dry bed.

At the shores on the windward side and along the catchment area these lakes are thickly covered with permanent moss carpets. These are usually frequented by snow petrels and skuas. Priyadarshani lake which is broad and shallow at the periphery with an area of about 0.75 km² invited special attention. This is because near this lake the Indian summer camp Maitri is located. One lobe of this lake receives melt water from snow bank while at the other end it is fed by glacial melt water.

MATERIAL AND METHODS

Four stations were fixed in the Priyadarshini lake, two in the centre and two at the peripheral lobes. Nine other lakes in the Schirmacher range were also sampled for water and sediment analysis. Surface water samples were collected by means of a clean polythene bucket during austral summer period from 18th to 24th January 1985. Depth of the lakes sampled varied from 3 to 8 m. The surface water samples were obtained by means of a clean polythene bucket. Niskin type Van Dorn bottle 5l capacity was used to collect water samples other than surface.

Sediment sampling was undertaken with the help of portable Van Veen grab. An air inflated rubber boat was used to obtain water and sediment samples. Water temperature was measured immediately after the sample collection. For nutrient analysis the water samples were frozen immediately and transferred to the ship. Urea, ammonia, nitrate, nitrite, phosphate, silicate, total nitrogen, dissolved organic phosphorus and dissolved oxygen were analysed using procedures outlined by Grasshoff (1976). In-situ primary productivity was studied by the method of Strickland and Parsons (1972). For this purpose a pyrex reagent bottle, 125 ml was filled with sea water sample and inoculated with 5 μ cu of ^{14}C in the form of $\text{Na}^{14}\text{CO}_3$. These samples were suspended at the depths sampled and allowed to stand for 24 hours. The contents were immediately filtered through millipore membrane filters and fumed with HCl. The ^{14}C on the filters was determined by liquid scintillation counting. Chlorophyll *a* and phaeophytin were measured fluorimetrically using Turner Designs Fluorometer (Strickland & Parsons, 1972).

Microfauna samples were collected from the periphery of all the lakes using hand held plastic corer (10 cm length, 4.5 cm inner diameter). Duplicate samples up to 6 cm sediment depth were fixed in 4% formaldehyde solution to which 1% rose bengal solution was added. A portion of sediment samples were used for the determination of the organic carbon content and particle size analysis. In some of the lakes a repeat set of samples were obtained on February 23, 1985. Organic carbon in the sediment was analysed using wet oxidation method of El-Wakeel and Riley (1956). A systronic digital pH meter was used to measure the hydrogen ion concentration of water samples.

Faunal samples were washed through 500 μ m and 0.063 mm sieves, in filtered fresh water on board MV Finn Polaris and the contents of the 0.063 mm sieve were then preserved in 4% formaldehyde solution. All organisms were sorted, counted, and identified to the possible taxon under Projectina microscope. Biomass (dry weight of nematods, turbilarians, tardigrades, olyochaetes and acarids were determined according to the method given by Dye and Furstenberg (1977), and dry mass of protozoans, ciliates, rotifers and cysts (resting eggs) was calculated following the method of Sarojani and Nagabhushanam (1967). Particle size analysis of the sediment was carried out following method of Holme and McIntyre (1971).

RESULTS AND DISCUSSION

The air temperature during sampling period varied from -3 to 1°C . The maximum wind speed recorded was 20 knots. Mean global radiation value for the month of January 1985 recorded at Schirmacher was $28.12 \text{ Megajoules m}^{-2} \text{ day}^{-1}$ (Rizvi, 1986). Compared to the air temperature, the surface water temperature of the lake was found to be much higher varying between 1.5 to 7°C (Table 1a&b). Similarly the sediment temperature was found to range from 4 to 8.1°C . Goldman *et al* (1972) have reported the water temperature of Antarctic lakes to be 9°C above the air temperature in summer. Similarly Kelley and Zumberg (1961) have observed rock surface temperature as much as 17°C higher than air temperature. As inferred by Goldman *et al* (1972) the large difference between air temperature and that of lake water and sediment indicates the effect of absorption of radiant solar energy in water and on relatively dark sediment and rock surfaces.

Dissolved oxygen values ranged from 4.3 to 6.02 ml l^{-1} . In the bottom water the oxygen content was higher than the surface waters. This suggests that the lakes are well aerated, the higher oxygen values in the bottom waters may probably show active photosynthesis by the benthic algae. pH of all the lakes was found to be alkaline in nature the values ranging between 7.6 to 8.8 . This could reflect the chemical composition of bed rock of the lake or the area from where the input water is received. In the Lake 3 the pH values fluctuated from 7.6 to 8.6 . One side of this lake (station 1) receives water from snow bank while at the other location (station 4) it is fed by glacial outfall water, passing through morain consisting of stones and boulder. Sengupta and Qasim (1983) have reported the Ca and Mg content of Antarctic lakes to be 107.0 and 67.1 mg l^{-1} respectively. The high content of calcium and magnesium and photosynthesis of benthic and pelagic algae may be responsible for the increased pH values observed in these lakes.

From the table 1a & b it can be seen that the nutrient concentrations highly fluctuated from one lake to the other. Some lakes showed very low levels of nitrates and phosphates. The maximum nitrate and phosphate values recorded were $3.1 \mu \text{ mol l}^{-1}$ and $1.1 \mu \text{ mol l}^{-1}$ respectively. The N : P concentration ratio in these lakes varied from 0 to 27.6 . Based on these results the lakes 1 and 3 can be termed as oligotrophic lakes.

The concentrations of urea and ammonia varied from 0 to $1.4 \mu \text{ mol l}^{-1}$ and 0.3 to $1.7 \mu \text{ mol l}^{-1}$ respectively. The total nitrogen values in these lakes ranged from 0.8 to $17.9 \mu \text{ mol l}^{-1}$ except for a very high value in Lake 7. The nitrogen sources like urea, ammonia and total nitrogen can therefore compensate for the deficiencies of NO_3 seen in some of these lakes. While nitrate and phosphate values were low the silicate concentrations remained quite high varying between 5.5 to $68.5 \mu \text{ mol l}^{-1}$. Only Lake 4 showed a low Si content of $0.9 \mu \text{ mol l}^{-1}$.

The silica concentrations in different locations of Lake 3, varied from 5.5 to $5.8 \mu \text{ mol l}^{-1}$ but station 4 showed exceptionally high value of $68.0 \mu \text{ mol l}^{-1}$. This station was located near the arm receiving melt water of the nearby glacier and the high Si values

may suggest Si input from silicious glacial morain. Dissolved organic P in the lakes varied from 0.13 to 0.52 $\mu\text{mol l}^{-1}$.

Chlorophyll *a* (Chl *a*) concentrations in all the lakes remained low varying between 0.07 to 0.65 mg m^{-3} . The only high value of 1.18 mg m^{-3} was seen in the bottom waters of Lake 2. This lake had a mat of filamentous algae at the bottom and the high chlorophyll may be due to the infiltration of these algae in the water sample. While chlorophyll *a* was low the surface primary productivity (PP) remained sufficiently high varying between 0.17 to 5.6 $\text{mg m}^{-3} \text{hr}^{-1}$. It can be seen from the Table 2 that the PP/Chl ratio for the surface waters was quite high. Similarly when the bottom waters were subjected to 100% irradiance high assimilation number was obtained varying between 1.2 to 27.1 $\text{mgc mgchl}^{-1} \text{l}^{-1}$. This indicates that the chlorophyll in the bottom waters was quite active. Similarly Table 3 shows that when the surface water of three different lakes was exposed to varying light intensities the maximum ^{14}C assimilation was observed at 60% irradiance. This indicates that the phytoplankton communities are inhibited at higher light levels.

Particulate organic carbon in different lakes varied between 0.38 to 1.04 mg l^{-1} . The dissolved carbohydrate content varied between 0.8 to 5.6 mg l^{-1} . The higher values were mainly located in the areas containing thick moss beds. Particulate carbohydrate values were higher than 147 $\mu\text{g l}^{-1}$.

The distribution of dissolved and particulate components suggest that while these lakes appear to be oligotrophic in nature, the concentration of organic matter is quite high. The sediment characteristics of each lake along with the microfaunal biomass is shown in Table 4. The faunal density in the upper 6 cm layer were found to vary from 450 to 1920 numbers m^{-2} . The high faunal density was located in the sediment containing silty sand covered with moss turf. The fauna mainly consisted of seven taxonomic groups which were dominated by nematodes 22.1%. Other groups present were protozoans 19.8% turbellarians 15.5%, tardigrades 9.02%, oligochaetes 1.4%, rotifers 0.9% and acarides 0.7%. All sediment samples showed the presence of varying numbers of invertebrate cysts. Algal communities associated with microfauna were of genus *Oscillatoria*, *Synechocystis*, *Desmidium* and *Chococcus* of blue green algae.

Organic carbon content of the sediment ranged from 0.05 to 1.8%. The sediment covered with the vegetation (moss or algae) showed higher organic carbon content compared those without vegetation. It has been reported (Heywood *et al.*, 1979) that many invertebrates are plant feeders. In the present observations the free living turbellarians and nematods were found to be abundant at the lake edge where dead organic material was high. And as suggested by Wynn-Williams (1983) it could be inferred that the particulate organic matter and sediment microflora may serve as a major food source for the littoral benthic communities.

The three major bird communities like Antarctic skua, snow petrel and Albatross were found to be visiting these lakes as seen from their carcasses and chicks inhabiting in the rock burrows at the sides of lakes. The analysis of faecal pellets and the ingested food by Antarctic skua have shown the presence of insect skeleton and frustules of

microorganism. This indicates that Antarctic birds feed on the littoral microfauna of lake sediments.

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Table 1a. Distribution of physico-chemical and biological parameters in the Antarctic freshwater lakes (Lake 1 & 3)

	Lake 1		Lake 3							
	Surface	bottom	# 1		# 2		# 3		# 4	
			Surface	bottom	Surface	bottom	Surface	bottom	Surface	
Temperature °C	7.0	5.0	3.0	2.0	3.0	1.5	2.7	1.7	3.2	
Salinity %	0.13	0.13	0.09	0.09	0.09	0.09	0.09	0.09	0.09	
Dissolved oxygen ml l^{-1}	5.79	5.94	4.79	5.86	5.01	6.02	4.9	5.9	5.7	
pH	7.7	8.8	8.55	8.33	8.53	7.91	8.52	7.72	7.58	
Chlorophyll a μg l^{-1}	0.07	0.2	0.2	0.44	0.13	1.18	0.1	0.14	0.18	
Phaeophytin μg l^{-1}	0.01	0.02	0.03	0.04	0.04	0.14	0.02	0.01	0.01	
Primary productivity mgC $m^{-3} hr^{-1}$	0.17	0.11	2.31	1.4	2.3	5.6	2.6	0.29	3.3	
PP/Chl mgC mg $Chl^{-1} hr^{-1}$	2.43	0.6	11.5	3.2	17.7	4.7	26.0	2.1	18.3	
Particulate oxidisable carbon mg l^{-1}	0.38	0.41	0.62	1.04	0.42	0.73	0.73	0.45	0.45	
Particulate carbohydrate mg l^{-1}	147.3	263.5	178.8	440.9	196.5	551.4	164.6	203.6	179.0	
Dissolved organic phosphorus μ mol l^{-1}	0.26	0.48	0.41	0.52	0.18	0.25	0.13	0.14	0.22	
PO ₄ -P μ mol l^{-1}	0.06	0.12	0.11	0.19	0.12	0.12	0.09	0.09	0.07	
SiO ₃ -Si μ mol l^{-1}	67.74	68.54	5.64	5.7	5.7	5.8	5.54	5.64	67.64	
Urea-N μ mol l^{-1}	0.5	0.43	0.04	0.08	0.7	1.1	0	0.14	0.65	
NH ₄ -N μ mol l^{-1}	0.33	0.27	0.47	0.44	0.43	0.48	0.44	0.72	0.28	
NO ₂ -N μ mol l^{-1}	0.05	0.08	0.06	0.06	0.06	0.06	0.06	0.06	0.06	
NO ₃ μ mol l^{-1}	0.24	0.15	0.14	0	0.12	0.13	0.07	0.11	0.15	
NO ₃ /PO ₄	4.0	1.3	1.3	0	1.0	1.1	0.8	1.2	2.1	
Total N μ mol l^{-1}	6.85	5.24	1.6	0.81	1.9	2.6	1.2	1.8	7.46	

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Table 1b. Distribution of physico-chemical and biological parameters in the Antarctic freshwater lakes (Lake 2, 4 to 10)

	Lake 2 Surface	Lake 4 Surface	Lake 5 Surface	Lake 6 Surface	Lake 7 Surface	Lake 8 Surface	Lake 9 Surface	Lake 10 Surface
Temperature °C	4.0	3.0	4.0	3.5	3.2	3.7	2.6	2.7
Salinity %	0.09	0.1	0.09	1.93	0.09	0.09	0.09	0.09
Dissolved oxygen ml l ⁻¹	5.8	5.8	4.7	4.6	4.8	4.5	4.3	4.6
pH	8.75	8.5	8.0	8.65	7.55	8.34	7.95	7.8
Chlorophyll a µg l ⁻¹	0.16	0.1	0.65	0.1	0.14	0.23	0.42	0.35
phaeophytin µg l ⁻¹	0.02	0.01	0	0.02	0.02	0.02	0.03	0.05
Primary Productivity mg C m ⁻³ hr ⁻¹	2.24	3.95	3.5	0.68	2.5	2.1	2.9	1.6
PP/Chl mgC mgChl ⁻¹ hr ⁻¹	1.4	39.5	5.4	6.8	17.9	9.1	6.9	4.6
Particulate oxidisable carbon mg l ⁻¹	0.59	0.79	0.68	0.43	0.46	0.41	0.53	0.45
Particulate carbohydrate µg l ⁻¹	162.3	241.3	224.9	186.3	179.5	231.5	223.1	189.3
Dissolved carbohydrate mg l ⁻¹	3.1	3.2	1.6	1.9	2.9	3.0	3.6	1.6
Dissolved organic phosphorus µ mol l ⁻¹	0.31	0.32	0.43	0.25	0.22	0.46	0.15	0.21
PO ₄ -P µ mol l ⁻¹	0.07	0.12	0.05	0.2	0.06	1.07	0.4	0.3
SiO ₃ -Si µ mol l ⁻¹	18.8	0.86	30.39	32.91	—	28.83	14.36	7.8
Urea-N µ mol l ⁻¹	0.55	0	1.36	0.89	1.39	0.75	1.28	0.21
NH ₄ -N µ mol l ⁻¹	0.33	1.3	0.84	0.53	0.44	1.72	1.01	0.45
NO ₂ -N µ mol l ⁻¹	0.08	0	0.06	0.06	0.06	0.06	0.06	0.05
NO ₃ -N µ mol l ⁻¹	0.21	3.08	1.38	1.89	1.37	2.41	2.47	1.6
NO ₃ /PO ₄	3.0	25.7	27.6	9.45	22.8	2.25	6.18	5.3
Total -N µ mol l ⁻¹	2.42	5.41	9.27	6.05	74.56	17.93	11.89	3.6

Table 2. PP/Chl ratio of surface and bottom water exposed to 100% light intensity ;
January, 1985

Location	Water depth m	Surface water	PP/Chl mg C mg Chl ⁻¹ hr ⁻¹	
			Bottom water with 100% irradiance	Bottom water in situ
Lake 1	4	2.43	1.2	0.6
Lake 3	# 1	3	11.5	7.1
	# 2	5	17.7	4.7
	# 3	8	26.0	2.1

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Table 3. PP when surface water is subjected to different light intensities ; January, 1985

Location	Chl <i>a</i> mg m ⁻³	100%	PP mg C m ⁻³ hr ⁻¹		
			60%	30%	16%
Lake 2	0.16	2.24	2.65	1.2	0.8
Lake 3	0.18	3.3	4.4	2.3	1.82
Lake 4	0.1	3.95	4.18	1.31	0.31

Table 4 . Sediment characteristics and faunal standing crops of 10 freshwater habitats.

Station No.	Sand %	Silt & clay (%)	Texture	Organic carbon (%)	Standing crops	
					Density nos./m ²	Biomass g/m ²
Lake 1	82.80	17.20	Silty sand covered with moss turf	0.85	1460	2.609
Lake 2	96.05	03.94	Coarse sand with pebbles	0.08	860	1.870
Lake 3	84.57	15.43	Silty sand covered with moss turf and algae	1.73	900	2.404
Lake 4	93.01	06.99	Coarse sand covered with moss turf	1.15	1610	5.376
Lake 5	87.83	12.17	Silty sand covered with moss turf	1.80	1920	5.525
Lake 6	97.58	02.42	Coarse sand with pebbles	0.01	510	0.960
Lake 7	91.67	08.33	Coarse sand with pebbles covered with moss carpet	0.01	450	1.491
Lake 8	96.18	03.82	Coarse sand with pebbles	0.05	490	2.517
Lake 9	86.53	13.47	Silty sand covered with moss carpet	0.85	1200	2.597
Lake 10	96.37	3.62	Coarse sand with moss carpet	0.05	450	1.225

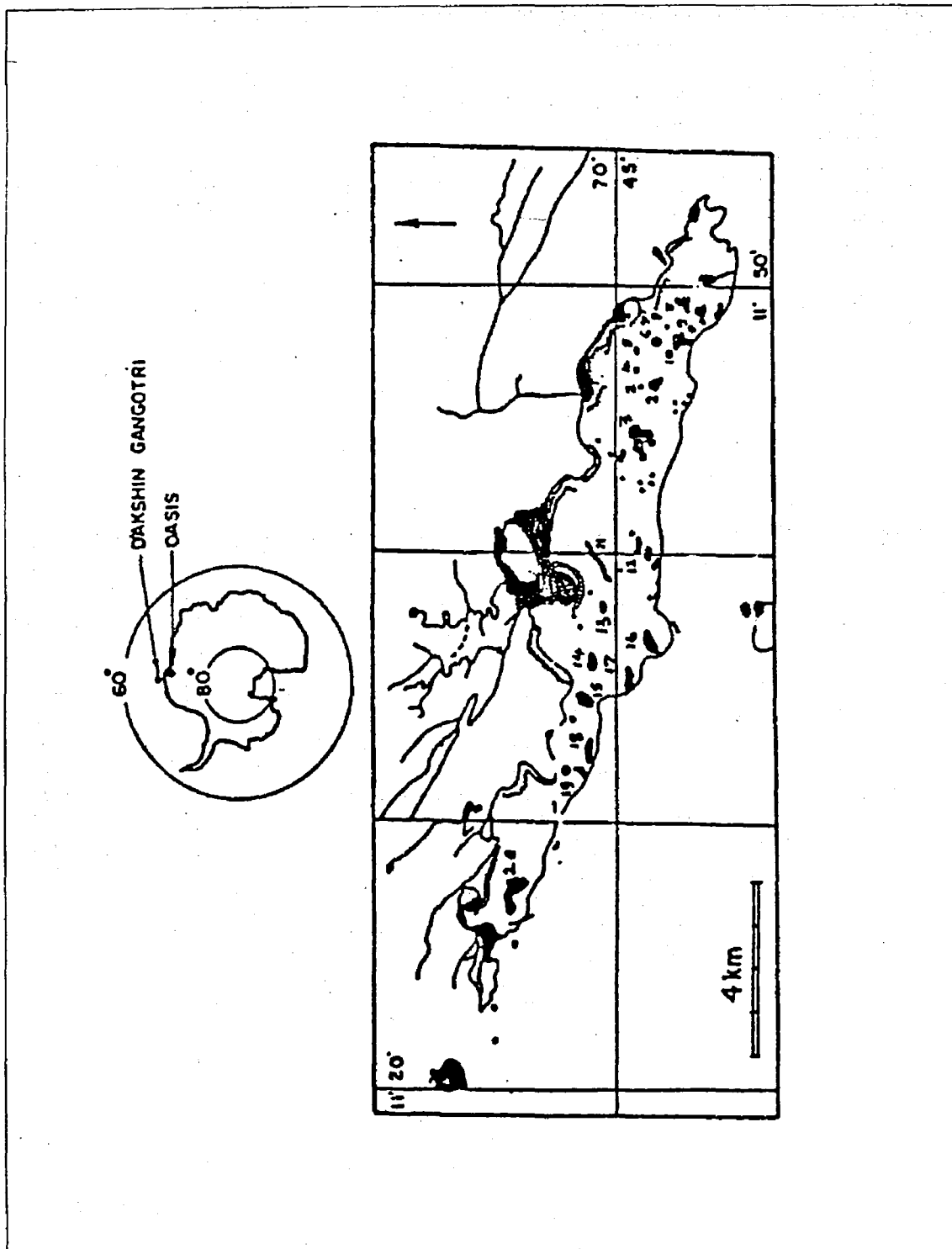


Fig. 1. Map of Schirmacher Oasis, Antarctica showing different lakes sampled. Numbers from 1 to 10 represent the lakes covered during austral summer of 1984-85.

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