

Limnology of Priyadarshani Lake, Schirmacher Oasis, Antarctica

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ABSTRACT Priyadarshani, an oligotrophic lake in Schirmacher Oasis (Antarctica), was surveyed during the austral summers of 1984-85 and 1986-87 in limnological and benthic studies. Benthic microfauna included seven taxonomic groups, dominated numerically by protozoa, rotifera, nematoda, turbellaria, tardigrada, oligochaeta and mites. Faunal density was high in moss-associated sediments. A maximum water depth of 6.5 m was recorded at the centre of the lake. A thick layer (25-90 cm) of moss and algal communities covered the bottom sediments. The total volume of water was estimated to be 62 million m³ over the submerged area of 0.297 km².

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Introduction

Freshwater lakes in the dry valleys of Antarctica remain frozen 8-10 months every year. Sources of water are either adjoining glaciers or snow fields which melt during the austral summer. These lakes are unique water bodies in several respects: most have a perennial 2-6 m ice cover, variable temperature profiles, and abundant microflora and fauna, and they lack grazers (Wright and Burton 1981; Parker and others 1982; Ingole and Parulekar 1987). Temperature in the benthic zone of shallow lakes may be 10°C higher than in the overlying water. The benthic community thrives probably because of the comparative warmth. Hence benthic production in these lakes is more prominent than planktonic production (Goldman and others 1972).

Lakes in McMurdo Sound, at Signy Island, Ross Island and Marion Island have been studied most intensively, but very little is known about the lakes in Schirmacher Oasis. The earliest records are those of Bardin and Leflat (1965) on the chemical characteristics, and by Komarek and Ruzicka (1966) on freshwater algae. During the First and Fourth Indian Scientific Expeditions to Antarctica (1981-82, 1984-85), Sengupta and Qasim (1983), Matondkar and Gomes (1983) and Ingole and Parulekar (1987) studied the chemical, microbiological and microfaunal characteristics of some of the lakes in the Schirmacher Oasis area.

This investigation is a part of a study of the whole littoral and peripheral microfauna of Priyadarshani Lake (70°45'S, 11°44'E), an oligotrophic lake in this area, situated close to the Indian station Maitree. The second biggest lake in the oasis, covering some 0.297 km², it is irregular in outline and surrounded by small hills sloping northeast (Fig. 1). The source of water is a glacier adjacent

to the southwest; snow fields melting in summer feed two small streams which enter the lake. A mat of blue-green algae and moss characterizes the supralittoral margin. Microfaunal samples were taken during two austral summers 1984-85 and 1986-87, and a bathymetric study estimated the total volume, depth variations and potability of the water.

Data collection and analysis

Ten stations were sampled along the peripheral shelf of the lake three times each season between December 1984 and February 1985, and between December 1986 and February 1987. Sediment samples were collected for microfauna, determination of particle size and organic content, using a metallic hand-coring device of 4.5 cm diameter. Five additional stations were sampled within the lake from an inflatable boat, using a piston corer sampler of inner diameter 4.0 cm. Niskin PVC samplers were used to collect water at all the stations for measurement of dissolved oxygen, pH, salinity and temperature.

Zooplankton samples were taken by horizontal hauls from five stations, using a 330 µ mesh rectangular plankton net. Duplicate hauls (each of five minutes) were taken at each station. All the samples were transferred to labelled jars for later concentration and preservation. Samples were identified and counted using an inverted binocular microscope.

January is the peak summer month at Schirmacher Oasis (maximum air and surface water temperatures of +5.0°C and +7.9°C respectively were recorded on 16 January 1987), resulting in the maximum melting of glacier and adjoining snow fields. Priyadarshani Lake was surveyed bathymetrically on 20 January 1987. Depth measurements were taken from the inflatable boat at 155 different locations using a lead line. To fix positions 10 shore markers were placed around the lake (Figure 2) and the distance between shore marker and bathymetric location was measured using a graduated nylon rope. For cross-checking, depths were also measured by divers using a depth gauge. A bathymetric map was prepared with a contour interval of 0.5 m.



Fig. 1. Priyadarshani Lake, Schirmacher Oasis, Antarctica.

Results and discussion

Environmental characteristics

A preliminary account of Priyadarshani Lake by Ingole and others (1987) provides environmental data for comparison. Table 1 compares environmental parameters recorded on 21 January 1985 and 16 January 1987, using means of three samples. Mean temperatures recorded on 21 January 1985 in the upper layer of sediment and overlying water were 4.7°C and 2.4°C respectively. Values for 16 January 1987 were 9.6°C and 7.8°C. pH values were higher in 1987 than in 1985, and much higher than values of pH 5–6.8 recorded in an ice covered lake at Schirmacher Oasis by Barding and Leflat (1965). The increase in pH may be due to alkaline rock present in the glacial meltwater. Inflow of mineral matter from the watershed, and structural changes in the littoral biocenosis can also affect pH (Rybak and others 1987). Dissolved oxygen content in the overlying water also showed increase of 1.10 ml O₂ l⁻¹ within 2 years. Salinity remained unchanged from 1985–87 at around 0.09 x 10⁻³S. Analysis of sand, silt and clay fraction indicated 1.27% increase in silt-clay fraction which may be due to a higher decomposition rate in mosses (Davis 1980).

Studied simultaneously for potability (Fondekar,

Table 1. Comparison of environmental factors and microfaunal standing stocks recorded during 21 January 1985 and 16 January 1987 at Priyadarshani Lake.

Parameters	1985	1987
temperatures (°C)		
air	-1.6	+5.0
surface water	+2.4	+7.9
bottom water	+4.7	+9.6
pH bottom water	8.10	8.77
dissolved oxygen (ml O ₂ l ⁻¹)	7.35	8.45
salinity (% S)	0.09	0.09
sediment composition (%)		
coarse sand	92.33	91.07
silt-clay	7.66	8.93
organic carbon	1.07	1.73
organisms		
mean density (individuals m ⁻²)	1639	2930
mean biomass (mg m ⁻²)	737.55	1318.50

unpublished), the lake water proves potable by available international and Indian standards (Table 2)

Table 2. Water quality of Priyadarshani Lake compared with World Health Organization (WHO) and Indian standards of potability (IS). Lake data from Fondekar 1987.

Parameter	Priyadarshani	WHO	IS
pH	7.5-8.1	7.0-8.5	7.5- 8.0
Susp. solids (mg l ⁻¹)	0.009-0.01		
Chlorides (mg l ⁻¹)	0.048-0.049	-	600
Dissolved O ₂ (ml l ⁻¹)	8.5-9.0	-	3.0
Nitrates (mg l ⁻¹)	0.002-0.003	-	50
Calcium (mg l ⁻¹)	10	-	-
Magnesium (mg l ⁻¹)	12	-	-

Microfauna

The luxuriant growth of benthic vegetation (moss and algae) in and around Priyadarshani Lake during both the sampling periods increases the amount of organic matter released into the lake (Heywood 1984). The lake bottom was covered with fine sediments with an overlying felt of filamentous blue-green algae (*Oscillatoria*, *Synechocystis*, *Chococus*, *Pharmidium* and *Nostoc* sp.) and diatoms. The vegetation serves as a food source for benthic fauna and provides insulation during the harsh winter (Goldman and others 1972).

Seven microfaunal groups were recorded, in which ten genera and four species were identified. Most of these are exclusively benthic animals of both peripheral and littoral zones. Protozoa (ciliata, mastigophora and sarcodina) were the most dominant (23%), followed by nematoda (15%), turbellaria (11%), tardigrada (9%) and rotifera (2%). Dormant eggs of invertebrates (rotifera, turbellaria and tardigrada) were abundant (39% at the littoral stations, Figure 3); this appears to be the most widely-used method of overwintering among micro-invertebrates. The ciliate *Oxytricha fallax* and rotifer *Philodina gregaria* were found in both peripheral and littoral habitats, most individuals appearing near luxuriant epiphytic vegetation. Nematodes *Teratocephalus tilbrookii* and *Aphelenchoides* sp. were recorded at all peripheral stations, whereas only *T. tilbrookii* was found at littoral stations.

Three genera of tardigrada were recorded in peripheral sediments at the water-moss interface. While *Macrobi-*

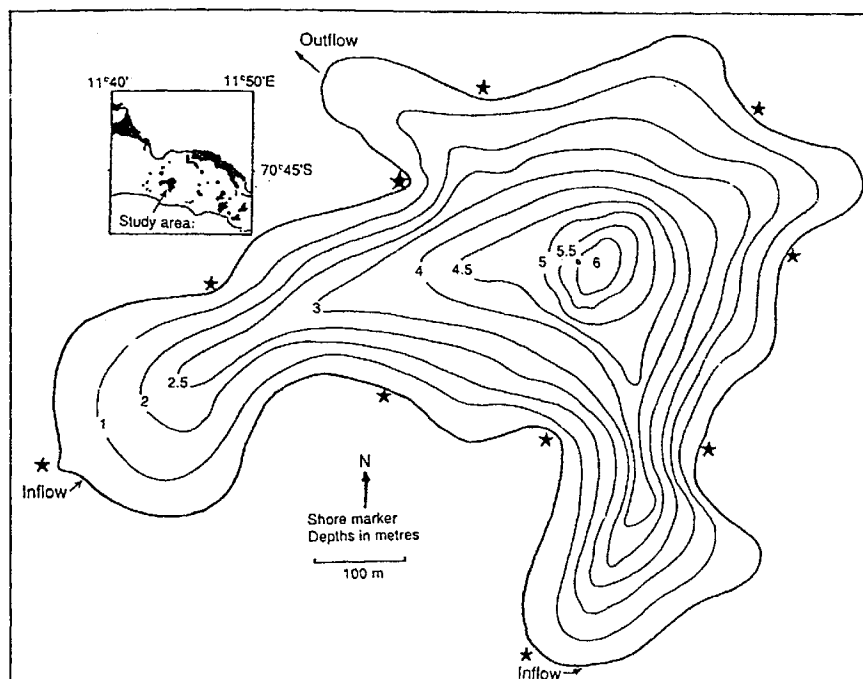


Fig. 2. Bathymetric map of Priyadarshani Lake: depth contours in metres (not referred to sea level).

otus sp. and *Echinoisoides* sp. dominated the algal sediment, genus *Hypsibius* was found mostly in moss-associated sediments (Table 3). Jennings (1979) on Signy Island found tardigrades most abundant (1032 individuals m^{-2}) in terrestrial habitats. Turbellarians *Neorhabdocoela* and *Kalyptorhynchia* sp. were found in both central and peripheral habitats, though densities were higher in the latter. The aquatic mite *Cryptopygus sverdrupi* was recorded only in moss carpets.

Table 3. Most common species of freshwater fauna of Priyadarshani Lake (values in parenthesis: biomass $\mu g^{-1} m^{-2}$, dry weight basis).

Taxon	Density m^{-2}	
	Peripheral	Littoral
Ciliata		
<i>Oxytricha fallx</i>	580 (0.029)	40 (0.002)
Rotifera		
<i>Philodina gregaria</i>	95 (0.004)	38 (0.002)
Nematoda		
<i>Teratocephalus tilbrooki</i>	1594 (697.05)	79 (35.55)
<i>Aphelenchoides</i> sp	510 (229.5)	- (-)
Tardigrada		
<i>Hypsibius</i> sp	356 (160.20)	24 (10.80)
<i>Echiniscoides</i> sp	286 (128.70)	83 (37.55)
<i>Macrobotus</i> sp	390 (175.00)	- (-)
Turbellaria		
<i>Neorhabdocoel</i> sp	896 (403.20)	66 (29.70)
<i>Kalyptorhynchia</i> sp	352 (158.40)	33 (14.85)
Insecta		
<i>Cryptopygus sverdrupi</i>	86 (38.70)	- (-)

Microfaunal standing stock (density/biomass) was higher in sediment collected from the lake periphery, where algal and moss growth was abundant. Higher microfaunal density in moss-associated sediment reported elsewhere by Ingole and Parulekar (1987) related to the high production of dissolved organic matter (DOM) in mosses (Davis 1980). Priddle and Dartnall (1978) observed that in summer the open structure of the mosses supported up to three times as many animals as the algal mats. Mean values for microfaunal standing stock recorded in 1987 were higher (2930 individuals m^{-2} ; 1318 $mg m^{-2}$) than in 1985 (1639 individuals m^{-2} ; 737.6 $mg m^{-2}$), possibly due to the higher air and water temperatures, which are known to play a very significant role in oasis ecosystems (Heywood 1984). Differences may be due also to differences in preservation techniques. 1985 samples were preserved in 5% formalin, which is known

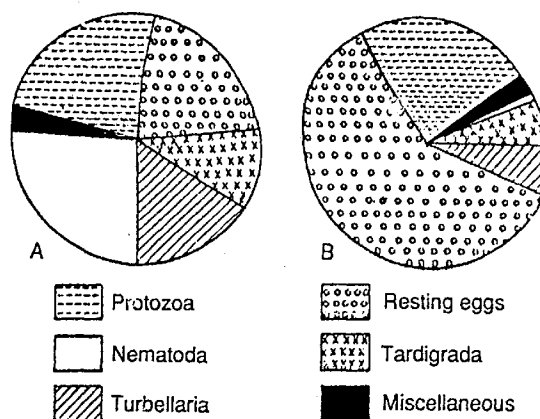


Fig. 3. Microfaunal composition (%) in peripheral (A) and littoral (B) zones of Priyadarshani Lake.

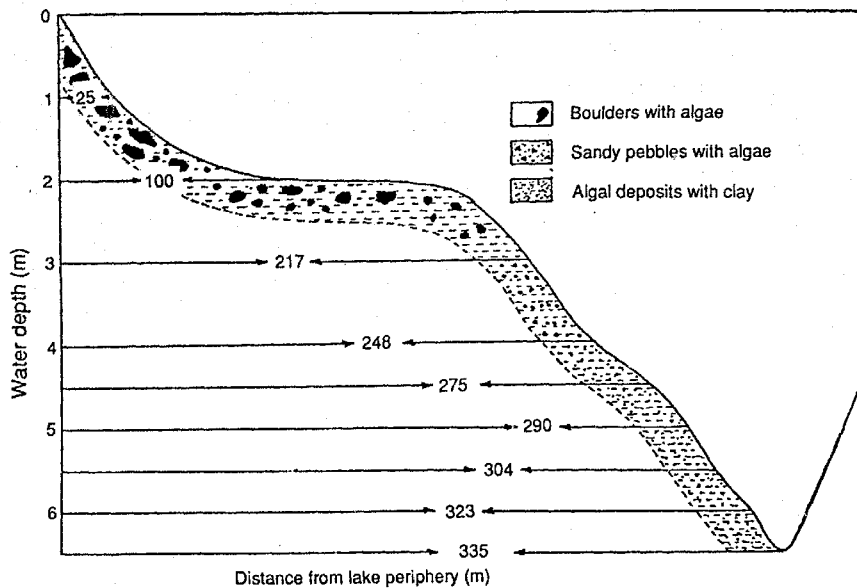


Fig. 4. Schematic profile of Priyadarshani Lake showing bottom deposits.

to destroy some microorganisms, and analysed two months later; 1987 samples were preserved in 70% ethanol and analysed within a week of collection.

Zooplankton

The lake lacked true planktonic herbivores. Fauna was largely made up of rotifers (47 individuals per haul) ciliates (39) and turbellaria (4). Many eggs of microinvertebrates (150 haul) were also found in the plankton samples. In general, the fauna was poor in both population density and diversity. However, only long-term or seasonal data will give the true picture of the lake ecosystem.

Bathymetry

Depth contours, prepared from spot soundings (Fig. 3), indicate a smooth gradient towards the cliffs, with a steep sloping bottom that drops to a central basin. Depth varies between 0.5 and 6.5 m. The west and south are characterized by shallow depths and gentle gradients. The central portion is flat, with a maximum depth of 6.5 m. Depth increases gradually from the shore mark to the bathymetric station (Figure 4) and the bottom topography also changes. The peripheral shelf, between 1 and 1.5 m deep, is surrounded by big boulders. The abundance of sand pebbles increases between 2 and 4 m. In the deeper area, the bottom is covered with a thick layer of algae and the amount of silt-clay was found to be higher. Diving on 7 January 1987 indicated that the sediment surface was covered with a 25–90 cm thick layer of filamentous blue-green algae.

The total volume of water over a submerged area (0.297 km²) has been estimated to be approximately 62 million m³. In summer the lake remains ice-free for about four months (mid-November to mid-March); for the rest of the year it has a blanket of 1–2 m of ice. The volume of water declines gradually in winter, due to reduced inflow and possibly to a subterranean outflow through porous

moraine around the 5 m isobath, which continues to flow even after the surface water has frozen (Heywood 1984). Climatic conditions are likely to cause changes in water levels from one year to the next.

Reporting the water volume in a moss lake at Signy Island, Light (1976) suggested that the minimum winter volume of lake water is 25% of the maximum summer volume. Accordingly, the volume of ice-free water available in Priyadarshani Lake for the winter period could be 15.5 million m³. Water could be supplied to the station throughout the year, using a heated pipe. The bathymetric study reported here will aid the selection of a suitable site for a water supply pipeline. However, the response of a fragile oasis ecosystem to increasing human activity needs to be monitored carefully.

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