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Aquatic ecology and plankton diversity of a freshwater lake (L5) at Bharti Island, Larsemann Hills, East Antarctica

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ABSTRACT

The Larsemann Hills range is an ice-free oasis on the Ingrid Christensen Coast of Princess Elizabeth Land, East Antarctica, which includes Bharti Island, Fisher Island, McLeod Island, Broknes Peninsula, Stornes Peninsula, and several other islands, promontories, and nunataks. The Larsemann Hills is an ice-free area of approximately 50 km^2, located halfway between the Vestfold Hills and the Amery Ice Shelf on the south-eastern coast of Prydz Bay, Princess Elizabeth Land, East Antarctica. The ice-free area consists of two major peninsulas (Stornes and Broknes), four minor peninsulas, and approximately 130 near shore islands. The Larsemann Hills area contains more than 150 freshwater lakes at different Islands and peninsulas. Bharti Island of Larsemann Hills in east Antarctica was selected as a sampling site for the present study. Water sample was collected from a freshwater lake during XXXth Indian Scientific Expedition to Antarctica (ISEA) and analysed for the physico-chemical parameters, major elements, trace metals & major plankton diversity in surface lake water by following standard methodology.

KEYWORDS

Aquatic ecology | Water quality monitoring | Antarctic lake | Bharti Island | water pollution

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Introduction

The different problems of the lake include excessive influx of sediments from the lake catchment, discharge of untreated or partially treated sewage and industrial waste waters, dumping of solid waste, entry of diffused nutrients source from agricultural and forestry, improper management of storm water, over abstraction, over-exploitation of lake for activities like recreation, fishing, encroachments, land reclamation *etc.* causing lake water shrinkage, shoreline erosion and impacting the lake hydrology, deteriorating water quality, impacting biodiversity, bringing climate changes *etc*. There is, therefore, an immediate need to know the pollution status of a lake at given time so that necessary conservation activities may be undertaken to regain/improve the health of water body (Sharma *et al*., 2010). Lakes are important feature of the Earth's landscape which are not only the source of precious water, but provide valuable habitats to plants and animals, moderate hydrological cycles, influence microclimate, enhance the aesthetic beauty of the landscape and extend many recreational opportunities to humankind. The lakes are also used for drinking, irrigation, fishing, eco-tourism, etc. apart from the above advantages (Bharti and Niyogi, 2015a).

High altitude lakes of Antarctica continent represent a relatively unique ecosystem in general; however, they remain less intensely studied than lowland lakes, mainly because of their remoteness and the short summer open-water period (Bhat *et al*., 2011). Nevertheless, Antarctic lakes are sensitive reference systems of global climatic change and other human impacts (Bharti, 2012a). In fact, although remote high altitude lakes are in general protected from direct human impacts, in the last few decades they have been increasingly affected by airborne contaminants, such as acids and nutrients (Rogora *et al*., 2006), organic pollutants and heavy metals (Carrera *et al*., 2002).

Due to the extreme environmental conditions (low temperature, strong radiations, mostly low buffering capacity and low nutrient level) these ecosystems have a relatively simple food web and react more rapidly and more sensitively to environmental changes than other lakes (Bharti and Gajananda, 2013). Even minor impacts are able to significantly affect the physical and chemical properties of soft water high altitude lakes, to induce changes in species composition and abundance of the biota and to cause accumulation of trace substances in higher trophic organisms (Hofer *et al*., 2001). In spite of the socio-economic and ecological importance of these lakes, better knowledge of several ecological aspects is needed for better understanding of their relationships with the environmental variables (Bharti and Niyogi, 2015b). These lakes have received little attention so far in terms of their limnology, diversity, conservation and water management, but they are becoming increasingly important due to the possible consequences of the global climate change (Bharti and Gajananda, 2013).

The Larsemann Hills area (69°20'–69°28'S, 76° 00'–76°30'E) is an ice-free oasis on the Ingrid Christensen Coast of Princess Elizabeth Land, East Antarctica, that includes Bharti Island, Fisher Island, McLeod Island, Broknes Peninsula, Stornes Peninsula, and several other islands, promontories, and nunataks (Fig. 1). The deglaciated terrain constitutes a transitional zone between marine and glacial ecosystems and includes gently rolling hills, glacially polished and striated bedrock hummocks (roches moutonnees), scoured surfaces, and broad valleys interspersed with lakes of varying dimensions. Indian scientific studies in the Larsemann Hills started in 2003 by various researchers and the present work was carried out from 2010 to 2011 during the construction of the third Indian research station Bharti. To investigate the aquatic ecology, lake water chemistry and characteristics in the area water sample was collected from a lake on Bharti Island. Few researchers are engaged in monitoring and assessment work especially on metal detection in water bodies and have done some work in this regards (Bharti 2012a; Bharti and Gajananda, 2013; Bharti and Singh, 2013; Bharti *et al.,* 2014; Bharti and Niyogi, 2015a; Bharti and Niyogi, 2015b; Bharti and Niyogi, 2015c; Bharti *et al.,* 2015;

2016; Kumar *et al*., 2017; Bharti, 2017).

The objective of this work is to identify, evaluate and predict the impact of increasing anthropogenic activities on environmental components of Antarctica especially on aquatic ecosystems. The generated data may reveal some interrelations of geo-genic and anthropogenic activities in natural aquatic ecosystem.

Material and Methods:

Study Area

Environmental monitoring and impact assessment studies were carried out in Antarctica during the austral summer seasons of various Indian Scientific Expeditions to Antarctica (SIIR, 2012).

Bharti Island of Larsemann Hills in east Antarctica was selected as a sampling site for the present

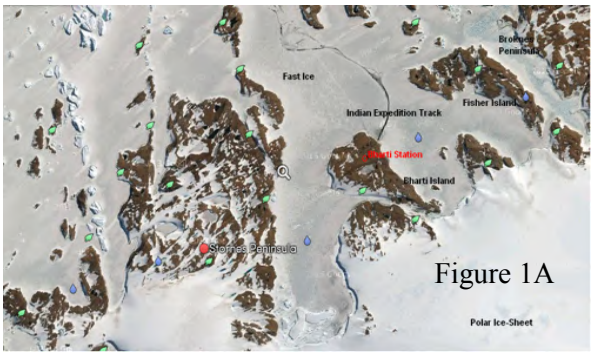


Figure 1A

study. Water sample was collected from L-5 lake of Bharti Island during XXXth Indian Scientific

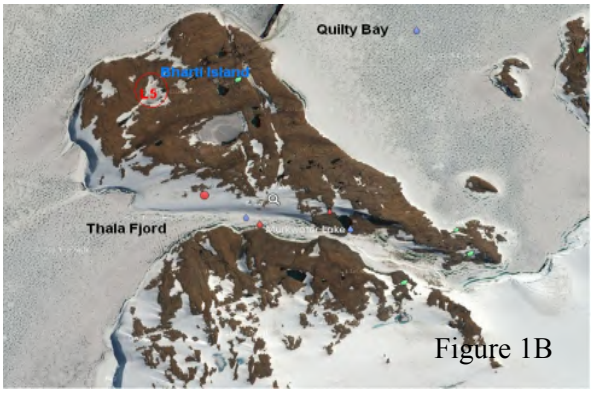


Figure 1B

Expedition to Antarctica (ISEA) and analysed for the physico-chemical parameters, major elements and trace metal in surface lake water (Bharti, 2012b). The location map of study area is given in the Fig.-1A and 1B. One sampling point L-5 was selected at Bharti Island, Larsemann hills in east Antarctica. Geo-coordinates of sampling point are given in Table-1.

Figure-1 (A-B): Location map of the study area and sampling site

Sampling

The sampling of lake water was carried out in the 1 L PET bottle and stored in a cold storage immediately after preservation by 1 ml 70 % HNO_3. The samples were transported to the laboratory after completion of expedition and analyzed for further analysis of the physico-chemical parameters, major elements, trace metals, plankton diversity and microbiological parameters.

Analytical Methods

Temperature and pH of lake water samples were recorded onsite using thermometer and digital pH meter. Standards methods as described in APHA (2005) were followed for the dilution and analysis for various parameters. Laboratory analysis work for metal analysis was carried out with the help of ICP-OES (Inductively Coupled Plasma Optical Emission spectroscopy).

Water sample was collected from sampling station on 16 January 2011. Neatly cleaned and rinsed double Stoppard polyethylene bottles were used for collection of water samples. Bottles were kept in ice box and brought to the laboratory for further analysis. Some of the physico-chemical characteristics of water including water temperature, color, pH were determined onsite using mercury thermometer, visual, digital pH meter respectively. While dissolved oxygen, turbidity and total dissolved solids were analyzed using Orion onsite water quality monitoring kit at the sampling stations. Separate samples were collected in sterile bottles for microbiological studies. Lake water was concentrated using plankton net and collected in a tube for further laboratory studies. Collected plankton were preserved by adding 4% Formalin solution and Lugol's solution. Other parameters including plankton diversity and metals were analyzed in the laboratory following the methods of APHA (2005) & Trivedi and Goel (1984). Plankton counting was conducted with the help of Bogorov / Sedwick Rafter Plankton Counter chambers as described in APHA (2005).

Results and Discussion

Geo-coordinates of sampling location are given in Table-1. Physico-chemical characteristics and trace metals of lake water sample are given in Table-2. Lake water temperature was found in very low conditions *i.e.* 1.0 ºC. The lake water chemistry of the area is greatly influenced by chemistry of the host rock rather than precipitation and evaporation (Gibbs, 1970). Numerous examples have appeared in the literatures which indeed support the idea that in an unpolluted environment, where anthropogenic activities are negligible, water quality can be correlated with minerals present in the bed rock (Asthana *et al*., 2013).

General physico-chemical characteristics

Lake water was found to be free from any colour, odour or turbidity. pH of selected freshwater lake sample was slightly acidic in nature and found to be 5.9. Total hardness of lake water sample was found to be 25 mg/l, while alkalinity was found to be 10 mg/l. Total dissolved solids were recorded 97 mg/l, whereas dissolved oxygen was measured to be 10.9 mg/l. Total organic carbon in lake water sample was found 0.085 mg/l.

Dominant elements

Chlorides and calcium were found to be the dominant constituents among the lake water contents. Maximum chloride and calcium were found to be 48 mg/l and 6.7 mg/l. Besides these, sulphate (7.0 mg/l), Nitrate (1.1 mg/l) and phosphate (0.025 mg/l) were also detected in L-5 lake water sample at Bharti station, Larsemann Hills.

Trace metals

Magnesium was found to be 3.8 mg/l, while iron was found to be 0.06 mg/l in lake water collected from freshwater lake L-5 at Bharti Island. Zinc and manganese were also detected 0.01 mg/l and 0.003 mg/l respectively. Fluoride was found to be 0.08 mg/l in lake water sample. Trace metals like cadmium and aluminum were found below detection level in lake water sample. Similar trend was observed for mercury, selenium, arsenic, lead & chromium metals in lake water sample collected from Bharti Island. Few metals are biologically essential to living organisms in trace quantities in aquatic ecosystems. These trace metals may recirculate from sediment and became available for biota (Campbell *et al*., 1988).

Complex organic compounds

Phenolic compounds (as C_6H_5OH), Anionic detergents (MBAS) and mineral oil were not detected in lake water sample at Bharti Island in east Antarctica.

Microbiology of lake water

Results for microbiological parameters of lake water samples are given in Table-3. Total bacterial count and psychrophillic counts were found to be less than 1 cfu. No growth was observed for MPN coliform in the sample. Yeast & Moulds, Salmonella, Staphylococcus and Pseudomonas spp. were also found to be absent in freshwater lake water sample. Few similar studies were also carried out by Bharti and Niyogi (2015c).

Plankton

Plankton community consists of two major groups namely phytoplankton and zooplankton in an aquatic ecosystem. Both groups have further various subgroups (families or phylum) having different characteristics, body structure and life cycles. Under phytoplankton group, Chlorophyceae members (600 individuals/m^3), Basillariophyceae members (1000 individuals/m^3) and Cyanophyceae members (80 individuals/m^3) were observed, while Rhodophyceae members were not found at the time of sampling. Some unidentified or phytoplankton of other groups (1000 individuals/m^3) were also found in the water of L-5 freshwater lake at Bharti Island. Among the Phytoplankton community, Basillariophyaceae and Chlorophyaceae groups were found dominant in the lake water at Bharti Island. Diatoms were found as a major constituent of Phytoplankton. Pinnularia, Nitzschia and Achnanthes were the major diatoms. Frazilaria, Navicula and Hantzchia might be present in Antarctic fresh waters as per some researchers (Gupta, 2002). Besides this, evidences of the presence of Nostoc, Osillotoria, in Antarctic water were also observed by Palanisamy (2010). Few unidentified Phytoplankton genera were also encountered in lake waters during the present study.

S. No.	Sample ID	Date	Latitude (S)	Longitude (E)	Altitude (m)
1	L-5	16-01-2011	69º 24’ 26.0”	76º 10’ 59.0”	52

Table 1: Location of lake’s water sampling site at Bharti Island

S. No.	Parameter	**IS: 10500-1991** Desirable (permissible)	L-5
1	Colour, Hazen unit	5, Max.	<5
2	Odour	Unobjectionable (UO)	UO
3	Turbidity, NTU	5, Max. (10)	<1
4	pH	6.5-8.5	5.9
5	Total hardness (as $CaCO_3$), mg/l	300, Max. (600)	25
6	Iron (as Fe), mg/l	0.3, Max. (1.0)	0.06
7	Chloride (as Cl), mg/l	250, Max. (1000)	48
8	Fluoride (as F), mg/l	1.0, Max. (1.5)	0.08
9	Dissolved Solids, mg/l	500, Max. (2000)	97
10	Magnesium (as Mg), mg/l	30, Max. (100)	3.8
11	Calcium (as Ca), mg/l	75, Max. (200)	6.7
12	Copper (as Cu), mg/l	0.05, Max. (1.5)	<0.001
13	Manganese (as Mn), mg/l	0.1, Max. (0.3)	0.003
14	Sulphate (as SO_4), mg/l	200, Max.	7
15	Nitrates (as NO_3), mg/l	45, Max	1.1
16	Phenolic Compounds (as C_6H_5OH), mg/l	0.002, Max	ND
17	Mercury (as Hg), mg/l	0.001, Max.	<0.001
18	Cadmium (as Cd), mg/l	0.01, Max.	<0.01
19	Selenium (as Se), mg/l	0.01, Max.	<0.005

S. No.	Parameter	IS: 10500-1991 Desirable (permissible)	L-5
20	Arsenic as As,mg/l	0.01, Max	<0.005
21	Cyanide (as CN), mg/l	0.05, Max	<0.01
22	Lead (as Pb), mg/l	0.05, Max	<0.01
23	Zinc (as Zn), mg/l	5 Max. (15)	0.01
24	Anionic Detergents (MBAS) mg/l	0.2, Max	ND
25	Chromium (as Cr^{+6}), mg/l	0.05, Max	<0.01
26	Mineral Oil, mg/l	0.01, Max	ND
27	Alkalinity (as $CaCO_3$), mg/l	200 Max.(600)	10
28	Aluminum (as Al), mg/l	0.2, Max	<0.02
29	Phosphate (as PO4), mg/l	0.05, Max.	0.025
30	Boron (as B), mg/l	1, Max (5)	<0.001
31	Total Organic Carbon (TOC), mg/l	-	0.085
32	Dissolved Oxygen (DO), mg/l	-	10.9

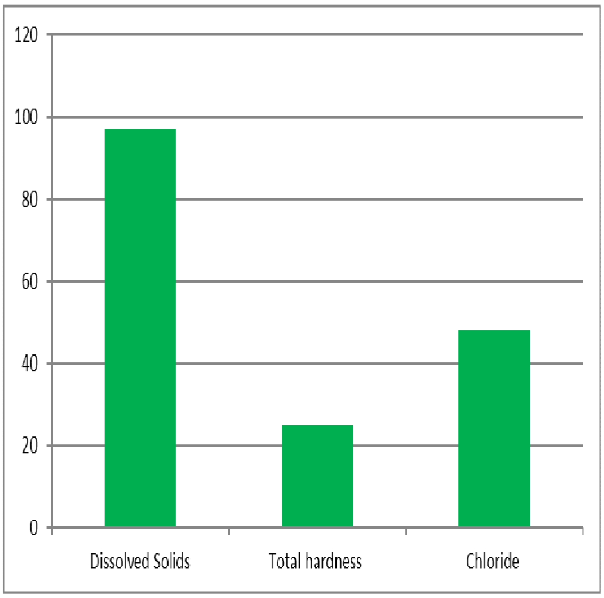
Table 2: Results of lake's water sample from Bharti Island

S. No.	Sample ID	L-5
1	Total Bacterial Count/ml(As per guidelines of IS : 5402-2002, Reaff. 2007)	Less than 1
2	Psychrophillic Count/ml (As per guidelines of IS: 1479 p-3, 1977, Reaff.: 2003)	Less than 1
3	MPN Coliform /100ml (As per guidelines of IS:1622-1981, Reaff. : 2003) Ed 2.4 (2003-05)	No growth observed
4	Yeast & Mould Count/ml (As per guidelines of IS: 5403 1999, Reaff.: 2005)	Absent
5	Salmonella/ 25ml (As per guidelines of IS: 5887 (p-3) 1999 Reaff.: 2005)	Absent
6	Staphylococcus aureus/25ml (As per guidelines of IS : 5887 P-2 1976 Reaff. : 2005)	Absent
7	Pseudomonas spp./10ml (As per guidelines of IS:13428, Amn.D, 2005)	Absent

Table 3: Microbiological Studies of lake water sample from Bharti Island (30^{th} ISEA)

S.No.	Plankton group	Nos. of Plankton (Ind./ m^3)
Phytoplankton		
1	Chlorophyacae	600
2	Basillariophyace	1000
3	Cyanophyacae	80
4	Rhodophyacae	-
5	Others / Unidentified	1000
B. Zooplankton		
1	Protozoa	20
2	Rotifera	-
3	Copepoda	60
4	Cladocera	120
5	Decapoda	-
6	Others / Unidentified	140

Table-4: Plankton diversity in lake water at Bharti Island (30th ISEA)



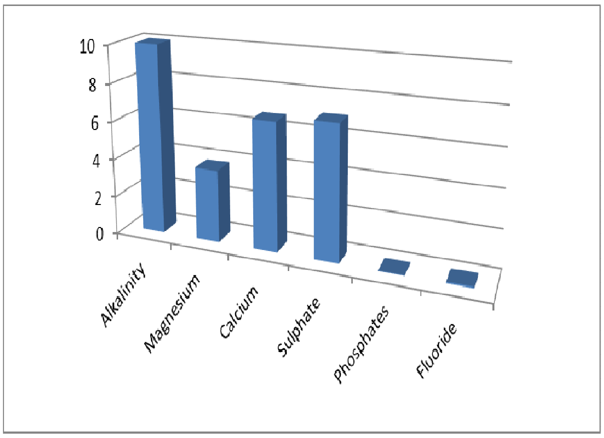
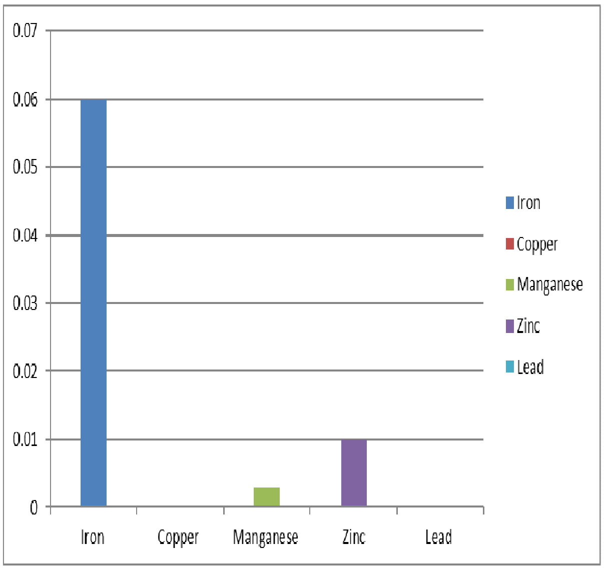


Fig-2: Showing total dissolved solids, hard-



ness and chlorides in lake water (in mg l^{-1})

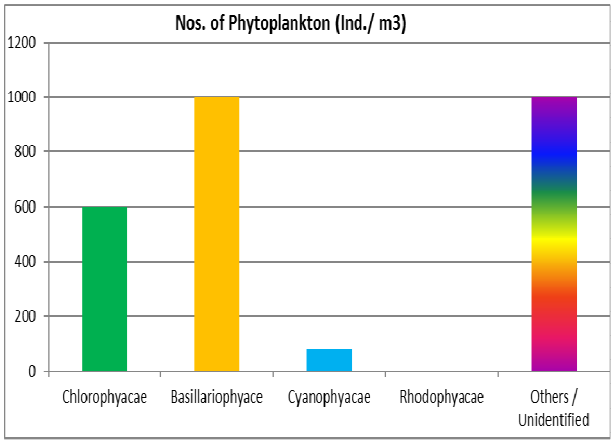


Fig-5: Showing major phytoplankton group in lake water (in Ind./m^3)

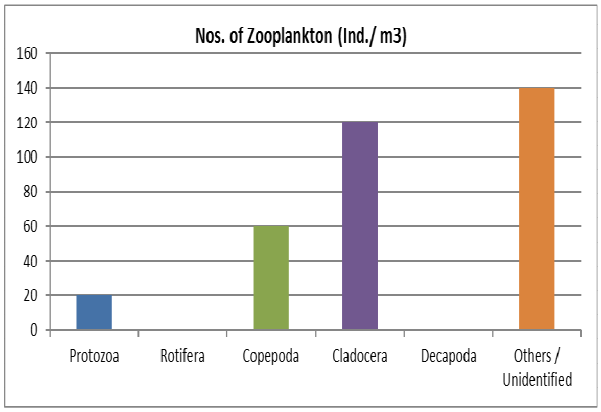


Fig-6: Showing major zooplankton group in lake water (in Ind./m^3)

In zooplankton group, members of phylum Protozoa (20 individuals/m3), phylum Rotifera (0 individuals/m3), phylum Copepoda (60 individuals/m3), phylum Cladocera (120 individuals/m3) were observed, while Decapoda members were not found during the sampling period. Some unidentified or zooplankton of other groups (140 individuals/m3) were also found in the water of L-5 freshwater lake at Bharti Island. Few Daphnia and others unidentified Ciliates were also found in Lake L-5, which indicates presence of some new species of Plankton (Bahrti and Niyogi, 2015b). During the study period in 30th ISEA, the lakes were found in frozen condition so the sample could not be collected for benthic diversity assessment from the deep regions of lake. Results for phytoplankton and zooplankton community in freshwater lake ecosystem are given in Table-4 and Fig.-5 and Fig.-6 respectively.

After evaluating general physico-chemical parameters, heavy metals and organic compounds in lake water, it has been observed that the water of the selected lake has no pollution load and no significance impact of any anthropogenic activity. Low organic load in lake water indicate the oligotrophic stage of lake ecosystems (Bharti and Niyogi, 2015a; Bharti and Niyogi, 2015b; Bharti and Niyogi, 2015c). In oligotrophic lakes that are low in primary productivity as a result of low nutrient content, the chemistry depends mainly on lithology, precipitation, evaporation and period of sojourn of water in the basin (Shrivastava *et al*., 2011).

Conclusion

It has been observed that the water of the selected lake has no pollution load and no significance impact of any anthropogenic activity. Low organic load in lake water indicate the oligotrophic stage of lake ecosystems. High dissolved oxygen content in lake water will support to aquatic organisms. This is indeed very good and healthy condition for any aquatic ecosystem. Lake water sample was found free from harmful pathogens and has no psychrophillic bacterial population in lake water. Total dissolved solids are also very low, so the raw lake water can be considered as drinking water.

It can be concluded that the presence of plankton community indicated the initial establishment of a healthy ecosystem in freshwater lake L-5 at Bharti Island. Abundance of major phytoplankton group members showed the favorable circumstances for photosynthesis in aquatic ecosystem. Phytoplankton and zooplankton observed in the aquatic ecosystem of freshwater lakes of Bharti Island can also serve as indicator for further pollution studies and to know the status of pristine Lake Ecosystem in Antarctica continent

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