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Diversity of Algal Flora in Six Fresh Water Streams of Schirmacher Oasis, Antarctica

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Abstract

Algae and cy anobacteria (blue-green algae) flora of six fresh water streams of Schirmacher Oasis was investigated. Over 30 species of algae predominantly belonging to cyanobacteria were recorded. Among the cyanobacteria contribution by N2-flxing species (both heterocystous and unicellular aerobic diazotrophs) was more than 50% and their distribution was abundant in the middle region of the stream. Composition of cyanobacteria and algae flora varied in different stream, and species diversity was maximum in stream which supported the highest number of species. Based on the diversity of the species, streams could be classified into two clusters.

Introduction

It is generally agreed that Antarctica provides a harsh environment for growth and survival of organisms. Nutrient pool is low in Antarctica, limiting the distribution of microflora in terrestrial and aquatic ecosystem. Following pioneering investigations on algal flora of Victoria Land by West and West (1911) and Fritsch (1912) several investigations have been conducted to study the pattern of distribution and taxonomic evaluation of aquatic algae (Hirano, 1979; Parker *et al,* 1972; Karasawa and Fukushima, 1979; Pridle and Belcher, 1982, Broady, 1989; Hawes, 1988; Howard Williams *et al,* 1986). Although most studies document on the productivity of fresh water lakes and/or their microflora (Goes *et al,* 1990; Verlencar *et al.,* 1990;Heywood et al., 1980; Howard Williams *et al,* 1986) little is known about fresh water streams. Most of the studies are limited to taxonomic evaluation only.

In the present report the results on the distribution of algae and cyanobacteria flora of fresh water streams of Oasis have been described. Although Alesinskaja and Bardin (1965) and Pankow *et al* (1987) have described the algal flora of this region, to the best of our knowledge no attempt has been made to examine the cyanobacteria and algae species diversity in fresh water streams of the Oasis.

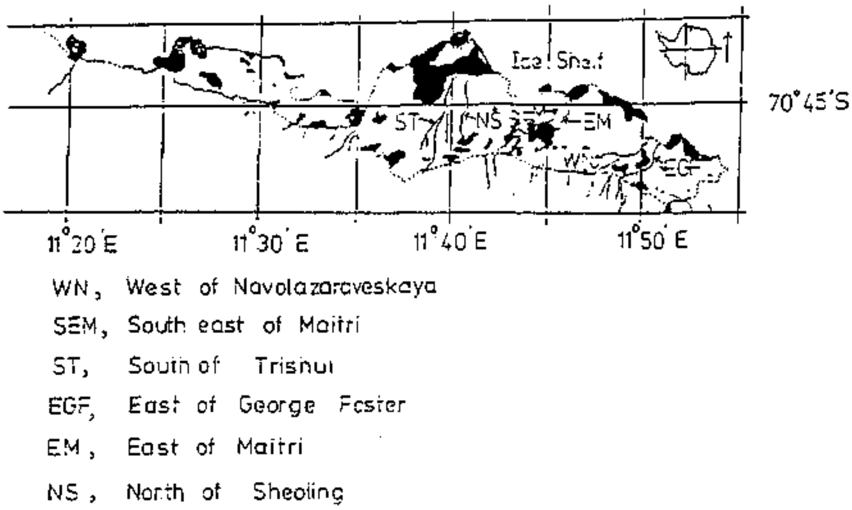


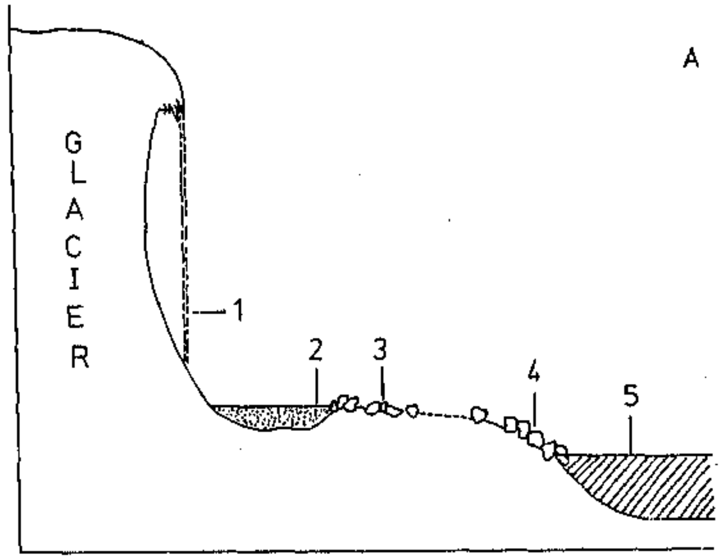
Fig. 1. Schumacher Oasis, Antarctica showing approximate position of different streams.

Study Site

The Schirmacher Oasis, oriented in east-west direction, lies between two types of large ice bodies (a) glacier in the south and (b) ice shelf at the north of the Oasis. During the polar summer the ice melts and water flows in the form of stream often adding water to the lakes. Depending on the origin, two types of streams could be observed (i) glacier-melt water streams which are formed as a result of melting of glacier. In this case water accumulates at the edge of glacier often forming small pool which eventually overflows forming a stream (Fig. 2) and (ii) the stream formed from the melt water received from the snow drift accumulated on the hill tops.

The upper reach of a stream passes through well defined channel in which stream runs steeply over stones and boulders. The middle portion, nearly one third of the total length, is flattened and steepness is comparatively less. Stream flows over gravel and fine material as well as stones and rate of flow is slow. The lower reach, which is shorter in length, consists of fast flowing flattened section near the meeting point of the lake.

Examination of algae and cyanobacteria was conducted in three glacier-melt water streams; west of Navolazarveskaya (WN), south east of Maitri (SEM) and south of Trishul peak (ST), which vary approximately 500-1000 meter in length. The snow drift/melt water streams, east of George Foster (EGF), east of Maitri (EM) and north of Sheoling peak (NS) were rather short in length (ca. 200- 400m).



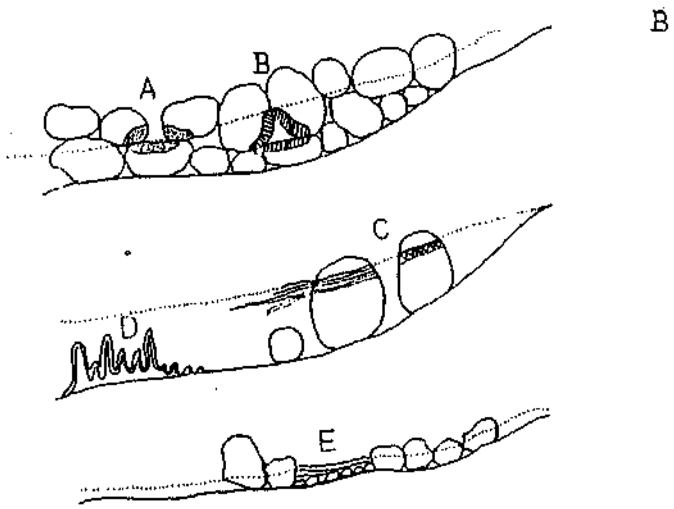


Fig. 2a. Schematic representation of vertical profile of a stream, originating from glacier and meeting in lake. The number represents different sites: water coming from glacier (J), pond (2), upper stream (3), lower stream (4) and pond (5).

Fig. 2b. Diagrammatic representation of different habitats of algae and cyanobacteria growing in stream from where samples were removed.

Methods

Algal and cyanobacterial samples were examined microscopically. Identification was made by consulting pertinent literature (Bourrelley, 1966,1968, 1970; Geitler, 1932; Desikachary, 1959). Relative frequency and density (RF, RD and RFD) of a species was determined as follows:

$$\text{Relative frequency(RF)} = \frac{\text{Number of samples in which species is present}}{\text{Total number of samples}} \times 100$$

$$\text{Relative density(RD)} = \frac{\text{Number of individuals of a species in microscopic field}}{\text{Total number of individuals in microscopic field}} \times 100$$

Where microscopic field represents an area of 1.31 mm .

The average between relative frequency and density i.e. $\frac{RF + RD}{2}$ was calculated for each species and represents an index for its relative dominance. The maximum value was considered as 100% and on this basis species of a site was divided into 4 classes, i.e. 0-25 (taxon present), 26-50 (common constituent), 51-75 (dominant) and 76-100 (important). The data about the distribution of algae and cyanobacteria are represented in Table 1 following the procedure of Priddle and Belcher (1982). The similarity matrix (Sj) was calculated following the method described by Jaccard (1908). Diversity indices, cluster analysis and polar ordination were determined according to Ludwig and Reynold (1988).

Results

An annotated list of the algae and cyanobacteria recovered from different streams and their contribution has been presented in Table 1 together with an indication of their location within the stream. The black epilithic crusts were abundant on rock surfaces which were occasionally covered by water during period of maximum water flow (Habitat A, Fig. 2). This habitat supported growth of *Phormidium. Frigidum* as an important constituent and was dominated mostly by non-N2-fixing species, Habitat B (Fig. 2) supported growth of N2-fixing cyanobacteria. The rock surfaces directly exposed to sunlight and submerged in water favoured the growth of thin reddish brown to blue-green encrustation (habitat C, Fig. 2). These crusts were composed of both N_2 and non-N_2-fixing species. The small pond at the beginning of stream and at the point where depth of the stream was comparatively more, supported growth of an extensive benthic red-brown to blue-green and sometimes black Oscillatorian felt that this was either flat and smooth or with finger like projections ranging from 0.5 to 2.5 cm high (Fig. 2, habitat D). The cyanobacterial patches only covered with high amount of mucilage were abundant on the soil surface near the edge of the stream and were also observed in the depressions created on turning the small rocks and stones in slow running streams. Sometimes

Table 1. Distribution Pattern of Algal and Cyanobacteria Species in Different Streams and at Habitat and Sites of Stream in Schirmacher Oasis, Antarctica

Species	Stream						Habitat					Site				
	WN	SEM	ST	EGF	EM	NS	A	B	C	D	E	1	2	3	4	5
Chroococcus minutus		Δ	×						Δ					Δ		Δ
Gloeocapsa kuetzingiana	Δ	Δ	Δ		Δ			Δ	●						O	Δ
G. ralfsiana	×	●	Δ		Δ	Δ	Δ	●	Δ					●	●	
G. magma	×	Δ		Δ		Δ	Δ	●						O	×	
Aphanbthece nidulans			Δ			Δ					×		×			×
Chaemosiphon subglobosus		Δ		×	×		Δ							Δ	×	
Lyngbya aeustuarii		Δ			●	Δ	Δ			Δ			Δ	×		•
L. attenuata	●		Δ			Δ					●		×			
Oscillatoria litnosa	O	O	Δ	●	●	Δ	Δ			O			O	Δ		O
O.kuetlitzii	O	●	Δ		●				Δ	●			Δ		•	
0. limnetica	Δ	●		Δ						Δ			●	×		●
O. agardhii			O		Δ	●				●			×			●
Phormidium fragile		Δ	O		×	Δ	Δ			Δ			•			Δ
P.frigidum	•	O	O	●	O	O				O			O	×	Δ	O
P. autumnale	×			Δ						Δ			×			
Plectonema sp.		Δ	Δ				×			×					O	Δ
Nostoc commune	Δ	O	O	Δ	O	●		O			O			Δ	O	O

Table 1 : *Contd.*.

Species	Stream						Habitat					Site				
	WN	SEM	ST	EGF	EM	NS	A	B	C	D	E	1	2	3	4	5
N.sphericum		Δ			Δ	Δ		Δ			Δ			Δ	O	Δ
N. punctiforme	×		Δ	Δ				Δ			Δ				×	
Nostoc sp.	×	×	×			Δ		Δ			Δ			×	Δ	
Anabaena sp.		Δ	Δ		Δ					×	Δ				●	●
Calothrix gracilis		Δ	Δ	O		Δ	Δ		O				×	×	Δ	
C. parietina	Δ	Δ		●	●	Δ		●			●			Δ	Δ	●
C. brevissima		×	Δ				×	Δ							Δ	
Tolypothrix conglutinata			×		×	Δ		●						Δ		
Uronema sp.	Δ	O	●	Δ		O			O		O				O	●
Cosmarium laeve		Δ	Δ	Δ	O	O	Δ				O				Δ	O
Pinnularia borealis	O	Δ	Δ							×			Δ			
Navicula muticopsis		Δ	×		×					×			Δ			Δ
Nitzschia obtusa		×	×			×				×			×			×

O Important constituent of the community

● Dominant species

Δ Dominant but not as above

x Just present

Table 2: Diversity Indices of Species in Six Different Streams of Schirmacher Oasis, Antarctica

Stream	Richness		Diversity	Evenness
	No	R_1	N_2	E_5
WN	15	3.05	11.36	0.93
SEM	24	5.00	19.16	0.97
ST	23	4.42	15.24	0.90
BGF	12	2.39	9.27	0.92
EM	16	3.13	11.40	0.93
NS	19	3.91	15.82	0.98

WN = West of Navolazaraveskaya

SEM = South East of Maitri Station

ST = South of Trishul peak

EGF = East of George Foster

EM = East of Maitri

NS = North of Sheoling peak

they are not covered with water, however, soil surface was always moist representing the semiaquatic conditions (habitat E, Fig. 2). This habitat was dominated by N2-fixing species.

In general, the occurrence of photosynthetic microorganisms was mainly constituted by cyanobacteria in Oasis. Glacier did not support growth of algae and cyanobacteria. The pond (site 2, Fig. 2) and upper stream supported less growth of algae and cyanobacteria. However, their growth was abundant and readily visible on the surface of the rocks, boulders and weathered soil of the middle portion of the stream. The water flow was comparatively slow due to large area covered which helped probably in the maximum growth of cyanobacteria (site 3, Fig. 2). The lower reach of the stream (site 4, Fig. 2) supported luxuriant growth of green filamentous algae (*Uronema* sp.) which was less frequently observed in the upper and middle reach of the stream. The glacier bound stream SEM near Maitri lake showed maximum abundance of cyanobacteria whereas number of species encountered was minimum in hill top snow drift bound stream EGF near German station. Among cyanobacteria, more than half of the species were N2-fixing and *Oscillatoria limosa, Phormidium frigidum* and *Nostoc commune* were present in all the six streams.

The species diversity indices bas.ed on relative frequency and density of different species in six streams was calculated to determine the richness, evenness and diversity. The species richness of algae and cyanobacteria was highest in streams SEM followed by streams NS, ST, EM, WN and lowest in EGF. The diversity indices revealed that maximum diversity exists in SEM and minimum in EGF. The

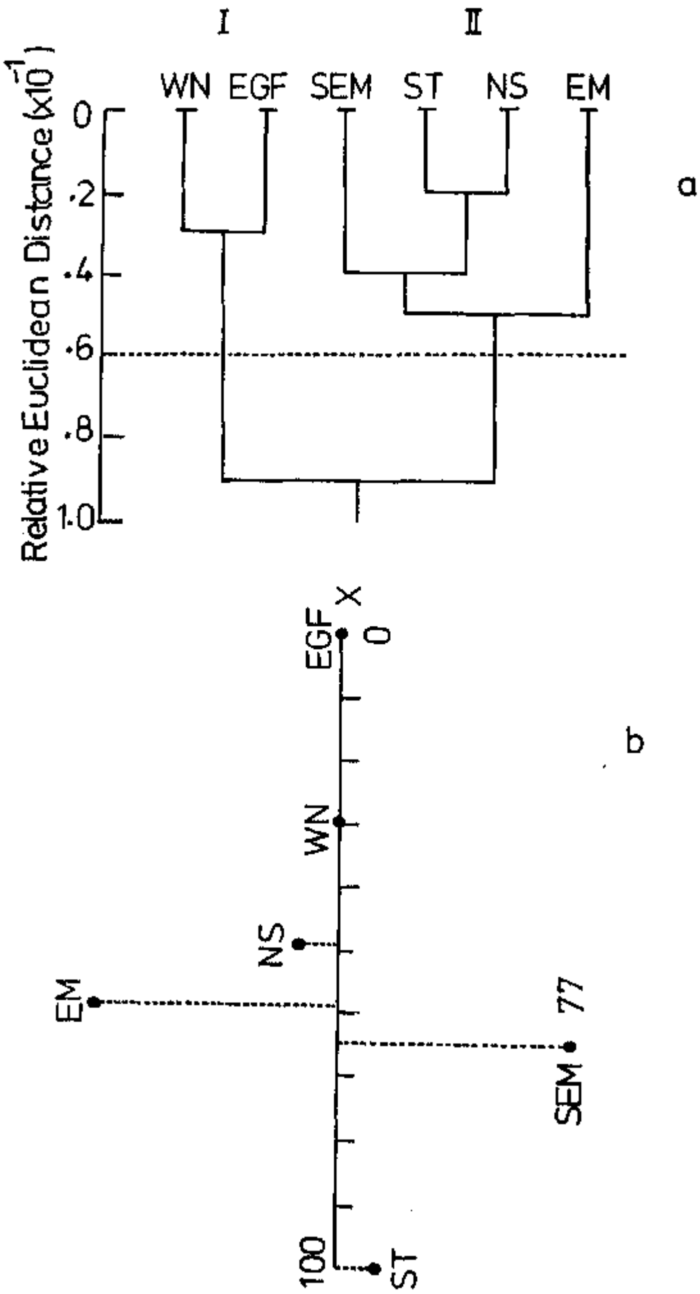


Fig. 3a. Dendogram of clustering of six streams using Euclidean distance.
Fig. 3b. Polar ordination of six streams based on relative frequency and density of species. The X and Y axes are drawn between their respective points.

evenness indices vary between 0.9 to 0.98; the higher values seem related to the dominance of several species (Table 2).

The pattern of clustering of six streams has been summarized in the dendogram (Fig. 3). The six streams form two clusters: I (stream WN and EGF) and II (rest all). The simplified polar ordination based on similarity indicated that stream EGF and WN lies apart on X-axis, abundance of species was similar in both the streams. Stream SEM and EM and ST and NS, closely located in Oasis, showed nearly equal deviation on Y-axis, however, SEM and EM are closely located and ST and NS lie apart on X-axis (Fig. 3). Jaccard similarity coefficient, Sj, based on presence and absence of species in different stream showed that Streams WN and EGF were more similar (Sj = 0.62) in occurrence of species than the other streams.

Discussion

Although a number of investigations were carried out on fresh water lakes of peninsular and continental Antarctica (Hirano, 1965; Heywood, 1977; Longton, 1973; Seaburg *et al.* 1979), the ecology and taxonomy of algae and cyanobacteria of Antarctic streams remain poorly understood, Broady (1982) described distinct zonation in the distribution of algal species along the entire length of a fresh water stream and their occurrence at different habitats. The abundance and the type of vegetation varies in individual stream depending upon the physico-chemical properties and volume and speed of water flow in the stream (Broady, 1989). A general picture of algal flora of Antarctic stream was presented by Howard Williams *et al.* (1986).

It is documented that the algal flora changes substantially over the length of water flow in most of the river ecosystem (Whitton, 1975) with change in the nature of substratum and physico- chemical properties of water. The results that algal flora of Schirmacher Oasis was dominated by cyanobacteria is in conformity to the observation of Broady who examined the algal flora in fresh water streams of Taylor valley of Antarctica and concluded that algal flora was dominated by cyanobacteria and specially the non-heterocystous filamentous forms. Among the cyanobacteria encountered in the streams of Schirmacher Oasis, contribution by N2-fixing species was more than 50% suggesting that they might play a significant role in nitrogen economy of the ecosystem through N_2-fixation.

Glacier meltwater stream located in the south east of Maitri station (SEM) supported the growth of maximum number of species of cyanobacteria. Also the species diversity was maximum in this stream. Streams located in the eastern side of Oasis (EGF and WN) seem to be similar in species abundance as indicated in the cluster analysis and polar ordination. The reason for similarity is quite intriguing but possibly could be related to the human activity in the region. The middle portion of the Oasis supported maximum number of streams and these streams exhibited maximum species diversity.

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References

Alesinskaja, Z.V. and Bardin, V.I. (1965): Diatomovaja flora oazisa Sirmachera. *Inf. Bjull. Sov. Antarkt.* 54,47-49.

Bourrelley, P. (1966): Les Algues d'eau douce. Initiation la systematique 1. Les algues et brunnes, Paris N Boubee et Cie.

Bourrelley, P. (1968): Les Algues d'eau douce. Initiation la systematique 2. Les algues Vertes. Paris N Boubee et Cie.

Bourrelley, P.-(1970): Les algues d' eau douce. Initiation la systematique 3. Les Algues blues et rouges. Paris N Boubee et Cie.

Broady, P.A. (1982): Taxonomy and ecology of algae in a fresh water stream in Taylor Valley, Victoria land, *Antarctica. Archiv. Hydrobiol.* 63, 331-349.

Broady, P.A. (1989): Broad scale pattern in distribution of aquatic and terrestrial vegetation at three ice free region on Ross island, Antarctica. *Hydrobiol.* 172**,**77-95.

Desikachary, T.V. (1959): *Cyanophyta.* Indian Council of Agril. Res. New Delhi, India.

Fritsch, F.E. (1912): Fresh water algae of National Antarctic .Expedition (under Captain Scott) 1902-1904. *National Antarct. Exped. Nat. History* 6, 1 -61.

Geitler, L. (1932): Cyanophyceae. In: Rabenhorst L. Kryptogamen Flora von Deutschand, Osterrelch und der Schioeiz Leipzig.

Goes, J.J., Fondekar, S.P. and Parulekar, A.H. (1990): Standing crop and growth rates of net phytoplankton in Antarctic water. In: S.N. Dwivedi B.S. Mathur and A.K. Hanjura (Eds.) Proceedings of Workshop on Antarctic Studies. Indian Council of Scientific and Industrial Research, New Delhi, pp. 419-434.

Hawes, I. (1988): Filamentous green algae in fresh water streams on Signy Island, Antarctica. *Hydrobiol.* 172**,**1-8.

Heywood, R.B. (1977): A limnological survey of Ablation point area, Alexan der Island, Antarctica. *Phil. Trans. Royl. Soc. London* B 279**,** 39-54.

Heywood, R.B, Dartnell, H.L.G. and Priddle, J. (1980): Characteristics and classification of lakes of Signy Island. South Orkeney Island, Antarctica. *Fresh water Biol.* 1,47-59.

Hirano, M. (1965): Fresh water algae in Antarctic regions. In: P. van Meighem, P.van Dye and J. Schell (eds.) Biogeography and Ecology in Antarctica. The Hague, 127-193.

Hirano, M. (1979): Fresh water algae from Yukidori Zava, near Syowa station, Antarctica. Mem. *Nat. Inst. Polar Res. Spec.* Issue **11,** 1-26.

Howard Williams, C, Vincent, W.F. Broady, P.A. and Vincent, C. (1986): Antarctic stream ecosystems: Variability in environmental properties and algal community structure. *Int. Revue ges Hydrobiol. 71:511-544*

Jaccard, P. (1908): Nouvelles resherches sur la distribution florale. Bulletin de la Societie Vaudoise des Science Naturelles **14:** 223-270.

Karasawa, S. and Fukushima, H. (1977): Diatom flora and environmental factors in some fresh water pond of East Ongul Island. *Antarct. Res.* 59,46-53.

Longton, R.E. (1973): A classification of terrestrial vegetation near Mc Murdo Sound, *Continental Antarctica. Can. J. Bot.,* 51,2339-2346.

Ludwig, J.A. and Reynolds, J.F. (1988): Statistical Ecology: A Primer on Methods and Computing. John Wiley and Sons, New York.

Pankow, von H., Haendel, D., Richter, W. and Wand, U. (1987): Algologische Beobachtungen in der Schirmacher und Utnetrsee Oases (Dronning Maud Land, Ostantarktika). *Arch. Protisten Kd.*, **134,** 59-82.

Parker, B.C., Samsel, G.L. and Prescott, G.W. (1972): Fresh water algae of Antarctic peninsula. 1. Systematics and Ecology in U.S. Palmer station area. In: Llaon G.A. (ed.) Antarctic Terrestrial Biology. American Geophysical Union, Washington DC, pp. 69-81.

Priddle, J. and Belcher, J.H. (1982): Fresh water biology of Rothera point, Adelaida Island. II Algae. *British Antarct. Surv. Bull.* 55, 1-9.

Seaburg, K.G., Parker, B.C., Prescott, G.W. and Whitford, L.A. (1979): The algae of southern Victoria land, *Antarctica. Bibliotheca Phycol.* 46, 1-169.

Verlencar, X.N., Ingole, B.S. and Paulekar, A.H. (1990): Characteristics of the fresh water lakes at the Schirmacher Oasis in Antarctica. In: Proceedings of Workshop on Antarctic Studies (Eds. S.N. Dwivedi, B.S. Mathur and A.K. Hanjura). Deptt. of Ocean Development, New Delhi, pp 144-153.

Vincent, W.F. and Howard Williams, C. (1986): Microbial ecology of Antarctic streams. In: P. Megusar and M. Canter (eds.) Perspectives in Microbial Ecology, Slovene Society for Microbiology, Ljubjana Yogoskvia, pp. 201-202.

West, W. and West, G.S. (1911): Fresh water algae in British Antarctic Expedition 1907-1909. Vol. I Biol. Part 6&7, 263-298.

Whitton, B.A. (1975): Algae. In: B.A. Whitton (ed.) River Ecology. Blackwell, Oxford. pp. 81-105.