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Temporal and spatial variations of phytoplankton from Boeckella Lake (Hope Bay, Antarctic Peninsula)

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Abstract: The main water body at Hope Bay, Boeckella Lake, was sampled at four sites for phytoplankton during summer 1991 to assess the influence of nutrients from nearby penguin rookeries on both phytoplankton density and composition. The site located at the base of the rookeries had total phosphorus values comparable to those reported from the most eutrophic Antarctic lakes. During the ice-free period most of the Chlorophyceae and Cyanophyceae recorded were concentrated at this site. Phytoplankton density increased strongly in the area opposite to the rookeries where ice began to form; an under-ice bloom of *Ochromonas* aff. *ovalis (Chrysophyceae)* was observed in this area.

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Introduction

The ecology of freshwater phytoplankton in the area of Hope Bay (Antarctic Peninsula) is poorly documented. Only one paper has been published (Corte 1962) on the algal flora and some general features of Boeckella, Esperanza and Flora lakes.

The present study is part of a major research project on the taxonomy and ecology of freshwater algae from Hope Bay lakes. Qualitative and quantitative changes in the summer phytoplankton community, and the abiotic factors involved in Boeckella Lake are presented. The lake was sampled at sites with different amounts of organic matter input to assess the effects of nutrients from the penguin rookeries on the phytoplankton community.

Study site

Lake Boeckella is the most important water body in the Hope Bay area, (63°23'S, 57°W, 41 m a.s.l.), and provides drinking water to the Argentinian Base Esperanza, located about 600 m away from it. It is situated on a fluvio-glacial depression dammed by moraine sediments which, at the SW margin, are covered by a thick layer of guano rich in calcium phosphates, derived from the nearby penguin rookeries (Tatur 1989). These ornithogenic soils are the most important source of lake nutrients and contribute to a considerable accumulation of organic matter on its bottom. Corte (1962) reported values of *c.* 0.06 g l^{-1} of organic matter in the deep waters.

The water of Boeckella Lake is chiefly supplied by inflowing streams from the Mount Flora glacier, with the addition of winter snow accumulation. The influence of the streams is minor during the winter, but in summer, during the thaw period, the discharge of the streams increases dramatically, depositing large amounts of allochthonous particles into the lake. Lake discharge into the sea also increases in summer. The main morphometrical features of Boeckella Lake are presented in Table I.

Materials and methods

Six series of samples were taken from 23 January–22 February 1991. Four littoral sampling sites were selected: S1: at the mouth of the main stream flowing into the lake; S2: on the shore opposite to the rookeries; S3: at the base of the rookeries; and S4: near the water supply pump and the outflowing stream (Fig. 1).

At each site water temperature, pH and conductivity were measured with Luftman P300 and C400 combined electronic meters. Water samples for chemical and phytoplankton analysis were collected in PVC flasks. Oxygen concentrations were determined according to standard Winkler methods (APHA-AWWA-WPCF 1975) and total phosphorus according to Mackereth *et al.* (1978).

Whole (non-filtered) samples for qualitative and quantitative analyses were collected by lowering 200 ml PVC flasks into the surface water layer. These samples were preserved with 1% Lugol's solution. As a complement to taxonomic analyses with the aid of cultures, and in order to obtain adequate numbers of the scarcest organisms, additional samples were obtained with a 15 μm net.

Counts were performed using an inverted microscope following Utermöhl (1958). Replicate subsamples were left to sediment for 24 h in 25 or 50 ml chambers, depending on

Table I. Main morphometric features of Boeckella Lake (E. Drago, personal communication.)

Area (m^2)	67 454
Volume (m^3)	124 097
Maximum depth (m)	4
Mean depth (m)	1.84
Length (m)	445
Maximum width (m)	230
Mean width (m)	151.6
Shoreline length (m)	1190
Shoreline development	1.28

phytoplankton density. Counting error was assessed according to Venrick (1978), accepting an error up to 20%.

During ice-cover periods 20 cm diameter holes were made in the frozen surface, through which samples were taken from the upper water layer.

Results and discussion

Physical and chemical properties

Table II presents the results of the physico-chemical analyses performed. The water of Boeckella Lake was slightly acid with fairly constant pH (5.5–6.5) during the study period.

Water temperature varied between 0 and 4°C, decreasing strongly towards the end of the summer. The lake surface began to freeze around site S2 due to the action of the prevailing winds (SW) about mid-February, ending with a complete ice cover during the last days of the same month.

Dissolved oxygen, measured only during the ice free period, generally fluctuated between 8 and 11 mg l^{-1}.

Total phosphorus and conductivity values exhibited considerable differences between sampling sites. The site at the base of the penguin rookeries (S3) showed the highest degree of eutrophication because of the increased organic matter inflow. Total phosphorus values were similar to those reported from one of the most eutrophic Signy Island lakes

Table II. Physical and chemical data collected during the summer 1991 at Boeckella Lake, Hope Bay.

Site	Date	Temp (°C)	Dissolved 0_2 (mg l^{-1})	pH	Conductivity (pS cm^{-1})	Total P (mg l^{-1})
	23/1	4	10.2	6.5	15.8	0.058
	30/1	3	9.8	5.5	-	-
	7/2	1	12.4	6.5	17	0.000
S1	13/2	2.5	9.6	6.5	-	-
	22/2	0	-	6.0	38.3	0.093
	27/2	0	-	6.5	-	-
	23/1	3	11.7	6.0	16	0.078
	30/1	4	10.8	6.0	-	-
	7/2	4	8.8	6.0	26.1	0.171
S2	13/2	3	9.0	6.0	-	-
	22/2	0	-	6.0	45.1	0.027
	27/2	0	-	6.0	-	-
	23/1	3	>14.0?	6.0	25.7	0.371
	30/1	3.5	10.2	6.0	-	-
	7/2	2.5	8.0	6.0	40.9	0.404
S3	13/2	3	9.4	6.5	-	-
	22/2	2.5	-	6.0	45.8	0.359
	27/2	0	-	6.0	-	-
	23/1	3.5	8.8	6.0	15.9	0.136
	30/1	3	10.6	6.5	-	-
	7/2	2.5	8.0	6.5	23.6	0.241
S4	13/2	2.5	7.7	6.0	-	-
	22/2	0	-	6.0	32.1	0.186
	27/2	0	-	6.0	-	-

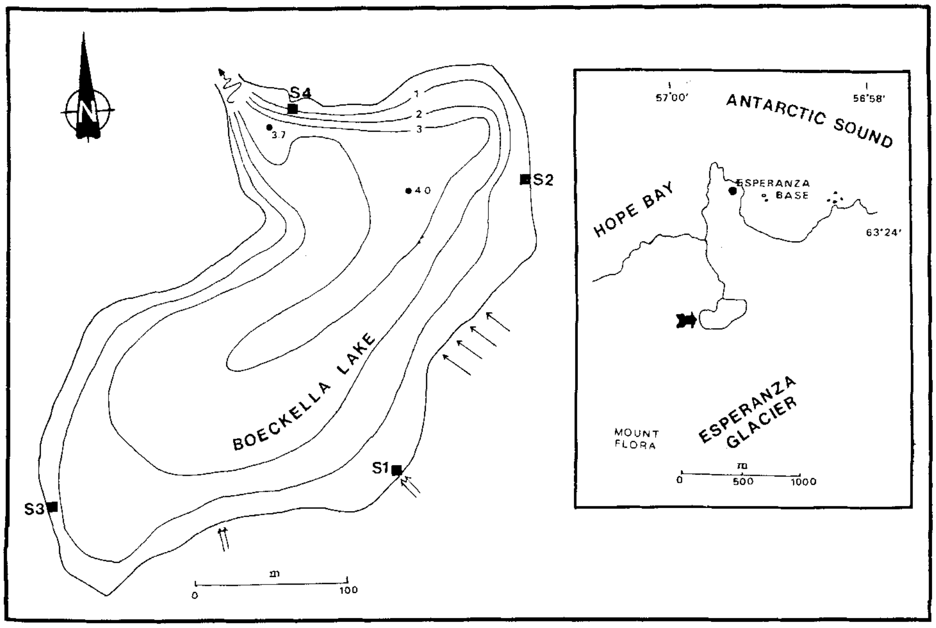

Fig. 1. Location map of the Boeckella Lake (Hope Bay, Antarctic Peninsula) showing the four sampling sites. Arrows represent the glacier melt streams flowing into the lake. Redrawn from unpublished original by E. Drago (INALI, Argentina).

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Table III. Dominant taxa identified from the four sampling sites in Boeckella Lake during summer 1991. Numbers 1 to 6 indicate the sampling dates 23/1, 30/1, 07/2, 13/2, 22/2 and 27/2 respectively.

Site	S1						S2						S3						S4					
Date	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
Cyanophyceae																								
Aphanocapsa delicatissima West *et* West				x						x			x			x								
Aphanocapsa elachista West *et* West										x	x		x	x										x
Aphanocapsa elachista var. *planctonica* G.M. Smith													x											
Chlorogloea purpurea Geitler													x											
Chroococcidiopsis sp.										x														
Chroococcus minimus (Kleissl.) Lemm.																		x						
Chroococcus minutus (Kütz.) Näg.													x											
Eucapsis minuta Fritsch										x						x	x	x						
Gloeocapsa dermochroa Näg.													x			x								
Gloecapsa ralfsiana Kütz.												x					x			x			x	x
Lyngbya aerugineo-coerulea (Kütz.) Gom.																	x							
Lyngbya lagerheimii (Mob.) Gom.			x	x	x		x				x	x	x		x	x	x				x		x	x
Lyngbya ochracea (Kütz.) Thuret													x											
Merismopedia tenuissima Lemm.													x			x	x							
Microcystis robusta (Clark) Nyg.																								x
Myxosarcina concinna Printz													x											
Oscillatoria acuta Bruhl *et* Biswas					x																			
Oscillatoria chlorina Kütz.													x					x	x	x		x		
Oscillatoria deflexa West *et* West						x					x		x				x	x	x			x		
Oscillatoria fracta Carlson			x								x													
Oscillatoria sp. 1			x										x											
Oscillatoria sp. 2																x								
Oscillatoria sp. 3																x								
Phormidium fragile (Menegh.) Gom.				x			x				x	x				x							x	x
Pseudoanabaena catenata Lauterb.												x											x	
Synechococcus elongatus Näg.																x								
Chlorophyceae																								
Chlamydomonas nivalis (Somm.) Wille		x	x		x		x	x			x	x		x	x	x	x	x		x				x
Chlamydomonas spp.				x	x	x				x	x	x	x	x		x				x		x	x	x
Cylindrocystis brebissonii (Menegh. *ex* Ralfs) De Bary				x																				
Mougeotia sp.																		x						
Pleurococcus antarcticus West *et* West							x			x	x			x									x	
Scenedesmus quadrispina Chod.							x																	
Scotiella antarctica Fritsch													x					x						
Prasiola crispa (Lightf.) Menegh.			x	x	x			x	x		x	x		x		x				x				x
Trochisia aff. *planctonica* Lind *et* Pearsall							x																	
Bacillariophyceae																								
Achnanthes laterostrata Hust.													x			x								
Cyclotella meneghiniana Kütz																			x	x				
Navicula muticopsis Van Heurck	x												x			x	x						x	
Pinnularia crucicula Freng.											x	x												
Pinnularia microstauron (Ehr.) Cleve			x			x		x			x			x	x		x		x	x	x		x	x
Pinnularia microstauron var. *ambigua* Meister																x				x		x		
Chrysophyceae																								
Ochromonas aff. *ovalis* Dofl.		x		x	x	x	x			x	x	x	x			x	x	x	x			x	x	x
Tribophyceae																								
Tribonema utriculosum (Kütz.) Hazen		x	x	x	x						x	x		x		x	x			x	x			x
Dinophyceae																								
Peridinium sp.																				x				

(Hawes 1990). On the other hand, lowest values for total phosphorus and conductivity were registered at the mouth of the main glacier melt stream flowing into the lake (S1). The site near the water supply pump (S4) showed intermediate values for both parameters. For all sampling sites, conductivity increased towards the end of the summer, probably due to the development of the ice cover and concomitant ion concentration. Greatest increases occurred at S1 and S2, where ice developed first, reaching a thickness of 30 cm.

Phytoplankton structure

On the basis of taxonomic analysis 43 specific and infraspecific taxa were identified (Table III). The algal flora recorded is

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very similar to those reported by other authors from various Antarctic ecosystems (Corte 1962, Broady 1979, 1986, 1987, Prescott 1979). In particular, the following taxa have been recorded repeatedly from Antarctica: *Oscillatoria deflexa, Phormidium fragile, Pleurococcus antarcticus, Scotiella antarctica, Navicula muticopsis* and *Chlamydomonas nivalis.* Some other species registered are clearly cosmopolitan. The geographic location of Boeckella Lake at the northern tip of the Antarctic Peninsula, probably accounts for the colonization of this maritime lake by non-endemic species.

Among the species registered there were a number of euplanktonic ones, i.e. *Aphanocapsa delicatissima, A. elachista* var. *planctonica, Merismopedia tenuissima, Cyclotella meneghiniana, Ochromonas* aff. *ovalis, Peridinium* sp., *Chlamydomonas* spp. and different species of *Oscillatoria* and *Lyngbya*. The development of some of these phytoplanktonic species was probably linked to the high level of dissolved nutrients in the water. On the other hand, some tycoplanktonic taxa were also recorded (i.e. *Phormidium fragile, Scotiella antarctica, Chlamydomonas nivalis, Navicula muticopsis*, etc.) being found in other kinds of environment, such as soils or snow. In agreement with Corte's (1962) observations, we also recorded an unusual planktonic filamentous form of *Prasiola crispa*, which can be mistaken for the dubious species *Ulothrix lamellosa* (Printz 1964).

In terms of species richness, the Cyanophyceae were the best represented group (26 taxa), followed by the Chlorophyceae (nine taxa), although within the latter class some *Chlamydomonas* species remained as a group because of the lack of information to identify them to species level. On the other hand, the Chrysophyceae showed the highest densities, being represented mainly by *Ochromonas* aff. *ovalis*. This small flagellate species produced an under-ice bloom reaching 365 000 ml^{-1} (S2, 27/2/91). For the Bacillariophyceae both density and species richness were very low, as reported from other Antarctic lakes (Priddle *et al.* 1986). Their mean densities ranged between 27 and 36.5 algae ml^{-1} (S2 and S4, respectively). Tribophyceae, represented by *Tribonema utriculosum* only, showed the lowest densities, never exceeding 13 algae ml^{-1}.

Phytoplankton abundance and taxonomic composition showed both temporal and spatial patterns. During the ice-free period at S3 both Chlorophyceae and Cyanophyceae exhibited the highest densities (76–128 and 8–35 algae ml^{-1}, respectively) in tandem with the most elevated nutrient values.

Mean species richness was highest at S3 (11 taxa), whereas site S1 hosted the poorest flora (five taxa). Some of the lowest species richness was recorded at this site during the main period of melt stream influence (23/1 and 30/1).

As formation of the ice cover, proceeded from the NE margin of the lake, phytoplankton species composition and cell numbers changed drastically at all sampling sites. A conspicuous increase in algal density was recorded at S1 and S2 (Fig. 2) and this was attributable to the rapid under-ice multiplication of *Ochromonas* aff. *ovalis.* Fig. 3 shows the

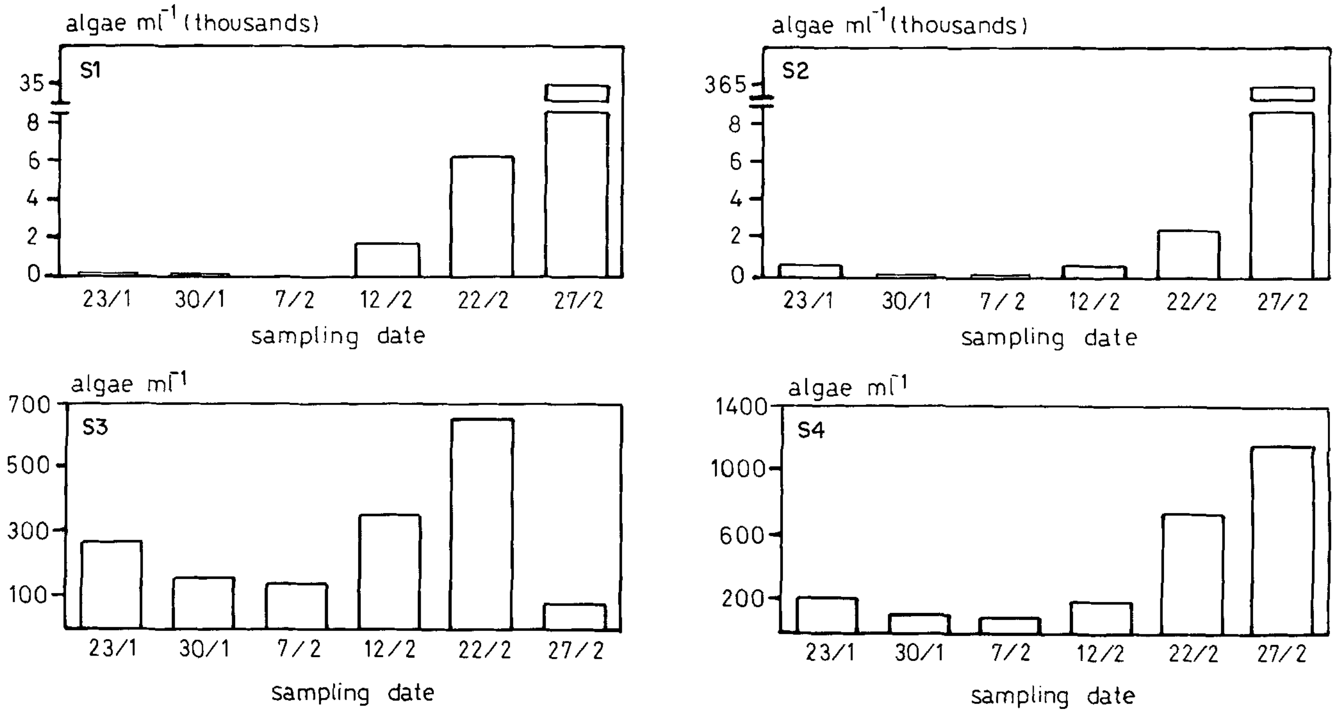

Fig. 2. Total phytoplankton densities found at the different sampling sites during summer 1991.

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change in the ratio of the different algal classes for all sites. Our results agree well with observations on the phytoplanktonic community from other Antarctic lakes discussed in Priddle *et al.* (1986). According to these authors, sedimentation is the fate of many algae in the absence of wind-induced turbulence as ice cover forms. Under such conditions, those small flagellate species adapted to low light intensities would, for a time, be favoured over larger or non-motile cells.

This first study suggests that the marked differences in qualitative and quantitative phytoplankton composition among the different sites of Boeckella Lake are principally determined by nutrient discharge and secondarily by factors such as differential surface freezing. The rookeries beside site S3 contribute significantly to the nutrient levels along that shore of the lake, influencing the phytoplankton quantity and taxonomic composition.

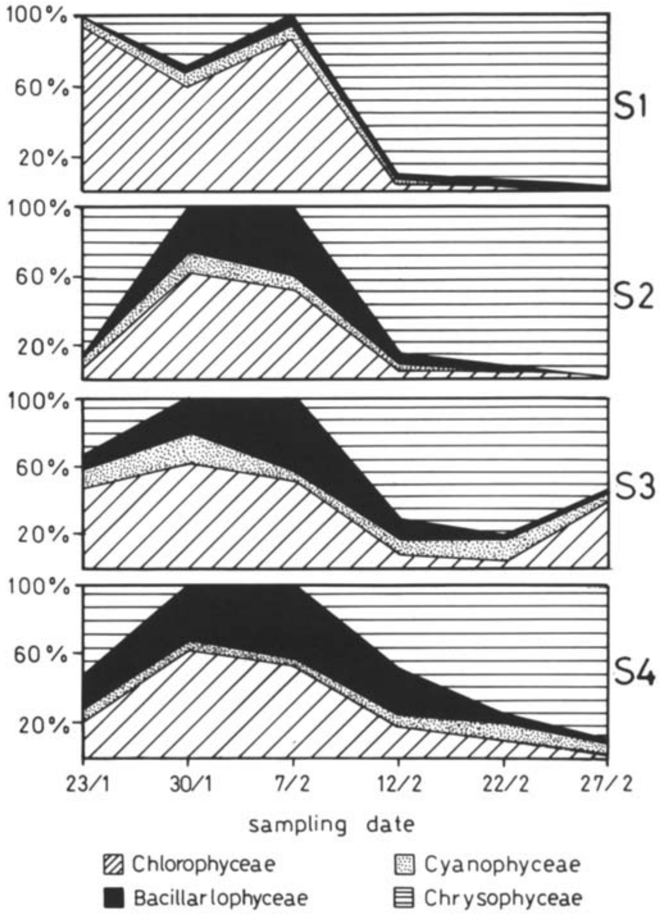

Fig. 3. Changes in the proportions of the four main algal groups at the four sampling stations.

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