Phytoplankton Diversity in Lakes of the McMurdo Dry Valleys, Antarctica

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Introduction

Long-term research in the McMurdo Dry Valleys, Antarctica has led to questions concerning the relationship between biodiversity and ecosystem function. A major theme of the latest MCM LTER proposal (2005-2011) is to understand both how the environment controls the diversity of organisms, and how diversity itself controls the functioning of the MCM ecosystem. Lakes in this ecosystem are likely hundreds of thousands of years old and lie at the end of the hydrologic continuum, representing a repository of past conditions within the MCM. As the key phototrophic organisms in the MCM ecosystem, phytoplankton have an essential role as primary producers of new carbon (Fig 1). We present phytoplankton diversity data collected from five lake basins within the MCM study area (Fig 2).

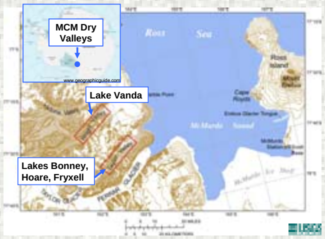

Fig 2. Location of the MCM Dry Valleys (77 °S, 163°E) (inset) and the study lakes in the Wright and Taylor Valley.

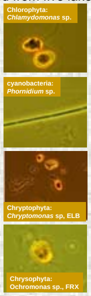

Fig 1. Dominant groups of phytoplankton found in the MCM dry valley lakes.

Study Site

The dry valley lakes contain highly stable water columns resulting from perennial ice covers, low advective stream inflow, and strong vertical chemical gradients. Each lake contains unique physical and chemical gradients (Table 1; Fig 3) which create distinct environments for phytoplankton populations. Temperature, salinity and nutrient conditions vary widely within each lake, and low light conditions (1-3% of surface PAR) persist throughout the 6 month growing season.

Lake	Size (km^2)	Ice Cover (m)	Max Depth (m)	Physical Characteristics
Fryxell	7.1	6.0	21	stratified water column; brackish, nutrient rich, anoxic deep water; N&P-deficient
Hoare	1.9	3.8	34	weak density stratification; relatively fresh water, oxic deep water; P-deficient
E. Lobe Bonney	3.5	4.6	40	highly stratified water column with hypersaline, nutrient-rich, sub-oxic deep water; P-deficient
W. Lobe Bonney	1.3	3.9	40	highly stratified water column with hypersaline, nutrient-rich, anoxic deep water; P-deficient
Vanda	6.7	3.3	80	highly stratified water column w/ strong chemocline at ~65m, temps >20°C below chemocline; N&P deficient

Table 1. Physical characteristics of dry valley lakes: Fryxell (FRX), Hoare (HOR), east lobe Bonney (ELB), west lobe Bonney (WLB), Vanda (VAN).

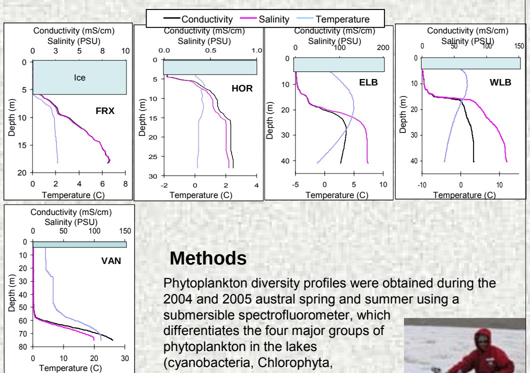

Fig 3. Temperature, salinity and conductivity profiles for each study lake.

Methods

Phytoplankton diversity profiles were obtained during the 2004 and 2005 austral spring and summer using a submersible spectrofluorometer, which differentiates the four major groups of phytoplankton in the lakes (cyanobacteria, Chlorophyta, Chrysophyta, Cryptophyta) based on the chlorophyll-a fluorescence excitation spectra of the light harvesting apparatus (Fig. 4). All samples were collected from the deepest portion of each lake.

Additional samples were collected and analyzed for extracted chlorophyll-a for comparison with results from the submersible spectrofluorometer.

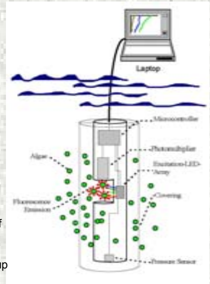

Fig 4. Principle of under water spectrofluorometry. Algal Chlorophyll-a is excited with light of five LEDs (emission wavelength 450 nm, 525 nm, 570 nm, 590 nm, 610 nm). An iterative gaussian fit weighted with the standard deviations of the normal spectra facilitates the estimation of the distribution of the spectral groups. Dissolved yellow substances measured at 370 nm are used to correct for background fluorescence in the algal algorithms. Algal group concentrations are given in µg chl-a/L water sample.

Results I

In situ spectrofluorometer and extracted chl-a: A Comparison

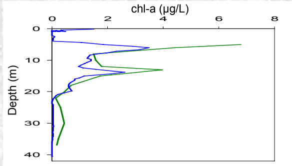

Fig 5. Depth profile of algal concentration (sum of all detected algae classes) determined using the spectrofluorometer (blue) and extracted chl-a (green) concentration in East Lobe Bonney.

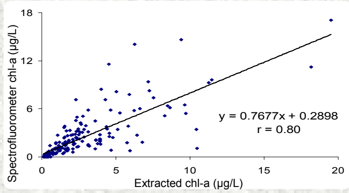

Fig 6. Correlation comparing total chl-a concentration determined using the spectrofluorometer with extracted chl-a concentration. Data from Lakes Fryxell, Hoare, Bonney and Vanda during the 2004 and 2005 austral spring and summer seasons.

• The depth profile and correlation analysis show that the *in situ* spectrofluorometer data are closely associated (p<0.01) with extracted chl-a. The slope of the relationship is 0.77 when all data are included indicating that the spectrofluorometer on average yields about 25% lower chl-a than that extracted in 90% acetone.

Results II

In situ spectrofluorometer algal group profiles

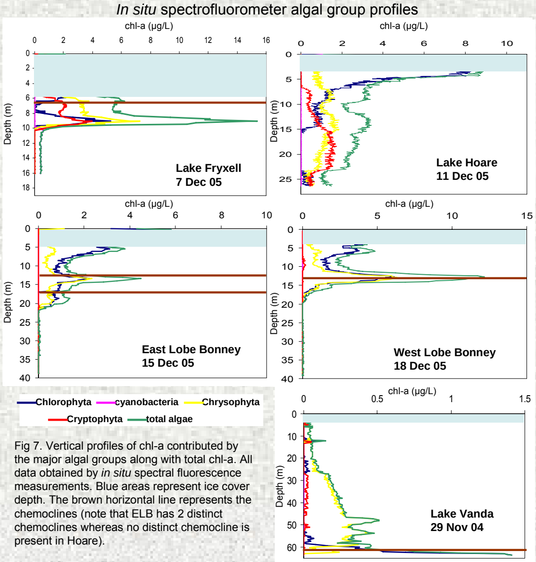

Fig 7. Vertical profiles of chl-a contributed by the major algal groups along with total chl-a. All data obtained by *in situ* spectral fluorescence measurements. Blue areas represent ice cover depth. The brown horizontal line represents the chemoclines (note that ELB has 2 distinct chemoclines whereas no distinct chemocline is present in Hoare).

• Chl-a profiles typically showed maxima in the high light, low nutrient regions immediately beneath the ice cover and just above the nutrient rich deep waters below the chemoclines.

• The highest chl-a levels occurred in the deeper waters associated with the chemocline in lakes where a chemocline was present.

• Chloropytes, cryptophytes and chrysophytes were abundant is all lakes; cyanobacteria were usually absent or present in relatively low numbers.

• Chlorophytes dominated the upper freshwater layers in all lakes; chrysophytes and cryptophytes were relatively more abundant in the deep chl-a layers associated with the upward diffusion of nutrients through the chemoclines.

Results III

Phytoplankton diversity in the MCM lakes – Cluster Analysis

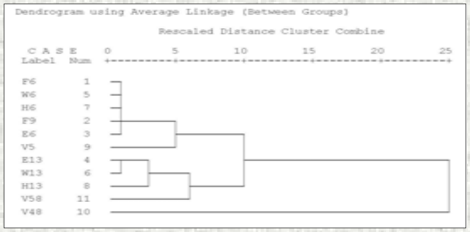

Fig 8. Phytoplankton diversity based on *in vivo* pigment spectrofluorescence. Cluster analysis performed using the ratio of chl-a for each algal group to total chl-a for depths representing the specific chlorophyll maxima within each lake. Label denotes the lake (F=FRX, H=HOR, E=ELB, W=WLB, V=Vanda) and depth included in the analysis.

• Phytoplankton relationships in the surface waters were similar among lakes (they clustered together) and differed from the phytoplankton relationships observed in the deep waters. The exception was the sample from the deep chl-a maxima in Fryxell (F9) dominated by chrysophytes, which clustered with the surface populations.

•The 48 m chl-a peak in Lake Vanda formed its own branch, as a result of its almost complete dominance by chrysophytes.

Results IV

Phytoplankton diversity in the MCM lakes - Shannon-Weiner Diversity Index

Lake	Shannon-Weiner Index H'		
	Whole lake	Surface waters	Deep waters
FRX	1.248	0.903	1.085
HOR	1.011	0.624	1.046
ELB	0.504	0.549	0.693
WLB	0.701	0.559	0.690
VAN	0.980	0.569	0.607

Fig 9. Phytoplankton diversity based on *in vivo* pigment fluorescence. Pi values for Shannon-Weiner Diversity Index H' were calculated using the proportion of fluorescence for each group to total chl-a averaged over all depths for "whole lake," and at selected depths in the near-surface and deep chlorophyll layer (FRX: 6 and 9m, HOR, ELB, WLB: 6 and 13m, VAN: 5 and 58m).

•Lake Fryxell showed the highest phytoplankton diversity of all MCM lakes studied reflecting the relatively high abundance of all algal groups. East and West Lobe of Bonney showed the lowest diversity (2 algal groups dominated the entire water column of Lake Bonney).

•The deep chl layers had higher diversity than the upper chl layers in all lakes.

Conclusions

• Phytoplankton diversity within the lakes of the McMurdo Dry Valleys reflects both contemporary and environmental legacies of past events. Phytoplankton in surface waters receive new nutrients from intermittent glacial stream inflow, release from the ice cover, and internal recycling, and are exposed to relatively high irradiances, whereas those in the deep chl-a layers receive upward diffusing nutrients from ancient nutrient pools that formed as the lakes evolved, and are extremely light limited. These conditions would likely lead to isolated deep water phytoplankton that interchange little between lakes or with surface populations, and live on legacy nutrients (Priscu, 1995). Similarities observed within the surface waters of each lake suggest that these populations are responding to contemporaneous conditions, or that there is interchange of surface organisms between lakes.

• Differences between deep water phytoplankton populations of Lake Vanda and the Taylor Valley lakes implies that differences in the evolution of these lakes produced different geochemical properties of deep waters. Differences between surface water populations may also be a result of subtle differences in climate between the two valleys, which has led to geochemical variations among surface waters of the lakes (Lyons, 2000).

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