The McMurdo Dry Valley Lake Microbial Observatory

Microbial Diversity and Function in the Permanently Ice-Covered Lakes of the McMurdo Dry Valleys, Antarctica

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Study Site

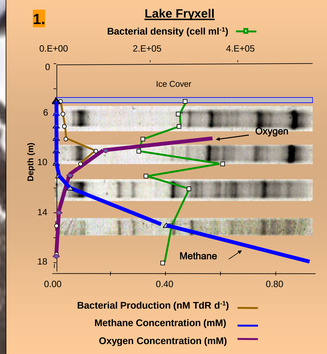
The valleys harbor the only permanently ice-covered lakes on Earth. The lakes occupy closed basins and vary in surface area (1–6 km^2), depth (20–85 m), and ice-cover thickness (3–5 m). The permanent ice covers greatly reduce several aspects of normal lake physical chemistry including (1) wind-driven mixing, resulting in vertical transport at the level of molecular diffusion; (2) direct gas exchange between liquid water and the atmosphere; (3) light penetration; and (4) sediment deposition into the water column. The long mixing times mean that gradients of conserved constituents exist in the water column for at least 20,000 years before being dissipated by diffusion. Ecosystem properties in the water columns of the lakes are also controlled by the seasonal uncoupling of photoautotrophic and heterotrophic processes resulting from the unusual solar cycle: 4 months of darkness followed by 4 months of continuous light with twilight in between.

McMurdo Dry Valley Averages and Extremes (1985-2000)

Surface air temperature (°C)	
average mean annual	-27.6
absolute maximum	10.0
absolute minimum	-65.7
Degree days above freezing	
mean annual	6.2
Soil temperature at surface (°C)	
average mean annual	-26.1
absolute maximum	22.7
absolute minimum	-58.2
Surface wind speed (m s^{-1})	
average mean annual	4.1
maximum	37.8

Community Structure Shift in the Anaerobic Waters of Lake Fryxell:

1.



Biogeochemical profile of the Lake Fryxell water column (1) overlays temporal temperature gradient gel (TTGE) bands of samples extracted from L. Fryxell, corresponding to 6m, 9m, 12m and 15m depths, October 2002. A distinct shift in the bacterial community is found below 10 meters where the water column becomes anoxic. 16SrDNA amplification with 341F-GC and 534R (*E. coli* ref.), TGGE gel was run for 16h @ 60V.

2.

An Archaea was isolated from the bottom sediments of L. Fryxell (2) with 16SrDNA sequence similarity to *Methanosarcina mazei*; a methylotrophic methanogen capable of growth on methanol, trimethylamines, acetate and dimethylsulfide.

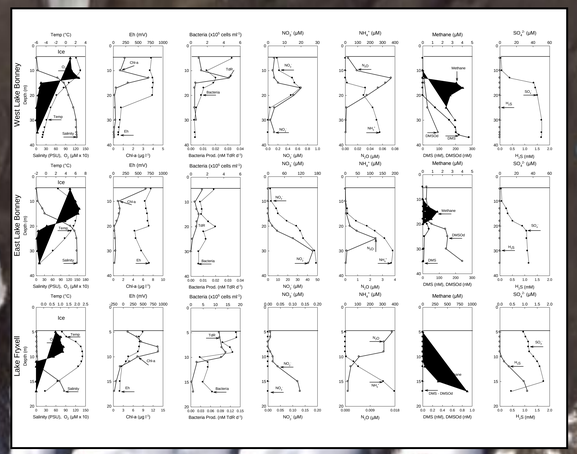
Taylor Glacier

L. Hoare

Canada Glacier

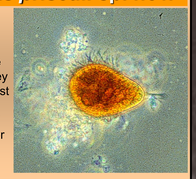
L. Fryxell

L. Bonney



Chlamydomonas priscuii sp. nov.

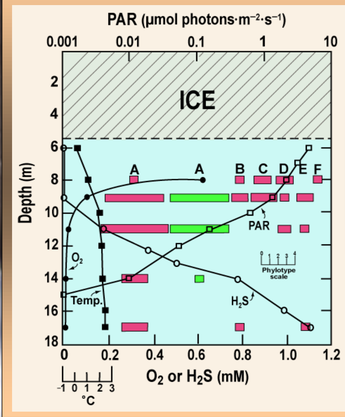
Recently characterized *C. priscuii* is the dominant phytoplankton species in the waters above the chemocline of all lakes in the Taylor Valley (Fryxell, Hoare, East and West Lobe Lake Bonney). This novel organism is capable of efficient photosynthesis under extremely low light and temperature.



Purple phototrophic bacteria in Lake Fryxell

distribution of *pufM:* DNA: mRNA

*puf*M = a gene encoding photosynthetic reaction centers in purple phototrophic bacteria



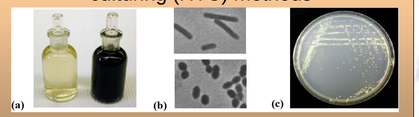
Karr et al. 2002

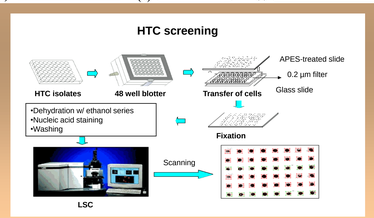
INTRODUCTION

The McMurdo Dry Valleys (MCM) represent the driest and coldest ecosystem known and have, until relatively recently, been thought to harbor little life. This ecosystem is comprised of a mosaic of glaciers, glacial streambeds, exposed soils, and permanently ice-covered lakes; the only permanently ice-covered lakes on Earth. The permanent ice eliminates wind-driven mixing resulting in vertical transport at the level of molecular diffusion, gas exchange between liquid water and the atmosphere, and reduces light penetration. The lakes present the only habitat in this ecosystem that contains permanent liquid water and supports year-round metabolic activity in an environment that would normally appear to be inhospitable to life. Lake levels in the MCM have changed dramatically in response to climate variability since the last glacial maximum. The most recent low stands of the lakes occurred ~1000 y ago when the lakes were thought to be ice-free and nothing more than brine ponds. During the recent evolution of these lakes, freshwater flowed over the salt brines producing present day chemical stratification. Isotopic dating indicates that the deep-water brines are more than 100,000 years old. The food web of the lakes is dominated by prokaryotes and protists; few metazoans have been observed. Biogeochemical studies on these lakes have revealed many biogenic chemical gradients (e.g., N_2O, CH_4, DMS, DMSO) that lack simple biochemical and thermodynamic explanations. These data beg one to ask if the microorganisms present in the water columns today are responsible for the geochemical gradients we now observe.

A primary reason for establishing a MO for the dry valley lakes is to understand not just how the environment controls the diversity of organisms, but also how diversity itself controls the functioning of ecosystems. Given the lack of metazoans, and the evolutionary history and resultant geochemistry of these lakes, they offer a unique experimental arena to search for novel microorganisms and study the interplay of microbial diversity and ecosystem function. We will focus on prokaryotic organisms within MCM lakes with the objective of elucidating those aspects of their genome and metabolism that are critical to understanding their role in biogeochemical cycles. Given the sensitive and relatively simple systems in the dry valleys, our integrated approach will point the way towards a broader integration of the biogeosciences.

Traditional (a-c) and high throughput culturing (HTC) methods





Overarching Theme: ***To understand both how the environment controls the diversity of organisms and how diversity itself controls the functioning of these ecosystems.***

Specific Hypotheses:

1. Microbial communities in dry valley lakes will be unlike those found in temperate lakes owing to demographic isolation, constant low temperatures, decoupled light/dark cycles, an unmixed water column, and strong legacy-derived geochemical gradients within the lakes.
2. Psychrophiles (*Bacteria* and *Archaea)* isolated from the lakes will have unique phylogenetic lineages relative to psychrotolerant species; the latter will be more closely related to temperate prokaryotes.
3. Application of novel culturing methods will yield organisms with unique physiological properties that allow for survival in the dark, cold and saline environments that have existed in these lakes for tens of thousands of years.
4. The major active nutrient cycles in the MCM lakes will be revealed from the diversity and physiology of cultured representative species obtained.
5. The application of thermodynamic principles to known lake geochemistries can be used to predict the distribution of different metabolic groups within the lakes.
6. *In situ* studies of extracellular enzyme activity and cell viability can be used as a measure of microbial and geochemical diversity in the lakes.