The response of microplankton in Antarctic lakes during the transition to polar night

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Introduction

The high latitude (77 S) lakes of the MCM are characterized by permanent, 3-5 meter thick ice-covers, which prevent vertical mixing of the water column, resulting in stable profiles of temperature, conductivity, nutrients and gases. Each lake lies in a hydraulically closed basin, allowing existing gradients to persist for many thousands of years (the mixing time exceeds 10,000 years). The lakes contain complex microbial food webs, which include heterotrophic bacteria (Takacs and Priscu 1998), chemolithotrophic bacteria (Sattley and Madigan 2006), phototrophic, mixotrophic, and heterotrophic flagellates, ciliates, and rotifers (Priscu et al. 1999; Roberts and Laybourn-Parry 1999). Higher organisms, such as macrozooplankton and fish, are absent from the lakes, making them an excellent locale for studying microbial processes associated with changes in the ecosystem. During summer, when irradiance is continuous, photosynthetic primary productivity serves as the major contributor of organic carbon to the lake ecosystems; little is known about microbial dynamics during the winter months when darkness prevails.

A majority of the research on the MCM LTER occurs during the austral spring and summer (October-January), when field support is readily available. Logistical constraints have prevented field work from being conducted during the austral fall and winter, and these time periods present significant gaps in our understanding of ecosystem function in the MCM. As a part of the 2007-2008 International Polar Year, we were able to extend routine LTER sampling of MCM lakes into the transition to polar night. The overarching hypothesis was that the onset of winter darkness induces a cascade of physiological changes that alters the functional roles of autotrophic and heterotropic microplankton within the lakes. Here, we specifically examine the response of heterotrophic bacterial activity to a diminished source of new, labile carbon as phytoplankton photosynthesis (^{14}C-bicarbonate incorporation) declined during the onset of winter darkness. A comparison of thymidine incorporation into DNA with leucine incorporation into protein allowed us to examine shifts in cellular function (DNA replication vs. protein synthesis) both within the water columns of each lake, and during the seasonal progression towards darkness.

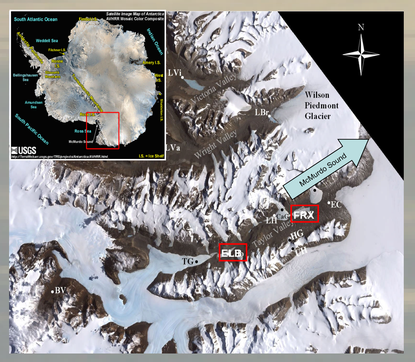


Figure 1
Site location
MCM lakes in the Taylor Valley in southern Victoria Land, Antarctica. The valley contains four major basins; Fryxell, Hoare, East Lobe Bonney, and West Lobe Bonney. Fryxell (FRX) and East Lobe Bonney (ELB) are discussed here and are indicated in red. The valley terminates at McMurdo Sound in the east and the Taylor Glacier in the west.

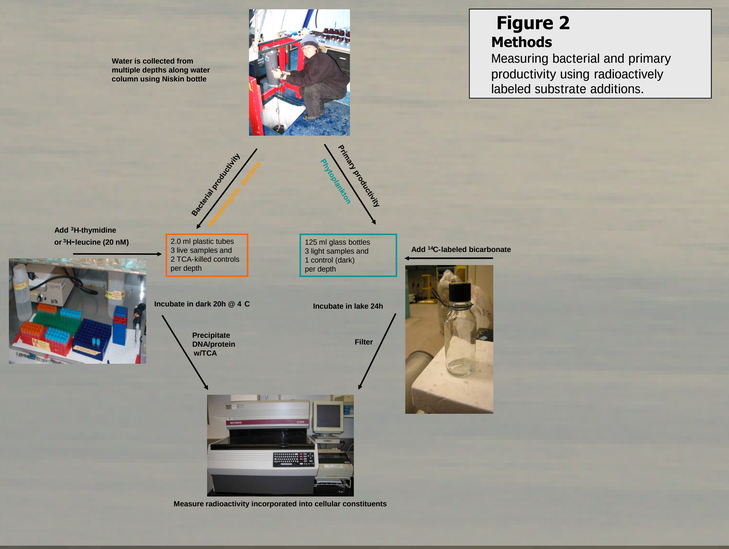


Figure 2
Methods
Measuring bacterial and primary productivity using radioactively labeled substrate additions.

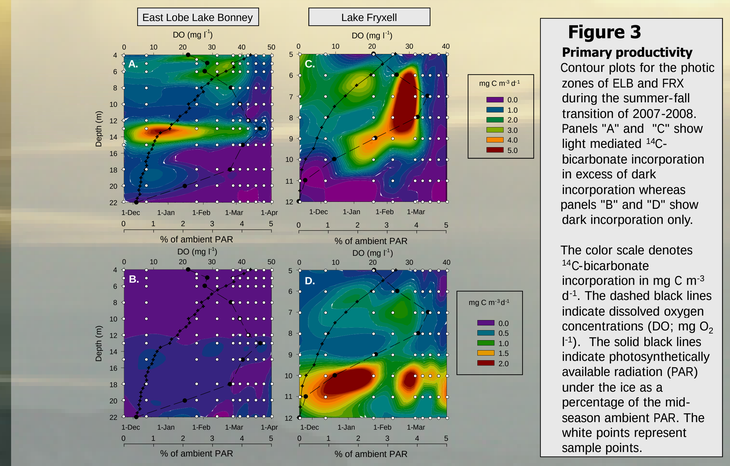


Figure 3
Primary productivity
Contour plots for the photic zones of ELB and FRX during the summer-fall transition of 2007-2008. Panels "A" and "C" show light mediated ^{14}C-bicarbonate incorporation in excess of dark incorporation whereas panels "B" and "D" show dark incorporation only.

The color scale denotes ^{14}C-bicarbonate incorporation in mg C m^{-3} d^{-1}. The dashed black lines indicate dissolved oxygen concentrations (DO; mg O_2 l^{-1}). The solid black lines indicate photosynthetically available radiation (PAR) under the ice as a percentage of the mid-season ambient PAR. The white points represent sample points.

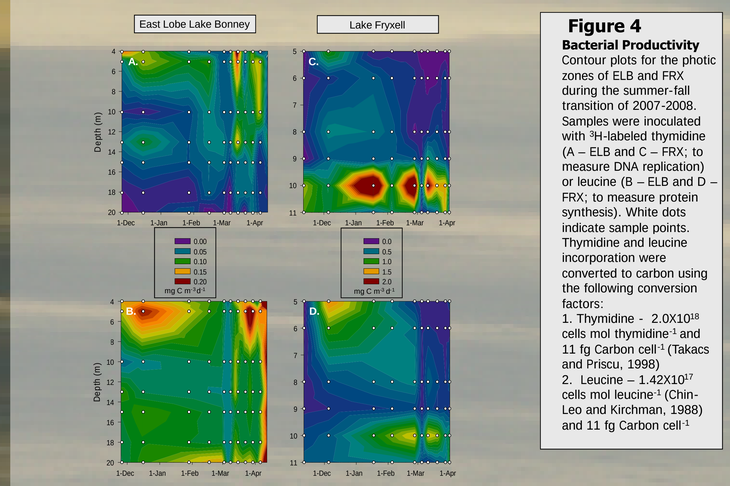
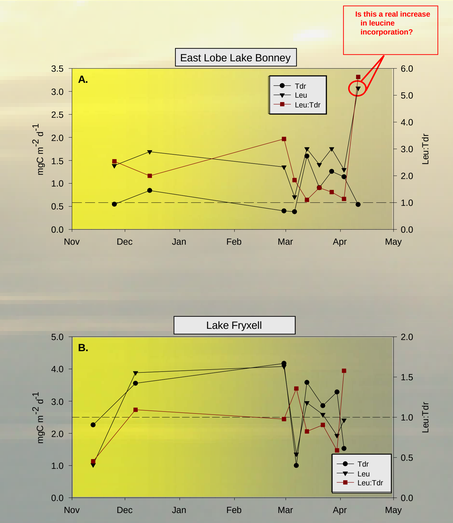


Figure 4
Bacterial Productivity
Contour plots for the photic zones of ELB and FRX during the summer-fall transition of 2007-2008. Samples were inoculated with ^{3}H-labeled thymidine (A – ELB and C – FRX; to measure DNA replication) or leucine (B – ELB and D – FRX; to measure protein synthesis). White dots indicate sample points. Thymidine and leucine incorporation were converted to carbon using the following conversion factors:
1. Thymidine - 2.0X10^{18} cells mol thymidine^{-1} and 11 fg Carbon cell^{-1} (Takacs and Priscu, 1998)
2. Leucine – 1.42X10^{17} cells mol leucine^{-1} (Chin-Leo and Kirchman, 1988) and 11 fg Carbon cell^{-1}

Figure 5
Depth-integrated bacterial productivity Time series plots integrated over the photic zones of ELB (A) and FRX (B) showing rates of thymidine (tdr; circles) and leucine (leu; triangles) incorporation, and leu:tdr ratio (squares). The dashed line indicates a 1:1 leu:tdr ratio. Note the different leu:tdr scales in A and B.

Leucine incorporation in Lake Bonney at the final April time point was nearly two-fold higher than at any other point during the season. While this cannot be explained by any known error in the sample or data analysis, we question the validity of this point from a physiological standpoint (red highlight).

Trends show unchanging bacterial productivity from November until March. During March and April, there was a downward trend in thymidine incorporation, but no change in leucine incorporation in Lake Bonney. After a sharp decrease in both thymidine and leucine incorporation in Lake Fryxell in early March, productivity recovered for the rest of March and April.



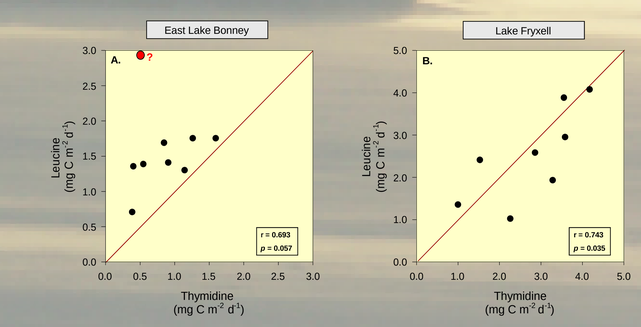


Figure 6 **Scatter plots** of depth-integrated leucine incorporation (protein synthesis) vs. thymidine incorporation (DNA synthesis) in ELB (A) and FRX (B). The outlying data point highlighted in Figure 5 is indicated in red on plot A. Correlation coeffecient (r), *p*-value, and number of samples were calculated without the outlying point. Correlation statistics including outlying point are: r=0.099 and *p*=0.800. The line indicates a 1:1 relationship between the variables. A least squares fit line for ELB has slope=0.15; FRX slope=0.74.

Conclusions

1. Photosynthetically based **primary productivity decreased** in both lakes (Figure 3A and C).
2. Rates of dark incorporation of ^{14}C-labelled bicarbonate were highest at 10 m depth in Lake Fryxell, and at 22m depth in Lake Bonney. On average, incorporation was 7-fold higher in Fryxell than in Bonney, indicating that **chemoautotrophic carbon fixation may provide an important source of new organic carbon during the winter, particularly in Lake Fryxell** (Figure 3B and D).
3. Heterotrophic bacterial productivity was measurable in both lakes, through the end of the season, but **peaked at variable depths** in the water column (Figure 4).
4. End of season increases in leucine incorporation indicate a **possible shift in cellular function** from population growth to survival (Shiah and Ducklow, 1997). Leu:Tdr was consistently >1 (Figure 5 and 6) in ELB.
5. There is a positive, linear, statistically significant association between depth-integrated thymidine incorporation (DNA replication) and leucine incorporation (protein synthesis) in FRX (*p*=0.035), indicating **coupling of DNA synthesis and protein synthesis** (Figure 6B). Thymidine and leucine incorporation are also positively correlated in East Lake Bonney (*p*=0.057), after the outlying point (Figure 5 and 6) is removed (Figure 6A).

References

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