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 McMurdo Dry Valleys (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 gasses. Each lake is in a hydraulically closed basin, allowing minimal 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 (Saffy and Madigan 2006), phototrophic, mixotrophic, and heterotrophic flagellates, ciliates, and rotifers (Priscu et al. 1999; Roberts and Laybourn-Parry 1999). Higher organisms, such as macroplankton 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 heterotrophic microorganisms within the lakes. Here, we specifically examine the response of heterotrophic bacterial activity to a diminished source of new, labile carbon as phytodetritus photosynthesis (DIC-bicarbonate incorporation) declines 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 column of each lake, and during the seasonal progression towards darkness.

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

Figure 3
Primary productivity
Concentration plots for the photic zones of ELB and FRX during the summer-fall transition of 2007-2008. Fitness (1-Leu) vs. thymidine incorporation (DNA replication) in areas of dark incorporation whereas symbols “W” and “Y” show dark incorporation only. The solid black lines show bivariate regression analyses, whereas the dashed black lines indicate non-linear trend lines. The open circles highlight the 1:1 ratio of leucine to thymidine, the black squares represent the different leu:tdr scales in Figure 4. The red dash-dotted line indicates a 1:1 leu:tdr ratio. Note the different leu:tdr scales in A and B.

Figure 4
Bacterial Productivity
Concentration plots for the photic zones of ELB and FRX during the summer-fall transition of 2001-2002. Samples were inoculated with [3H]-thymidine (frx & ELB) and [14C]-leucine (FRX) to measure protein production. Leucine incorporation and thymidine incorporation were converted to carbon using known conversion factors: 1. Thymidine: 2.3 pg C-cell~1 (White et al. 2002); 2. Leucine: 1.4 pg C-cell~1 (Bjorseth et al. 2000; Britton et al. 1998 and Britton et al. 1998). The solid black lines represent the ratios of thymidine incorporation (DNA replication) and leucine incorporation (protein synthesis) in ELB and FRX. The dashed black lines indicate non-linear trend lines.

Figure 5
Depth-integrated bacterial productivity
Time series plots of daily integrated bacterial productivity of ELB (A) and FRX (B) showing changes in thymidine incorporation (DNA replication) and leucine incorporation (protein synthesis) and leu:tdr ratio (upper panel), the latter being the ratio of incorporation per depth. The solid black lines indicate a 1:1 leu:tdr ratio. Note the different leu:tdr scales in A and B.

Figure 6
Scatter plots of depth-integrated thymidine incorporation (protein synthesis) vs. leucine incorporation (DNA replication) in FRX (A) and ELB (B). The red line indicates the ratio highlighted in Figure 5. A linear regression analysis was performed on the data sets for each lake and the data points are highlighted in red on plot A. Correlation coefficients (r, pvalue, and n) are significant for both FRX and ELB. The line indicates a 1:1 relationship between the variables. A linear regression for the ELB has a slope=0.58, r=0.35, and n=51.

Conclusions
1. Photosynthetically based primary productivity decreased in both lakes (Figure 3A and C).
2. Rates of dark incorporation of [3H]-labelled bicarbonate were highest at 10 m depth in Lake Fryxell, and at 22 m depth in Lake Bonney. On average, incorporation was 7-fold higher in Fryxell than in Bonney, indicating that chemosynthetic 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 measured 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 1:1 (Figure 4, E and F) in ELB.
5. There is a positive, linear, statistically significant association between depth-integrated thymidine incorporation (DNA replication) and leucine incorporation (protein synthesis) (Figure 6B). Thymidine and leucine incorporation are also positively correlated in East Lake Bonney (p<0.05), after the outgoing point (Figure 6A and 6B) is removed (Figure 6A).

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