Microbial dynamics in lakes of the McMurdo Dry Valleys of Antarctica during the transition to polar night

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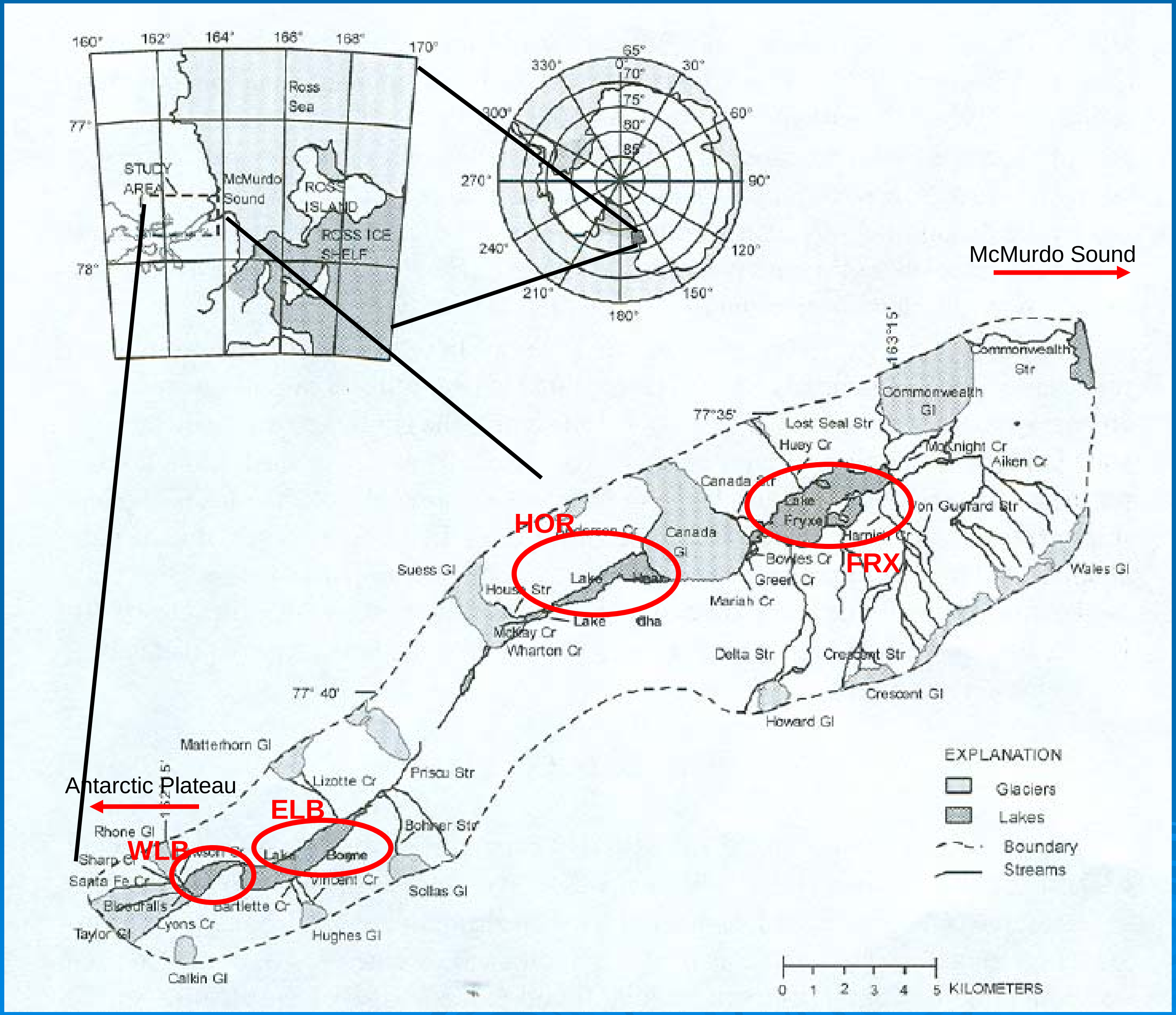
The McMurdo Dry Valleys

- Largest ice-free portion of the Antarctic continent (~4800 km^2)
- <10 cm annual precip
- Avg annual temp -20°C
- 3 major valleys
  - Victoria
  - Wright
  - Taylor

Photo cred: http://www.rosssea.info/pix/big/Taylor_Dry_Valley.jpg

Photo cred: AP Photo/PNAS, A. Lewis

Study site: Taylor Valley lakes

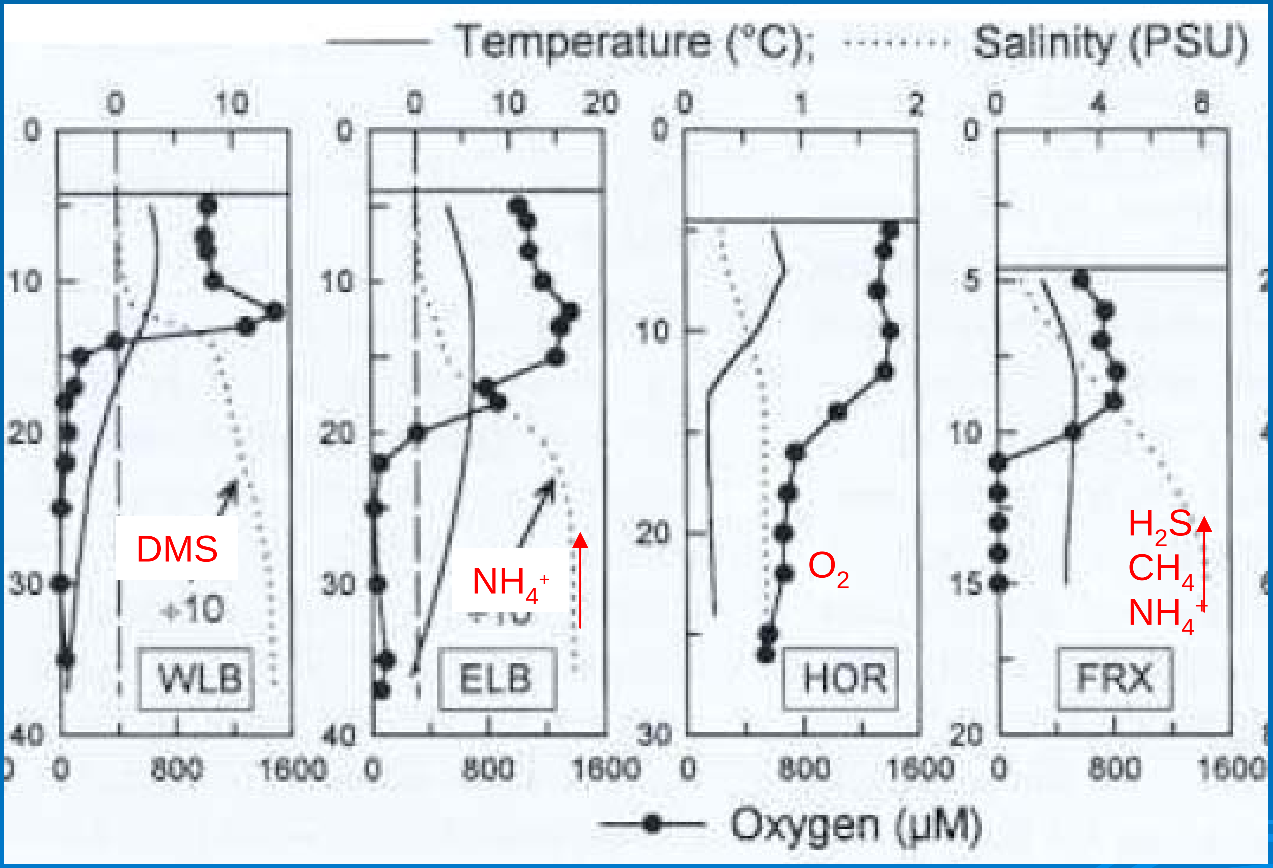


Lyons et al., 2001

Why study these lakes?

- Only lakes in the world with perennial ice-cover
  - Restricted atmospheric gas exchange
  - Low light penetration
  - Permanently chemically stratified vertically
- Closed basins – end member systems
- Relatively pristine environment
- Part of LTER – long term dataset

Differences in lake geochemistry



Priscu, 1997

Life as we know it…

- In your backyard, photoautotrophs are the **primary producers**
  - $CO_2 + H_2O \xrightarrow{light} CH_2O + O_2$
- Provides useable **carbon**
  - Fixation of inorganic carbon
- Provides useable **energy**
  - Creating thermodynamic disequilibrium so that organisms can use energy

Images from: www.grinningplanet.com and blogs.citypages.com/ctg/images/skatkat2.jpg

Life in the Taylor Valley lakes

- A microbial ecosystem
  - Primary production by phytoplankton
  - Heterotrophic bacteria
  - Rotifers are the highest trophic level (no fish)

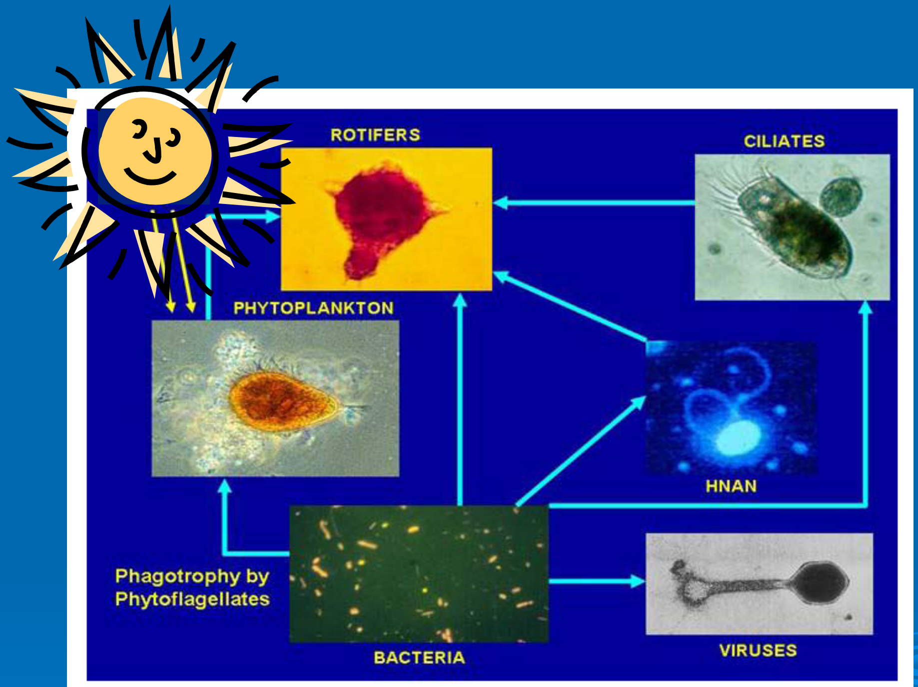
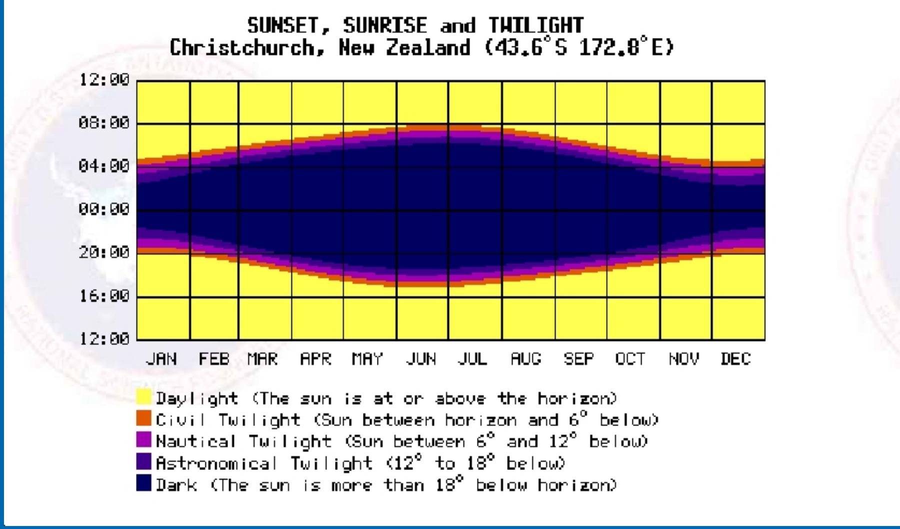


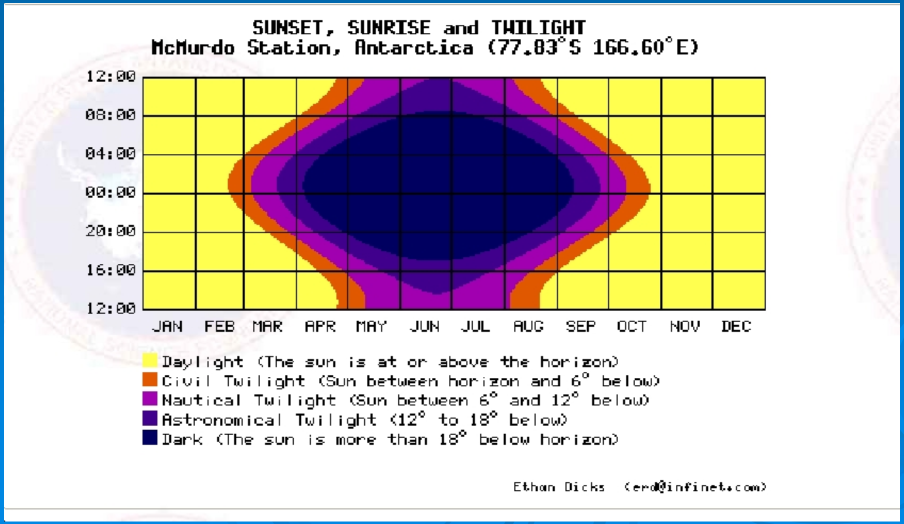
Figure 2. Typical foodweb found in the water column of MCM lakes. HNAN= heterotrophic nanoflagellates. No higher life forms exist.

Source: Priscu, et al., 1999

This model is dependent on sunlight…
…so what happens during the winter?

Sunlight and the Antarctic winter





Polar night: the "black box"

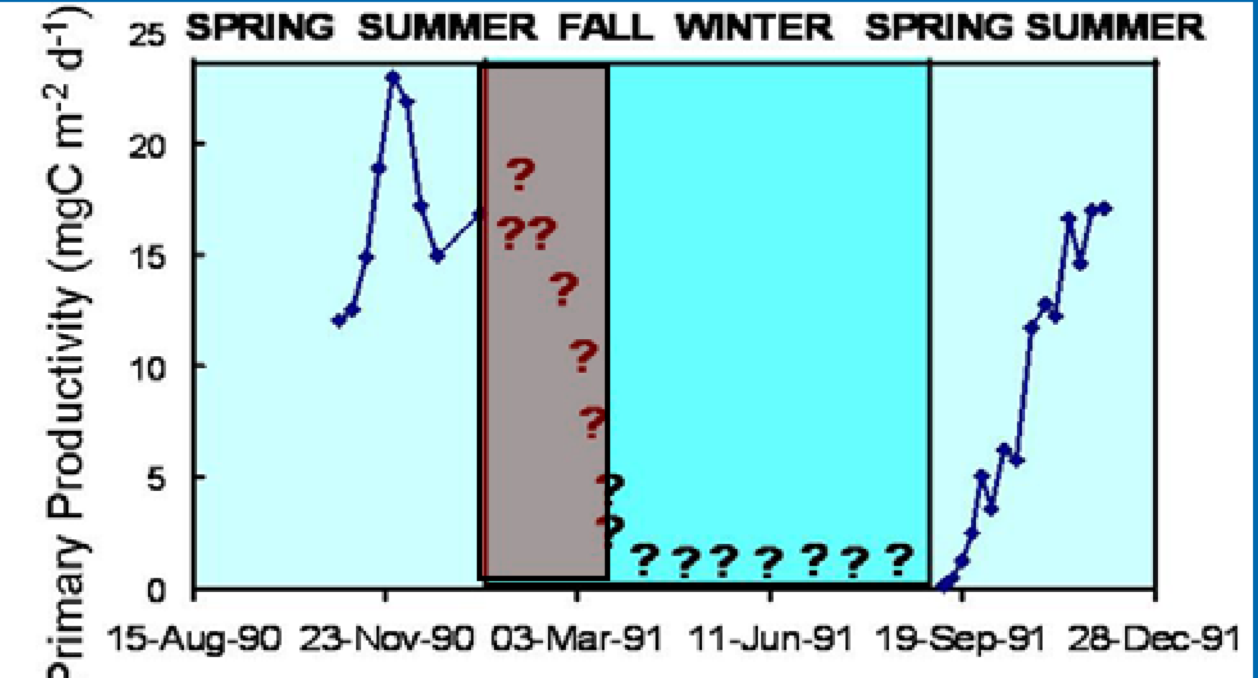


Figure 4. PPR in L. Bonney showing the period when data have never been collected.

"…the onset of darkness induces a cascade of physiological changes that alters the functional roles of autotrophic and heterotrophic microplankton within the lakes."

~Polar night project proposal

Question: do the lakes sleep during the (polar) night?

- H_o:
  - Bacterial productivity (organic carbon demand) **decreases** with light-driven primary productivity (organic carbon supply)
- H_1:
  - Bacterial productivity (organic carbon demand) is **sustained** throughout the year by an organic carbon supply other than light-driven primary productivity

Photo credit: Matt Charnetski

Approach:
Antarctic field experiments

- Summer/fall season Oct. 07-April 08: watching the sun set
  - Measure primary productivity (organic carbon supply)
    - ^{14}C-bicarbonate incorporation (carbon fixation) in light and dark containers
  - Measure bacterial productivity (organic carbon demand)
    - Incorporation of ^{3}H-thymidine (DNA synthesis) and ^{3}H-leucine (protein synthesis)
- Summer season Oct. 08-Jan. 09: dark ^{14}C-bicarbonate and primary productivity experiments
  - Measure light (photoautotrophic) and dark (chemoautotrophic) incorporation of ^{14}C-bicarbonate in FRX and ELB

Methods: Fall 2007-2008

Measuring bacterial productivity and primary productivity by radioactive substrate incorporation

Water is collected from multiple depths along water column using Niskin bottle

Bacterial productivity — Heterotrophic bacteria

Primary productivity — Phytoplankton

Add ^{3}H-thymidine or ^{3}H-leucine (20 nM)

2.0 ml plastic tubes
3 live samples and
2 TCA-killed controls
per depth

125 ml glass bottles
3 light samples and
1 control (dark)
per depth

Add ^{14}C-labeled bicarbonate

Incubate in dark 20h @ 4°C

Incubate in lake 24h

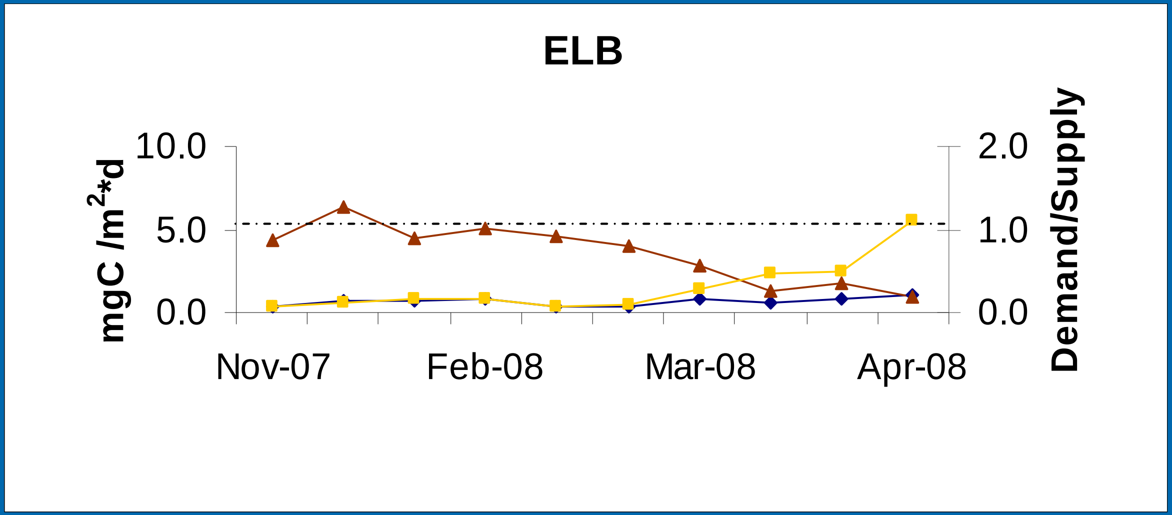
Precipitate DNA/protein w/TCA

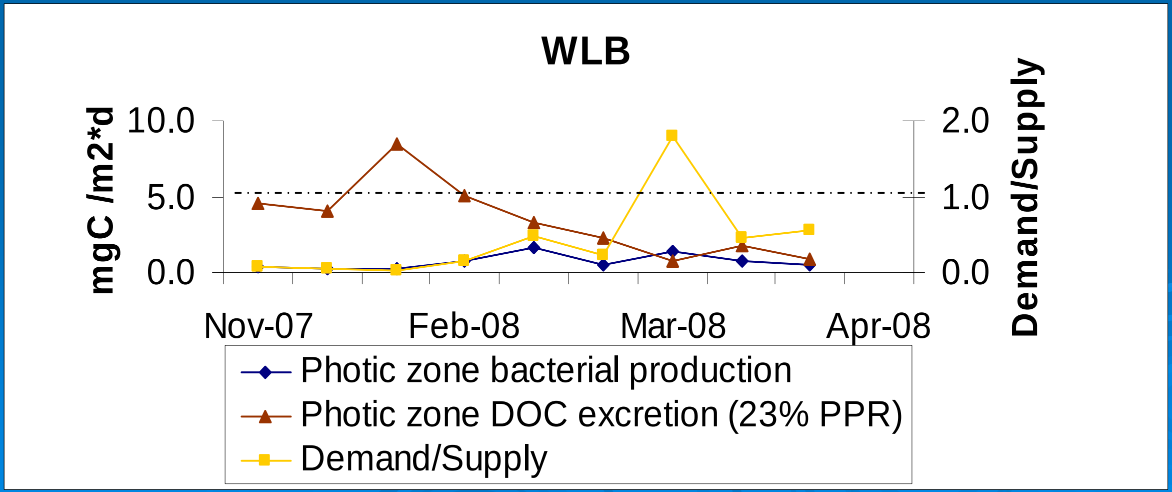
Filter

Measure radioactivity incorporated into cellular constituents

Results: Fall 2007-2008

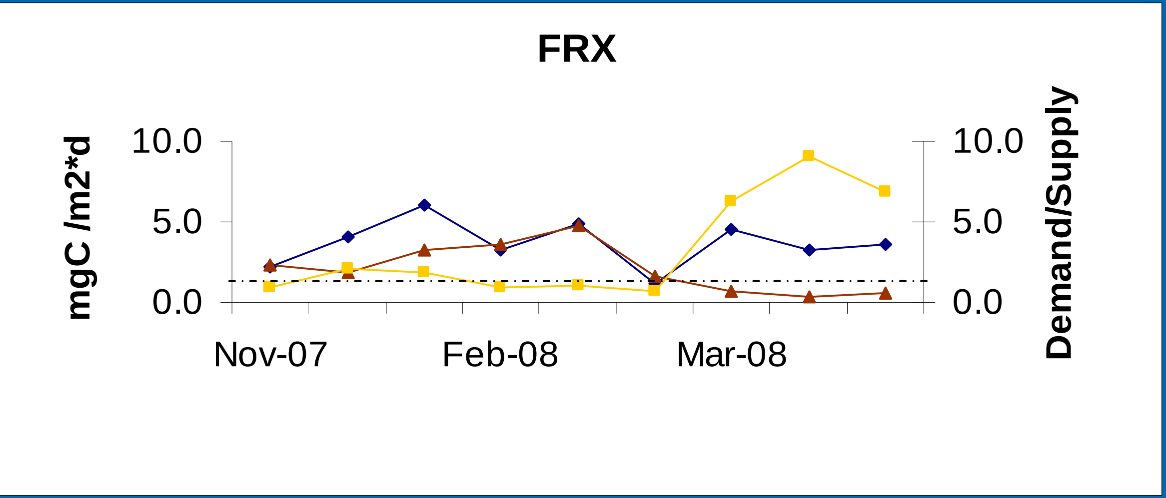
Carbon supply and demand

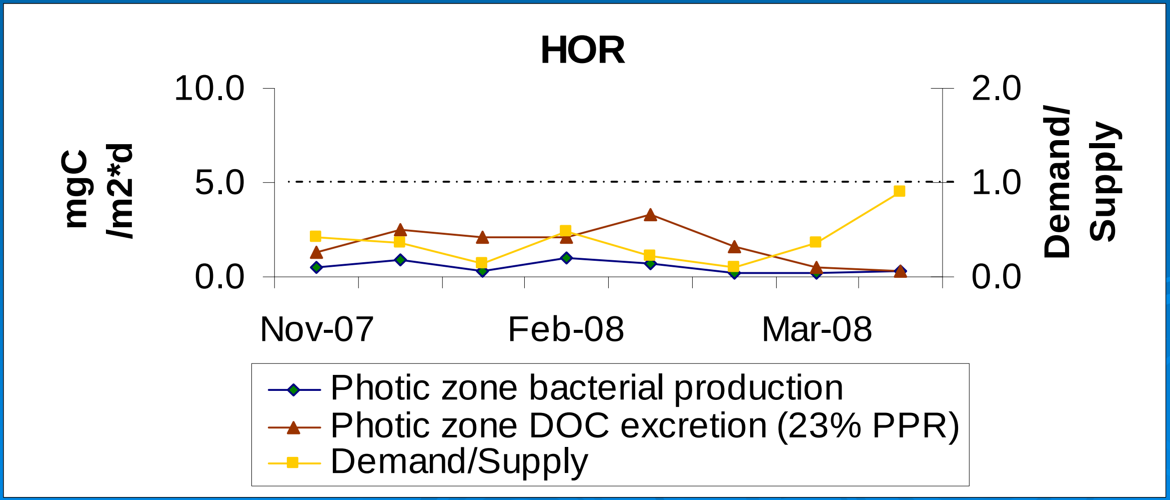




Results: Fall 2007-2008

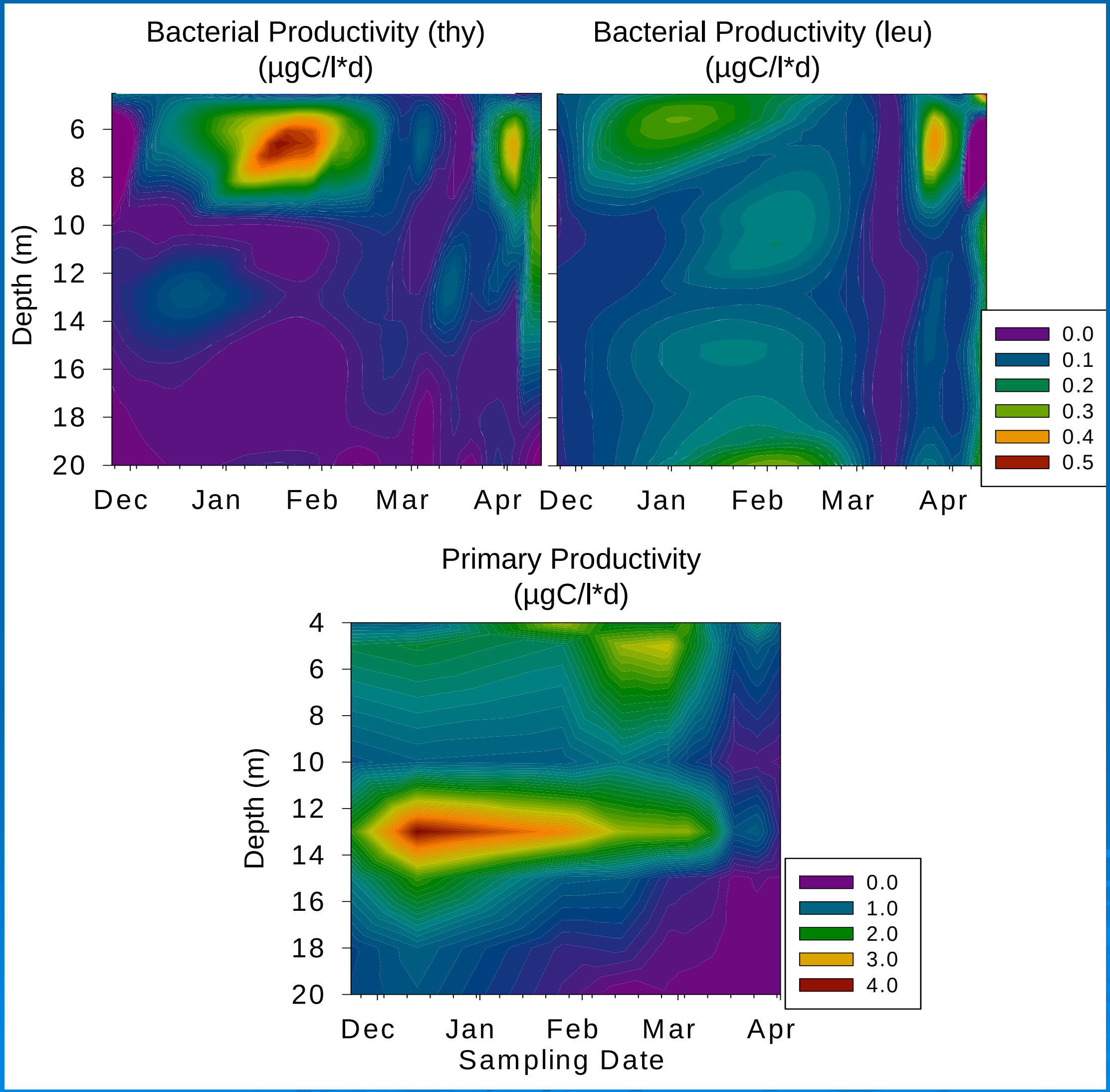
Carbon supply and demand





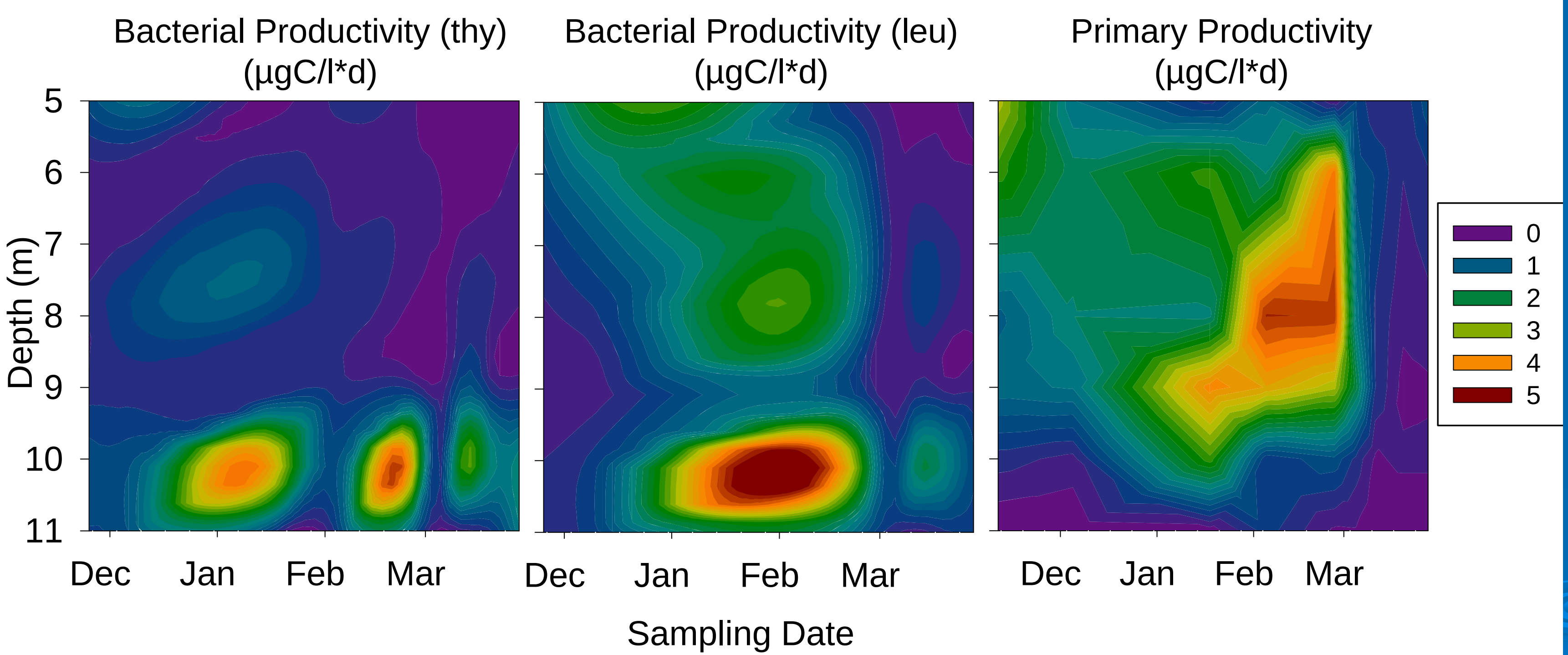
Results: Fall 2007-2008

ELB depth profiles



Results: Fall 2007-2008

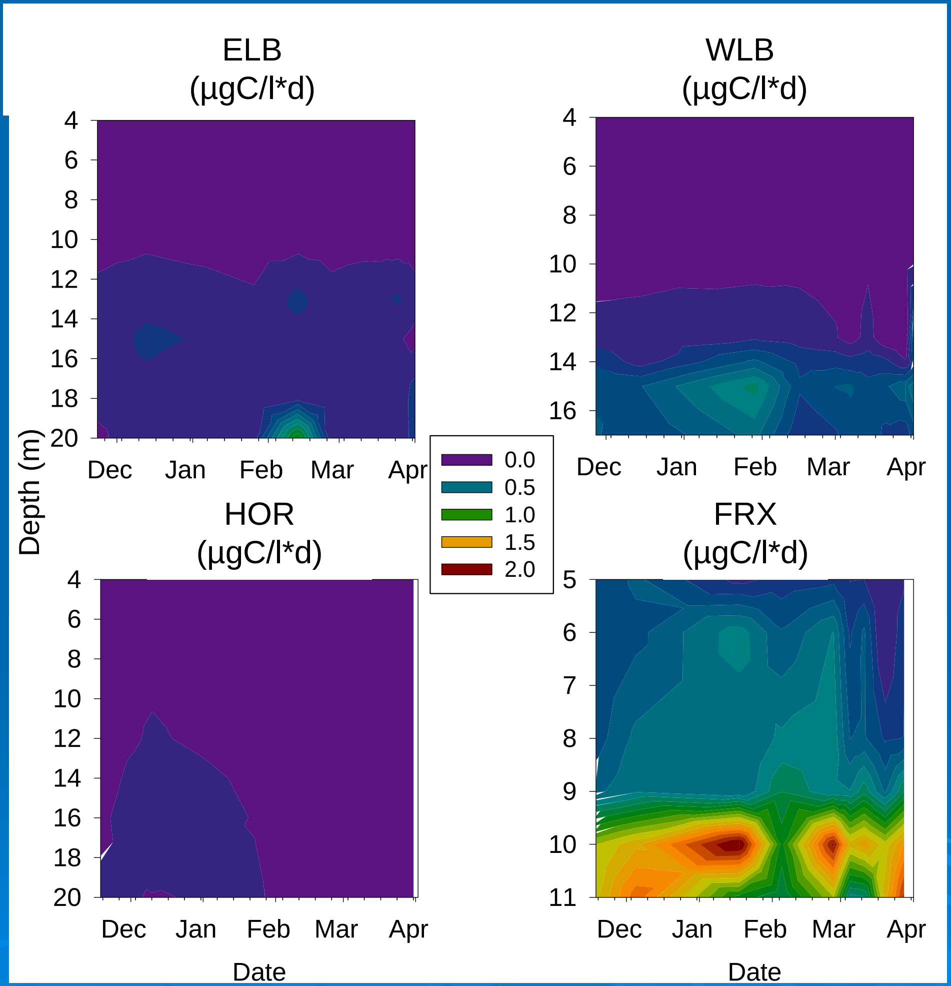
FRX depth profiles



Results: Fall 2007-2008

Dark ^{14}C-bicarbonate incorporation

***These data are from the dark (control) bottles in the normal primary productivity experiments**

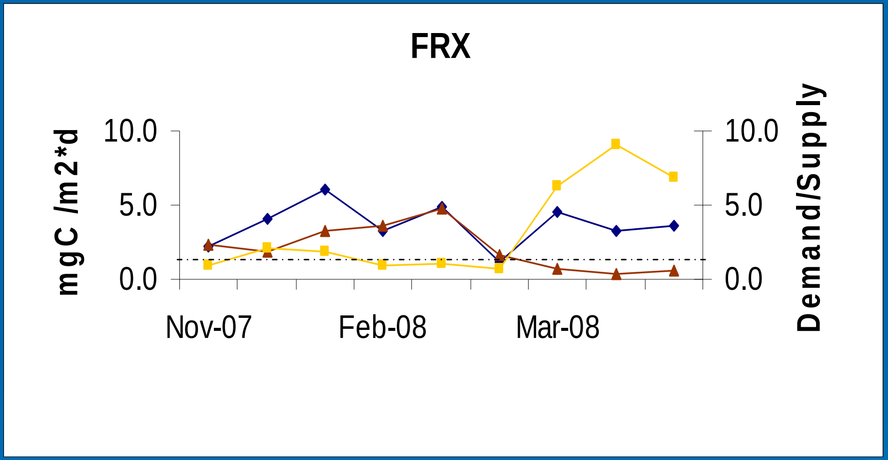


Fall 2007-2008 summary

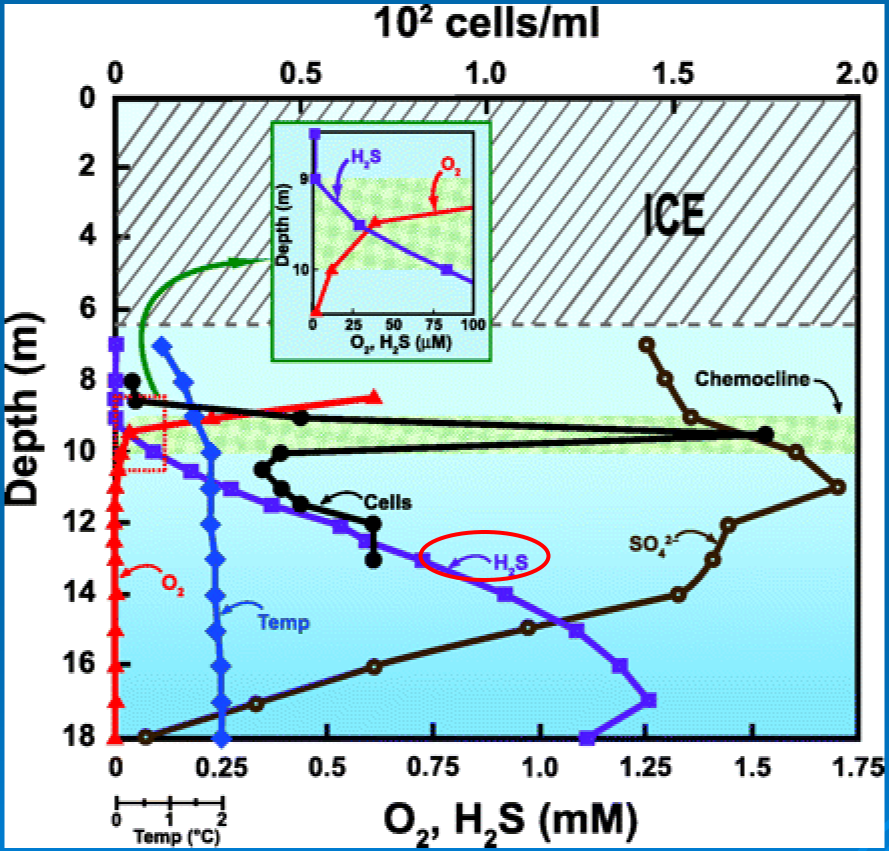
- Throughout the season:
  - Bacterial productivity changed by less than 8% per day in all four lakes, and decreased only in HOR
  - The ratio of organic carbon demand to supply was >1 in FRX and <1 in ELB
- Rates of leucine incorporation were higher than rates of thymidine incorporation, especially late in the season
  - Is this a clue to metabolic changes occurring in bacterial populations as the sun sets? Perhaps cells are synthesizing more protein, but are not dividing?

How is heterotrophic activity in Fryxell sustained?

- Hypothesis: chemolithoautotrohpy driven by the upward flux of e$^-$ donors is an important year-round source of organic carbon production in MCM Dry Valley lakes, particularly in lake Fryxell.

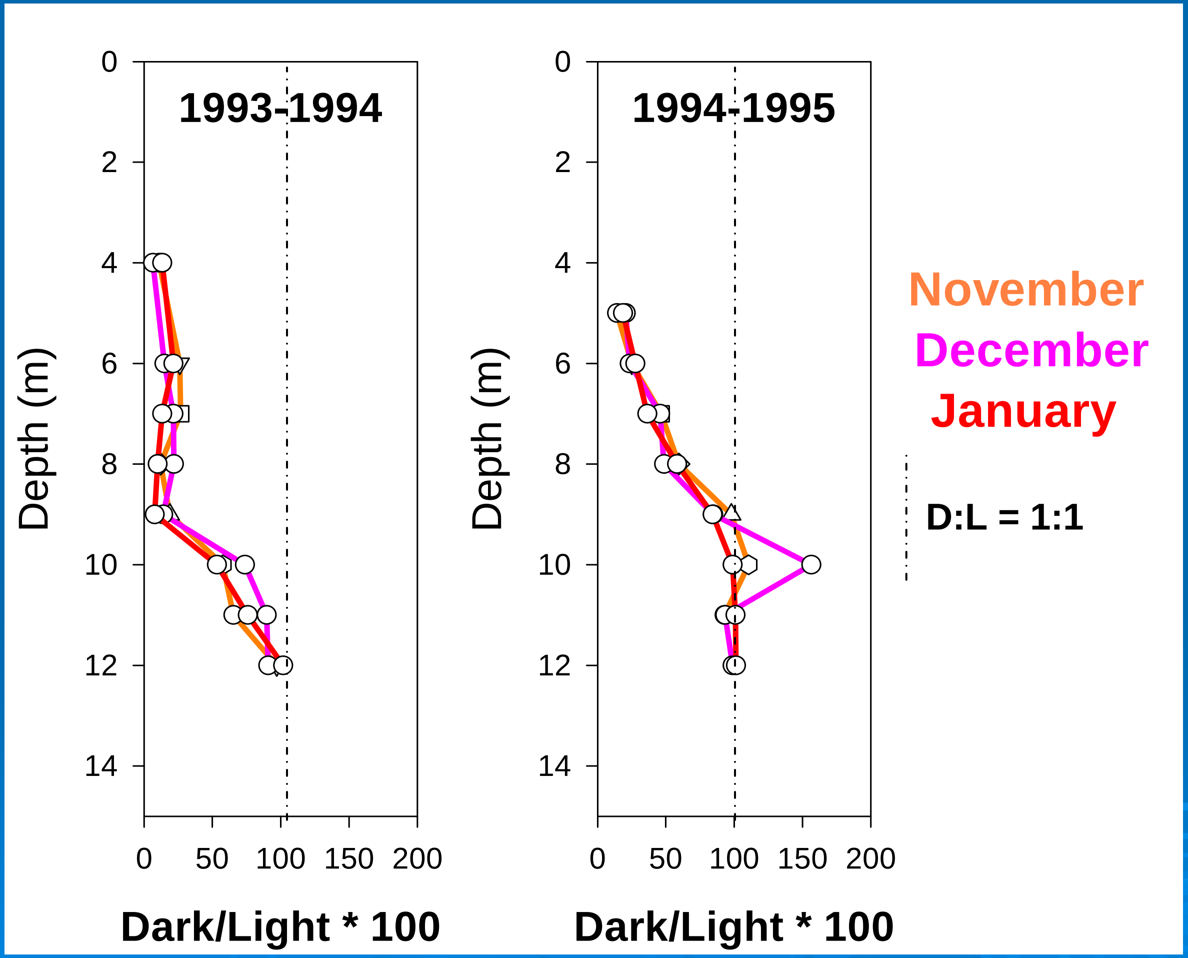


Lake Fryxell: a closer look



Madigan et al., 2006

Dark ^{14}C-bicarbonate incorporation in Lake Fryxell



Takacs and Priscu, unpub data

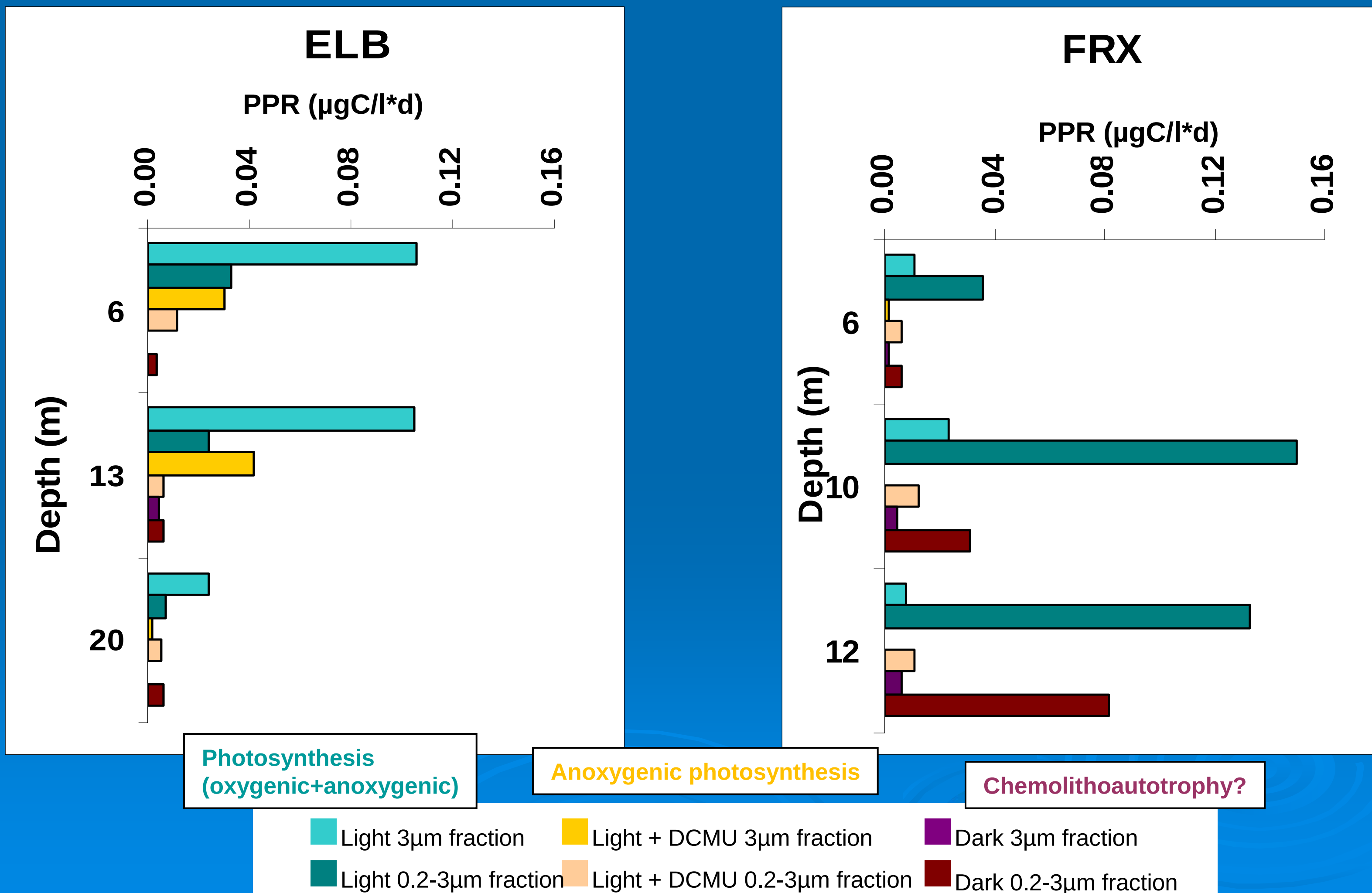
Methods: Summer 2008-2009

Exploring carbon fixation in Fryxell and Bonney

- Method:
  - FRX & ELB
  - Light, dark, DCMU-treated, and formalin-killed ^{14}C-labeled bicarbonate incorporation at 3 depths in each lake
  - Filter through 3 and 0.2 µm filters
  - Determine radioactivity using liquid scintillation

Results: Summer 2008-2009

^{14}C-bicarbonate incorporation



Conclusions

- Fall 2007-2008: watching the sun go down
  - BP does not decrease as the sun goes down – evidence against H_o
  - The average ratio of organic carbon demand to supply in FRX was 3.63
  - Dark carbon fixation accounts for a larger portion of the carbon supply in FRX than the other lakes
- Summer 2008-2009: dark ^{14}C incorporation in FRX and ELB
  - The highest level of dark ^{14}C incorporation in ELB (13m) is <88% of the highest level in FRX (12m)
  - More important than anoxygenic photosynthesis in FRX
  - BUT…is it chemolithoautotrophy?

Future directions

- Stats!
- Repeat dark ^{14}C-bicarbonate experiments
- Collect material in tandem for nucleic acid extraction
  - 16S and functional genes
- Further study of relationship between thymidine and leucine incorporation rates

Thank you!

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