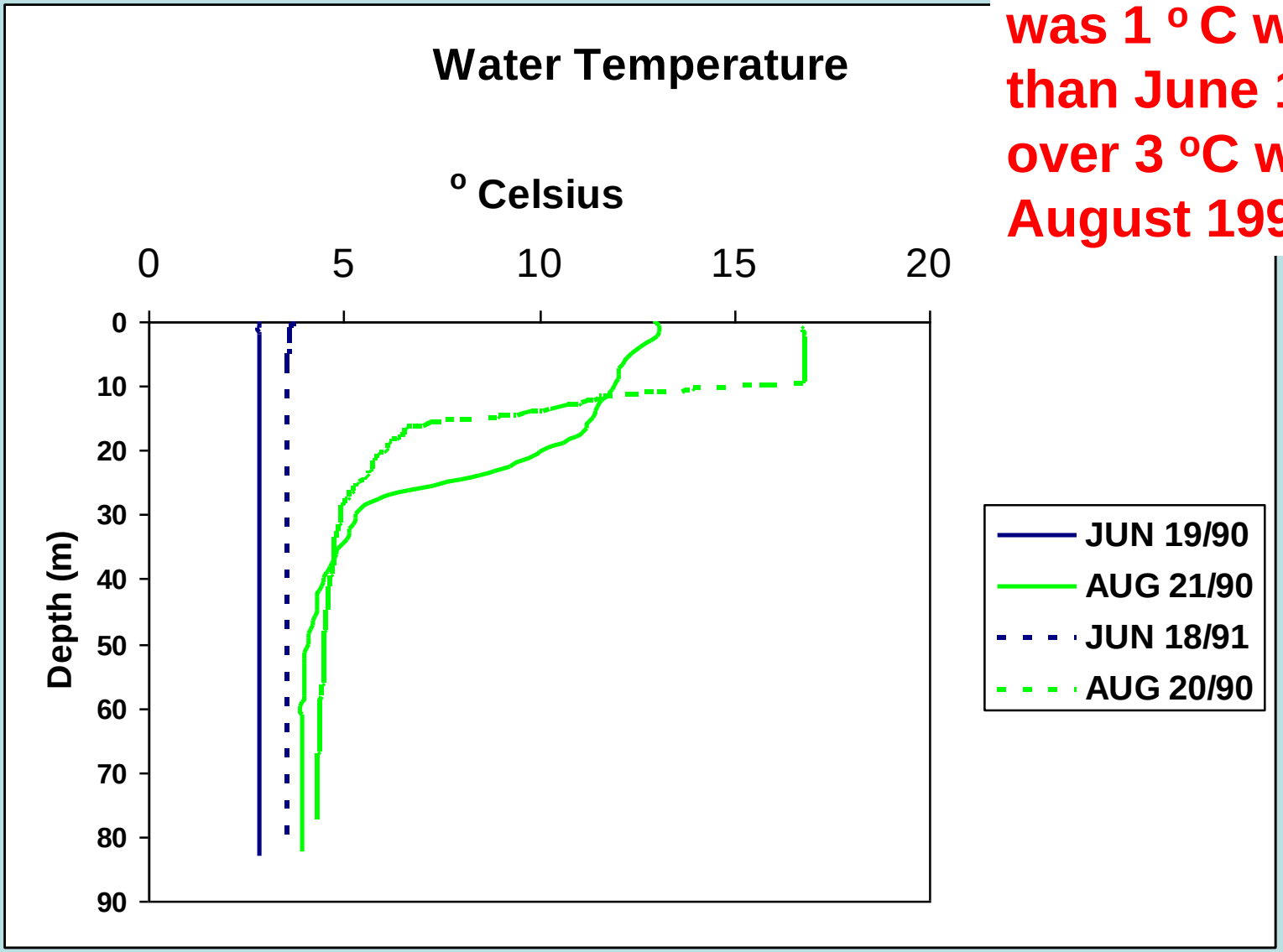
How will climate change affect phytoplankton photosynthesis in Lake Superior ?

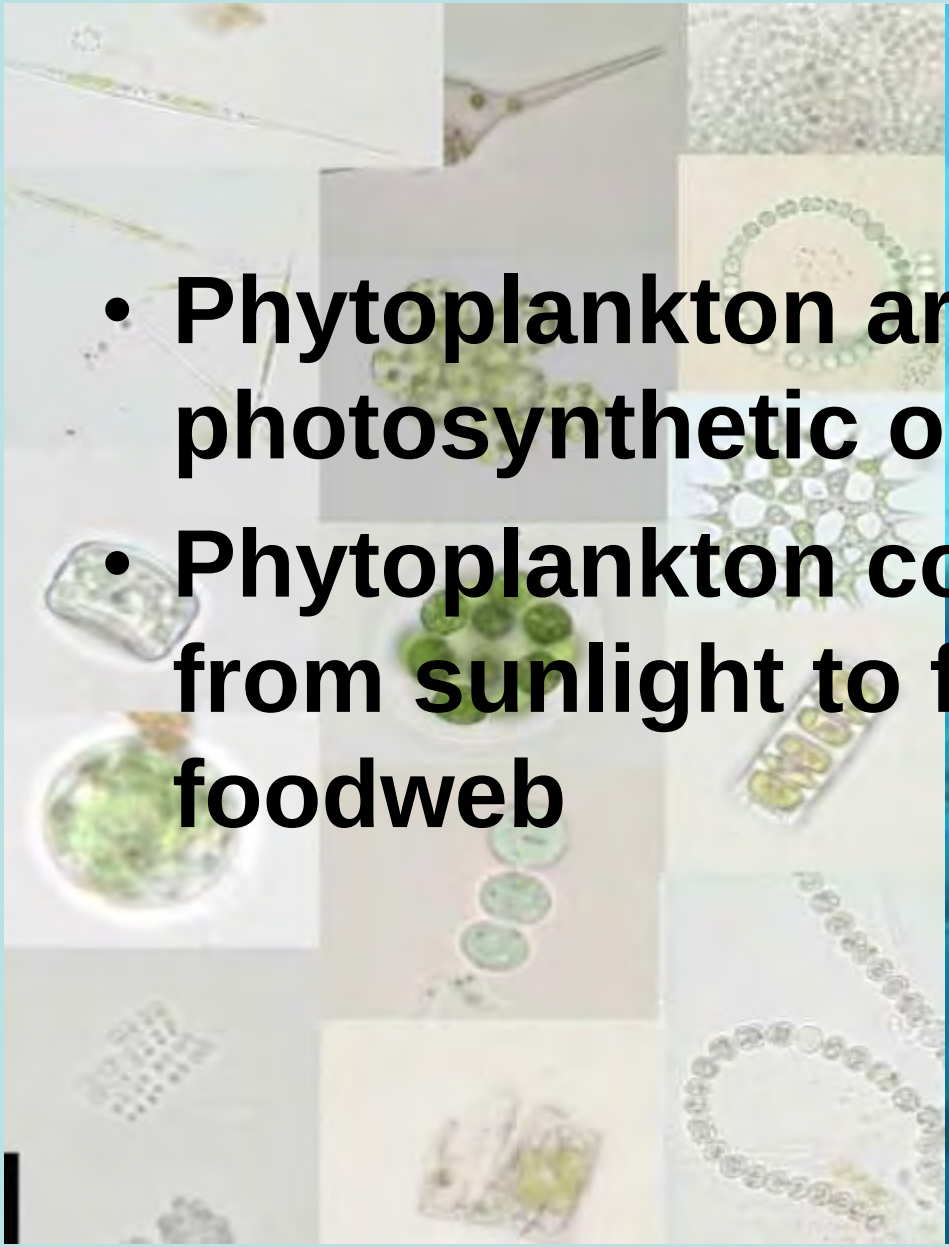
Stephanie Guildford[1], Rebecca North[2], David Depew[2], Greg Silsbe[2], Ralph Smith[2]

[1] Department of Biology and Large Lakes Observatory, University of Minnesota Duluth, Duluth, MN, USA

[2] Department of Biology, University of Waterloo, Waterloo Ontario, Canada

In June 1991 water was 1 ^{o}C warmer than June 1990 and over 3 ^{o}C warmer in August 1991

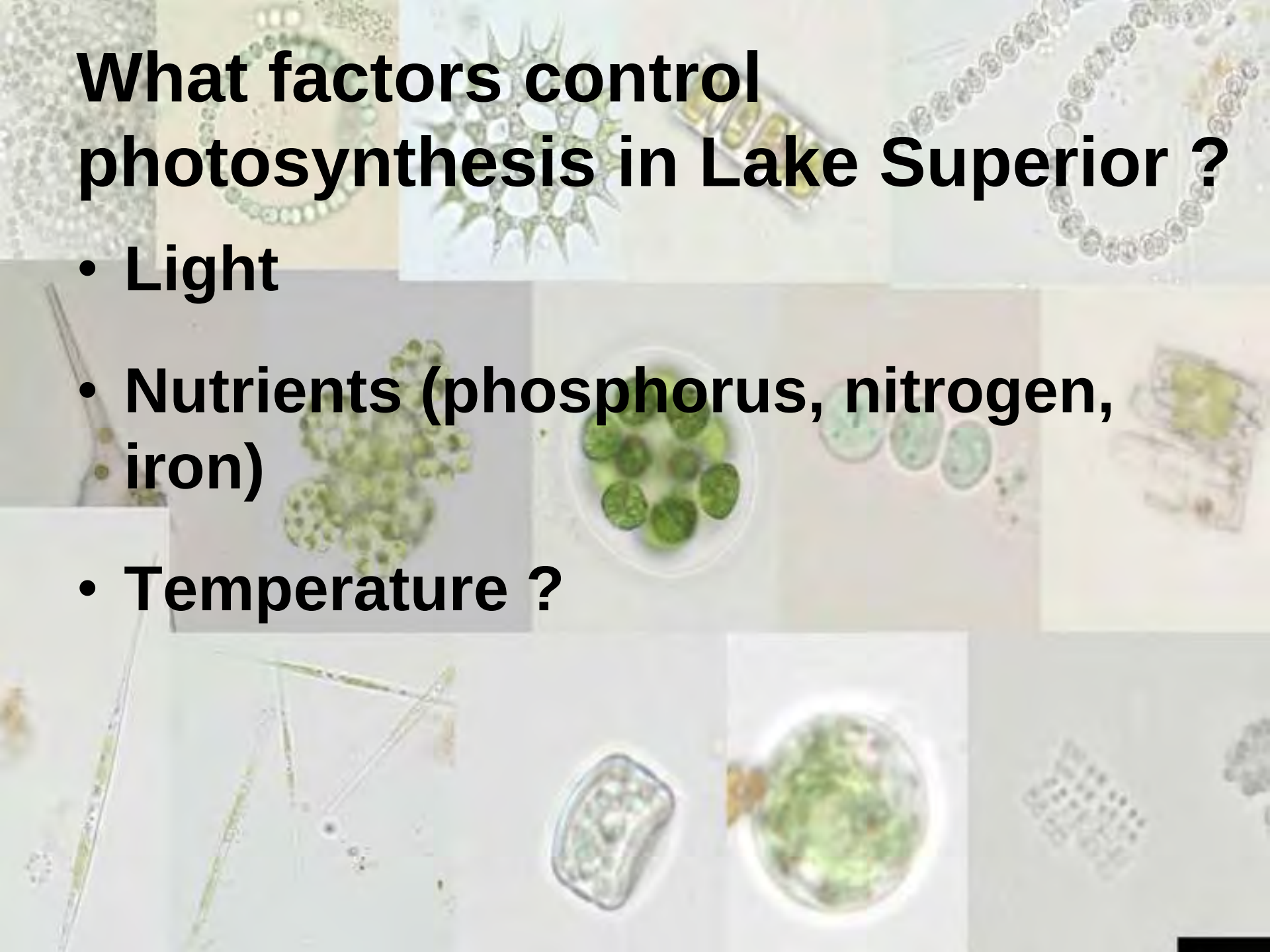




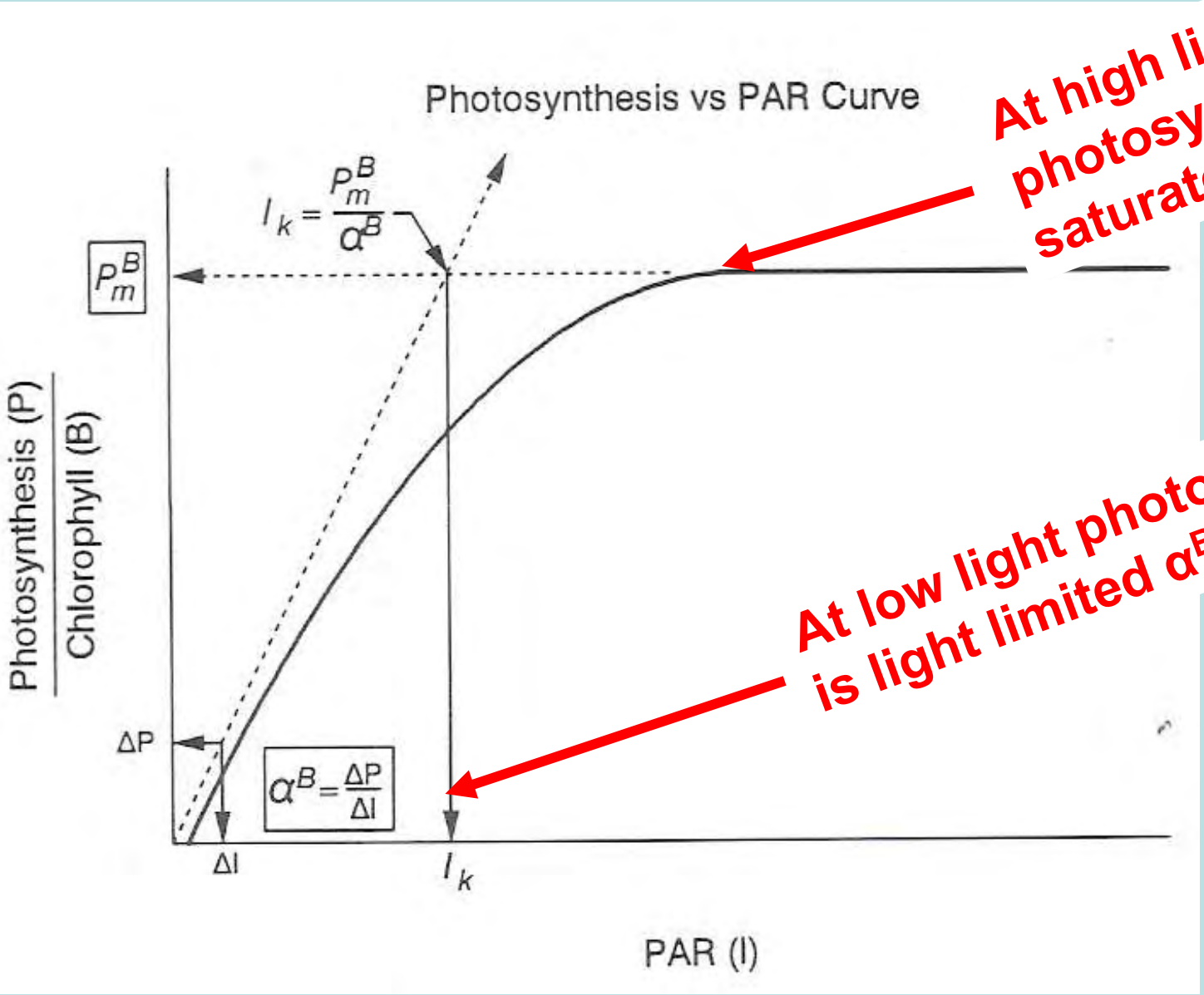
- **Phytoplankton are microscopic photosynthetic organisms**
- **Phytoplankton convert energy from sunlight to fuel the aquatic foodweb**

What factors control photosynthesis in Lake Superior ?

- Light
- Nutrients (phosphorus, nitrogen, iron)
- Temperature ?



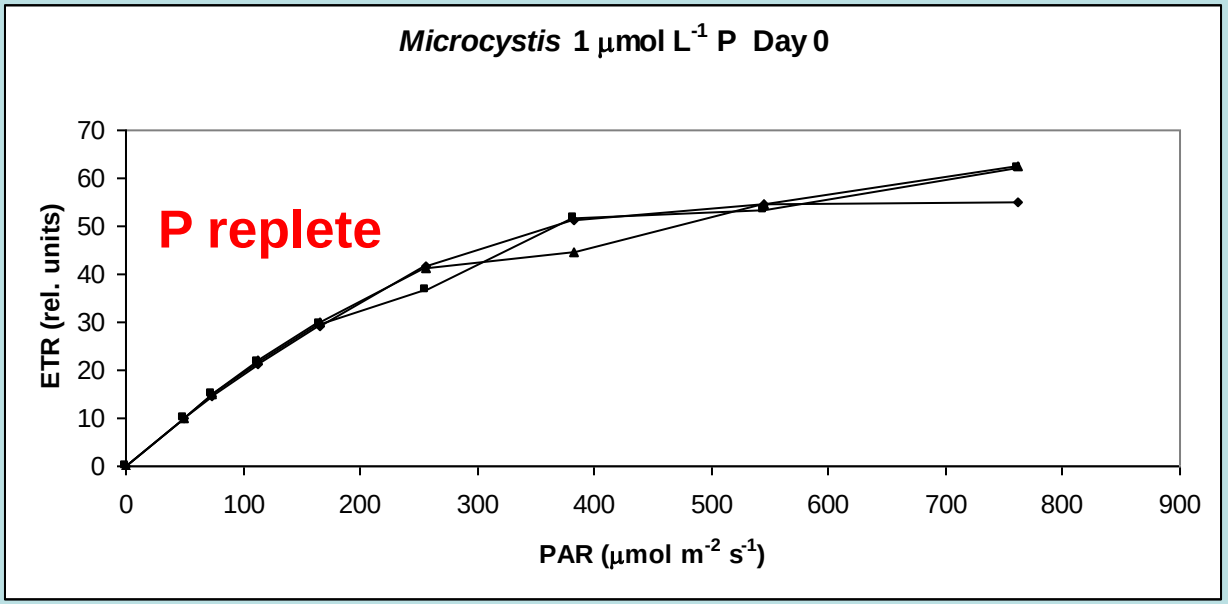
How does light affect photosynthesis?

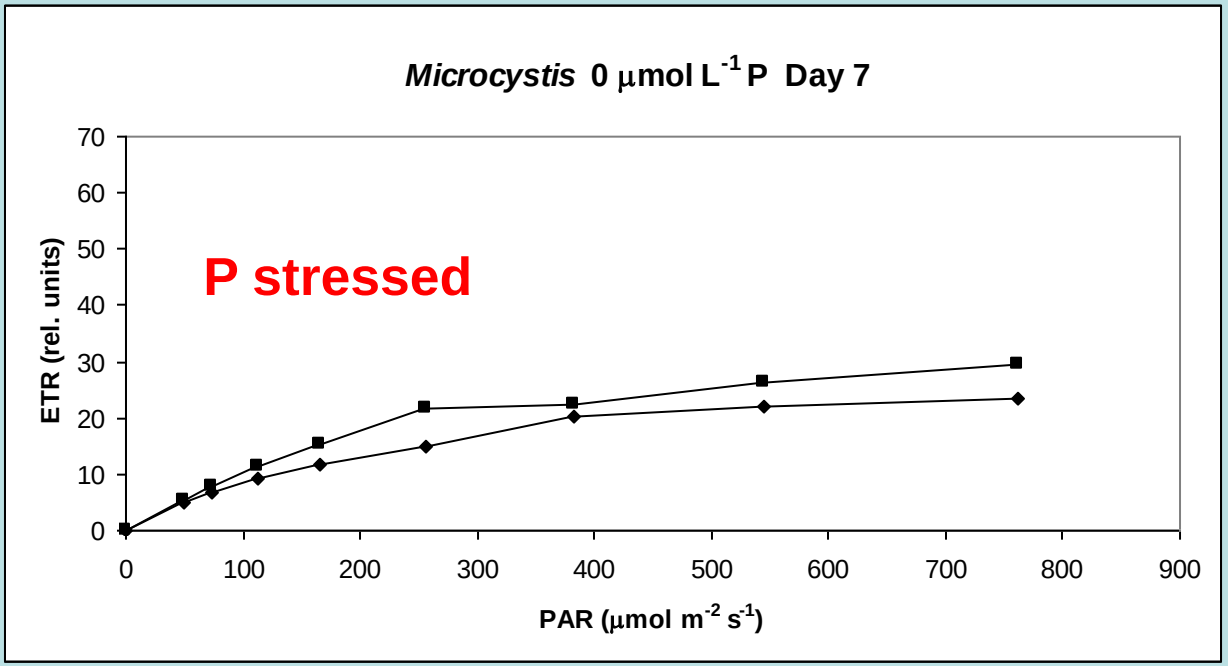


At high light photosynthesis is saturated (P_m^B)

At low light photosynthesis is light limited α^B

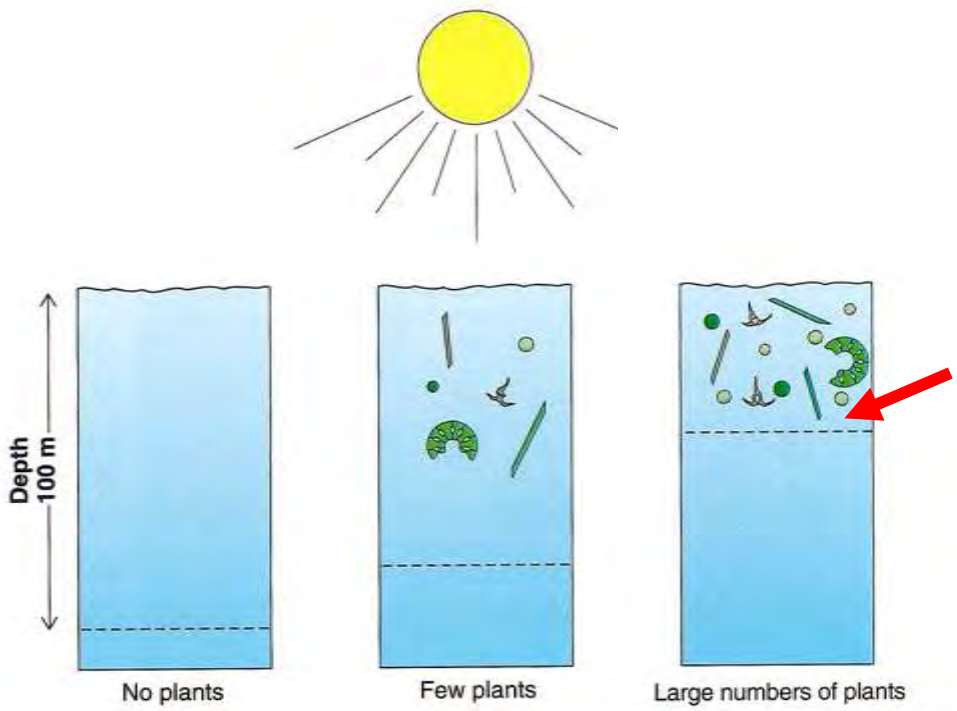
How does P stress affect photosynthesis?





P stress reduced (P_m^B) and (α^B)

How can temperature affect light for phytoplankton photosynthesis?

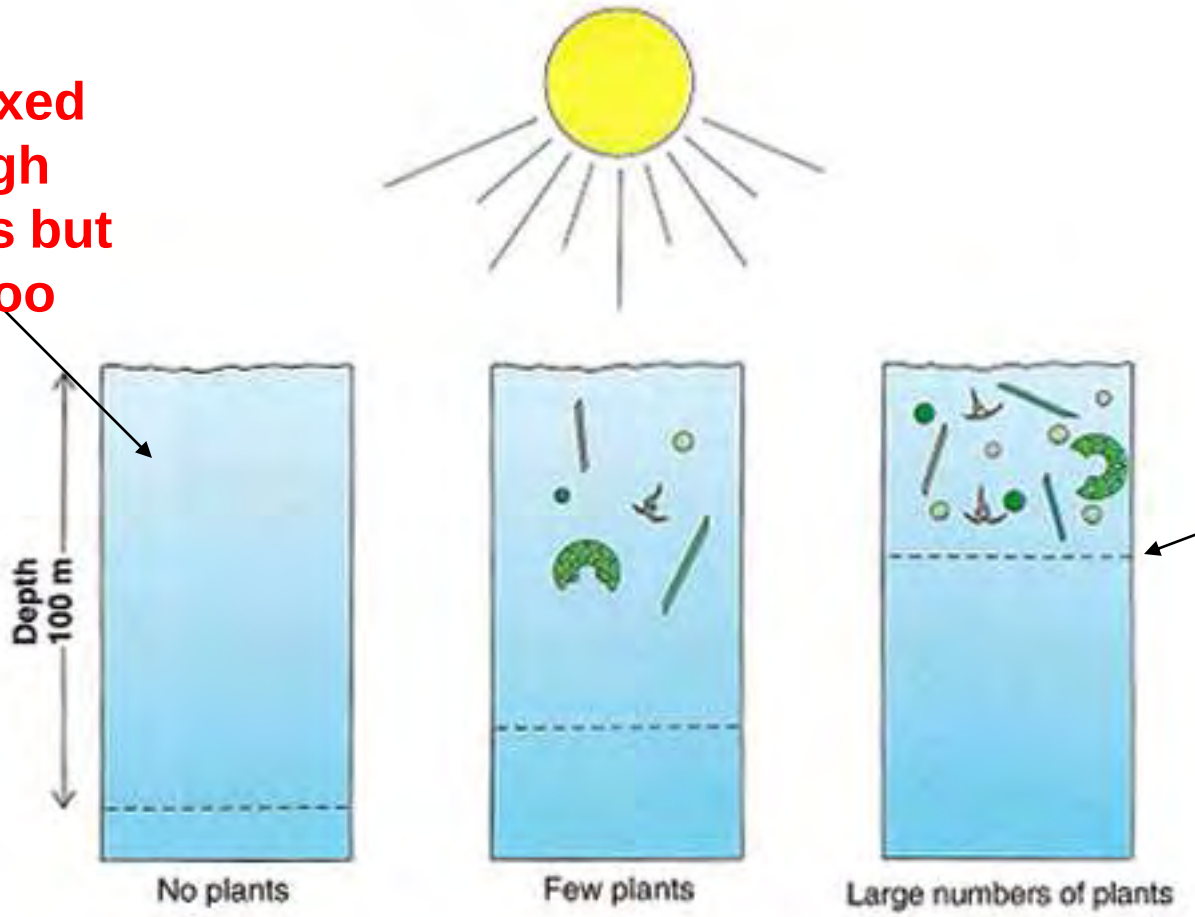


Phytoplankton circulating in a shallow mixed layer receive more light on average than phytoplankton circulating through a deep mixed layer

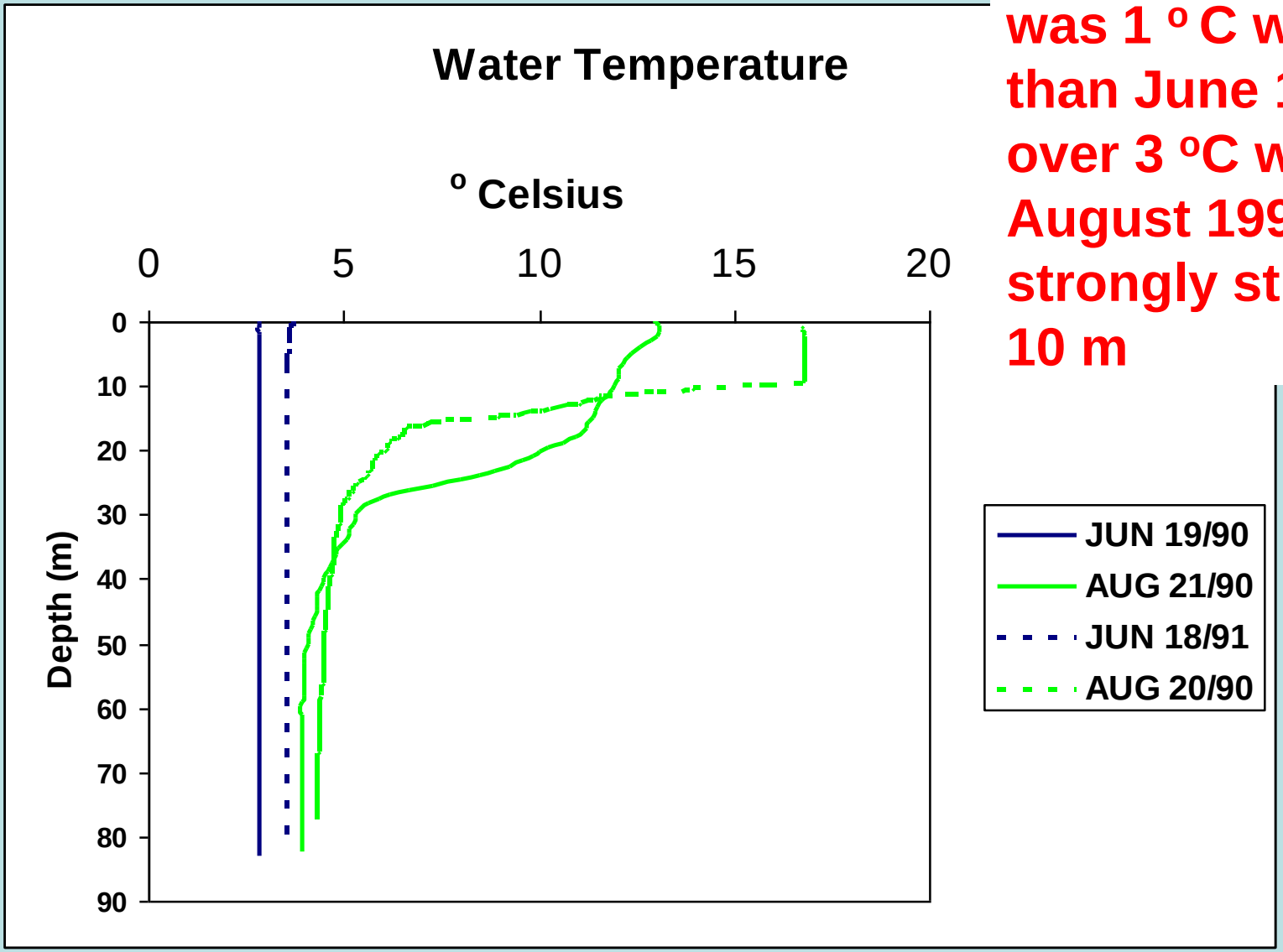
Fig. From Nybakken , 2001

How can temperature affect nutrients available for photosynthesis ?

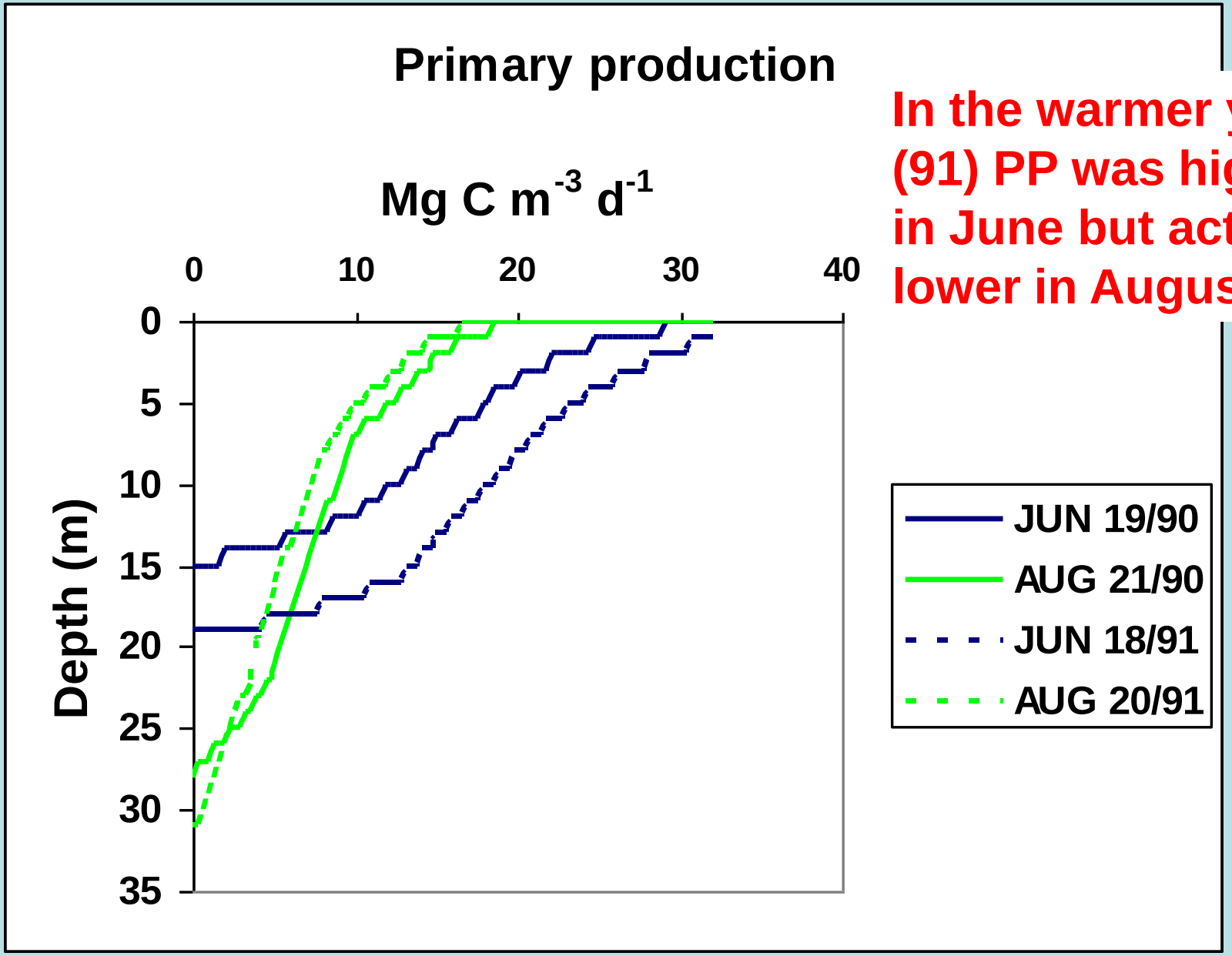
Deep mixed layer, high nutrients but light is too low for positive growth



Shallow mixed layer light is high and nutrients are quickly exhausted

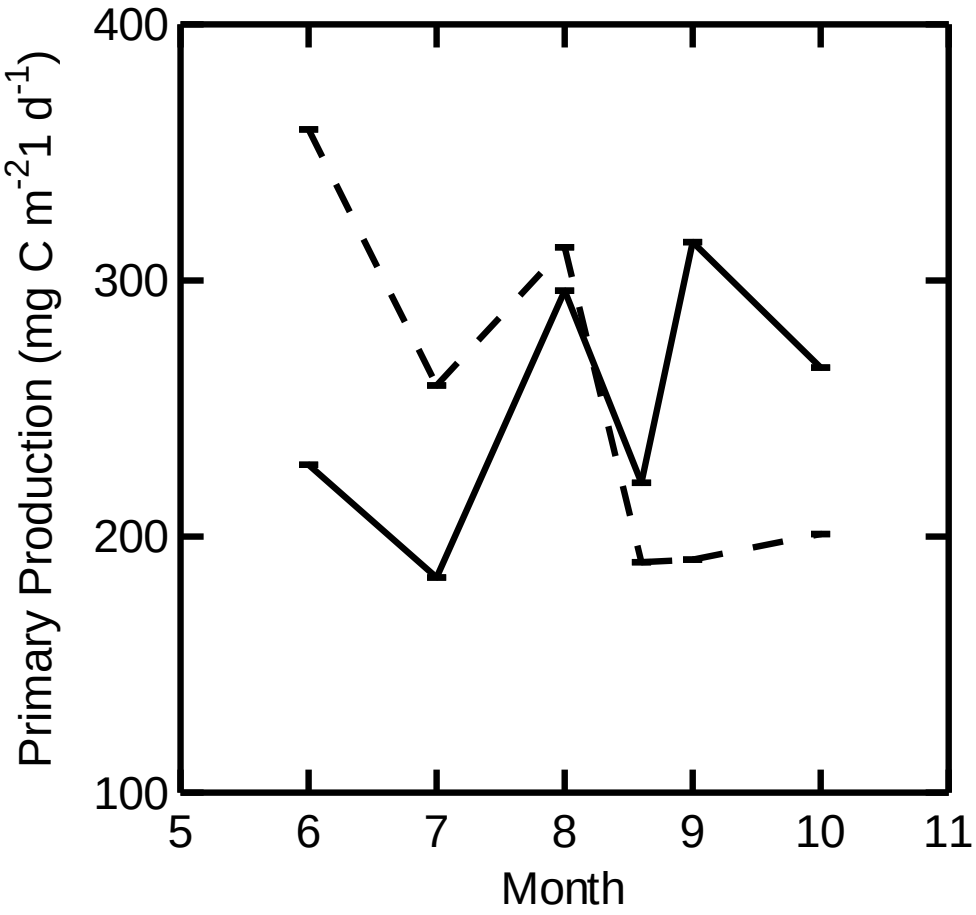


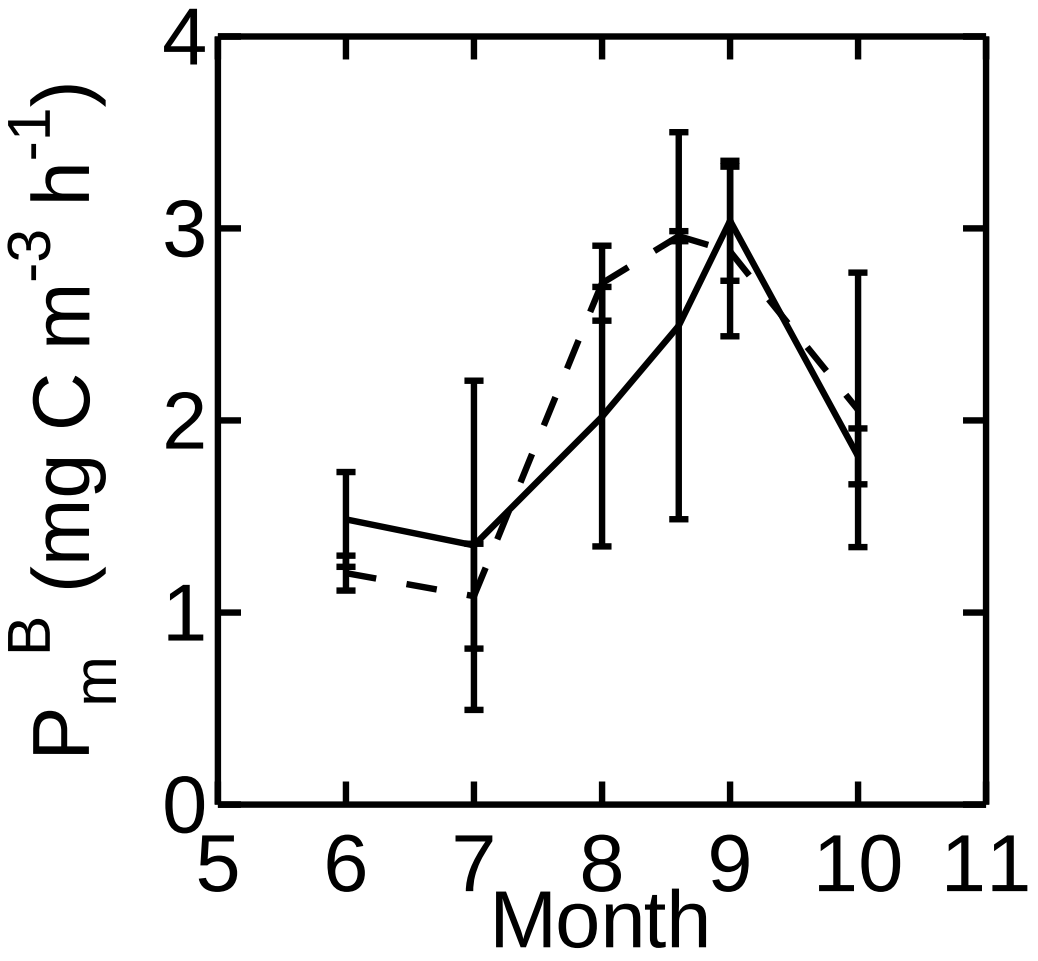
In June 1991 water was 1 °C warmer than June 1990 and over 3 °C warmer in August 1991 and strongly stratified at 10 m



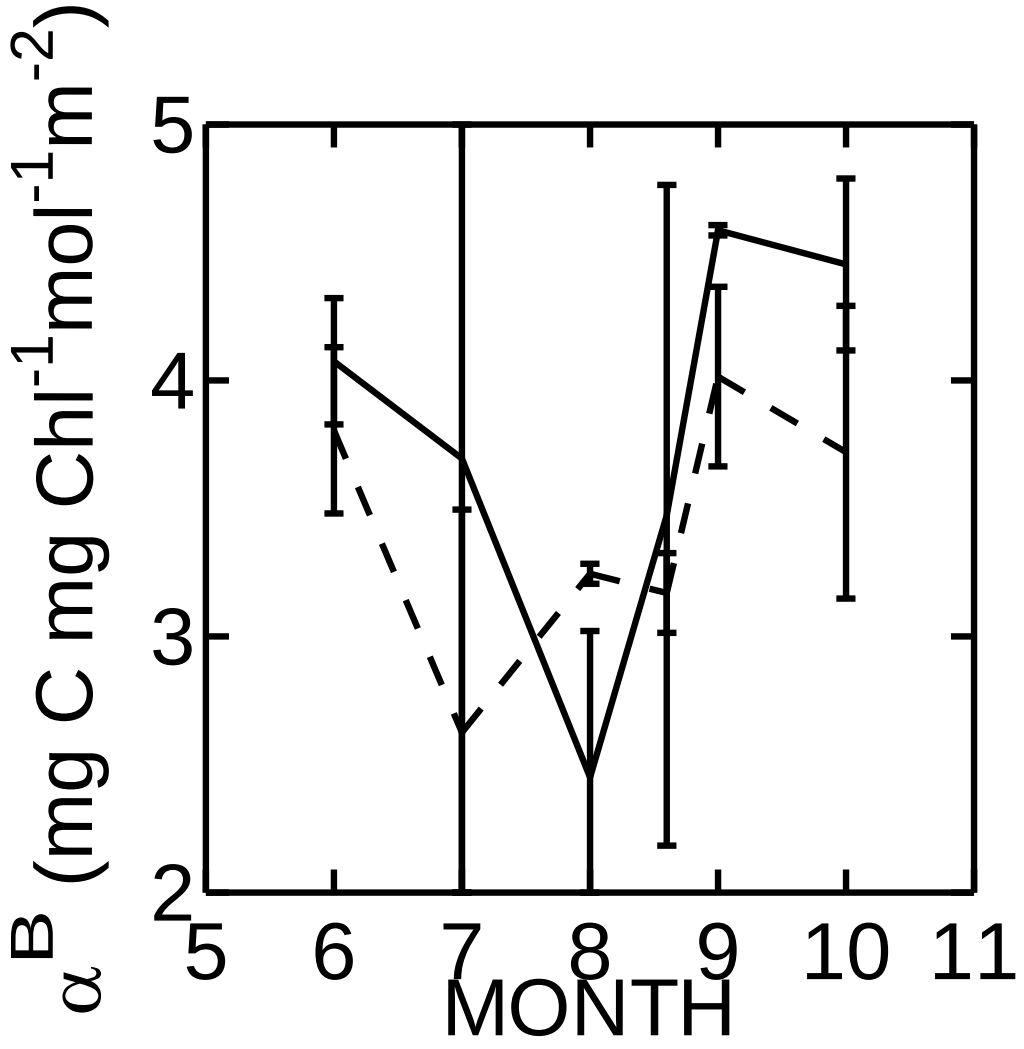
In the warmer year (91) PP was higher in June but actually lower in August

Primary production was higher in the early part of the warm year 1991 and lower in the latter half of the warm summer



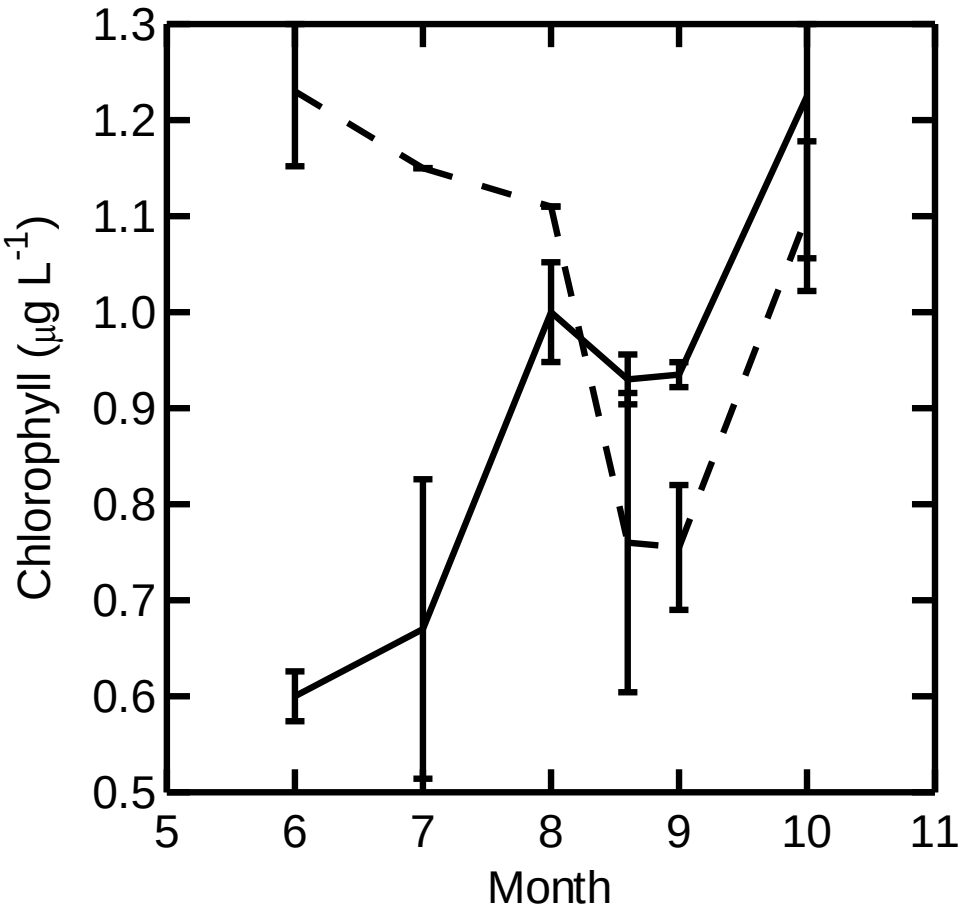


P_m^B was slightly higher in 1991

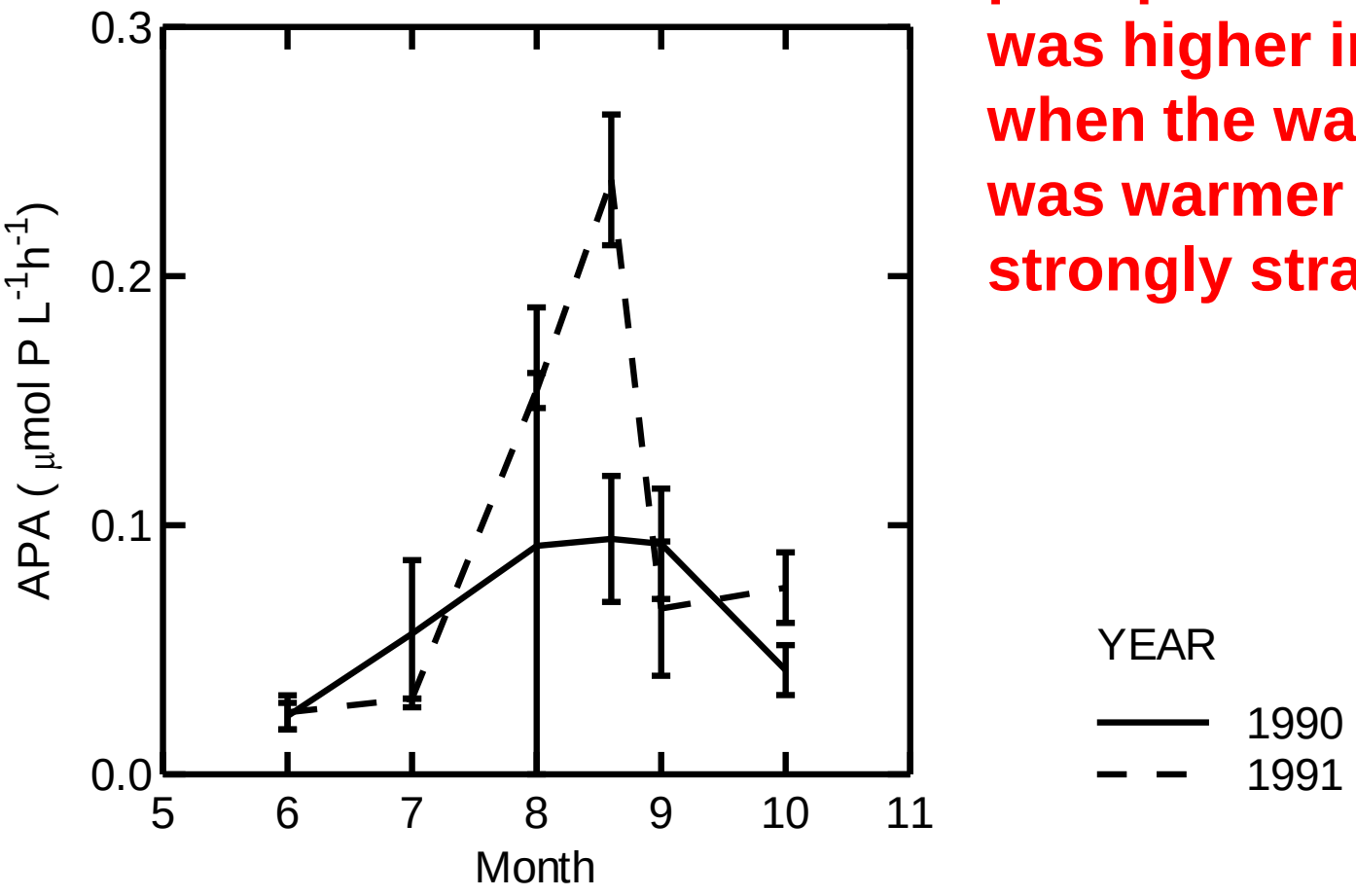


α^B was lower in 1991

Chlorophyll was higher in the early part of the warm year and lower in the latter part of the summer

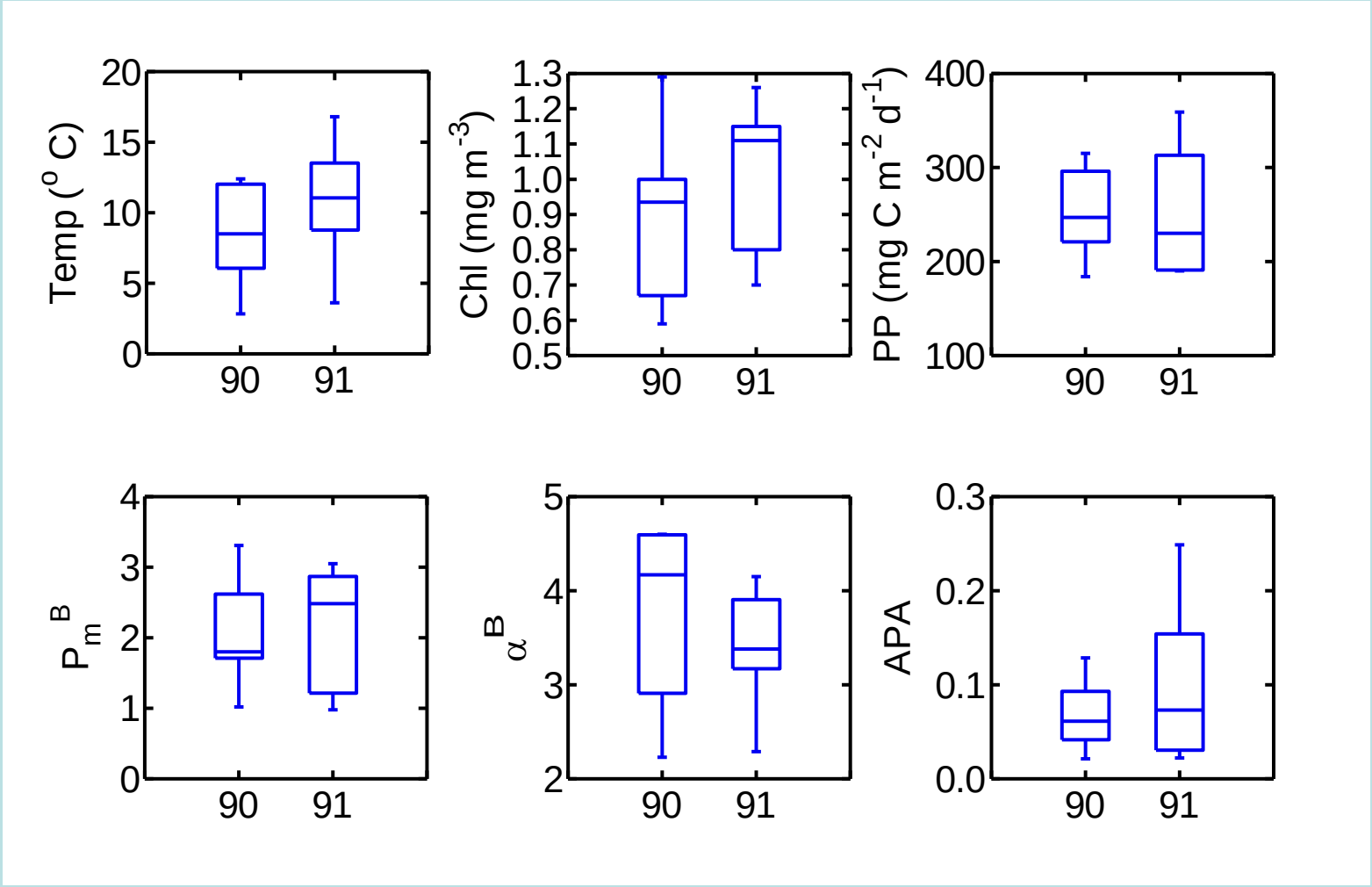


APA (a measure of phosphorus deficiency) was higher in 1991 when the water column was warmer and more strongly stratified



Lake Superior 1990-1991

↑ Temperature ↑ Chlorophyll <> Productivity



↑ PmB ↓αB ↑APA

Consequences of a warmer year?

- Shallower, stronger stratification
- Changes in timing and magnitude of chlorophyll peak
  - Food supply for consumers
- Stronger P stress
  - Food quality

Strengths and limitations of this study

- Complete seasonal data
- Measured process as well as bulk parameters
- One sampling location
- Two years
- One sampling depth (3 m within the mixed layer)

New technology

FRRF

- **Productivity**
- **Health**

FluoroProbe

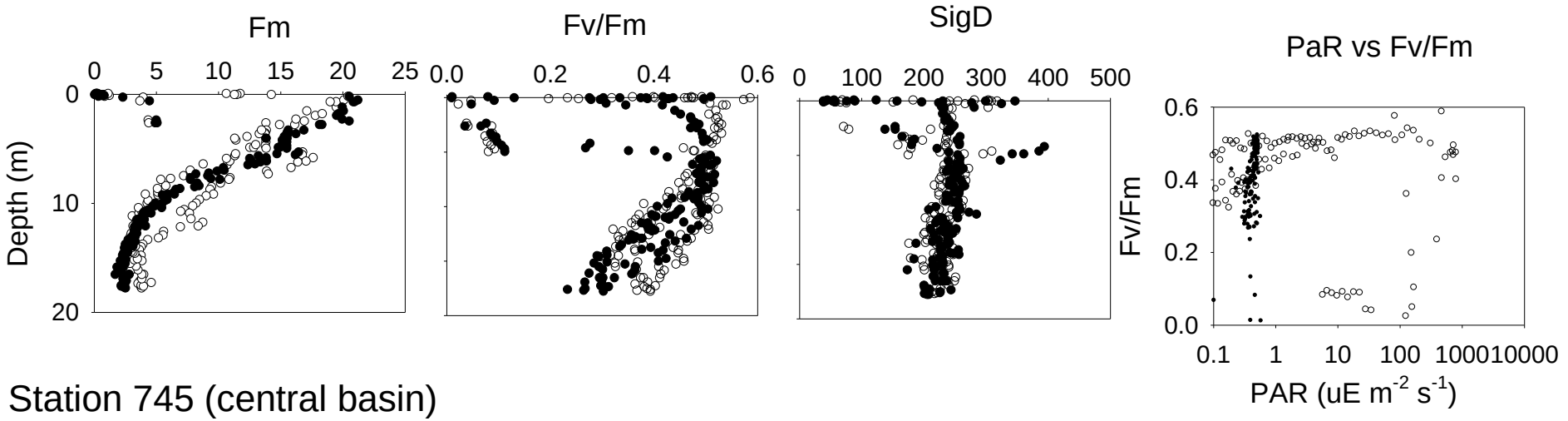
- **Biomass**
- **Type**

High resolution

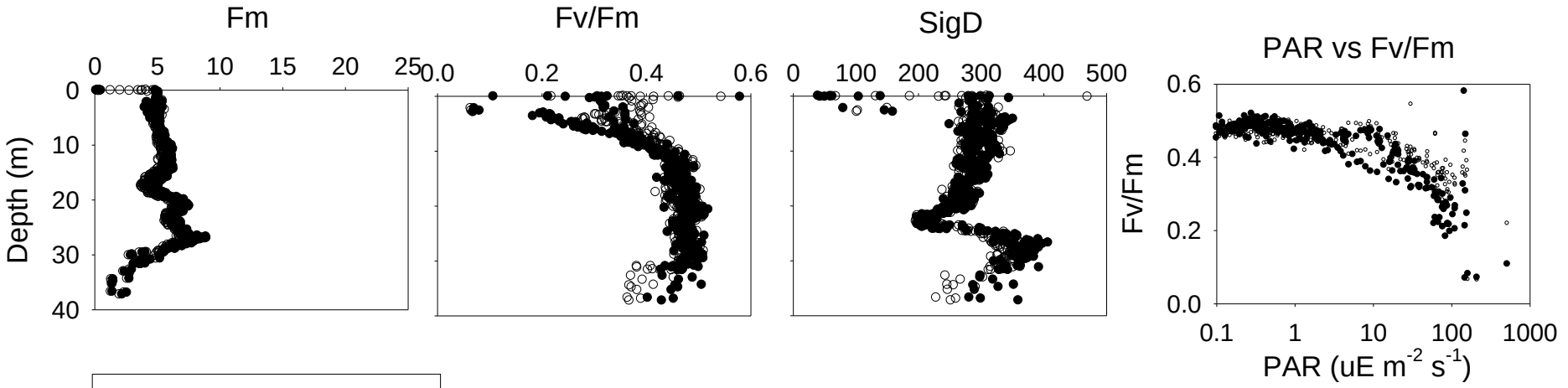
- **Time**
- **Space**

Fast Repetition Rate Fluorometry will increase our temporal and spatial resolution of photosynthesis in Lake Superior

Station 1001(Hamilton Harbour)



Station 745 (central basin)



Dark chamber
Light chamber

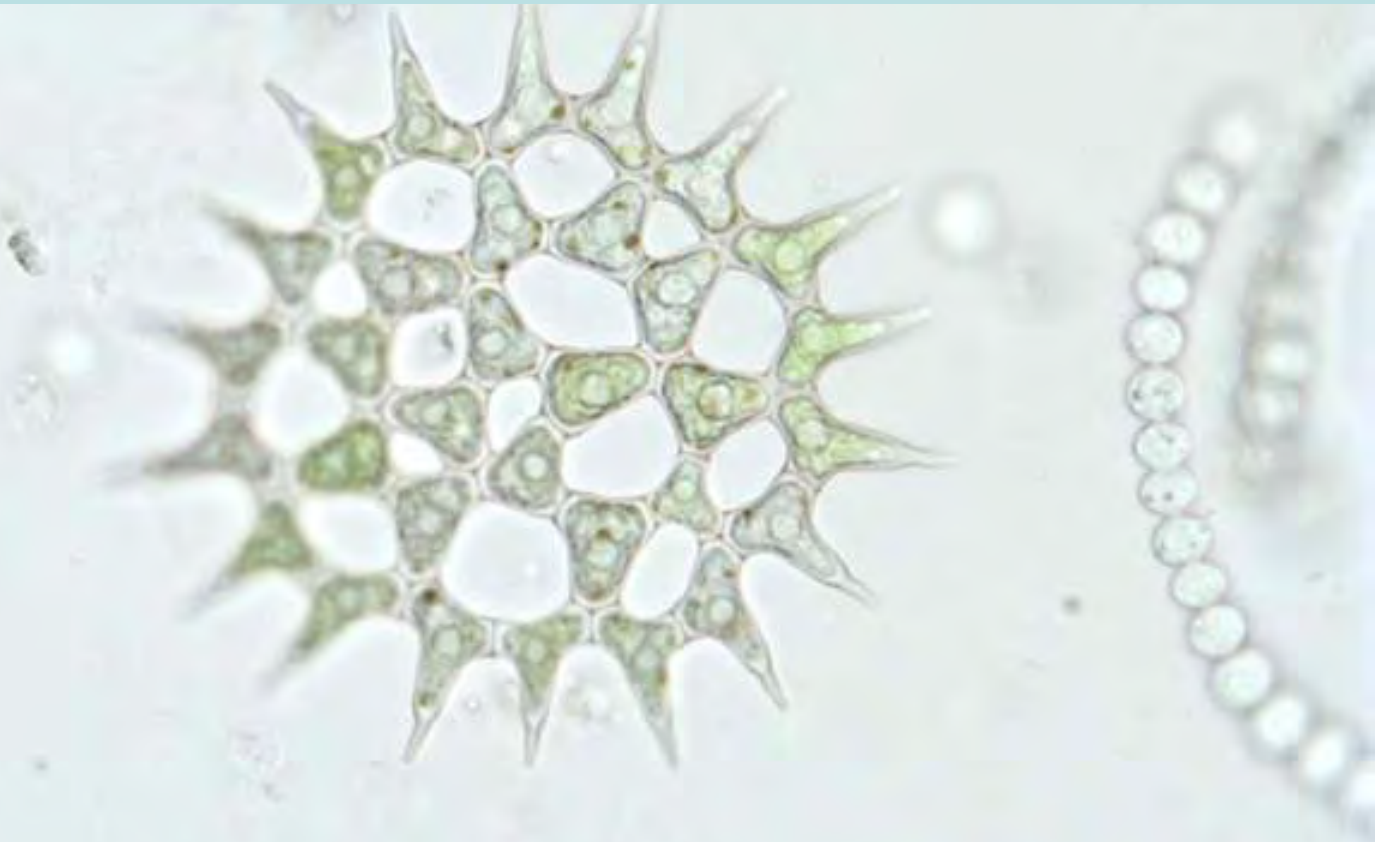
$$P(z)=1.87x10^{-4}*F_v/F_m(z)*SigD*E_{par}(z)*Chl(z)$$

Global Perspective

Lake Erie 2001-2003

- increased water temperatures,
- decreased PP
- increased P stress

Month	Year	Temp ^{o} C	Zmix (m)	PP Int (mg C m^{-2} d^{-1})	Chla (mg m^{-3})	C:P (molar)
July	2001	18.6	10	476	1.39	206
August	2001	21.3	16	1668	1.33	287
July	2002	22.7	5	750	1.17	278
August	2002	22.9	11	554	2.46	309
August	2003	24.6	9	na	1.36	689



Depew et al 2007, North unpublished data

Global perspective

Lake Malawi, east Africa PP may be declining with warming

Guildford et al 2007

Year	Annual primary productivity (g C m^{-2} y^{-1})	Range of daily primary productivity (mg C m^{-2} d^{-1})
1980	270	240-1140 n=21
1990	219	45-3046 n=96
1997-2000	182	124-937 n=20

Thanks!

Canada Department of Fisheries and Oceans

Department of the Environment

Malawi Government

Ontario Ministry of Natural Resources

University of Waterloo

NSERC