

How will climate change affect phytoplankton photosynthesis in Lake Superior ?

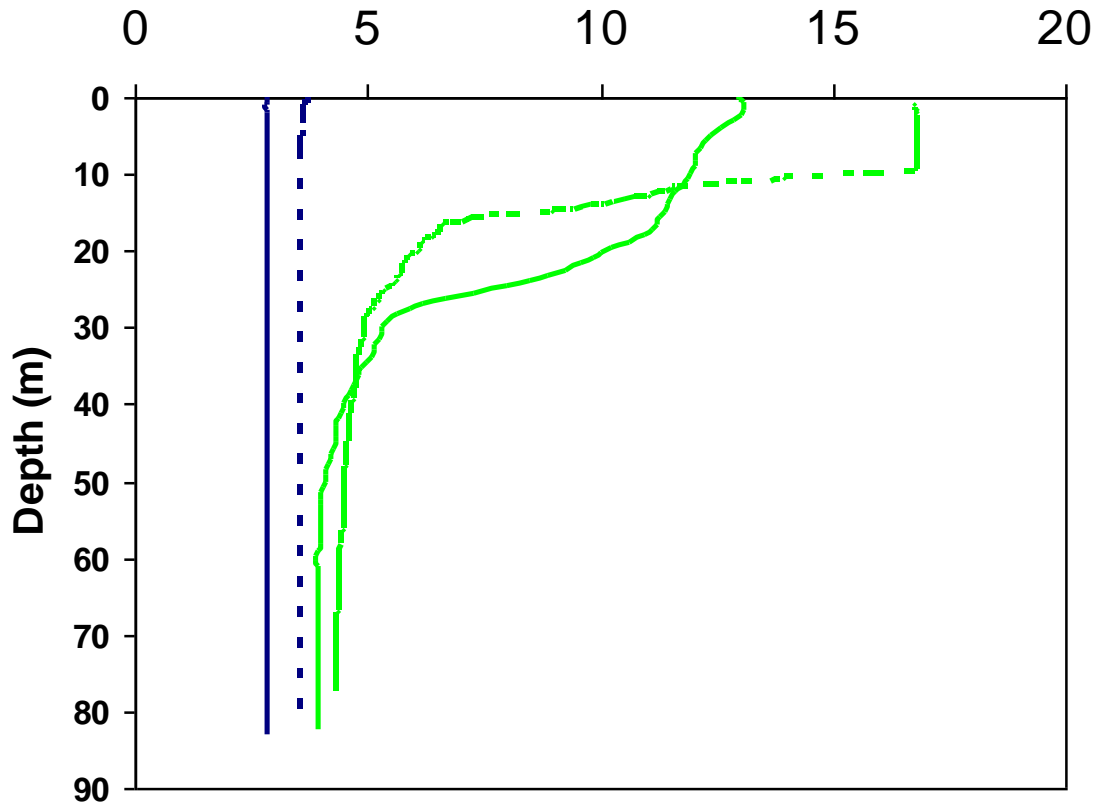
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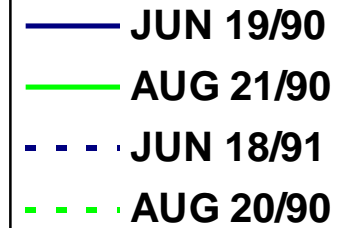
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Water Temperature

° Celsius



In June 1991 water was 1 °C warmer than June 1990 and over 3 °C warmer in August 1991



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

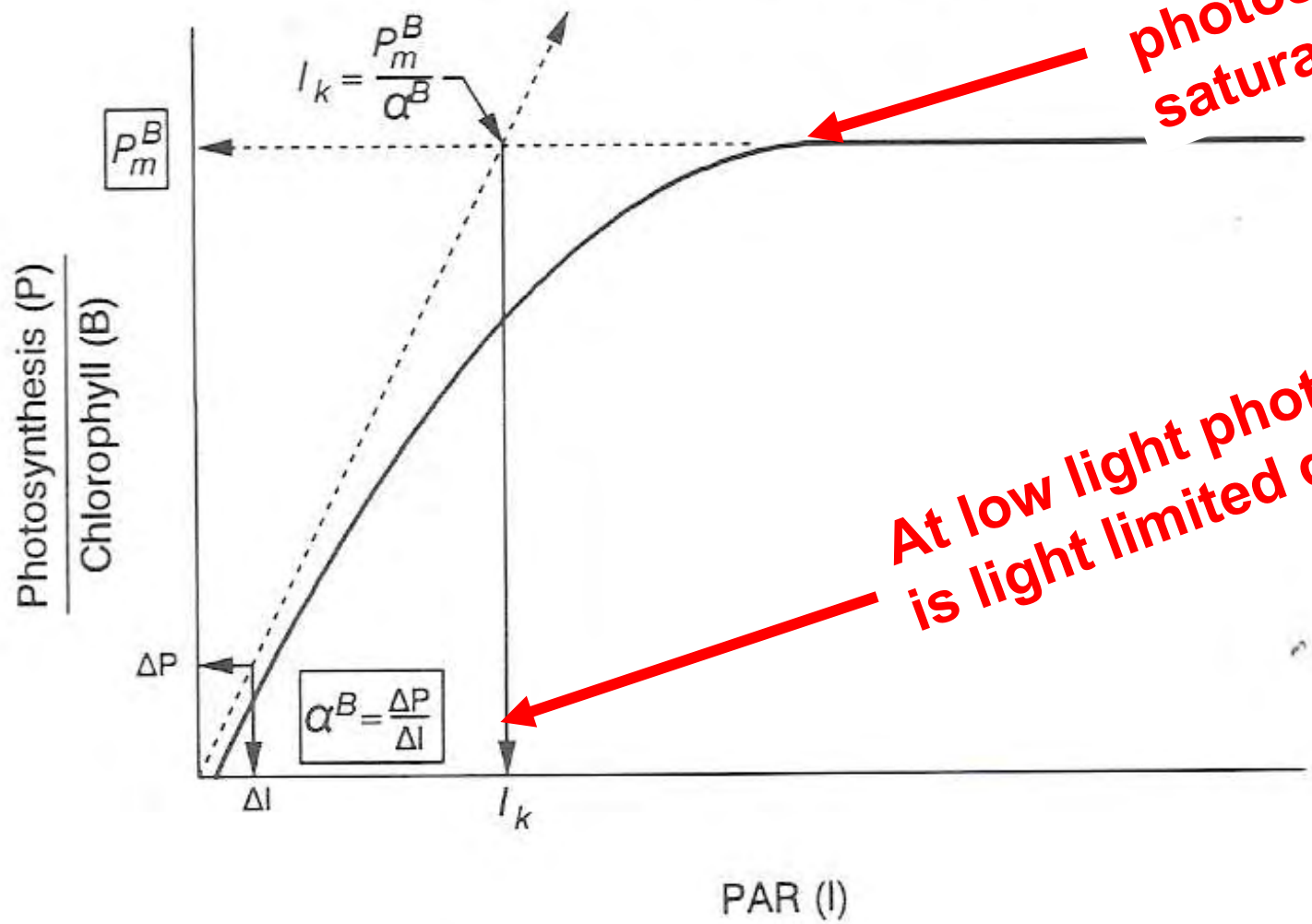
What factors control photosynthesis in Lake Superior ?

The background of the slide is a collage of various microscopic organisms, primarily algae and cyanobacteria. It includes circular colonies of cells, some with star-like or radiating structures, and long, thin, filamentous chains of cells. The organisms are shown in different colors, including green, blue-green, and brownish, against a light background.

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

How does light affect photosynthesis?

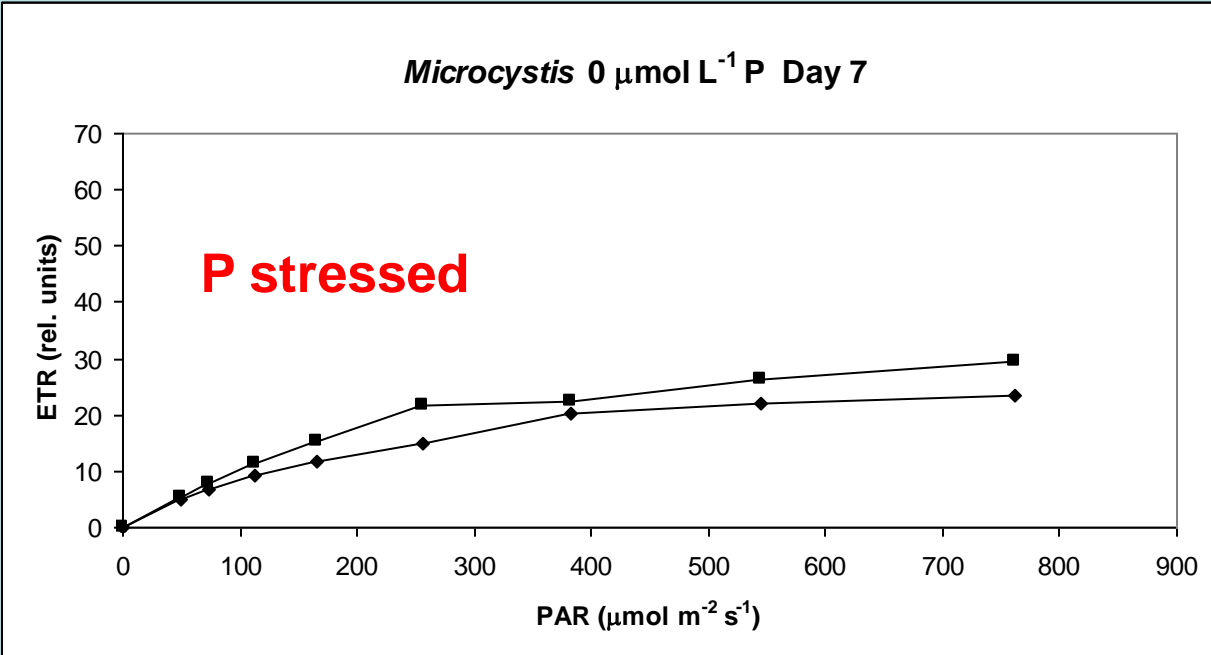
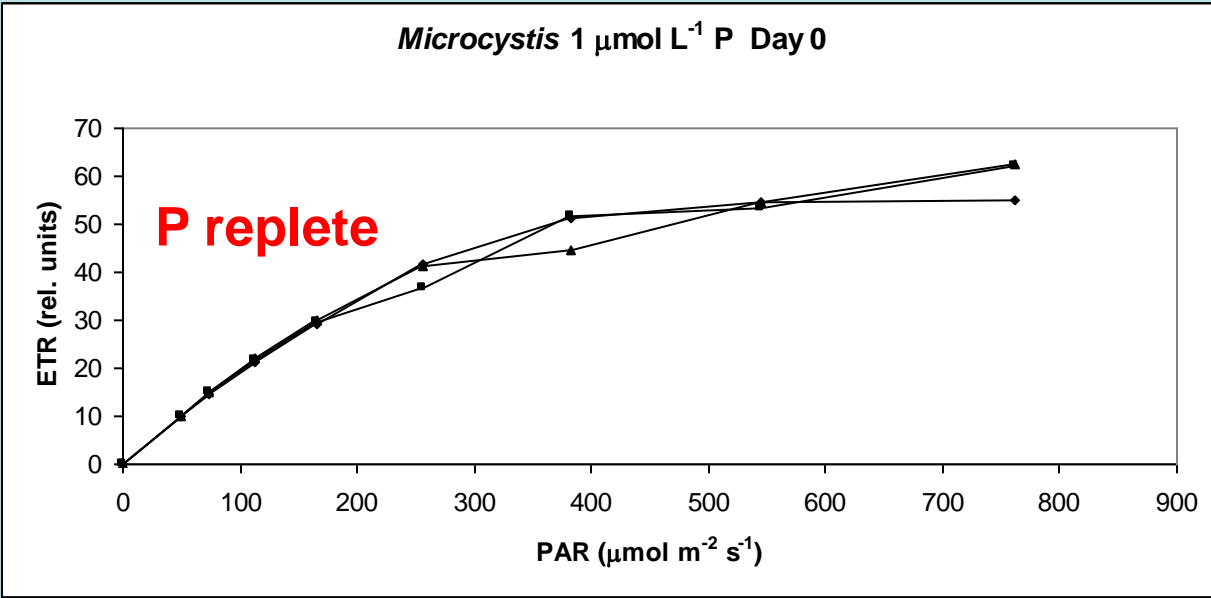
Photosynthesis vs PAR Curve



At high light photosynthesis is saturated (P_m^B)

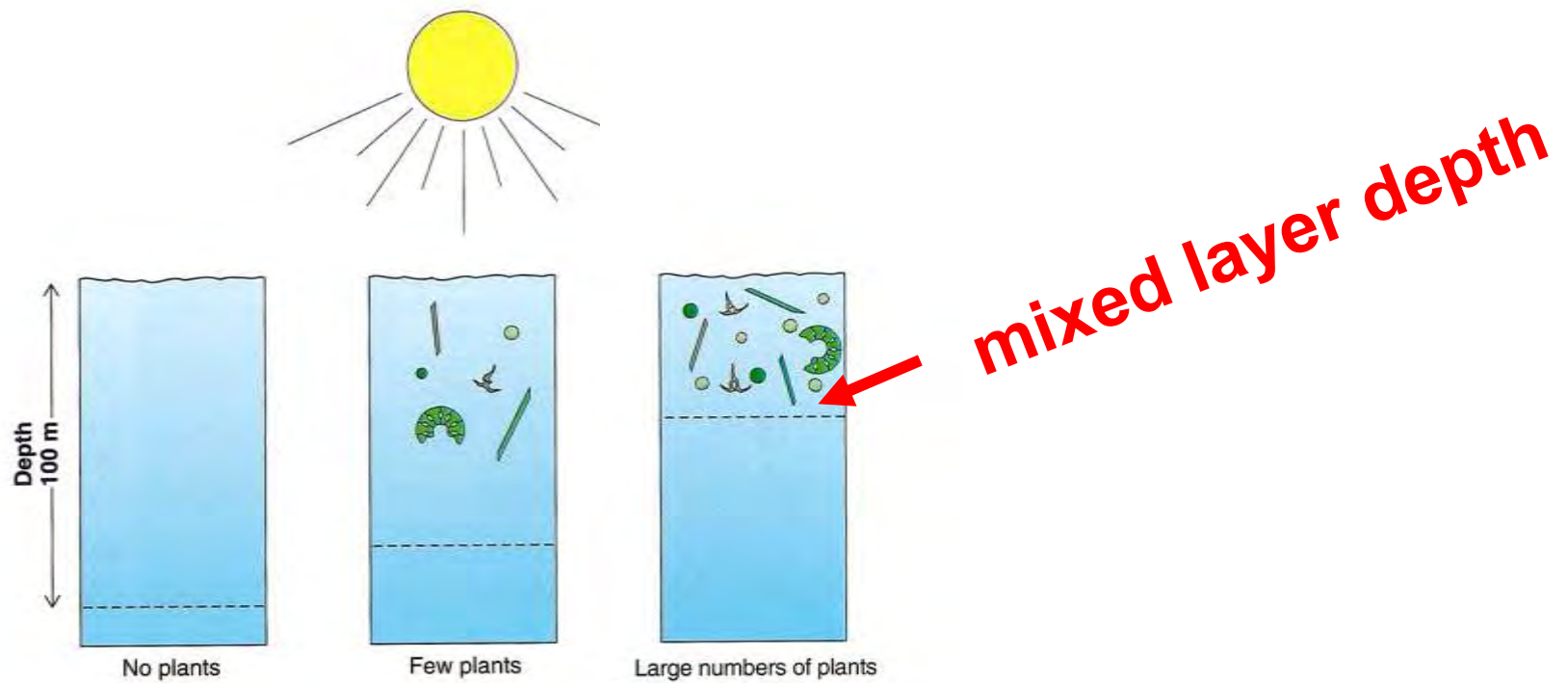
At low light photosynthesis is light limited α^B

How does P stress affect photosynthesis?



**P stress
reduced
(P_m^B) and
(α^B)**

How can temperature affect light for phytoplankton photosynthesis?

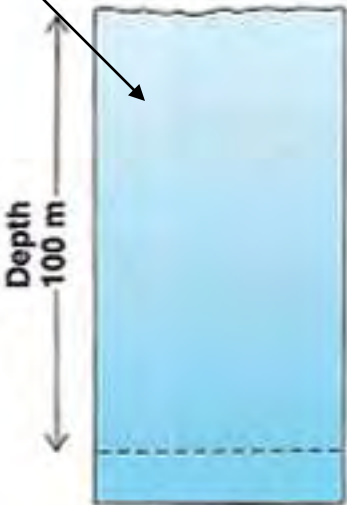


Phytoplankton circulating in a shallow mixed layer receive more light on average than phytoplankton circulating through a deep mixed layer

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



No plants



Few plants

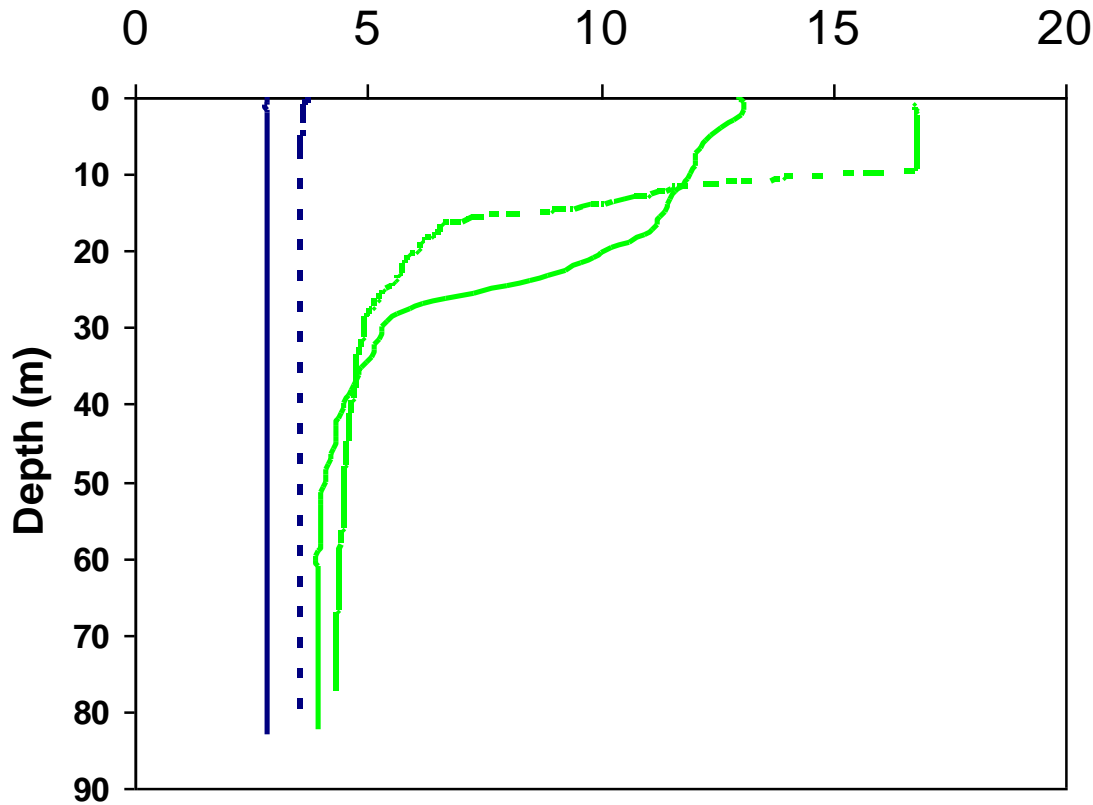


Large numbers of plants

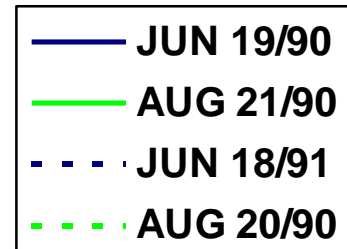
Shallow mixed layer light is high and nutrients are quickly exhausted

Water Temperature

° Celsius

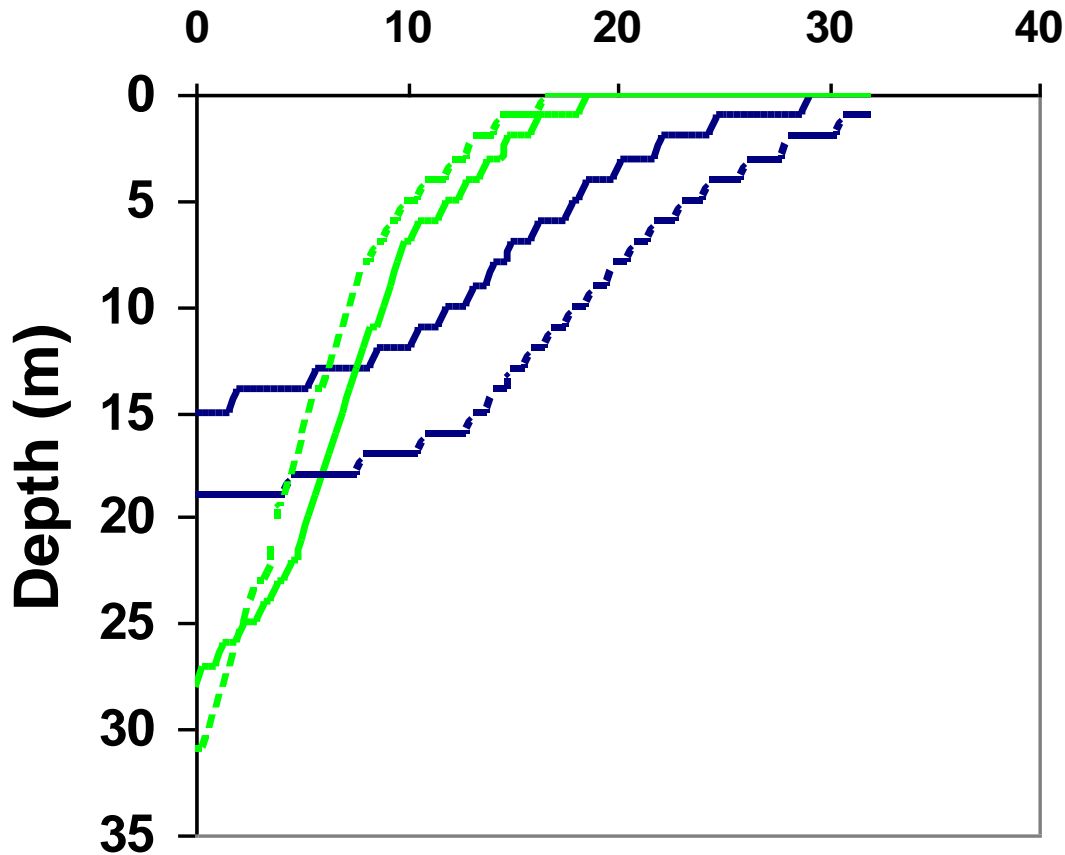


In June 1991 water was 1 °C warmer than June 1990 and over 3 °C warmer in August 1991 and strongly stratified at 10 m

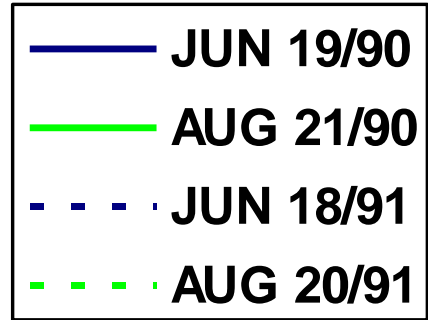


Primary production

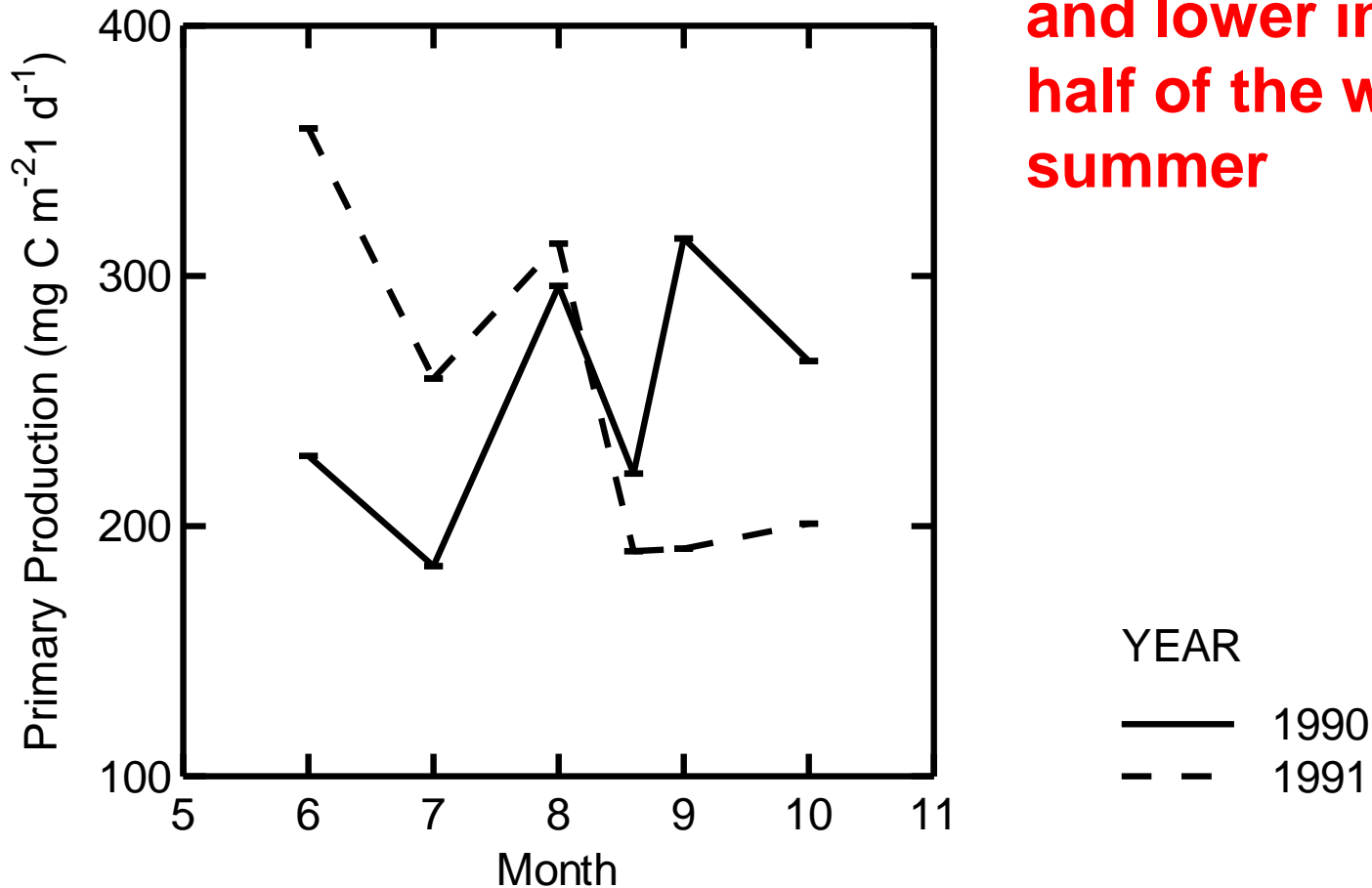
$\text{Mg C m}^{-3} \text{ d}^{-1}$

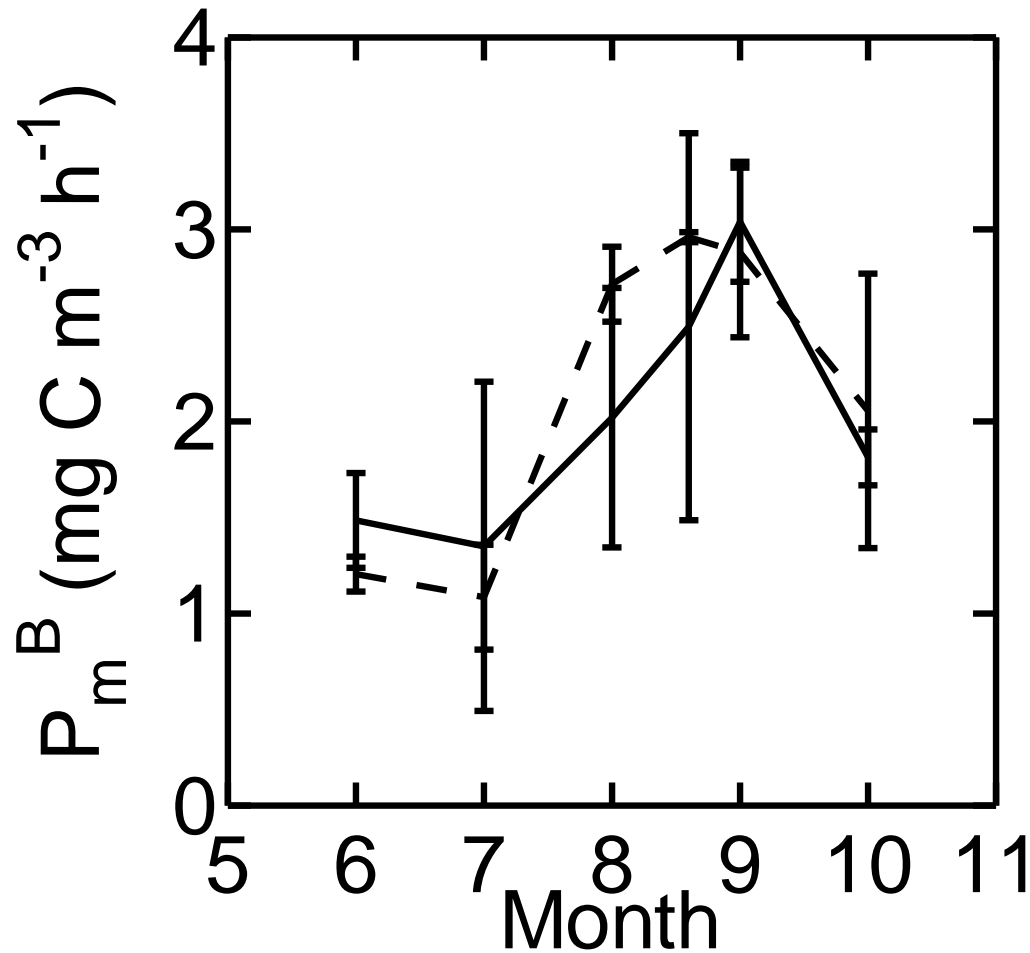


In the warmer year (91) PP was higher in June but actually lower in August



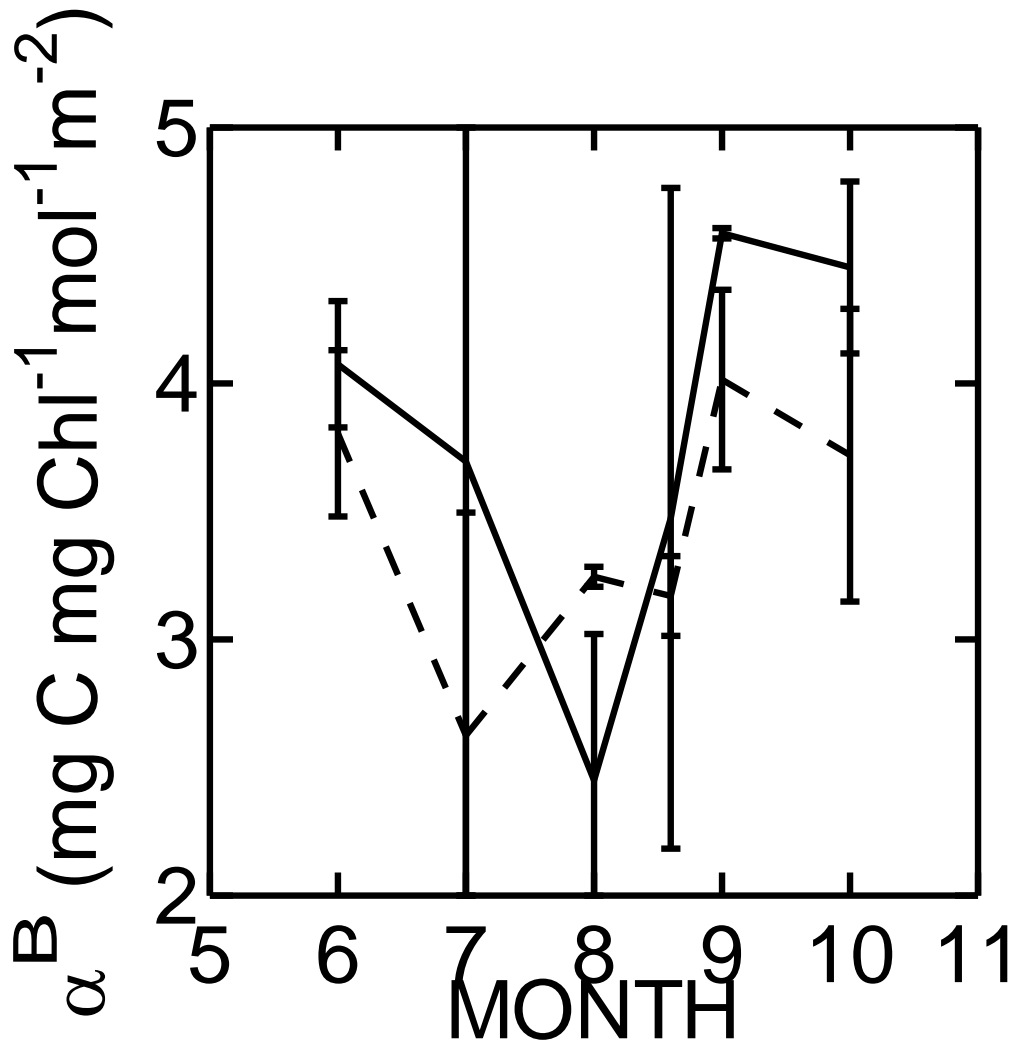
Primary production was higher in the early part of the warm year 1991 and lower in the latter half of the warm summer





P_m^B was slightly higher in 1991

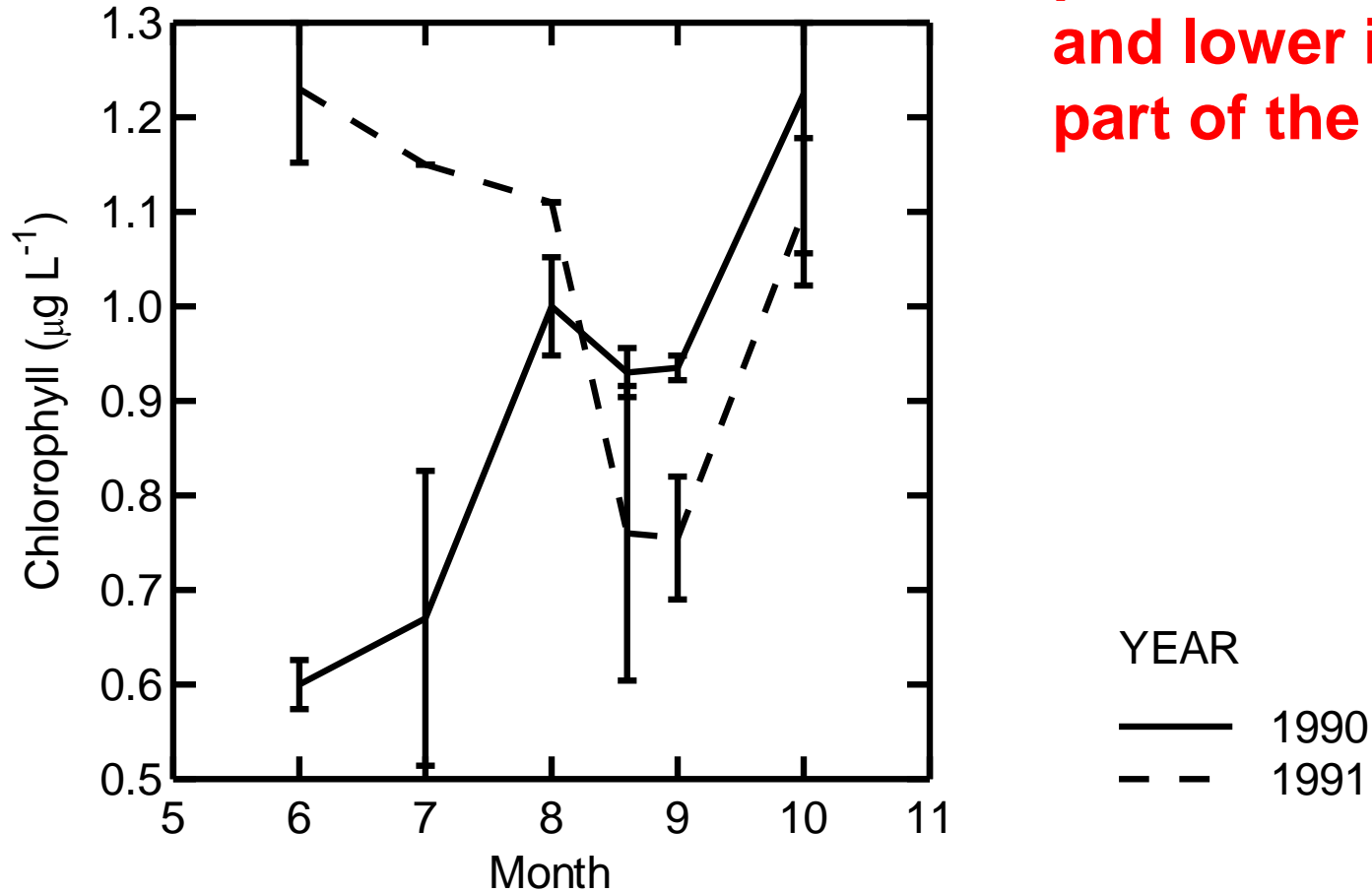
YEAR
— 90
-- 91



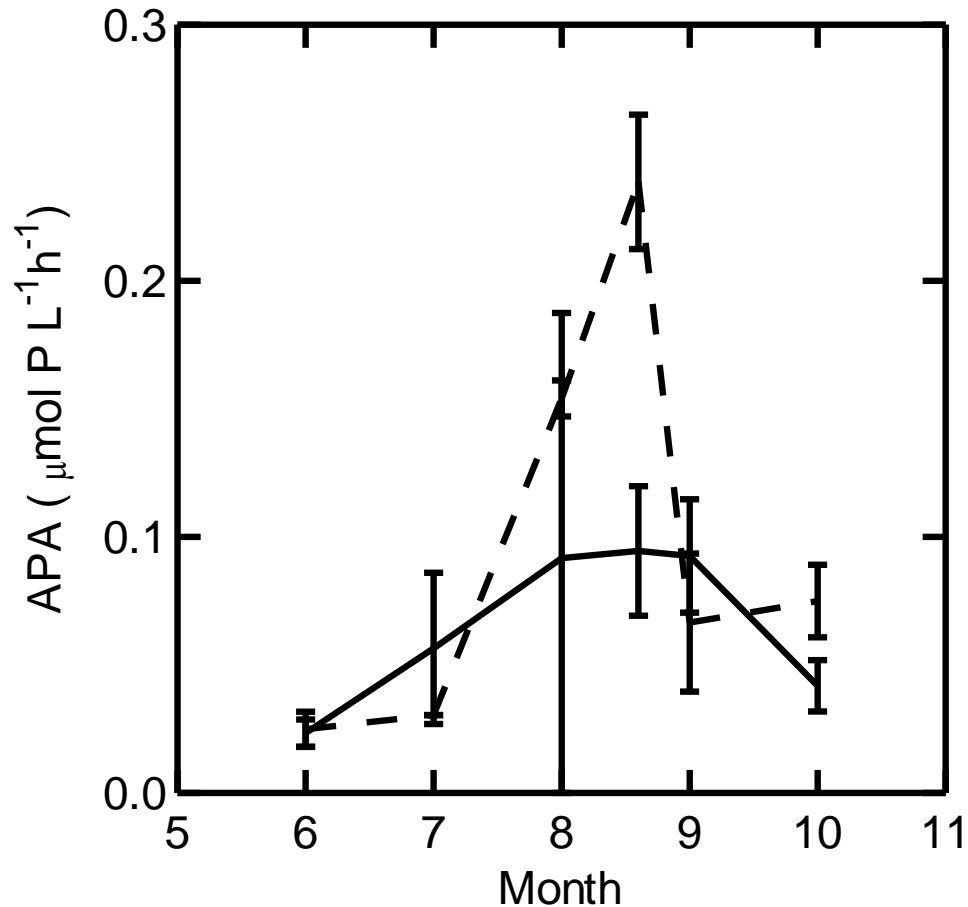
α^B was lower in 1991

YEAR
— 90
-- 91

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



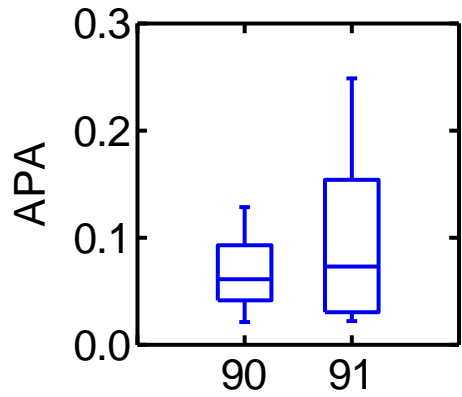
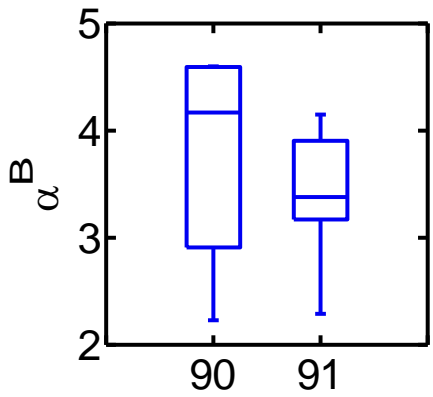
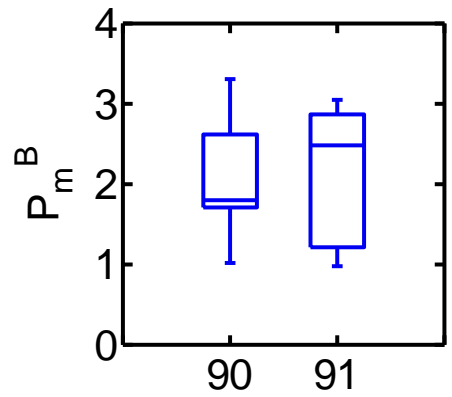
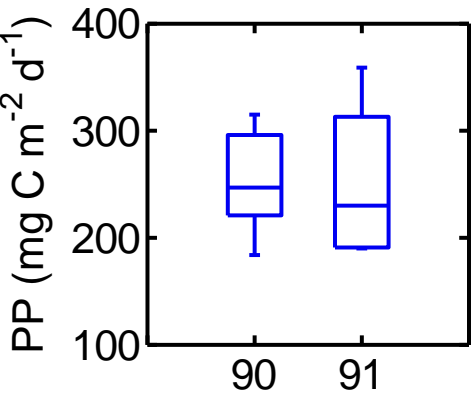
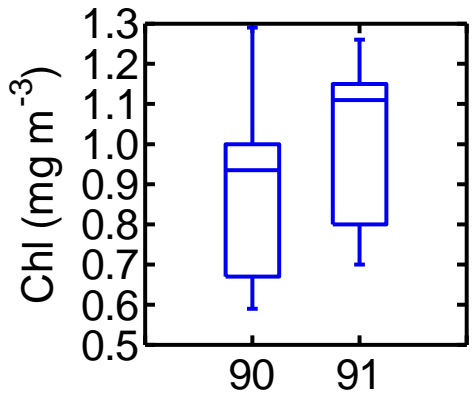
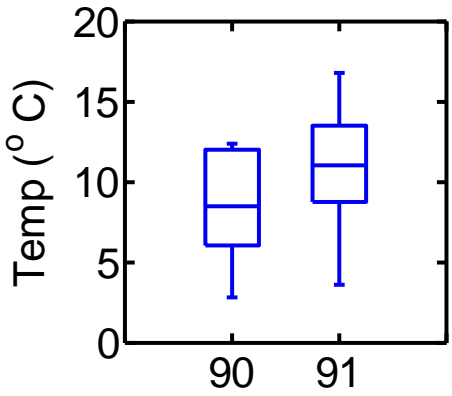
APA (a measure of phosphorus deficiency) was higher in 1991 when the water column was warmer and more strongly stratified



YEAR
— 1990
- - 1991

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

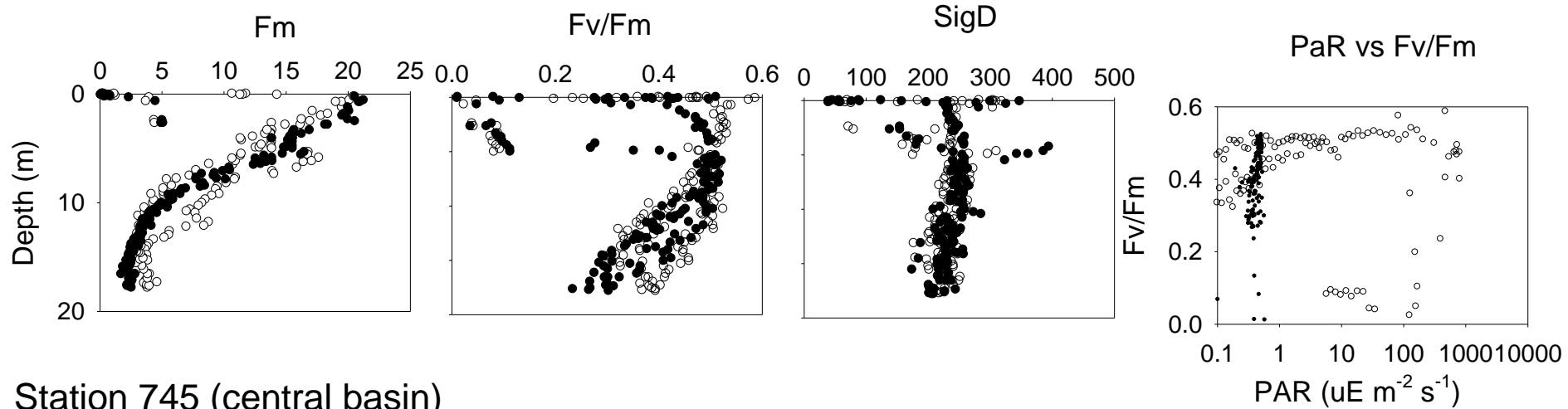
High resolution

Time

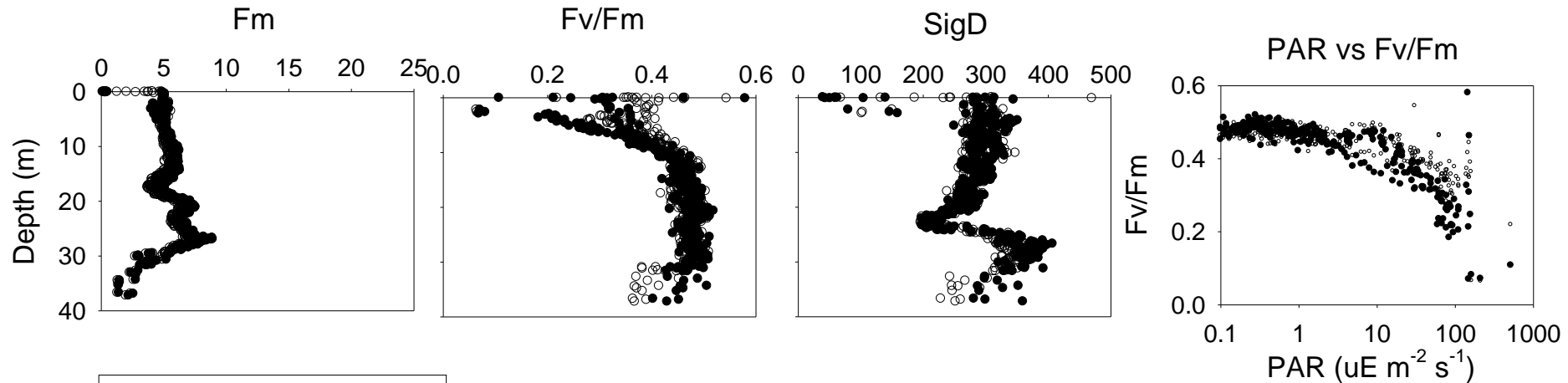
Space

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

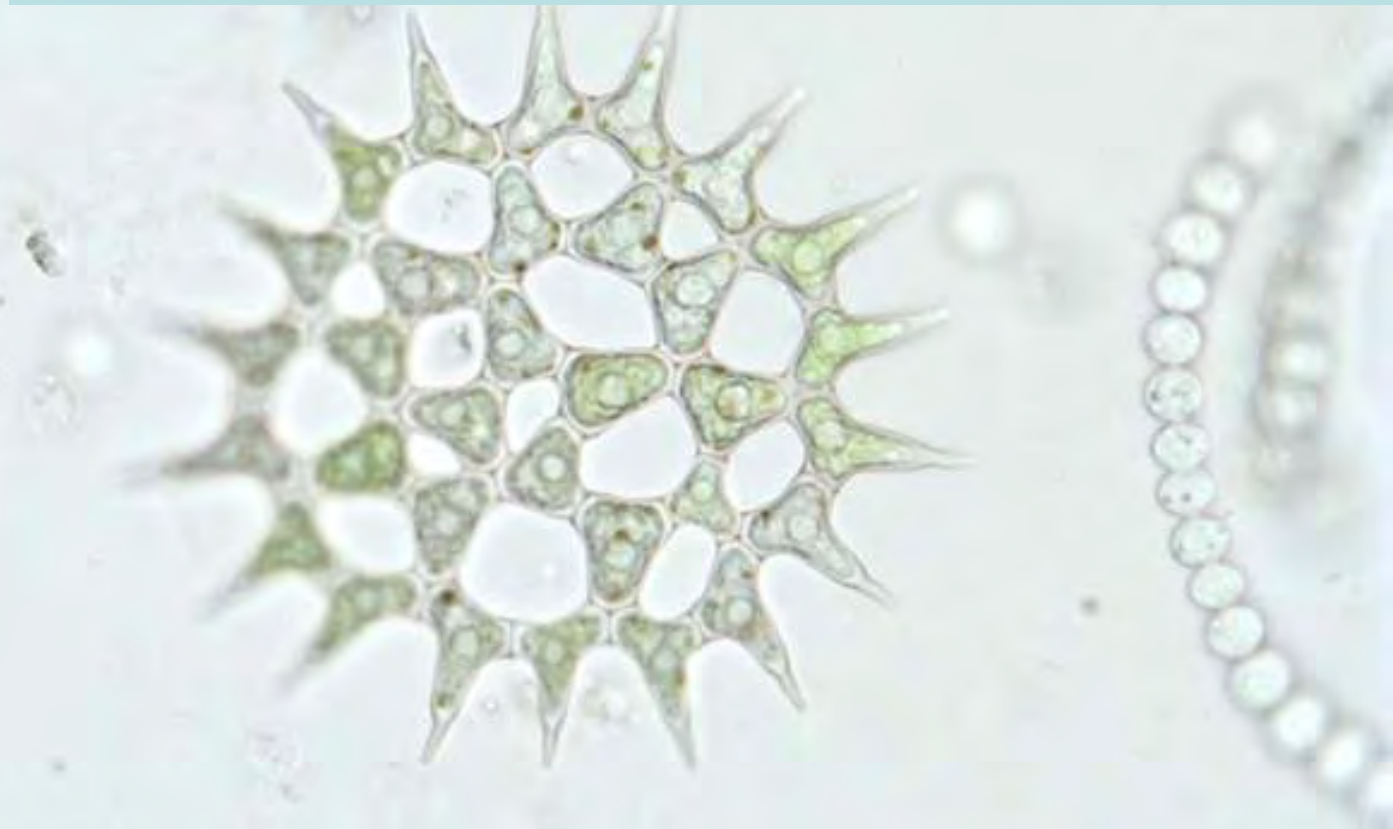
$$P(z) = 1.87 \times 10^{-4} * F_v / F_m(z) * SigD * E_{par}(z) * Chl(z)$$

Global Perspective

Lake Erie 2001-2003

Month	Year	Temp ° 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

increased
water
temperatures,
decreased PP
increased P
stress

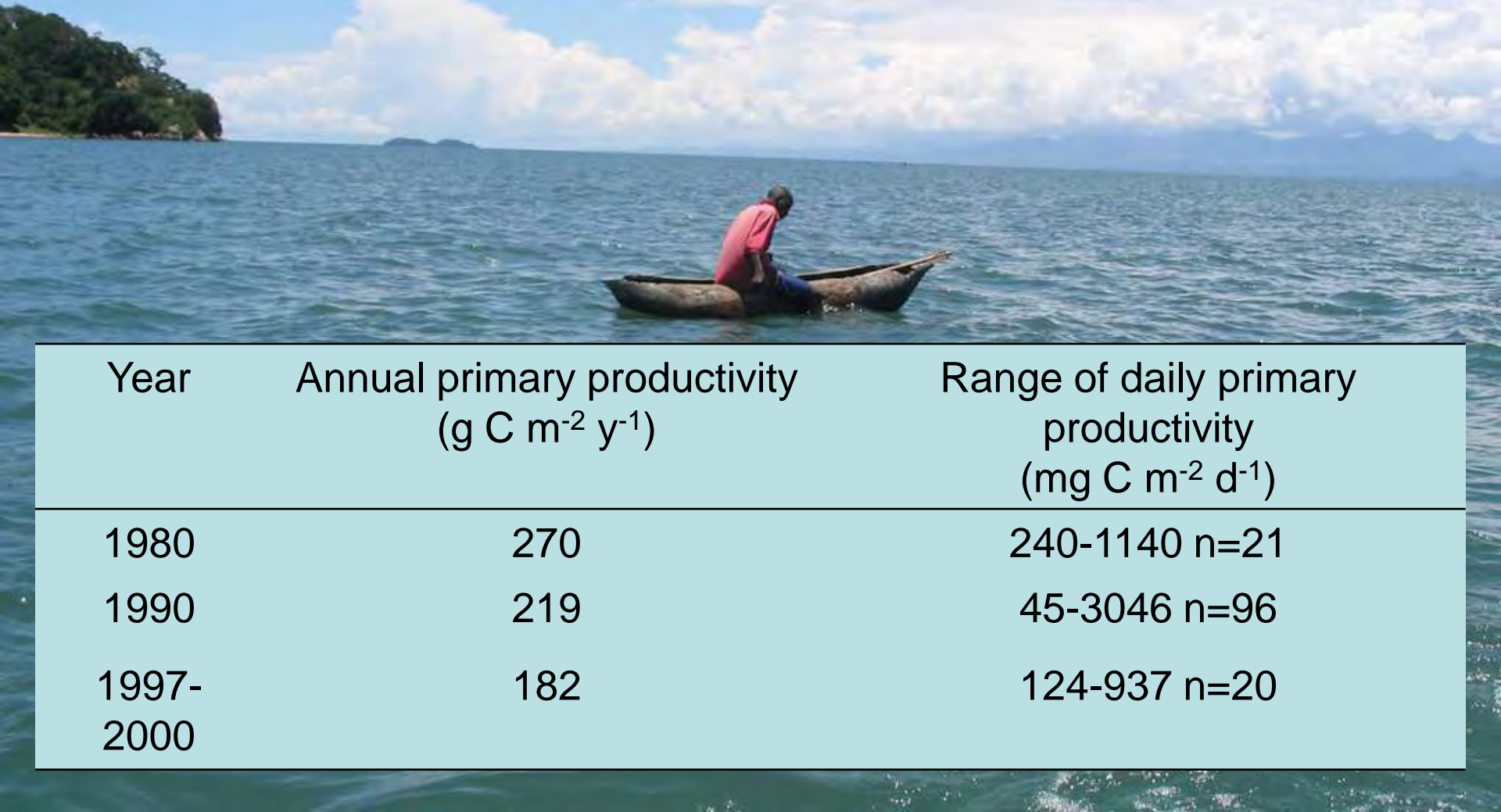


Depew et al 2007, North unpublished data

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

