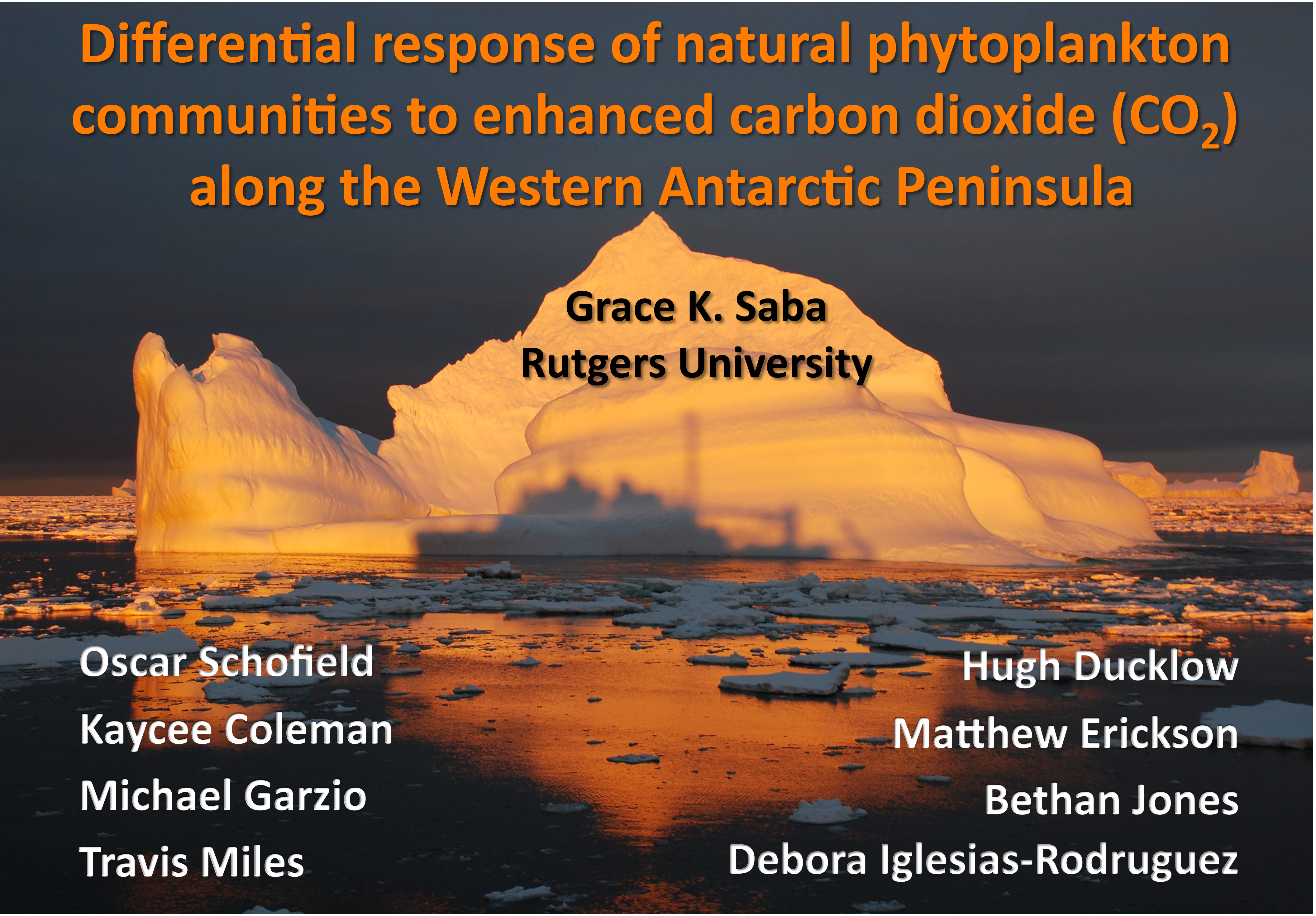


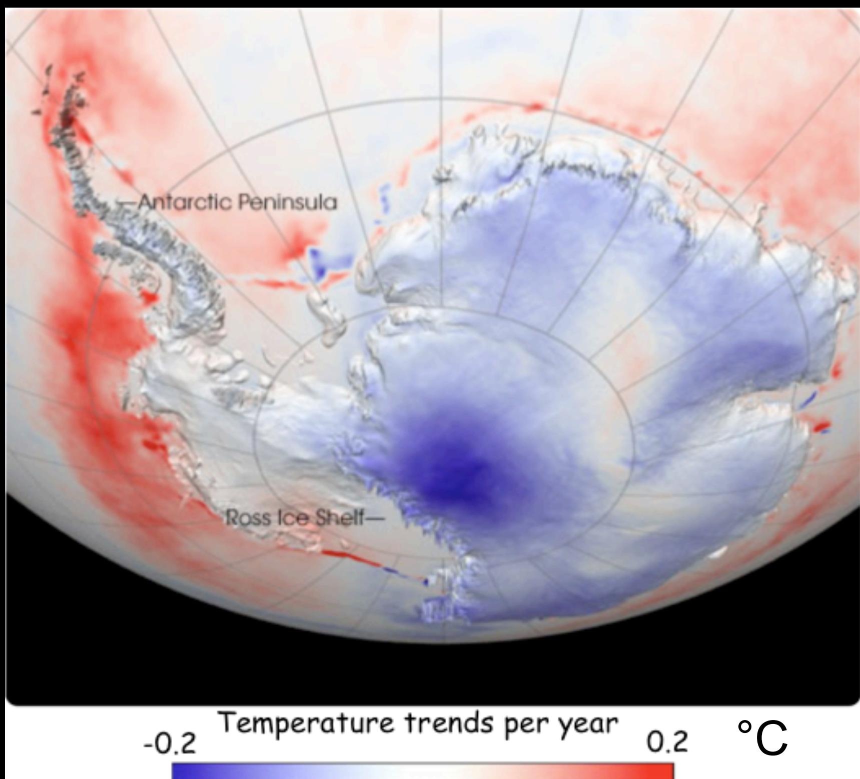
Differential response of natural phytoplankton communities to enhanced carbon dioxide (CO_2) along the Western Antarctic Peninsula

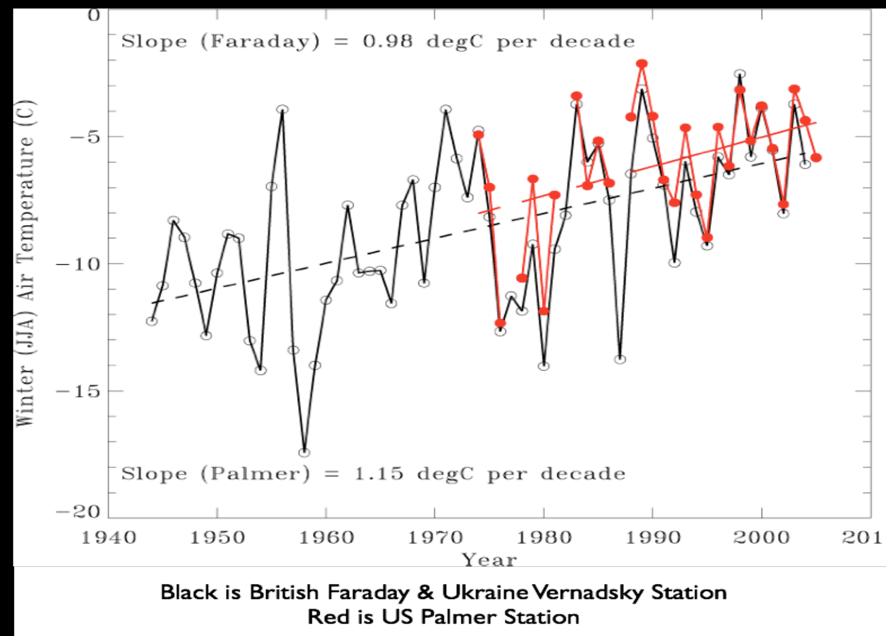
Grace K. Saba
Rutgers University

Oscar Schofield
Kaycee Coleman
Michael Garzio
Travis Miles

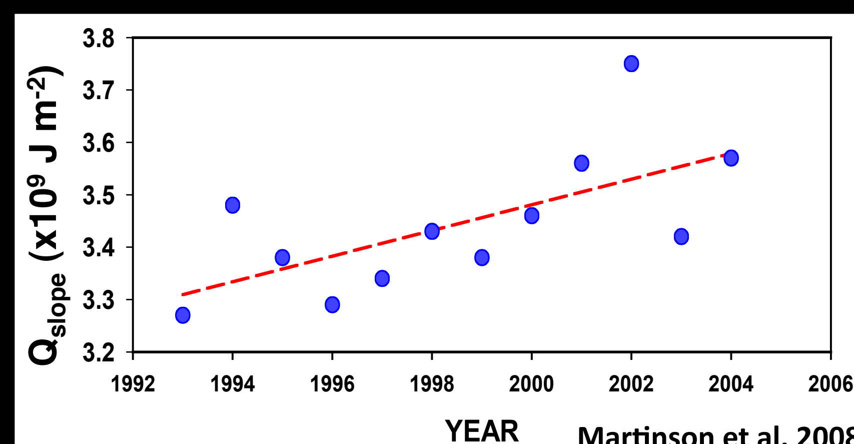
Hugh Ducklow
Matthew Erickson
Bethan Jones
Debora Iglesias-Rodruguez

Using the WAP as zone to study how rapid climate change can alter food webs



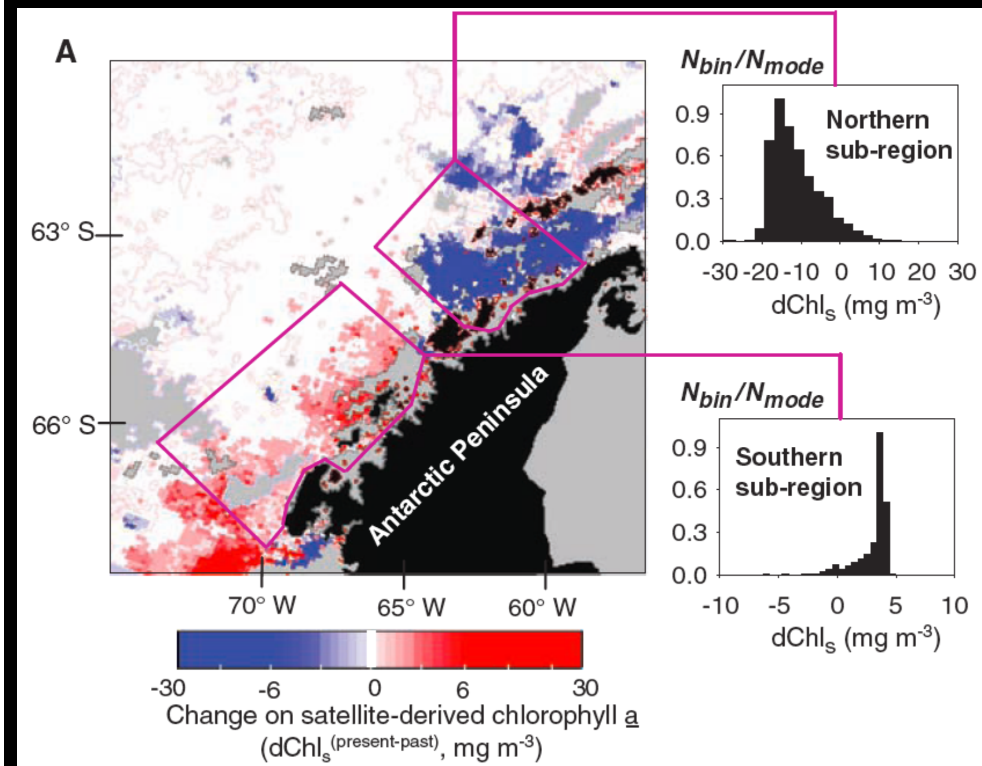


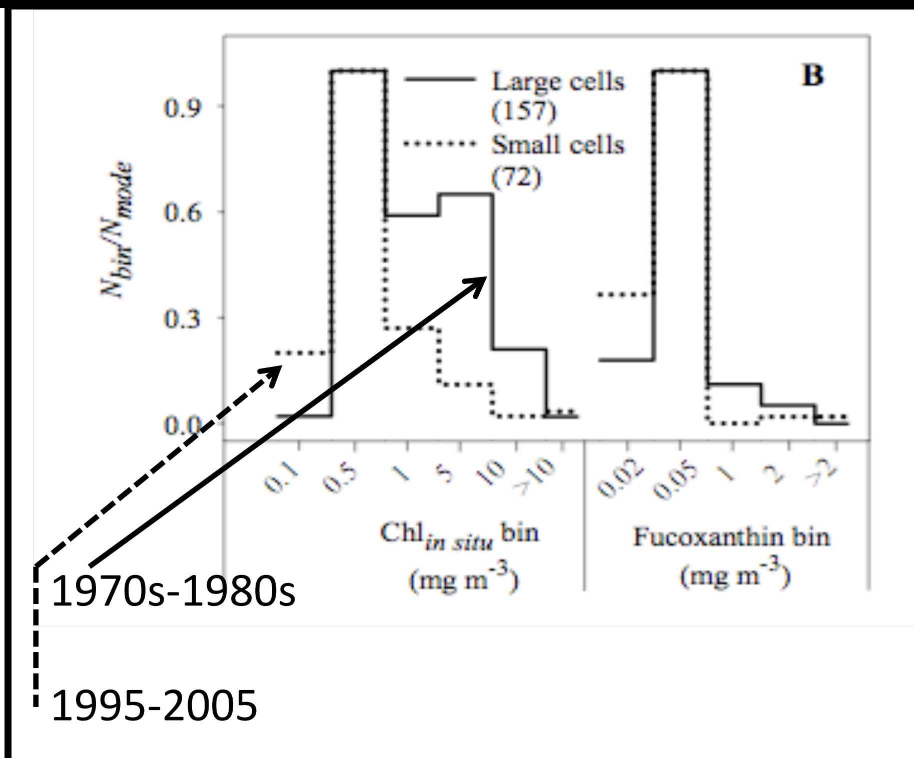
- Fastest winter warming location on Earth
- Increase of 6°C in the past 50 years
- Increase in ocean heat content
- 87% of glaciers in retreat
- Sea ice duration decreased by ~90 days
- Northern WAP perennial ice is gone



Recent changes in WAP phytoplankton

- 12% decrease in chl a over past 30 years, particularly northern WAP
- Shift from large to small phytoplankton

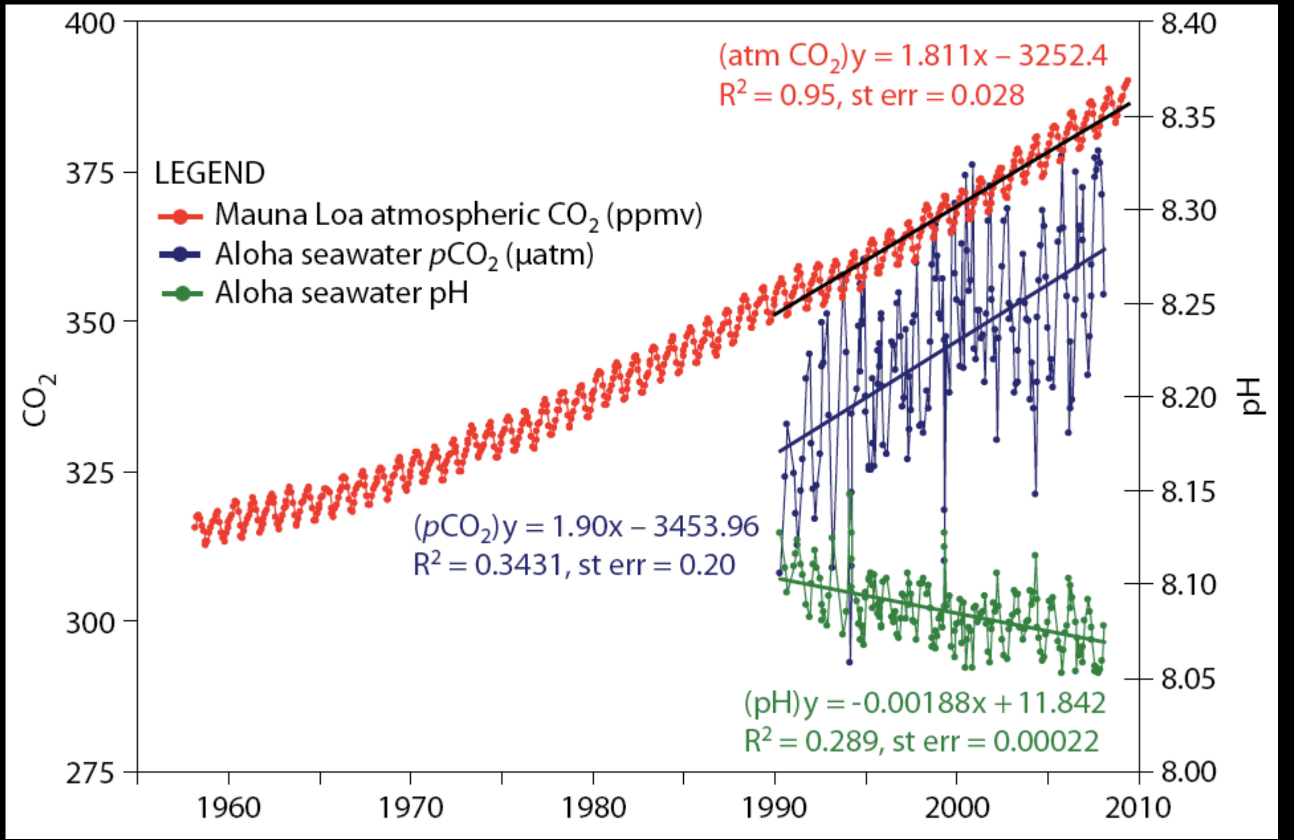




Montes-Hugo et al. 2009

The CO_2 Problem

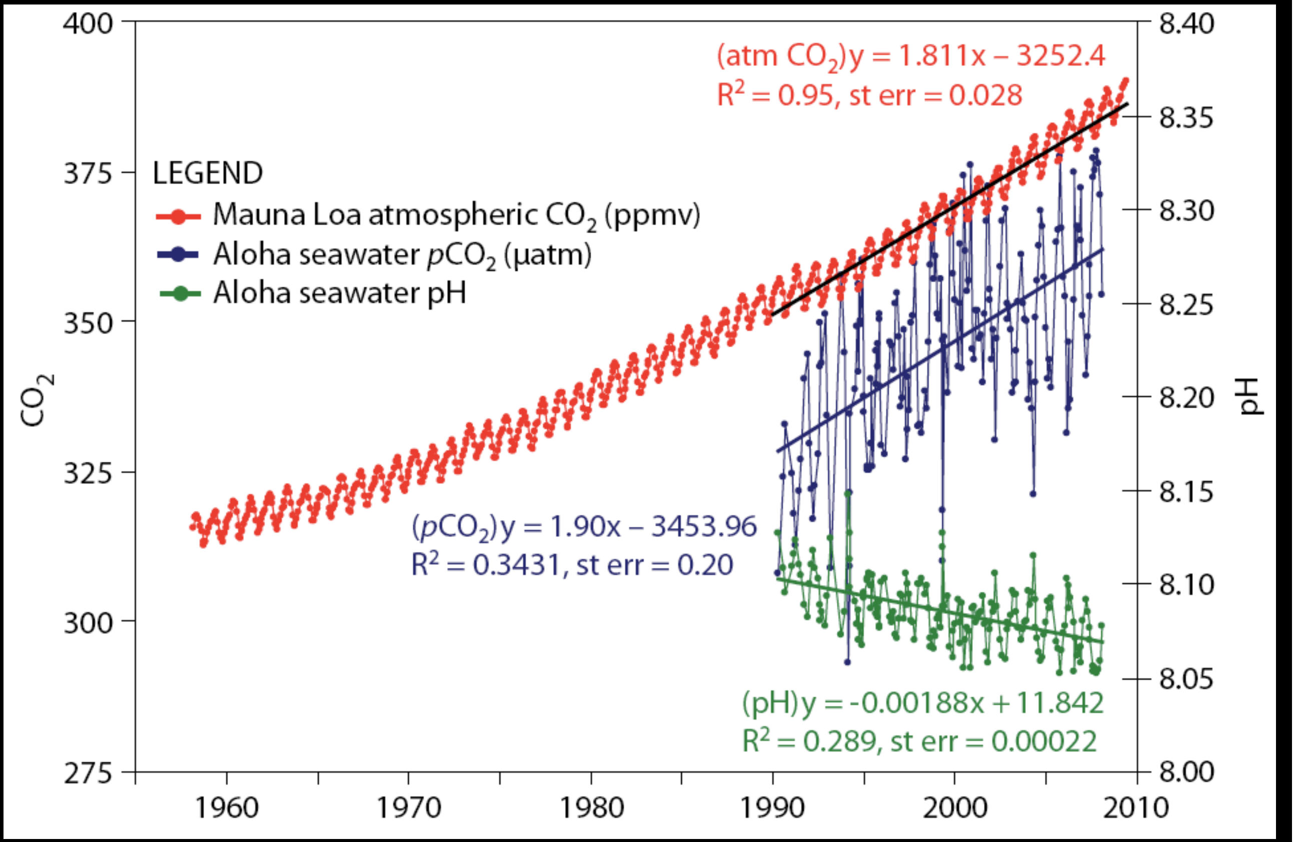
- Atmospheric CO_2 has increased 40% since the 1800s
  - Drop of 0.1 pH unit
  - 28% increase in ocean acidity



The CO_2 Problem

- Atmospheric CO_2 has increased 40% since the 1800s
  - Drop of 0.1 pH unit
  - 28% increase in ocean acidity

- CO_2 is projected to double by 2100 (IPCC)
  - Additional drop of 0.2-0.3 pH units
  - Equivalent to 100-150% increase in ocean acidity

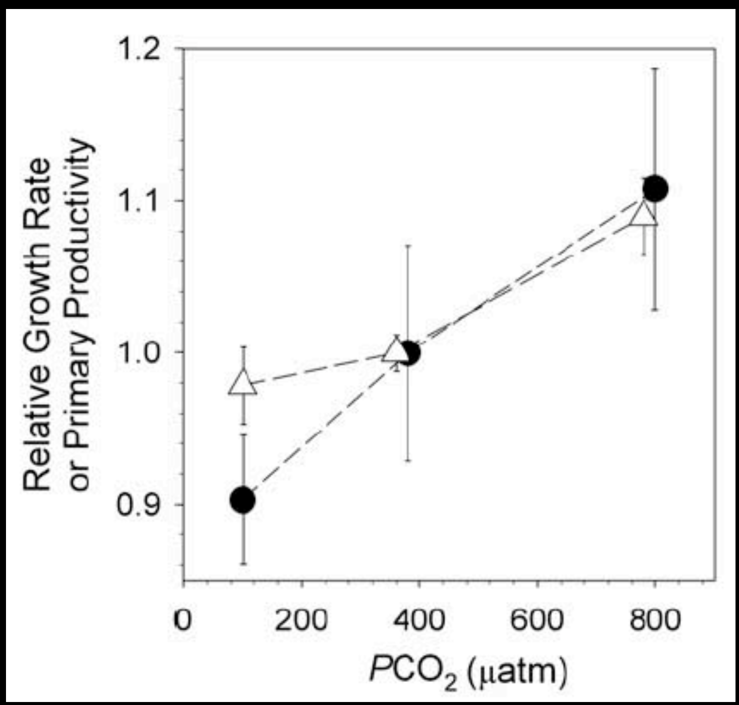


Most ocean acidification studies to date have focused on biocalcification rates in corals, shellfish, and planktonic organisms.

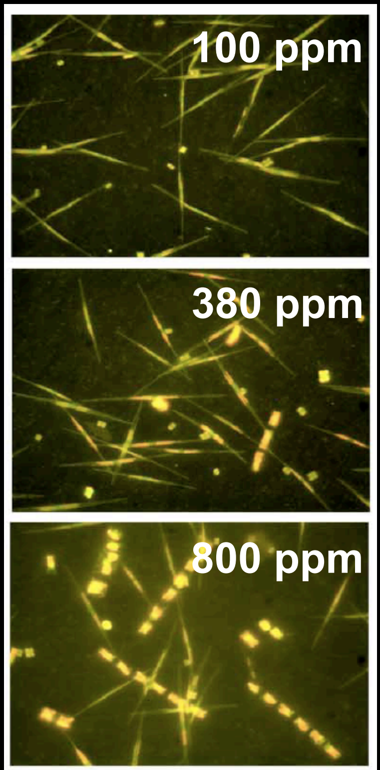
⇒ Effects of enhanced CO_2 on plankton community composition, food web dynamics, and biogeochemistry remain largely unanswered.

Effects of enhanced CO_2 on Ross Sea phytoplankton and nutrient utilization

- Increased primary productivity



- Change in community structure



Tortell et al. 2008

CO_2 Scenarios: Effects on phytoplankton community

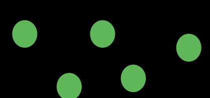
Low CO_2

↓

- Cellular C transport, fixation capacity
- Active CCM
- CCM efficiency
- Efficiency of DIC utilization
- Internal DIC storage

↓

Small cells



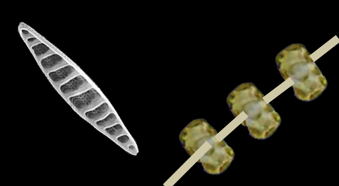
High CO_2

↓

★ CCM requirements still present, but relaxed, giving fast-growing species a competitive advantage over slower growing cells

↓

Large cells



Objectives and Hypotheses

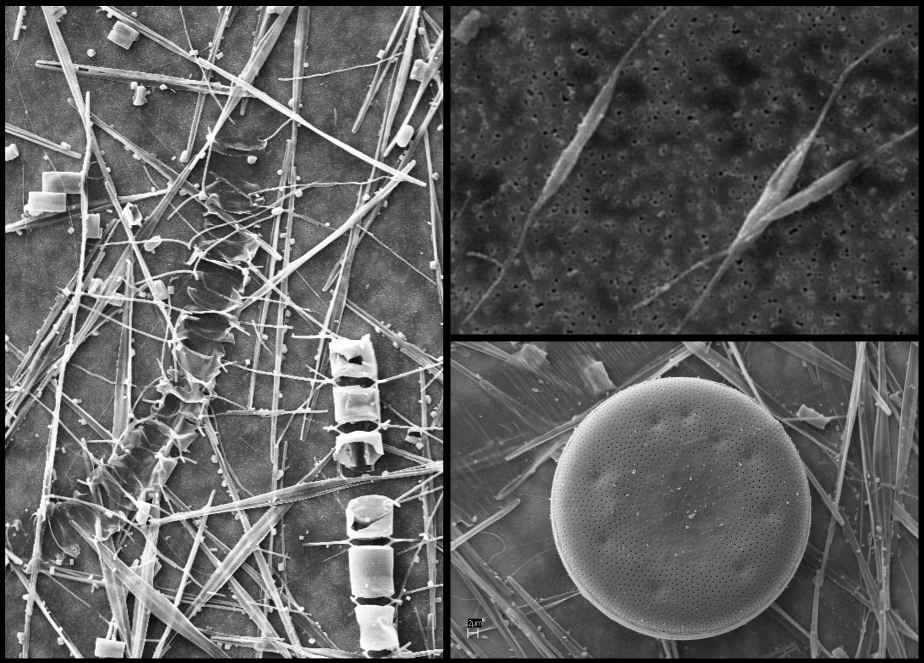
- Effects of enhanced CO_2 on different Antarctic plankton communities:

1. Large diatom – dominated system (Marguerite Bay, Southern WAP)
    - *Hypothesis: A large diatom-dominated community will respond positively to enhanced CO_2*

2. Small diatom – dominated system (Palmer Station, Northern WAP)
    - *Hypothesis: Dominance will shift to large diatoms in the high CO_2 treatment while lower CO_2 will favor small cells*

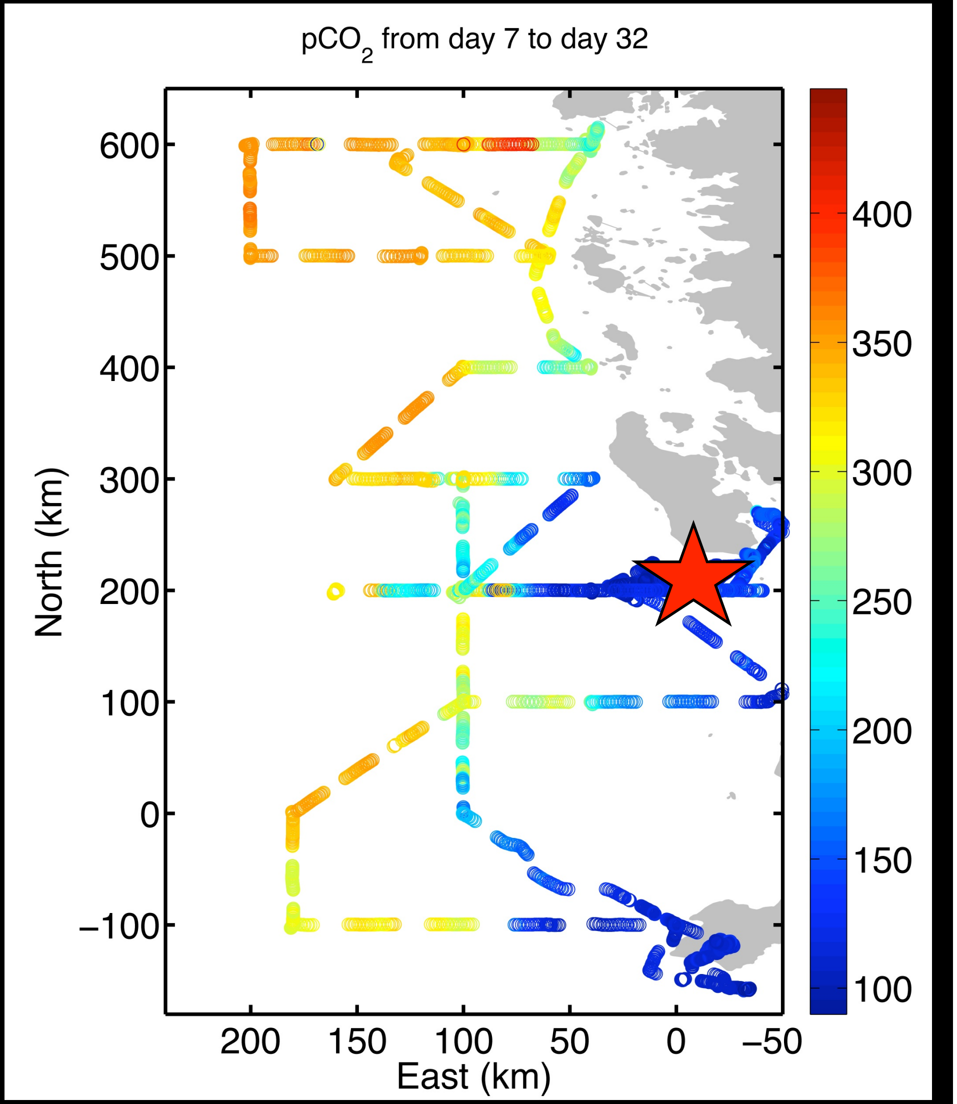
Marguerite Bay: Large diatom-dominated Mesocosm

- High Chl: 12 mg m^{-3}
- High Prod: 230 mg C m^{-3} d^{-1}
- Diatom bloom (mainly pennate):
  - ✓ *Cylindrotheca* sp.
  - ✓ *Pseudo-nitzschia* sp.
  - ✓ *Chaetoceros* sp.
  - ✓ *Thalassiosira* sp.



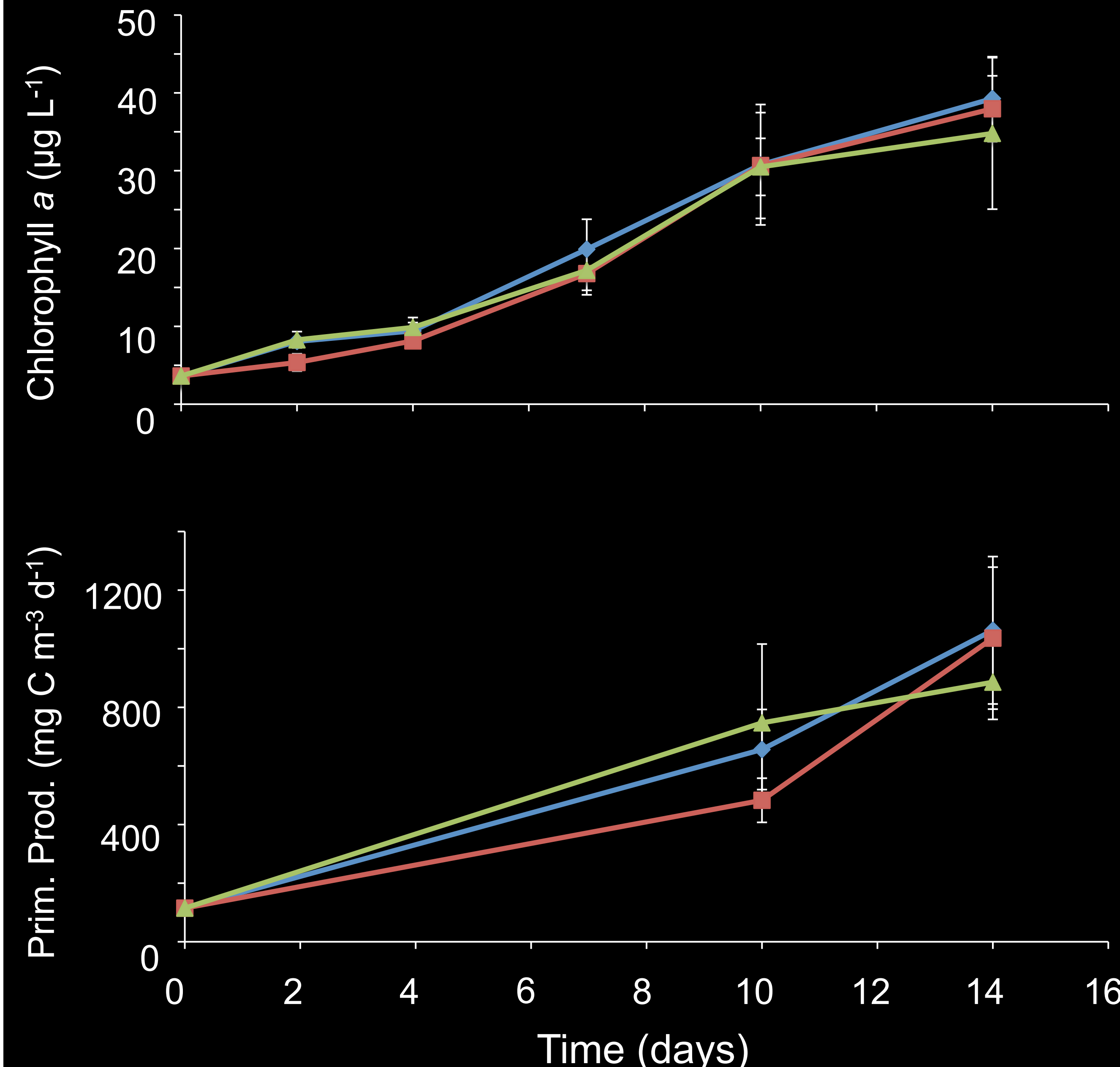
SEM images from B. Jones

- Low surface pCO_2



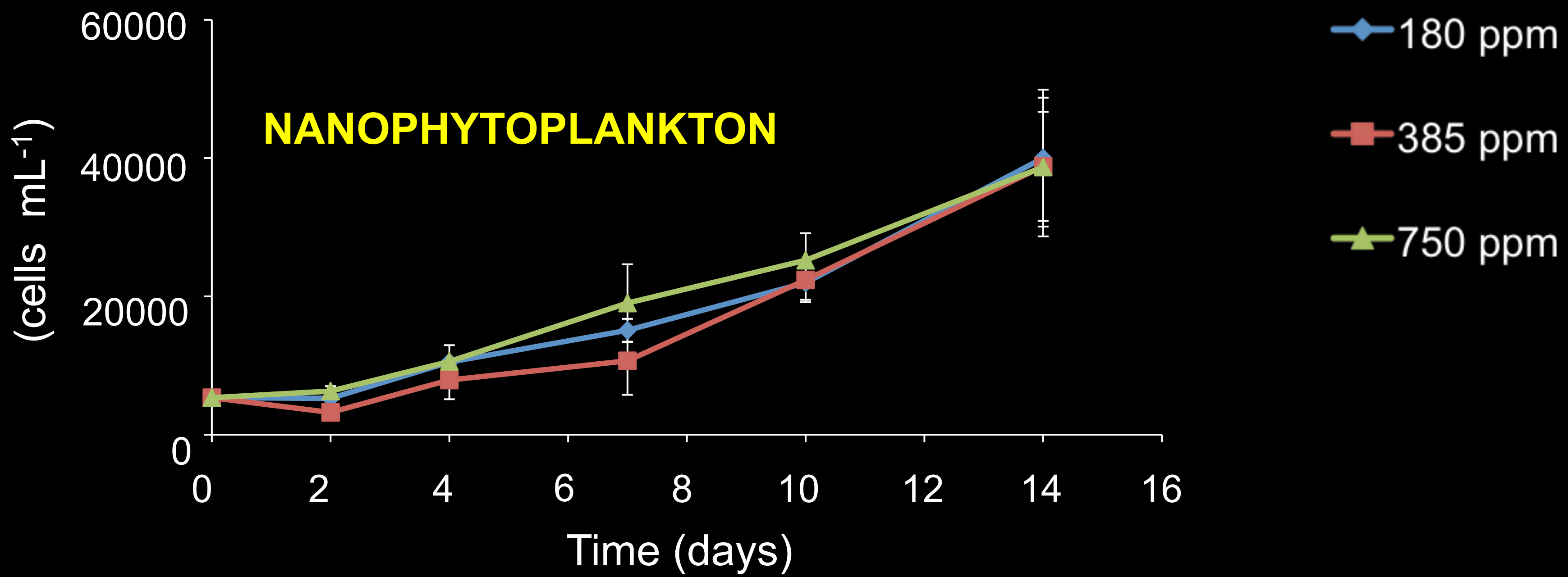
Data from T. Takahashi; Figure from K. Huang

Similar increases in biomass and productivity



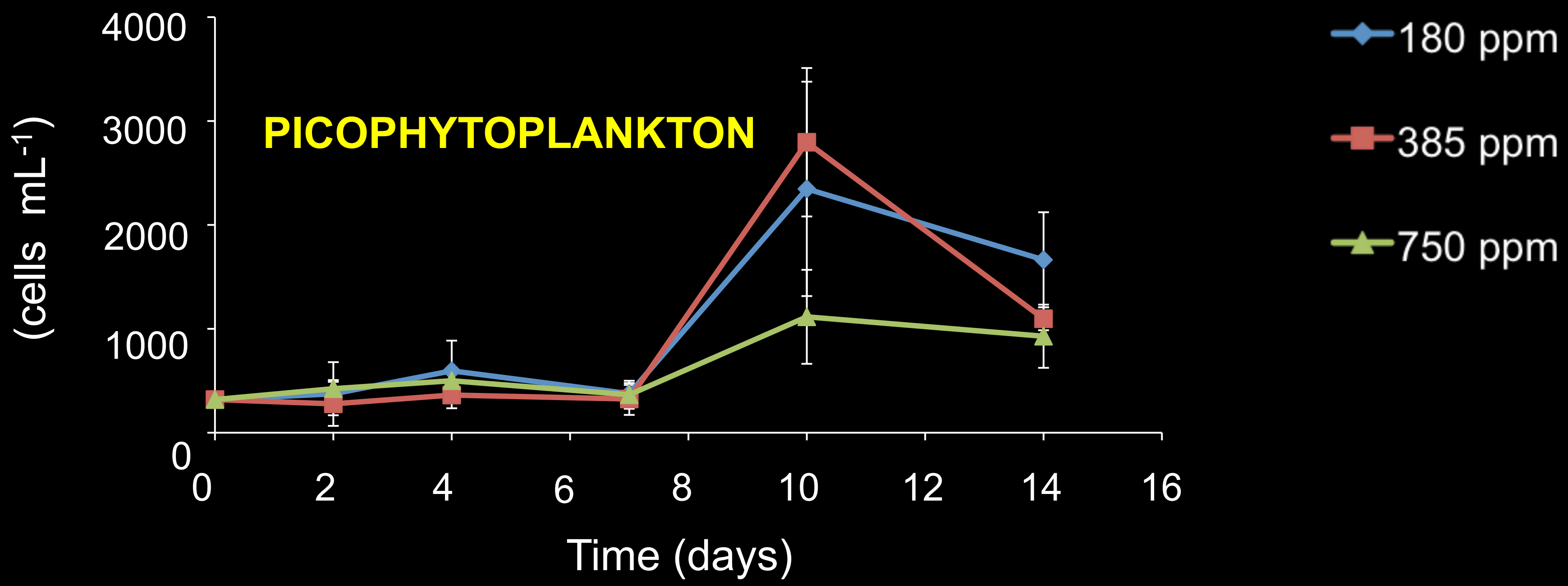
- 10-fold increase in chl *a* & productivity
- No differences between CO_2 treatments

Similar increases in all algal size classes



- Increase in chlorophyll biomass attributed to:
  - Similar increases in nanophytoplankton, picophytoplankton, and diatoms >20 µm

Similar increases in all algal size classes



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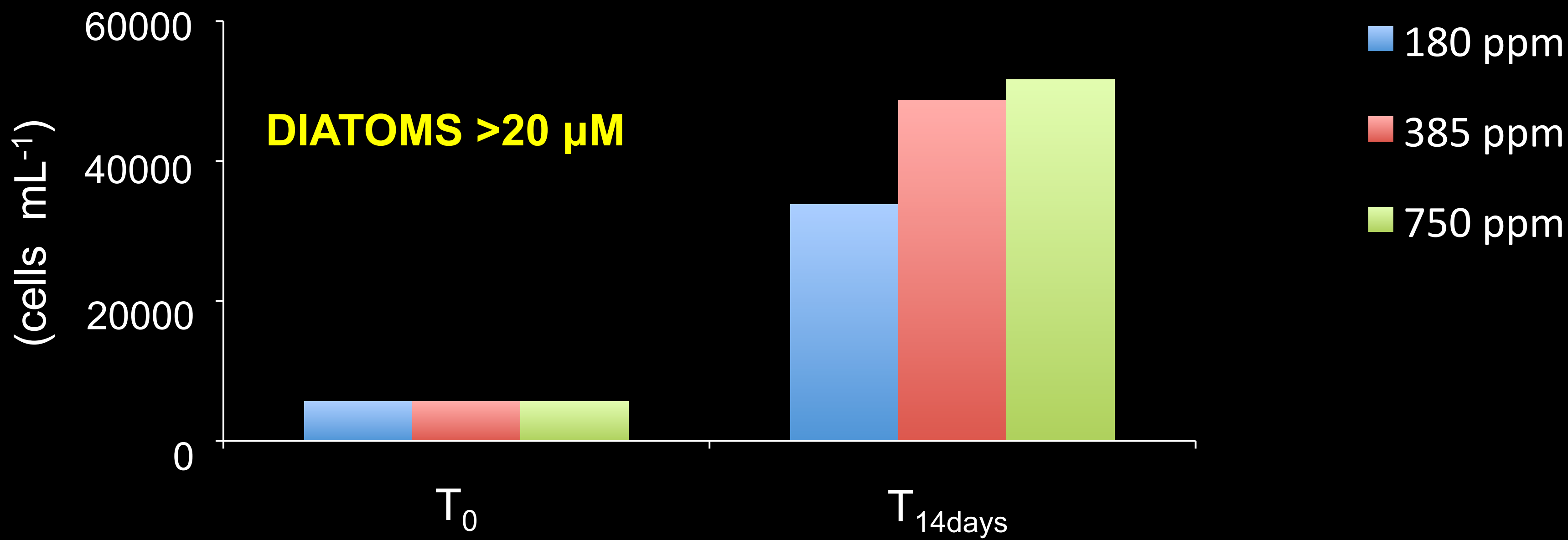

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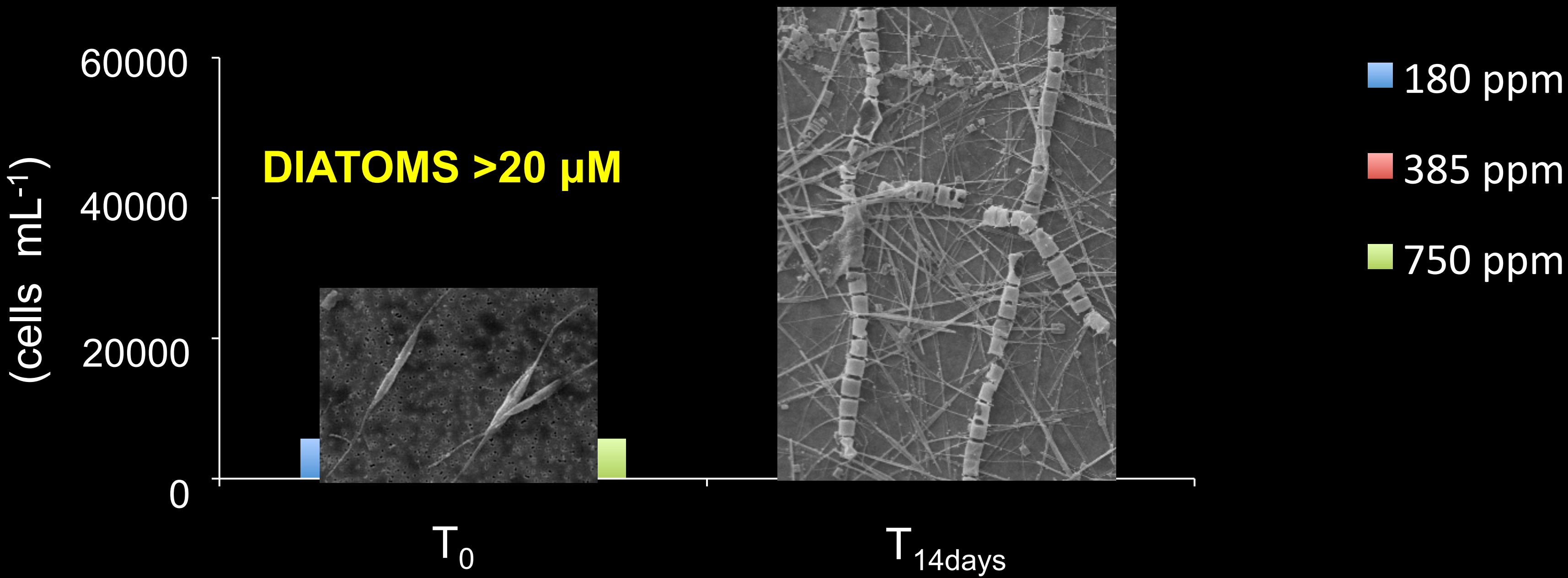
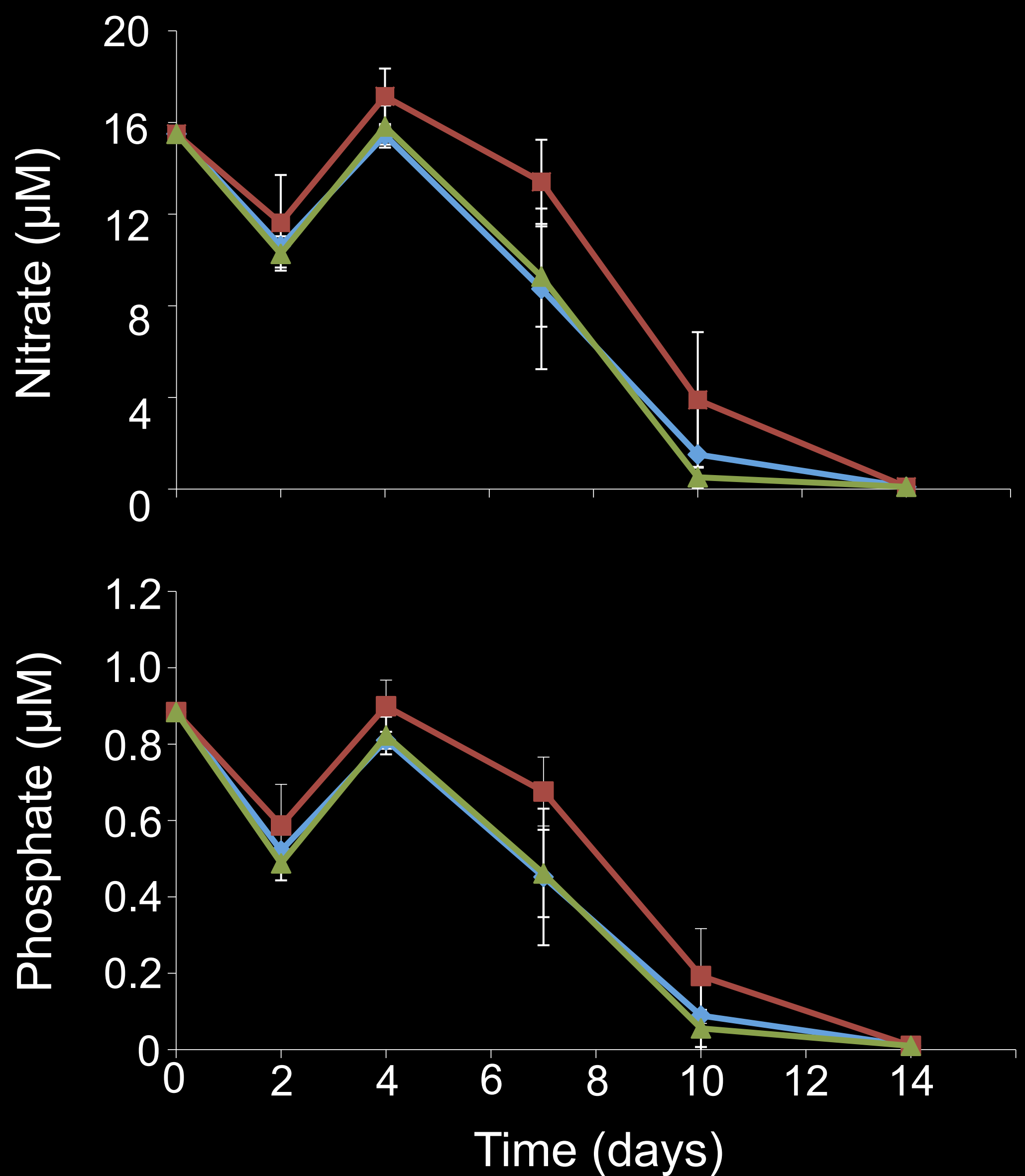
Similar increases in all algal size classes



- Increase in chlorophyll biomass attributed to:
  - Similar increases in nanophytoplankton, picophytoplankton, and diatoms >20 μm
- Chain-forming centric diatom *Chaetoceros* sp. increased by 22-fold, driving a 3-fold increase in the centric:pennate diatom ratio
- No differences between CO_2 treatments

Similar drawdown of nutrients

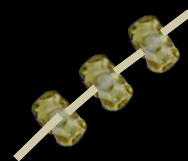


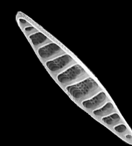
- NO_3 & PO_4 drawdown by day 10 in all mesocosms
- No differences between CO_2 treatments

Significance and Consequences

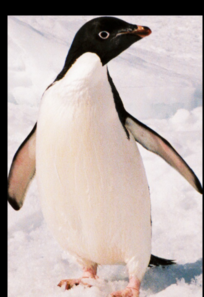
High CO_2

Large cells





Biomass
Productivity

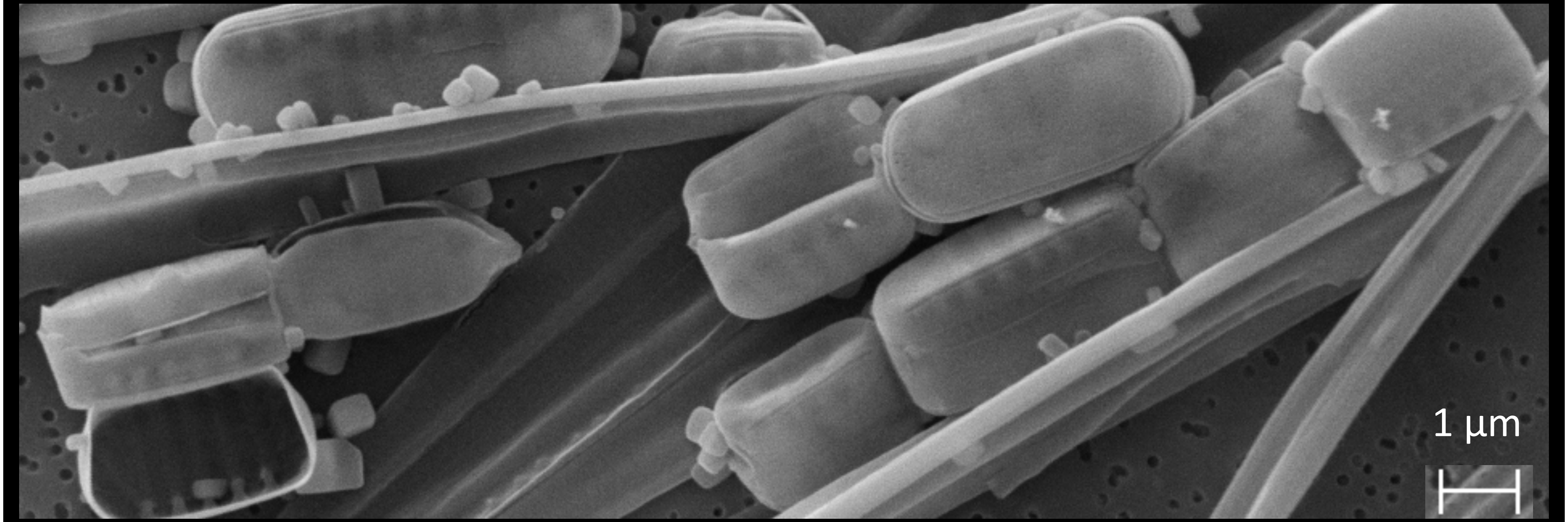


N, P, Si, Fe uptake

Would diatoms ultimately become nutrient limited?

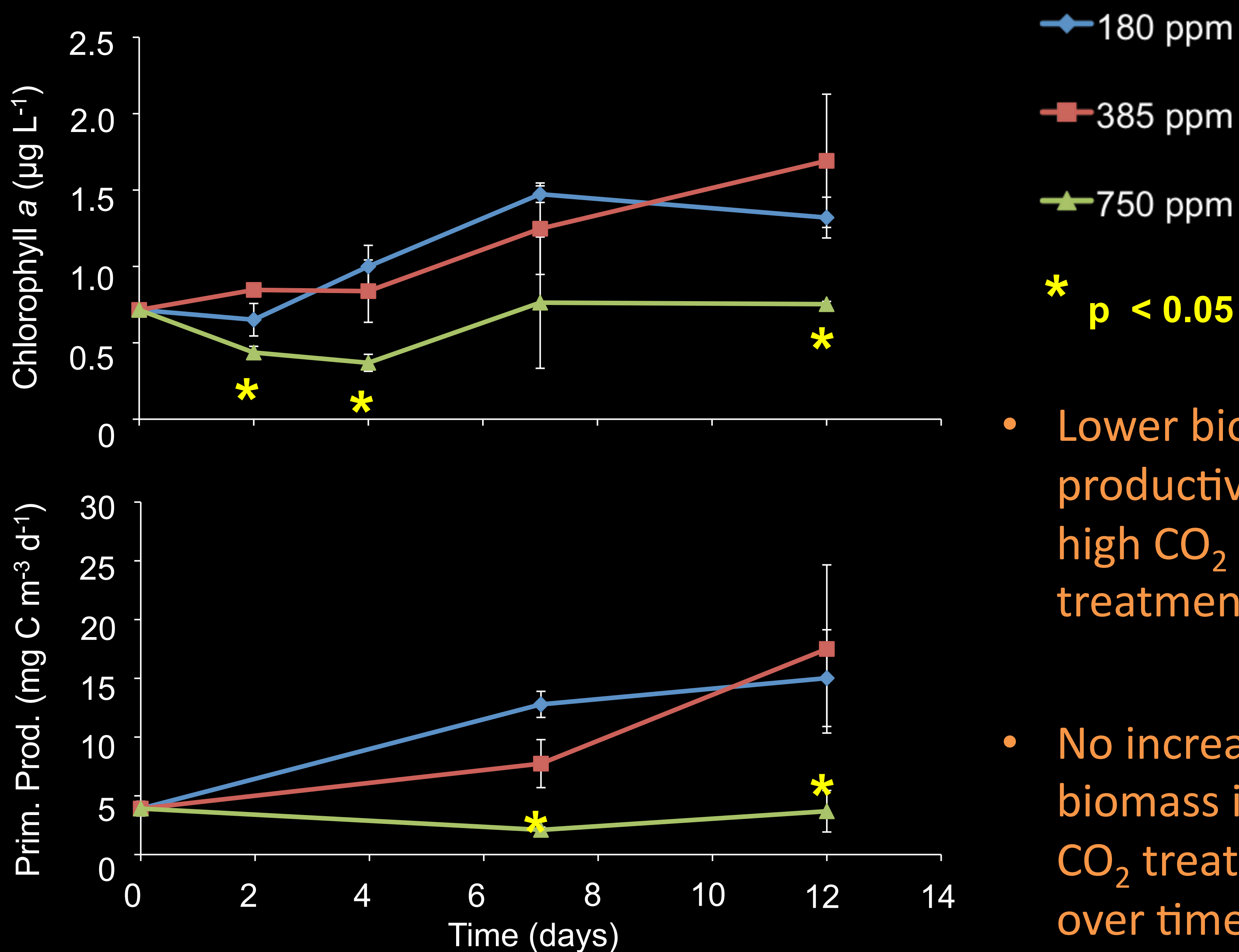
Palmer Station: Small diatom-dominated Mesocosm

- Low Chl: 1.5 mg m^{-3}
- Low Prod: 2.5 mg C m^{-3} d^{-1}
- Dominating diatoms:
  - ✓ *Fragilariopsis* sp. (2 x 4 µm)
  - ✓ *Unidentified small pennate*
  - ✓ *Rhizosolenia sp.*
  - ✓ *Coscinodiscus sp.*



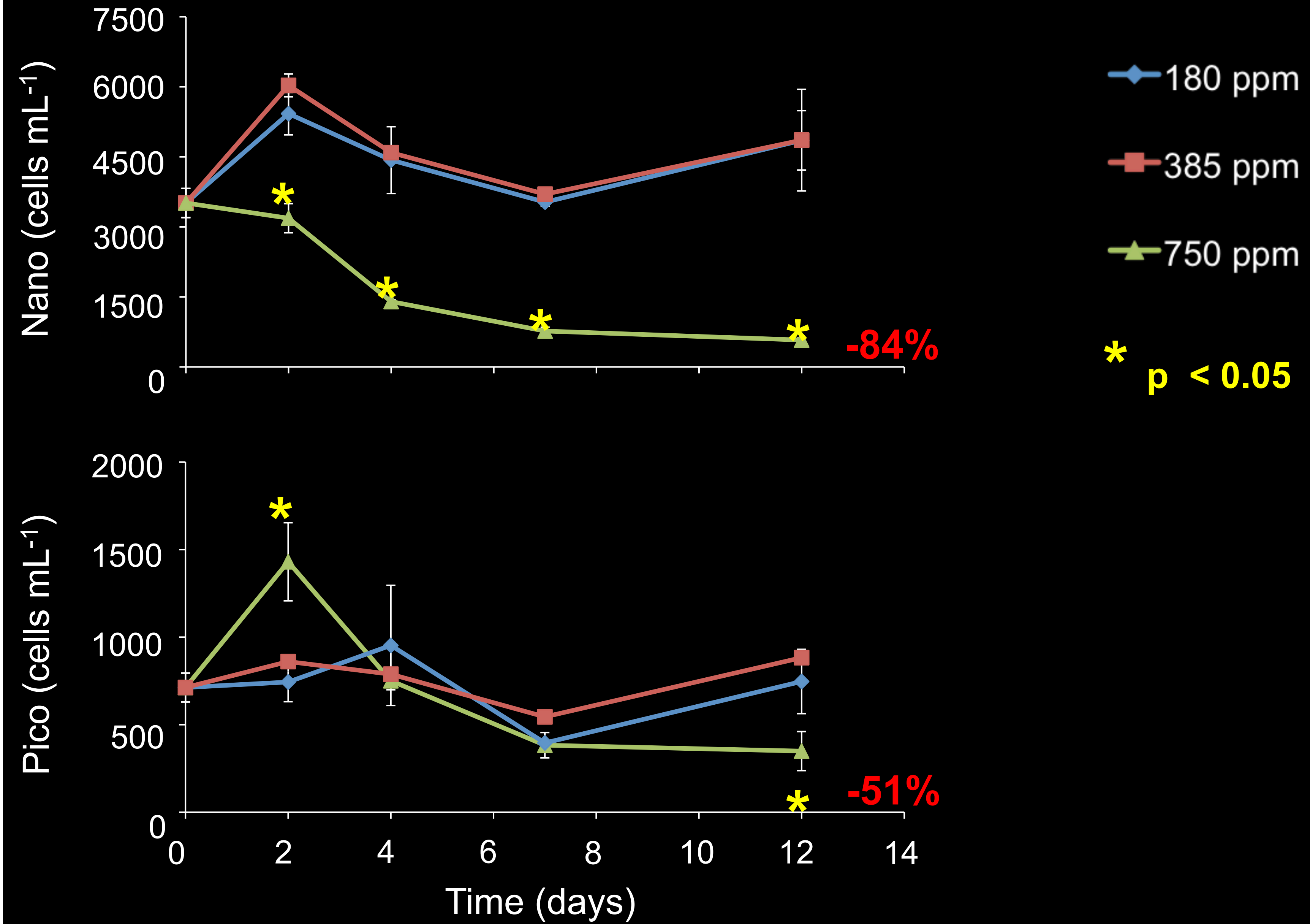
SEM images from B. Jones

High CO_2 effect on biomass and productivity

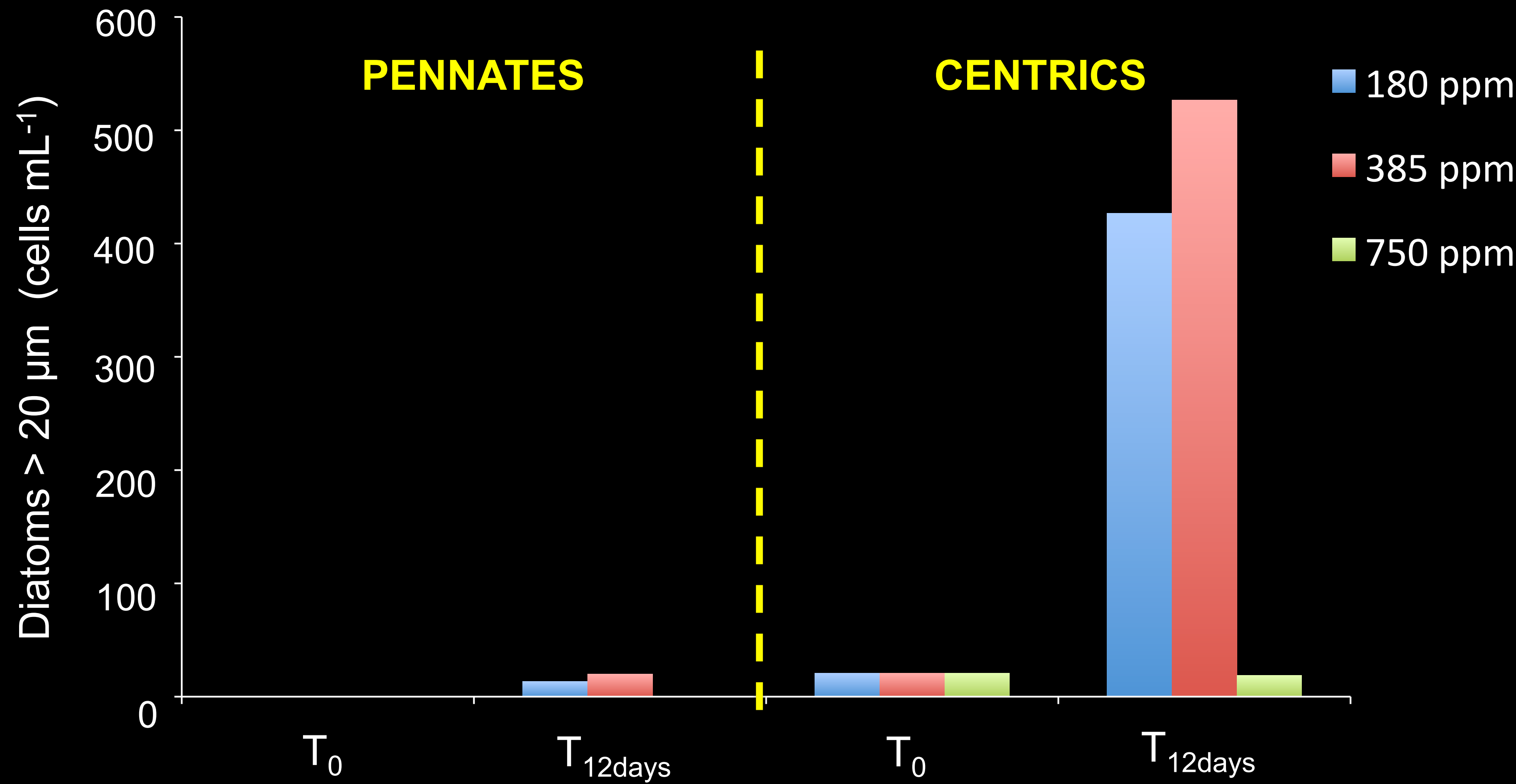


- Lower biomass & productivity in high CO_2 treatment
- No increase in biomass in high CO_2 treatment over time

High CO_2 effect on small (<20 µm) algae

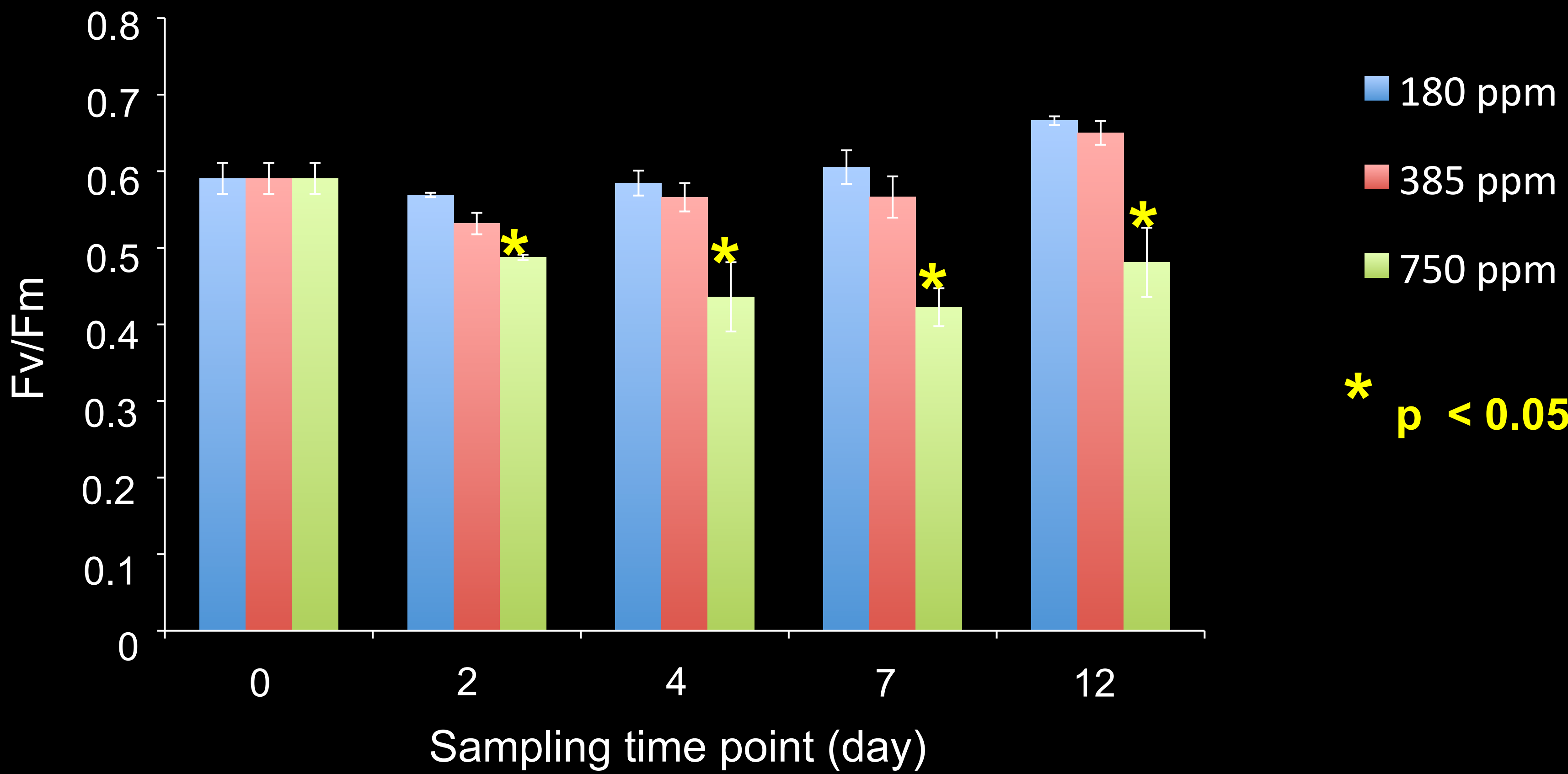


High CO_2 effect on large (>20 µm) diatoms



- Increase of pennates and centrics over time in low and ambient CO_2
- No growth of large diatoms in the high CO_2 treatment

High CO_2 effect on photosynthetic efficiency



- Decrease in Fv/Fm in lower pH:
  - Change in pigments in PSII?
  - Damage to photosynthetic apparati?
  - Nutrient limitation?

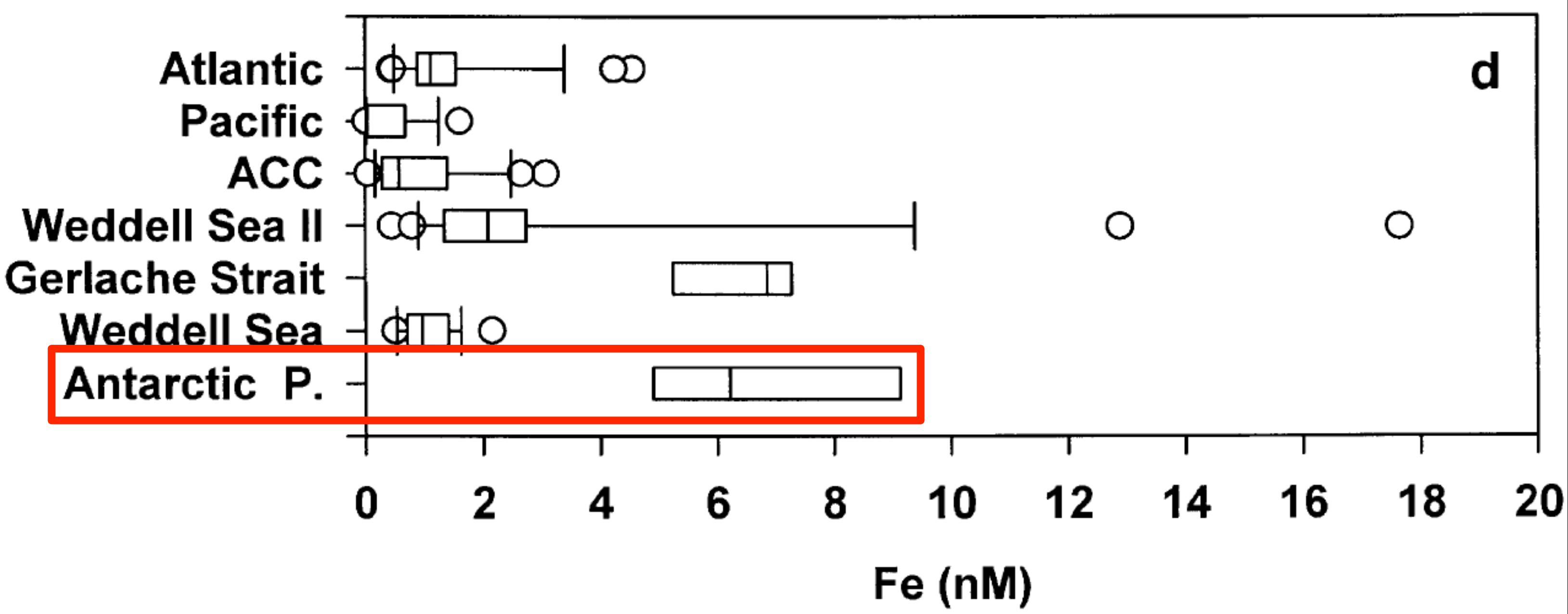
→ Decrease in photosynthetic activity, efficiency

Nutrient limitation?...Doubtful

- Phosphate = 1.8 μM, Nitrate = 25.1 μM

Nutrient limitation?...Doubtful

- Phosphate = 1.8 µM, Nitrate = 25.1 µM
- Typically high Fe near Palmer Station due to ice melt, although these inputs can be episodic

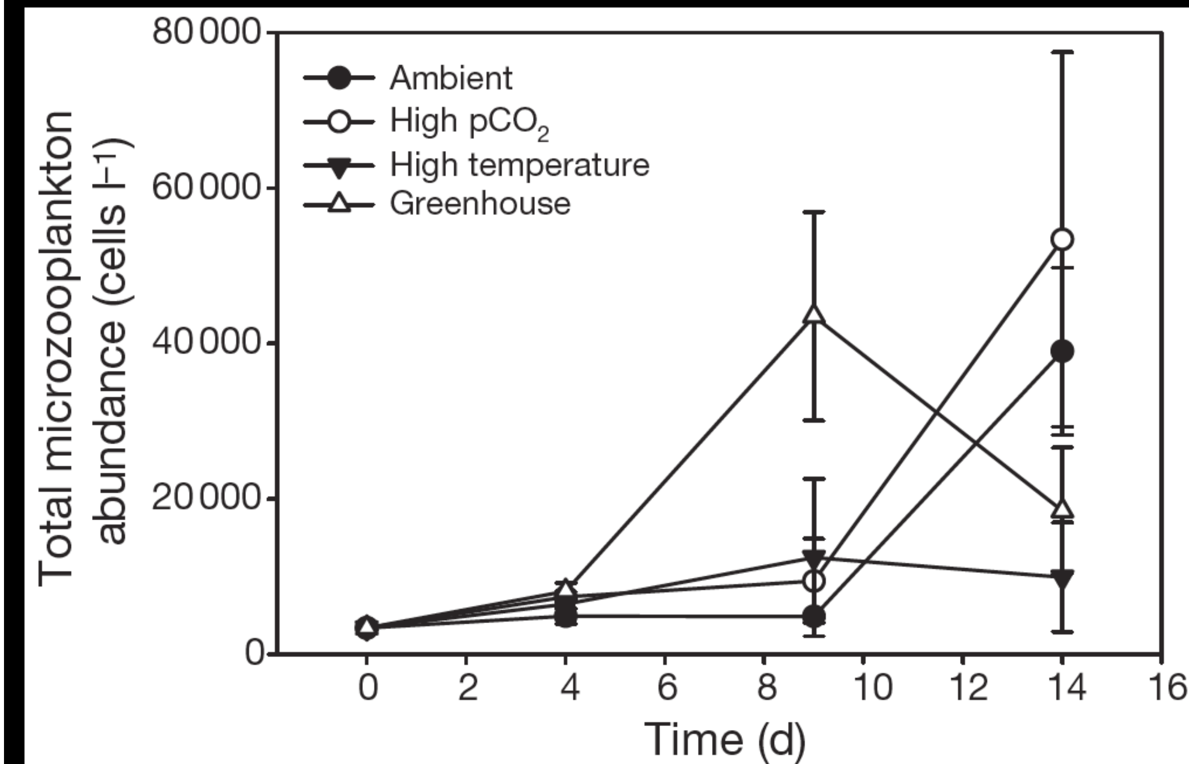


Sañudo-Wilhelmy et al. 2002

Grazing?...Maybe

Microzooplankton abundance and grazing were enhanced in greenhouse conditions in the North Atlantic

(Rose et al. 2009)



Treatment	μ_n (d^{-1})
T0	0.17
Ambient	0.33
High pCO_2	−0.31
High temperature	−0.16
Greenhouse	−0.56

Summary and Conclusions

- Non-uniform responses of WAP phytoplankton communities

- Positive CO_2 effect on large diatom-dominated system
  - Large diatoms were C limited: undersaturation of surface pCO_2
  - Large diatoms are weakly regulated by CO_2
  - Eventual nutrient limitation?

- Lower biomass, productivity, and photosynthetic efficiency in the high CO_2 treatment of small diatom-dominated system
  - Ocean acidification along with synergistic interactions of increased temperature and shifts to small phytoplankton could be detrimental to the food web in the Northern WAP region, resulting in further declines in higher trophic level organisms such as Antarctic krill

THANK YOU

R/V Laurence M. Gould captain and crew
Palmer Station lab staff
Palmer LTER
Raytheon Polar Services
United States Antarctic Program

RUTGERS UNIVERSITY

UNITED STATES ANTARCTIC PROGRAM · NATIONAL SCIENCE FOUNDATION

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