Microzooplankton feeding and growth in an acidified ocean

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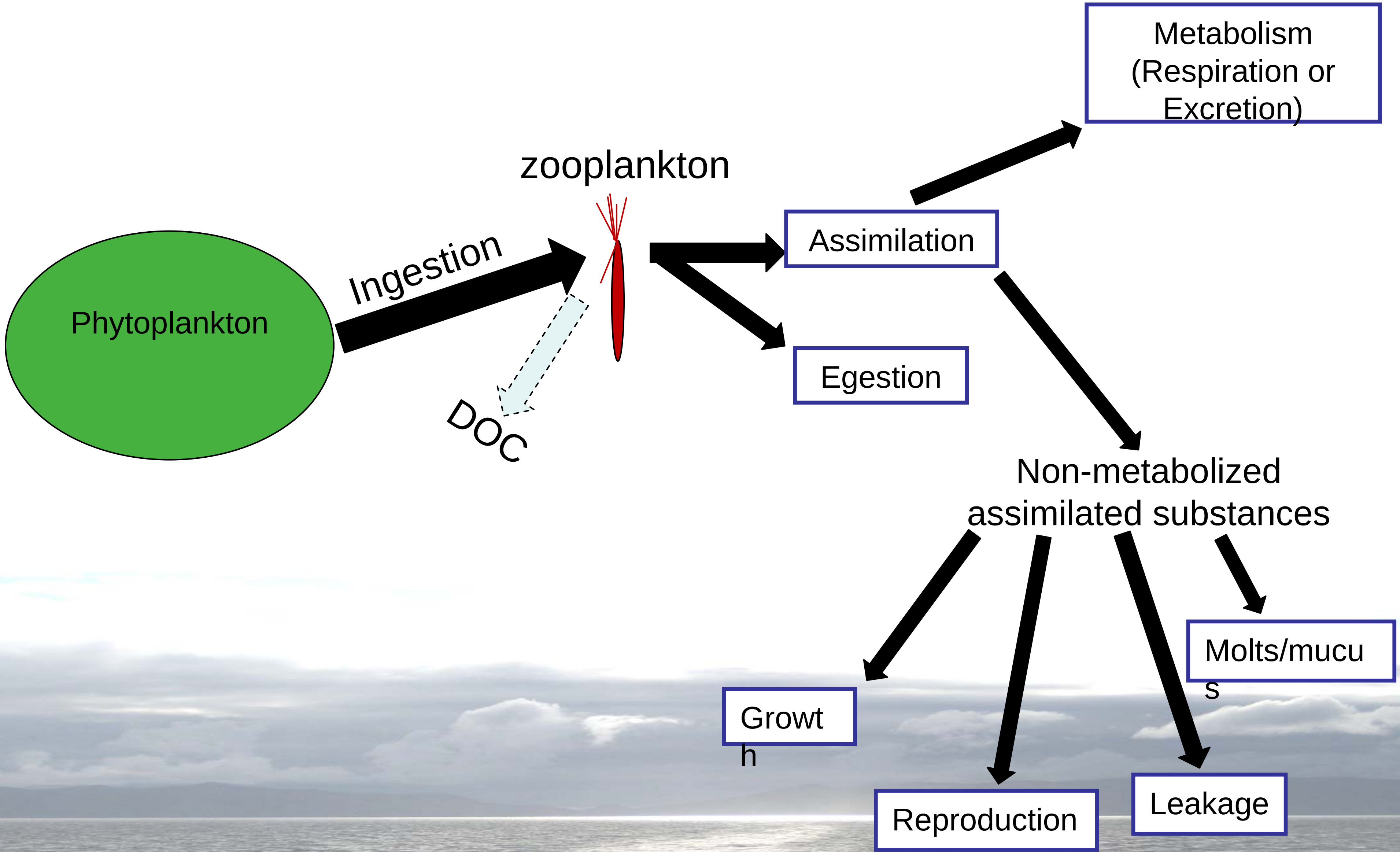
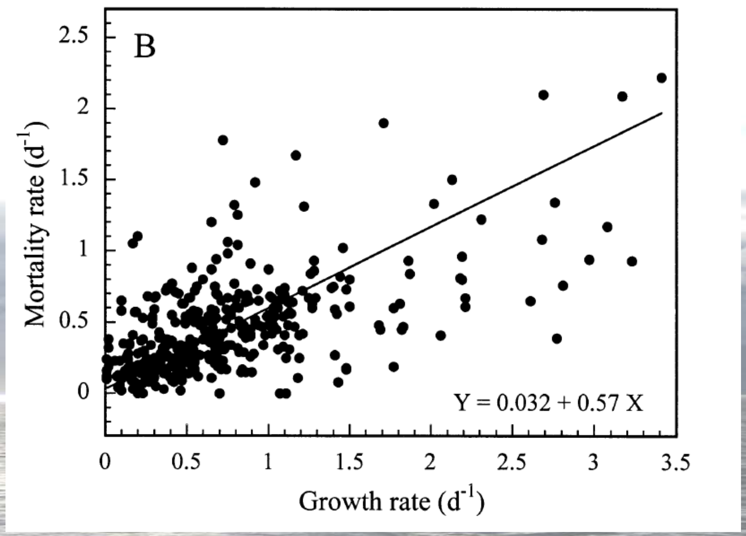

Metabolism (Respiration or Excretion)
zooplankton
Ingestion
Assimilation
Phytoplankton
Egestion
DOC
Non-metabolized assimilated substances
Molts/mucu s
Growt h
Reproduction
Leakage

- Ingestion
  - Prey abundance
    e.g. Verity, P. G. 1985; Jakobsen, H. H. & P. J. Hansen, 1997
  - Prey growth rate
    e.g. Calbet, A., Landry, M.R. 2004
  - Prey nutritional quality (C:N:P)
    e.g. Butler, N. M., C. A. Suttle & W. E. Neill, 1989; Cowles, T. J., R. J. Olson & S.W. Chishom, 1988
  - Prey size
    e.g. Gonzalez, J. M., E. B. Sherr &B. F. Sherr, 1990; Jakobsen, H. H. & P. J. Hansen, 1997
  - Prey defense mechanisms
    e.g. Strom, S.L., G.V. Wolfe, A. Slajer, S. Lambert, and J. Clough. 2003

- Assimilation (egestion)
  - Prey abundance (high or low)
    e.g. Landry et al. 1984
  - Prey nutritional quality (C:N:P)
    e.g. Mitra and Flynn 2005



From Calbet, A., Landry, M.R. 2004

Microzooplankton will be indirectly affected by ocean acidification (elevated pCO_2) through…

I. Alterations in physiology, rate processes and biochemistry of phytoplankton

- i. Photosynthetic rate
- ii. C:N:P stoichiometry
- iii. Size, cell division rate, defense properties
- iv. DOC/TEP release

II. Alterations in zooplankton ecology

- i. Feeding and growth rates
- ii. Excretion rate, products, stoichiometry

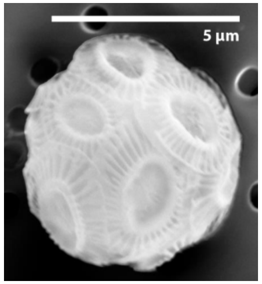
Possible consequences:

Change in food we efficiency

Shift to microbially dominated food web

Design and Methods:

- Grow phytoplankton cultures semi-continuously in lab across a range of [pCO_2]
  - Model phytoplankton: calcifying (CCMP 2668) and non-calcifying (CCMP 374) *Emiliania huxleyi*



  - [pCO_2] of ambient (~395), 750 and 1000 pCO_2
    - Measure: cell growth rate, C:N, chlorophyll *a,* photosynthetic rate, DMSP, PIC:POC, cell size, calcification rate, coccolith morphology

- Feed acclimated *E. huxleyi* to microzooplankton
  - Model microzooplankton: *Amphidinium longum*, *Oxyrrhis marina*, *Eutintinnis* sp., *Strombidinopsis* sp., more to come…
    - Measure: grazing rate, ingestion rate, growth rate

Shear affects ‘normal’ microzooplankton behavior:

- Mortality

Laboratory culture of marine planktonic oligotrichs (Ciliophora, Oligotrichida)

Dian J. Gifford 1985

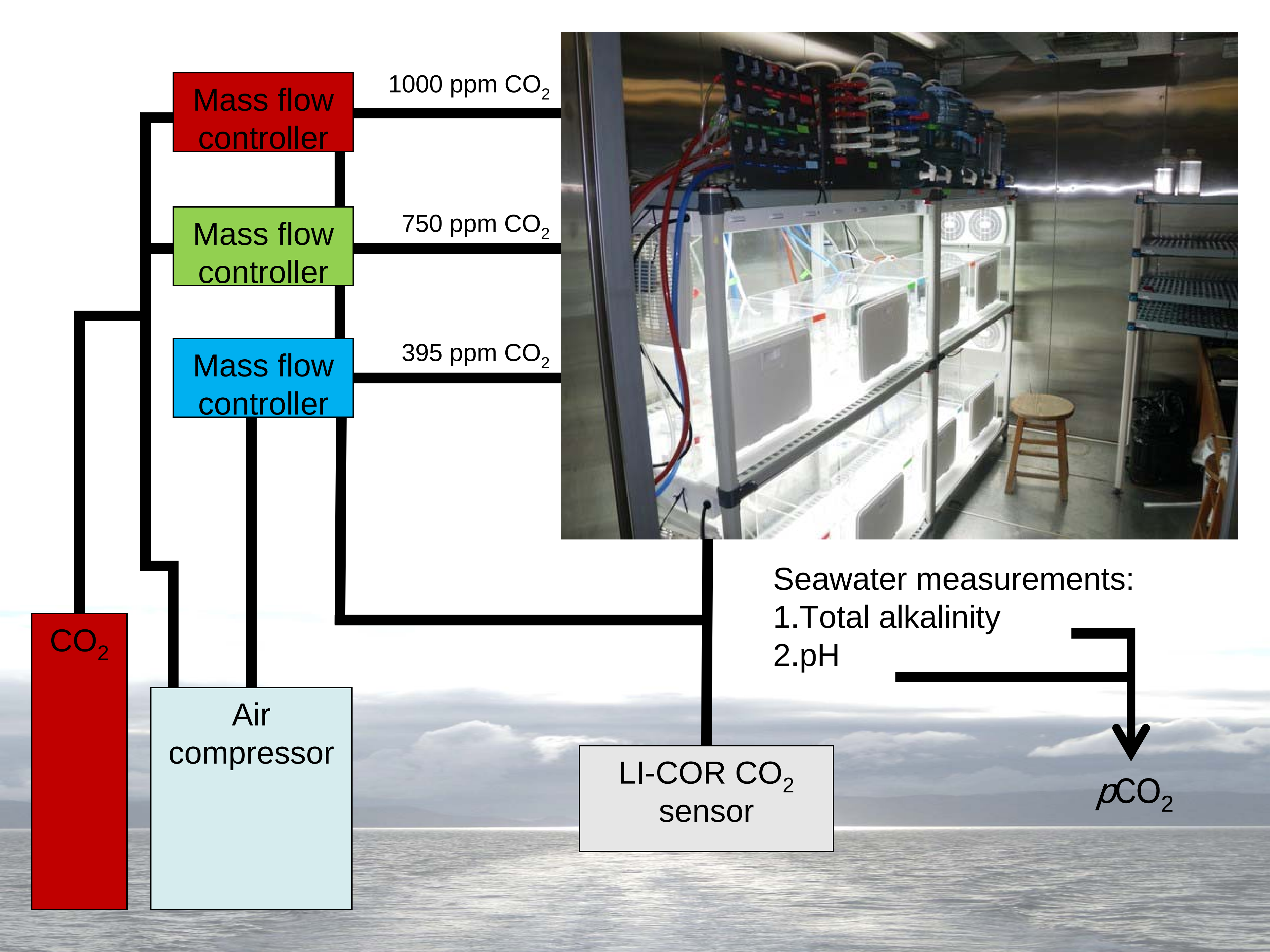
Conserving original *in situ* diversity in microzooplankton grazing set-ups

Martin Günter Joachim Löder et al. 2010

- Feeding behavior

Influence of turbulence on suspension feeding by planktonic Protozoa; experiments in laminar shear fields

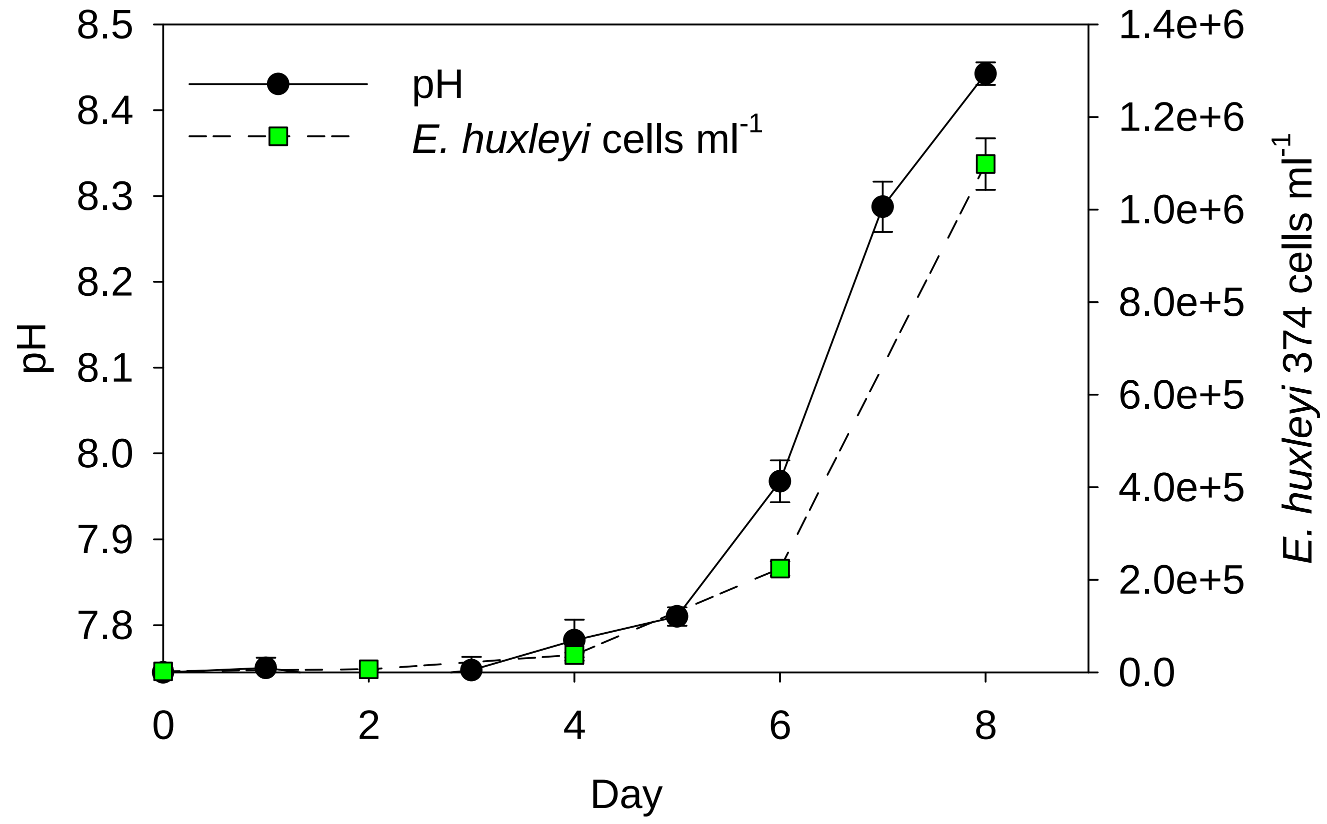
Martin Günter Joachim Löder et al. 2010



Mass flow controller
1000 ppm CO_2
Mass flow controller
750 ppm CO_2
Mass flow controller
395 ppm CO_2
CO_2
Air compressor
LI-COR CO_2 sensor
Seawater measurements:
1.Total alkalinity
2.pH
pCO_2

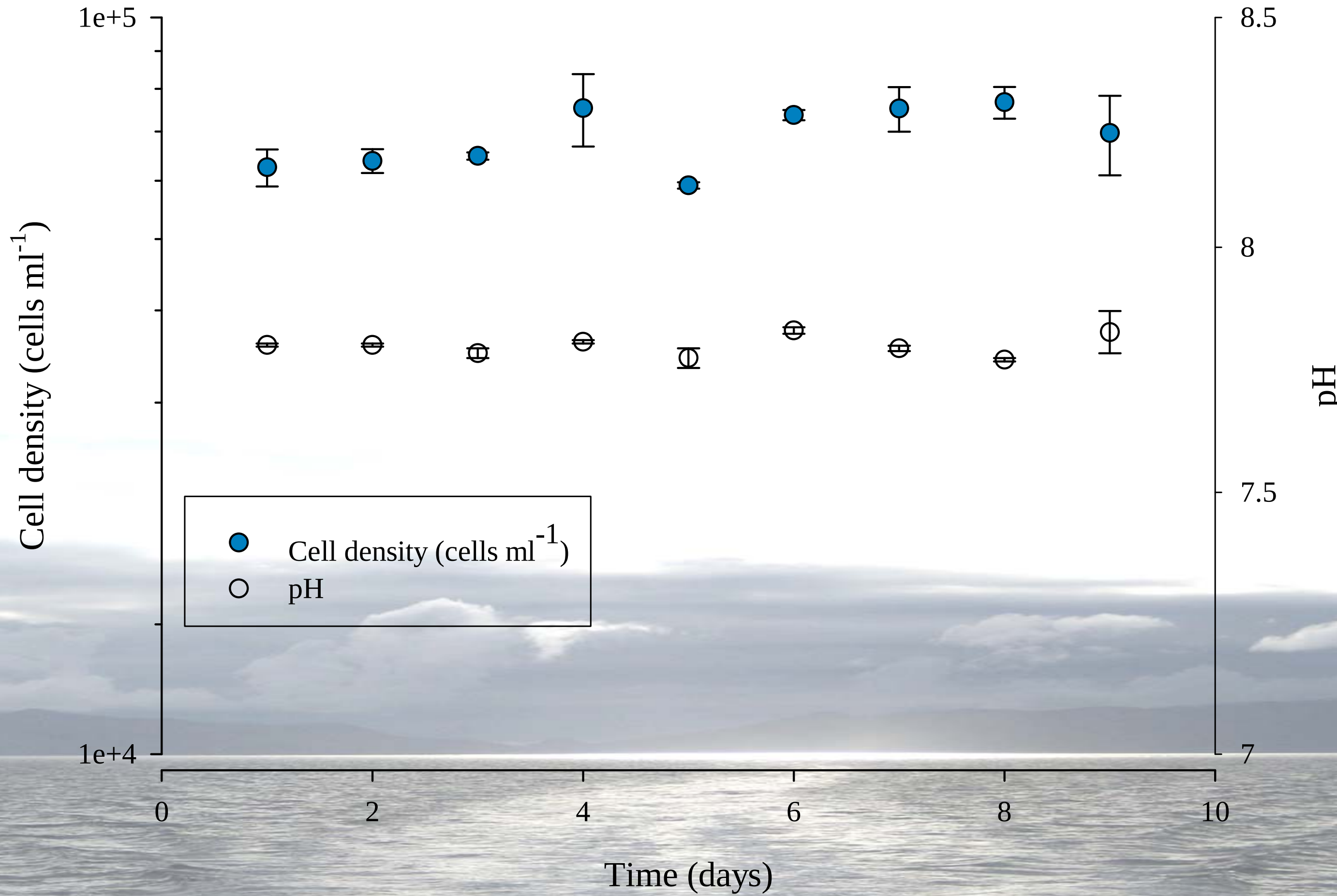
E. Huxleyi biomass eventually consumes CO_2 faster than it is supplied through gas exchange

- Conditions: *E. huxleyi* (CCMP 374) grown at 1000 pCO_2
- Daily cell counts (FC) and pH measurements (Metrohm 888 Titrando)



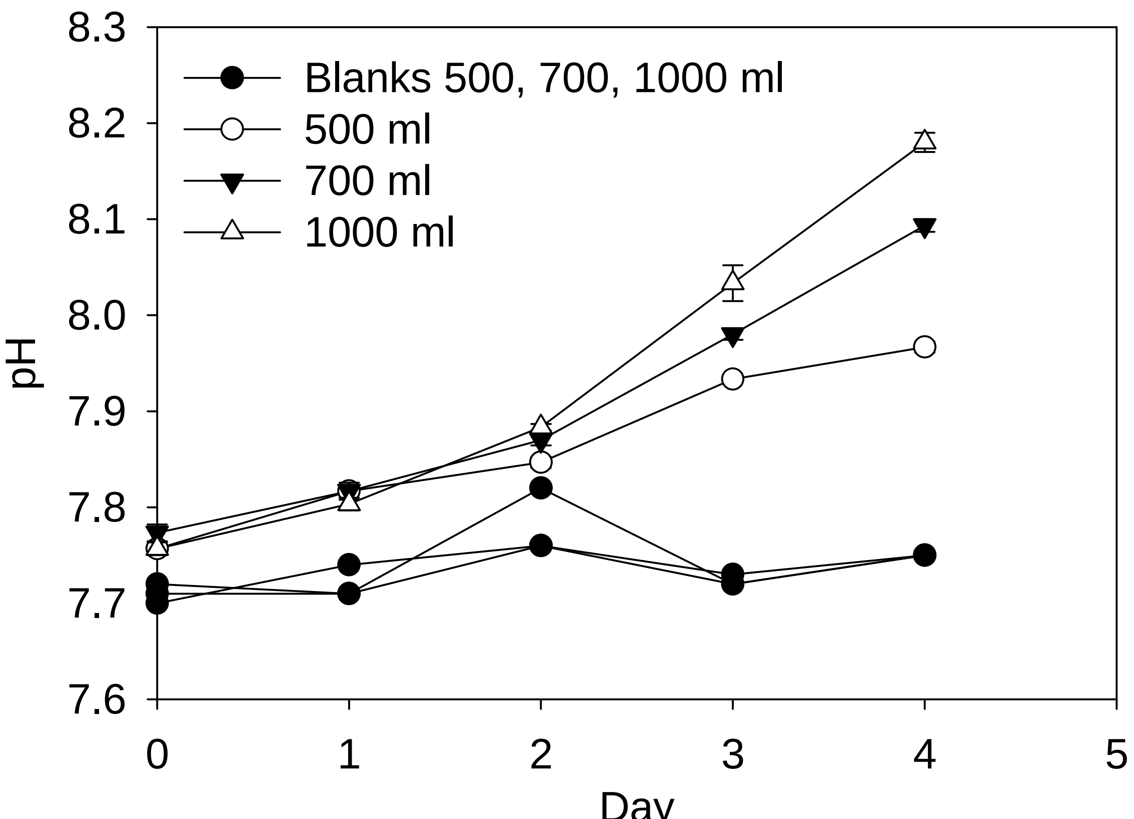
At cell concentrations ≤100,000 cells ml^{-1} CO_2 chemistry maintained

- Conditions: *E. huxleyi* (CCMP 374) grown at 1000 pCO_2
- Daily cell counts (FC) and pH measurements (Metrohm 888 Titrando)



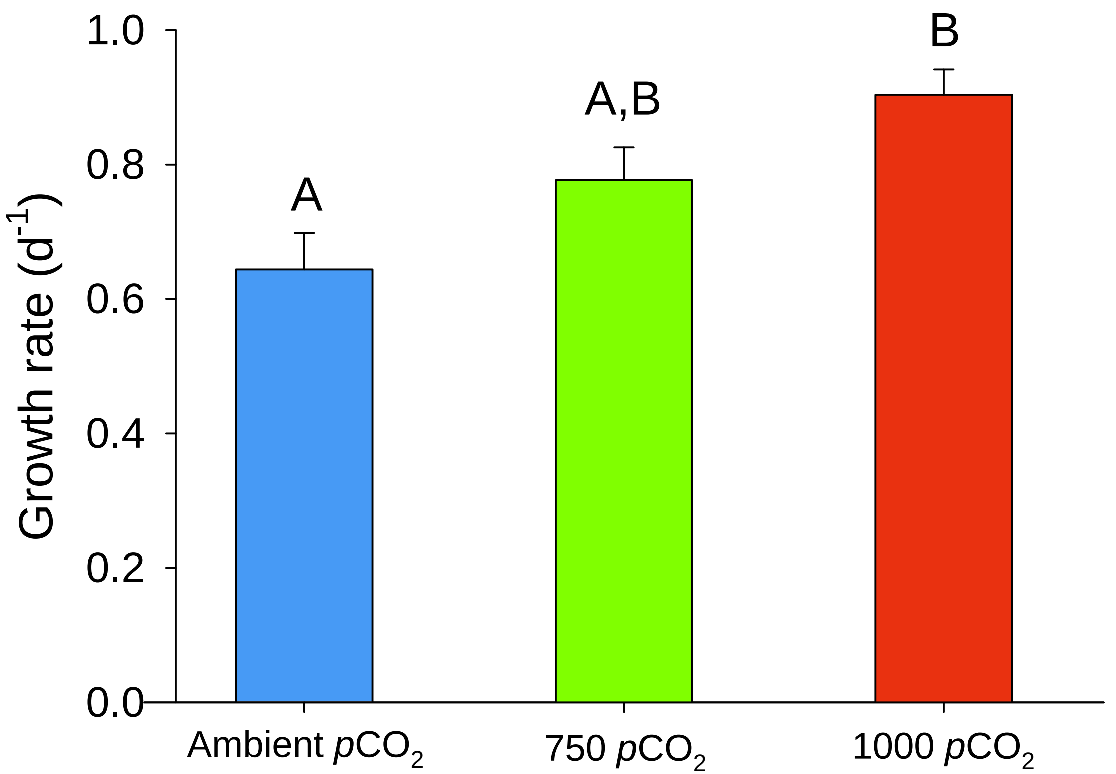
Can we find surface area:volume ratio that balances sample volume needs with gas exchange?

- Conditions: *E. huxleyi* (CCMP 2668) grown at 1000 pCO_2
- Daily cell counts (FC) and pH measurements (Metrohm 888 Titrando)



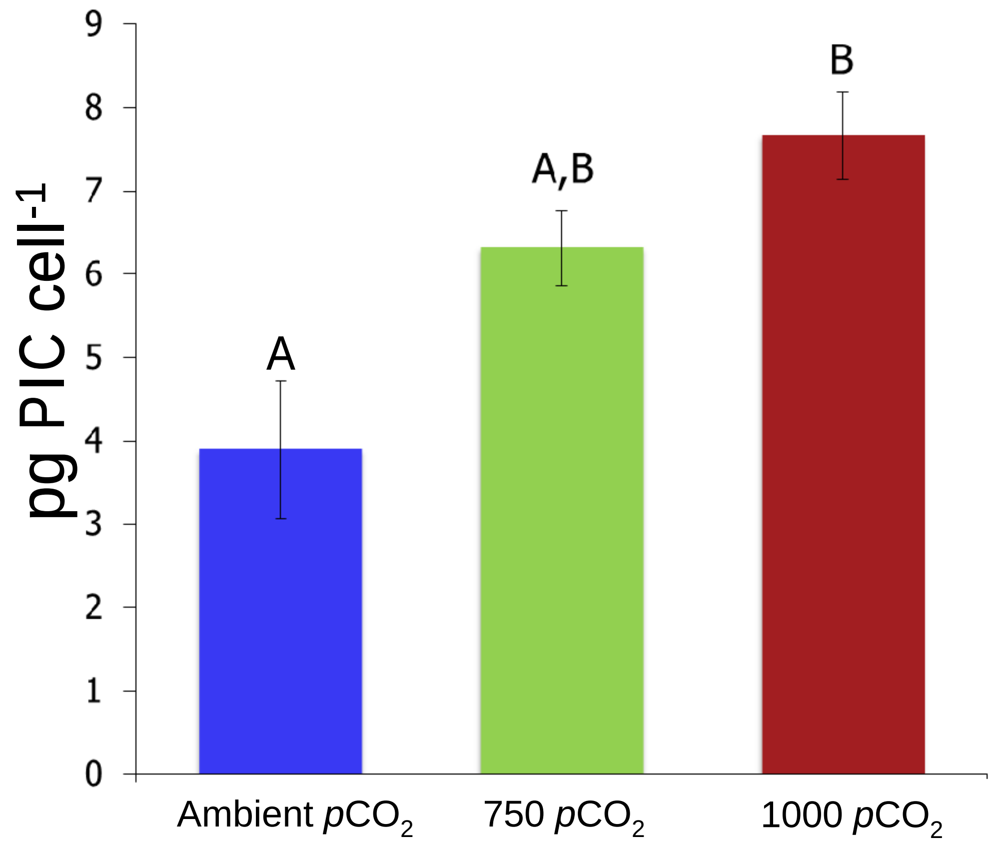
Physiological/biochemical responses of *E. huxleyi* (CCMP 2668) to elevated pCO_2

- Conditions: *E. huxleyi* (CCMP 2668) grown semi-continuously for 10 days at ambient, 750 and 1000 pCO_2
- Daily cell counts

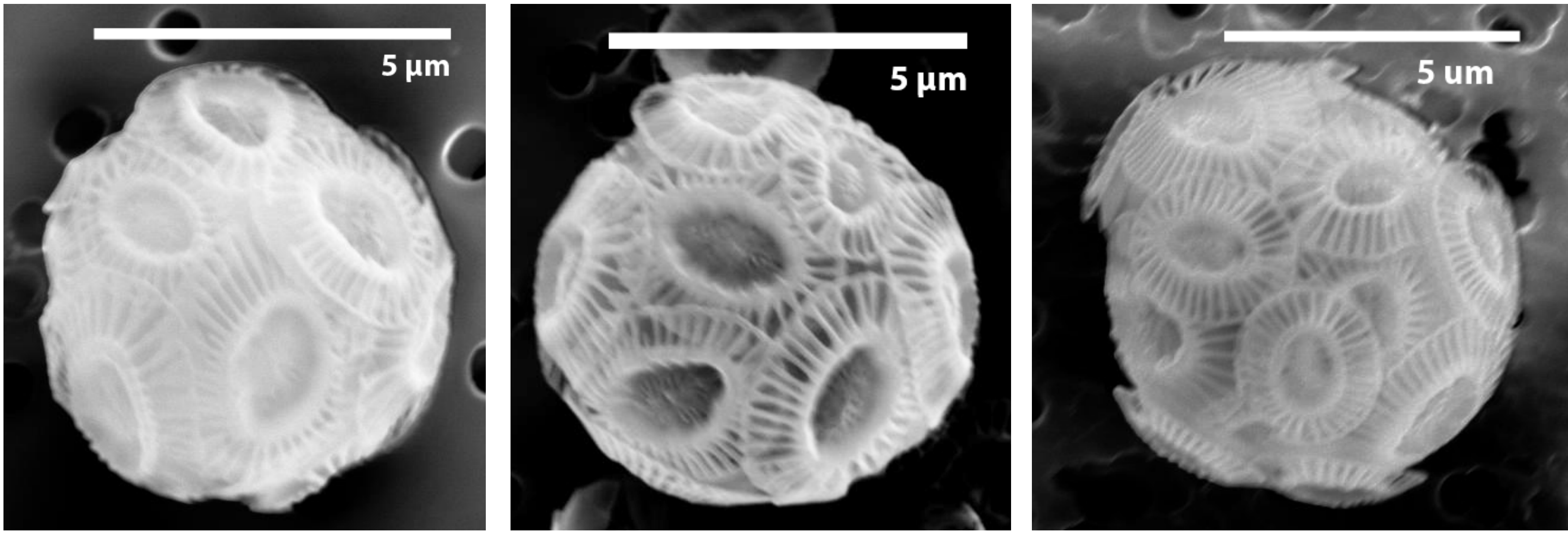


More PIC per cell at higher pCO_2

- Conditions: *E. huxleyi* (CCMP 2668) grown semi-continuously for 10 days at ambient, 750 and 1000 pCO_2
- Daily cell counts and PIC measurements day 8



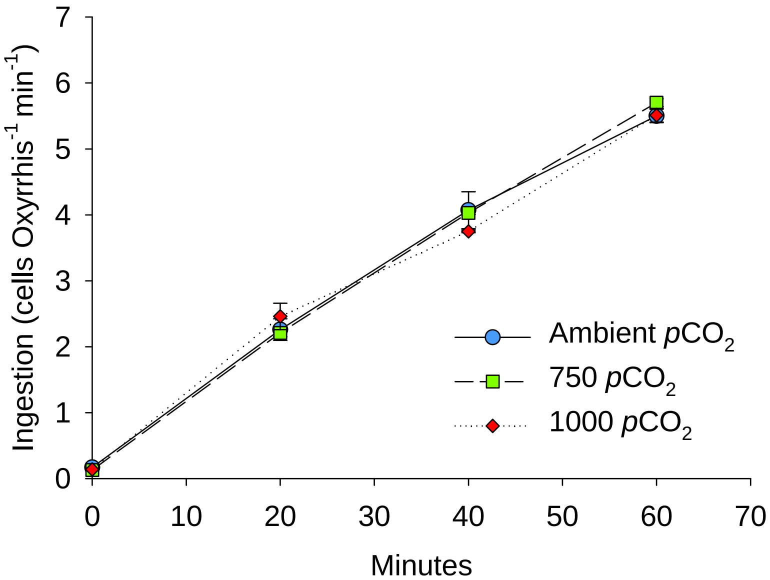
Increasing coccoliths cell^{-1}, cell diameter (2668)

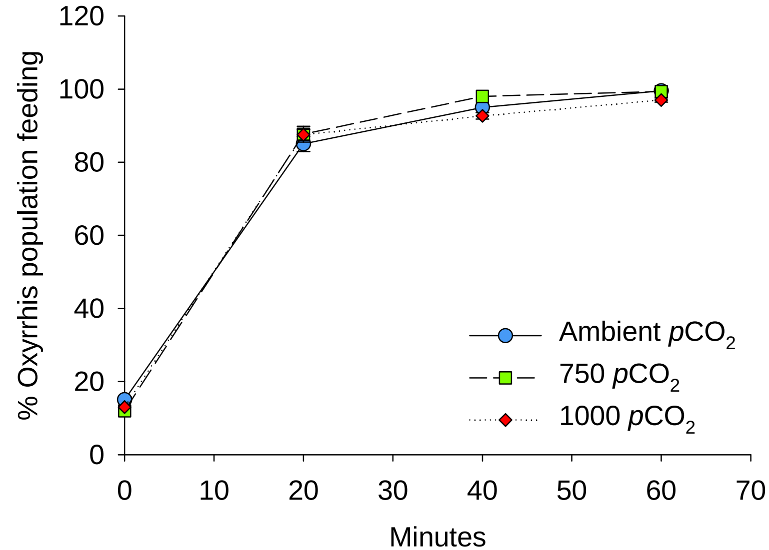


Ambient ($395\ pCO_2$) | Moderate ($750\ pCO_2$) | High ($1000\ pCO_2$)

Experimental conditions:

- *Oxyrrhis marina* acclimated (8 days) to 3 [pCO_2]
- *O. marina* fed non-acclimated *E. huxleyi*
- *O. marina* short-term ingestion and growth (24h) measured





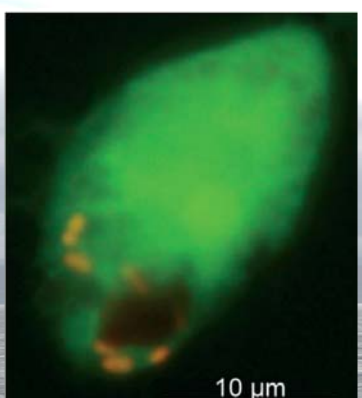
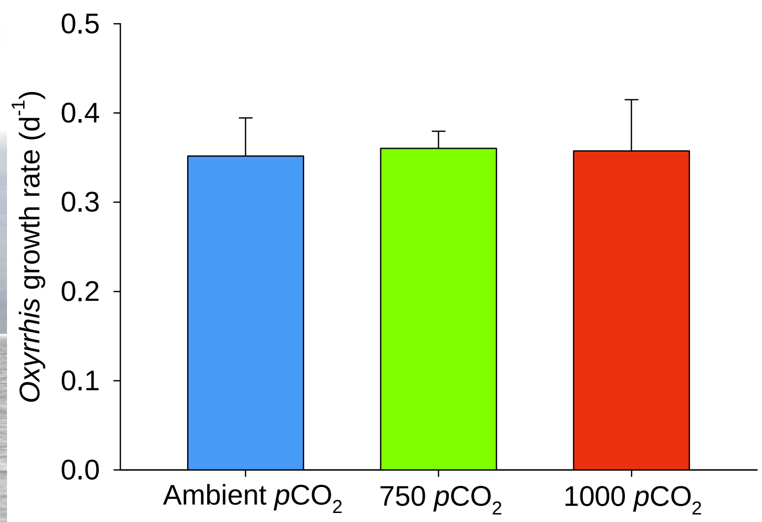
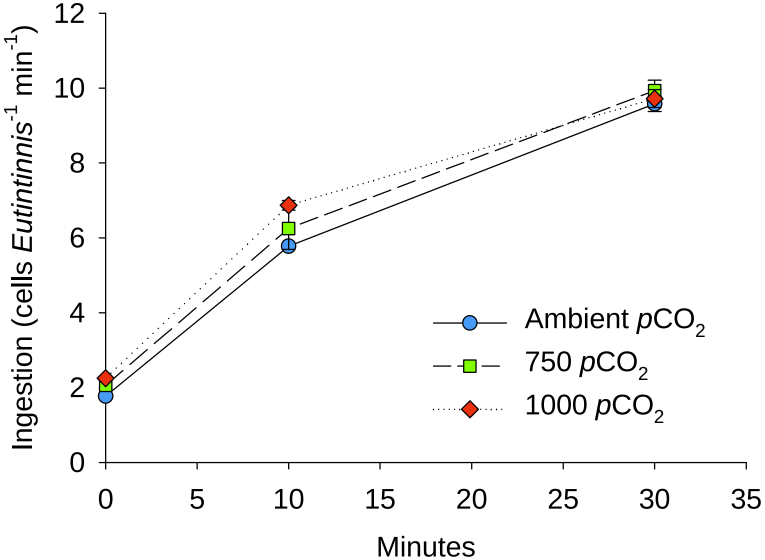


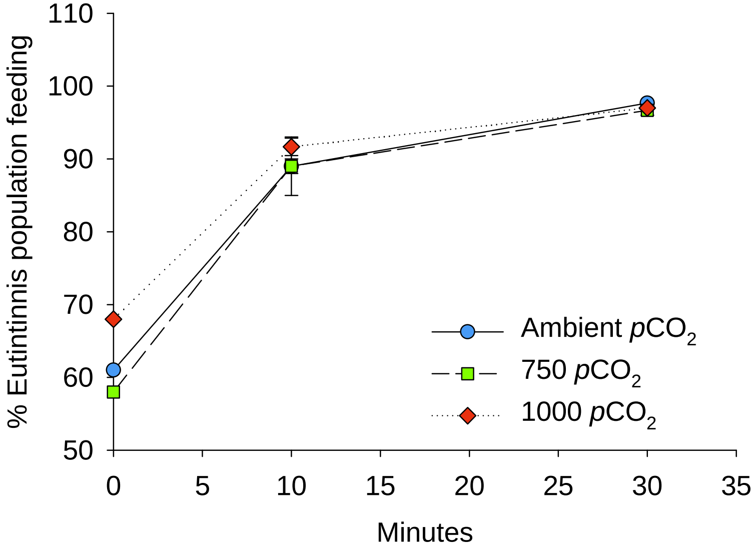
Photo: Jude Apple



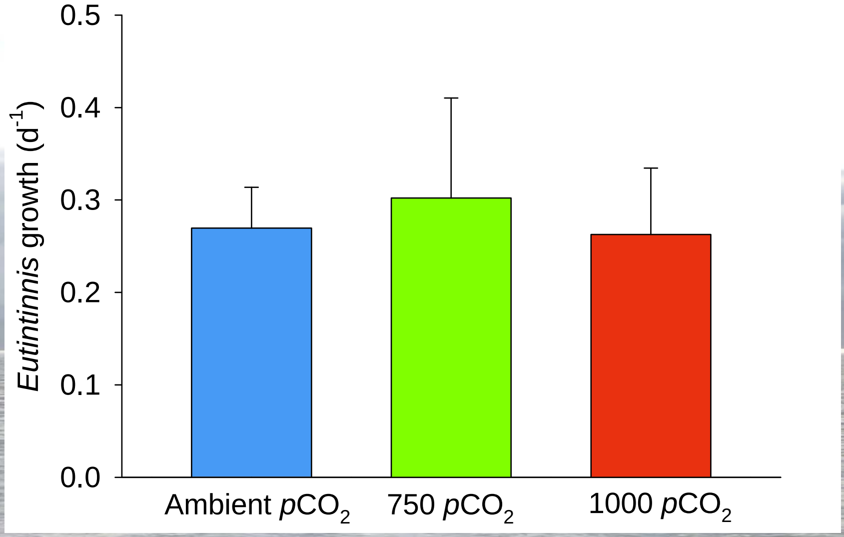
Experimental conditions:

- *Eutintinnus* sp. acclimated (8 days) to 3 [pCO_2]
- *Eutintinnus* sp. fed non-acclimated *E. huxleyi* CCMP 374
- *Eutintinnus* sp. short-term ingestion and growth (24h) measured





http://forum.mikroscopia.com/index.php?showtopic=4907



Experimental conditions:

- *Amphidinium longum* acclimated (8 days) to 3 [pCO_2]
- *A. longum* fed non-acclimated *E. huxleyi* CCMP 374
- *A. longum s*hort-term ingestion and growth (24h) measured

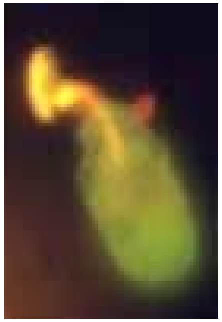
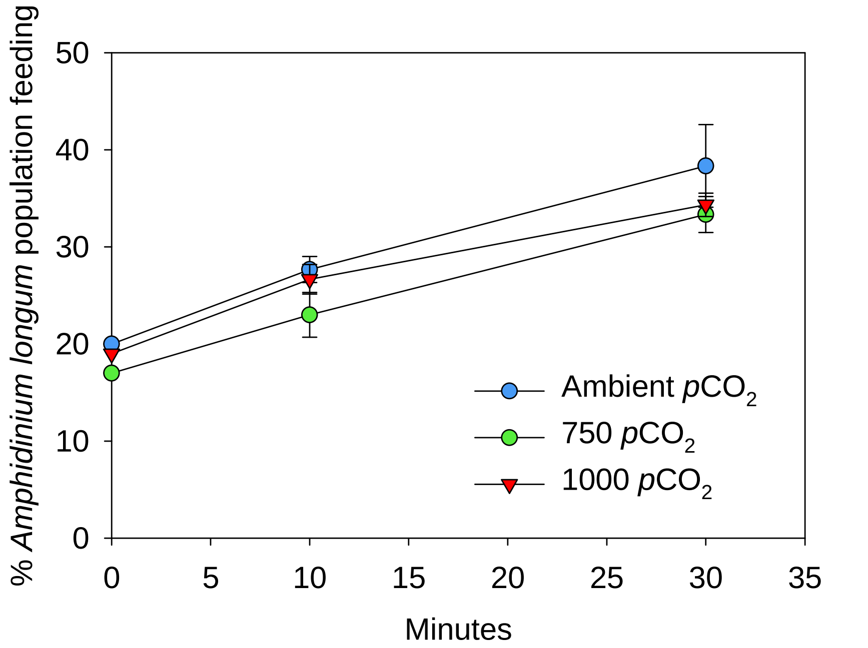
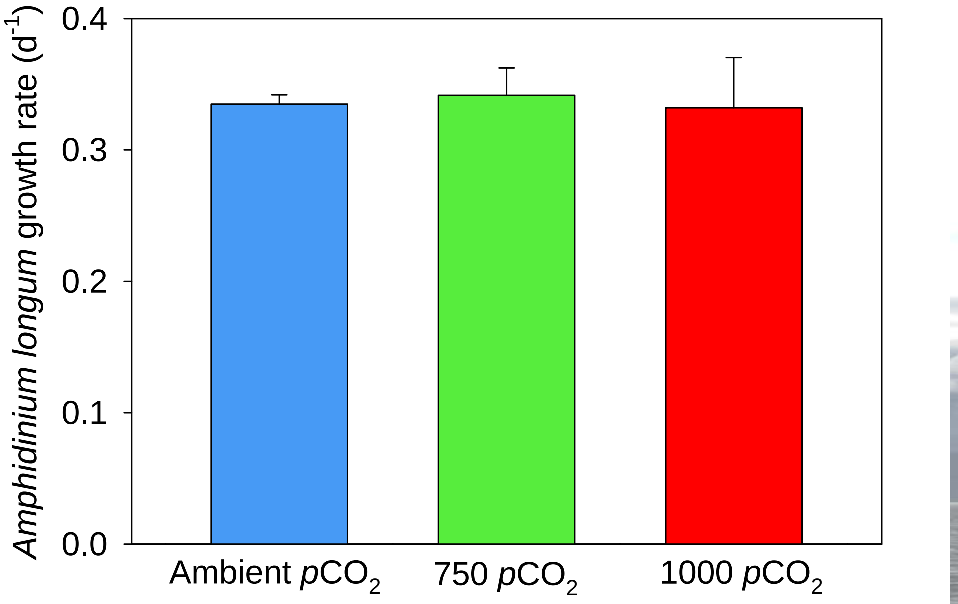


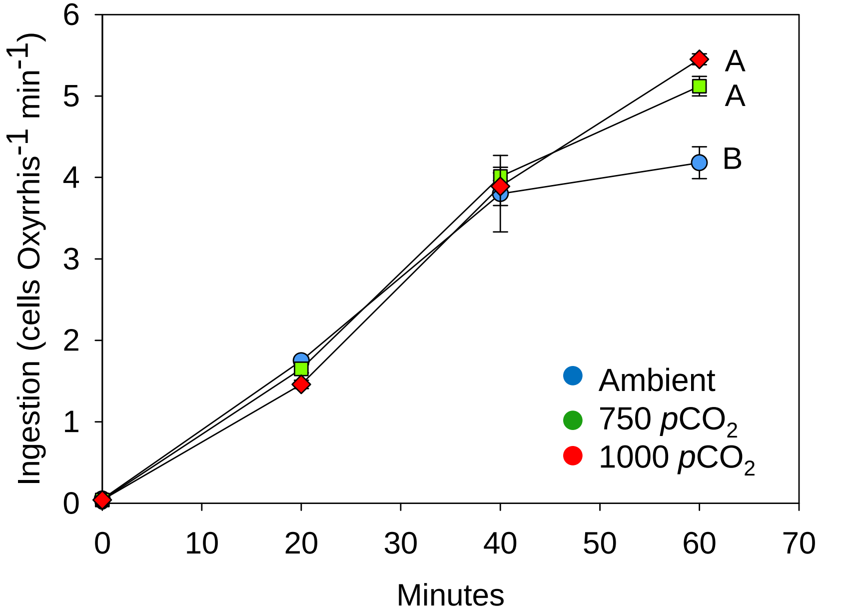
Photo: Gordon V. Wolfe

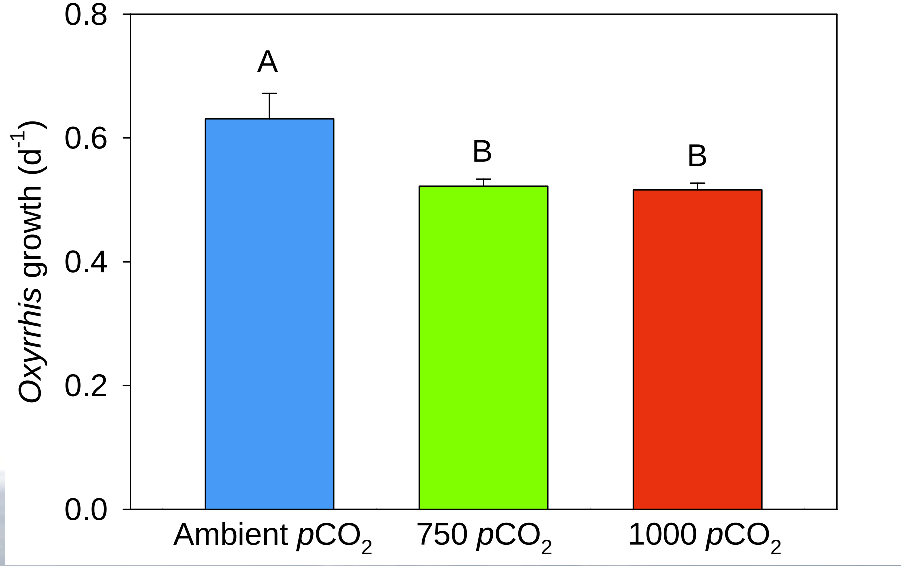




Experimental conditions: Testing for indirect effects

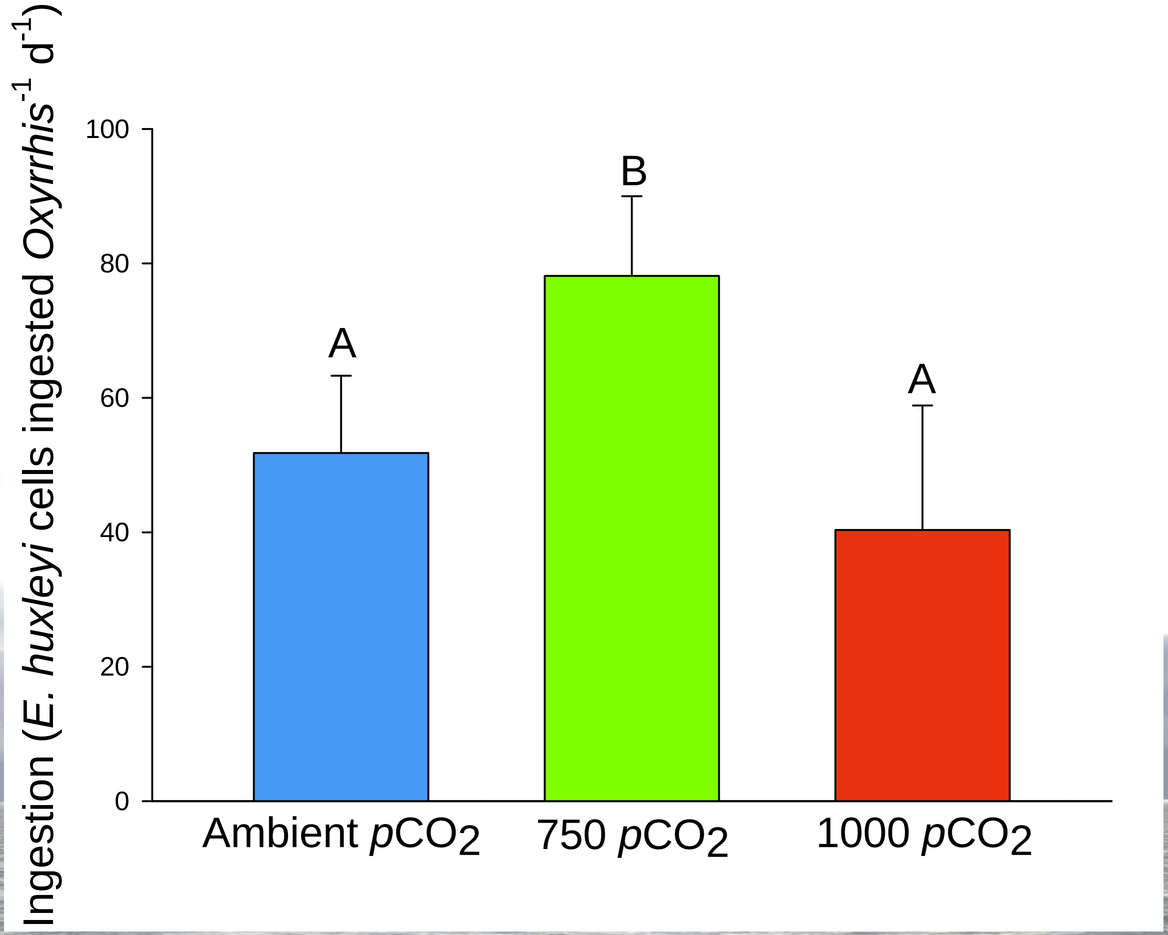
- *E. Huxleyi* 374 – grown semi-continuously for 8 days at 3 [pCO$_2$]
- pCO$_2$ acclimated *E. Huxleyi* 374 fed to non-acclimated *O. marina*
- *O. marina* short-term ingestion and growth (48h) measured





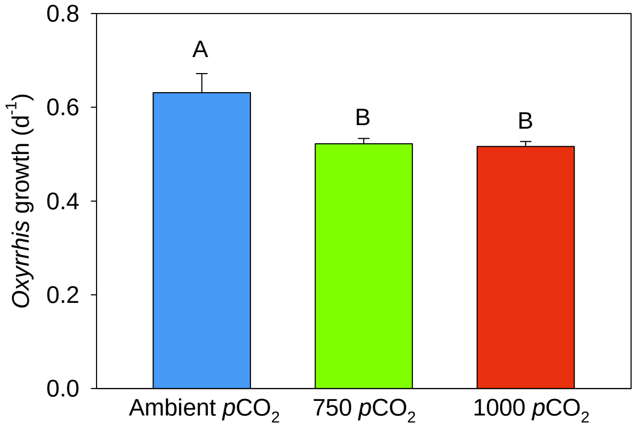
Experimental conditions:

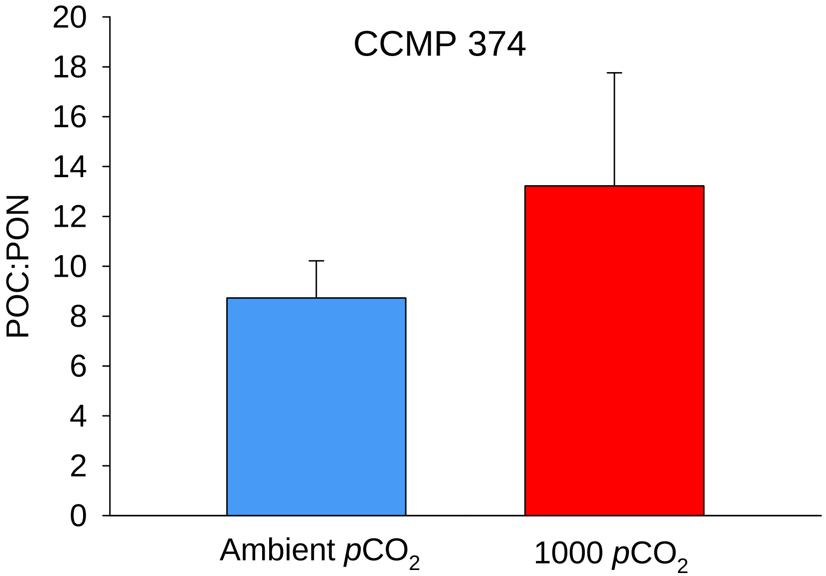
- *E. Huxleyi* 374 – grown semi-continuously for 8 days at 3 [pCO_2]
- pCO_2 acclimated *E. Huxleyi* 374 fed to non-acclimated *O. marina*
- *O. marina* ingestion measured by cell disappearance (24h)

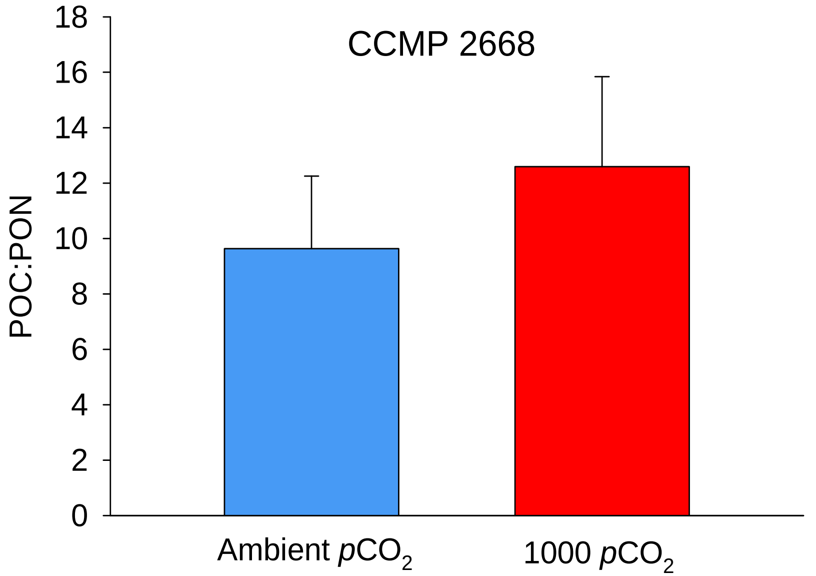


Experimental conditions:

- *E. Huxleyi* CCMP 374 and 2668 grown semi-continuously for 10 days at 3 [pCO_2]
- C:N measured on days 1, 6 and 10
- Averaged C:N for days 1, 6 and 10







Conclusions:

- There is no conspicuous direct effect of elevated *p*CO2 to microzooplankton
- This study and others show physiological and biochemical responses by phytoplankton to elevated pCO_2
- Microzooplankton may alter their feeding behavior in response to pCO_2-induced changes in phytoplankton
- Changes in microzooplankton feeding ecology will affect many important ocean processes

Thanks to students, SPMC, WWU, and NSF OCE 0961229