Impact of ocean acidification on benthic organisms

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EPOCA
European Project on OCean Acidification
epoca-project.eu

Introduction

- 1st High-CO_2 meeting (2004):
  - very little information on the response of benthic organisms, except reef-building corals, to environmentally-relevant pH or pCO_2 levels
  - calcification (and net photosynthesis) were the main processes investigated
  - little information on early life stages
  - lack of knowledge on synergisms and antagonisms
- Strong initial focus on shallow-water organisms and ecosystems
- Relatively little known on deep organisms

- Mostly discuss results obtained at environmentally-relevant CO_2 levels (ca. 1750-2100) because physiological mechanisms not addressed
- Use of selected examples, mostly perturbation experiments

Calcification: coralline algae

THE BIOGEOCHEMICAL ECOLOGY OF POROLITHON GARDINERI (FOSLIE)

A DISSERTATION SUBMITTED TO THE GRADUATE DIVISION OF THE
UNIVERSITY OF HAWAII IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE OF

DOCTOR OF PHILOSOPHY

IN

OCEANOGRAPHY

DECEMBER 1985

By

Catherine R. Agegian

Dissertation Committee:

Keith E. Chave, Chairman
James Archie
Maxwell Doty
Fred T. Mackenzie
Stephen V. Smith

- Tropical species:
  - Calcification declines at elevated pCO_2 (Agegian, 1985)
  - Decreased growth and recruitment (Kuffner et al., 2007)
  - Decreased calcification and bleaching (Anthony et al., in press)
- Temperate species (Martin & Gattuso, sbm):
  - No response of calcification at 750 ppm, except in summer when combined with elevated temperature
  - Temperature is the main factor controlling net calcification

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Kuffner et al. (2007)

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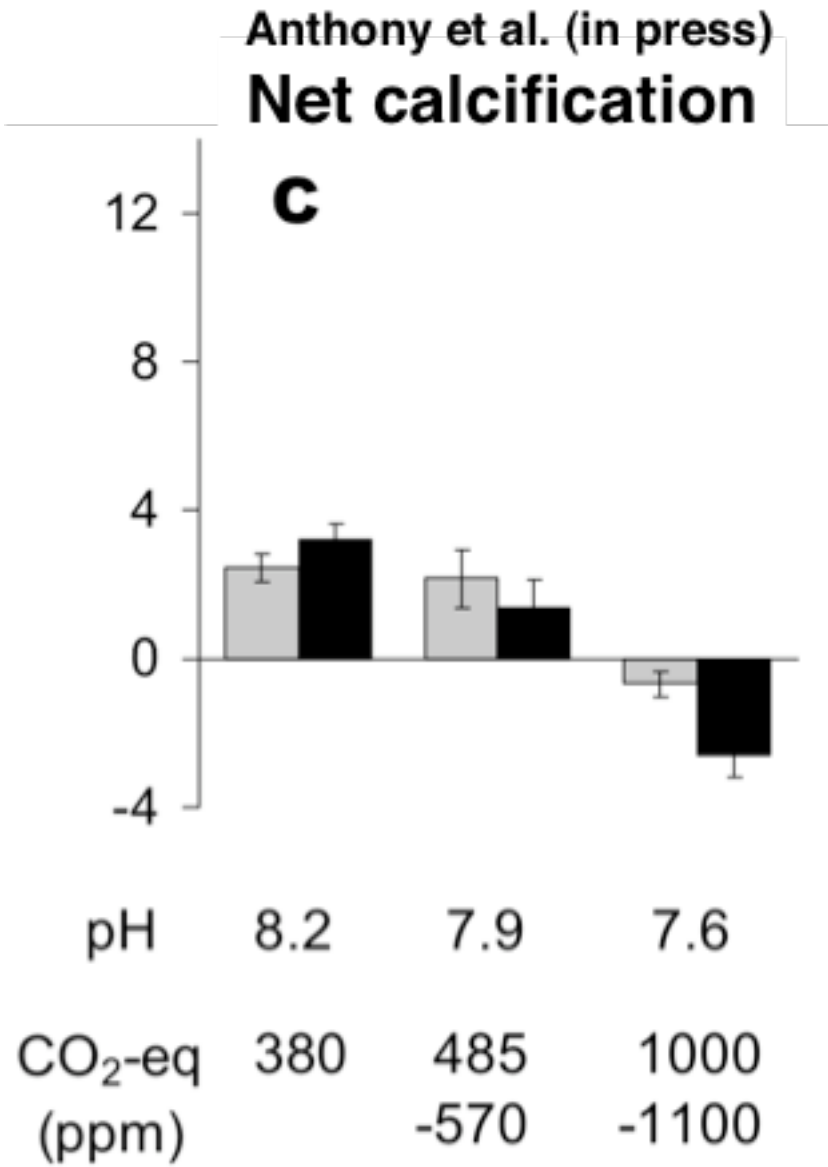

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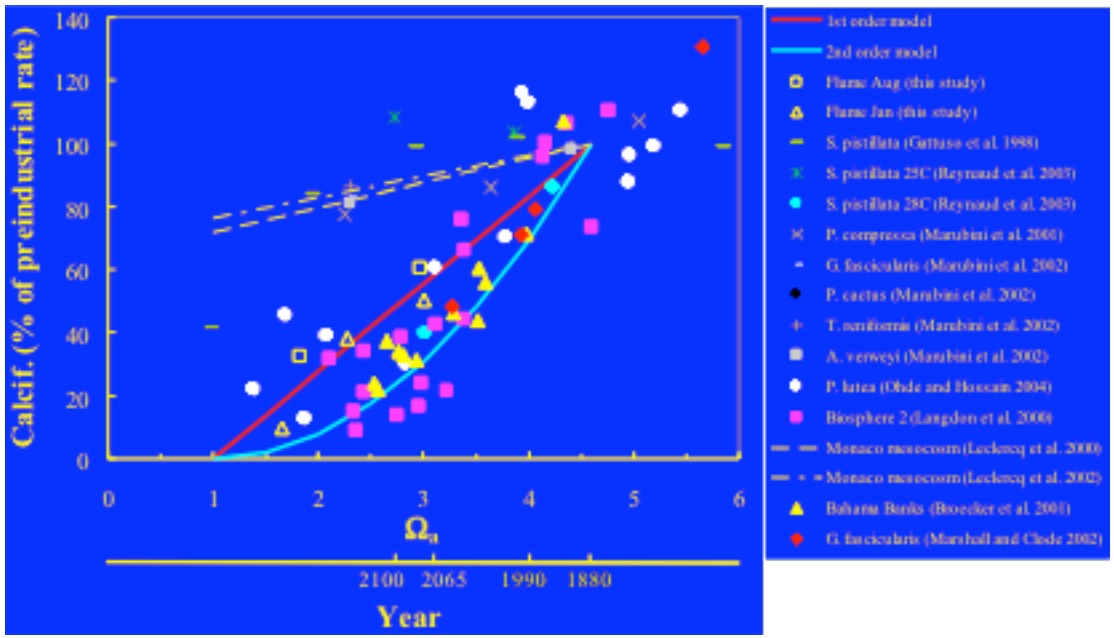
Calcification: zooxanthellate scleractinian corals and coral communities



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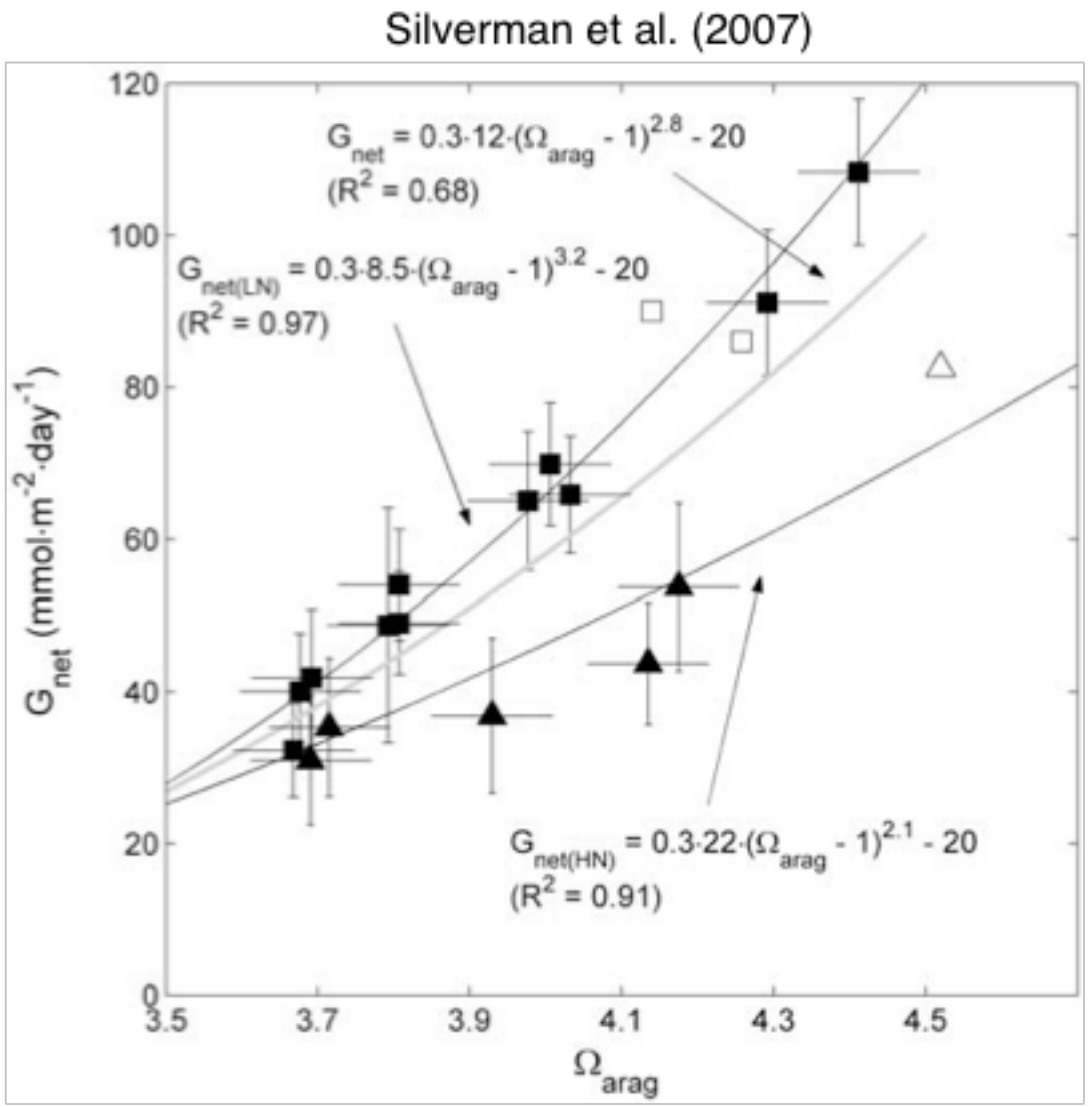

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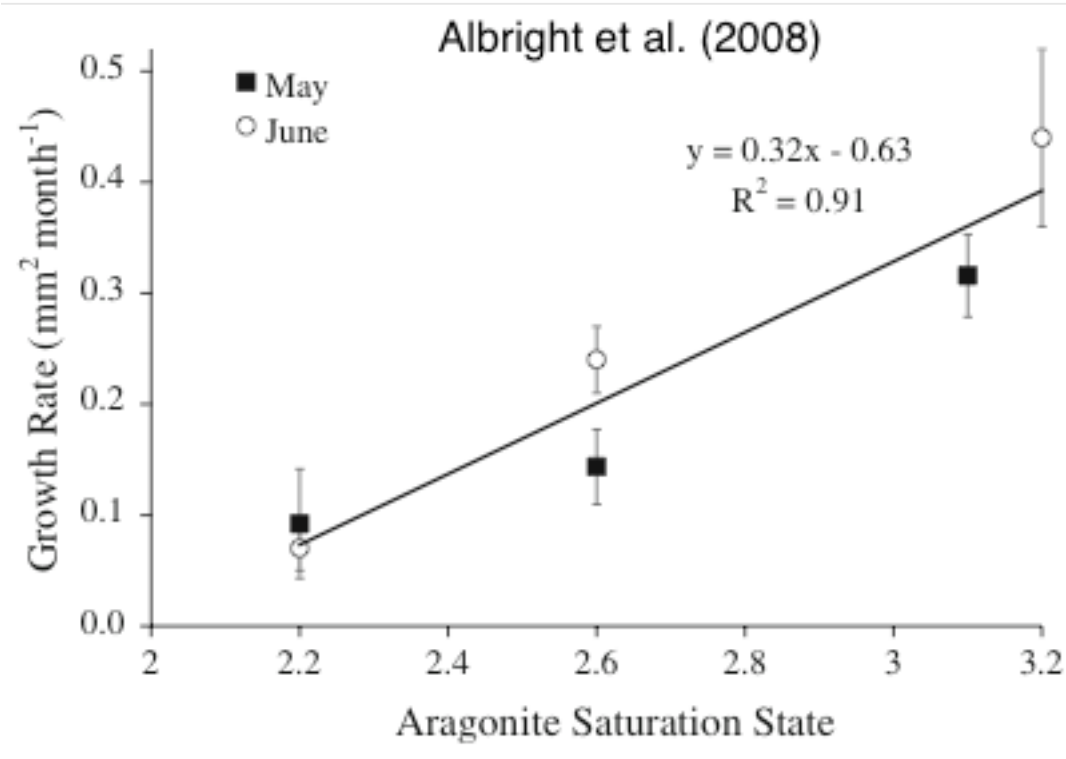

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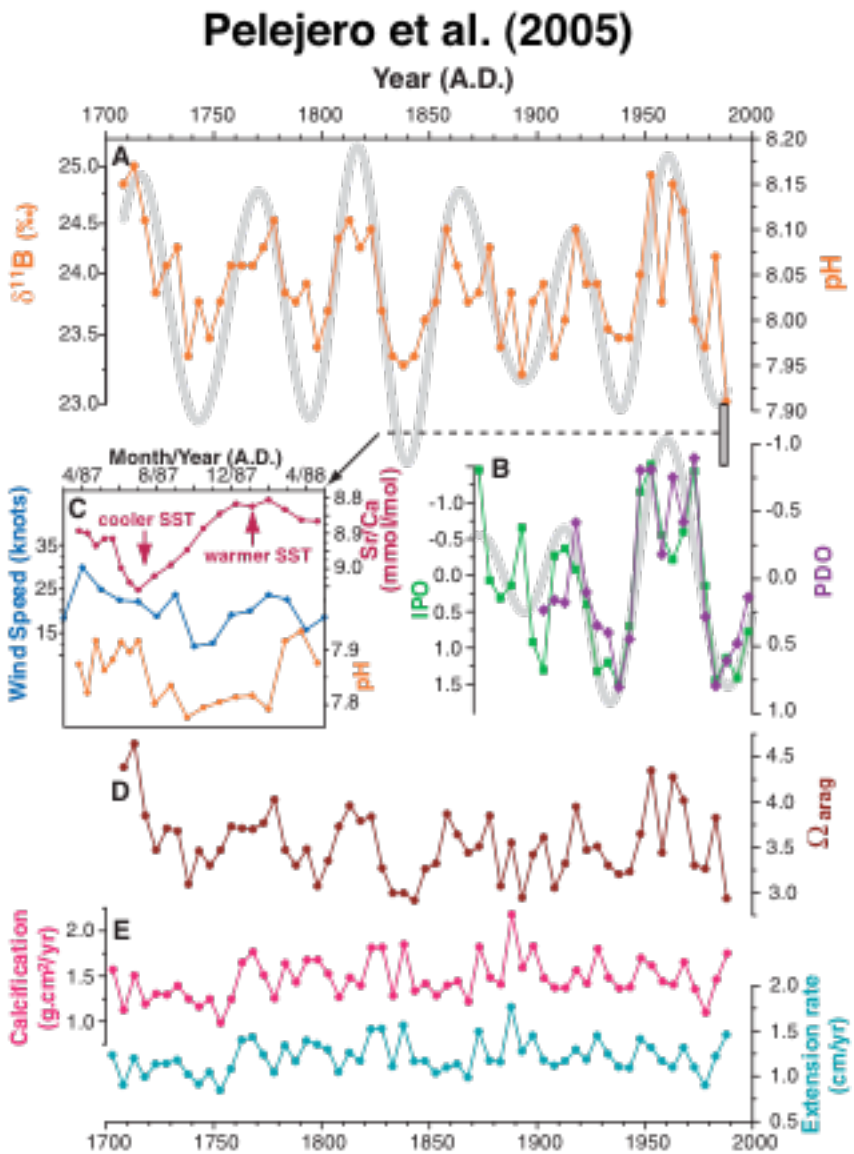

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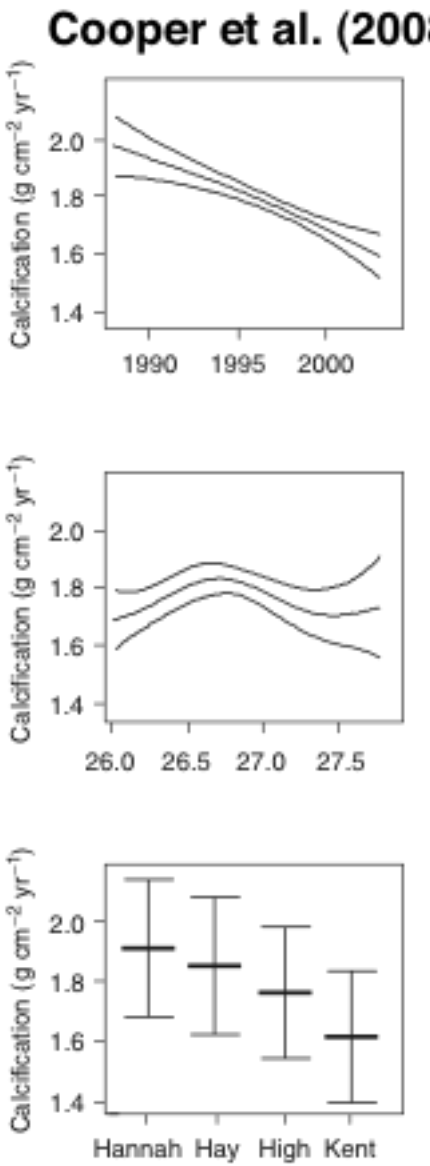

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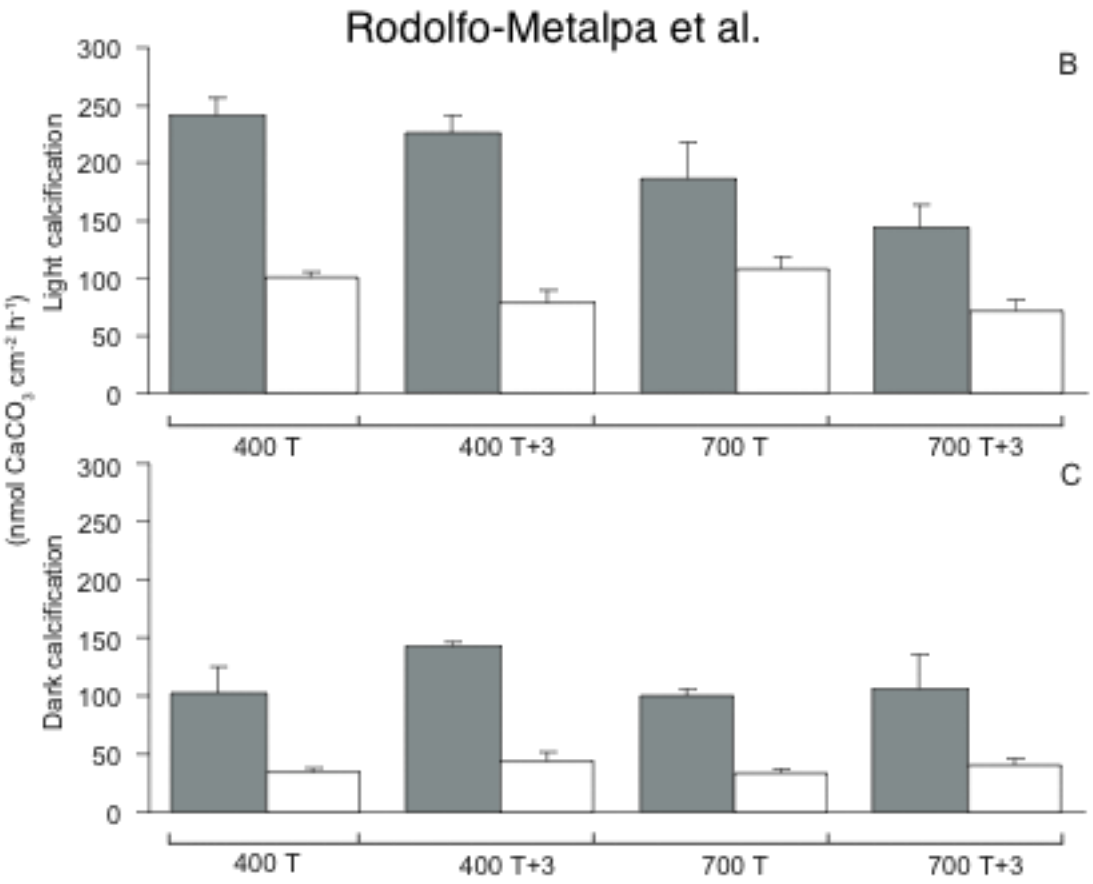

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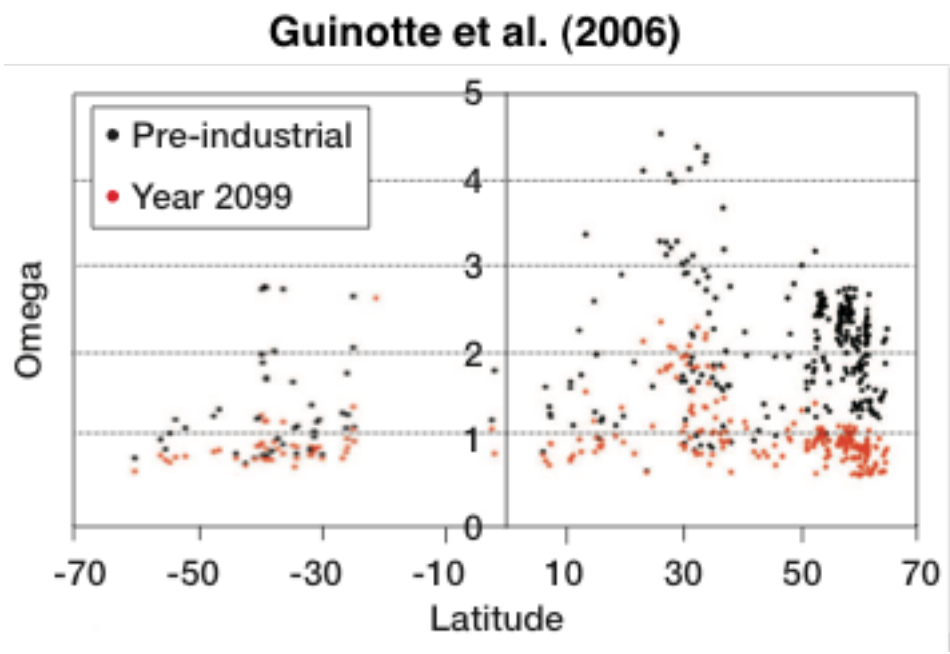

- Guinotte et al. (2006):
  - >95% of 410 coral locations occurred in saturated waters during pre-industrial times
  - 70% of these locations will be in undersaturated waters by 2099
  - Perturbation experiments needed
- Maier et al. (poster):
  - calcification declines at lower pH
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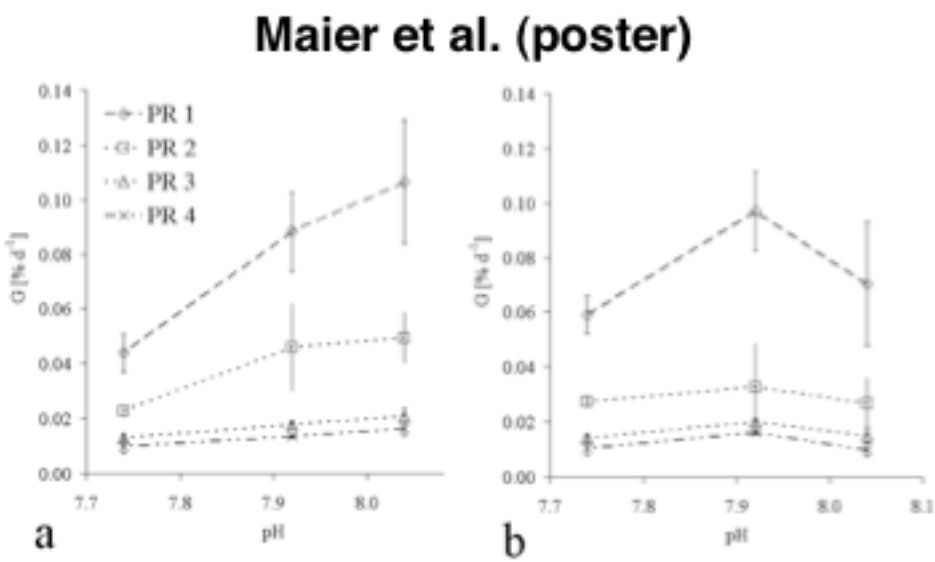

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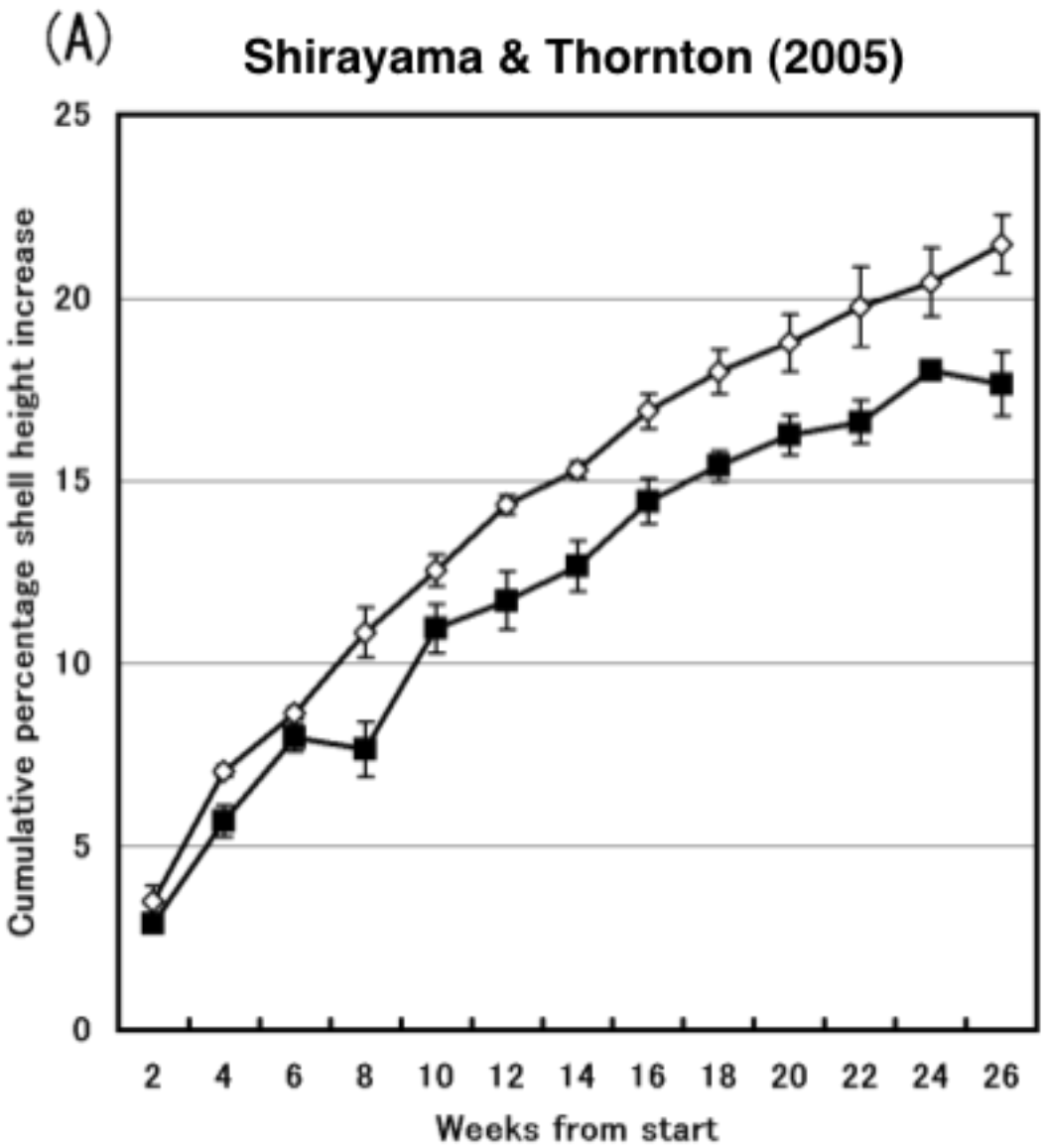

- Many studies carried out prior to 2000; most at very high pCO_2
- Gastropods:
  - Growth and shell extension lower at 560 ppm than in control (Shirayama & Thornton, 2005)
- Bivalves:
  - no effect until pH=7.4 (Berge et al., 2006)
  - strong linear effect (Gazeau et al., 2007)

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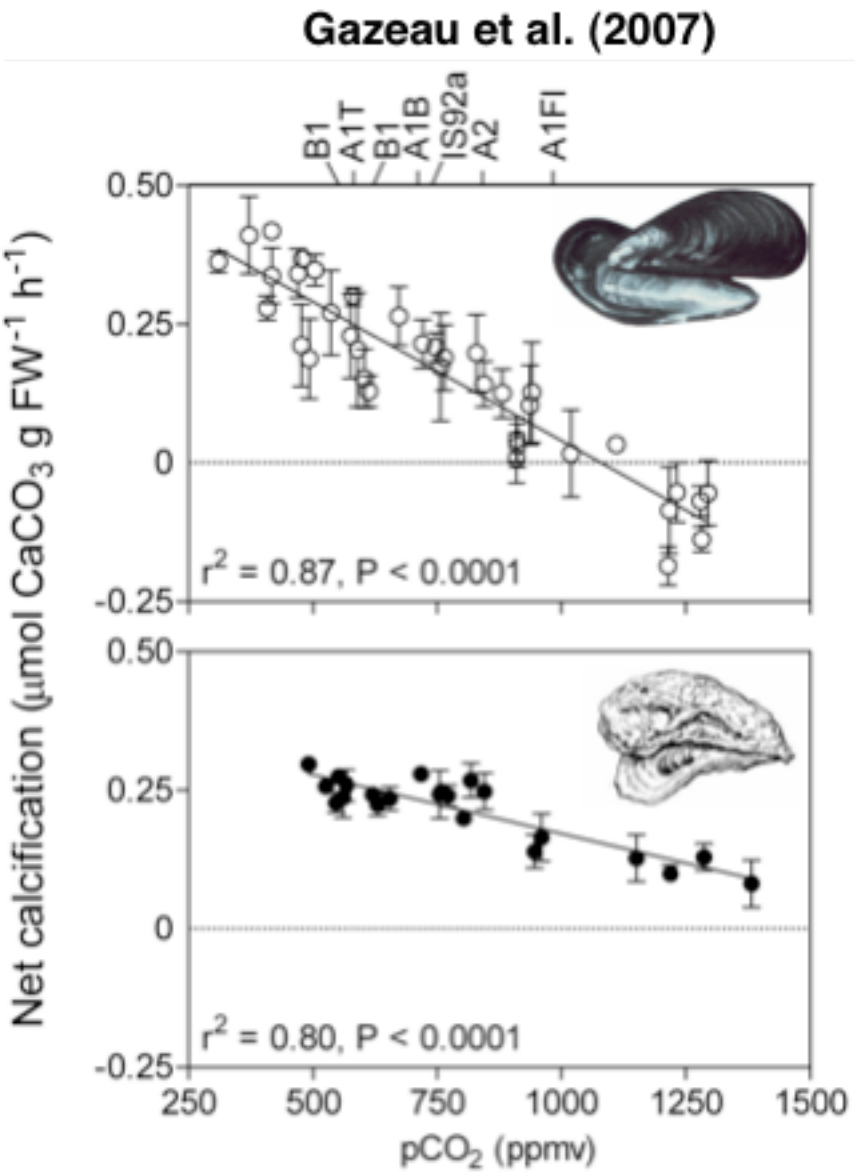

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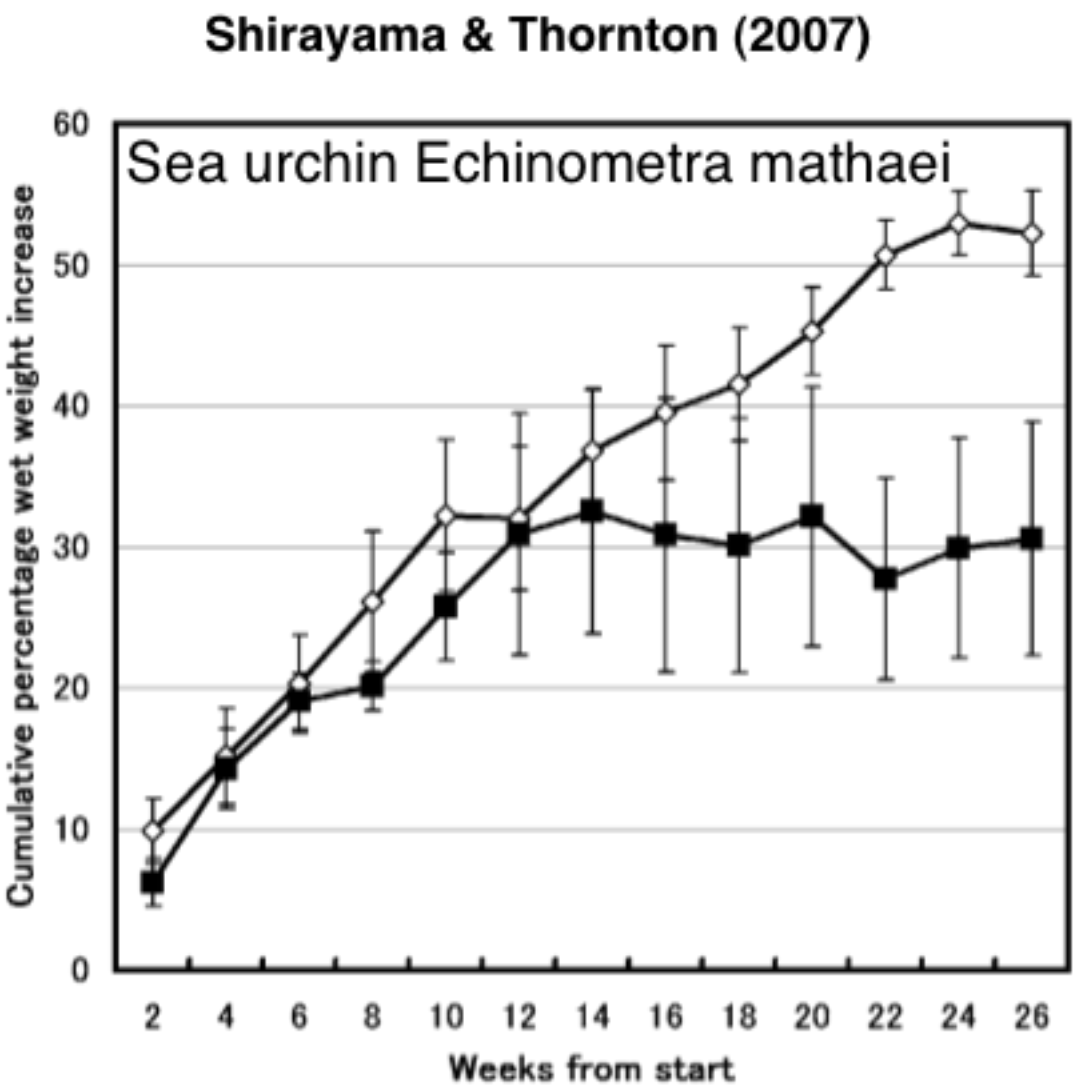

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  - At a cost: decreased mass of muscles. Likely not sustainable.

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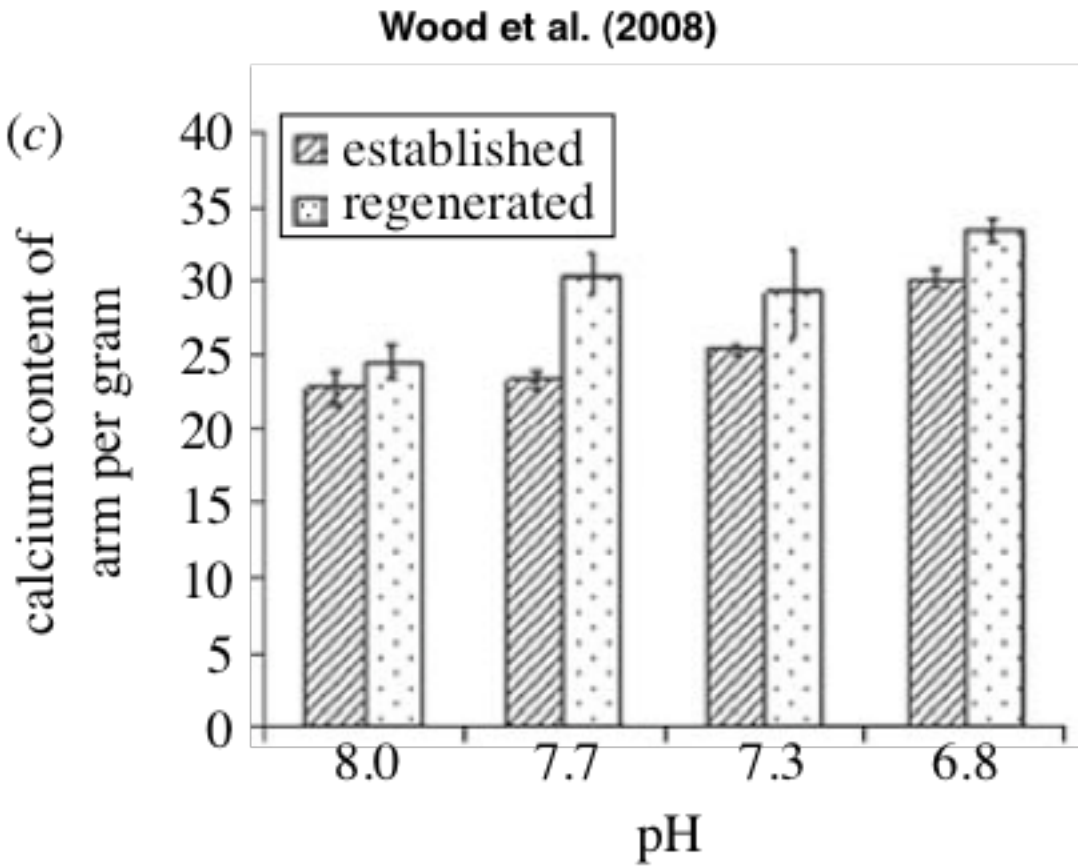

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Dissolution and bioerosion

- Coral reefs (Yates & Halley, 2006):
  - threshold values vary a lot
  - on average: 654 μatm or CO_3 =152 μmol/kg
  - thresholds reached 13% of the time at present
  - predicted that thresholds will be exceeded in the year 2100
- Mediterranean coralline algae (Martin & Gattuso, sbm)
- Cements and bioerosion in Eastern Pacific reefs (Manzello et al., 2008). Similar situation expected in deep-sea coral communities
- Global impact (Andersson et al., 2003):
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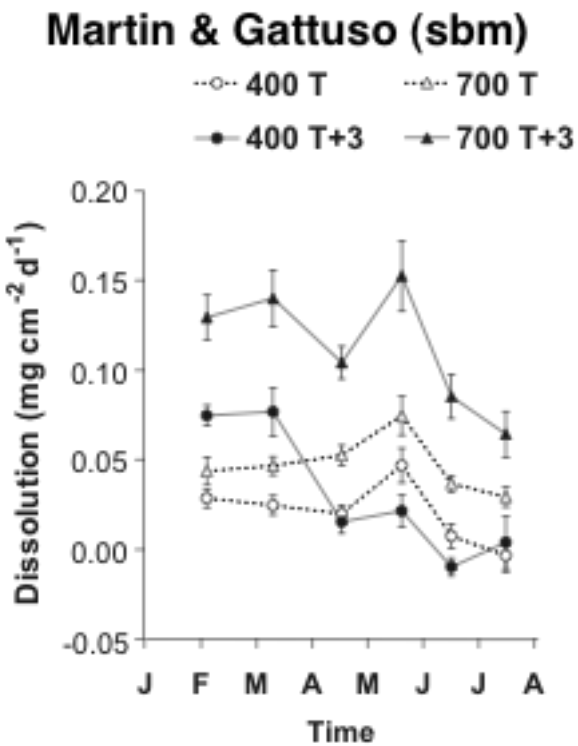

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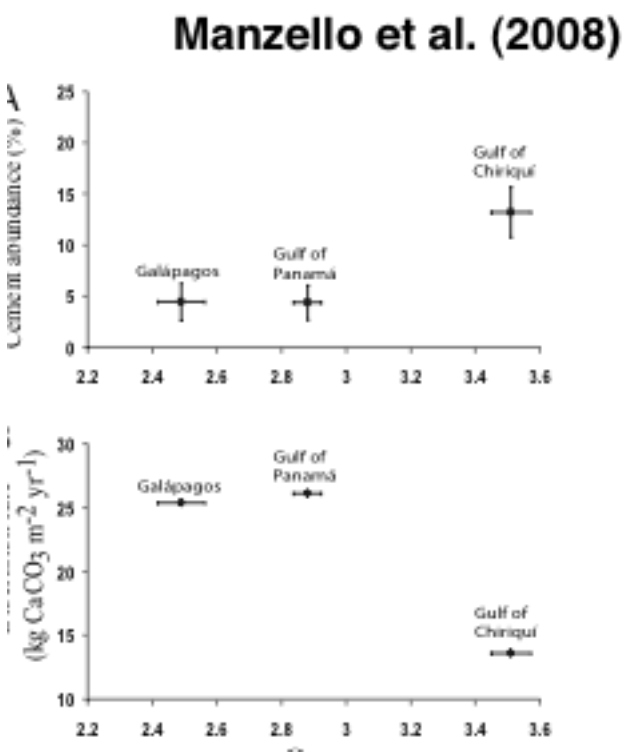

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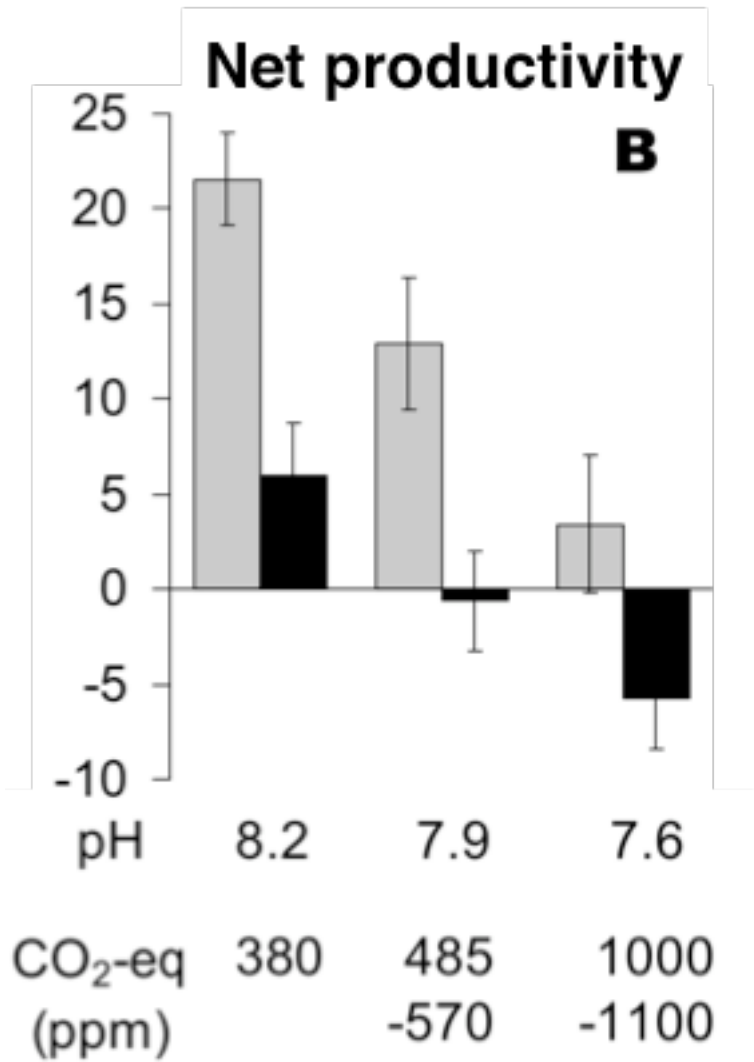
Photosynthesis and respiration: coralline algae



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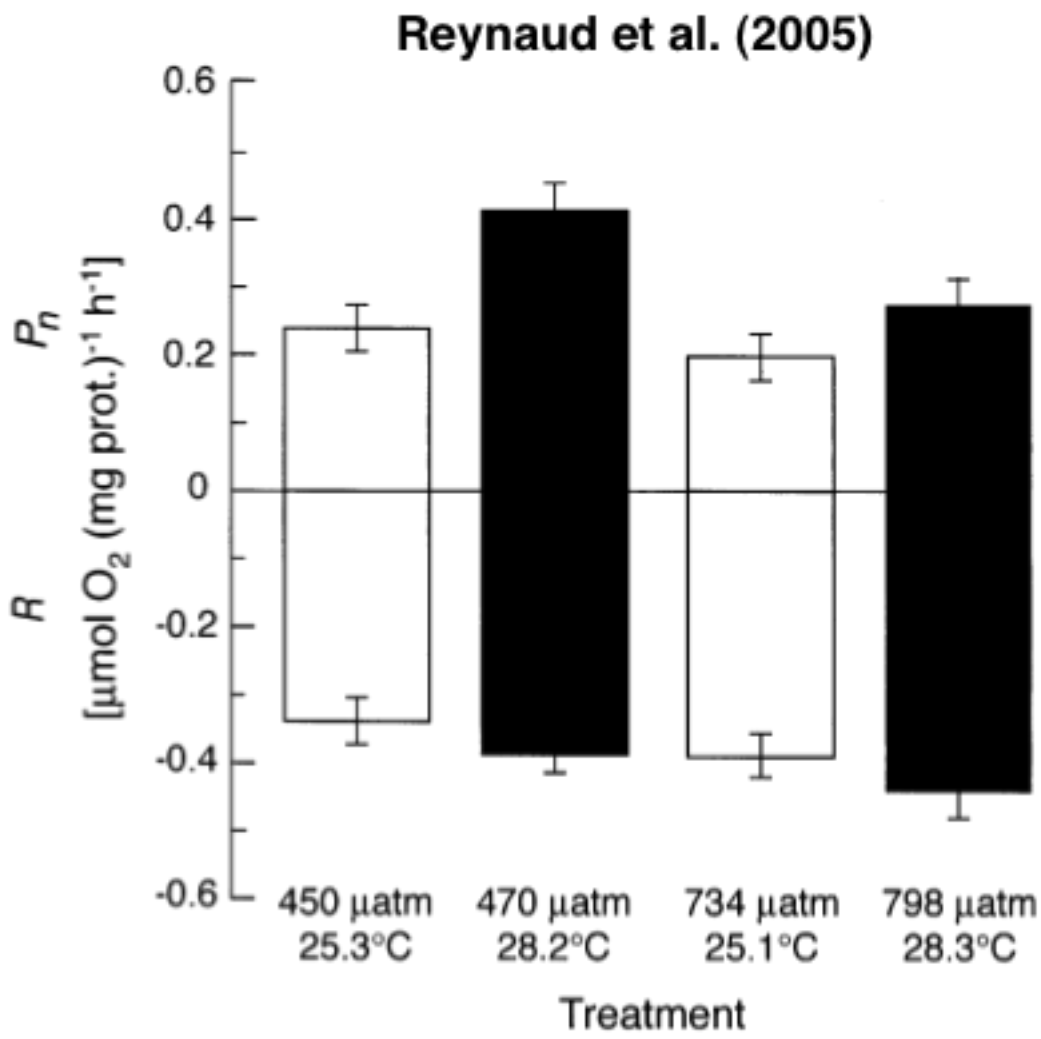

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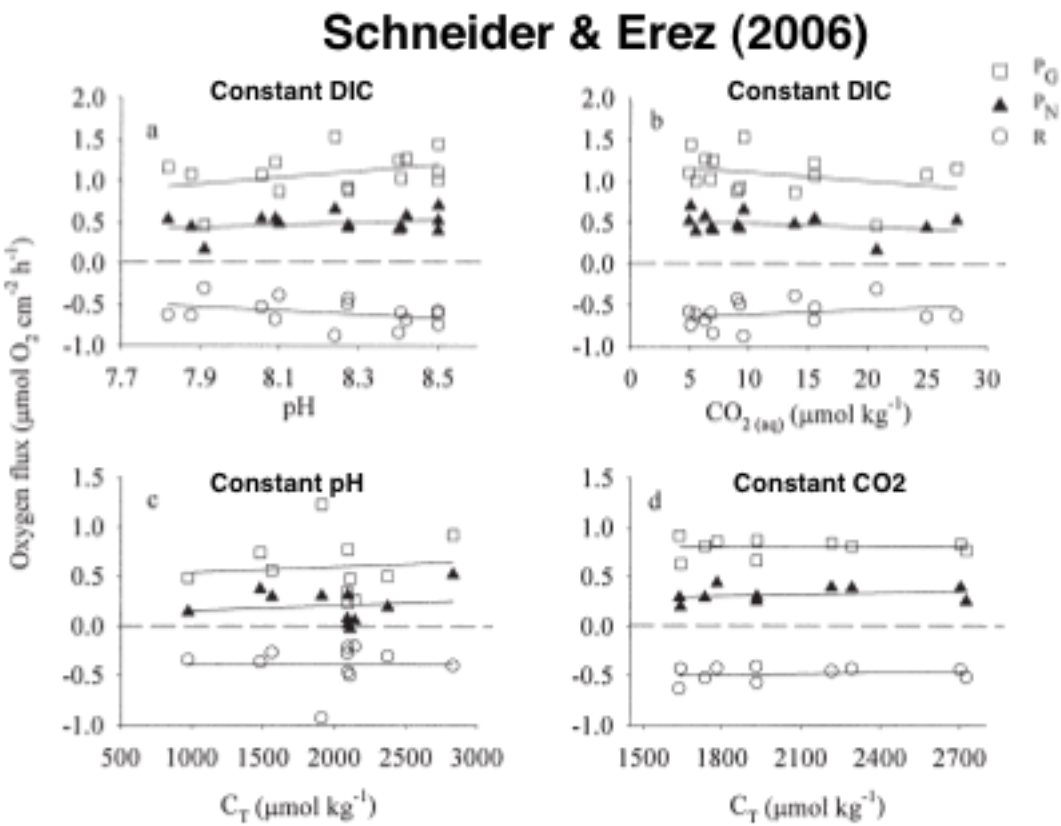

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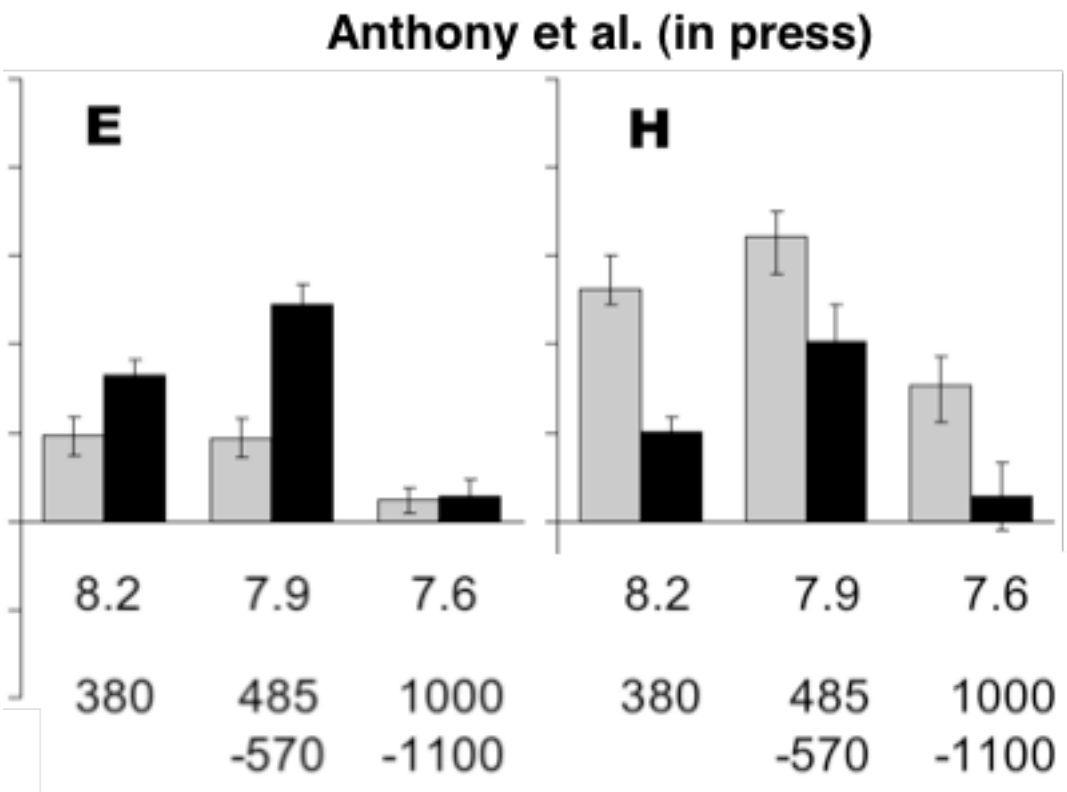

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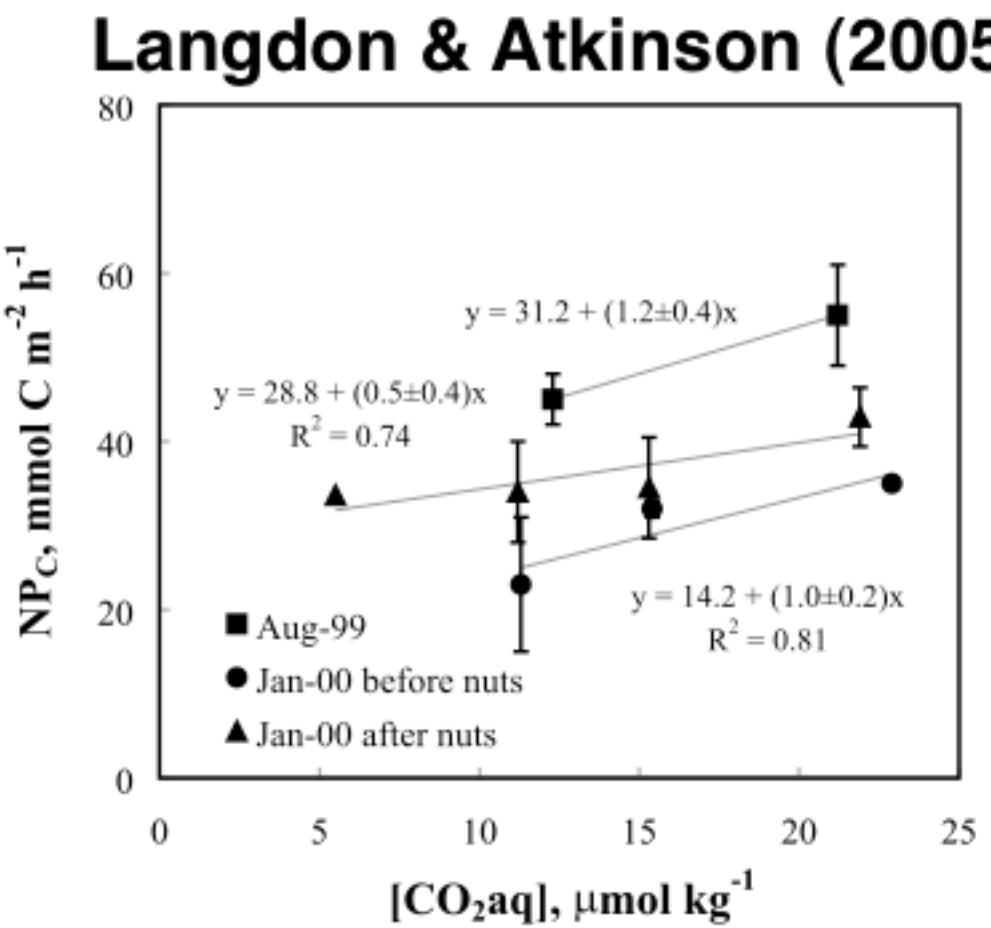

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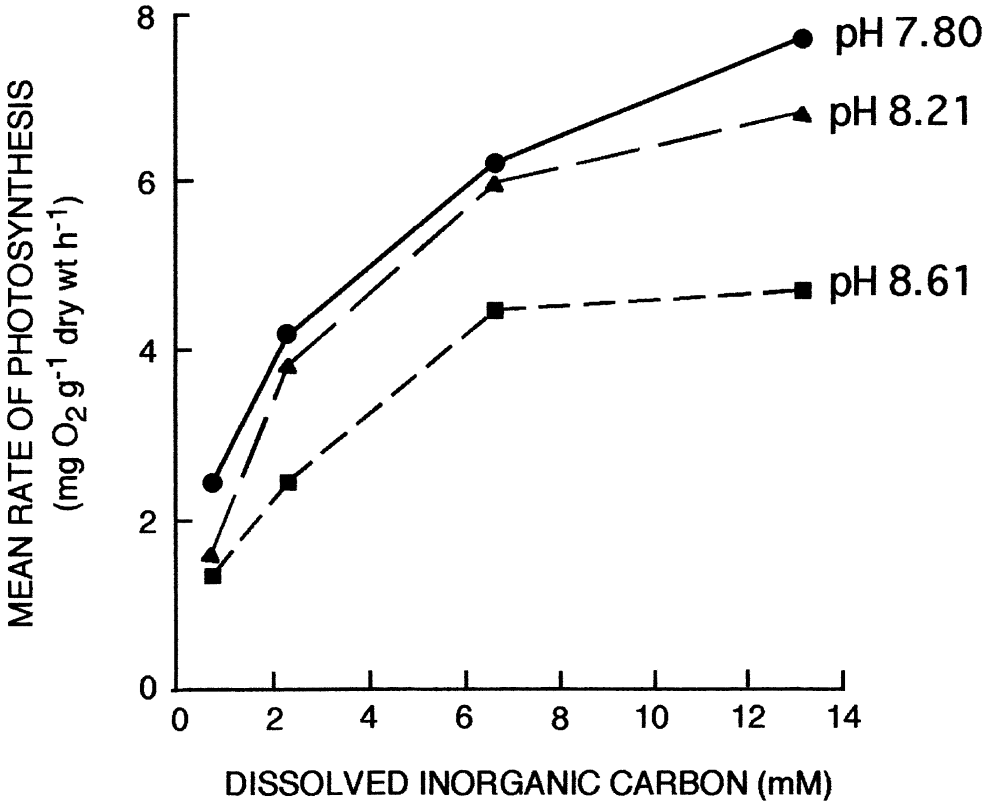

Durako (1993)

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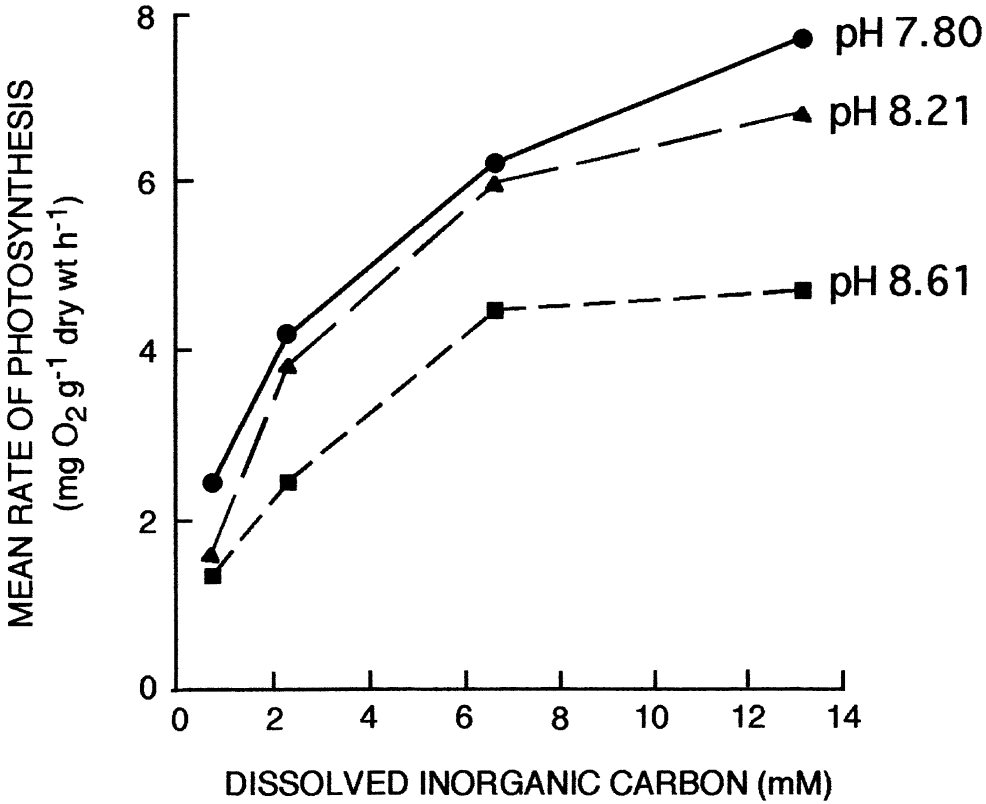

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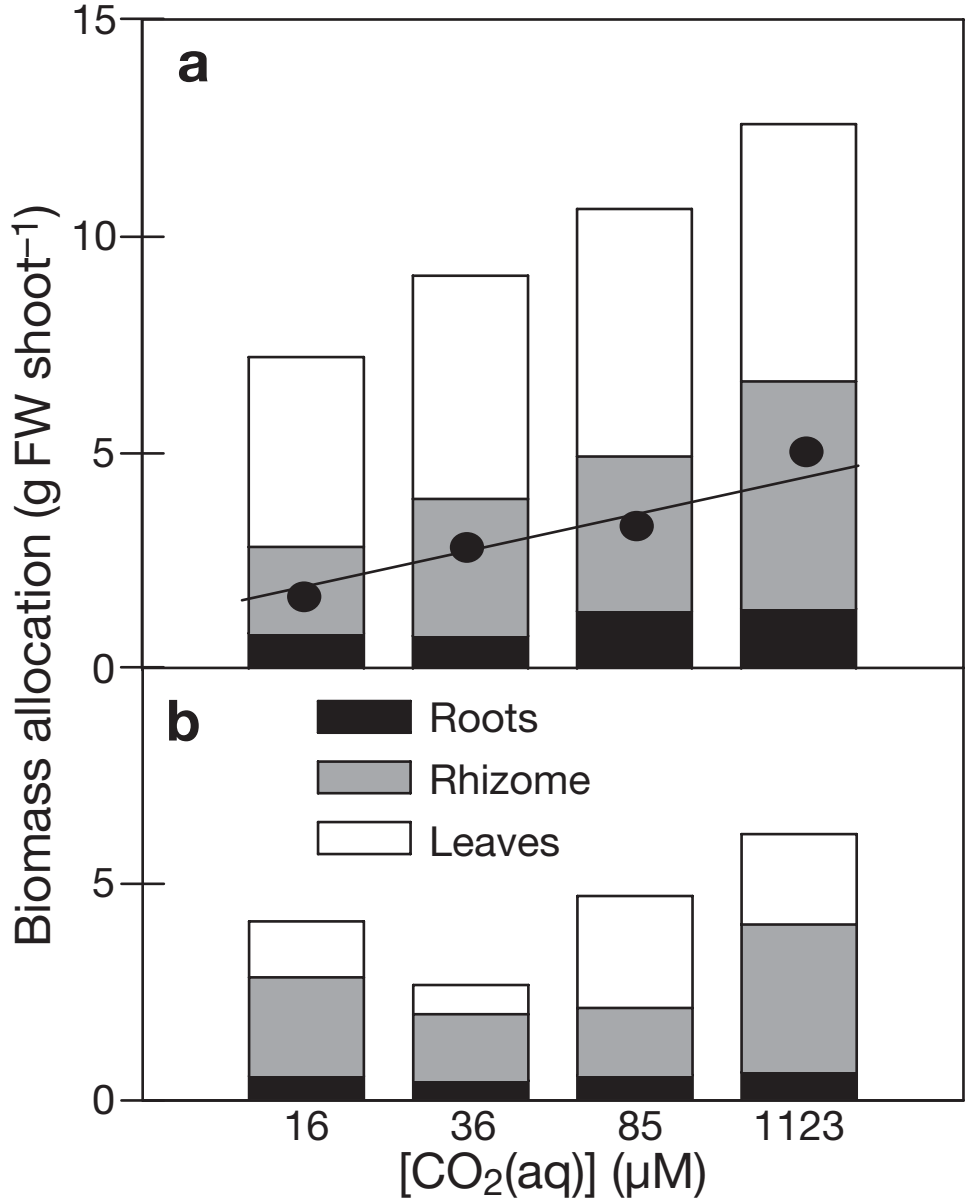
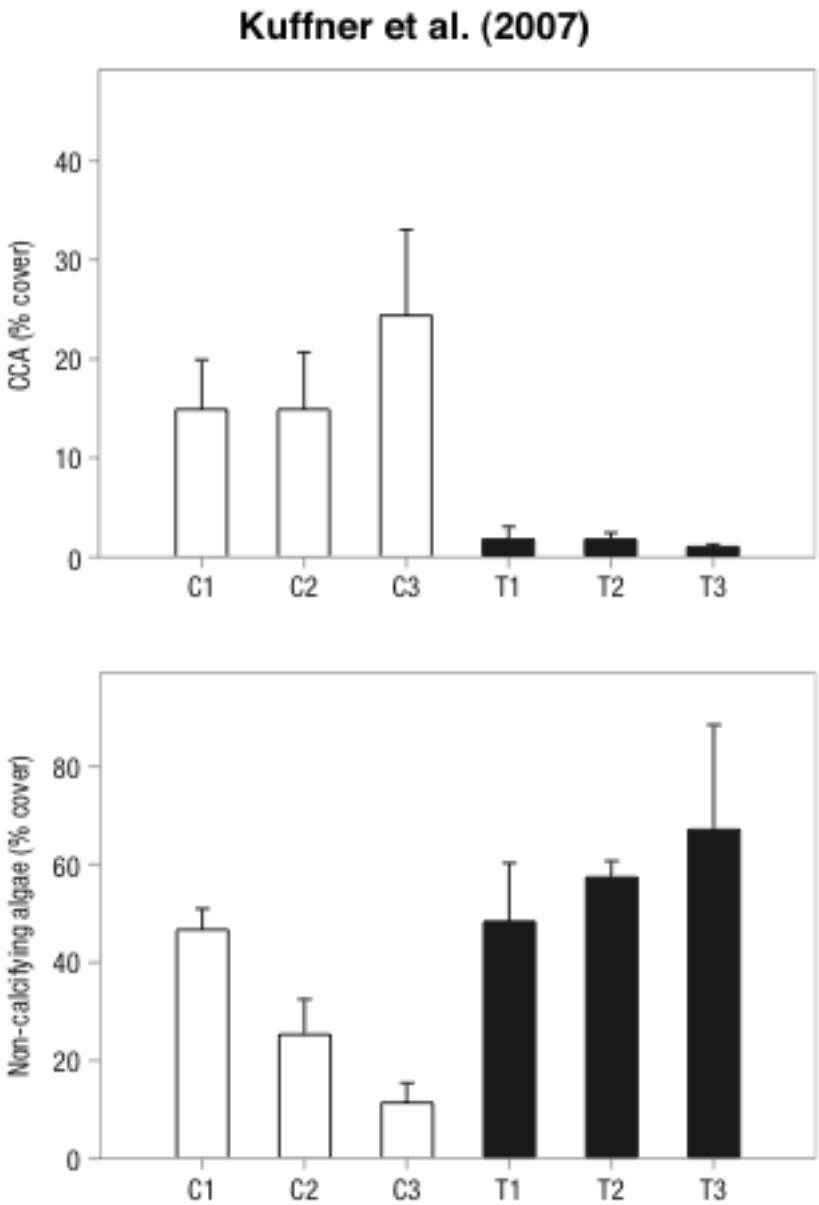


Palacios & Zimmerman (2007)

Reproduction, early life stages and recruitment



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  - Recruitment severely inhibited (Agegian, 1985; Kuffner et al., 2008)
- Coral larvae
  - No effect on settlement (Albright et al., 2008)
- Sea urchins
  - Impact at very high pCO_2 (Kurihara & Shirayama, 2004)
  - Reduced fertilization success (Havenhand, 2008)
  - Depends on the life stage considered (Dupont et al., poster)
- Sea stars
  - No effect on fertilized eggs; larvae highly affected (Dupont et al., poster)
- Brittlestars
  - Species-specific: dramatic decline in one species, more subtle effects in some, no effect in one (Dupont et al., in press; poster)
- Mollusks
  - Mussels (Gazeau et al., unpubl.):
    - 7.8: no impact on hatching and mortality; 10-16% decrease of shell growth
    - 7.6: decreased hatching rate (and growth)
- Tunicates
  - Higher survival and fecundity, faster development (Dupont, poster?)

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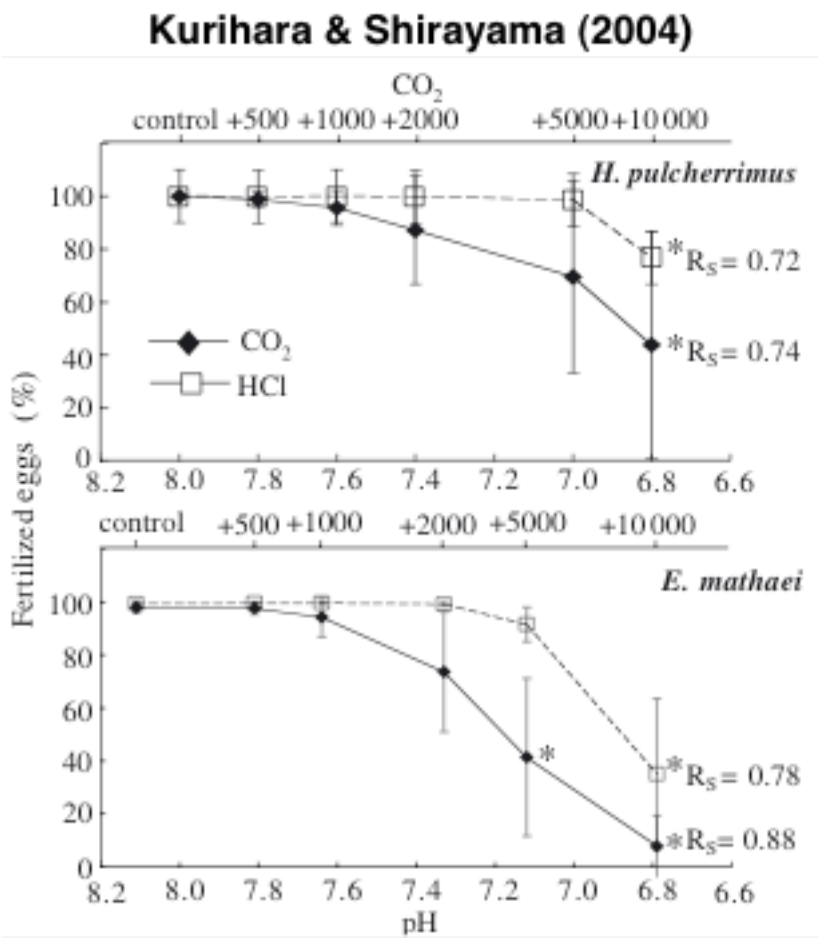
Reproduction, early life stages and recruitment



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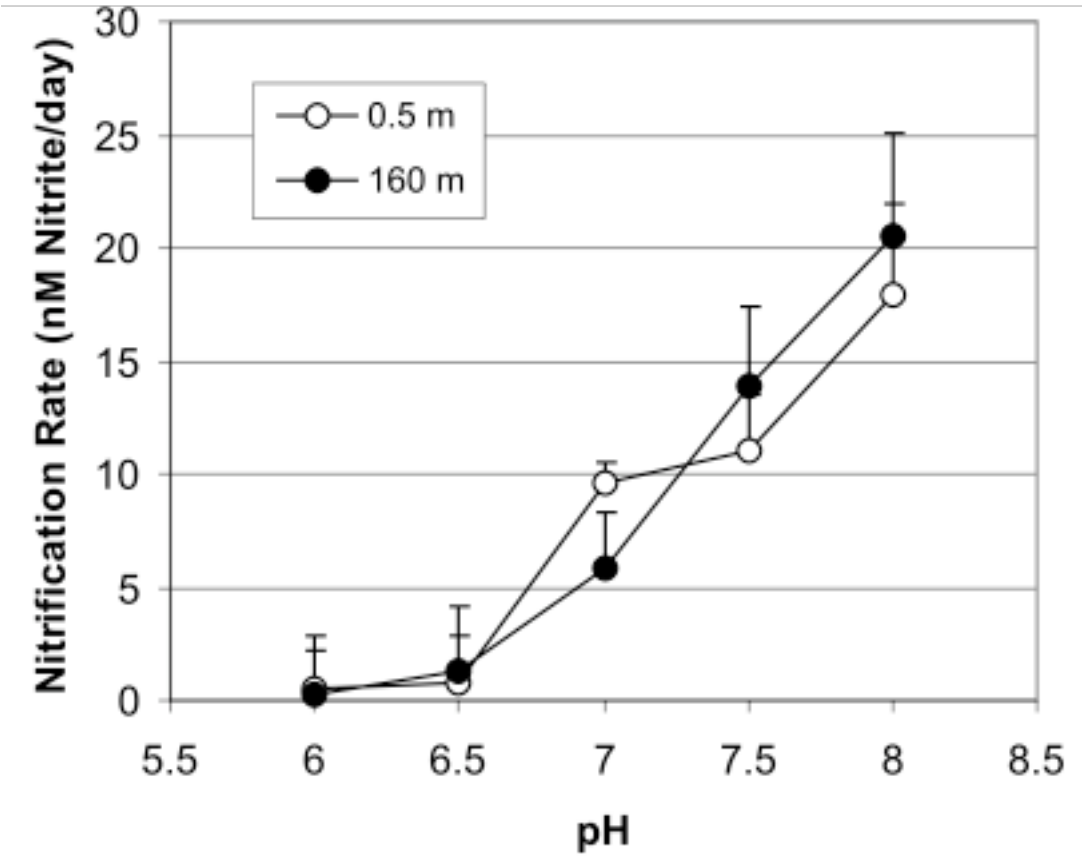

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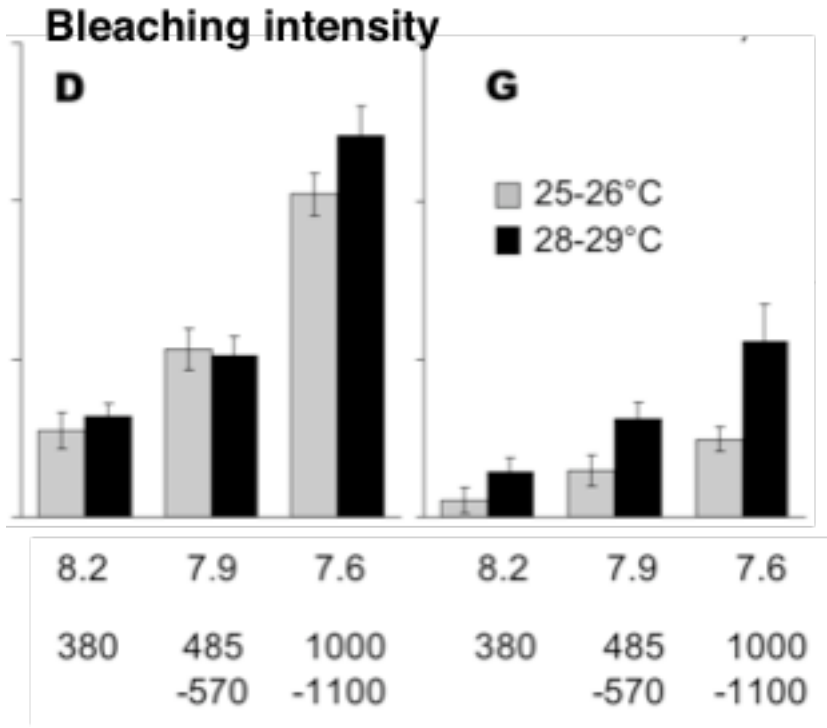

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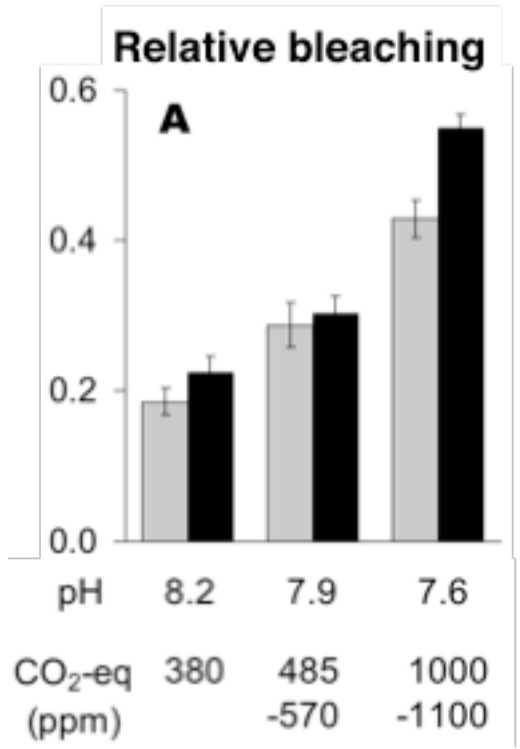

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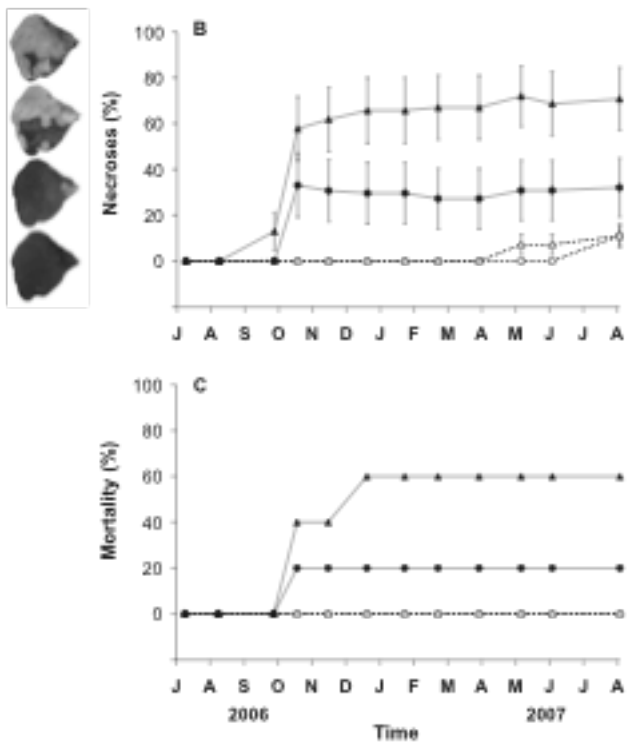

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Biodiversity

- Very few data on the impact on biodiversity. Organism responses difficult to upscale at the community level due to species-specific responses (Widdicombe & Spicer, in press)
- Mediterranean ecosystem affected by CO_2 vents (Hall-Spencer et al., 2008):
  - No calcifying organisms at $pH_T < 7.4$
  - Low pH benefits seagrasses
  - Overall, steep decrease of biodiversity at low pH (more sensitive to invasive species?)

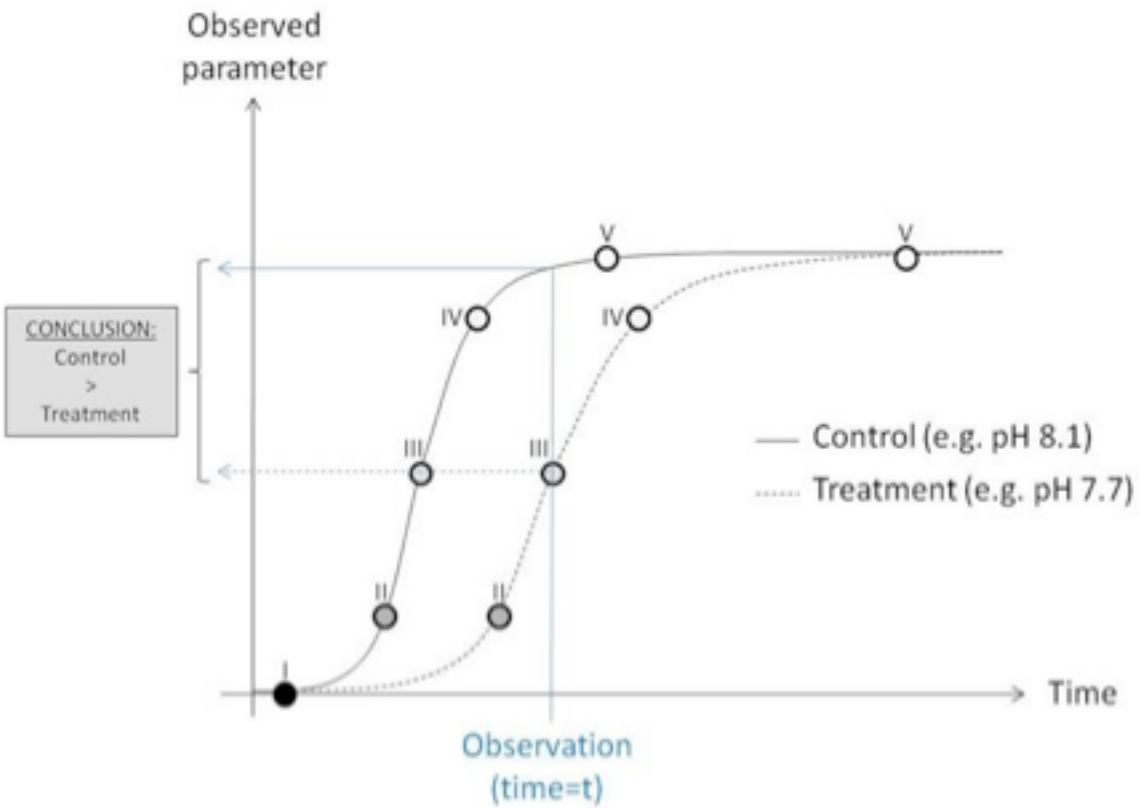
Summary

- Balance of evidence overwhelmingly indicates a negative impact on calcification but some exceptions point to a lack of understanding:
  - A Mediterranean coralline algae and a zooxanthellate coral seem largely insensitive to elevated pCO_2
  - 9 of the 21 species investigated by Ries et al. (unpubl.) exhibit increased calcification at 560 ppm or higher
  - 2 reef-building corals maintain a skeleton at pH=7.3 whereas others dissolve (Fine; but no calcification data yet)
- It is critical to clarify the differences: methodological flaw, differences in physiological or molecular mechanisms, species or strain differences?

A plea for providing open access to data (once published)

- Number of perturbation experiments has increased and much more data to come
- Meta-analysis: a key tool to investigate very diverse responses
- Few publications include data
- Data required:
  - carbonate chemistry (at least 2 parameters) measured according to Dickson et al. (2007)
  - salinity and temperature
  - processes investigated
  - any other ancillary data
- Could be in the paper, as supplementary information or uploaded in a database (cf. EPOCA)
- Both environmentally-relevant and extreme pCO_2/pH (to investigate molecular and physiological processes)

Gaps (1)



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- Go beyond calcification
- Interactions:
  - temperature
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  - light
- Acclimation/adaptation:
  - some long-term experiments now available
  - CO_2 vents

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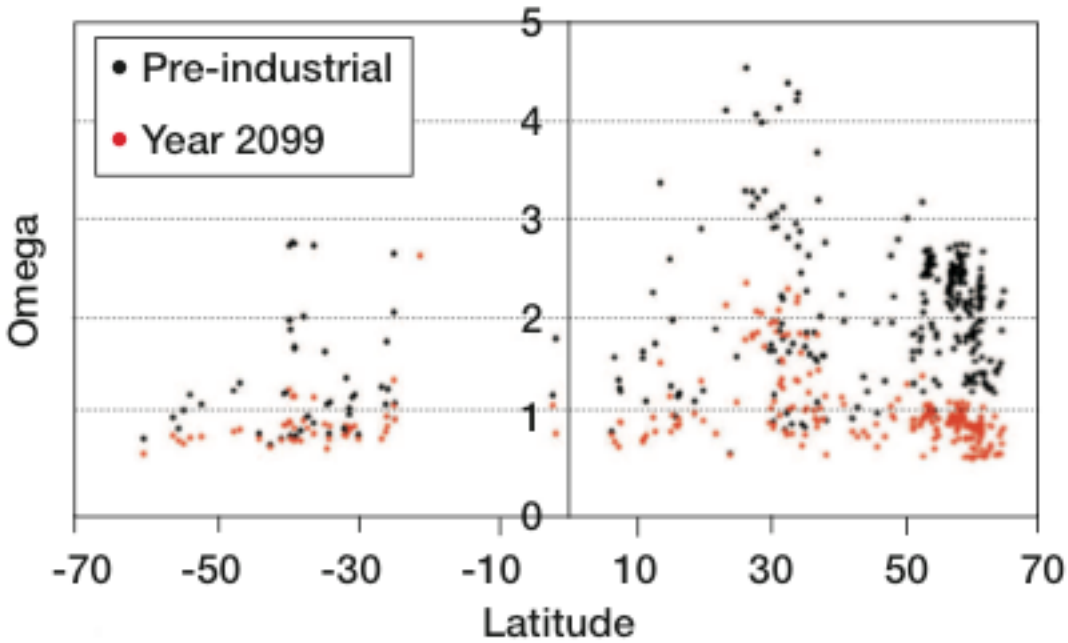

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  - bacteria, archea and viruses
- Sedimentary processes:
  - uptake and release of nutrients and pollutants
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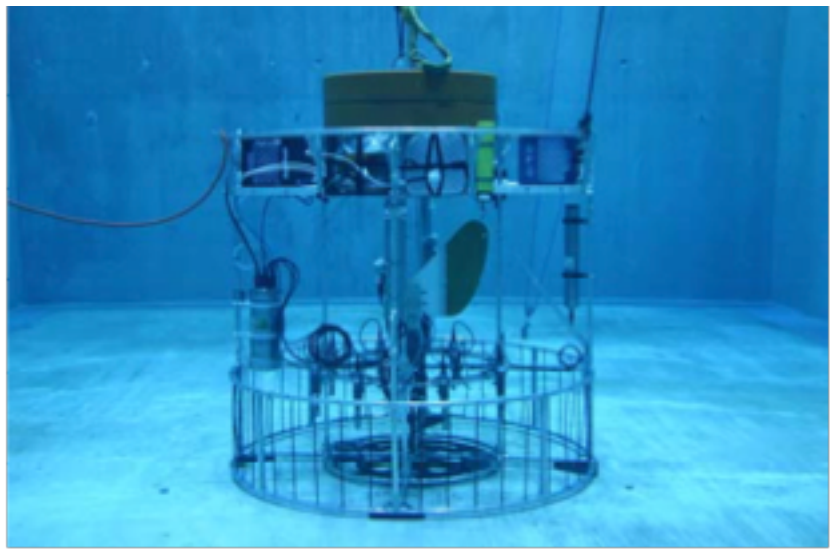

FOCE Prototype in the MBARI test tank (Kirkwood & Brewer)

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EPOCA

European Project on OCean Acidification

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