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The effects of rising seawater CO_2 on marine zooplankton

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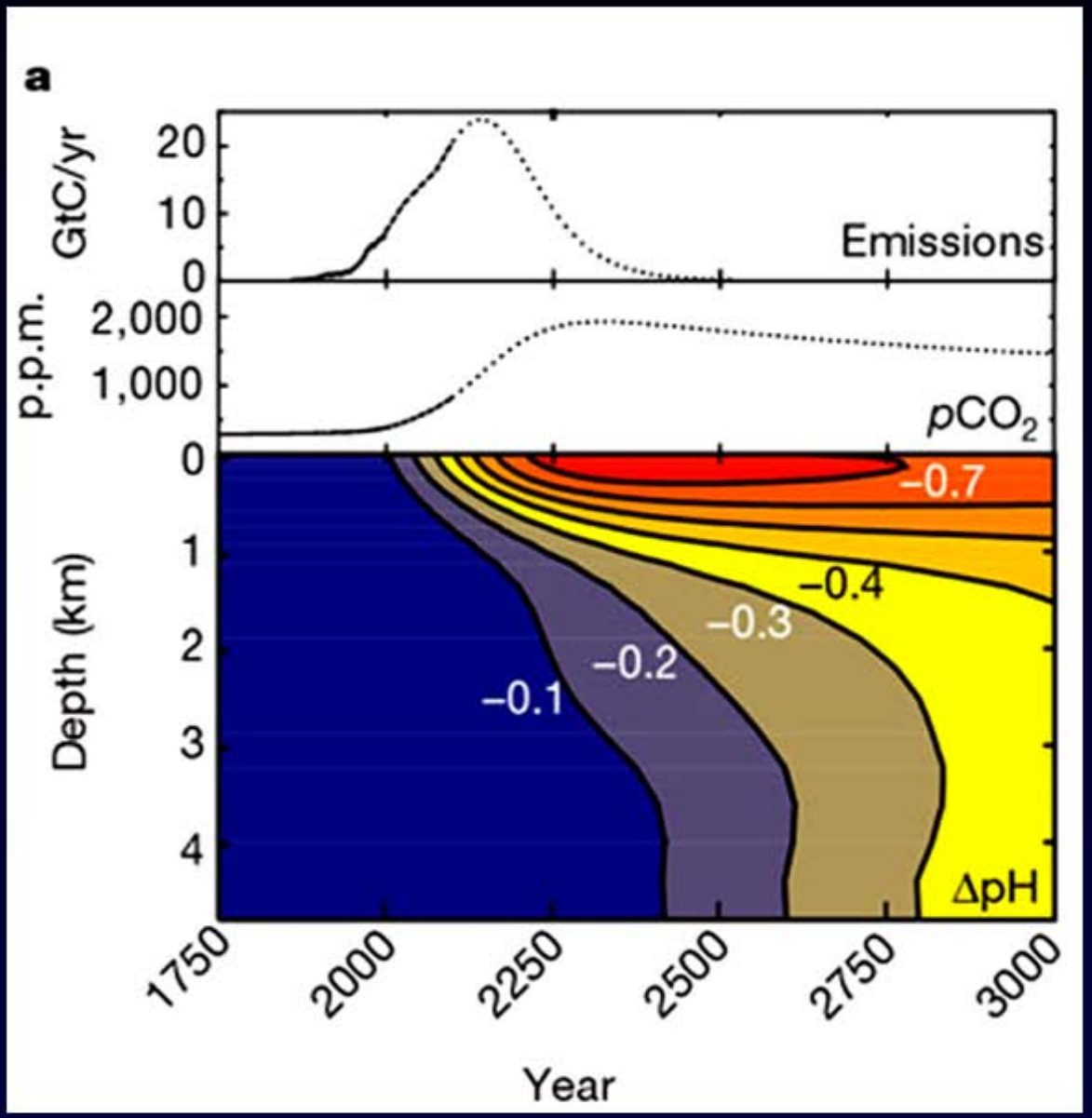
Projected ocean acidification by elevated CO_2



Based on IPCC 1992a emission scenario till 2100 and logistic function thereafter

Caldeira & Wickett 2003

High CO_2 acidifies sea water and reduces $CaCO_3$ saturation state

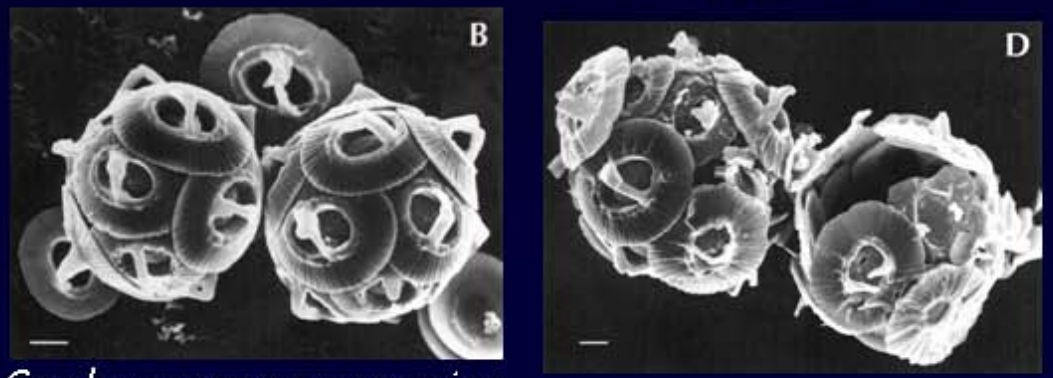
$$CO_2\uparrow + H_2O \rightleftharpoons H_2CO_3 \rightleftharpoons H^+ + HCO_3^-$$

$$HCO_3^- \rightleftharpoons H^+ + CO_3^{2-}\downarrow$$

$$\Omega = \frac{[Ca^{2+}]_{sw} \times [CO_3^{2-}]_{sw}}{K_{sp}}$$

Today's world
pCO_2: 280-380 ppmV

High-CO_2 world
pCO_2: 580-720 ppmV



Gephyrocapsa oceanica

Ulf Riebesell
Leibniz-Institut für Meereswissenschaften
Kiel University, Germany

Calcification rates of corals, foraminiferans and coccolithophores decrease even when Ω is > 1 by high CO_2.

Aims of this study

1. Clarify short-term (acute) effects of high CO_2 seawater on the planktonic larval stages of sea urchins and oyster

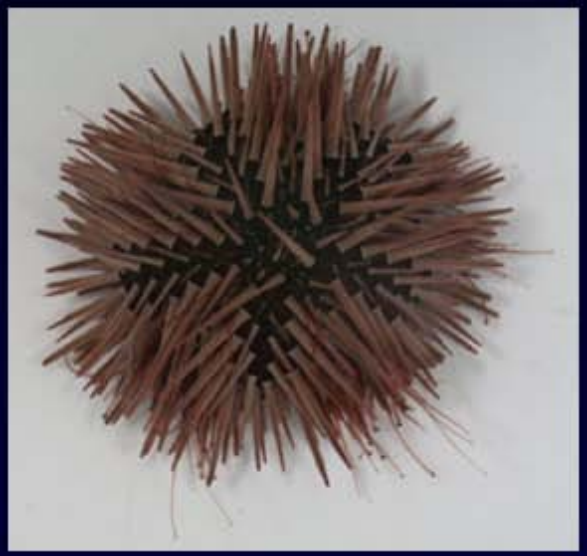
2. Clarify long-term (chronic) effects of high CO_2 seawater on copepods and shrimps

Effects of high CO_2 seawater on sea urchin larvae

バフンウニ

Hemicentrotus pulcherrimus

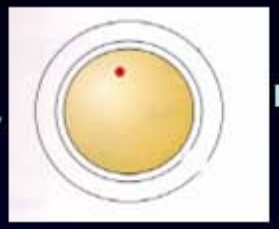
ナガウニ

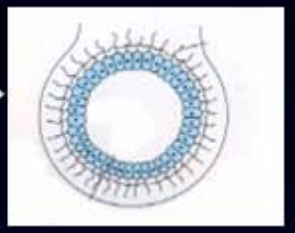


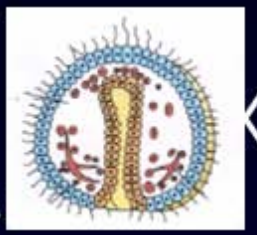
Echinometra mathaei

Experimental conditions

Hemicentrotus pulcherrimus

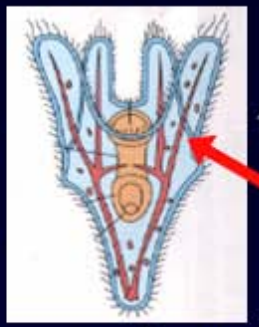






Start to secrete $CaCO_3$

Pluteus larvae



$CaCO_3$ spicules

Settlement

Benthic stage

Planktonic stage

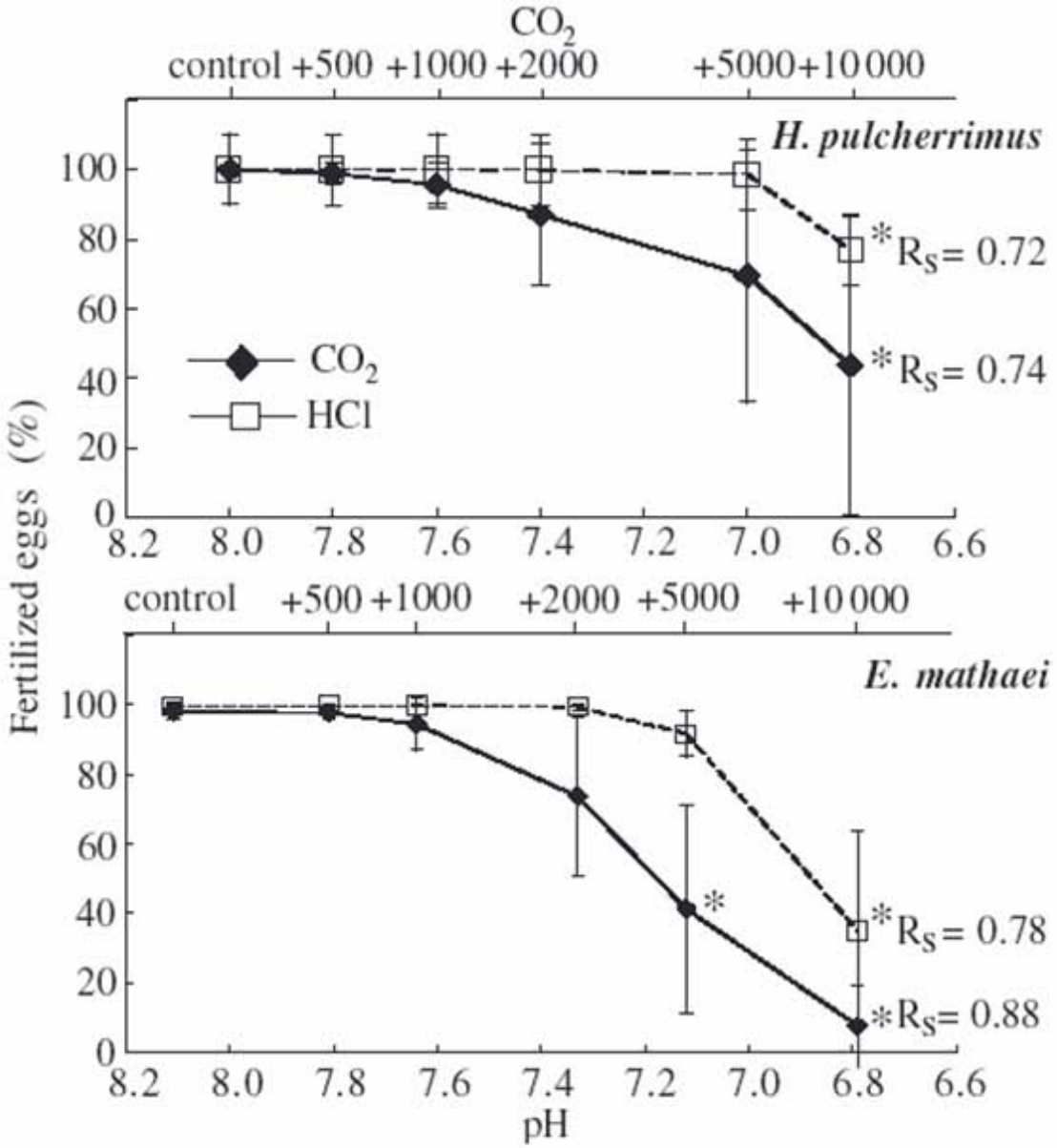
CO_2	control (360ppm)	+500	+1,000	+2,000	+5,000	+10,000
pH	8.1	7.8	7.6	7.3	7.1	6.8

Fertilization rate

H. pulcherrimus

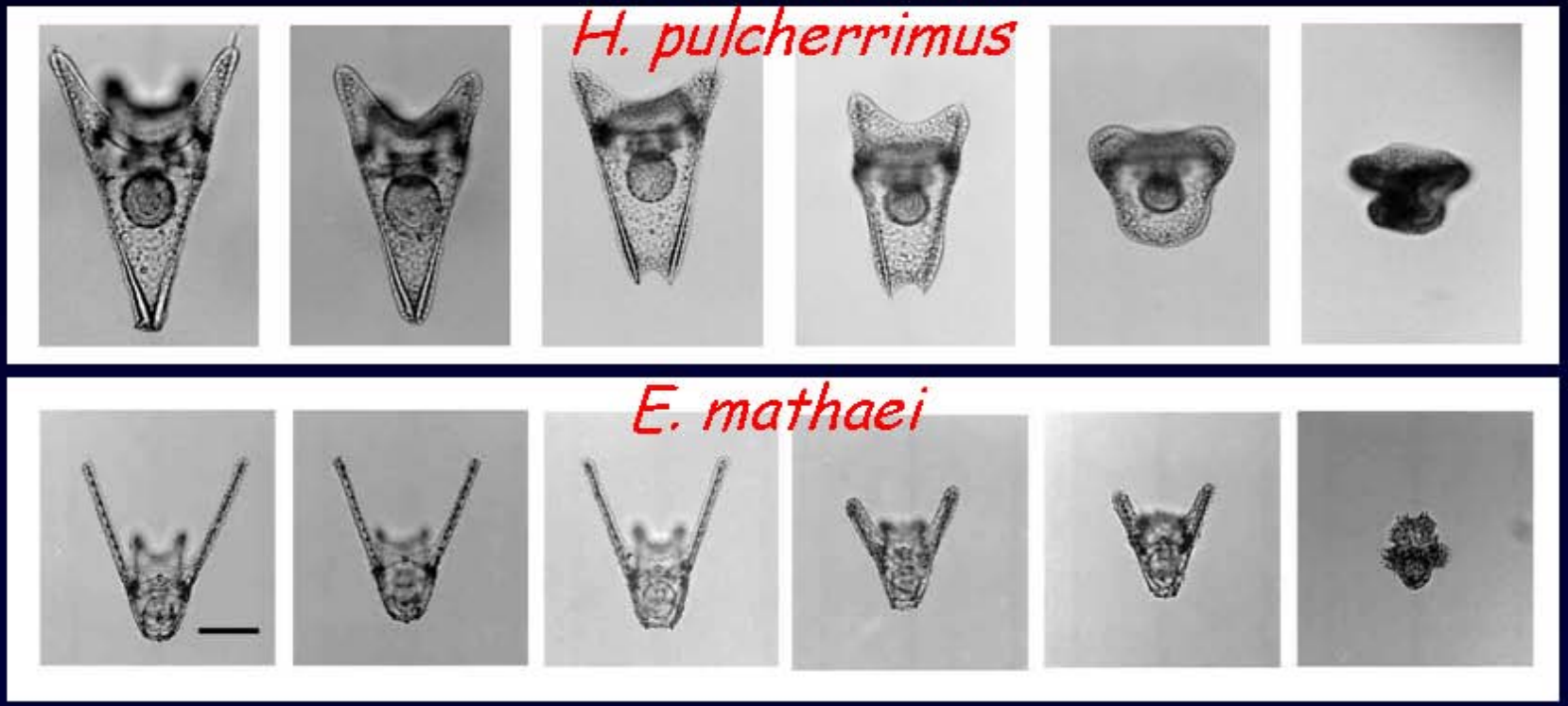
E. mathaei

Kurihara & Shirayama (2004) MEPS



Pluteus larval morphology

CO_2	control	+500	+1000	+2000	+5000	+10000
pH	8.1	7.8	7.6	7.3	7.1	6.8



Kurihara et al. (2004) J. Oceanog.

Effects of high CO_2 seawater on oyster larvae

マガキ　*Crassostrea gigas*

http://upload.wikimedia.org/wikipedia/commons/3/37/Oysters_p1040741.jpg

Experimental conditions

Crassostrea gigas

Planktonic stage

Egg+sperm

Fertilized egg

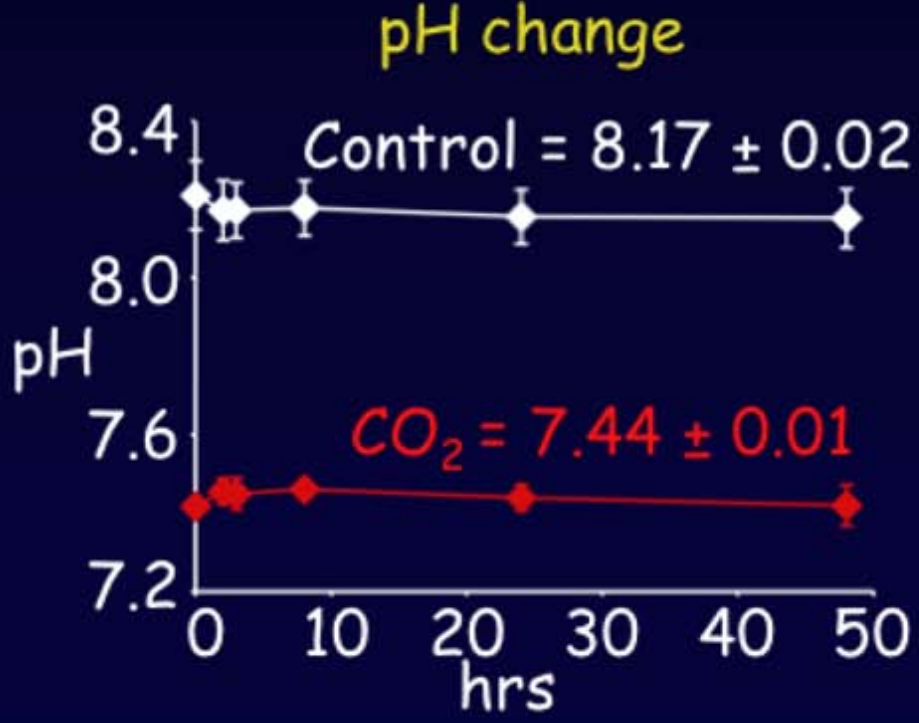
Trocophore larvae

Veriger-larvae

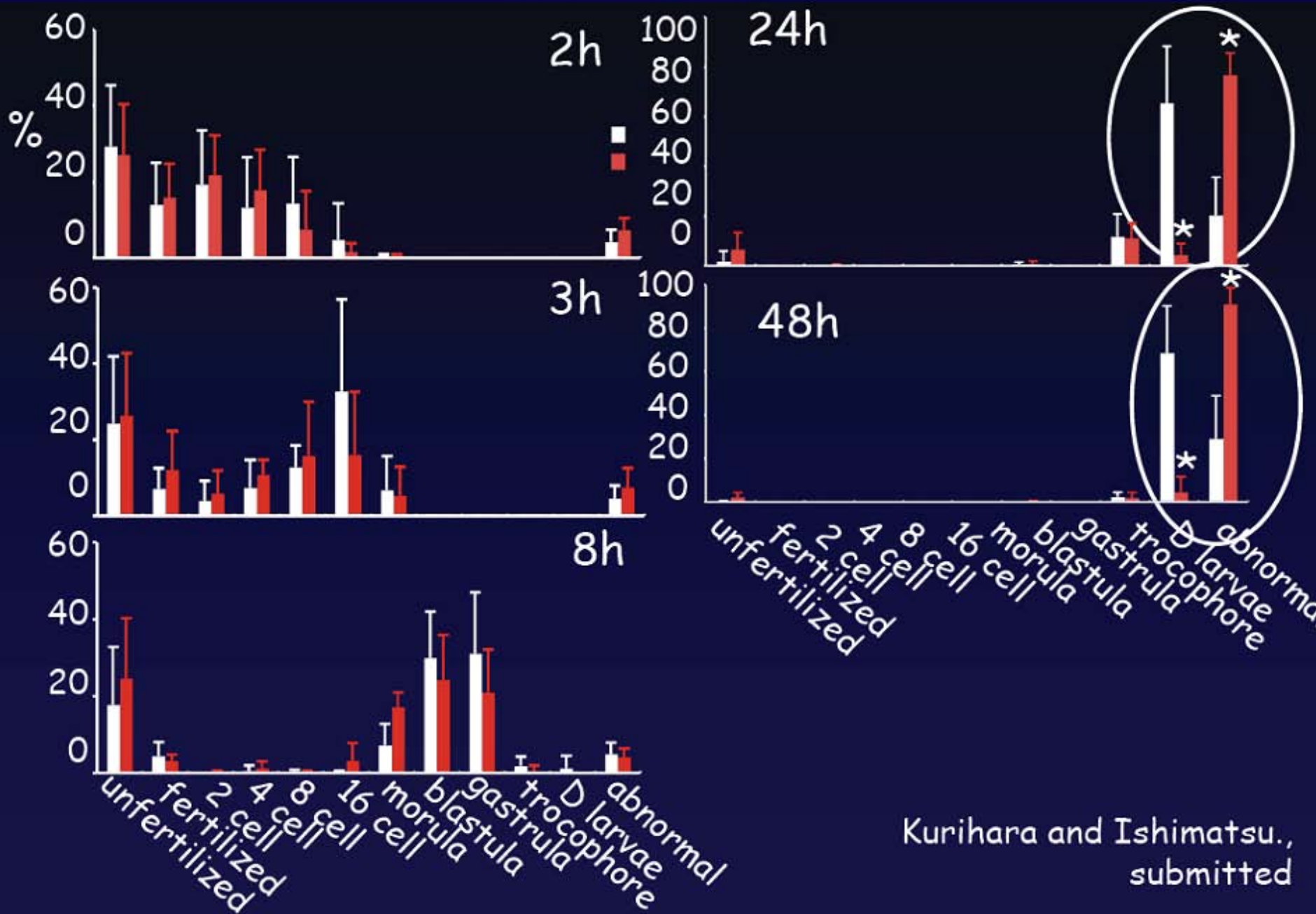
Juvenile

Start to secrete $CaCO_3$

	Control	CO_2
pH	8.2	7.4
Temp (°C)	23	23
Sampling	2, 3, 8, 24, 48hrs	

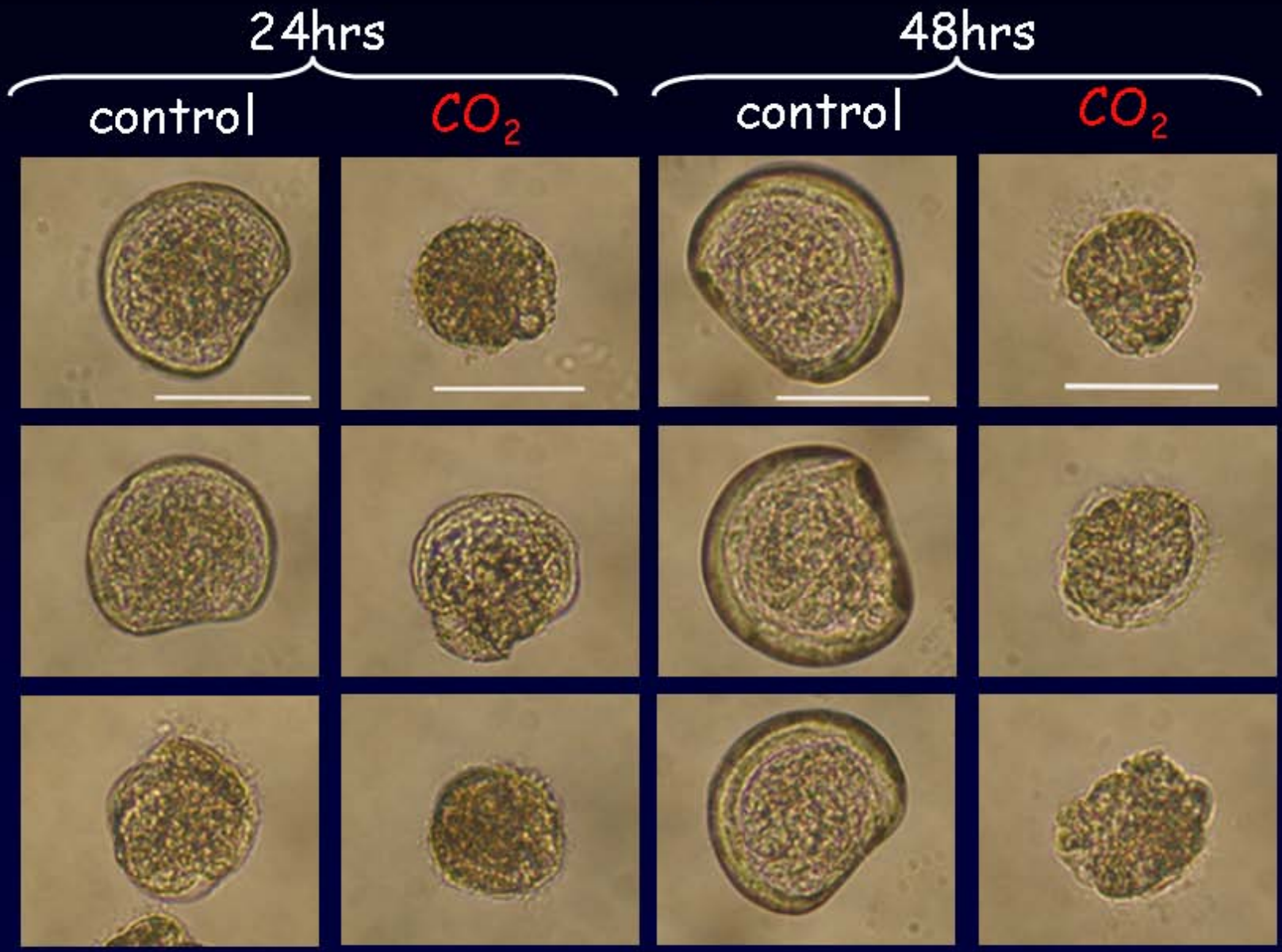


Development

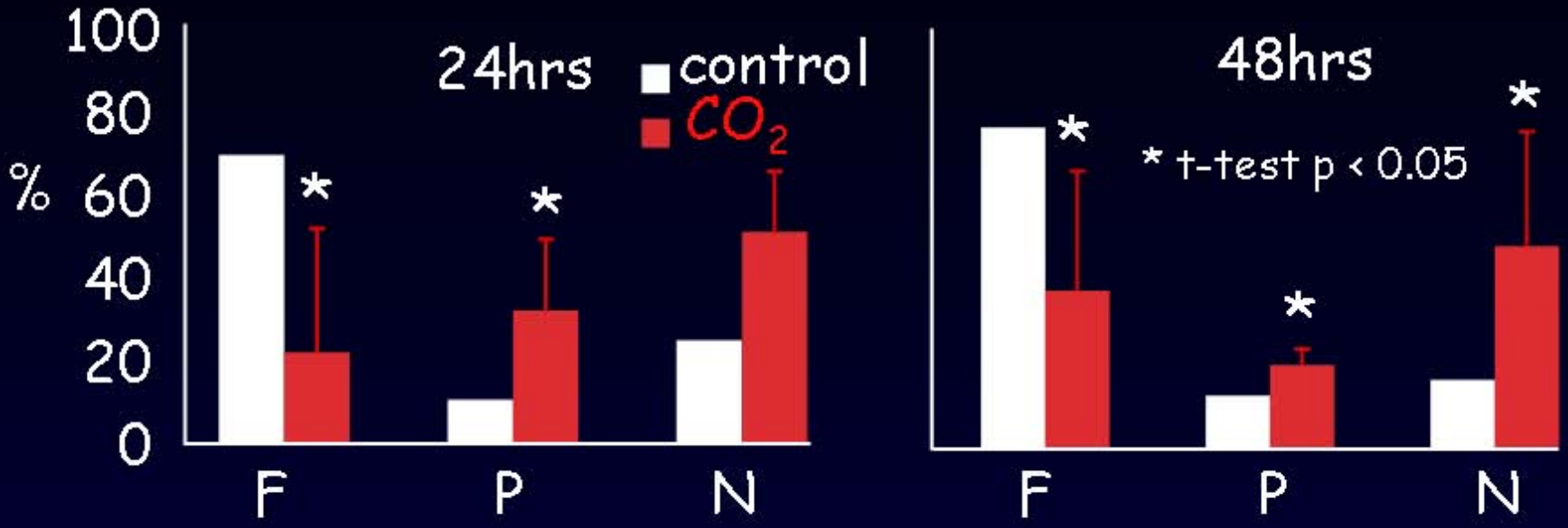


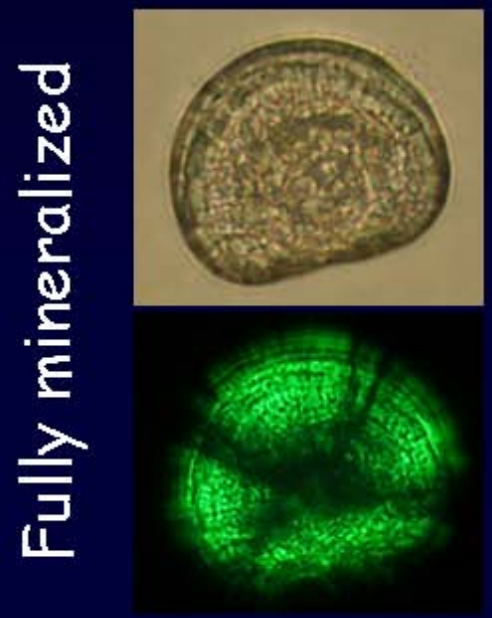
Kurihara and Ishimatsu., submitted

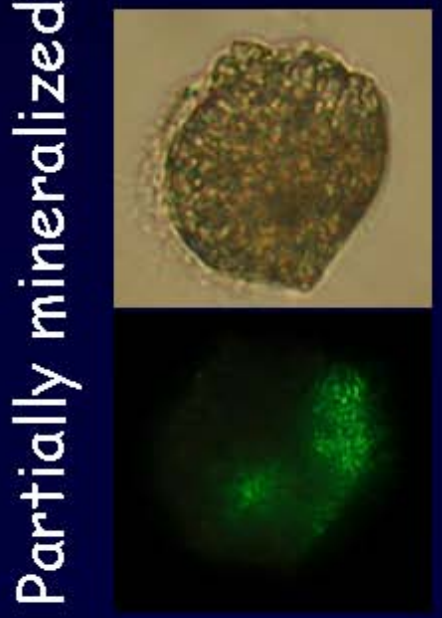
Larval morphology

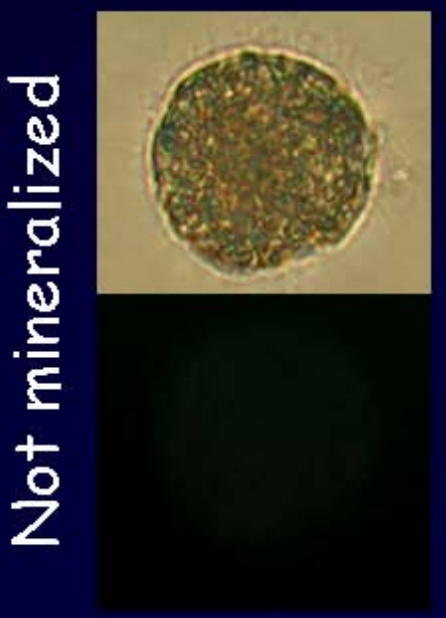


Shell mineralization









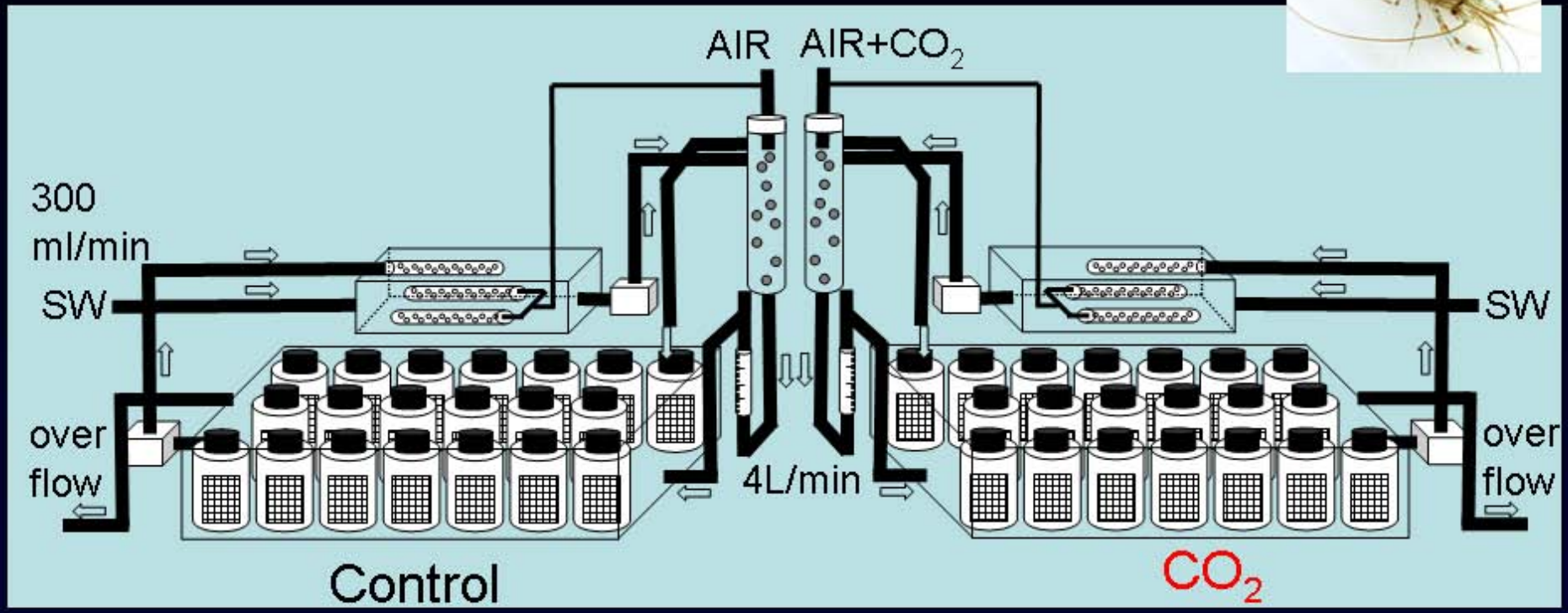
Long-term effects of high CO_2 seawater on crustaceans

イソスジエビ

Palaemon pacificus

Acartia tsuensis

Experimental conditions



CO_2 (ppm)	1900	1000
Period (week)	15	30
pH	7.64 ± 0.09	7.87 ± 0.05
Temperature (℃)	26.2 ± 0.4	24.9 ± 0.4

Survival and growth

Palaemon Pacificus

Survival rate %

100
90
80
70
60
50

—control
—1900ppm

Log-Rank test
$p < 0.05$

— control
— 1000ppm

Growth rate %

150
125
100
75

control
1900ppm

*
*
*
*

300
250
200
150
100

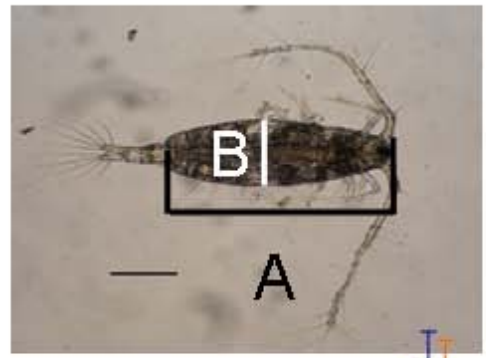
control
1000ppm

0 3 6 9 12 15

0 6 12 18 24 30

Weeks

Body size



μ m

A: promosome length

B: width

control

2000ppm

1000
800
600
400
200
0

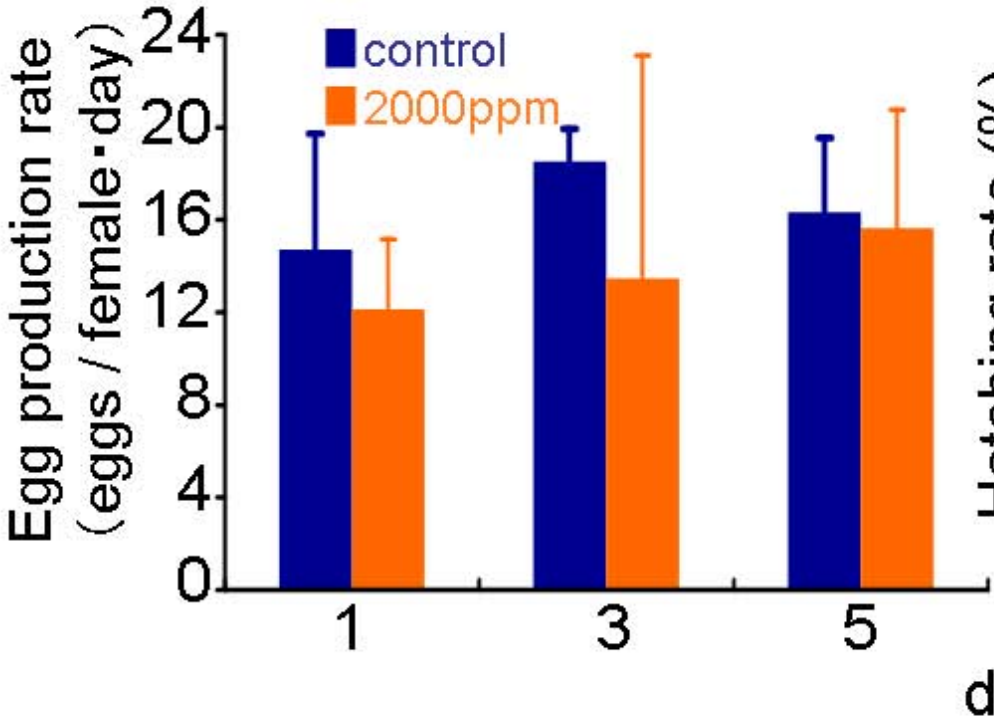
300
250
200
150
100
50
0

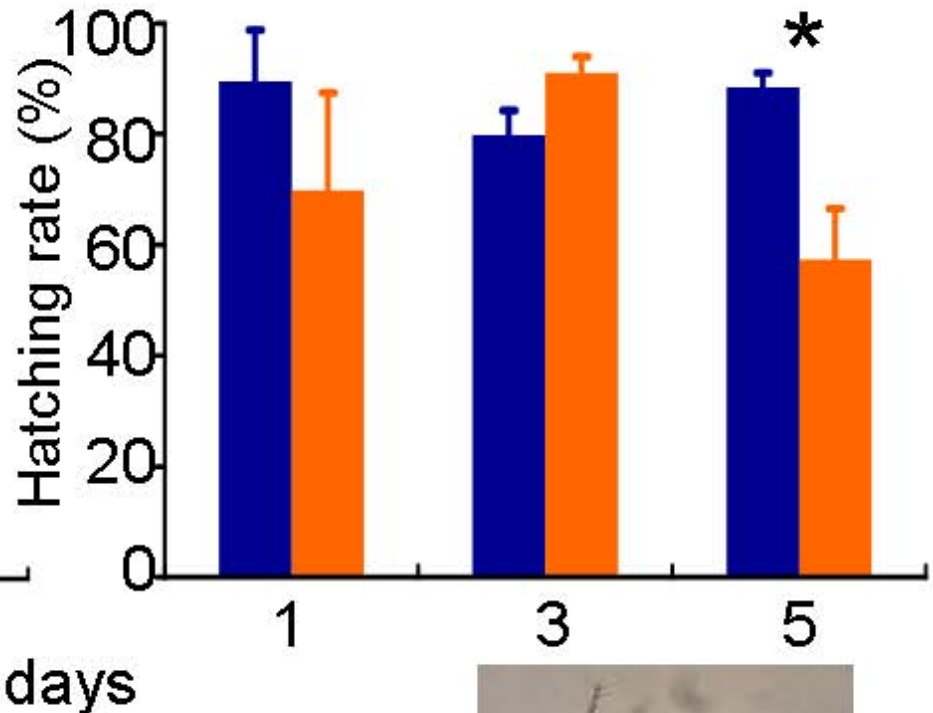
2 3 4 5 6 1 2 3 ♀ ♂ ♀ ♂ ♀ ♂

nauplius copepodite

Mean ± SD, N = 60-70 depending on survival

Egg production and hatching rate





days

* t-test $p < 0.05$

N of female = 10

Summary

1. Short-term impacts on early development

-Fertilization rate decreased with increasing CO_2.

-Larval morphology was altered with increasing CO_2.

-$CaCO_3$ skeleton & shell mineralization were impaired.

2. Long-term impacts on growth and survival

-Survival and growth of shrimps were depressed.

-Growth, egg production and hatching rate of copepods were largely unaffected.

Future studies

1. Synergetic effects of high CO_2 and temperature.

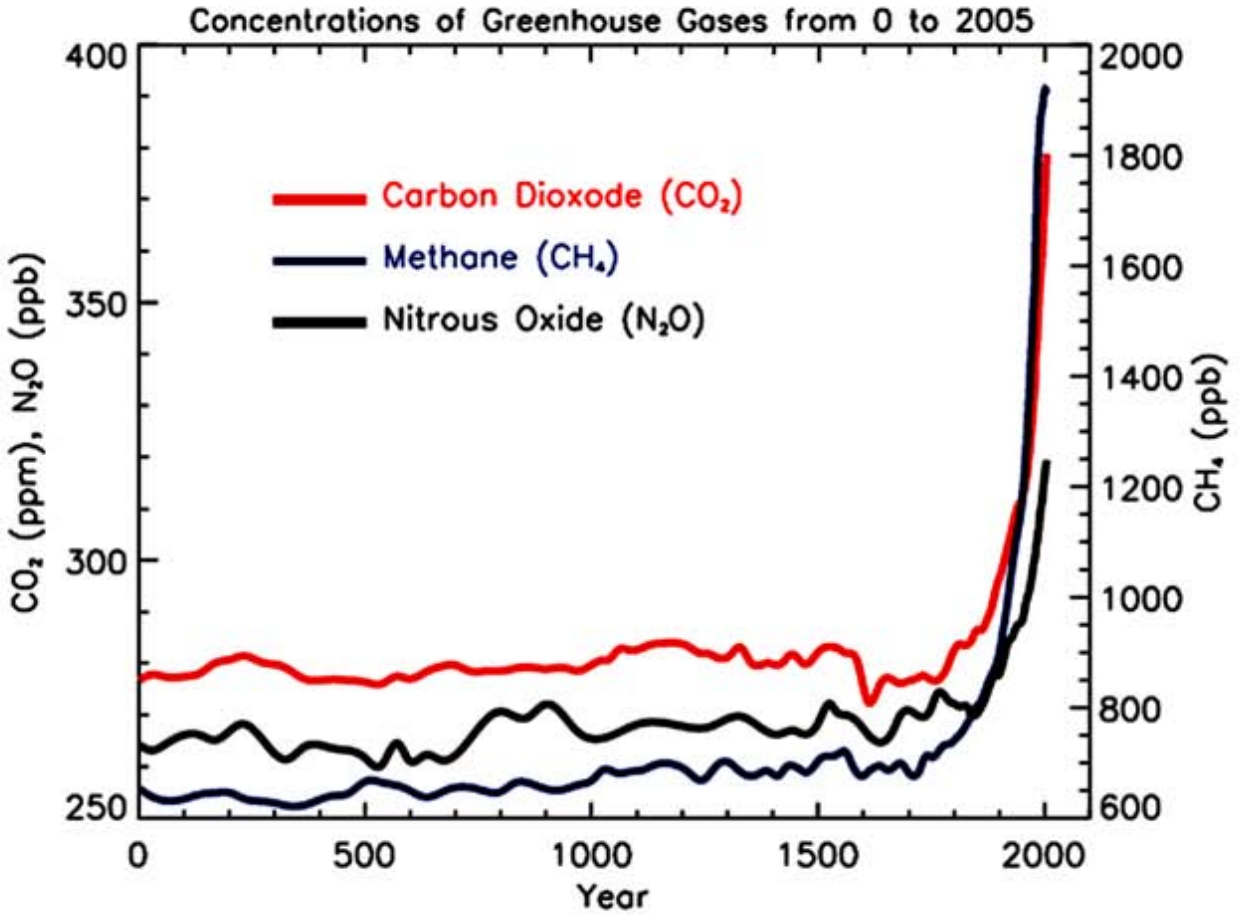
Compare oyster development at 23 °C 380ppm (present sea)
27 °C 1000ppm (year 2100)

2. Mechanism underlying effects of high CO_2 on calcification.

Study skeletogenic related genes expression in sea urchin embryos

3. Effects of high CO_2 on FW organisms

Study early development of FW molluscs



FAQ 2.1, Figure 1. *Atmospheric concentrations of important long-lived greenhouse gases over the last 2,000 years. Increases since about 1750 are attributed to human activities in the industrial era. Concentration units are parts per million (ppm) or parts per billion (ppb), indicating the number of molecules of the greenhouse gas per million or billion air molecules, respectively, in an atmospheric sample. (Data combined and simplified from Chapters 6 and 2 of this report.)*

Effects on oceanic carbon cycle