Effect of ocean acidification on shellfish early life stages

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EPOCA

European Project on OCean Acidification

Larval stage: more fragile?

- Numerous studies show a negative effect of ocean acidification on marine organisms (coccolithophorids, corals, forams, pteropods, echinoderms, molluscs etc..)
- Many reports consider that the larval stage of calcifiers is the most fragile period
- Critical stage for the survival of the populations (1-2 % success *in situ*)
- Evidence that pH control recruitment (i.e. Green et al. 2009)
- Few studies so far

Previous results

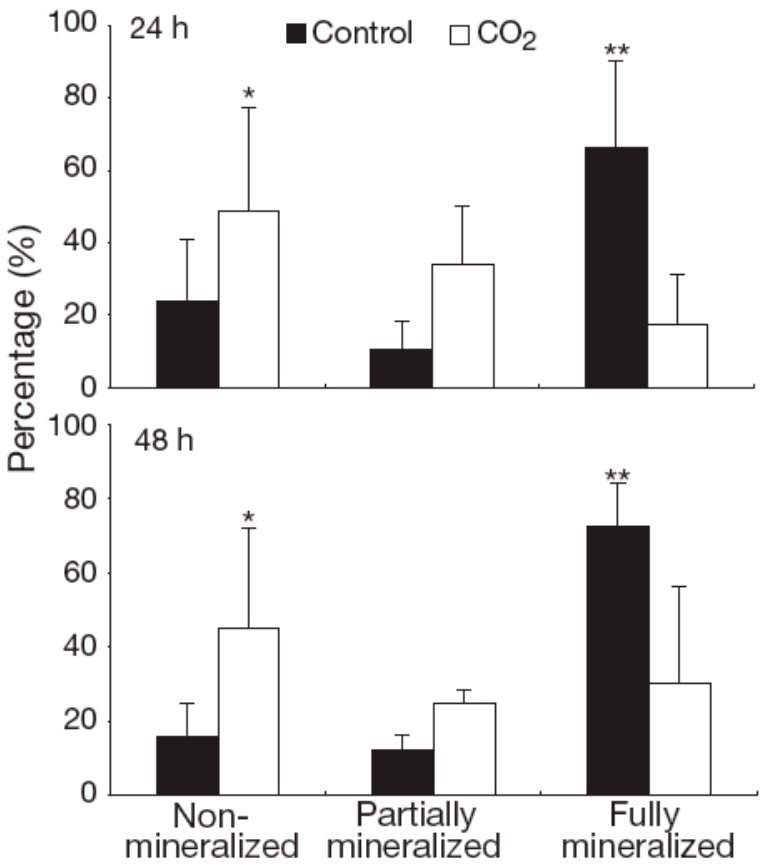

Fig. 4. *Crassostrea gigas*. Shell mineralization in embryos incubated for 24 or 48 h in control or CO_2 groups, determined by polarized light microscopy (mean ± SD; n = 5). Significant difference between control and CO_2 groups by paired *t*-test: $^{*}p < 0.05$, $^{**}p < 0.005$

- Kurihara *et al.* (2007)
- *Crassostrea gigas*
- Control: pCO_2 = 348 ppm, pH = 8.1, Ω_{arag} = 3
- CO_2: pCO_2 = 2268, pH = 7.4, Ω_{arag} = 0.68
- Large effects on success rates (60 to 25%)
- Significant effects on growth rates
- **$\Omega = [CO_3^{2-}] [Ca^{2+}] / K_s$**

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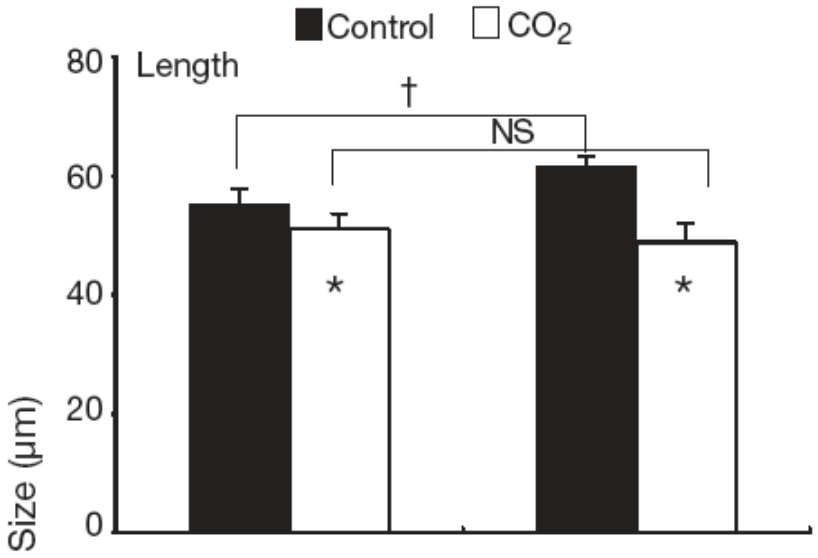

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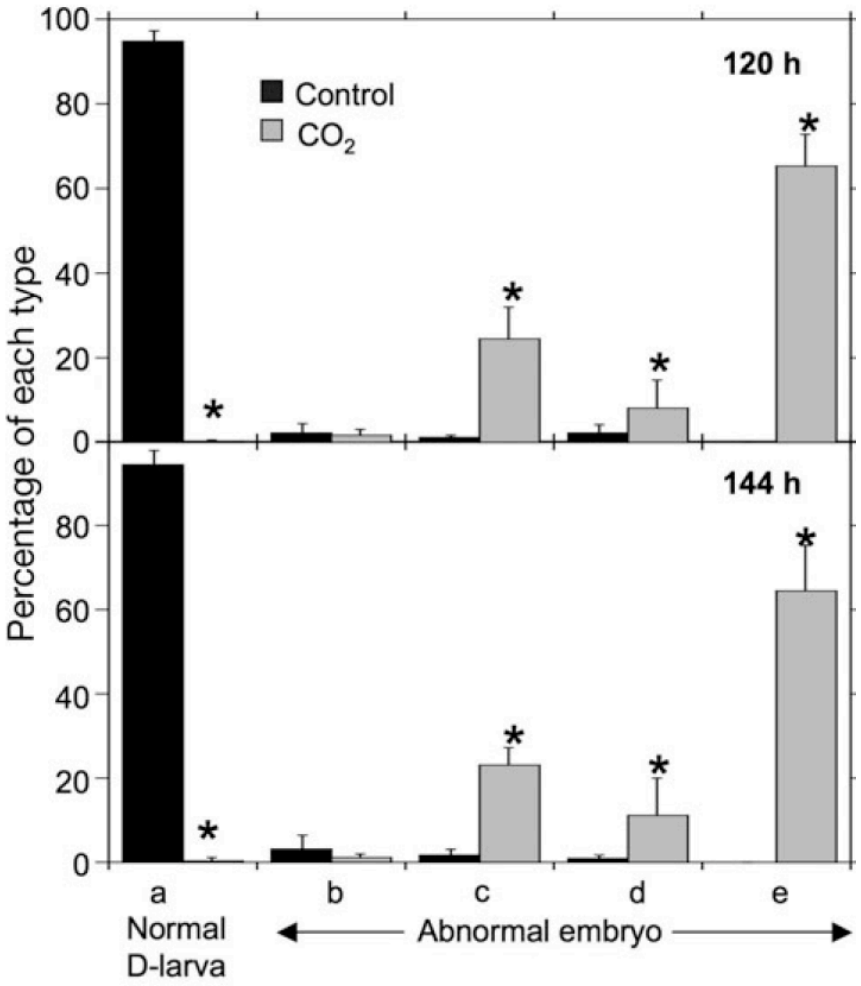

- Kurihara *et al.* (2008)
- *Mytilus galloprovencialis*
- Control: pH = 8.2, Ω_{arag} = 2.2
- CO_2: pH = 7.4, Ω_{arag} = 0.5
- Large effects on success rates (>90 to ≈0%)
- Significant effects on growth rates

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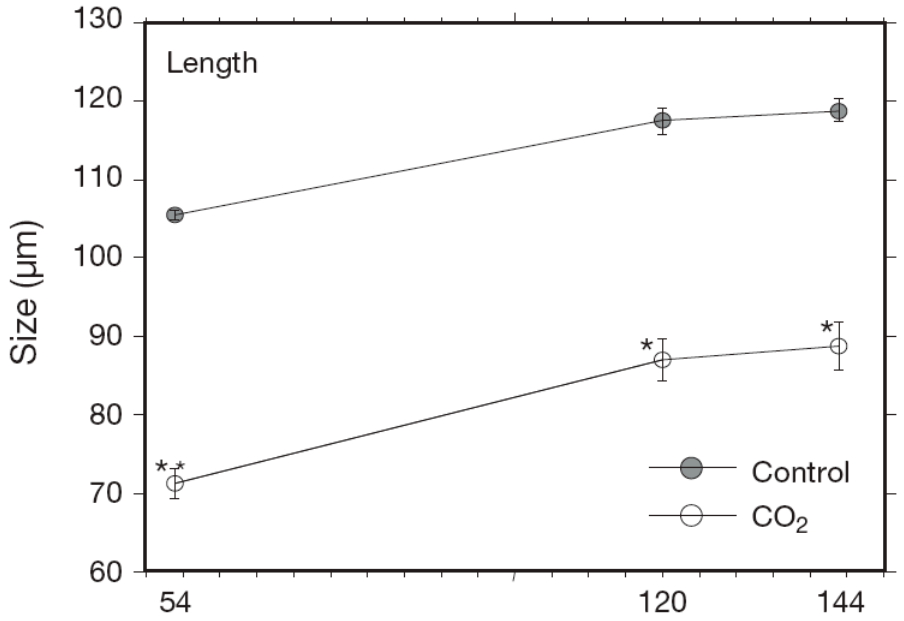

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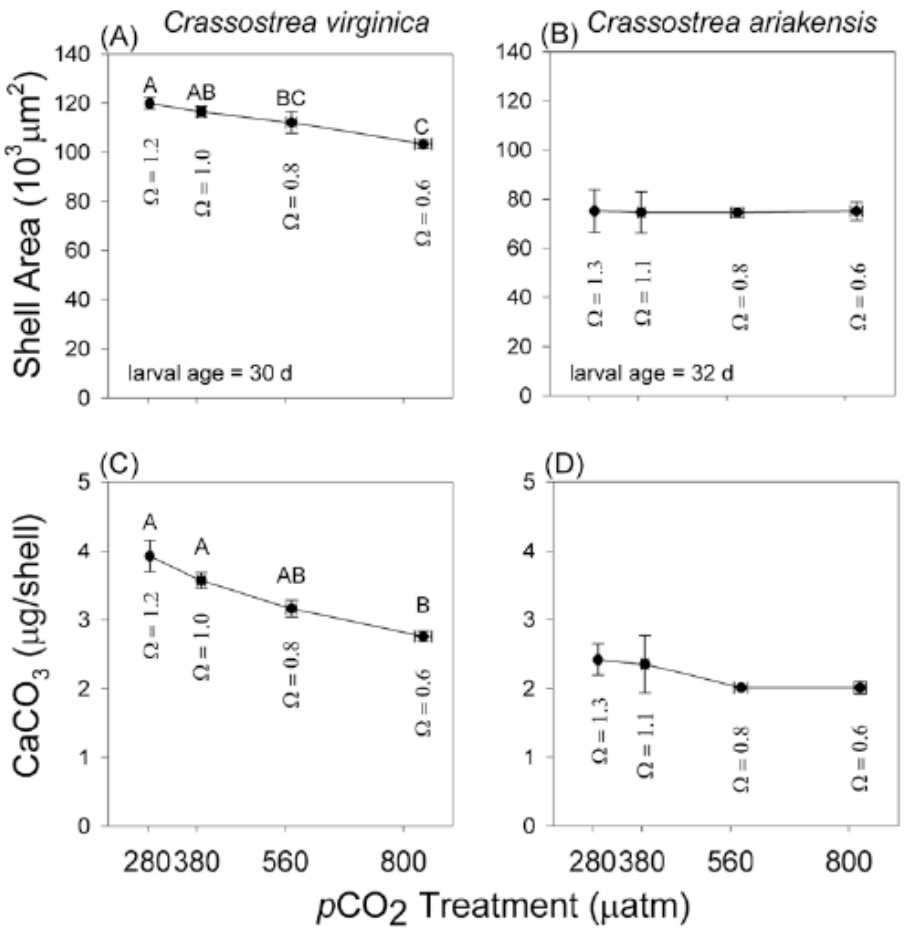
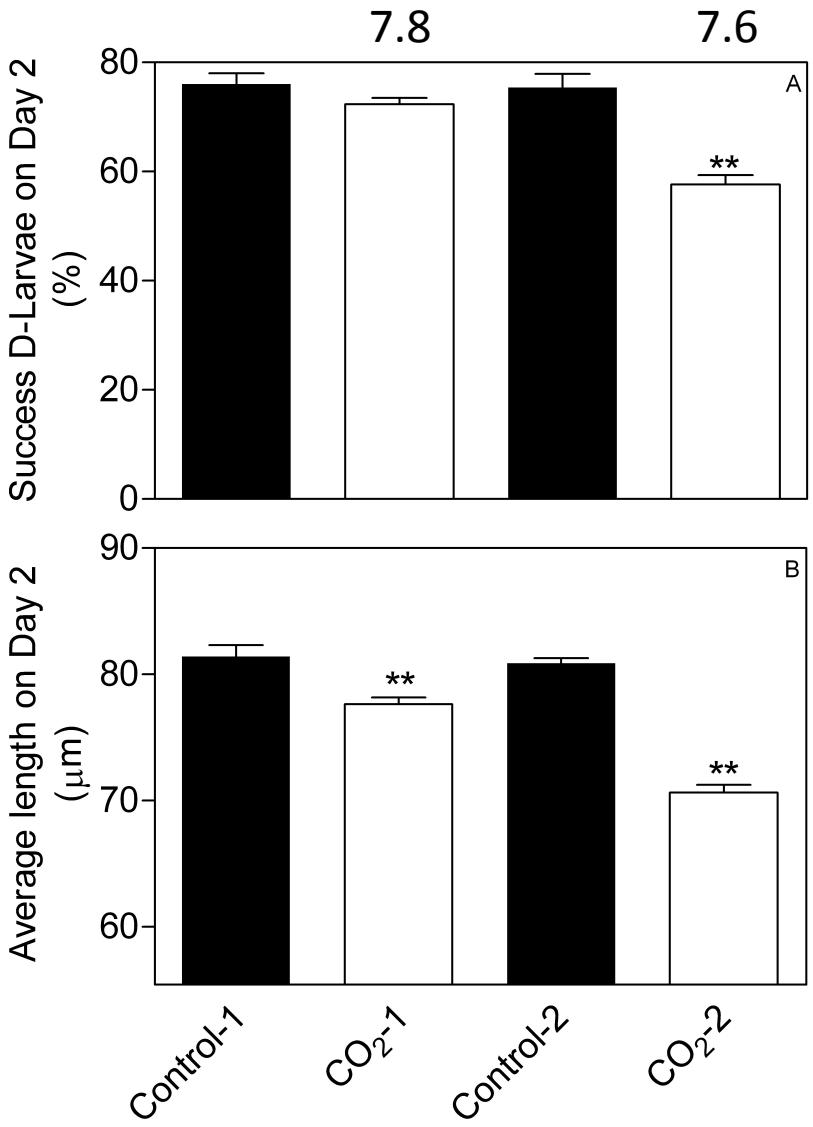


- Miller *et al.* (2009)
- *Crassostrea virginica*
- *Crassostrea ariakensis*
- pH from 8.2 to 7.8 (NBS)
- Ω_{arag} from 1.2 to 0.6
- From day 2 to 32
- Significant effects on growth rates for 1 species and effects on shell carbonate content

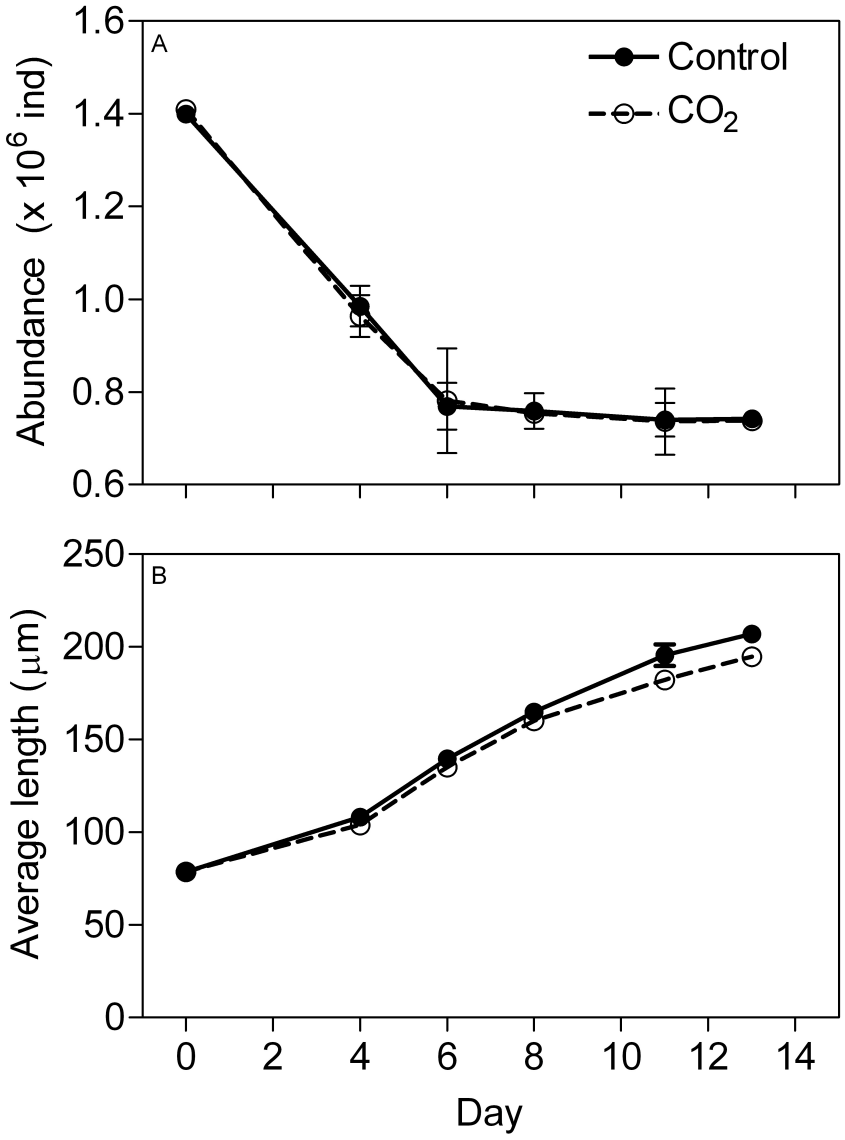
Effects on *Mytilus edulis*



- Experiment carried out on the first 2 days of development (egg to D-larvae)
- pH (NBS) of 8.1, 7.8 and pH of 8.1 and 7.6
- At 7.8, no effect on hatching rates, significant effect on growth rate (-15%)
- At pH 7.6 (Ω_{arag}<1), decreases of both hatching (-25%) and growth rates (-40%)

Submitted to Aquatic biology

Day 2 to day 15



- No effect on mortality
- Decrease of growth by 10%

Submitted to Aquatic biology

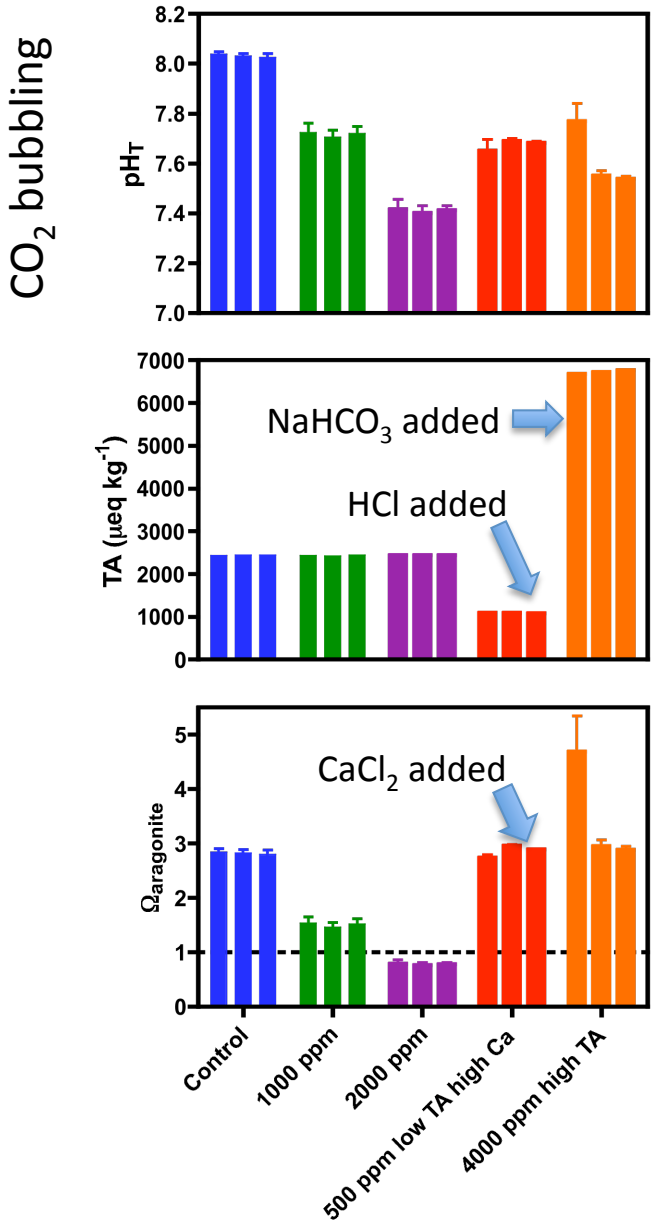
Resume

- Growth decrease (10-15%) of mussel larvae for a decrease of 0.3 pH unit. This pH decrease is expected for the end of the century. Effect which IS NOT stronger than for adults
- At pH 7.8, water is oversaturated with respect to aragonite.
- Decreasing pH so that water is undersaturated with respect to aragonite leads to a strong decrease of hatching and growth rates, but they still produce a shell (show that they control their calcification rates)
- Are we sure that this strong effect is “only” due to the aragonite undersaturation?
- Can be solely due to the pH decrease that disrupt the intra-membrane fluxes

New experiment (May/June 2009)

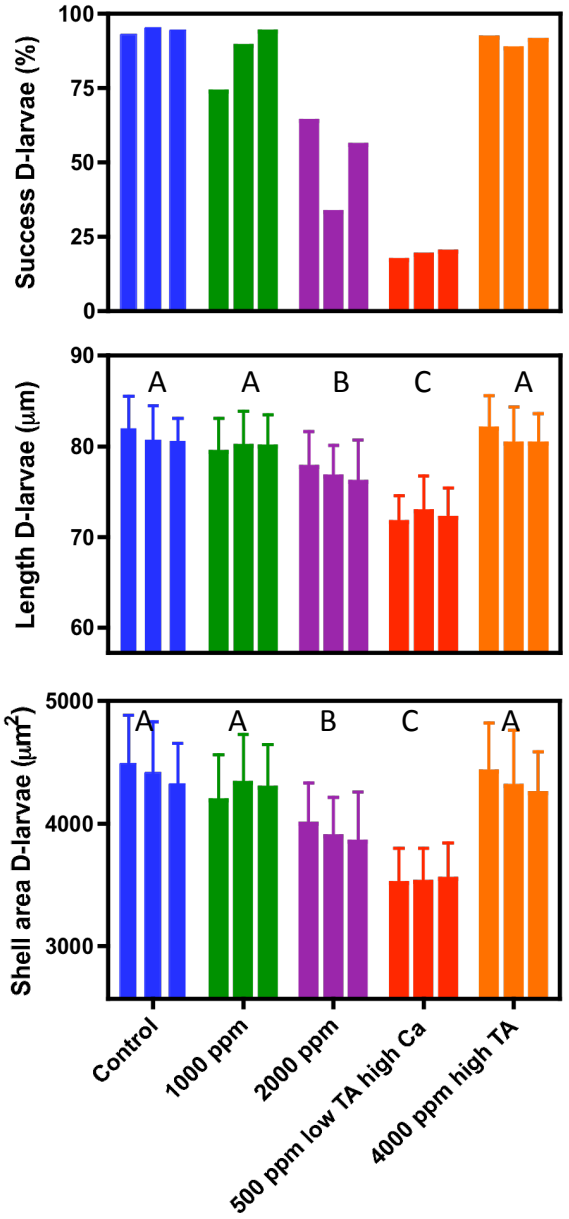
- Studying larval development from egg to D-shape larvae (2-3 days), under contrasting conditions of pH and of the carbonate system
- High pH/low pH, high TA/low TA
- Ω also controlled in 1 treatment by increasing calcium concentration
- 5 different treatments, triplicate incubations
- pH monitored continuously, TA measured before and after incubation.

New experiment



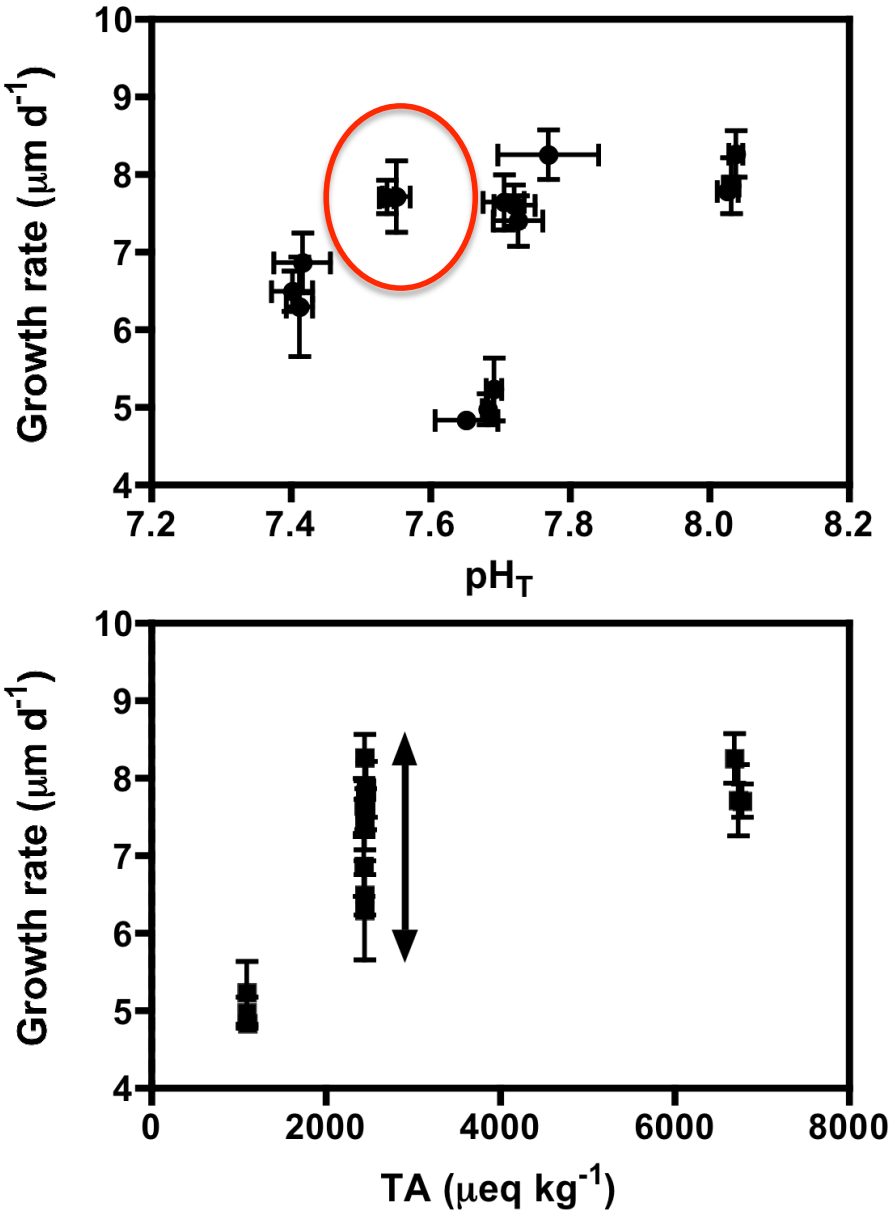
- pH successfully controlled via CO_2 bubbling (390, 1000, 2000 and 4000 ppm)
- TA controlled by adding HCl or $NaHCO_3$
- Calcium increased by $CaCl_2$ addition (6x ambient Ca)

Results



- Preliminary Success rate results suggest significant effects only at high CO_2 ($\Omega_{aragonite} < 1$) and low TA/high Ca conditions
- Growth rates (length and shell area) also decrease at 2000 ppm ($\Omega_{aragonite} < 1$) and at low TA/high Ca (although $\Omega_{aragonite} > 1$)
- No effects at 1000 ppm and at high TA/low pH ($\Omega_{aragonite} > 1$)
- Hatching and growth are still occurring even if $\Omega_{aragonite} < 1$

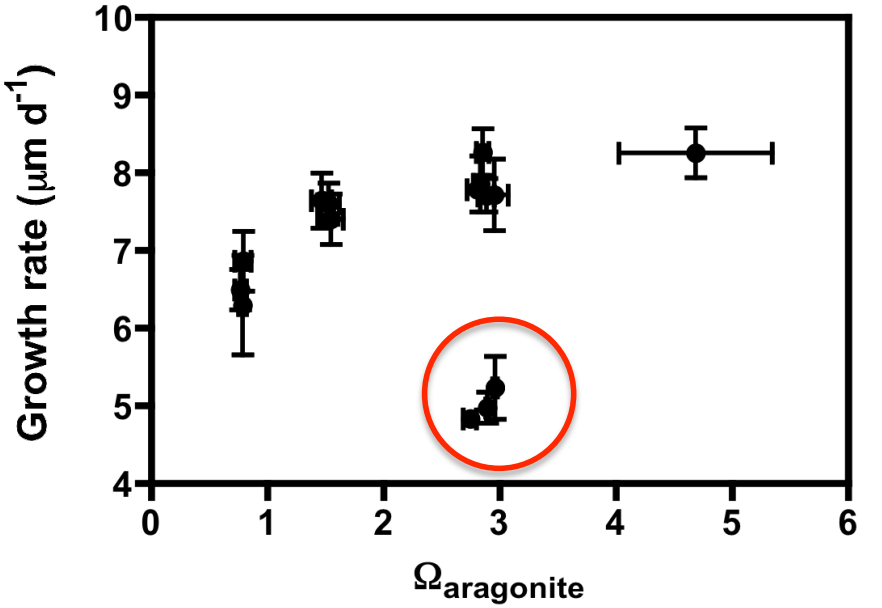
What is the controlling parameter?

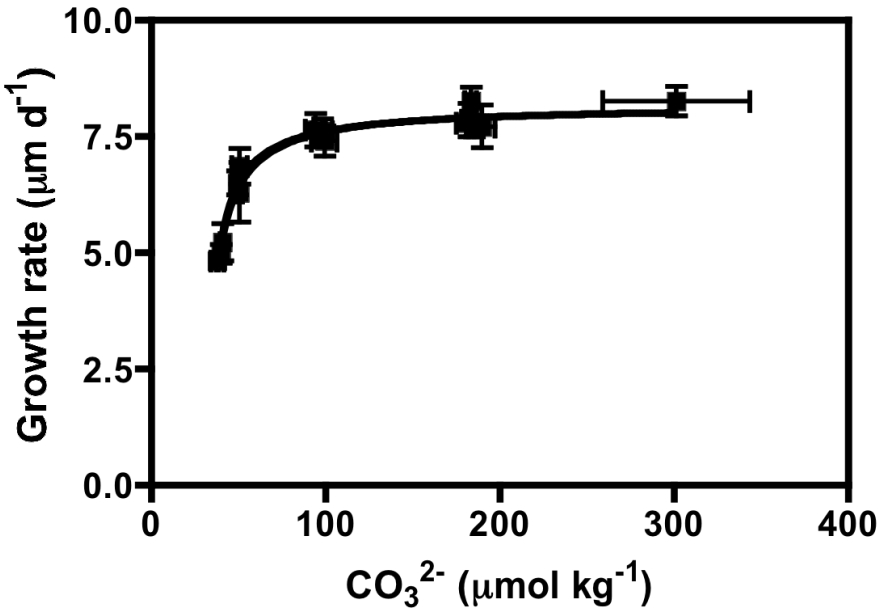


- No effects on hatching and growth at 4000 ppm (pH_T = 7.5) but with high TA suggest that pH is not critical in that range

- TA per se is not the controlling parameter since a broad range of growth rates were measured for the same TA level

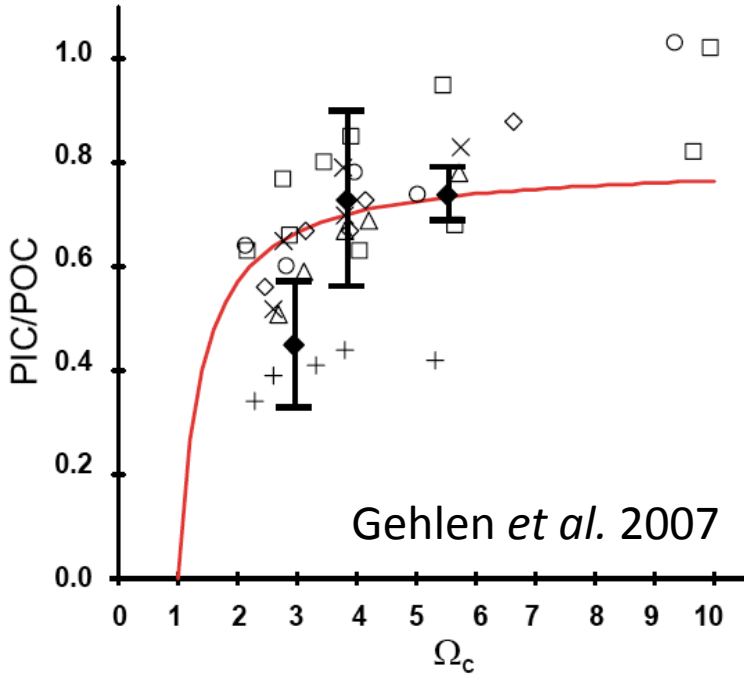
What is the controlling parameter?

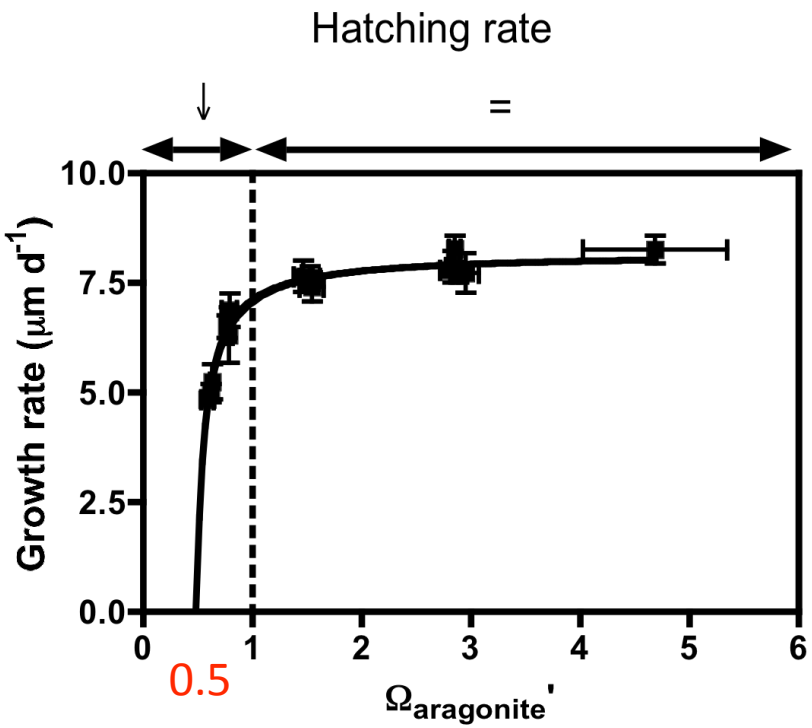




- $\Omega_{aragonite}$ is also not the critical parameter since addition of calcium does not favor hatching and/or growth

- Clear relationship between growth and CO_3^{2-} concentration, hatching and growth are limited via a limitation of calcification





- Growth no favored by Ca addition above ambient levels
- Calculation of Ω_{arag}' considering no change of Ca
- Larvae still able to develop under Ω_{arag}' = 1
- However, below 1, both hatching and growth significantly decrease, leads to population collapse?

Conclusion

- Different studies show that shellfish larvae are negatively affected by ocean acidification
- Growth decrease above aragonite saturation is relatively low and not always found
- Below saturation, both development success and growth rates are altered, potentially leading to population collapse
- CO_2 dissolves much better in cold waters. They will experience aragonite undersaturation first, we need to focus on these high latitude populations!