Effects of ocean acidification on the coccolithophore *Emiliania huxleyi* and their modulation by light

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Background – The other CO_2 problem…

Increasing atmospheric CO_2 partial pressures (pCO_2) lead to increased CO_2 concentrations and higher acidity in surface waters, a phenomenon known as ocean acidification (Figure 1). As the seawater becomes more corrosive for calcium carbonate ($CaCO_3$), researchers´ focus was especially directed towards calcifying organisms, like e.g. coccolithophores. By the formation and export of organic carbon and $CaCO_3$, these calcifying microalgae sustain vertical gradients of dissolved inorganic carbon and alkalinity. Furthermore their shells aggregate with particulate organic matter and enhance its export by ballasting. These processes affect the CO_2 exchange with the atmosphere and thereby also Earth's climate.

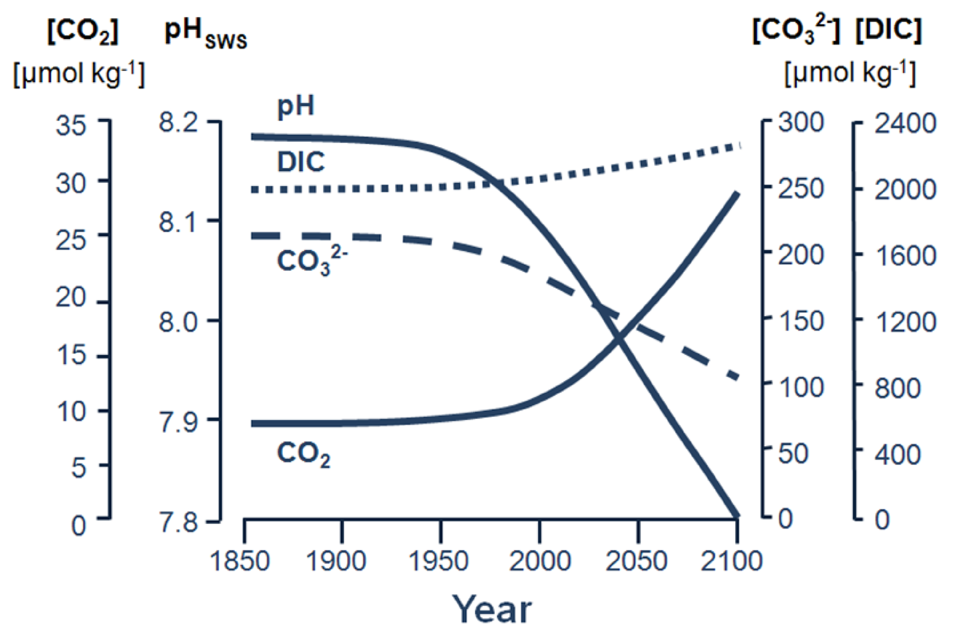

Figure 1: Ocean acidification; after Wolf-Gladrow et *al*. (1999)

Past research – Diverse response patterns …

Riebesell et *al.* (2000) found that in response to increased pCO_2, the calcification rate was reduced in a strain of the coccolithophore *E. huxleyi*. Langer and coworkers (2006) found nonlinear response patterns or no responses at all in other coccolithophore species. Iglesias-Rodriguez et *al*. (2008) observed even increased calcification rates as an effect of high pCO_2. Langer et *al*. (2009) could show that response patterns can differ between strains, i.e. within the very same species (Figure 2).

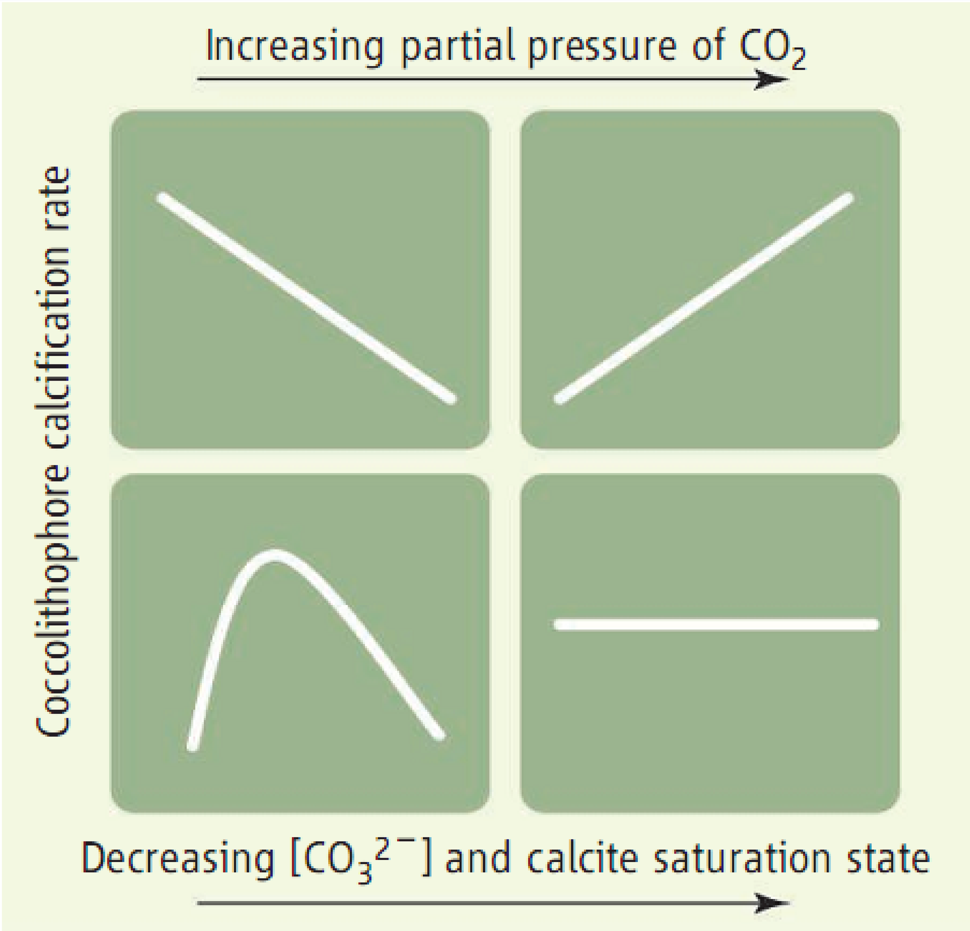

Figure 2: Results of different studies, compiled by Fabry (2008)

This study – Interactive effects …

As light is the only energy source for phototrophs and because energy supply is a crucial component in any biological system, we examined the effect of energy availability on the responses to ocean acidification. We acclimated the *E. huxleyi* strain RCC1216 to limiting and saturating light intensities (50 vs. 300 µmol photons m^{-2} s^{-1}; LL, HL) under ambient and high CO_2 levels (380 vs. 1000 ppm; LC, HC). Among other parameters, growth rates and cellular quotas of particulate organic as well as inorganic carbon (POC/PIC) were measured. Photosynthetic performance and cellular affinities to dissolved inorganic carbon (DIC) were assessed by means of membrane-inlet mass spectrometry.

Results – Mutual influence of effectors…

- POC production (Fig. 3A) increased as an effect of high pCO_2, but this relative stimulation was more pronounced under low-light conditions.
- PIC production (Fig. 3B) declined due to increased pCO_2, but the relative effect was stronger under low-light conditions.
- Cellular DIC-affinities as well as chlorophyll contents (Fig. 3C and D) did not significantly change in response to high pCO_2.
- The rates of light saturated O_2 evolution (V_{max}; Fig. 3E) and those that apply to acclimation conditions ($V_{in\text{-}situ}$; Fig. 3F) decreased as an effect of high pCO_2. These relative effects were more pronounced under low-light conditions.

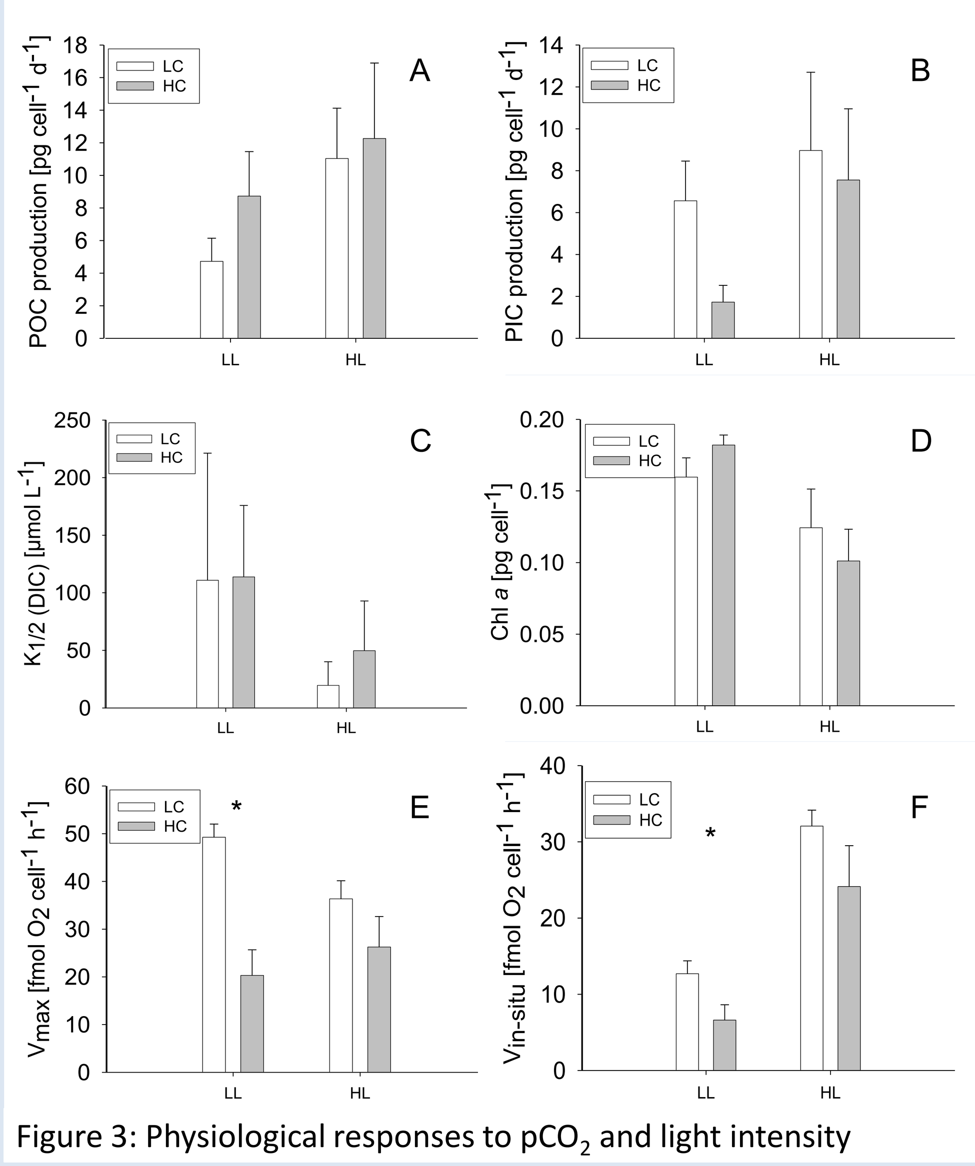

Figure 3: Physiological responses to pCO_2 and light intensity

Conclusion – From response patterns to response landscapes…

- Ocean acidification response patterns are strongly modulated by energy availability, changing the amplitude or even inverting the observed trends (Fig. 3 A-F).
- Effects of ocean acidification were typically more pronounced under limiting light. Consequently *E. huxleyi* RCC1216 might cope (better) with future increased acidity, when energy availability is high.
- Despite a decreased energy generation which cannot be attributed to altered DIC-affinity or light harvesting properties, cells build up more biomass. This increased energy use efficiency may derive from either a reduced need for active DIC uptake and/or a reallocation of energy due to impaired calcification.

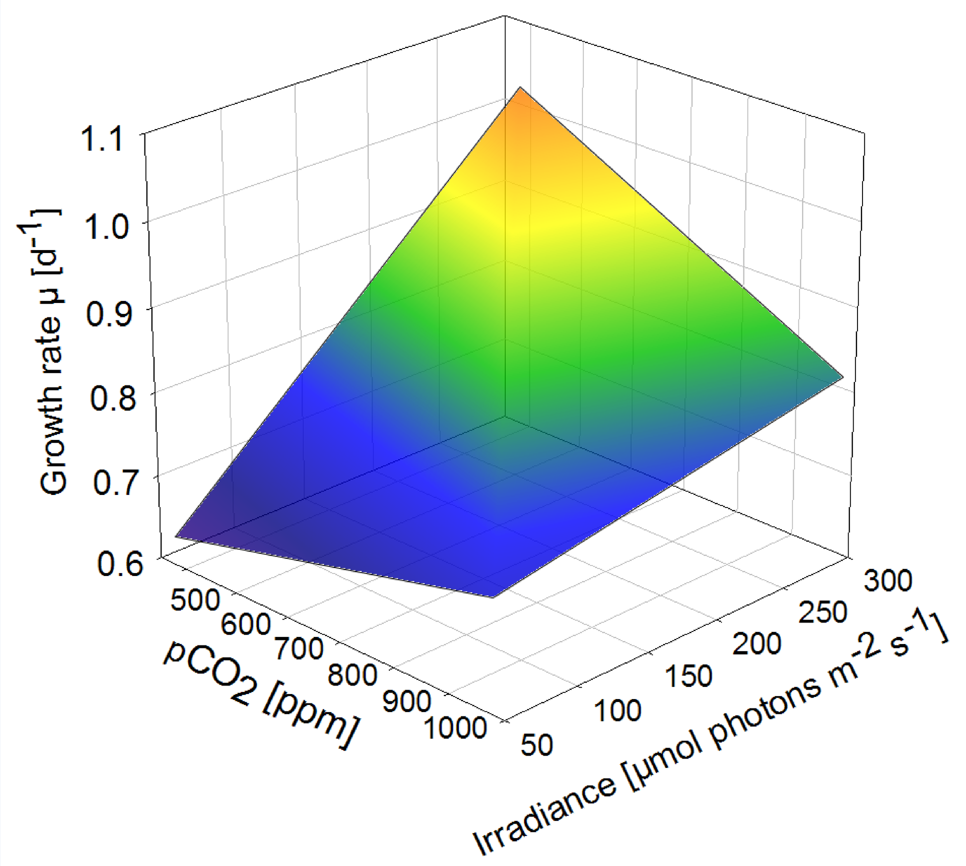

Figure 4: Growth rate in response to pCO_2 and light intensity

References:

Wolf-Gladrow et *al*. (1999). Direct effects of CO_2 concentration on growth and isotopic composition of marine plankton. *Tellus* 51B:461-476.
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