Effects of Ocean Acidification and their modulation by light intensity in the coccolithophore *Emiliania huxleyi*

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Background - The other CO_2 problem...

Increasing atmospheric CO_2 partial pressure (pCO_2) leads to increased $[CO_2]$ and $[H^+]$ in surface waters, a phenomenon known as ocean acidification (OA). Coccolithophores, calcifying microalgae, have been shown to be affected by OA. These algae form biomass (particulate organic carbon, POC), but unlike other phytoplankton they also form $CaCO_3$ (particulate inorganic carbon, PIC). By mediating the depth export of POC and PIC, they sustain vertical gradients of dissolved inorganic carbon (DIC) and alkalinity, and thereby affect the CO_2 exchange with the atmosphere.

Numerous studies have investigated the effects of OA on coccolithophores, especially the bloom-former *Emiliania huxleyi*, yielding versatile response patterns of POC and PIC productions, not only between but also within species-complexes (Fig. 1; Fabry, 2008).

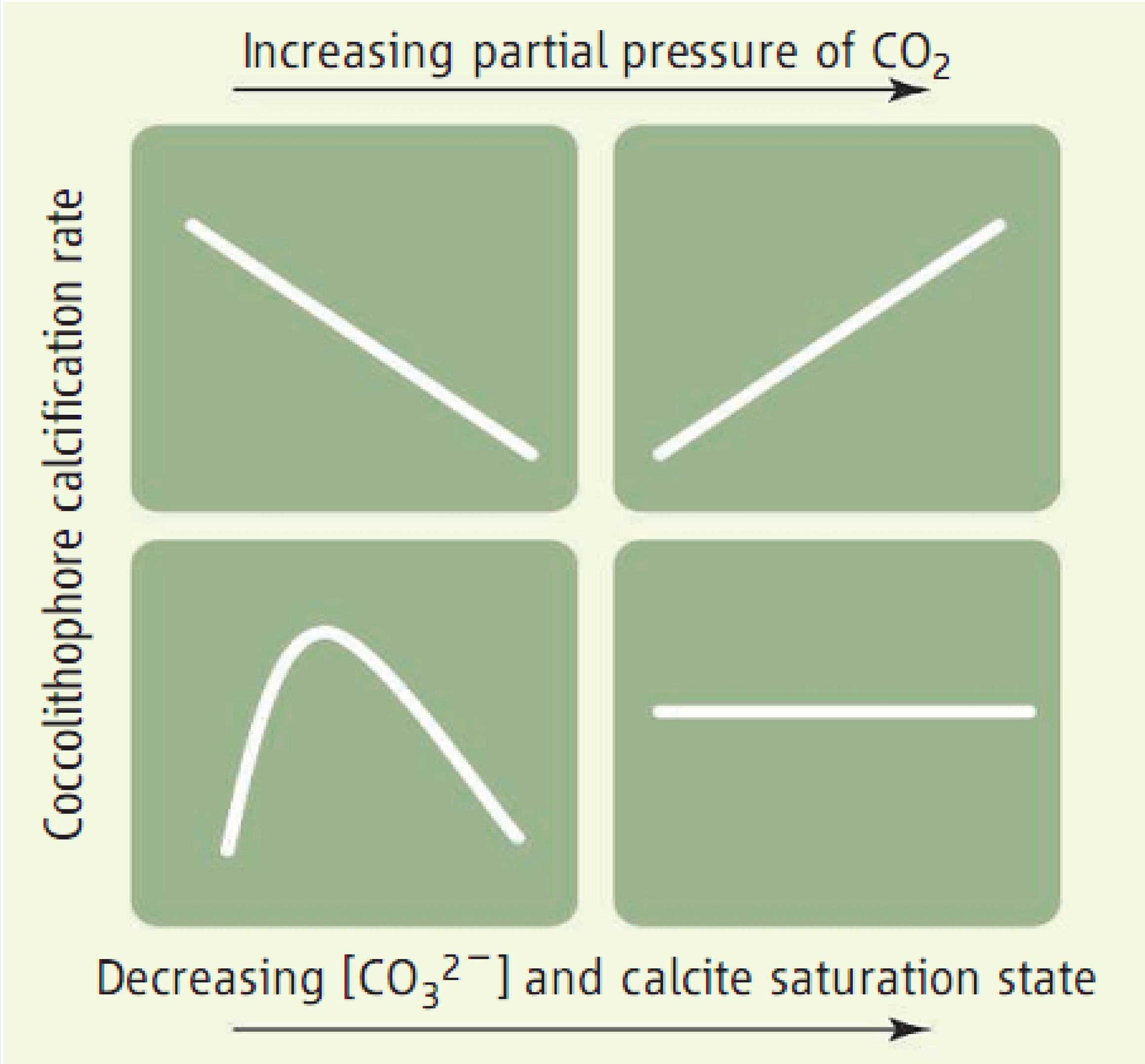

Figure 1: OA response patterns obtained in different studies

This study - Testing combined effects of OA and light ...

To investigate the modulation of OA-responses by light intensity, cells of *E. huxleyi* strain RCC 1216 were acclimated to ambient and high pCO_2 (380 vs. 1000 µatm) under limiting and saturating light intensities (50 vs. 300 µmol photons m^{-2} s^{-1}). Growth rates and cellular quotas of POC and PIC were measured. Photosynthetic O_2 evolution was measured as a function of light and of [DIC].

Results - Energy determines magnitude of effects...

- OA increased POC production, the relative response was more pronounced under low-light conditions (Fig. 2A) .
- OA decreased PIC production, the relative response was more pronounced under low-light conditions (Fig. 2B).
- DIC-affinities (Fig. 2C) and HCO_3^--usage (~80%; not shown) were unaltered by OA.
- Pigment content and photosynthetic net O_2 evolution decreased under OA (Fig. 2 D-F). The responses were more pronounced under low-light conditions.

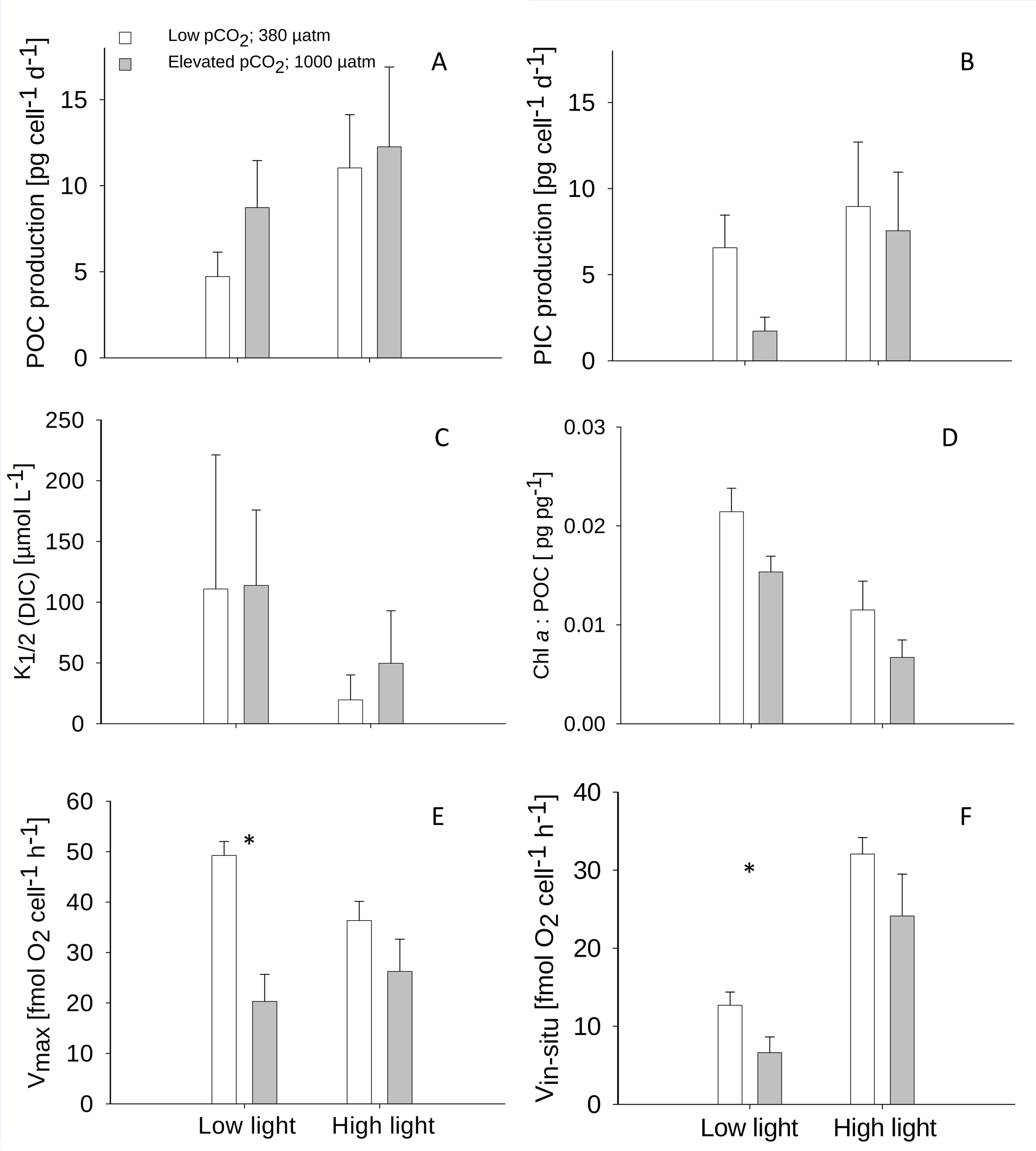

Figure 2: Physiological responses to pCO_2 and light intensity

Conclusions - Energy modulates OA-responses...

- OA enhances POC production and reduces PIC production (Fig 2 A,B), resulting in stable TPC production. As the uptake of inorganic carbon is apparently not impaired (Fig. 2 C), OA seems to cause an internal shunting of acquired carbon between the competing processes of biomass buildup and calcification.
- Cells achieve higher POC quotas despite lowered pigment content and net photosynthesis (Fig. 2 E-F). This enhanced 'energy efficiency' may derive from a reallocation of energy due to lowered costs of inorganic carbon acquisition and/or impaired calcification.
- OA response patterns are strongly modulated by light intensity (Fig. 2 A-F). A conceptual model explaining this energy dependence is proposed:

❖ *The rate of a given process (Fig. 3, grey kinetic curve) is generally governed by energy availability (usually irradiance). Changes in environmental parameters (e.g. pCO_2) readily alter the amount of energy that is available to the given process (dotted black lines). Although effects are of the same magnitude, observed responses (solid black lines), i.e. changes in rates, are stronger when energy availability is low.*

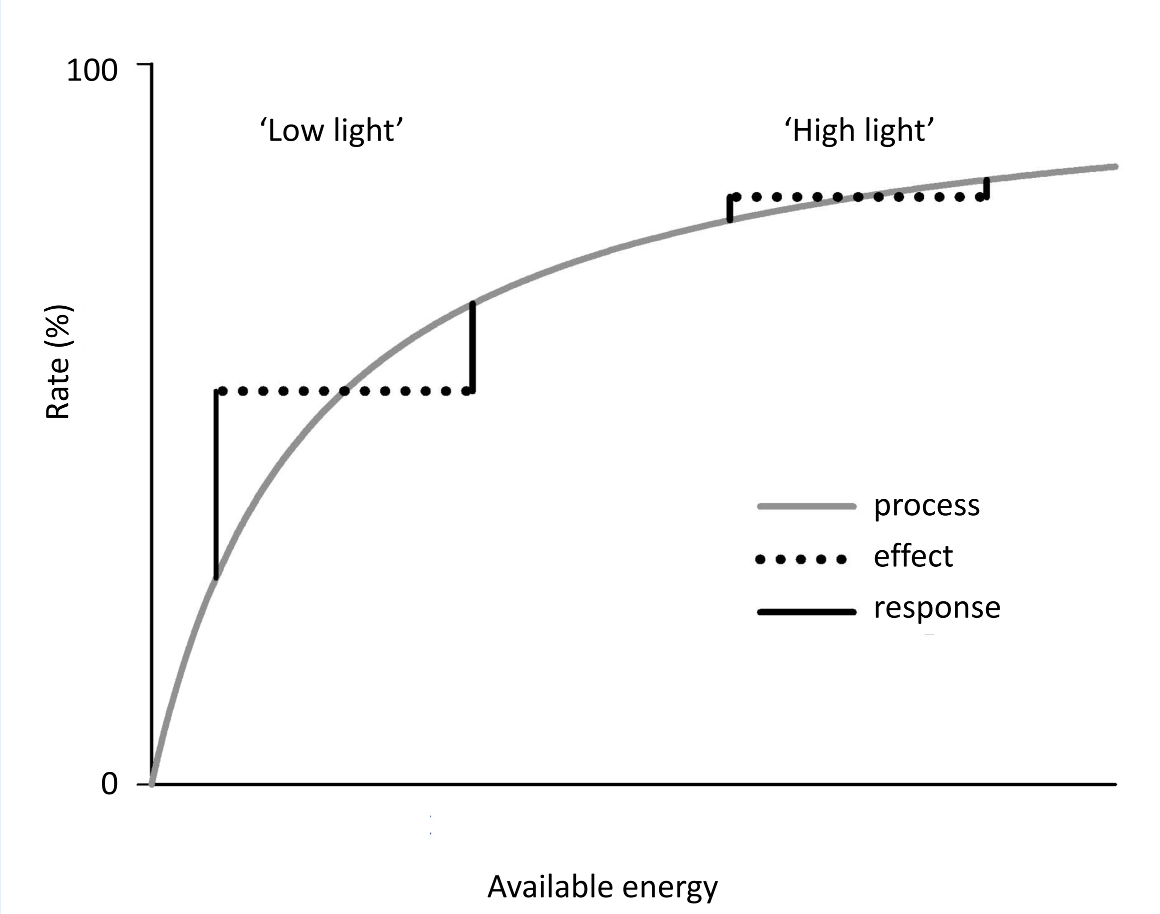

Figure 3: Energy-modulation of responses to a changing environmental parameter.

References:

Fabry (2008). Marine Calcifiers in a High-CO_2 Ocean. *Science* 320:1021-1022.

Rokitta and Rost (2012). Effects of CO_2 and their modulation by light in the life-cycle stages of the coccolithophore *E. huxleyi*. *Limnol. Oceanogr.* 57(2):607-618