Physiological Responses of the Toxic Dinoflagellate *Karenia brevis* to Climate Change

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Introduction: Anthropogenic emission of CO_2 will not only affect our climate due to its greenhouse gas potential, but also marine productivity as CO_2 is an essential nutrient. Here I investigated the responses of the ecologically and economically important algae *Karenia brevis* to enhanced CO_2 concentrations. Changes in growth, primary productivity and the kinetics of acquiring inorganic carbon were investigated.

Background: *K. brevis* frequently forms dense blooms on the Western coast of Florida, so-called red tides (Figure 1). These blooms release potent neurotoxins (brevetoxins) which can have significant impact on human health, and can cause mortalities of marine mammals, birds and fish. Besides this potential toxic effect, *K. brevis* performs around 20% of the primary production in the West Florida Shelf during blooms and is a prominent phytoplankton species throughout the year, thus representing a large carbon sink and important source in the food chain.

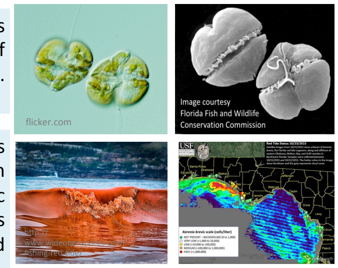

Figure 1. *Karenia brevis*. A) Light microscope picture; B) electron microscope picture, C) Water with a dense *Karenia* bloom D) Satellite image of chlorophyll identified as mainly *Karenia* species in the Florida Big Bend/ Pensacola area.

Hypothesis 1: Increasing CO_2 will reduce the amount of cellular energy needed to supply CO_2 for effective carbon fixation, leading to changes in growth and productivity.

Hypothesis 2: CO_2 will alter the light use efficiency. Reduced energy dissipation is expected under enhanced CO_2, allowing for higher light capturing rates, energy conversion and thus growth.

Methods:

- Cells of *K. brevis* (isolate from the Gulf of Mexico/Tampa area) were grown in temperature and light controlled incubators and supplied with ambient CO_2 (400ppm) and CO_2 concentrations predictions for the year 2100 (750ppm).
- Growth rate was estimated by measuring the pigment content of the incubation over time.
- Productivity was estimated by measuring the evolution of O_2 as a product of photosynthesis over the day.
- Photophysiology was measured using a Fast Repetition Rate Fluorometer which can estimate electron transport rates and non-photochemical quenching.
- Half saturation rates for inorganic carbon usage was measured by analyzing photosynthesis over a gradient of increasing inorganic carbon concentrations.

Results: Growth

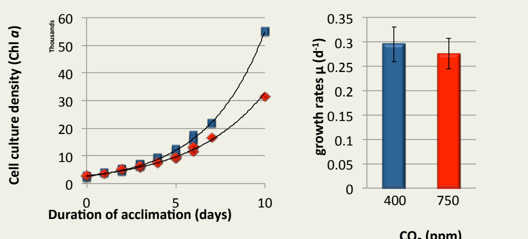

Fig. 2. Growth rate for *Karenia brevis*. A) increase of cell density over time (blue 400ppm CO_2, red 750ppm O_2). B) Calculated growth rate for both acclimations (n>9)

- Increase in biomass was exponential.
- Growth is slightly reduced under high CO_2 concentrations, statistically not different to ambient CO_2.

Productivity

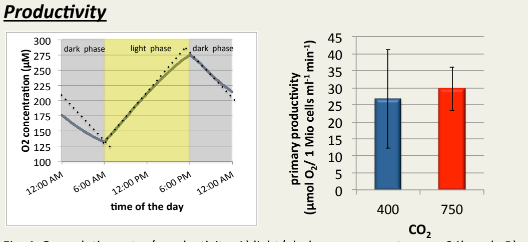

Fig. 4. O_2 evolution rates/ productivity. A) light/ dark measurement over a 24h cycle B) maximum O_2 evolution measured at noon (data from DIC kinetic measurements (n=3)

- Measurements over a 24h cycle revealed diurnal changes both in productivity and respiration with lower rates towards the end of the light and dark period, respectively.
- Maximum productivity rates around noon were similar between CO_2 acclimations (n=3)

Photophysiology

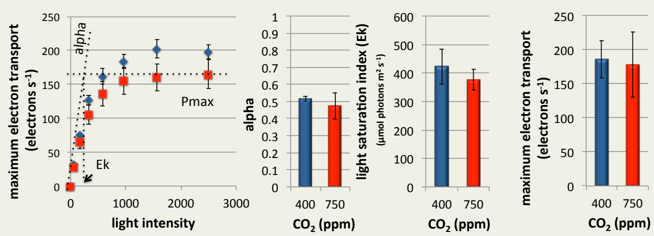

Fig. 3. Photophysiological characterization. A) light response curve; electron transport at different light intensities, B) alpha: electron transport rate increase at low light intensities, C) light saturation index calculated from the intersection of alpha and Pm, D) maximum electron transport. Data were fitted using internal FRRF software n=6

- No significant changes in light use efficiency (alpha and Ek) as well as maximum electron generation.
- No significant differences in size of the light capturing apparatus, electron transfer rate within the photosystem and energy dissipation (data not shown) at higher light intensities between acclimations.

Half-saturation kinetics

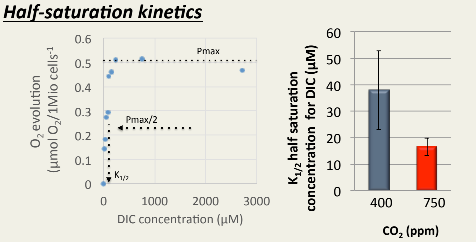

Fig. 5. Half saturation concentrations. A) O_2 evolution rates at different DIC concentrations B) half saturation concentrations of the cells. Lower values indicate more efficient carbon acquisition!

- Half saturation for DIC is lower in high CO_2 cells (n=3). Rates are overall very low compared to other dinoflagellates or phytoplankton species. The lower values at 750ppm rates showed a more efficient CO2 concentration mechanism.

Discussion:

Dinoflagellates such as *Karenia brevis* are hypothetically prone to be affected by changes in CO_2 due to their biochemical constraints in their carbon fixing enzyme Ribulose-1,5-bisphosphate carboxylase/oxygenase (RubisCO). Yet, both our hypotheses were disproven. Increasing CO_2 did not significantly affect cell division rates and productivity of *Karenia brevis* nor did it affect photophysiology. The data on productivity, however, revealed a distinct diurnal rhythm, both in productivity as well as respiration – this finding is important as future research has to carefully investigate the underlying reasons for these changes, and data taken at random times over the day must be re-analyzed. *Karenia brevis* also showed very low values for $K_{1/2}$, indicating a very efficient carbon concentration mechanism (CCM). Overall, the high E_k and efficient electron transport at very high light as well as the efficient CCM allow the cells to thrive in the upper ocean and build the dense toxic blooms this species is known for. The increase in atmospheric CO_2 and the co-occurring ocean acidification will likely not affect this species in the future.

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