The calcification response of coccolithophores to elevated ocean alkalinity

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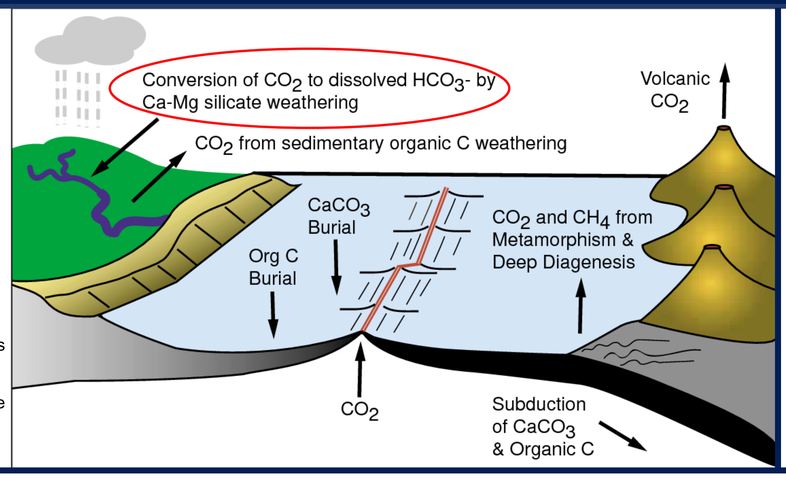
CO_2 drawdown

To keep within 2°C of pre-industrial global temperatures, we are going to need to start actively removing CO_2 from the atmosphere, in addition to reducing greenhouse gas emissions.

One way of doing this would be to elevate the alkalinity of the oceans. This shift of the carbonate system would enhance CO_2 drawdown into the surface ocean and store carbon as HCO_3-. Enhancing alkalinity could be achieved by two different ways:

1. Acclerating the natural weathering process, which already draws down 1 Gt C/year.
2. Directly adding alkaline materials to the ocean.

A key unknown for these proposed schemes is how phytoplankton, the basis of life for all marine ecosystems, will respond. It is particularly crucial that the response of calcifying plankton is constrained, because the formation of their $CaCO_3$ skeletons actually releases CO_2, which could undo net carbon sequestration through elevated alkalinity.



Experimental design

Treatment	Total Alkalinity (µmol/kg)
Synthetic Ocean Water (SOW)	2400-2600
SOW + $NaHCO_3$	3000
	3500
	4000

Which phytoplankton groups?
Coccolithophores are arguably the dominant calcifying plankton in the world's surface oceans. *Emiliania huxleyi* and *Gephyrocapsa oceanica* are the most abundant, bloom-forming species.

What alkalinity levels?
It has been suggested that at point-source sites of alkalinity addition, local levels of alkalinity could reach up to 4000µmol/kg. Once ocean circulation has distributed this alkalinity through the surface ocean, levels would likely be ~3000µmol/kg in order to achieve a drawdown of ~10 Gt C/year. It is crucial that any experimental design accommodates this expected range.

Batch culture experiments using *E. huxleyi* (strain OA15) and *G. oceanica* (strain RCC1314) were run in triplicate at each of the alkalinity treatments summarised in the table to the left. Cultures were allowed to acclimate to alkalinity treatments for at least 10 generations before results were collected from these experiments.

GROWTH

Growth curves:
o Both species show an increased number of cells per ml of culture under elevated alkalinity.

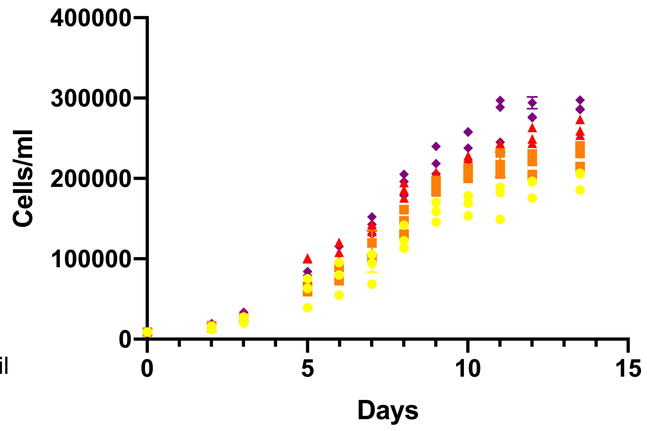
o *G. oceanica* has a far more pronounced increase in the numbers of cells per ml of culture than *E. huxleyi*.

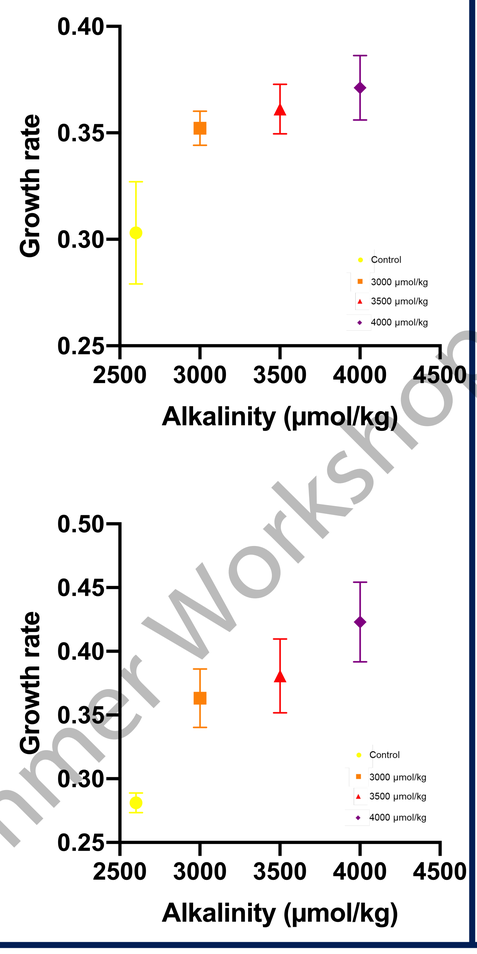
o Cell counts were taken each day using a Coulter counter until the cells reached stationary phase.

Growth rates:
o Both species show an increased growth rate under elevated alkalinity.

o *G. oceanica* has a far more pronounced increase in its growth rates than *E. huxleyi*.

o Growth rates were calculated as specific growth rates i.e. by performing linear regression on the portion of growth curves for which the species were in exponential growth phase.





CALCIFICATION

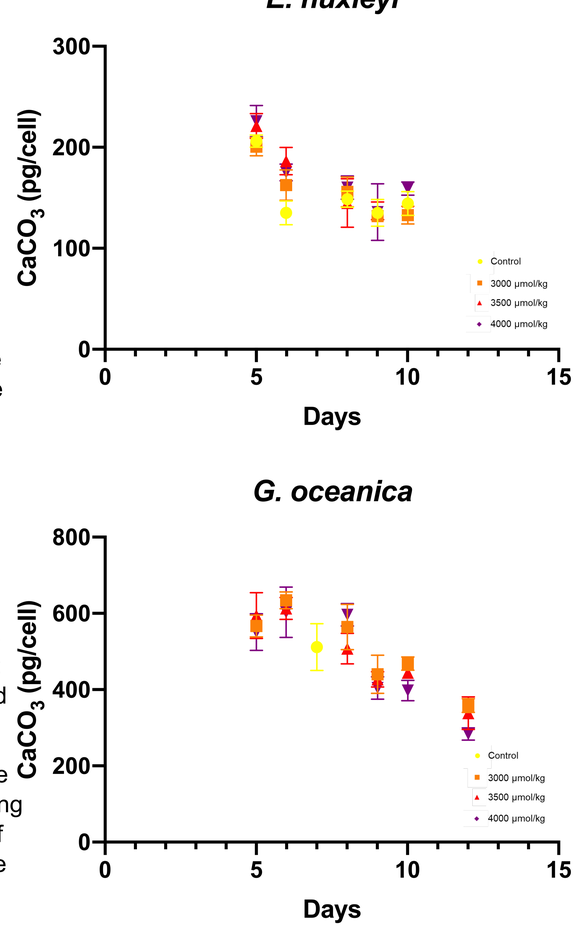
o Both species show no consistent difference in the amount of $CaCO_3$ per cell for each alkalinity treatment through the course of the experiments.

o Cell material was filtered onto acid-cleaned polycarbonate filters and fully dried. Filters were then acidified with HNO_3 and aliquots of the solution were taken for analysis by quadrupole mass spectrometer for Ca.

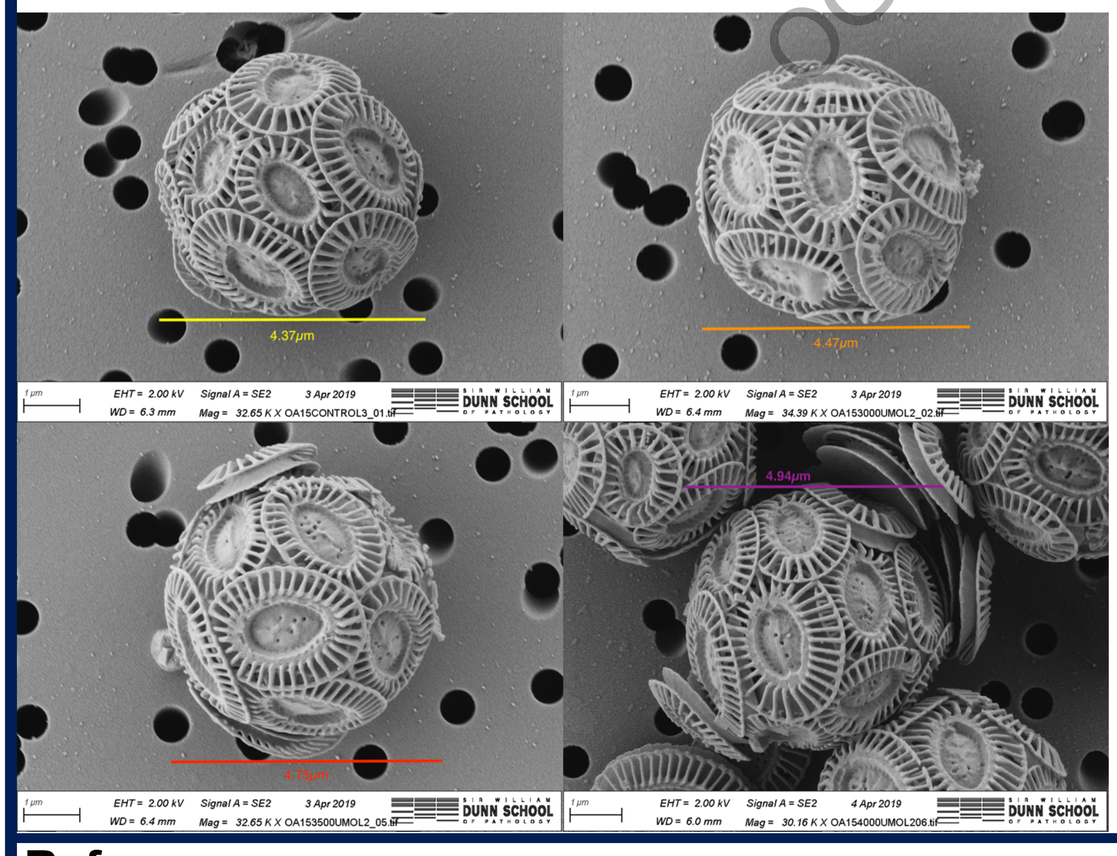
o $CaCO_3$ was then calculated from this Ca data in conjunction with the cell counts in the panel to the left.

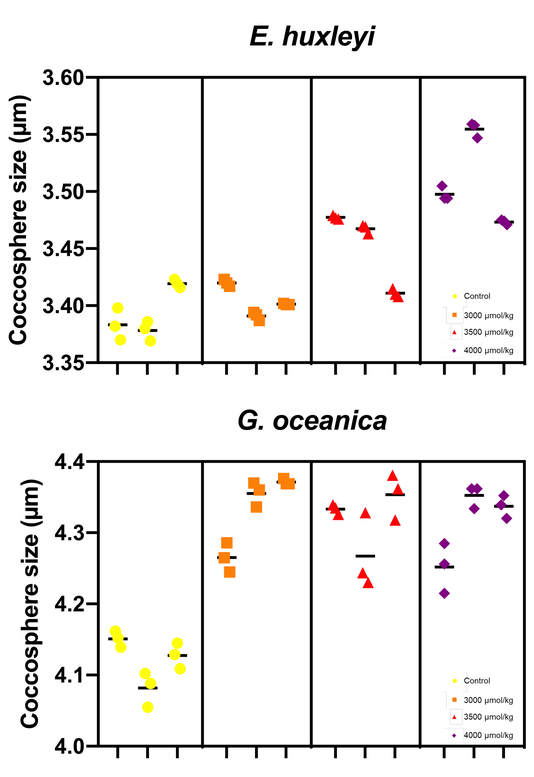
o Samples for PIC:POC and alkalinity drift were taken for this experiment for both species, but analysis has not been conducted yet.

o It will be interesting to compare these three measures of recording calcification. Multiple methods of determination allows for effective ground-truthing.



Coccosphere size





o Both species show an increase in coccosphere size under elevated alkalinity

o There is a step-wise change observed for *E.hux*, whereas *G. oceanica* seems to have a more sudden increase in response to raised alkalinity.

o Increase in coccosphere size was measured using a Coulter counter, and corroborated using SEM imaging. Only the images for *E. hux* are shown here because sadly the cells in the *G. oceanica* SEM samples had burst. Re-imaging is in the works!

o The data plotted is from late exponential phase for the cultures i.e. before they drop out of their metabolic optimum.

Still to come...

There are still samples for PIC:POC, alkalinity and DIC of media, Redfield ratio for *E. hux* and *G. oceanica*, plus SEM images of *G. oceanica* which need to be produced to finish up this experiment.

Future experiments include:
o Exposing *E. hux* and *G. oceanica* to different forms of elevated alkalinity i.e. by adding $Ca(OH)_2$ to SOW.
o Exposing different species to the same alkalinity treatments. *C. braarudii* has been acclimated to $NaHCO_3$ treatments ready to see whether high $CaCO_3$/cell and low culture density species react in the same way as low $CaCO_3$/cell and high culture density species such as *E. hux* and *G.oceanica*.
o Lab experiments to constrain the alkalinity response of planktonic foraminifera, the next most abundant group of calcifying plankton after the coccolithophores.
o Ocean biogeochemical modelling to constrain the impact of the calcification reponse of coccolithophores and forams on a wider scale.

References

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