Short-term response of natural microbial communities to abrupt shift in carbonate chemistry in temperate and polar areas of the ocean

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The Third Annual Science Meeting of the UK Ocean Acidification Research Programme

Objectives of Bioassays

• Perform multiple bioassay experiments under close to natural settings within highly-replicated shipboard experiments on a large geographical scale

• Investigate the responses of natural microbial communities to rapid shifts in carbonate chemistry

• Ascertain the short-term response of a large number of planktonic organisms and processes

Bioassay experiment general procedure

Water collection

Sea surface water from CTD

Filling of incubation bottles

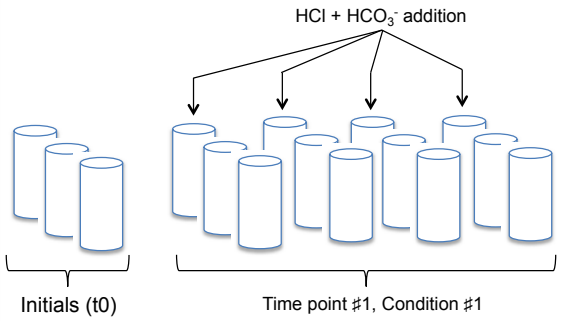
UK cruise

On deck at arrival

Arctic & Southern Ocean

Trace-metal clean container

Carbonate chemistry manipulation / iron addition

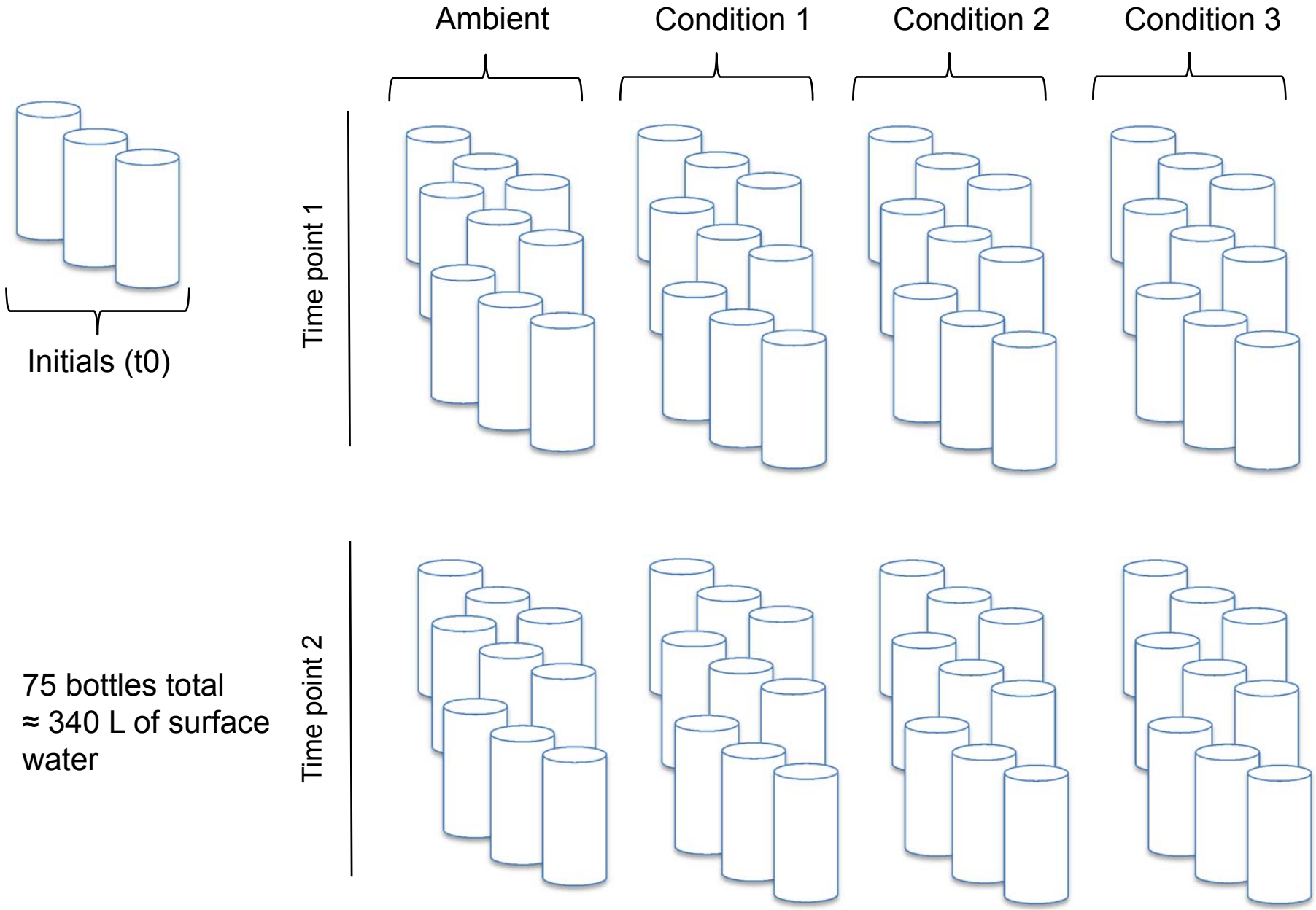


In trace-metal clean container for Arctic and Southern ocean

Incubation

Refrigeration unit (temperature adjusted to *in situ*)

LED panels (100 µE m^{-2}. s^{-1})


Ambient
Condition 1
Condition 2
Condition 3
Initials (t0)
Time point 1
Time point 2
75 bottles total
≈ 340 L of surface water

On and around the Northwestern European continental shelf (June-July 2011)

Objective:

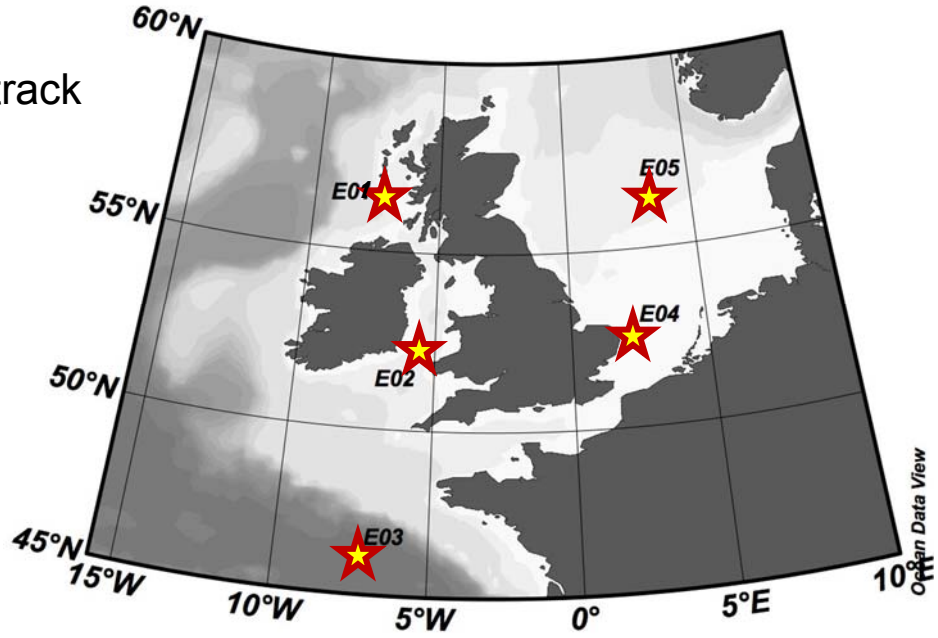
Five bioassay experiments were run along the track

4 conditions tested:

- Ambient
- 550 µatm
- 750 µatm
- 1000 µatm

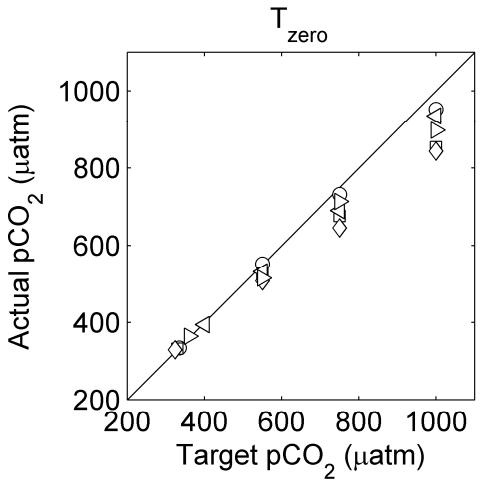
Timescale of each experiment: 4 days

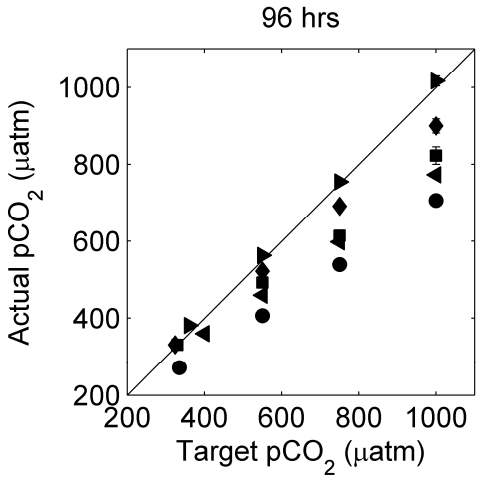
2 time points: 48h and 96h

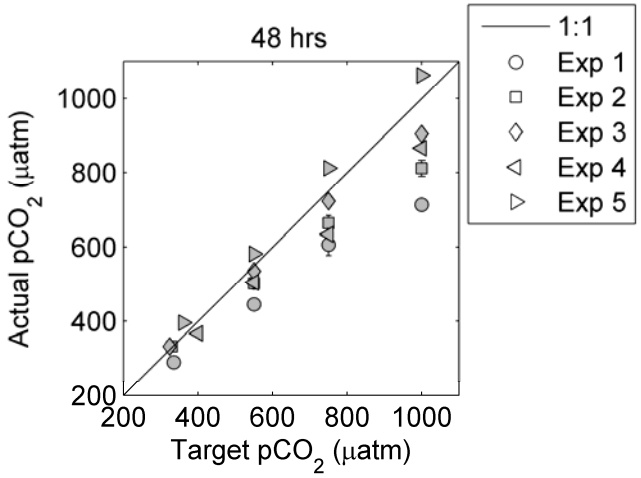


On and around the Northwestern European continental shelf (June-July 2011)

High reliability of the carbonate chemistry manipulation method



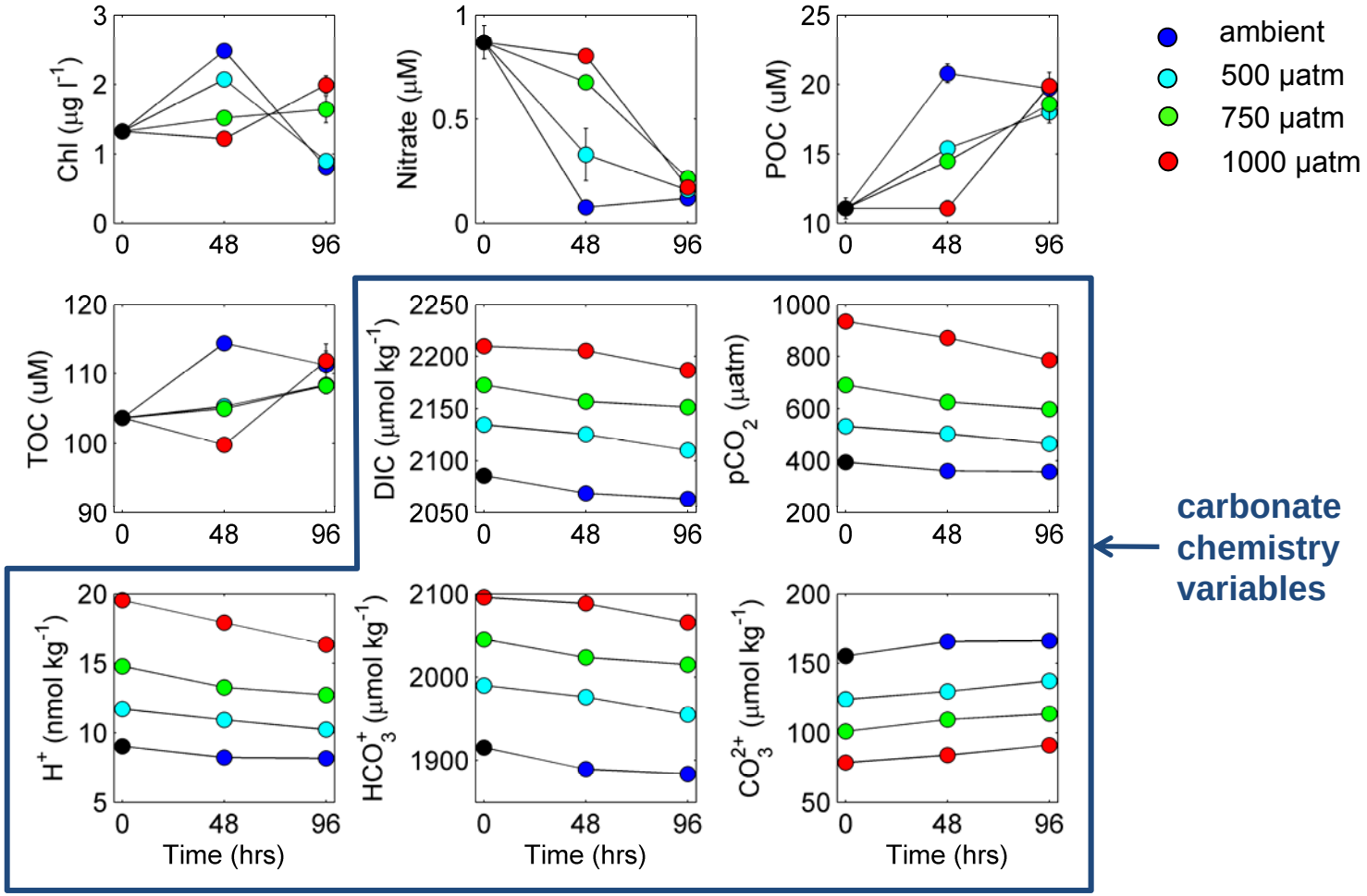




Drift in [pCO_2] (some deviation between target and achieved pCO_2 at high pCO_2)

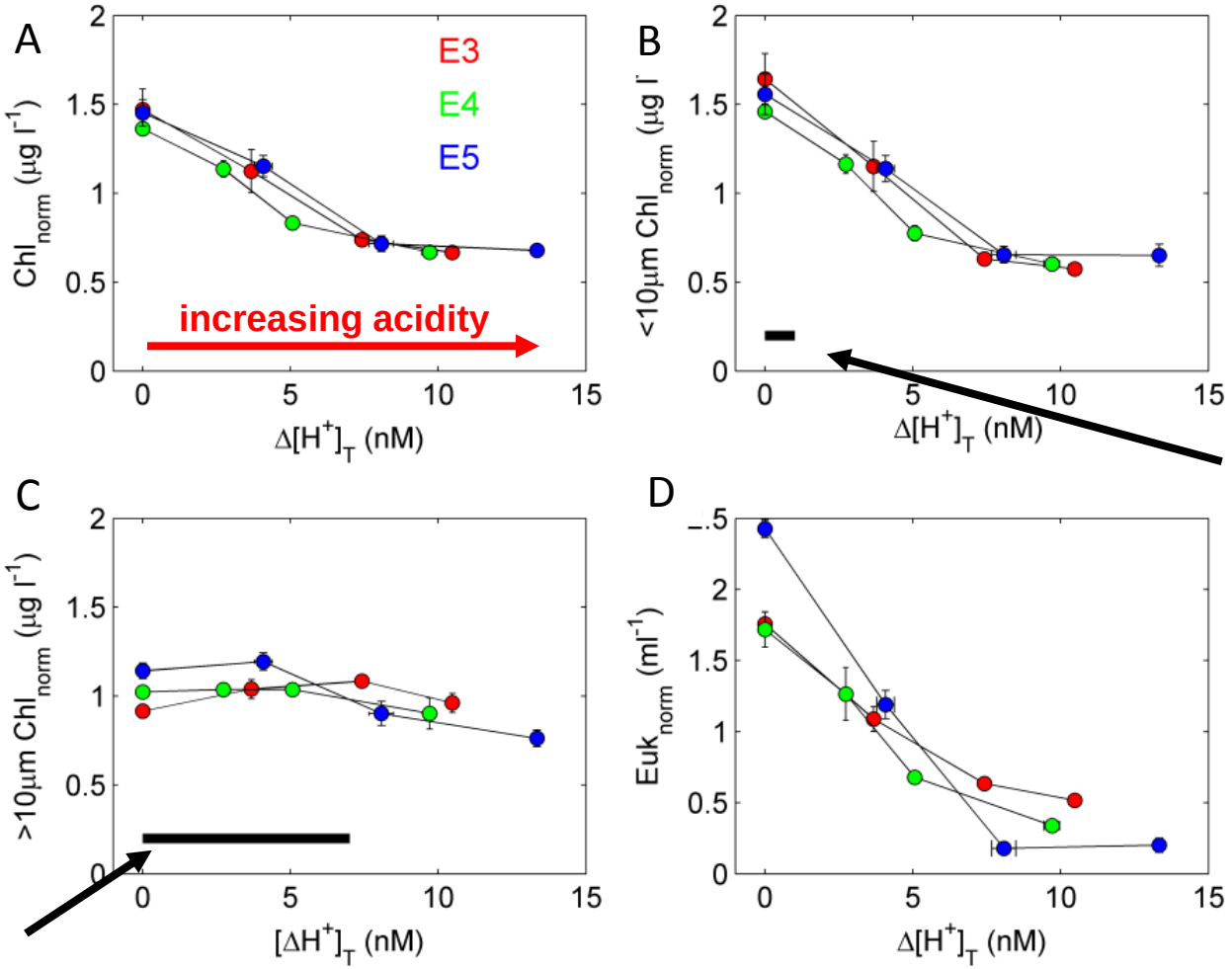
On and around the Northwestern European continental shelf (June-July 2011)

A consistent well controlled carbon cycling



Growth rates, nutrient uptake rates and related POC production are sensitive to [H^+] increase

On and around the Northwestern European continental shelf (June-July 2011)



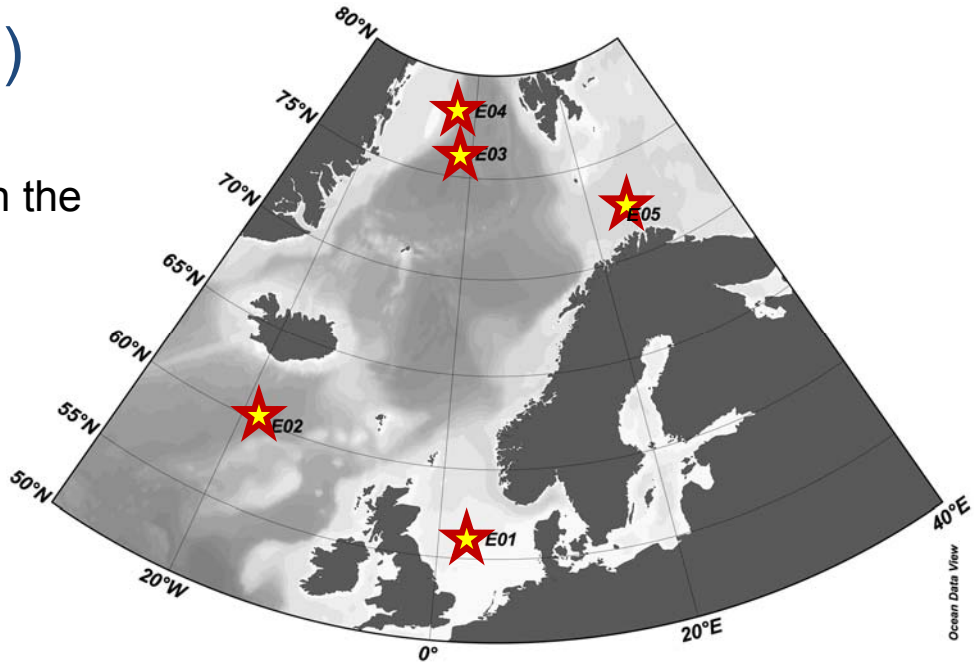
Estimated range of daily near surface [H$^+$] variability

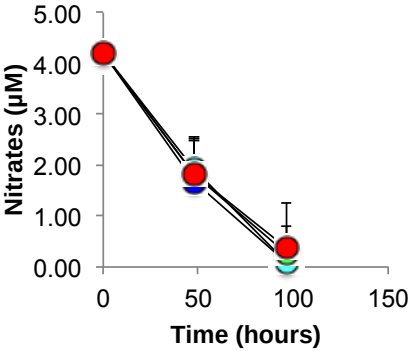
Rapid deliberate change of external (and hence cell surface) [H+] within experiments is beyond that which is likely experienced by small cells.

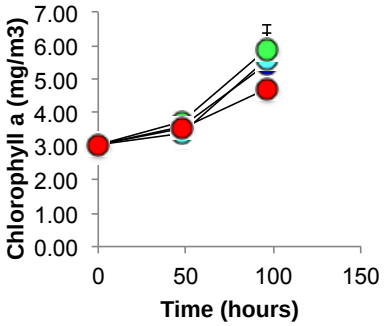
However, change is actually similar in magnitude to that typically experienced by larger cells in situ over a diel cycle...

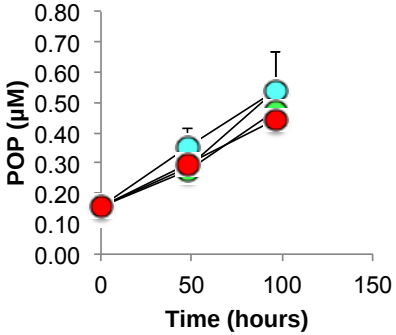
Arctic waters (June-July 2012)

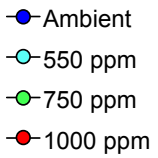
Same objectives and experimental design then the previous cruise







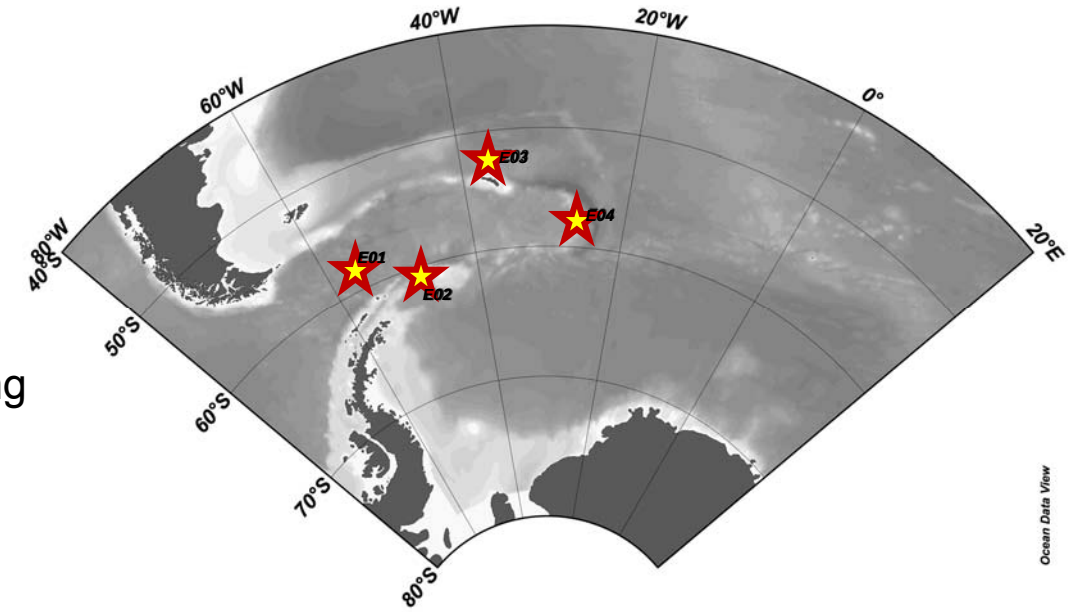




Unlike the first cruise, no significant response was observed that was consistent across all stations. At this stage of our analysis, we attribute the difference to different community compositions between the cruises, or to different buffer factors.

Southern ocean (January-February 2013)

Also looked at the impact of **iron enrichment** on natural microbial communities in polar waters



Four bioassay experiments were run along the track

Tested conditions:

- Ambient
- A + iron addition (2 nM)
- 750 µatm
- 750 µatm + iron addition

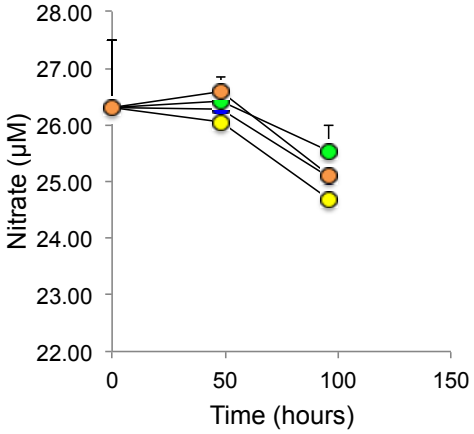
- Ambient
- 750 µatm
- 1000 µatm
- 2000 µatm

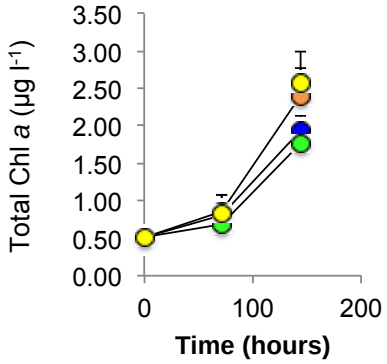
Timescale: 4-8 days

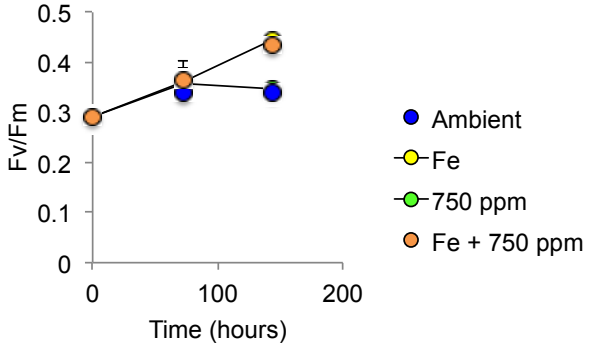
2 time points: 48-96h and 96-168h

Southern ocean (January-February 2013)

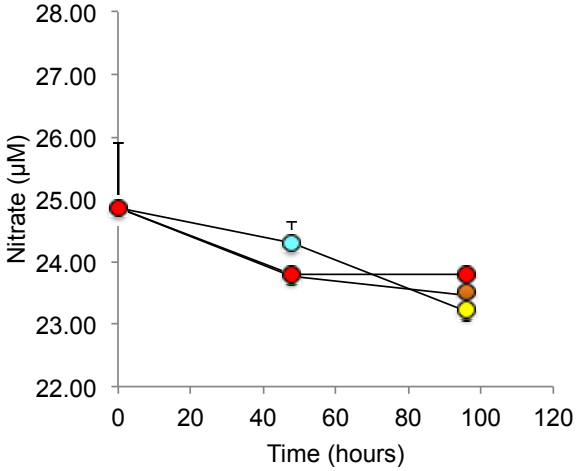
Experiment 2 (6 days)

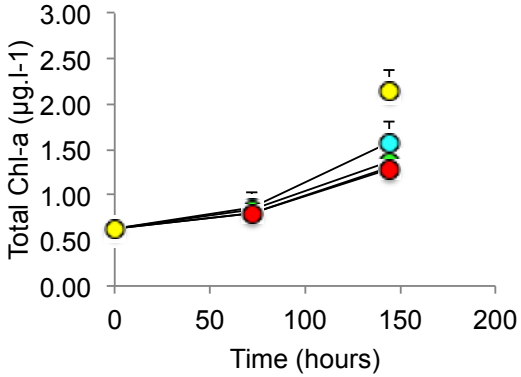


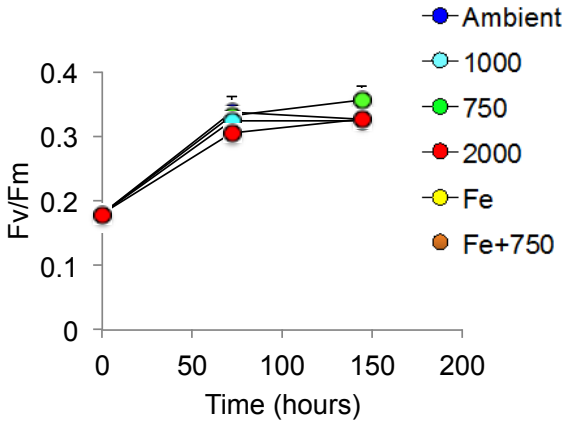




Experiment 3 (6 days)



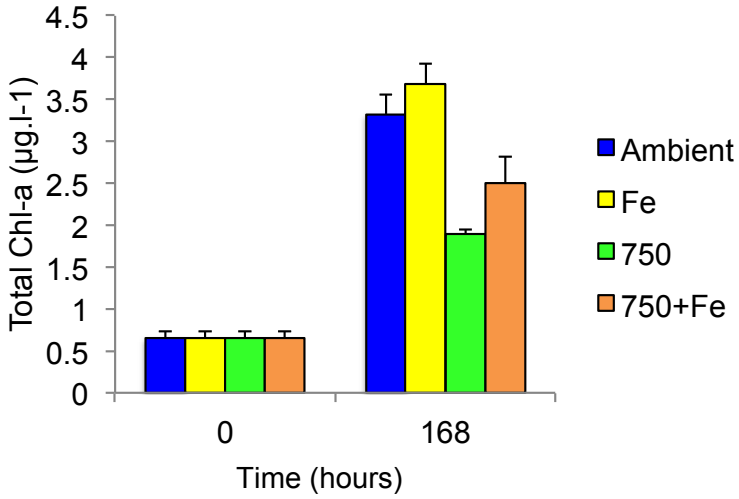


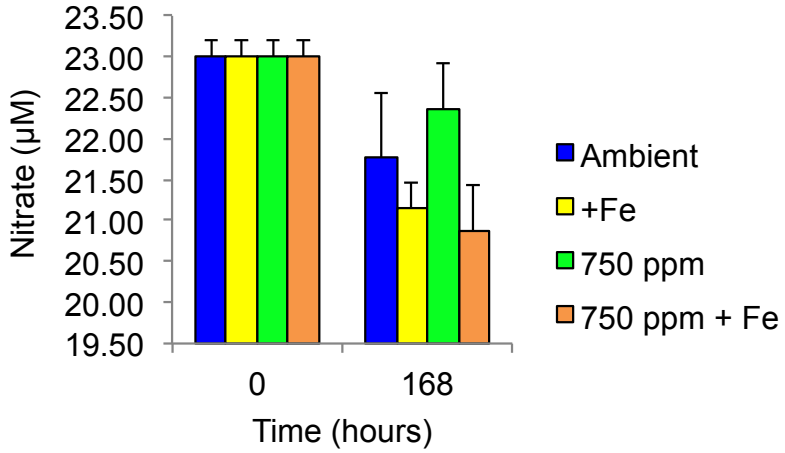


We observed a significant response to Fe addition and to the combination of both parameters (high pCO_2 + Fe)

Southern ocean (January-February 2013)

Additional experiments (on deck incubations, for 7 days)
Iron addition: 0.2 µM





We observed a combined effect of both the iron addition and the increase of pCO_2 on nutrients drawdown and Chl *a* content after a 7 day incubation period.

Summary Table (NB – preliminary)

	Around the UK	Arctic	Antarctic		
Parameters tested	High pCO_2	High pCO_2	High pCO_2	+Fe	High pCO_2 + Fe
Number of exp.	5	5	2	5	5
Total Chl *a*	↓	-	↓	↑	↓
<10µm Chl *a*	↓	-	↓	↑	↓
Fv/Fm	↓	-	↓	↑	↓
POC/PON/POP	↓	-	na	na	na

Conclusions (NB – Preliminary)

The carbonate chemistry manipulations worked well.

We observed a significant response to Fe addition and the combination of (Fe addition and high pCO_2) in Southern Ocean waters.

The clear responses to iron additions show: (1) our bioassay method is capable of picking up expected responses, (2) we were successful in avoiding trace metal contamination.

We observed quite contrasting physiological responses of phytoplankton communities between temperate and polar seas.

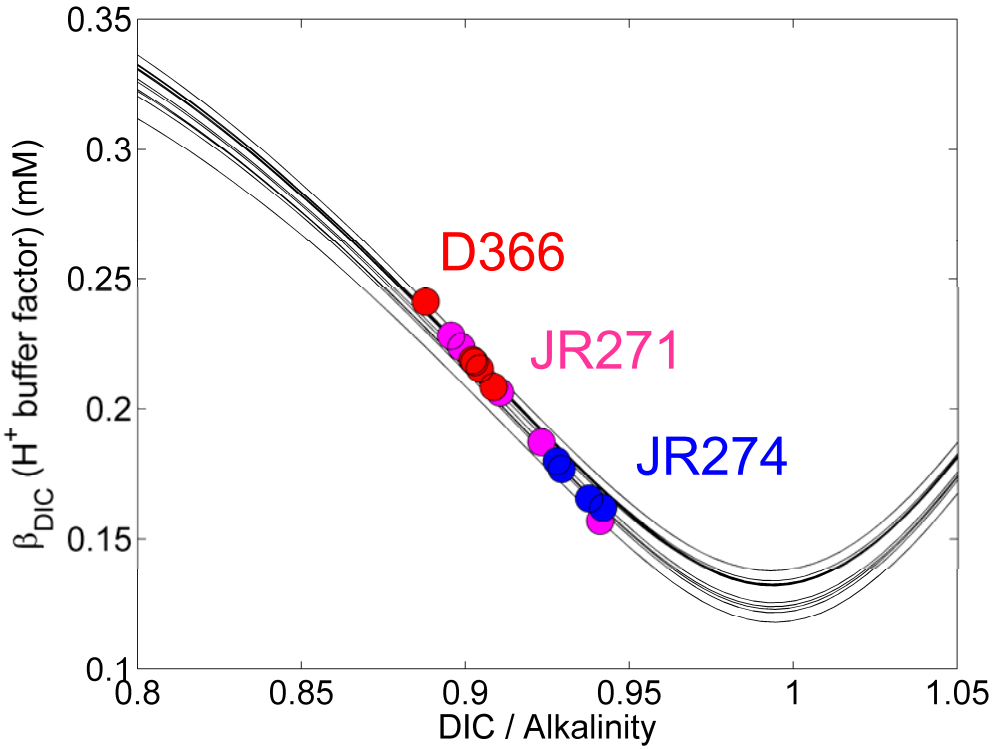
The rate of organic matter production was consistently slower under high CO_2 in temperate waters, whereas fewer significant differences were observed at high latitudes.

Buffer Factor Differences

In situ buffer factor varied greatly between initial conditions across full set of experiments.

High for D366 (UK shelf), variable for JR271 (Arctic), low for JR274 (Antarctic).

So for example, for a given forcing (e.g. diurnal variability in photosynthesis, or a large bloom), natural variability in $[H^+]$, Ω etc. may be >40% lower in the Southern Ocean than over the UK shelf.



Potentially implies that high latitude populations will be better adapted to cope with variability in e.g. $[H^+]$, $[CO_3^{2-}]$ etc.?

Acknowledgments

Cynthia Dumousseau - *Southampton Uni*

Ross Holland - *NOCS*

Mark Stinchcombe - *NOCS*

Philip Williamson *(UKOA Science coordinator)* – *Uni East Anglia*

All the people involved in the Sea Surface Consortium

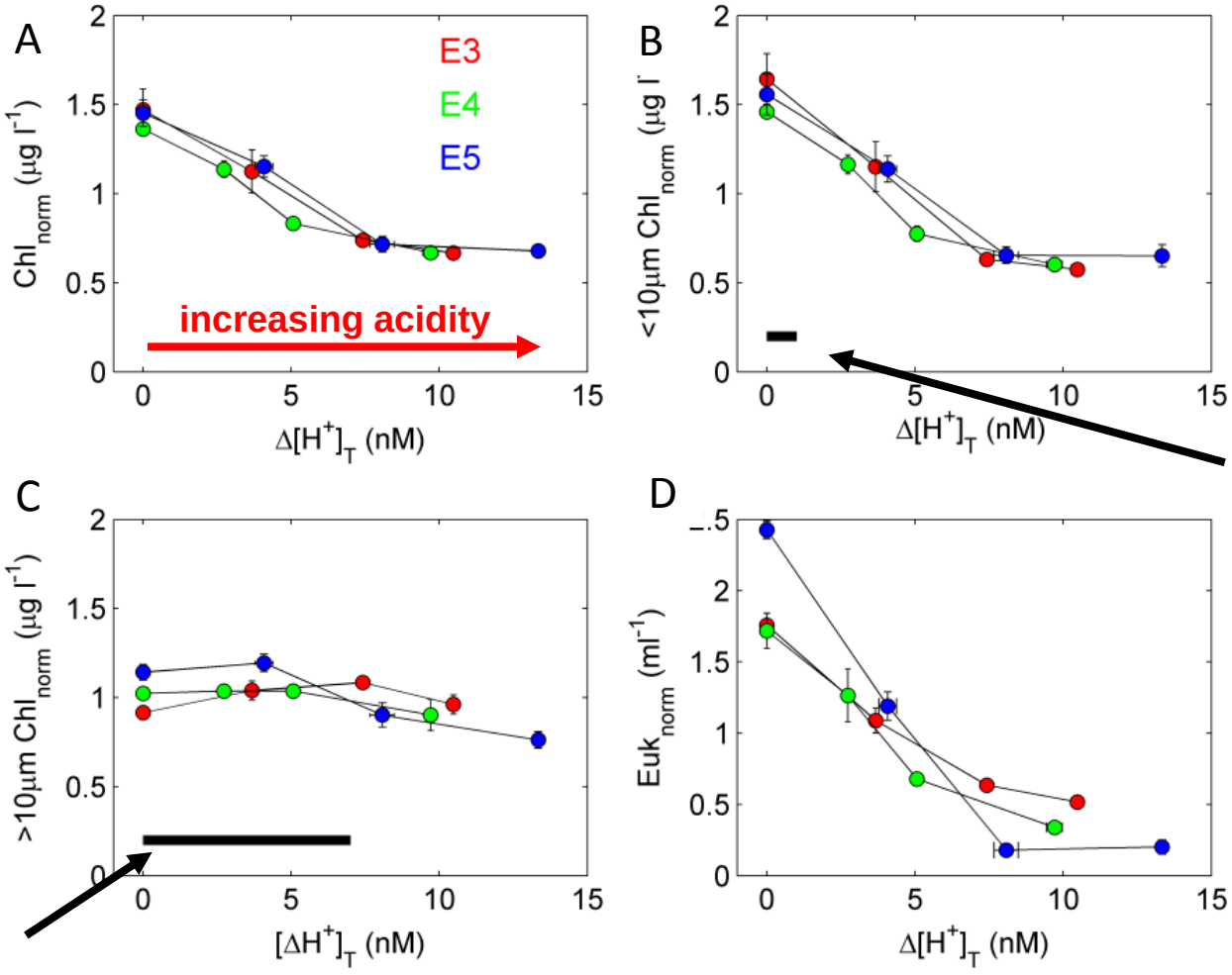
All the scientists on board the three cruises

The crew on the RRS Discovery and James Clark Ross

THE END

Timescales

- **Phytoplankton bioassay durations: 4 to 7 days**
- **Acclimation of *E. huxleyi* to CO_2: <26 hours (Barcelos e Ramos et al., 2010)**
- **Typical phytoplankton lifespan: few days**



Estimated range of daily near surface [H⁺] variability