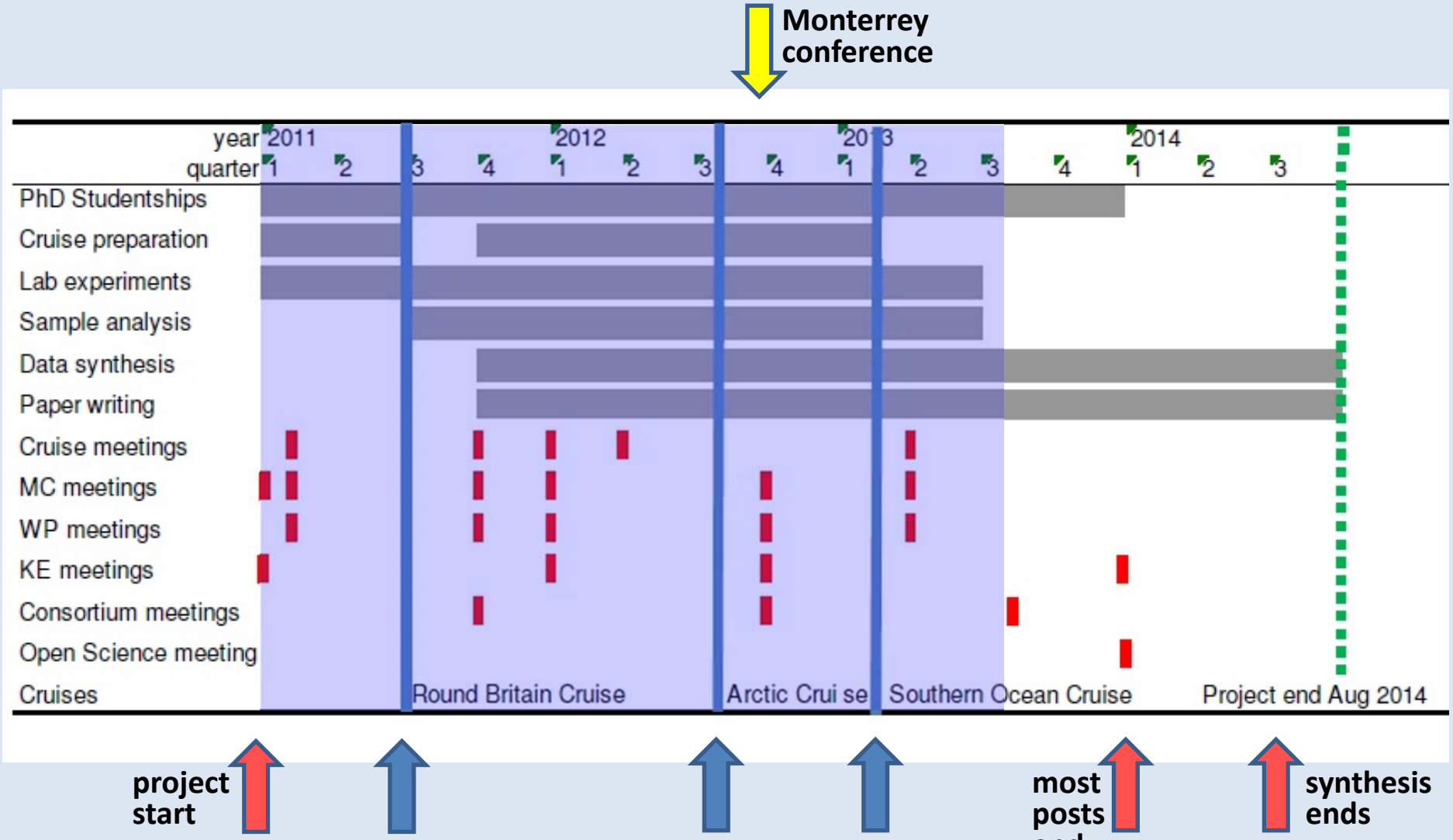

UK Ocean Acidification Research Programme
Sea Surface Consortium UKOA
Sea-Surface Consortium: Overall Progress
Toby Tyrrell
UKOA ASM, St. Andrews, 22-24 July, 2013
National Oceanography Centre Southampton
University of Southampton
School of Ocean and Earth Science

Main Approaches

1. **Bioassay experiments (in-situ populations, natural conditions)**
   (conducted 14 in total)

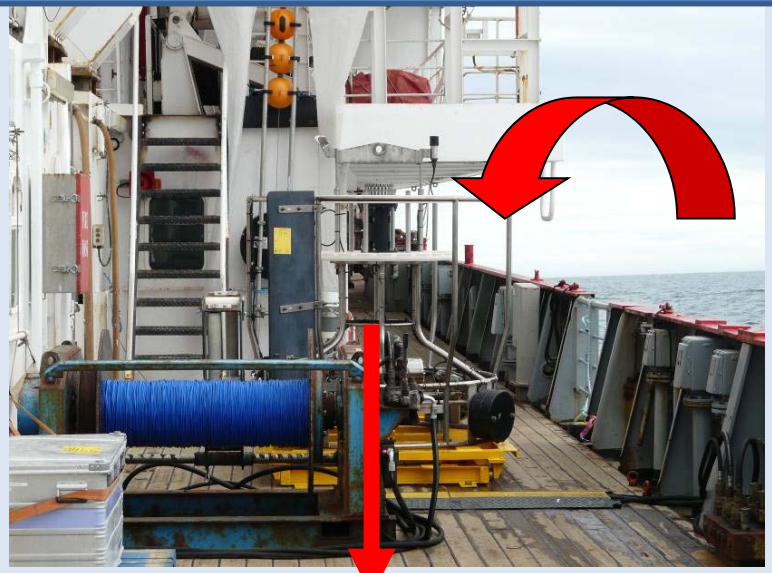
2. **Observational study (how do organisms and processes differ with carbonate chemistry?)**
   (measurements on all three cruises)



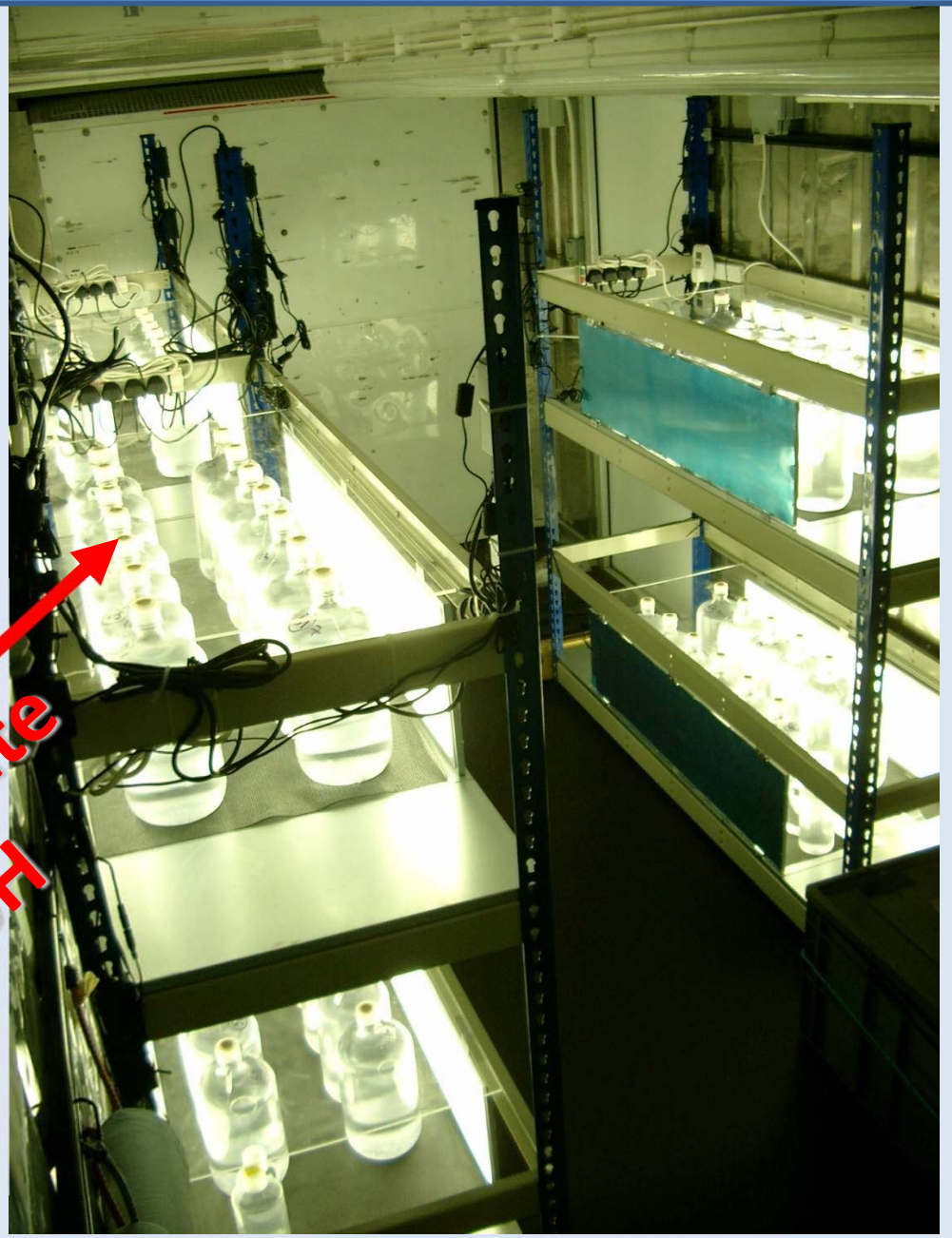
Timeline

Sea Surface Consortium UKOA

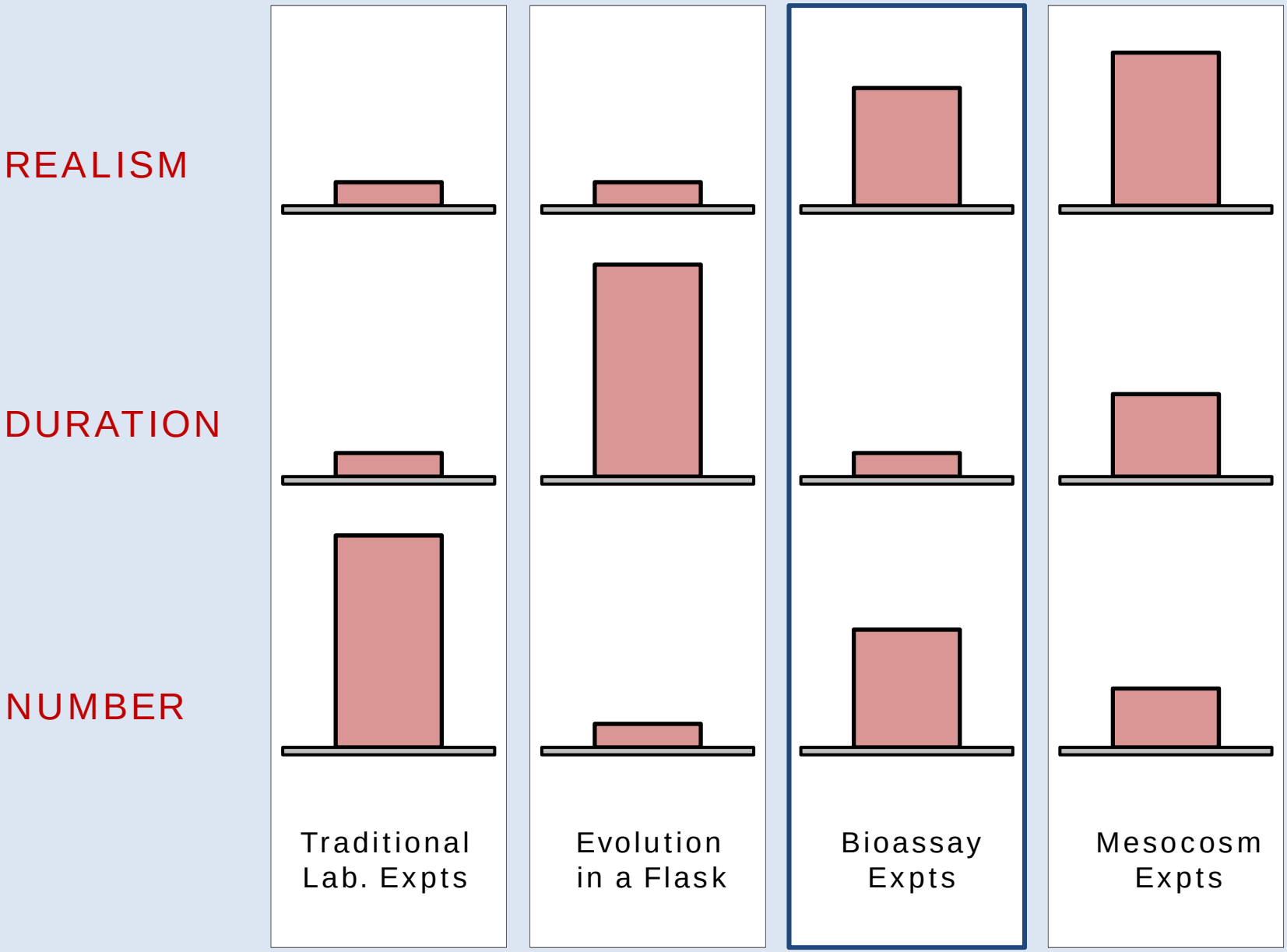
Bioassay experiments



Manipulate pCO_2/pH



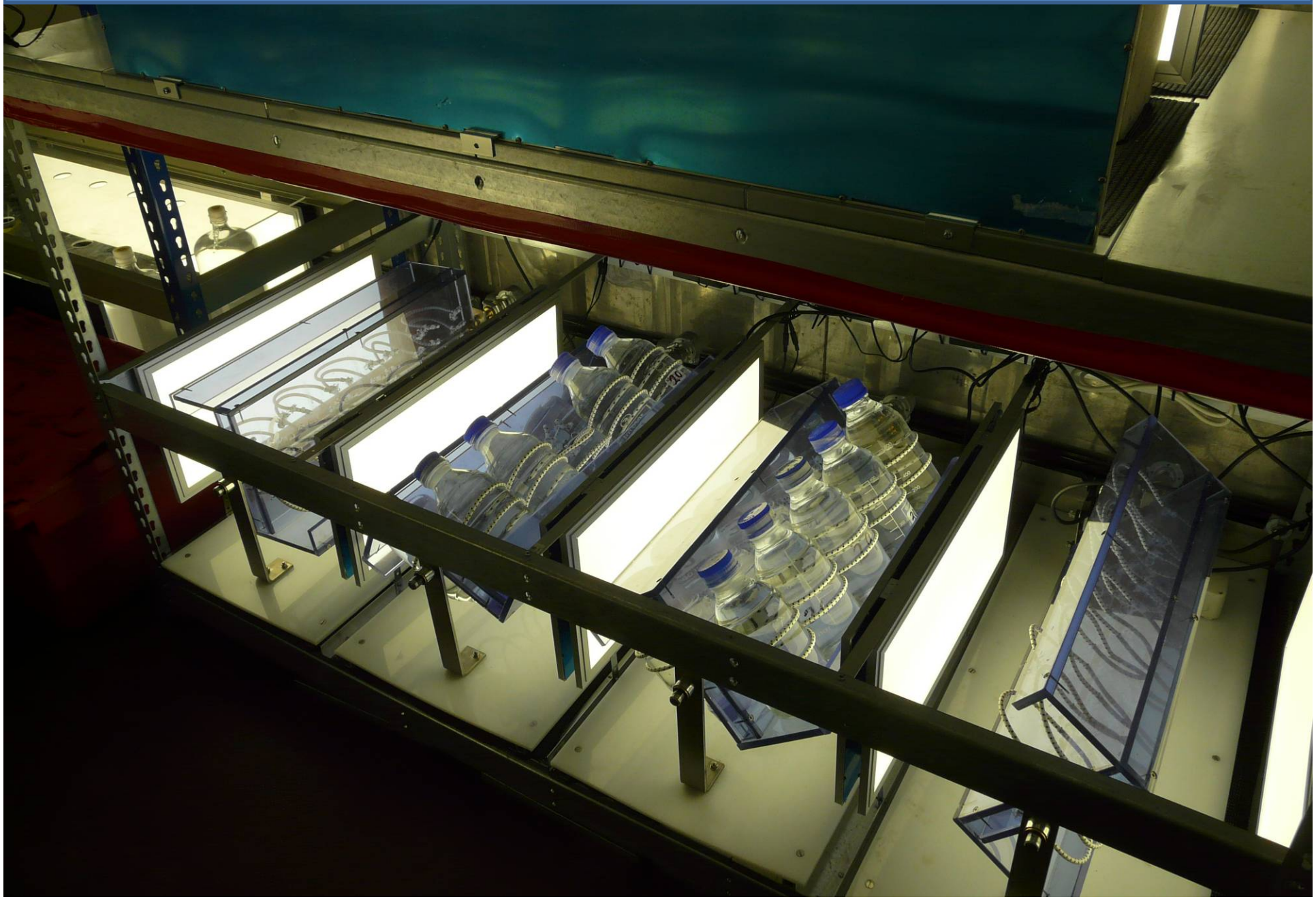
Bioassays compared to other methods



Trace metal clean procedures

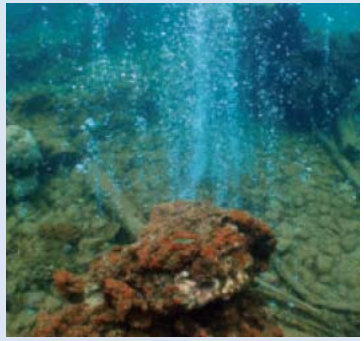
Lots of plastic, no metal

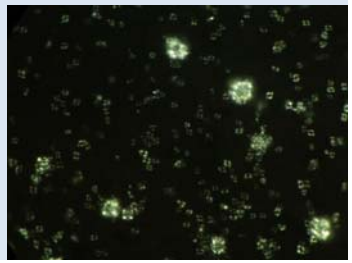
Additional zooplankton experiments



Observational approach now widely used

- Baltic and Black Seas (coccos)
- CO_2 vents near Naples (various)
- CO_2 cold seep off Papua New Guinea (corals)
- Submarine volcano, Mariana Arc (mussels)
- Upwelling, Kiel fjord (mussels)
- Submarine springs, off Mexico (corals)
- Great Barrier Reef (corals)
- 3 cruises, South Pacific and Southern Ocean (coccos)
- …





Collection of observational data

Collection of observational data

Collection of observational data

Collection of observational data

Progress so far

- Three cruises ✓
- Carbonate chemistry manipulations ✓
- Carbonate chemistry measurements ✓
- Bioassays (trace metal clean) ✓
- Collection of observational data ✓
- Dataset submissions - ongoing
- Manuscripts – first special issue in preparation

Special Issue from first cruise

Biogeosciences

8 or 9 papers

Guest editor: Jean-Pierre Gattuso

Submission window opened 01 June 2013

Other editors: Eric Achterberg & Toby Tyrrell

First thoughts on overall findings

NB: Still early days for results from cruises

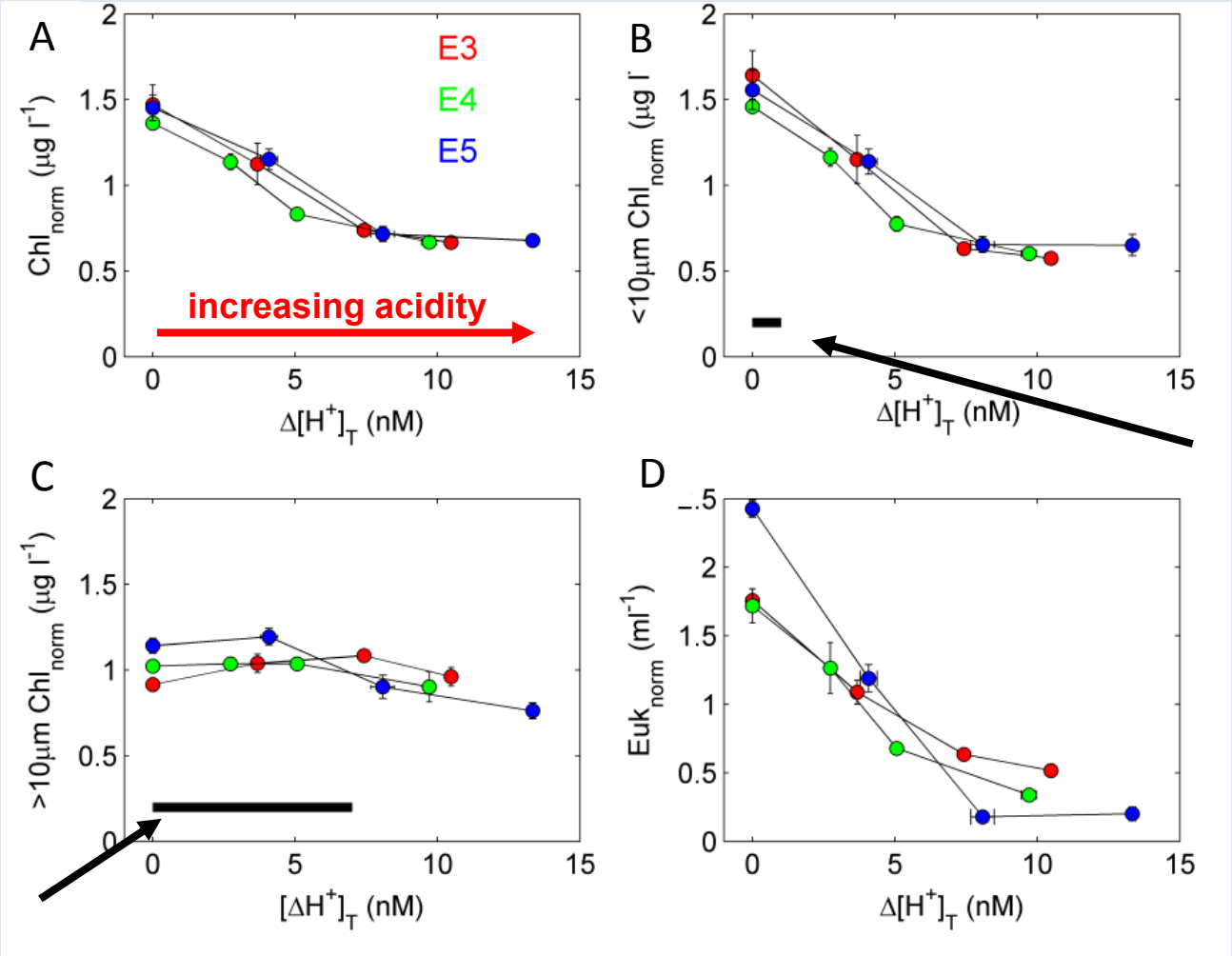
Absence of clear-and-consistent effects of OA on most processes and organisms, according to bioassays

Probable exceptions: pteropods, externally-calcifying coccos, sub-surface nitrification, DMS, phytoplankton assemblage and total chl in shelf waters

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

List of potentially OA-sensitive variables that were measured

CTD

- Primary production
- Microplankton primary production
- POC-PON-POP
- DMS-DMSP
- CH4-NO2
- PIC
- PvE
- Flow cytometer
- Lugols
- Genetic

UW

- Primary production
- Microplankton primary production
- Genetic
- CH4-NO2
- PIC
- PvE

Measured many things that OA could affect

List of potential forcing variables measured

CTD

- Nutrients
- Ammonia

UW

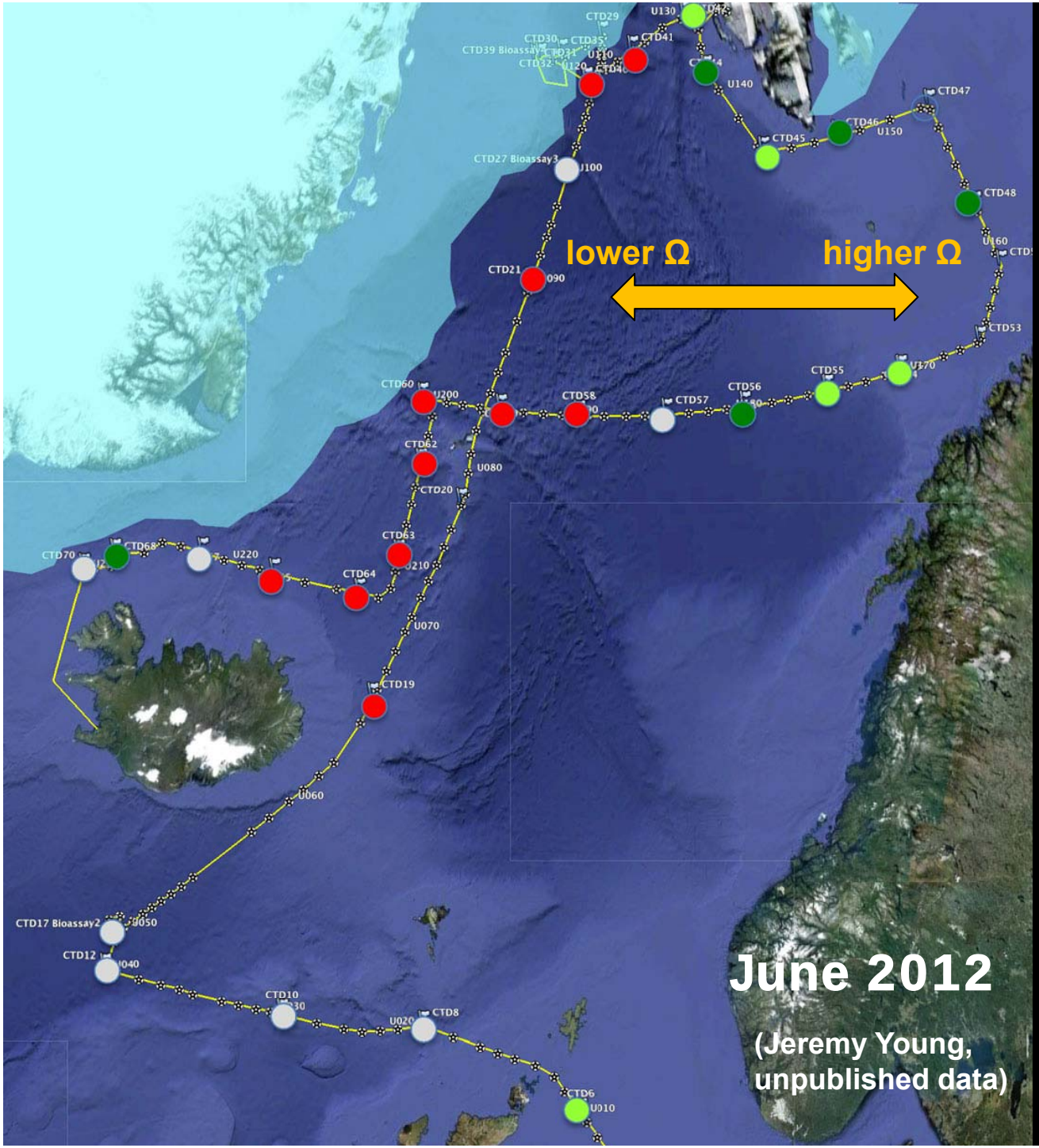
Because correlation does not prove causation

forcing variables

- Irradiance
- DIC & TA
- pH
- pCO2 (PML&UEA)
- Wind strength
- Dissolved Fe and Cu

Multivariate statistics

- Principal components analysis
- Correspondence analysis
- Multidimensional scaling
- Clusters
- Multiple linear regression
- …

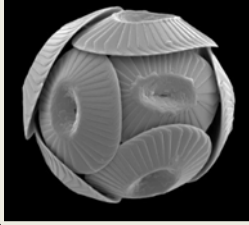


E. huxleyi

PIC:POC = 0.8

- Ehux:CPel < 5
- Ehux:CPel > 5
- Ehux:CPel > 50
- Ehux:CPel > 500

C. pelagicus



PIC:POC = 1.7

Bioassay experiments, UKOA

Experiments on the natural plankton community

Carried out in the same seawater they live in

Manipulation of CO2

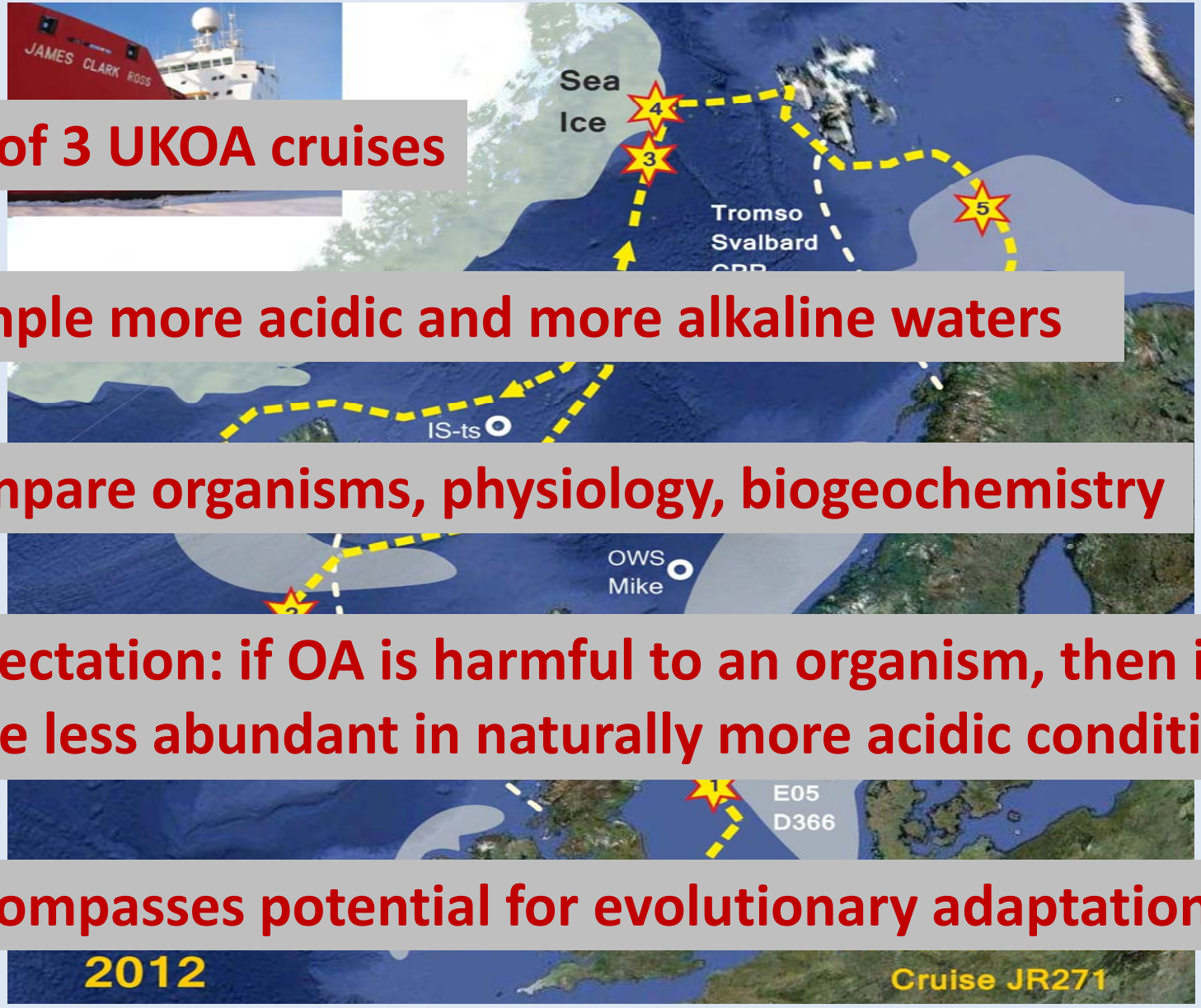
Short-term, between 4 and 7 days long

Quite small volumes (4 litres each)

Lots of bottles - replication

Refrigerated shipping container (customised)

UKOA cruise to the Arctic, June 2012



2nd of 3 UKOA cruises

Sample more acidic and more alkaline waters

Compare organisms, physiology, biogeochemistry

Expectation: if OA is harmful to an organism, then it will be less abundant in naturally more acidic conditions

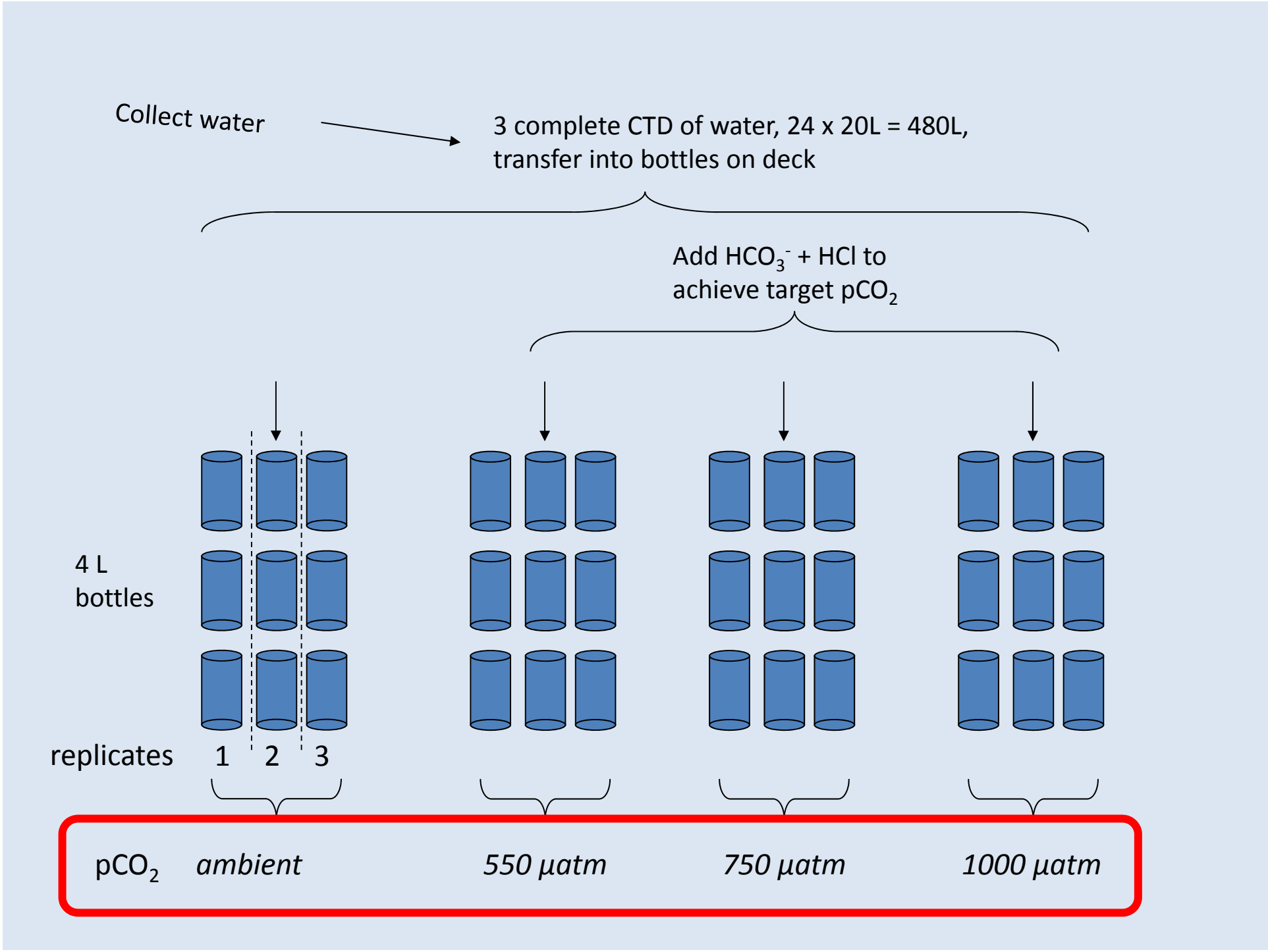
Encompasses potential for evolutionary adaptation

Carbonate chemistry manipulations

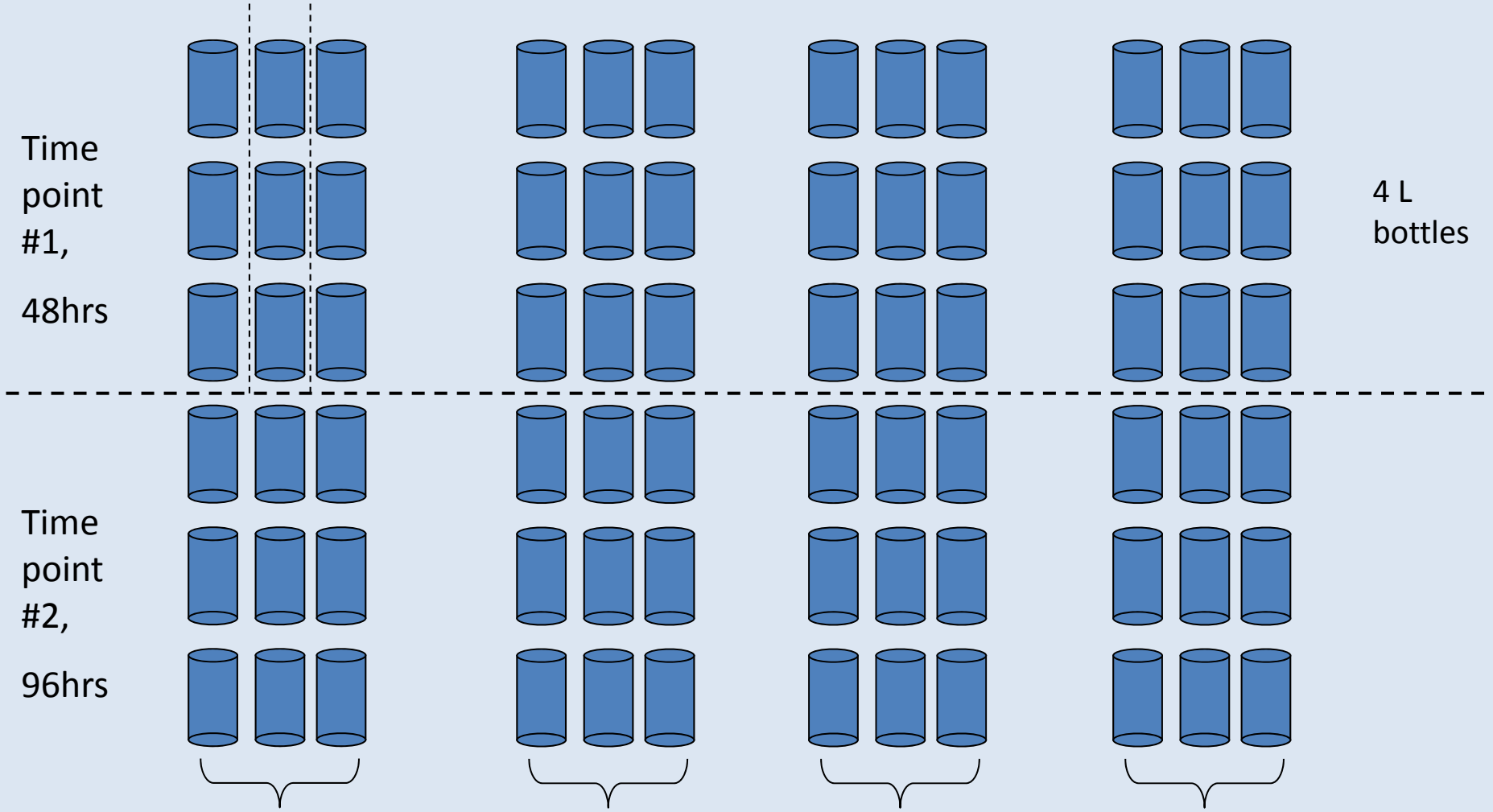
Addition of equimolar concentrations of acid and bicarbonate

Raises CO_2 and lowers pH identically to adding CO_2, but without physical disturbance of bubbling

Carbonate chemistry was subsequently measured to check


Collect water
3 complete CTD of water, 24 x 20L = 480L,
transfer into bottles on deck
Add HCO_3^- + HCl to
achieve target pCO_2
4 L
bottles
replicates
1
2
3
pCO_2
ambient
550 µatm
750 µatm
1000 µatm

More than 80 bottles each time



plus initials…

Advantages and Disadvantages of Bioassays

Advantages

- Realistic environmental conditions
- Realistic, complex ecosystem
- Ability to manipulate CO2
- Replication

Disadvantages

- Short-term
- No evolution
- Interpretation of results less straightforward than for lab expts
- Logistics: requires ship, lots of people, specialised container

Conclusions

Trends in ocean acidification research are towards:

(1) more realistic experiments

(2) longer-term experiments

(3) observational studies

(4) Also, not discussed here, work on fundamental mechanisms

One reason is because we need to understand how well organisms can evolve to cope with OA

new book “On Gaia”

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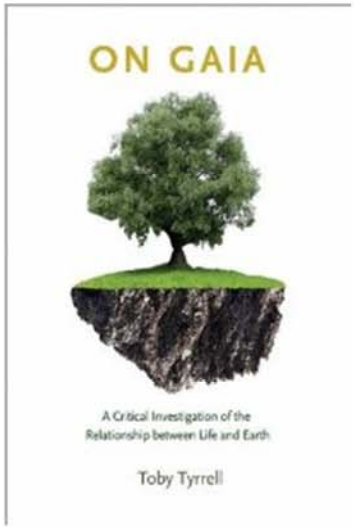

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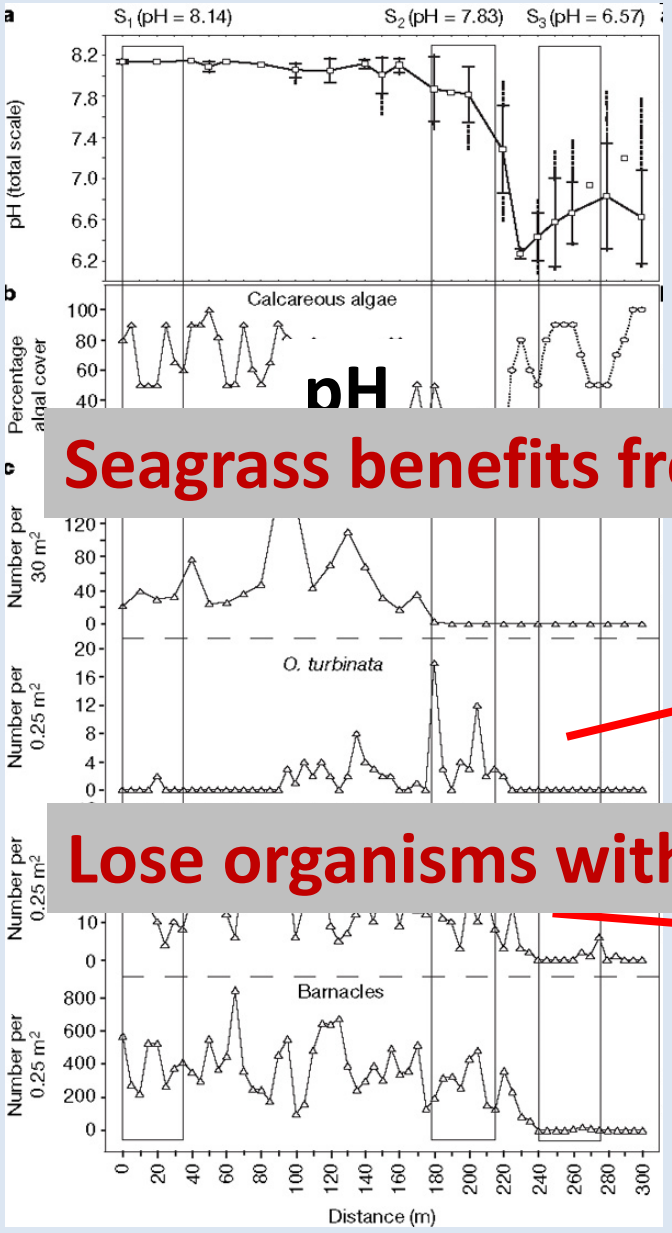
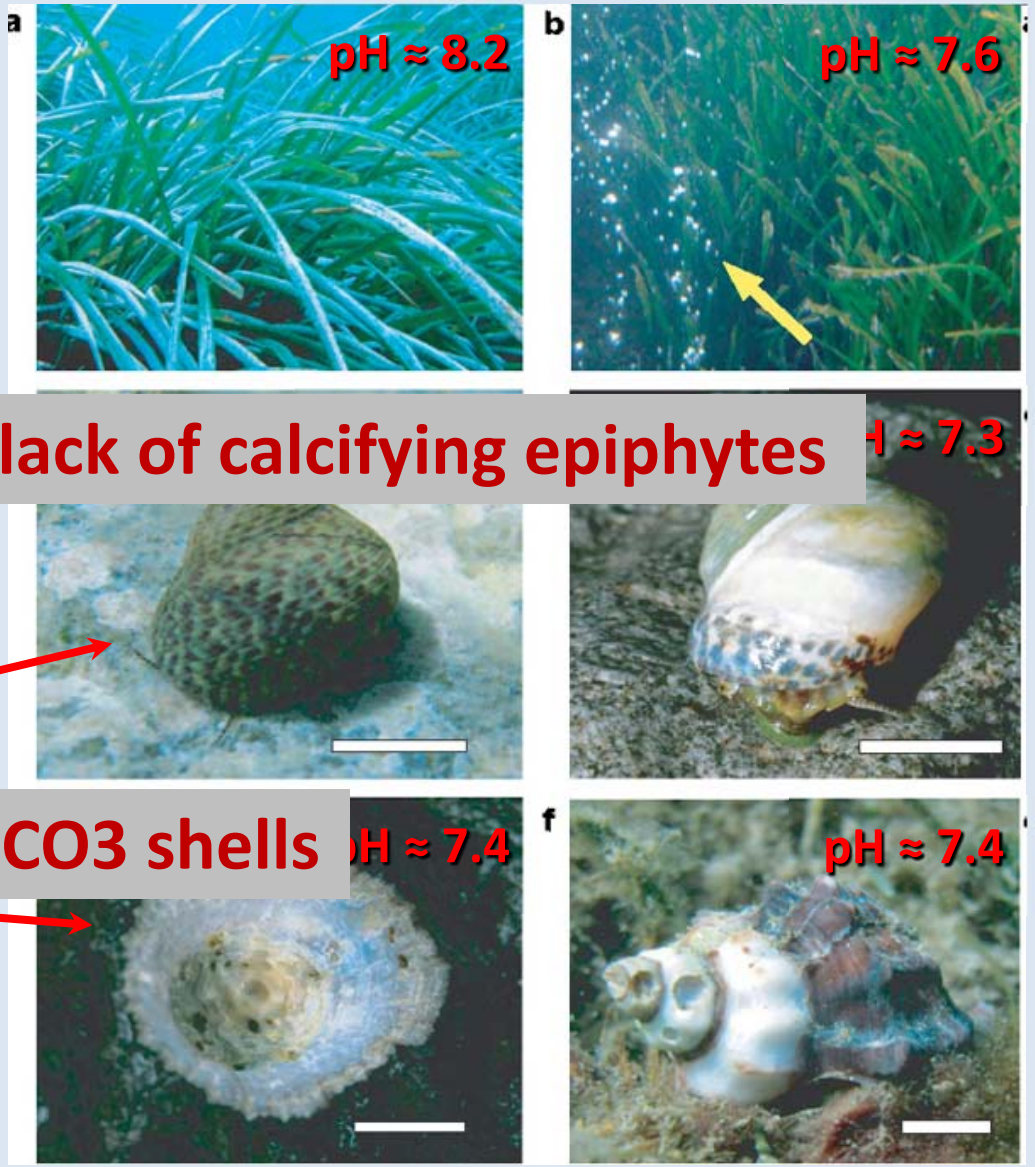
Biological surveys in and around vent





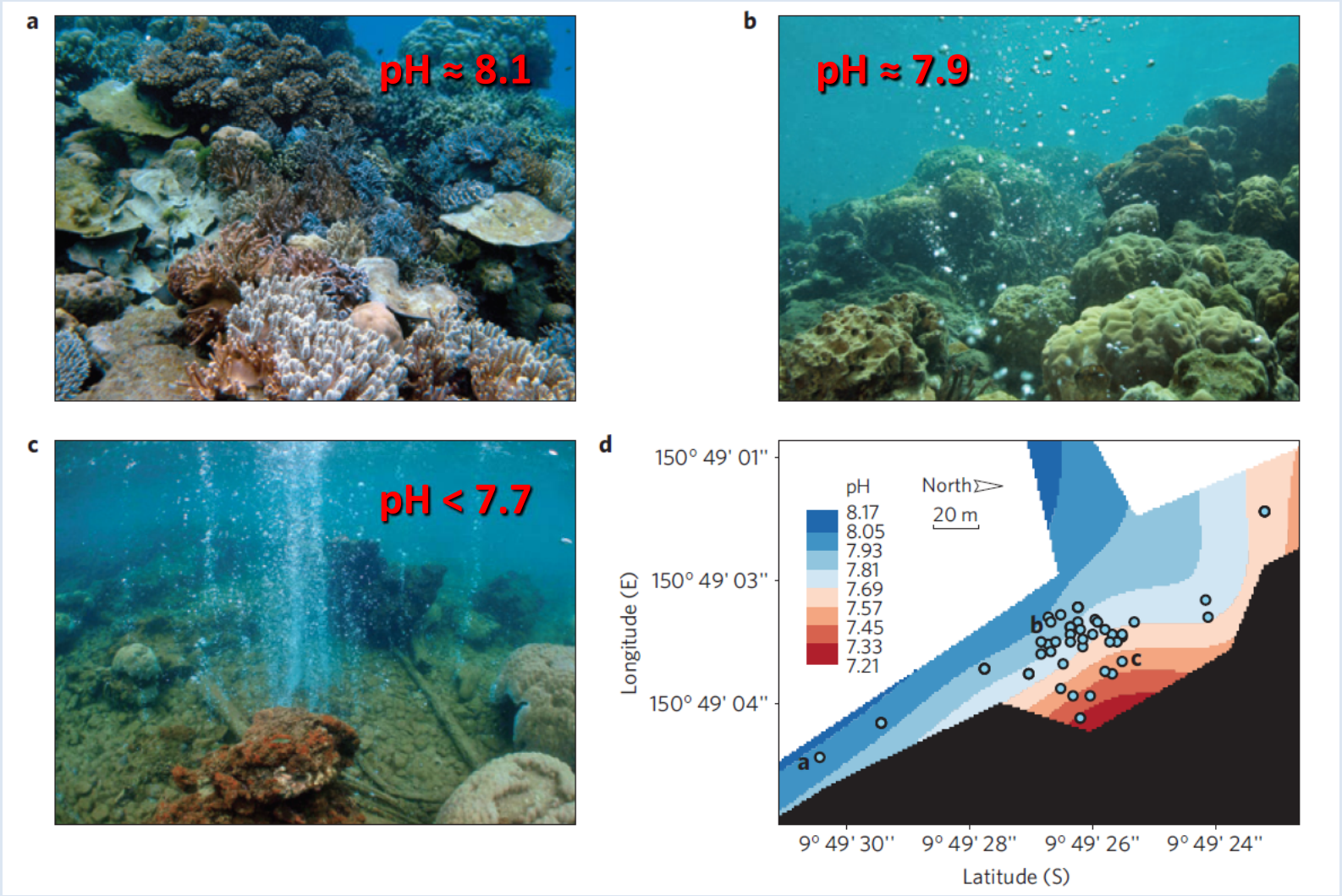
Seagrass benefits from lack of calcifying epiphytes

Lose organisms with CaCO3 shells

High pH Low pH

(Hall-Spencer et al, 2008, Nature)

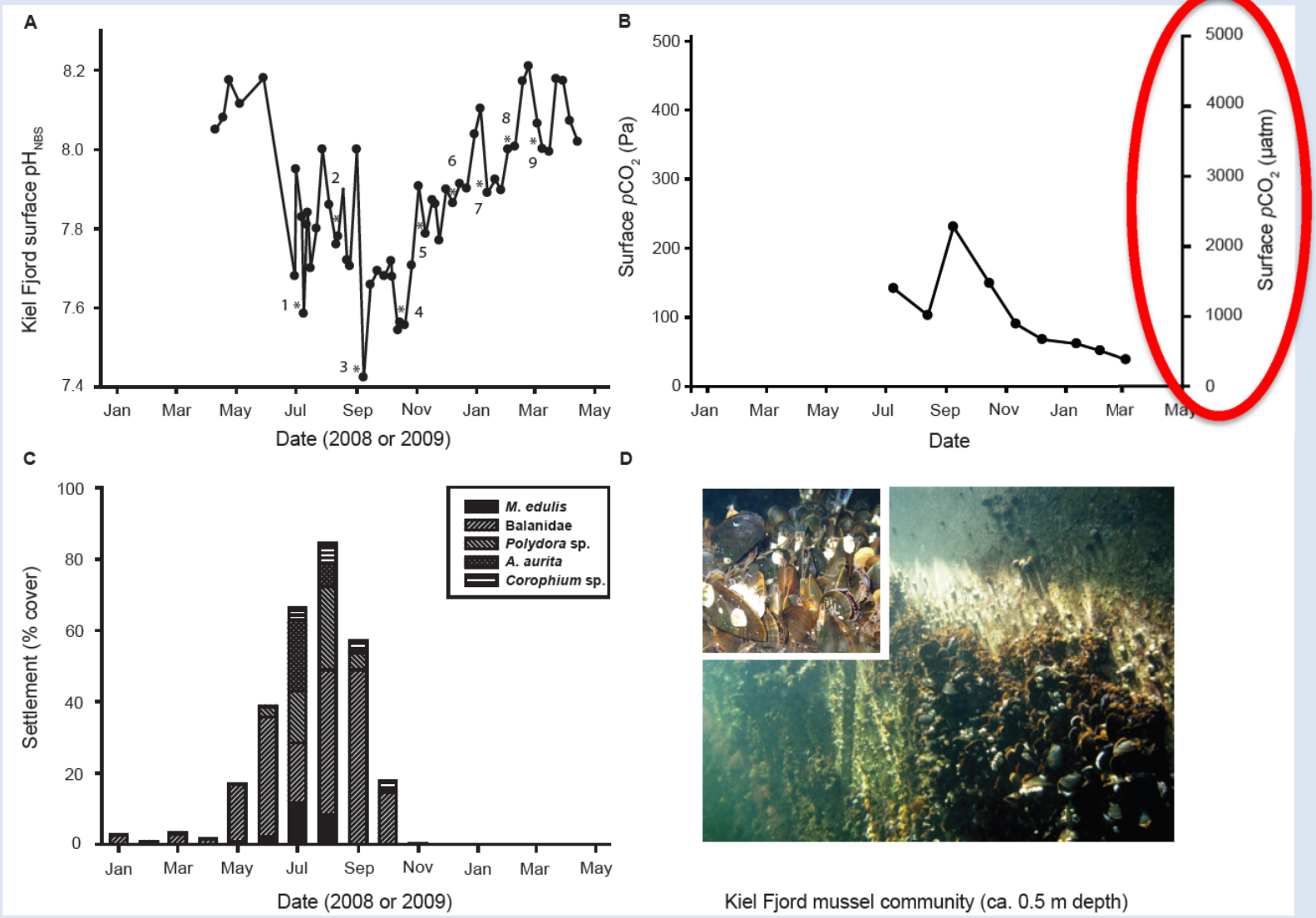
CO2 cold seep, Papua New Guinea



Reduced coral diversity and abundance at lower pH

(Fabricius et al, 2011, *Nature Climate Change*)

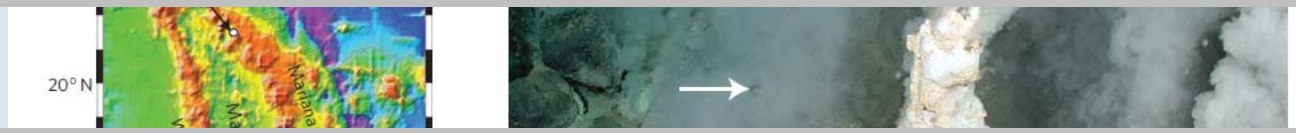
Mussels at high CO2 (low pH) in Kiel fjord



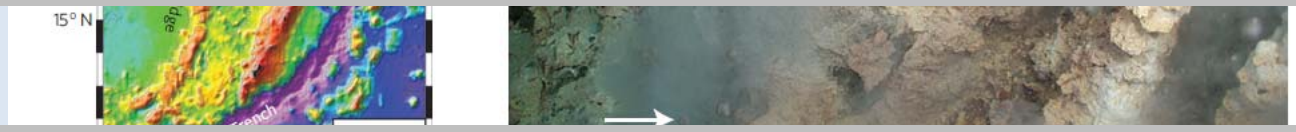
(Thomsen et al, 2010, *Biogeosciences*)

Mussels at high CO2 (low pH) at a submarine volcano

Another example of using a naturally acidified habitat



Helps understand OA susceptibility of organisms



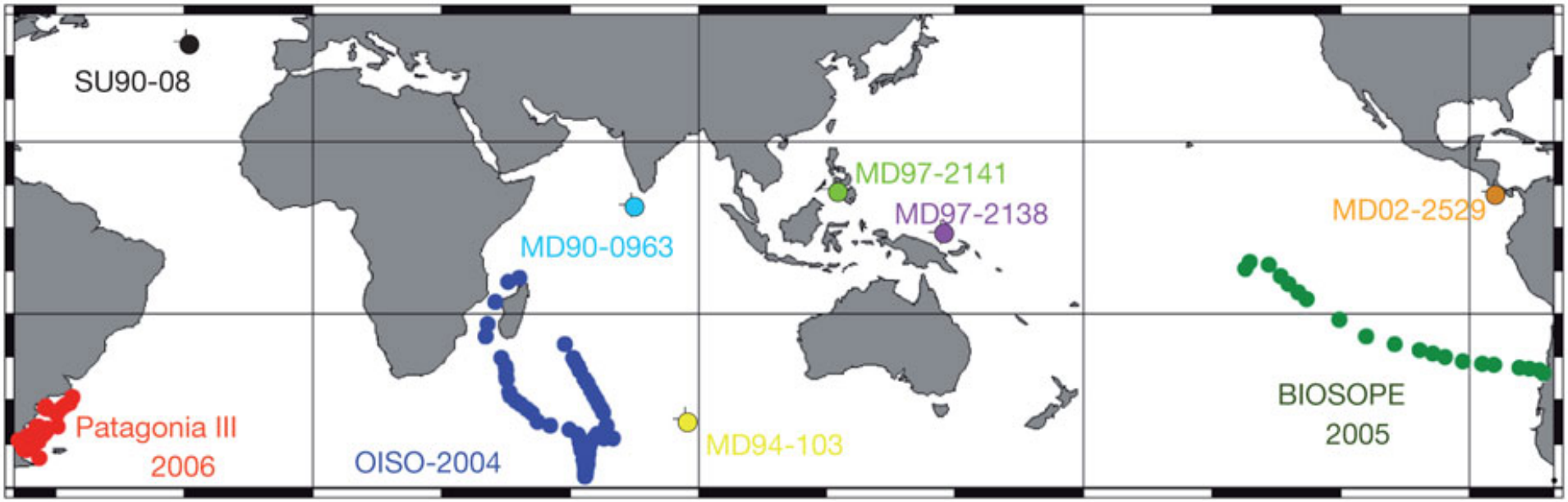
Mussels have shells, but only half normal thickness

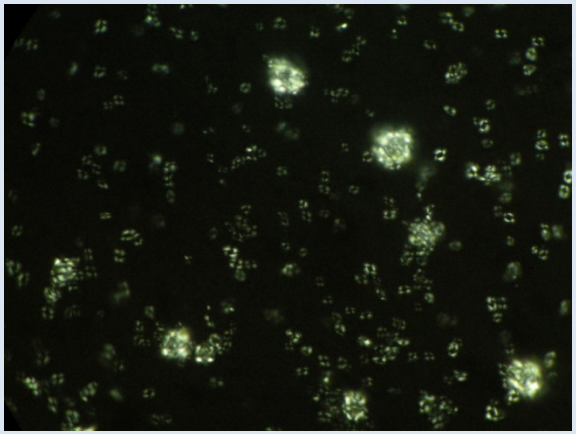
pH between 5.4 and 7.3

1600 m deep

(Tunnicliffe et al, 2009, *Nature Geoscience*)

Large observational study using birefringence

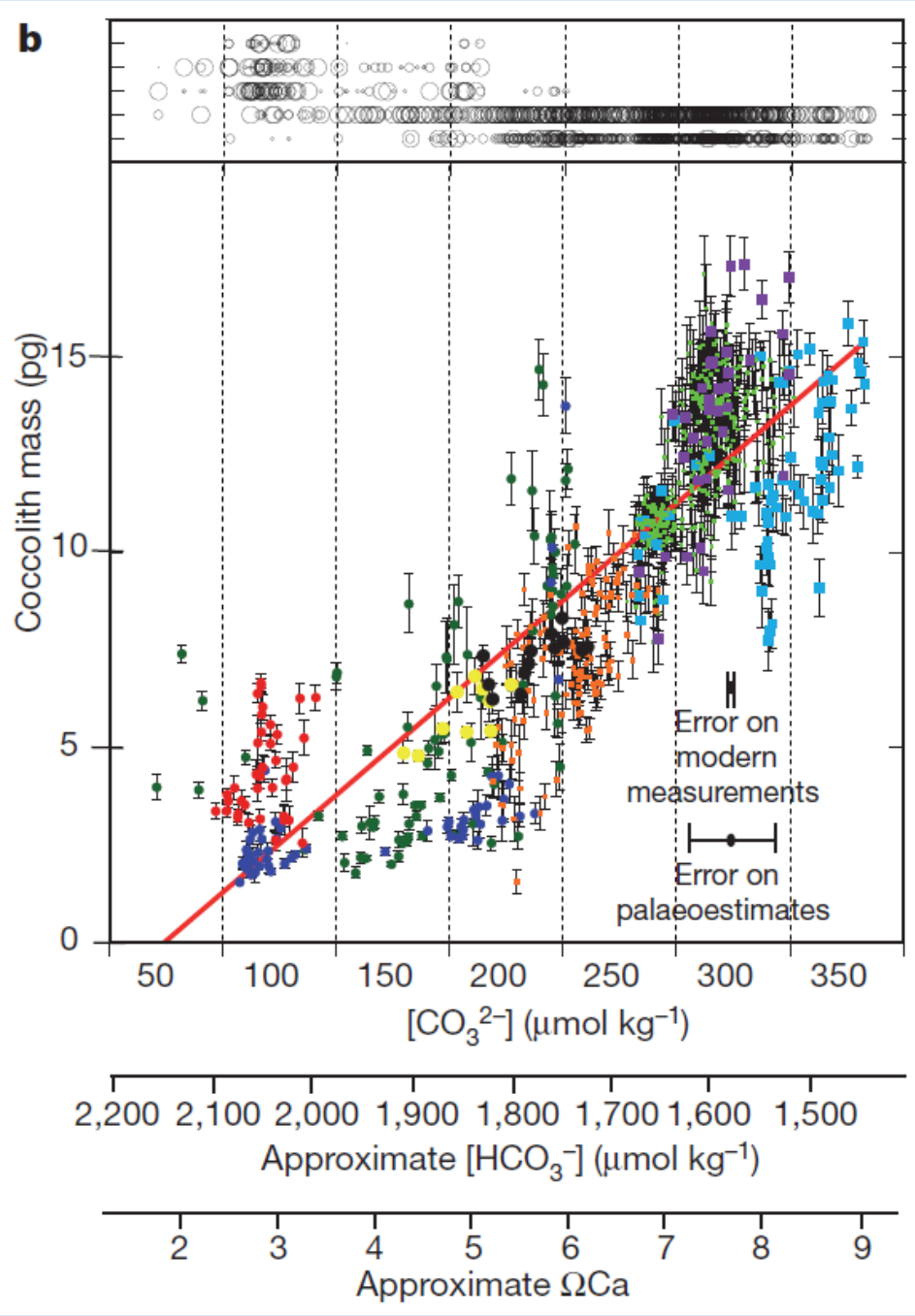


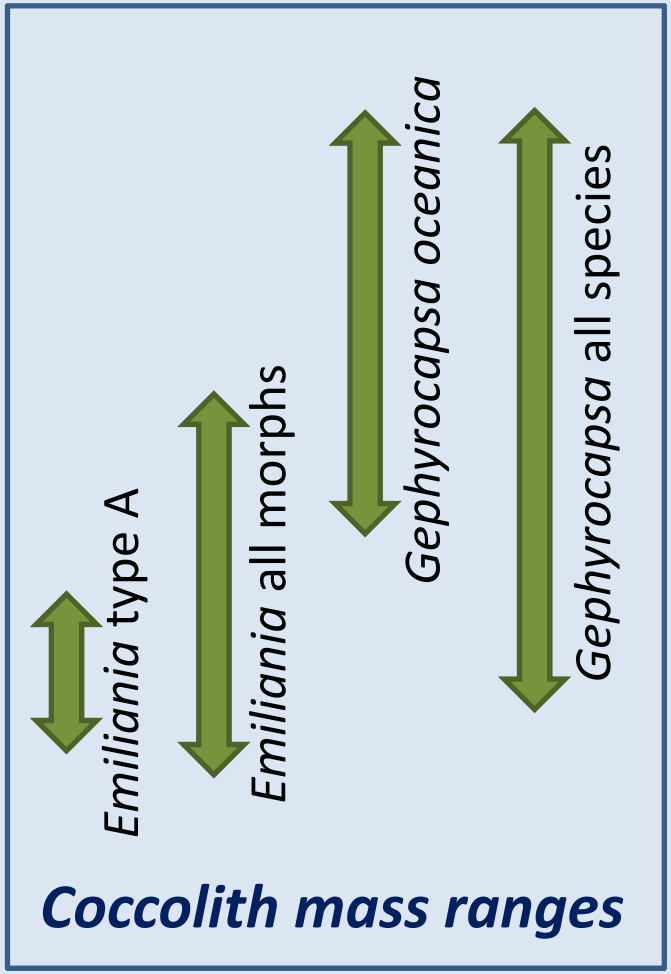


Size & brightness of features under polarised light → coccolith mass

Then compare distribution of coccolith mass to that of [CO_3^{2-}]

(Beaufort et al, 2011, *Nature*)





(Beaufort et al, 2011, *Nature*)