UKOA Sea Surface Consortium

Initial results from the UKOA cruise to the Arctic, summer 2012.

R Leakey[1], E Achterberg[2], I Brown[3], D Clark[3], F Hopkins[3], D Johns[4], M Moore[2], V Peck[6], A Poulton[5], A Rees[3], M Ribas-Ribas[2], S Richier[2], G Tarling[6], E Tynan[2], T Tyrell[2], J Young[7], M Zubkov[5].

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3. Plymouth Marine Laboratory, Plymouth, UK.
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UK Ocean Acidification Research Programme

Sea Surface Consortium UKOARP

Ocean Acidification Impacts on Sea Surface Biology, Biogeochemistry and Climate Consortium

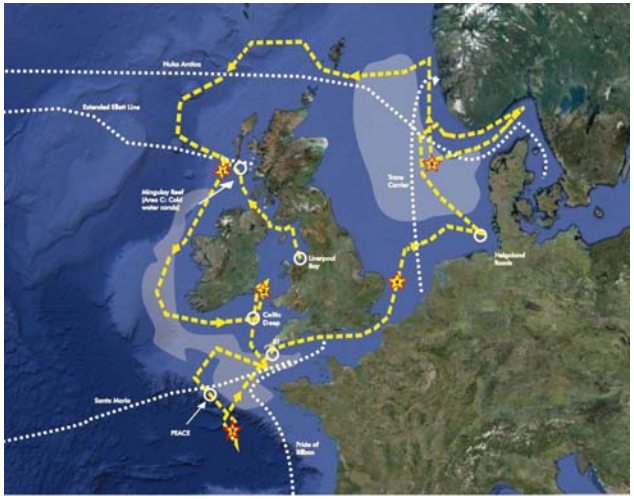
High-level objectives are:

- To determine the impact of OA on **planktonic organisms** (in terms of physiological impacts, morphology, population abundances and community composition).
- To quantify the direct and indirect impacts of OA on **biogeochemical processes** affecting the ocean carbon cycle.
- To quantify the impacts of OA on the air-sea flux of **climate active gases** (DMS and N_2O in particular).

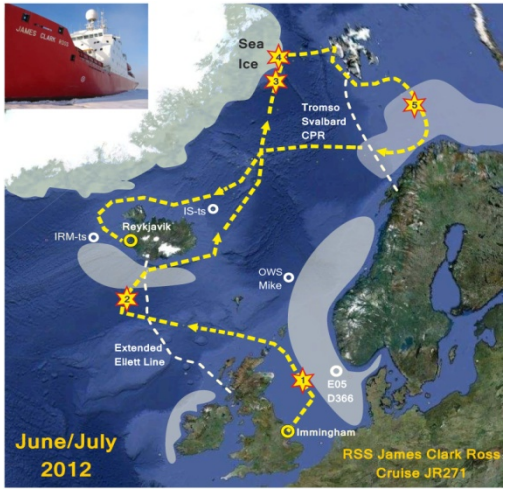
Underlying Approach to Research

- **Comparative:** Observations of physical, chemical and biological ocean variables across a wide range of environmental conditions.
- **Experimental:** On-ship bioassays using natural plankton communities.

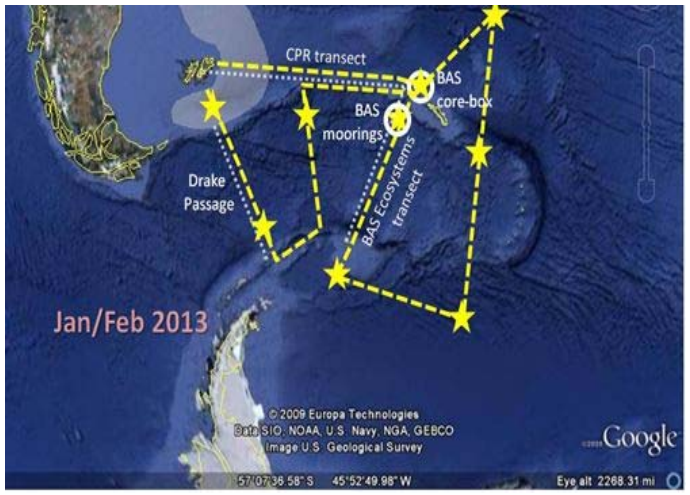
European Seas
June 2011

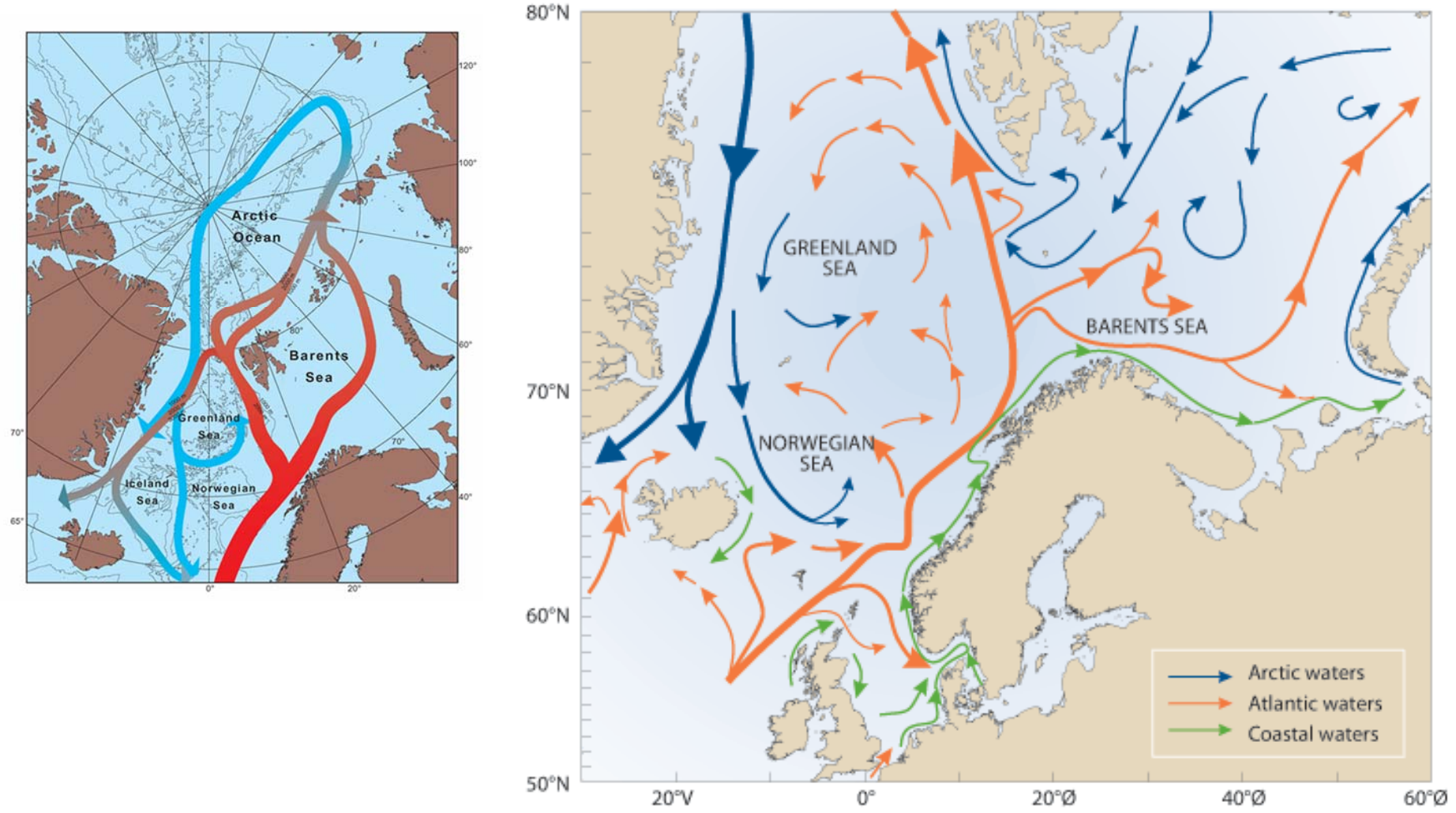


Arctic Seas
June/July 2012



Southern Ocean
Jan/Feb 2013



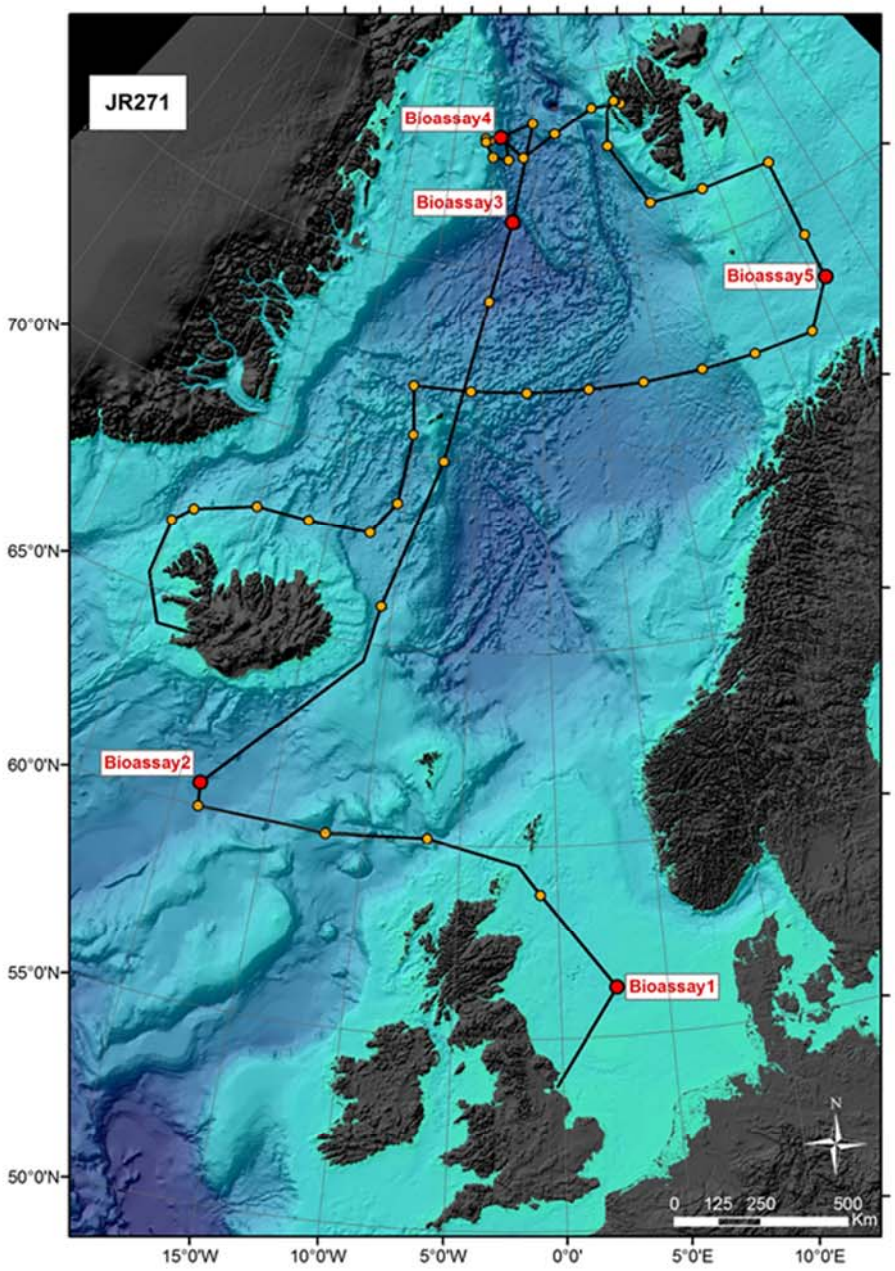


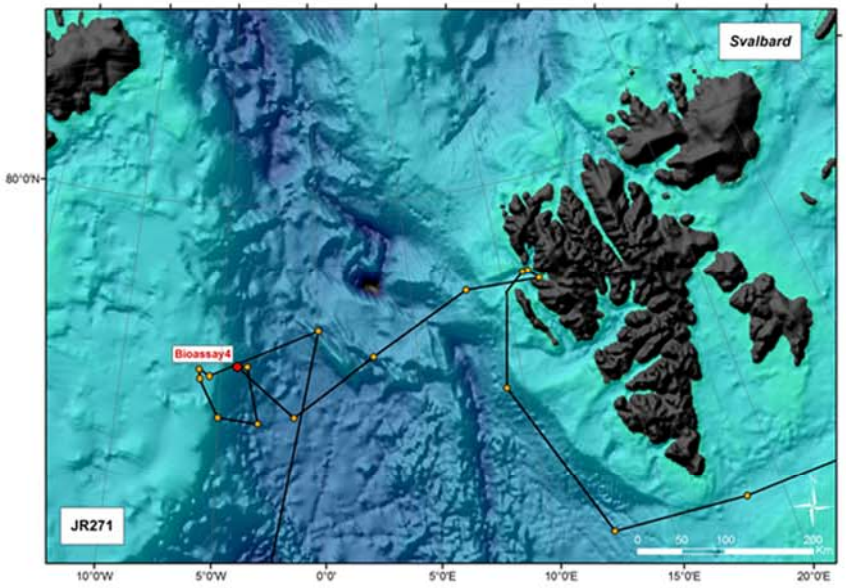
Source: North Sea Task Force, 1993. *North Sea Quality Status Report 1993*, Oslo and Paris Commissions, London, Olsen & Olsen, 132+vi pp.

Arctic Cruise Track

2 June to 2 July 2012

RRS *James Clark Ross*





Comparative Observations

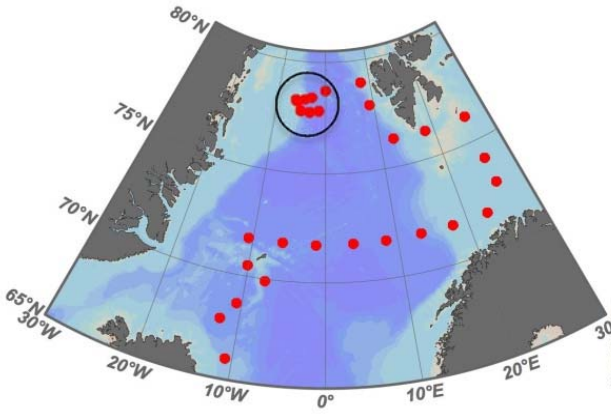
Environmental Variables:

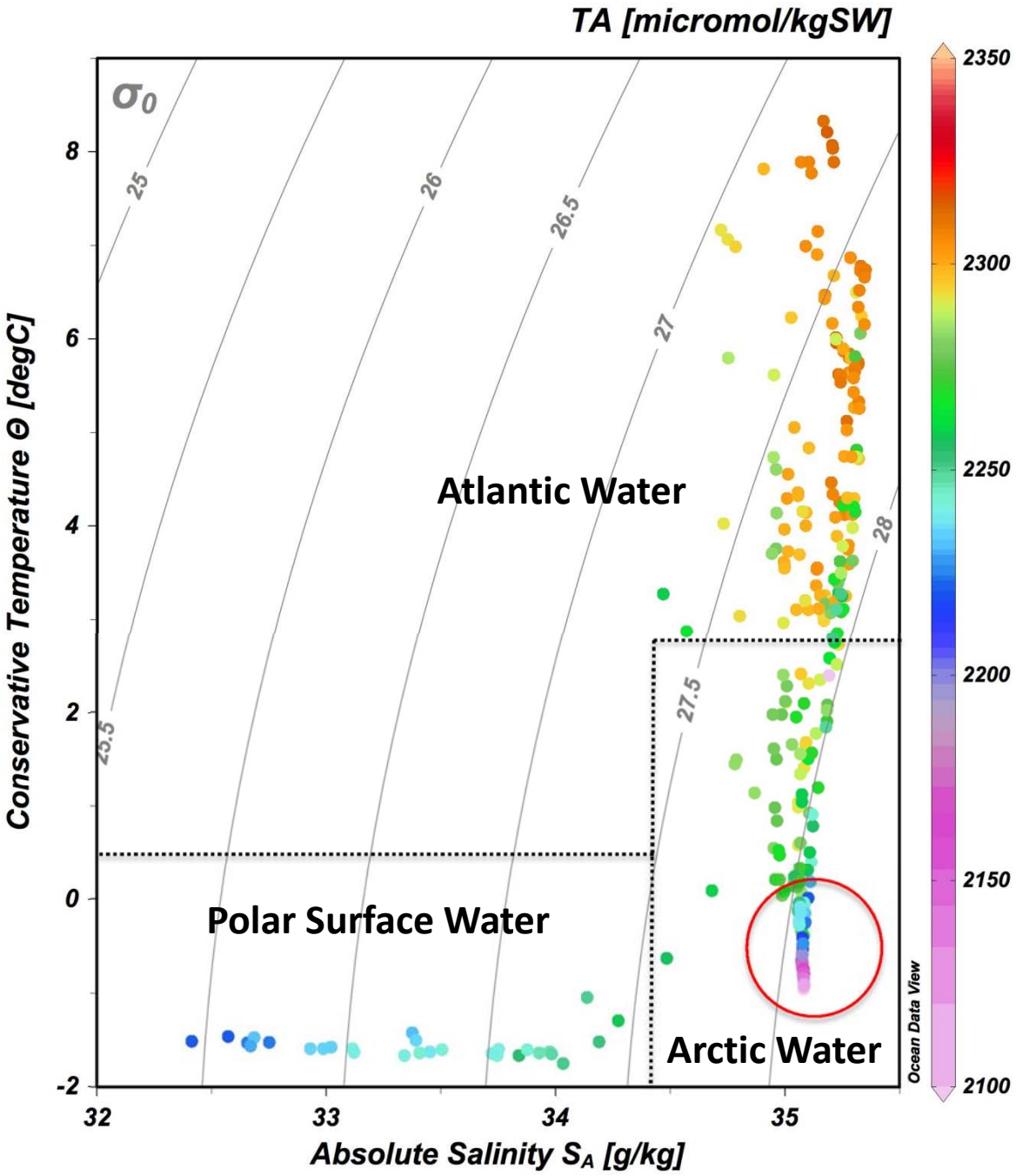
- Temperature
- Salinity
- Irradiance
- Carbonate chemistry
- Oxygen
- Macronutrients
- Micronutrients (Fe)

Response Variables:

- Chlorophyll
- POC/N, DOC, TEP
- Photosynthesis
- Primary production
- Calcification
- Plankton Community
- Nitrification & N_2O
- DMS and DMSP

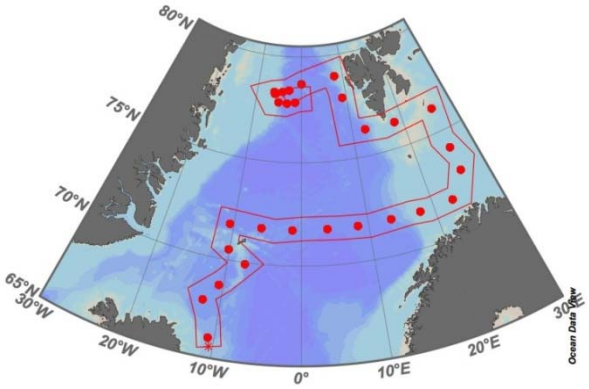
Total Alkalinity



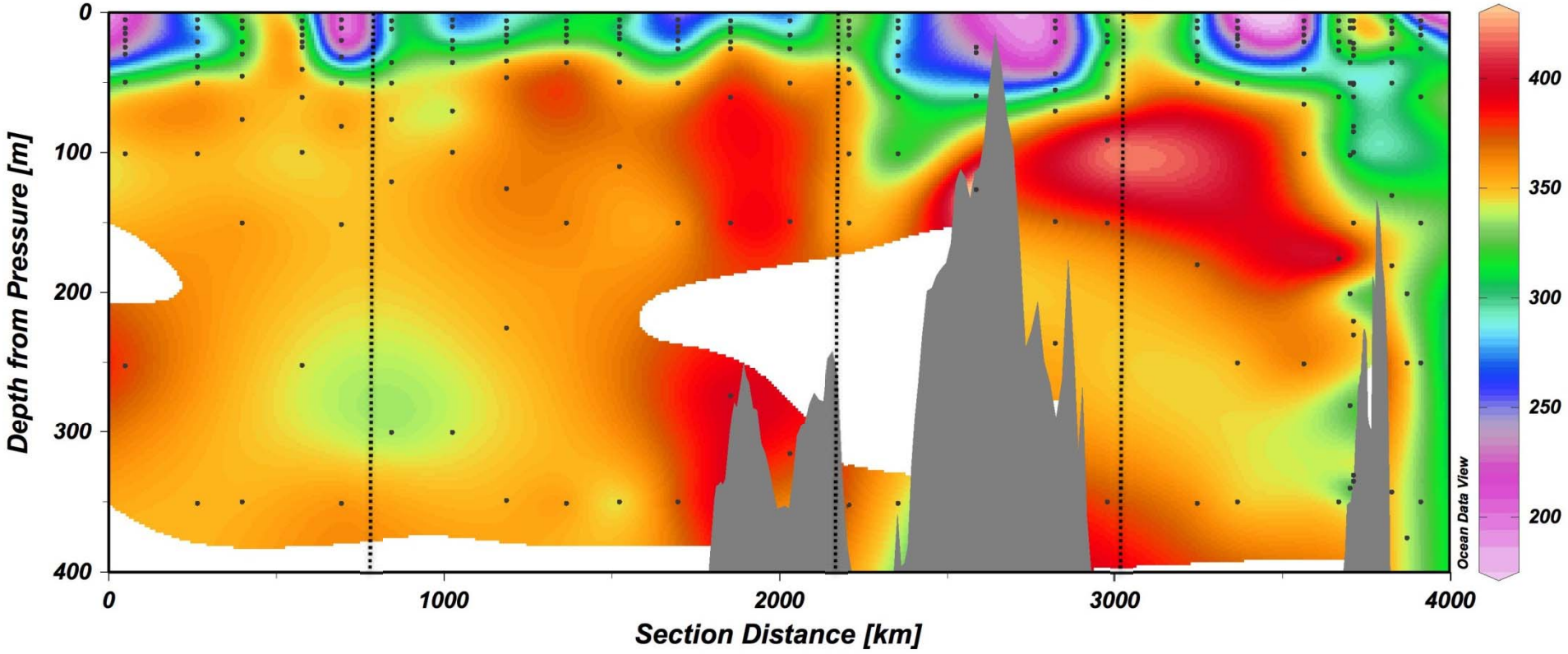


Data c/o E Tynan, M Ribas-Ribas and E Achterberg

Distribution of *p*CO2 (µatm)

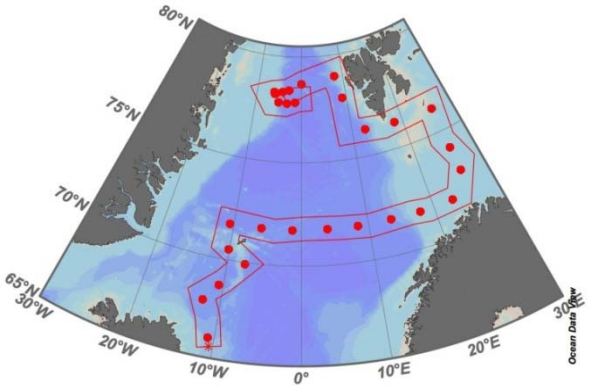


South of Jan Mayen | 72°N Transect | Barents Sea | Fram Strait

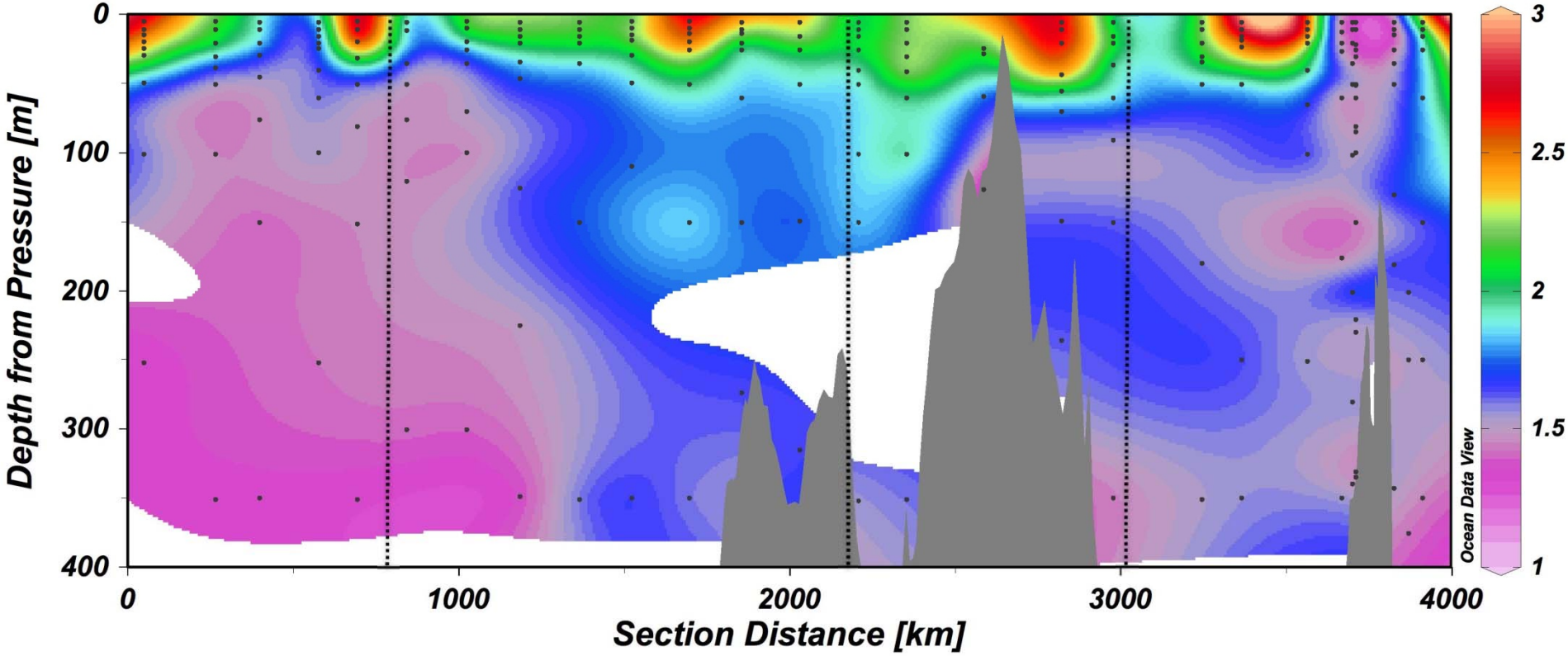


Data c/o E Tynan, M Ribas-Ribas and E Achterberg

Distribution of Ωar

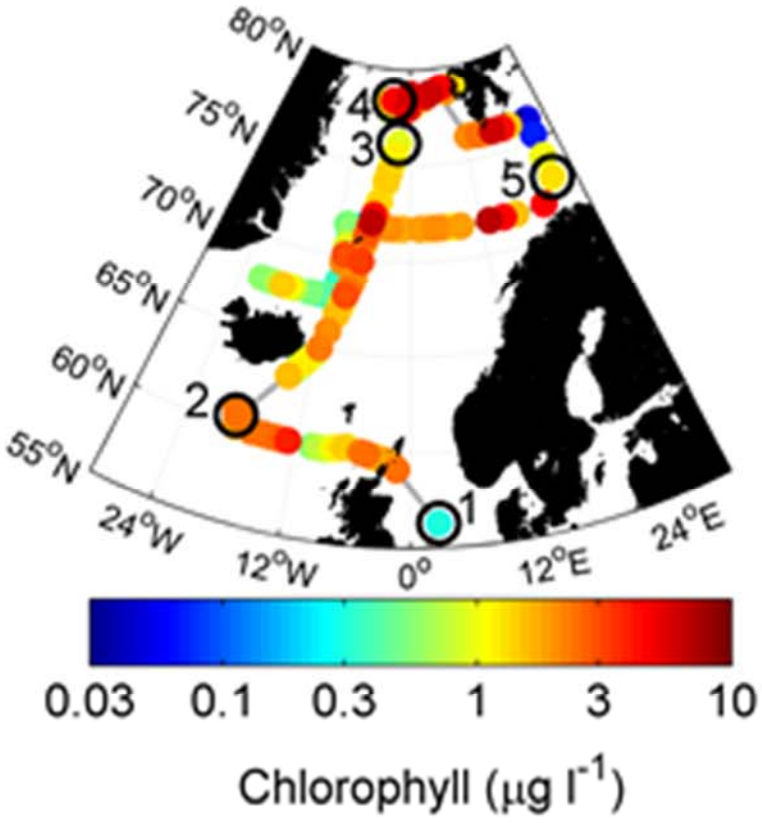


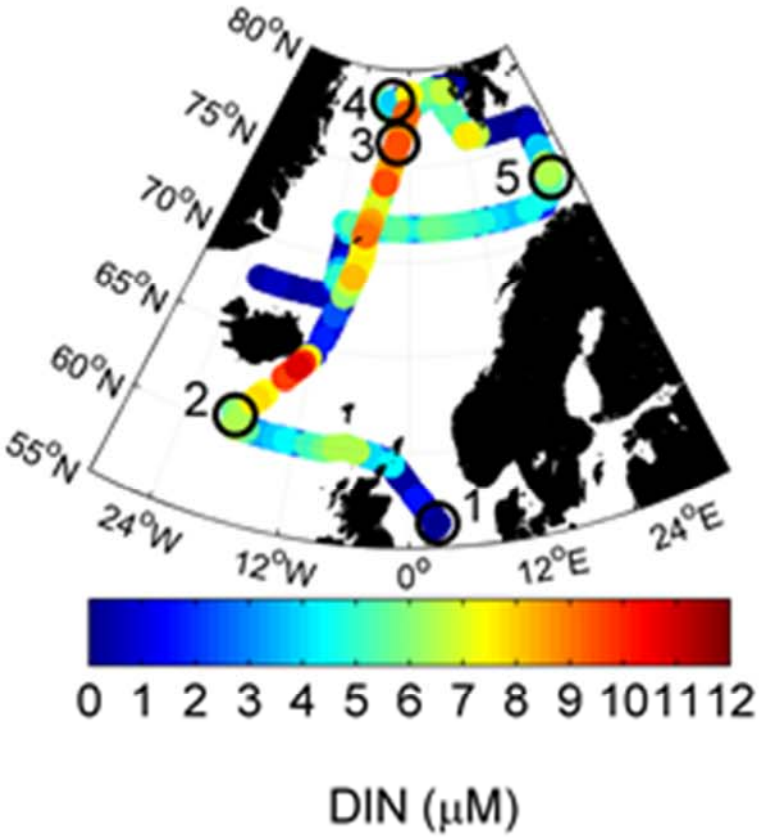
South of Jan Mayen | 72ºN Transect | Barents Sea | Fram Strait



Data c/o E Tynan, M Ribas-Ribas and E Achterberg

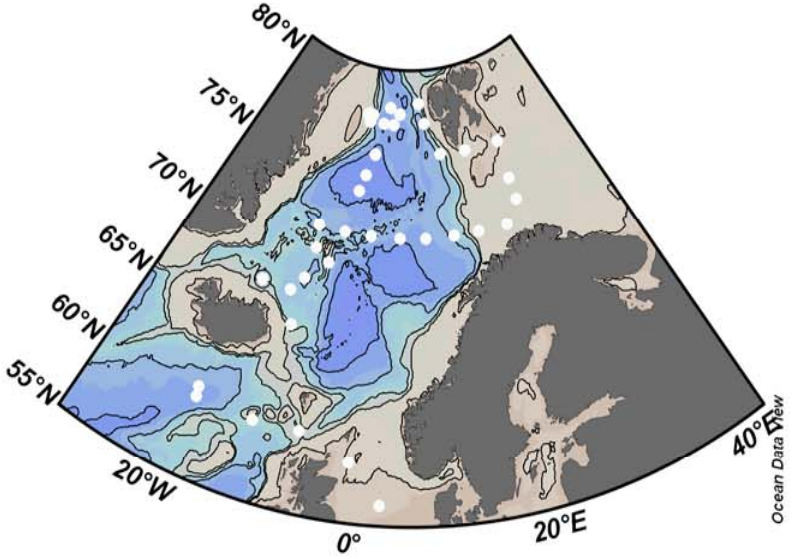
Chorophyll and Dissolved Inorganic Nitrogen



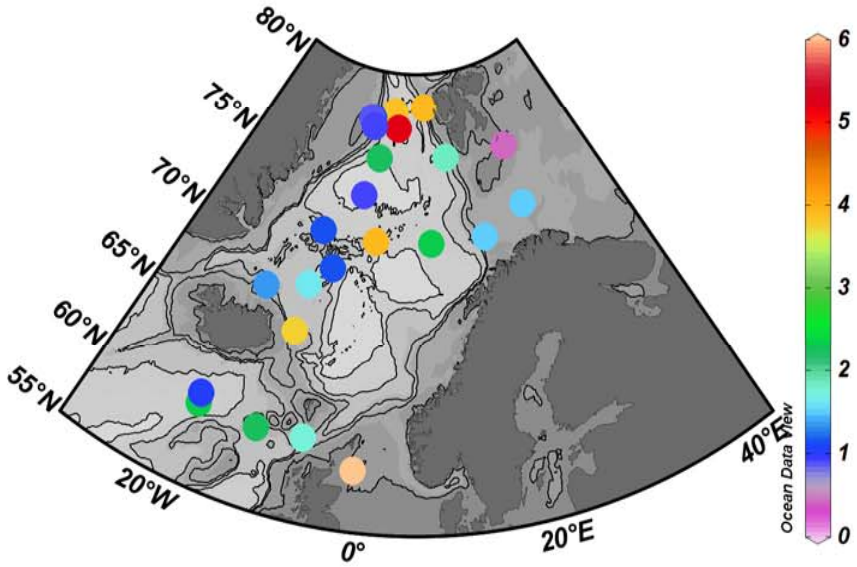


Data c/o S Richier, M Moore, A Poulton and M Esposito

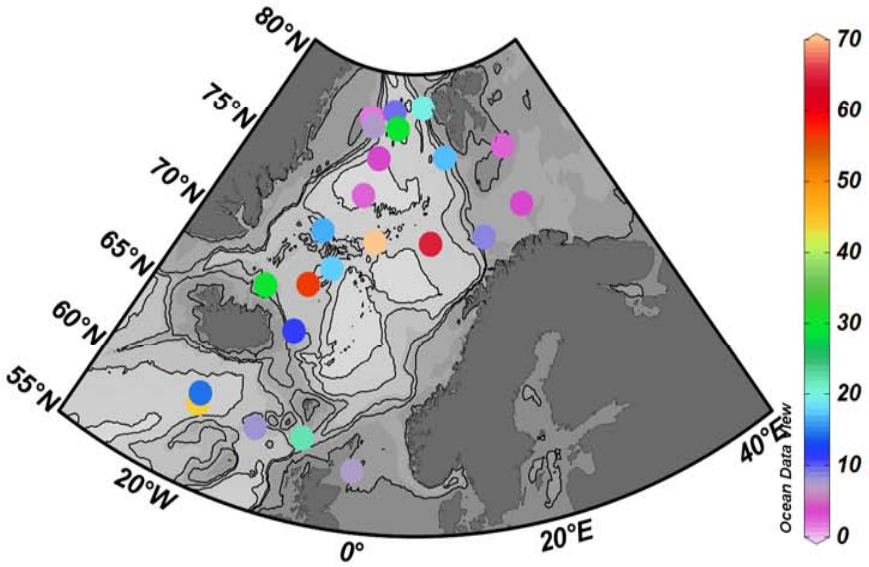
Primary Production and Calcite Production



Primary Production
(mmol C m^{-3} d^{-1})

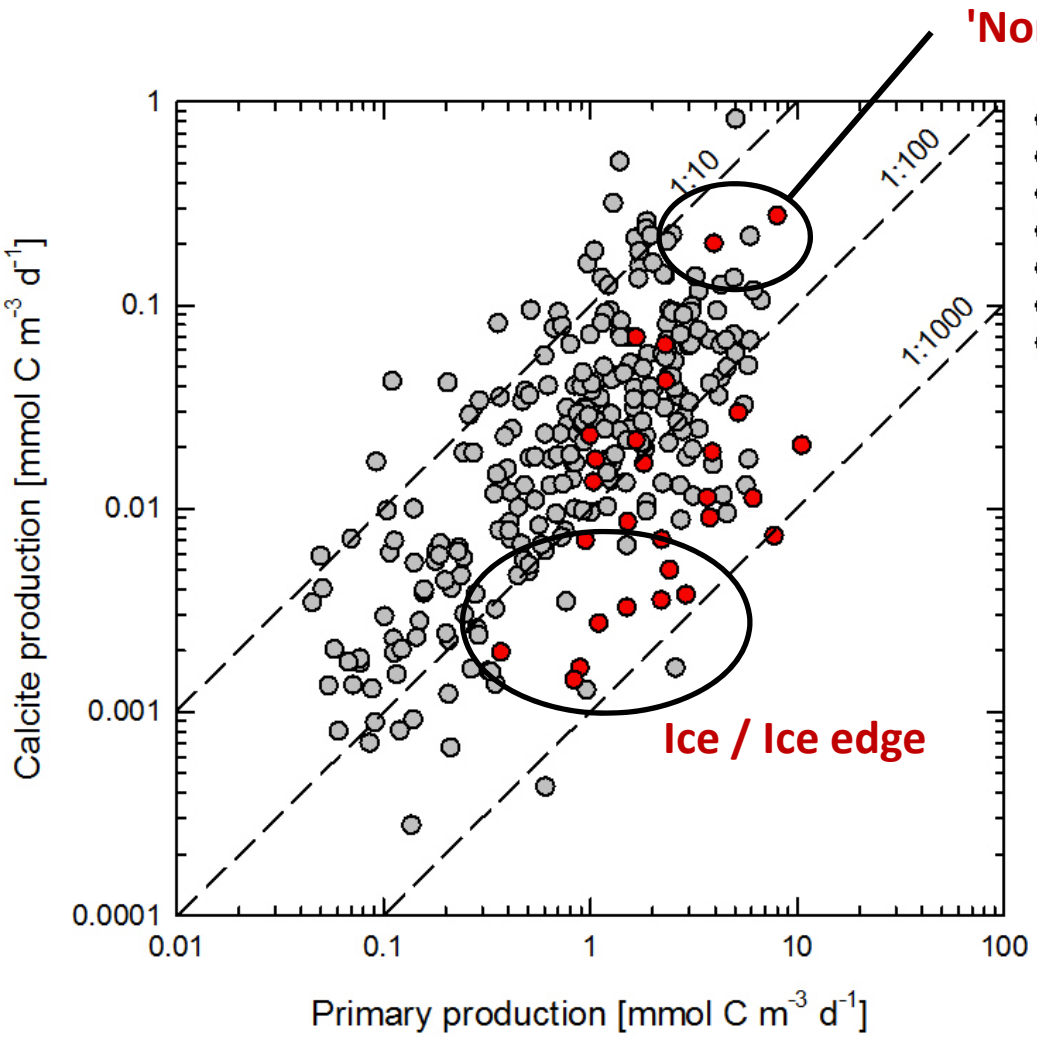


Calcite Production
(μmol C m^{-3} d^{-1})



Data c/o A Poulton and C Daniels

Calcite versus Primary Production



- (Sub-)tropical Atlantic Ocean (AMT-14, 16 & 17)
- Iceland Basin 2007, 2010 (D321, D354)
- NW European Shelf waters 2011 (D366)
- Equatorial Pacific
- Patagonian Shelf
- Arctic and Drake Passage
- JR271 Arctic Ocean 2012

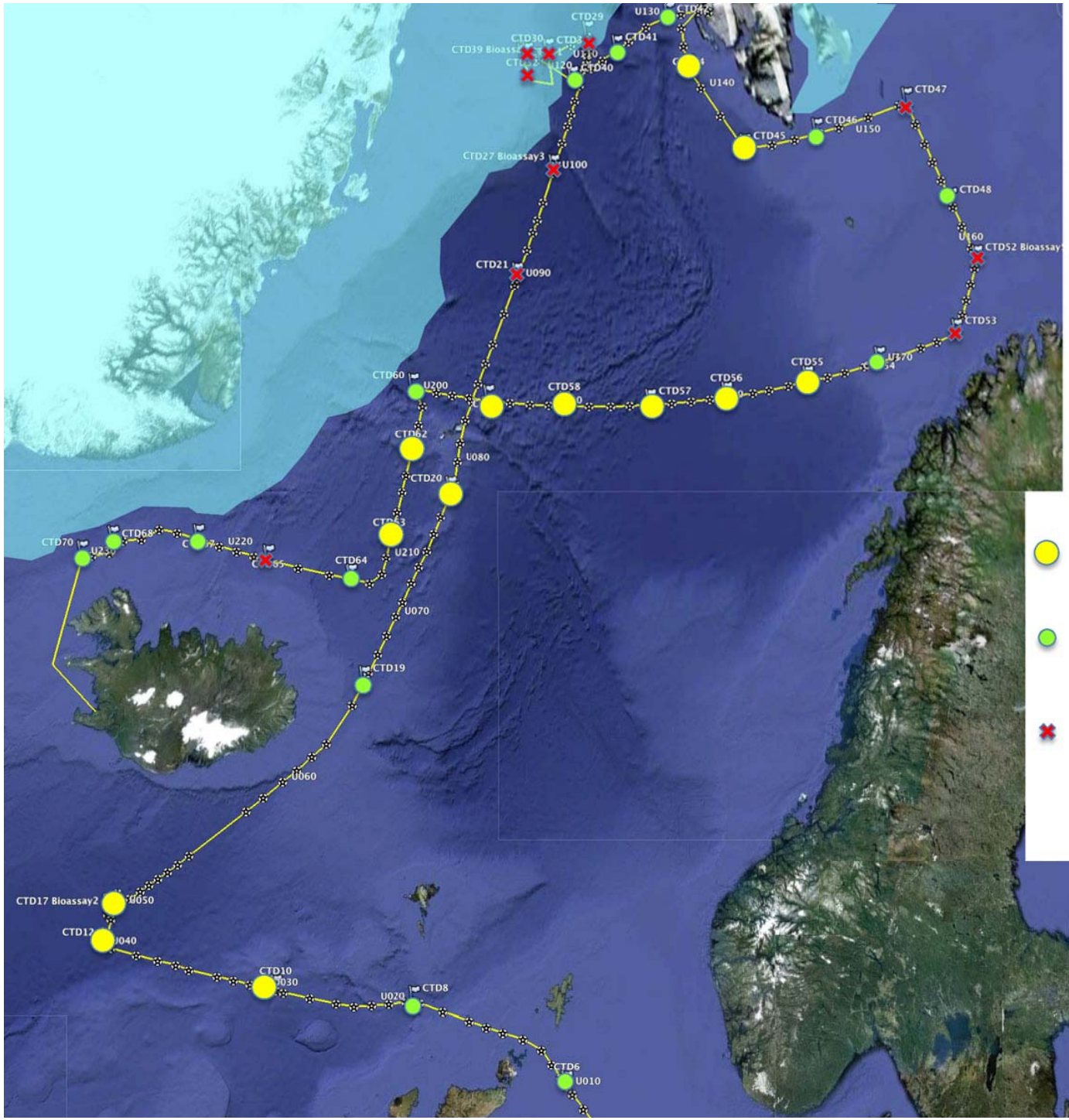
Earth System Science Data (ESSD),

Collation of all discrete CP data

(Global), Micro-Diffusion Technique

~20 cruises, published / unpublished with Meta-data (analysis) 2013 Poulton, Balch et al

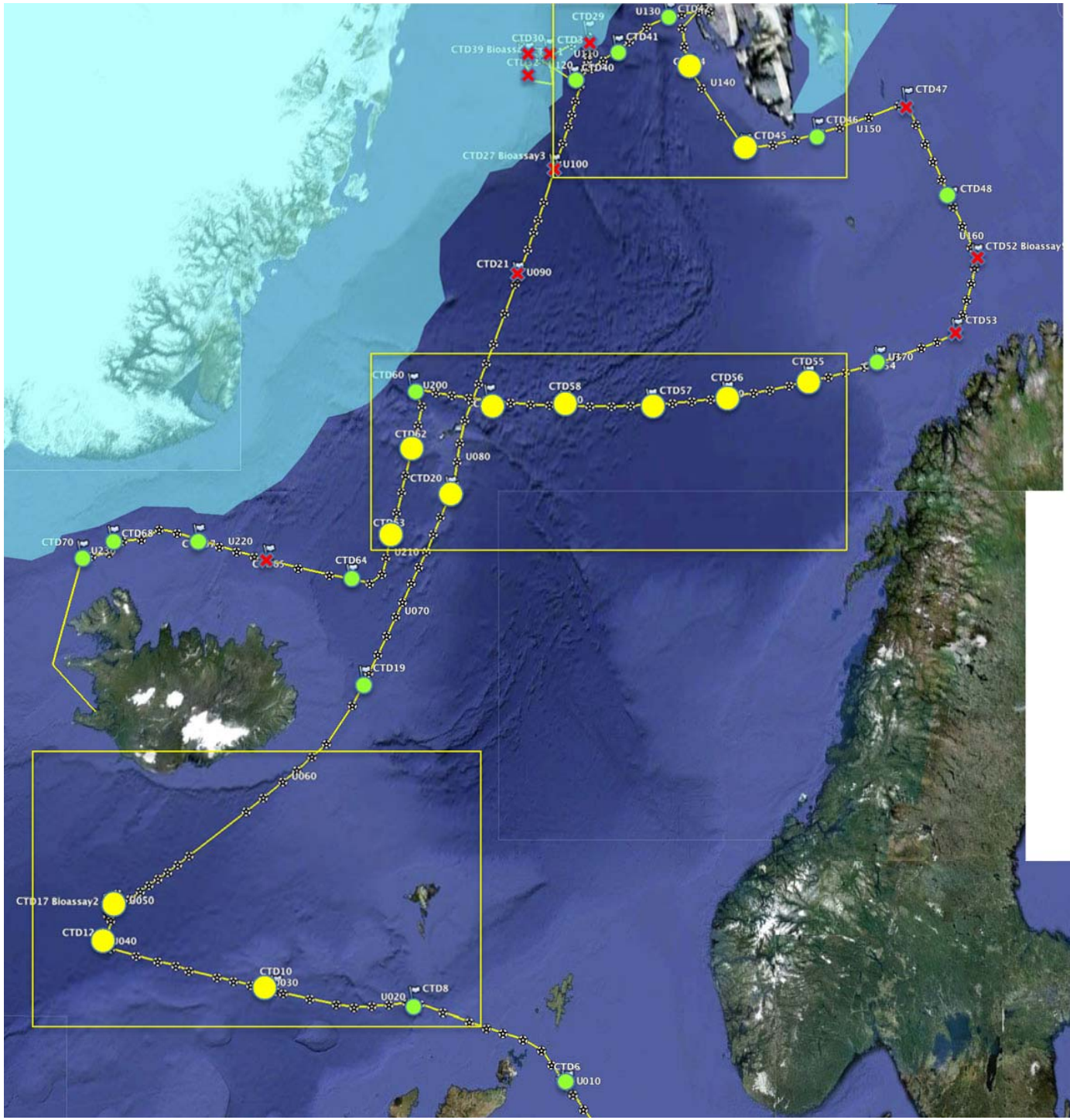
Data c/o Poulton, Balch and others (2013)



Coccolithophore Abundance

- >100,000 cells/l
- 10-100,000 cells/l
- <10,000 cells/l

Data c/o J Young



Greenland Sea

Emiliania
Coccolithus
Algirosphaera

Norwegian Sea

Emiliania
Calciopappus
Coccolithus
Algirosphaera

South of Iceland

Emiliania
Calciopappus
***Coccolithus* HET**
Syracosphaera

Data c/o J Young

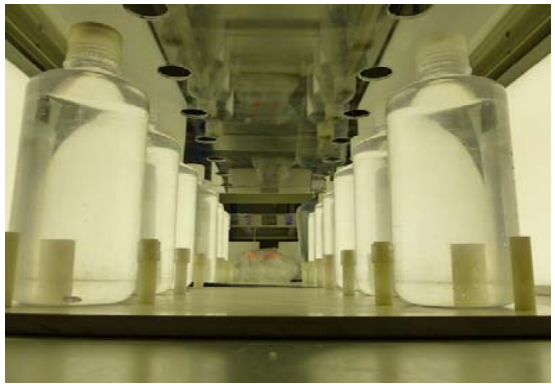
Experimental Bioassays

Bioassay experiments, designed to evaluate the short-term response of multiple organisms and processes to artificial carbonate system manipulation.

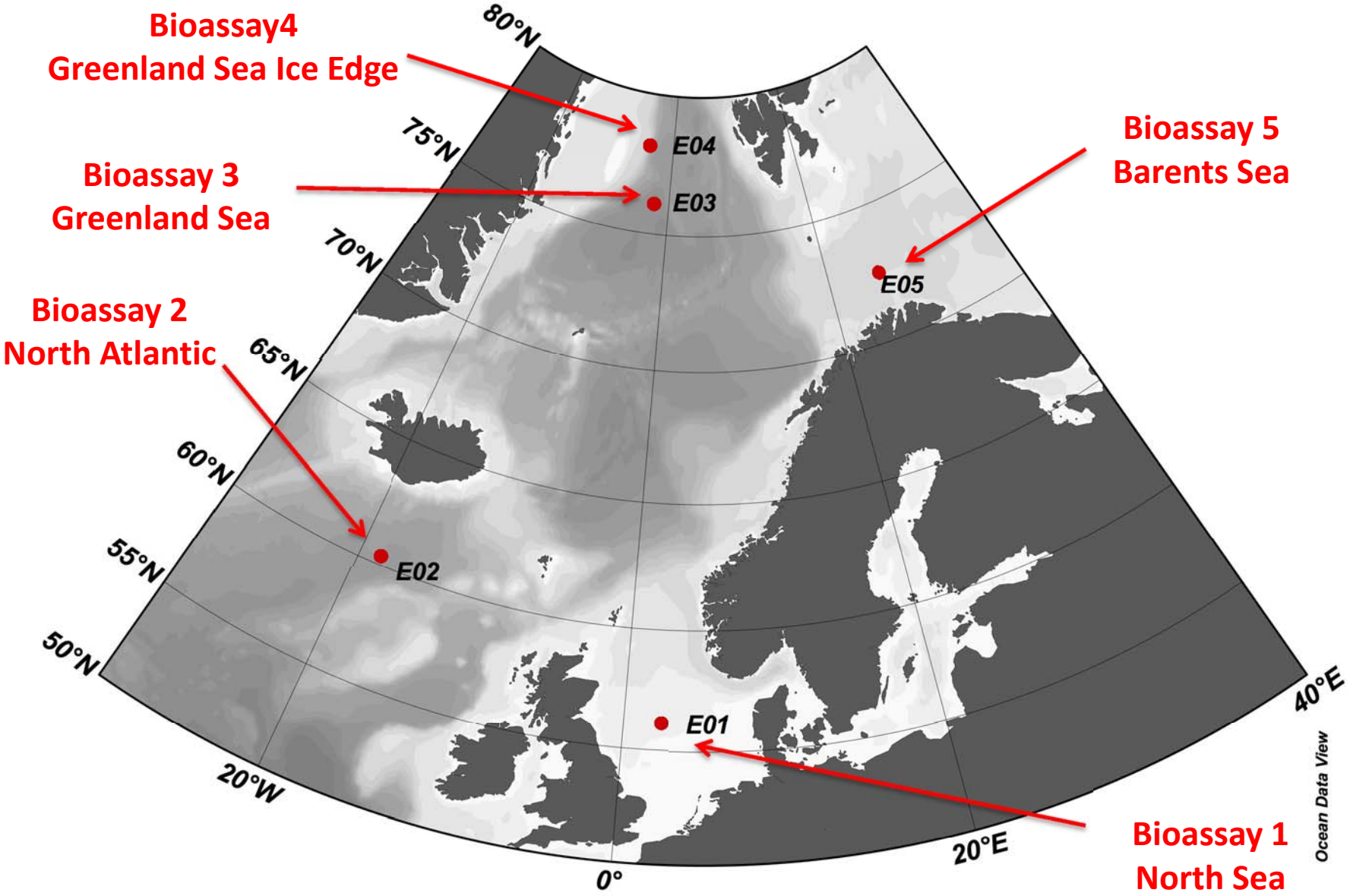
Bioassays were set up in different locations along the cruise track with different initial environmental conditions, reflecting both spatial variability within the study region and likely the temporal progression of the bloom.

Experimental Design

- **Natural seawater samples collected:**
  3 replicate CTD Niskin Rosettes
- **pCO_2 manipulated ($NaHCO_3$ + HCL addition):**
  Ambient, 550 ppm, 750 ppm and 1000 ppm
- **Incubated on-ship at:**
  Light : 100 µE m^{-2}. s^{-1} (14/8 L/D cycle)
  In situ temperature
- **Sampled at 3 time points:**
  0, 48h and 96h



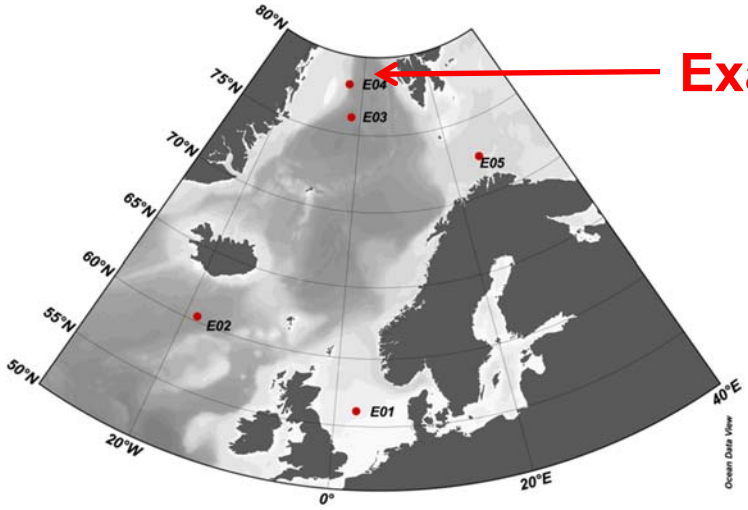
Results from Bioassay Experiments



Changes in Parameters in Control Samples after 48 & 96 hours

	Bioassay 1		Bioassay 2		Bioassay 3		Bioassay 4		Bioassay 5	
	North Sea		North Atlantic		Greenland Sea		Greenland Ice		Barents Sea	
	48 h	96 h	48 h	96 h	48 h	96 h	48 h	96 h	48 h	96 h
Nitrate	↓	↑	↓	↓	↓	↓	↓	↓	↓	↓
POP	↔	↑	↑	↑	↑	↑	↑	↑	↑	↑
Total Chlorophyll	↔	↑	↑	↑	↑	↑	↑	↑	↔	↑
>10 µm Chlorophyll	↔	↔	↔	↔	↔	↔	↑	↔	↓	↑
<10 µm Chlorophyll	↑	↓	↑	↑	↑	↓	↓	↓	↑	↑
PNAN Abundance	↑	↑	↔	↔	↓	↓	↔	↑	↑	↑
Bacterial Abundance	↑	↑	↓	↓	↓	↓	↔	↑	↓	↓
Bacterial Production	↔	↑	↓	↓	ND	↔	ND	↔	↔	↓
HNAN Abundance	↑	↔	↔	↔	↑	↑	↔	↑	↔	↑
DMS	↔	↑	↑	↑	↔	↑	↔	↔	↔	↑
DMSP	↓	↑	↑	↑	↓	↑	↑	↑	↔	↑
Nitrous Oxide	↑	↔	↑	↔	↑	↔	ND	ND	ND	ND

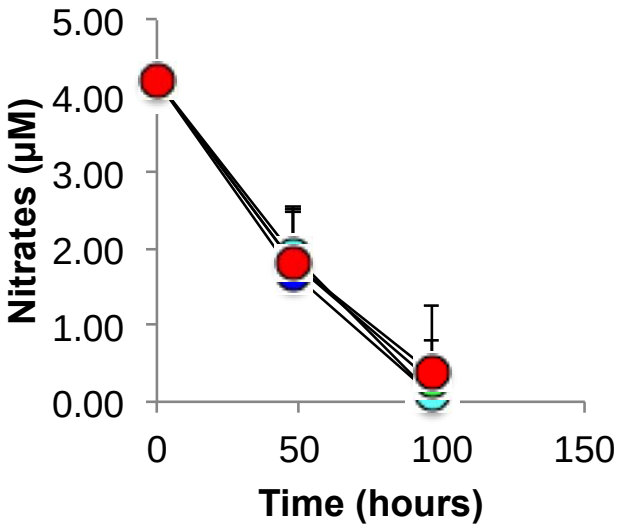
Nitrate, Chlorophyll and POP Dynamics within Bioassays

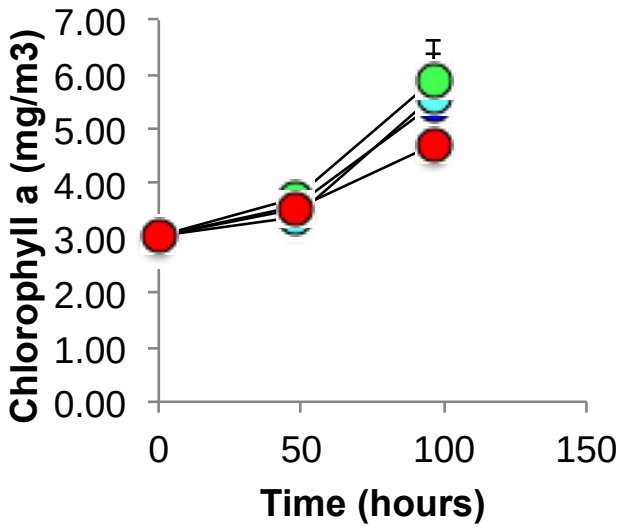


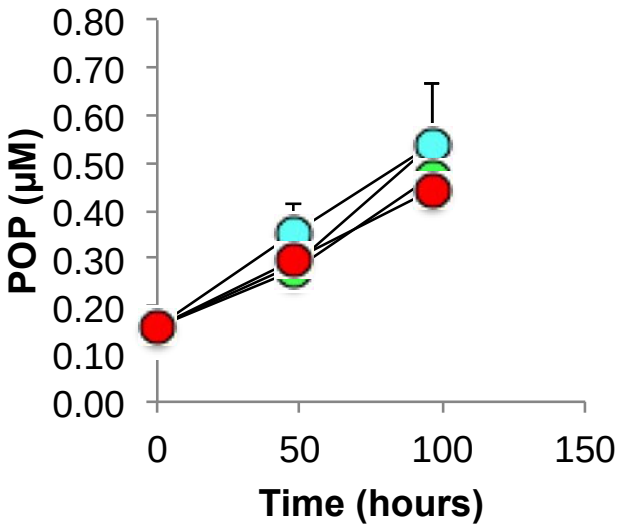
Example: Bioassay 4 Greenland Sea Ice Edge

Temp (°C):	**-1.76**
pH:	**8.133**
pCO_2 (ppm):	**295.7**
Ω_{calc} :	**2.38**
Ω_{ar}:	**1.49**

Ambient
550 ppm
750 ppm
1000 ppm



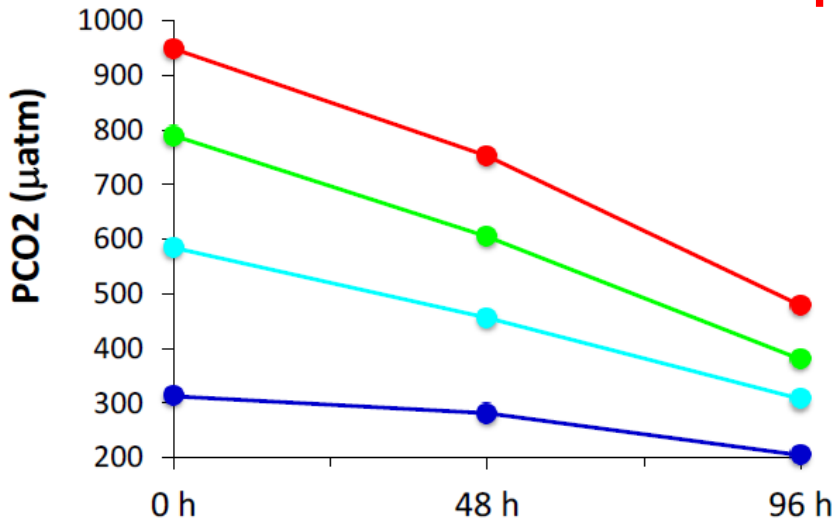


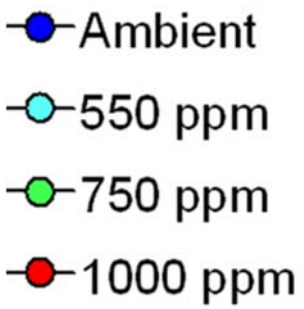


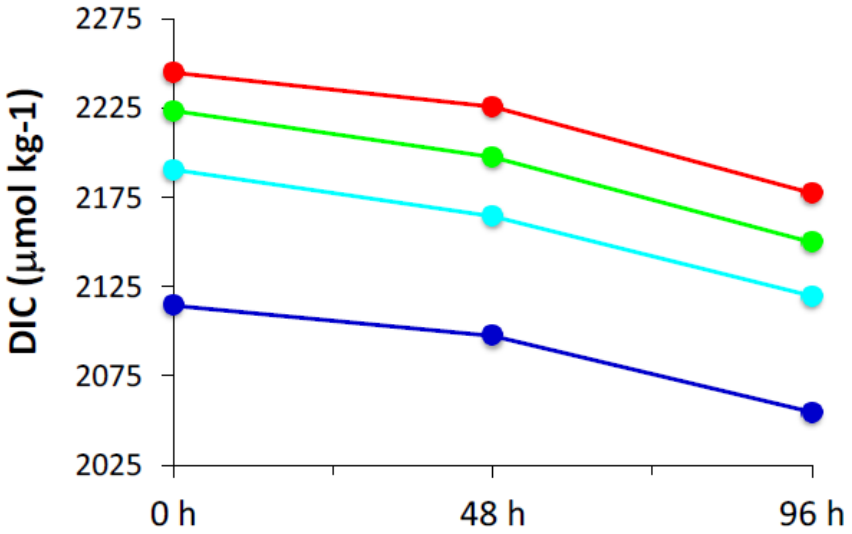
Data c/o S Richier and M Moore

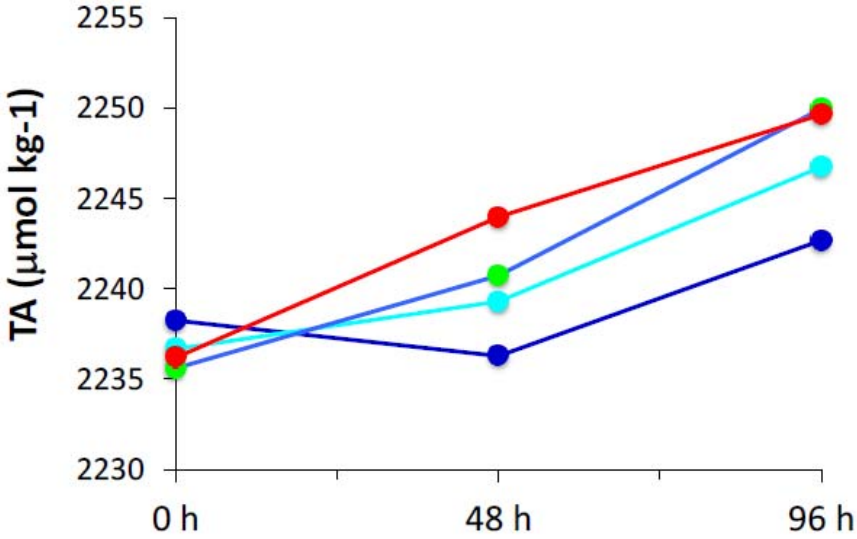
Carbonate Chemistry Dynamics within Bioassays

Example: Bioassay 4 Greenland Sea Ice Edge







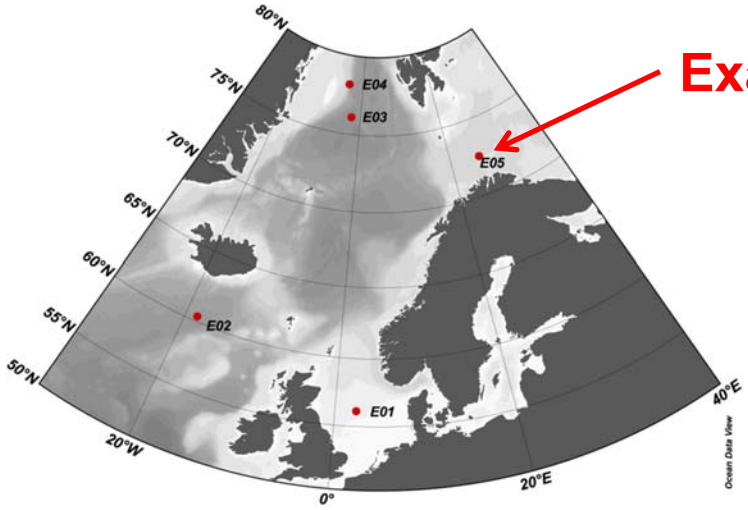


Data c/o E Tynan, M Ribas-Ribas and E Achterberg

Response of Parameters to Acidification after 48 & 96 hours

	Bioassay 1		Bioassay 2		Bioassay 3		Bioassay 4		Bioassay 5	
	North Sea		North Atlantic		Greenland Sea		Greenland Ice		Barents Sea	
	48 h	96 h	48 h	96 h	48 h	96 h	48 h	96 h	48 h	96 h
Nitrate	-	-	-	-	-	-	-	-	-	-
POP	-	-	-	-	-	-	-	-	-	-
Total Chlorophyll	-	-	-	-	-	-	-	-	⇧	⇧
>10 µm Chlorophyll	-	-	-	-	-	⇧	-	-	-	-
<10 µm Chlorophyll	⇩	-	-	-	-	-	-	⇧	-	-
PNAN Abundance	-	-	-	-	-	-	-	-	-	-
Bacterial Abundance	⇧	-	-	-	-	-	-	-	-	-
Bacterial Production	⇧	-	-	-	ND	-	ND	-	-	-
HNAN Abundance	-	-	-	-	-	-	-	-	-	-
DMS	-	-	-	-	-	-	-	-	-	-
DMSP	⇧	-	-	-	-	-	-	-	⇩	-
Nitrous Oxide	⇩	-	⇩	-	⇩	-	ND	ND	ND	ND

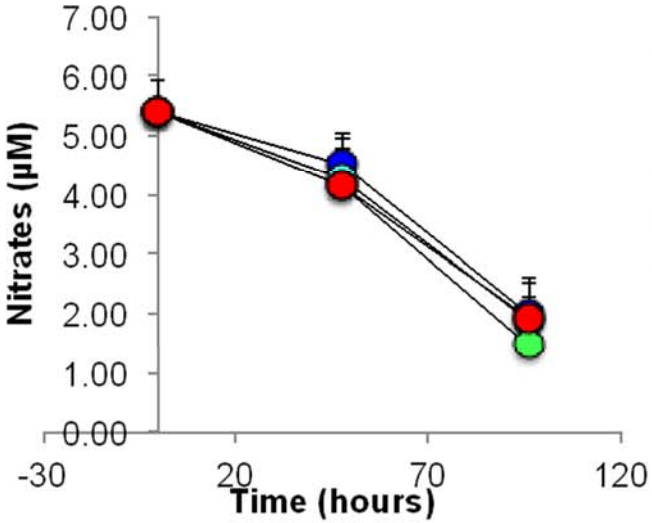
Nitrate, Chlorophyll and POP Dynamics within Bioassays

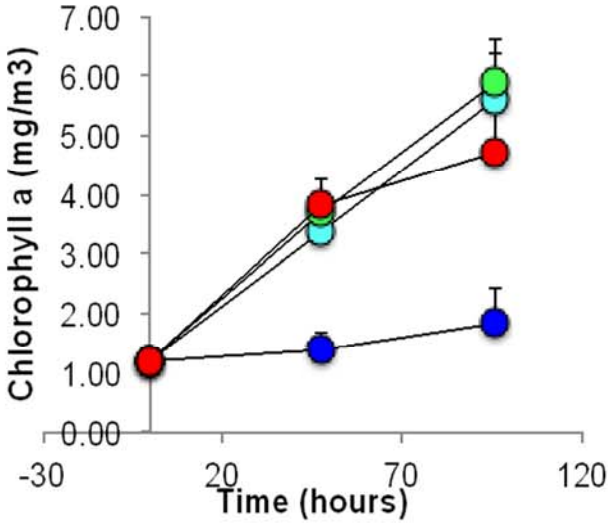


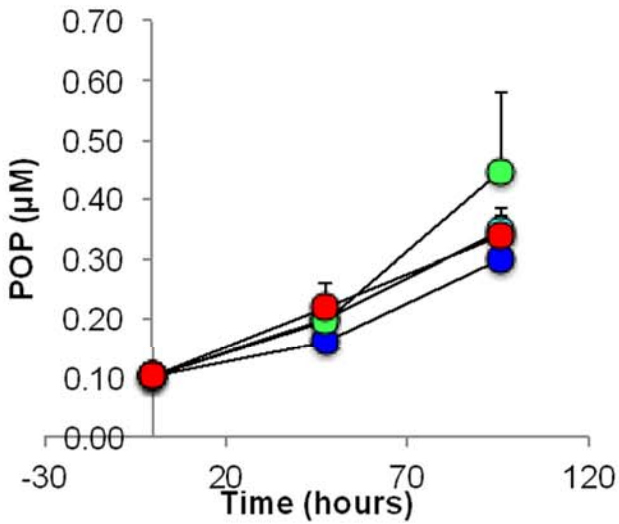
Example: Bioassay 5 Barents Sea

Temp (°C):	**6.01**
pH:	**8.14**
pCO_2 (ppm):	**302.1**
Ω_{calc} :	**3.48**
Ω_{ar}:	**2.29**

Ambient
550 ppm
750 ppm
1000 ppm







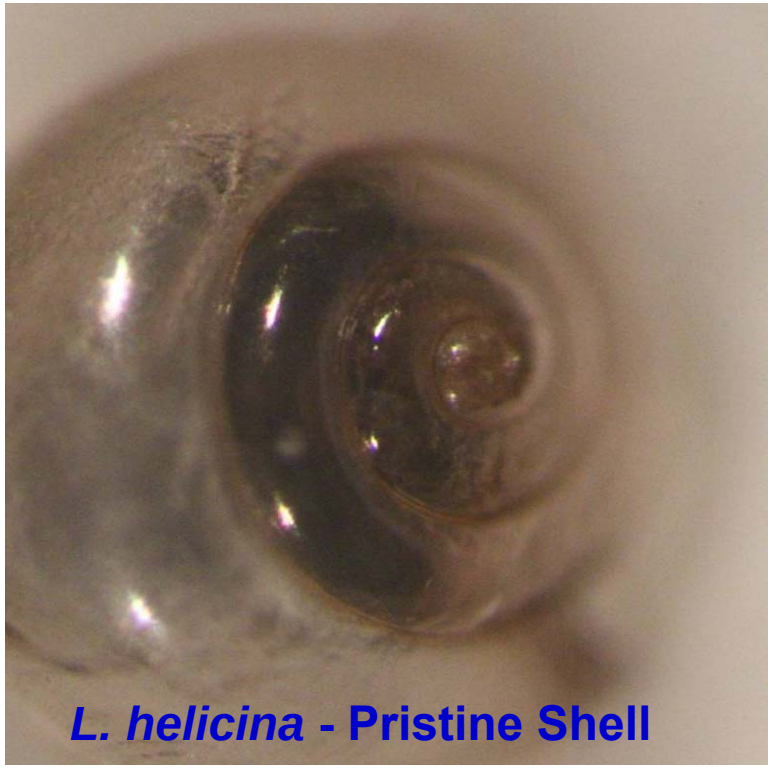
Data c/o S Richier and M Moore

Effect of Acidification on Pteropods

Limacina helicina **collected from Kongsfjorden, Svalbard**

Incubated for 8 days at Ambient, 550, 750, 1000 ppm pCO2

Examination of shell condition – damage and dissolution

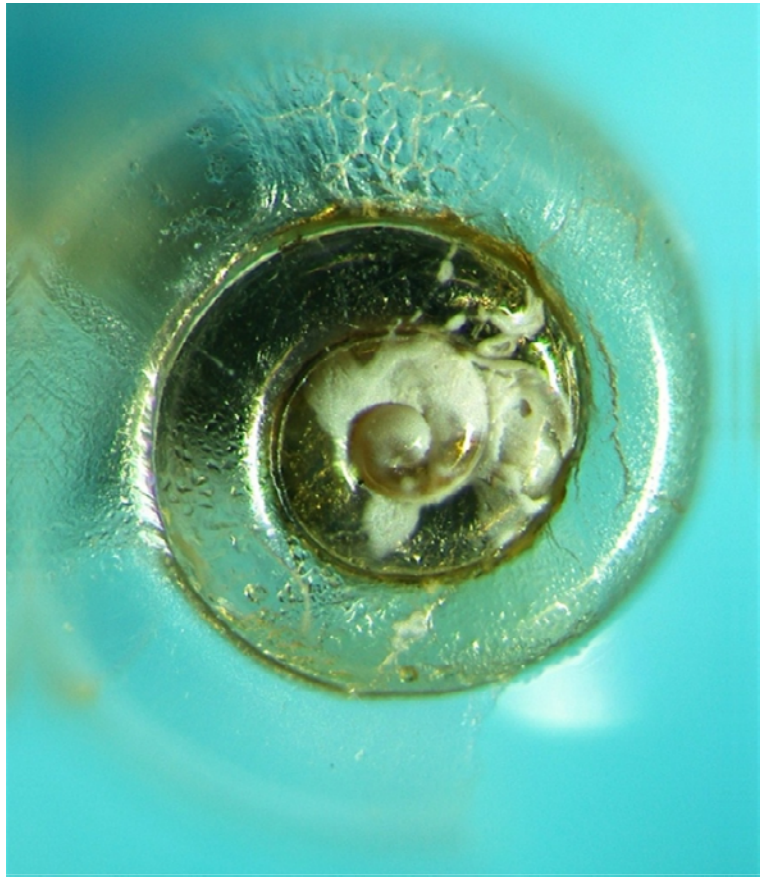


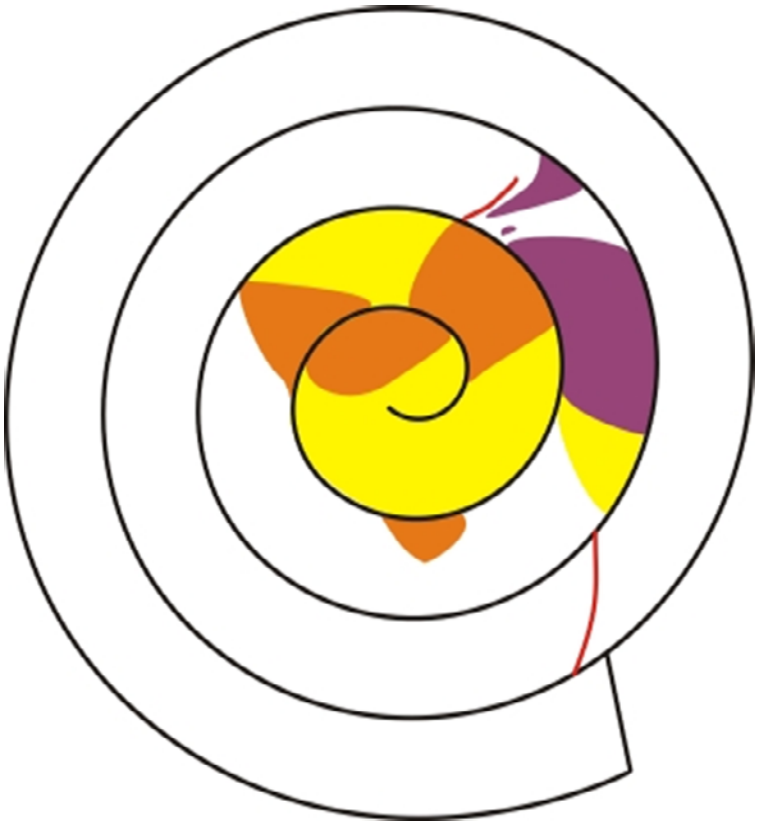
L. helicina **- Pristine Shell**

Damage to Shell Inner Whorls

Data c/o V Peck and G Tarling

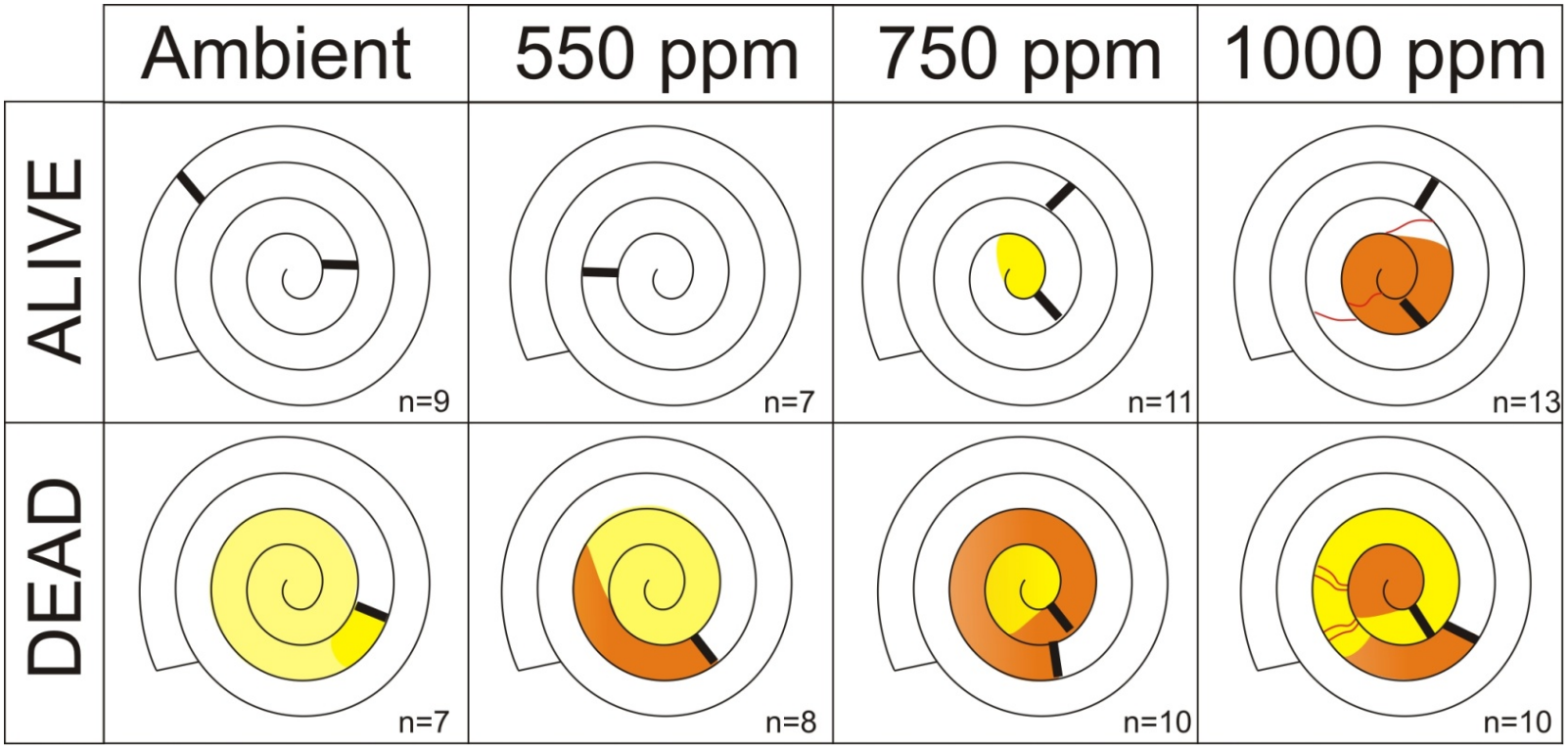
Imaging and Assessment of Shell Damage





Data c/o V Peck and G Tarling

Effect of 8 Day Incubation on *L. helicina*



Dissolution in living specimens was not observed below 750 ppm and localised to inner whorl(s)

Dissolution of dead specimens was present at ambient pCO2 conditions and more uniformly distributed through shell

Data c/o V Peck and G Tarling

Conclusions

- **Wide range of observed variables measured with which to examine statistically the effects of carbonate chemistry.**
- **Biological response to *incubation* observed for most parameters measured to date in experimental bioassays.**
- **But no clear response to *CO2 treatment* for most parameters measured to date in experimental bioassays**
- **Clear differential effect of CO2 treatment on shell morphology of living and dead pteropods.**
- **These are preliminary results with much data still to be analysed.**

Acknowledgements

Thanks to the captain, scientists and the crew of RSS *James Clark Ross* for assistance during the cruise.

This work is a contribution to the UK Ocean Acidification Research Programme (UKOA) which was jointly funded by the UK Department for Environment, Food and Rural Affairs (Defra), the UK Natural Environment Research Council (NERC) and the UK Department of Energy and Climate Change (DECC) under grant agreement no. NE/H016988/1.

defra
Department for Environment Food and Rural Affairs

UK Ocean Acidification Research Programme

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