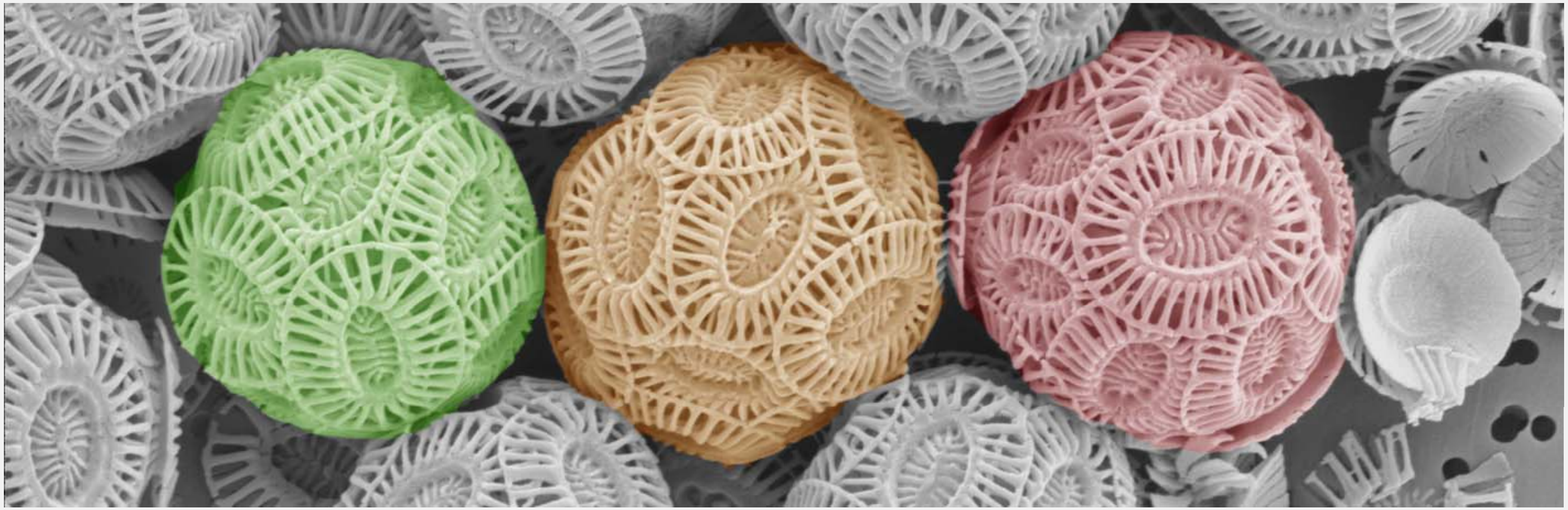
Activities, outputs and outcomes from the UKOA sea surface consortium

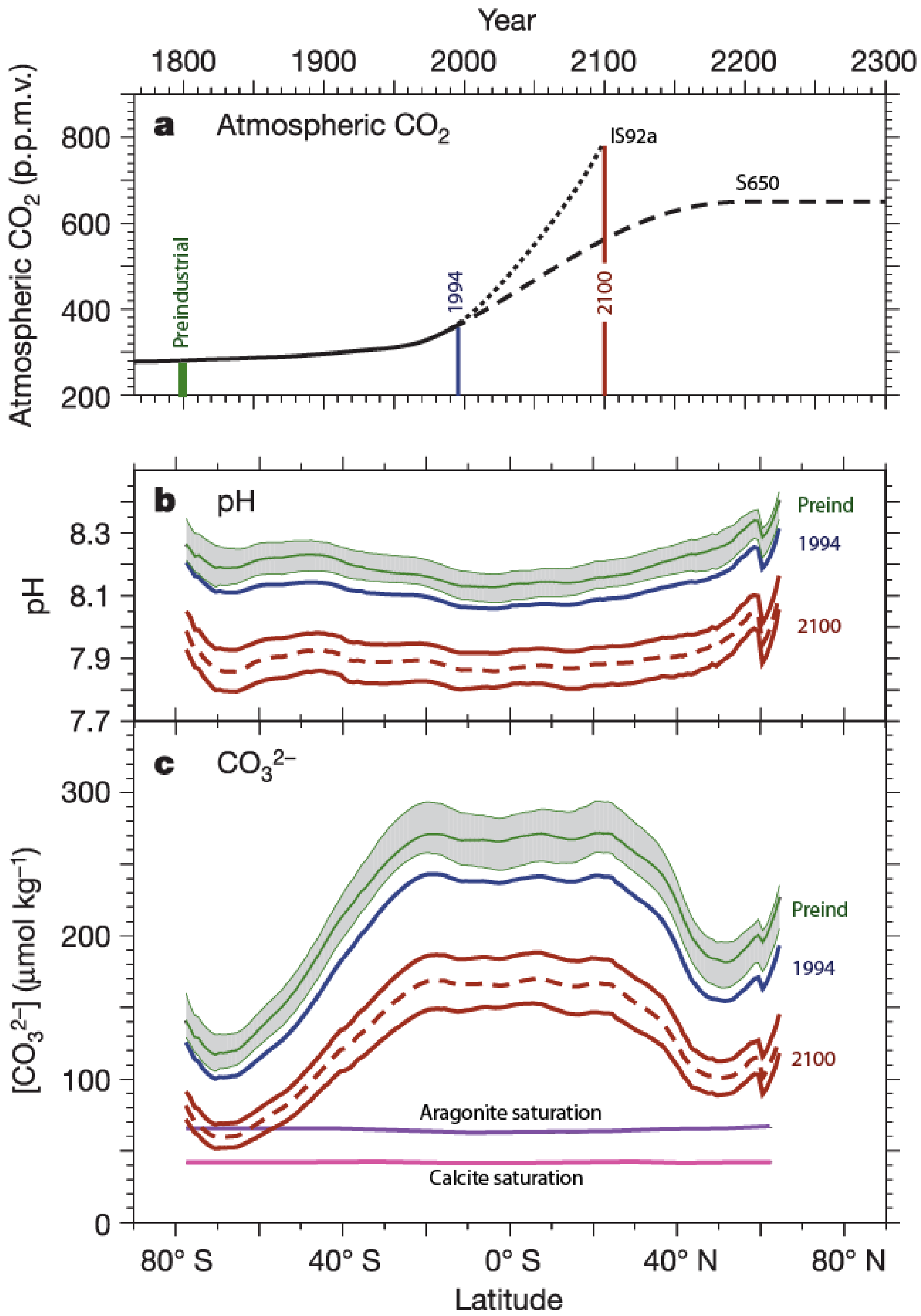
Coccolithophorid distributions and Bioassay Responses

Jeremy Young, University College London
Alex Poulton, Toby Tyrell, NOC Southampton
and many others

UK Ocean Acidification Research Programme

Sea Surface Consortium UKOA



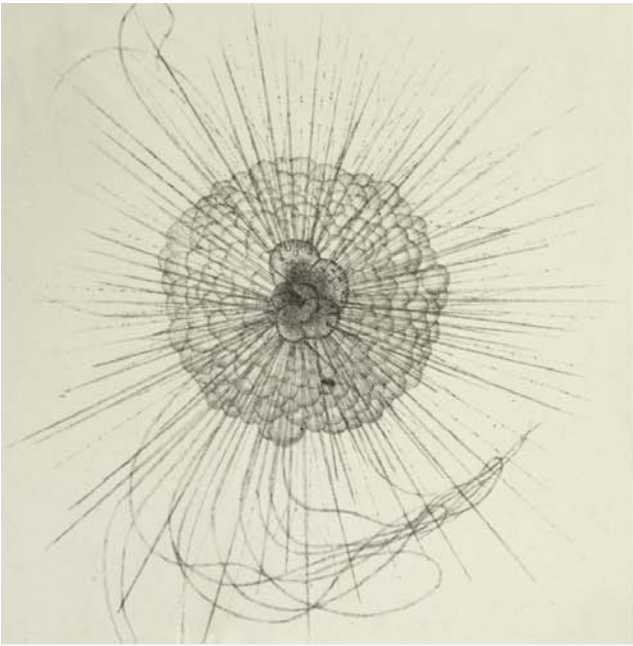


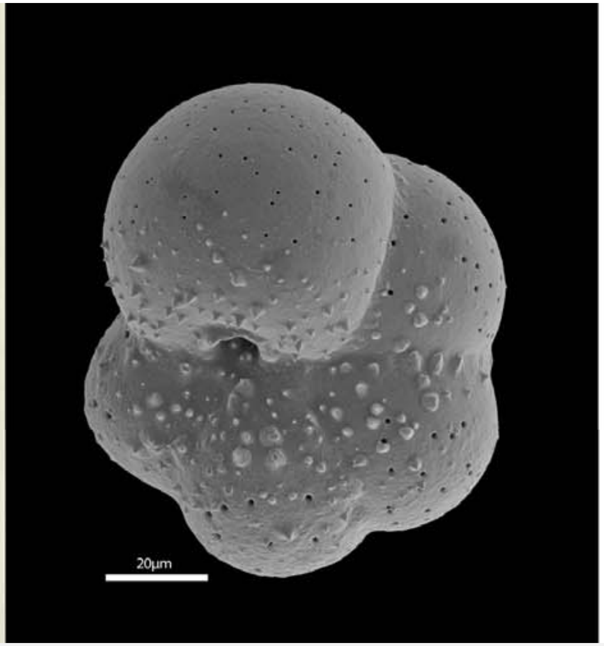
Hypotheses

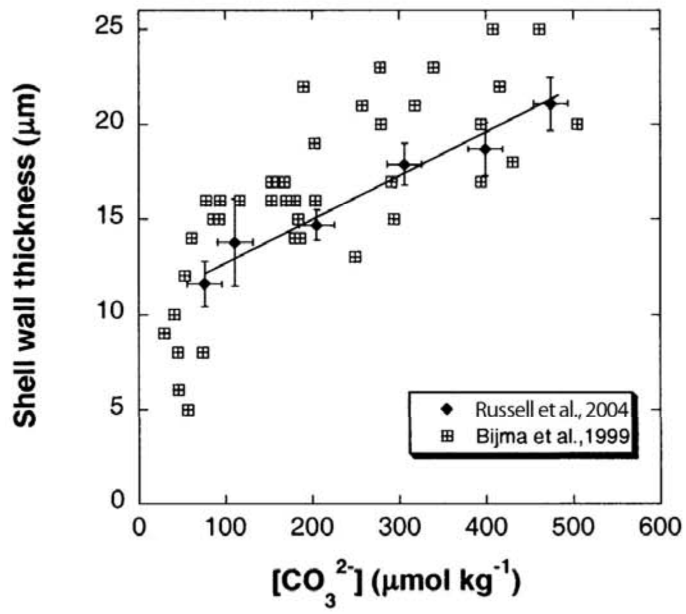
Overarching: that OA will have significant deleterious impacts on the oceanic ecosystem at CO2 levels below those which will cause catastrophic global warming

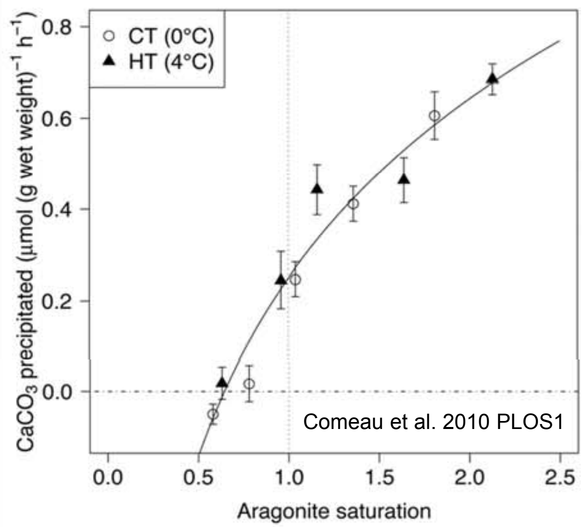
More specific: that calcification by coccolithophores is sensitive to change in degree of calcite super-saturation in order of $\Omega_{calcite}$ = 3-5

Redrawn from Orr 2005

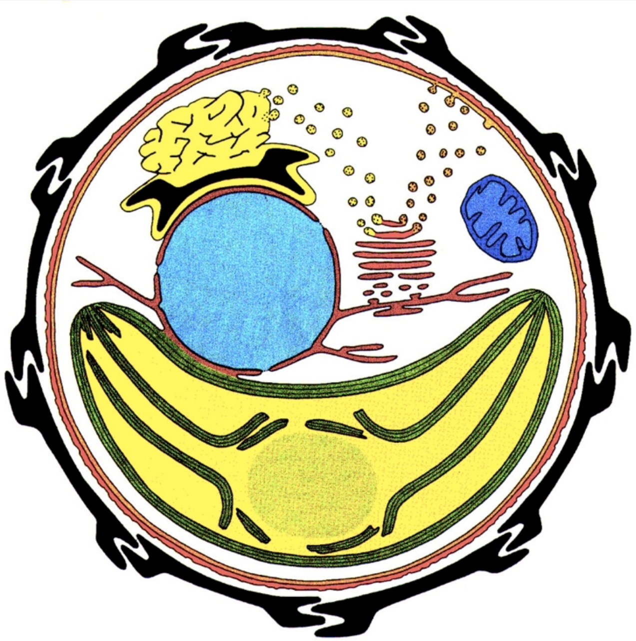


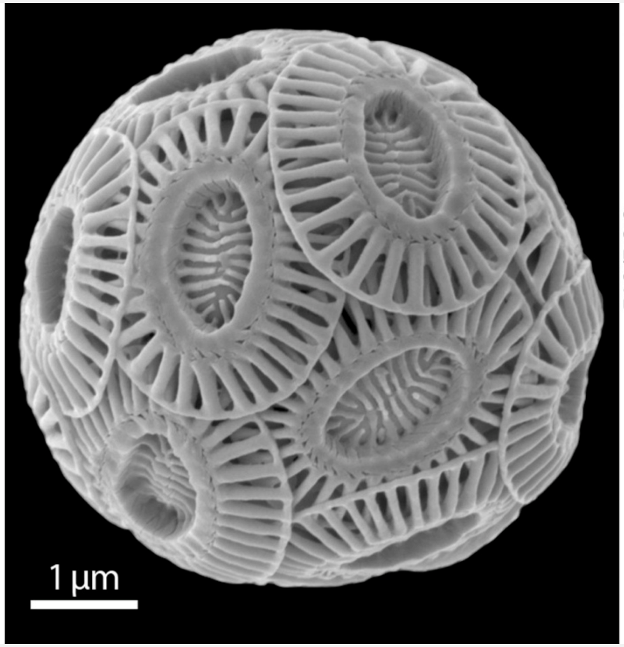


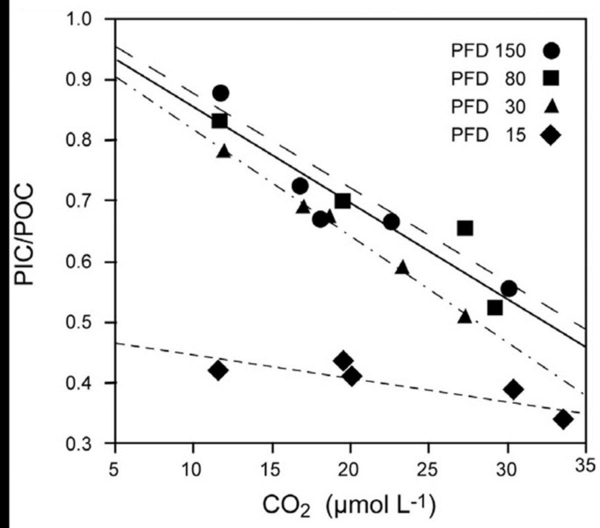




calcification by forams and pteropods does seem to be sensitive to change in degree of super-saturation

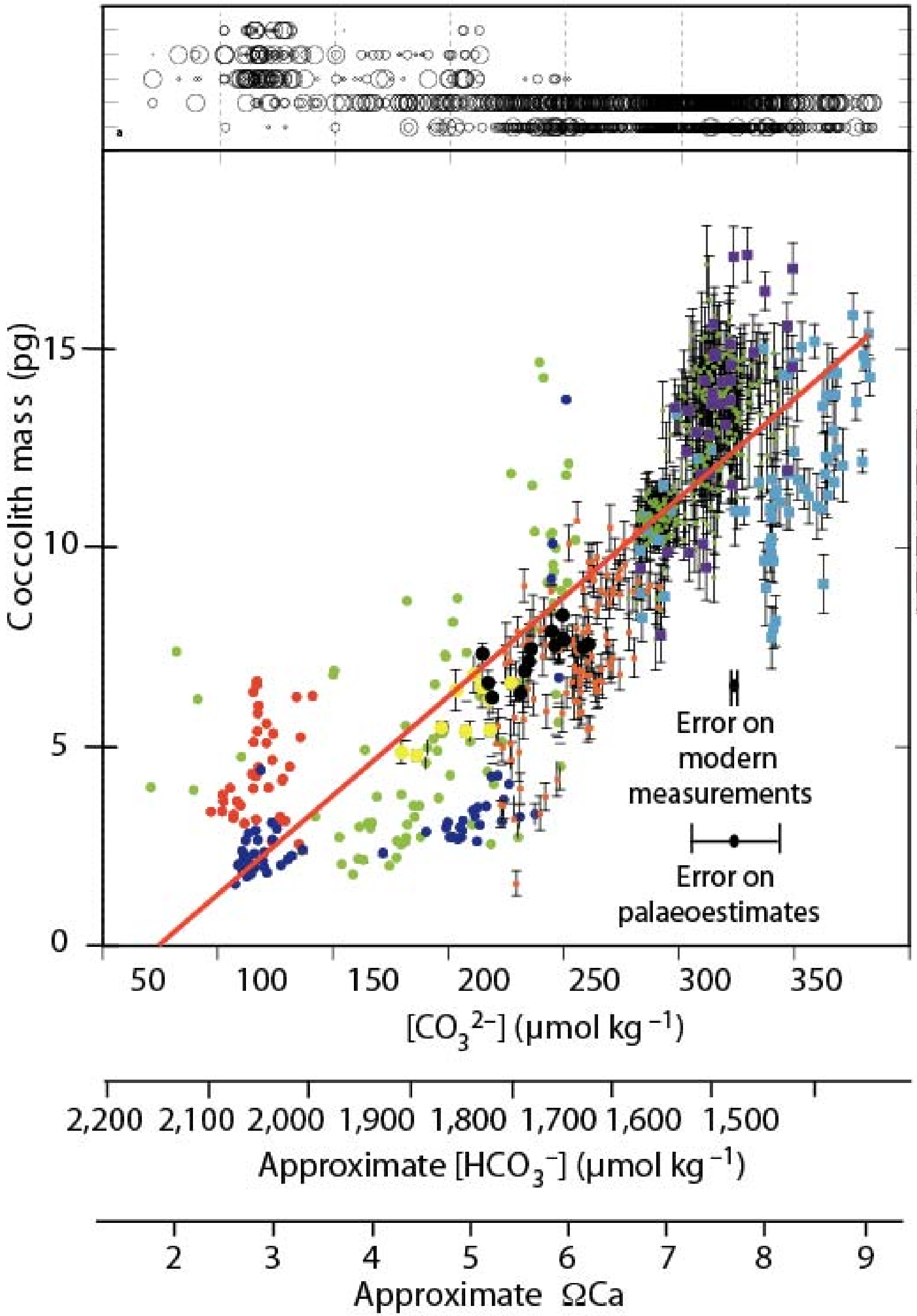




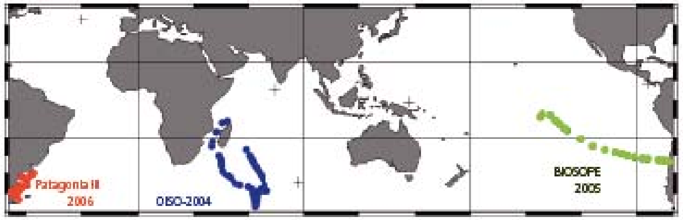


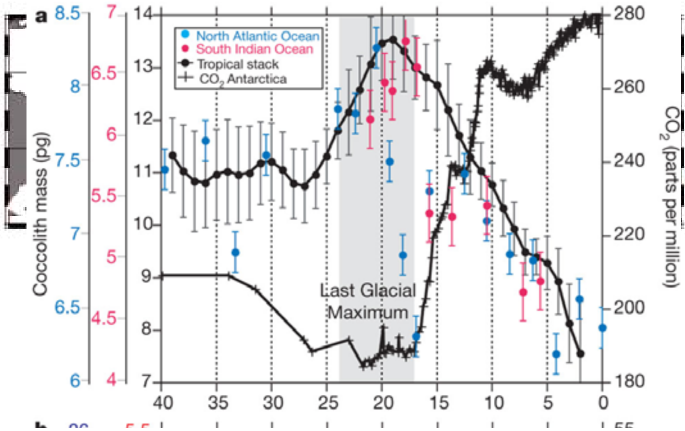
Riebesel et al 2004 J Oceanography

some lab work suggests calcification by coccolithophores is sensitive to change in degree of super-saturation

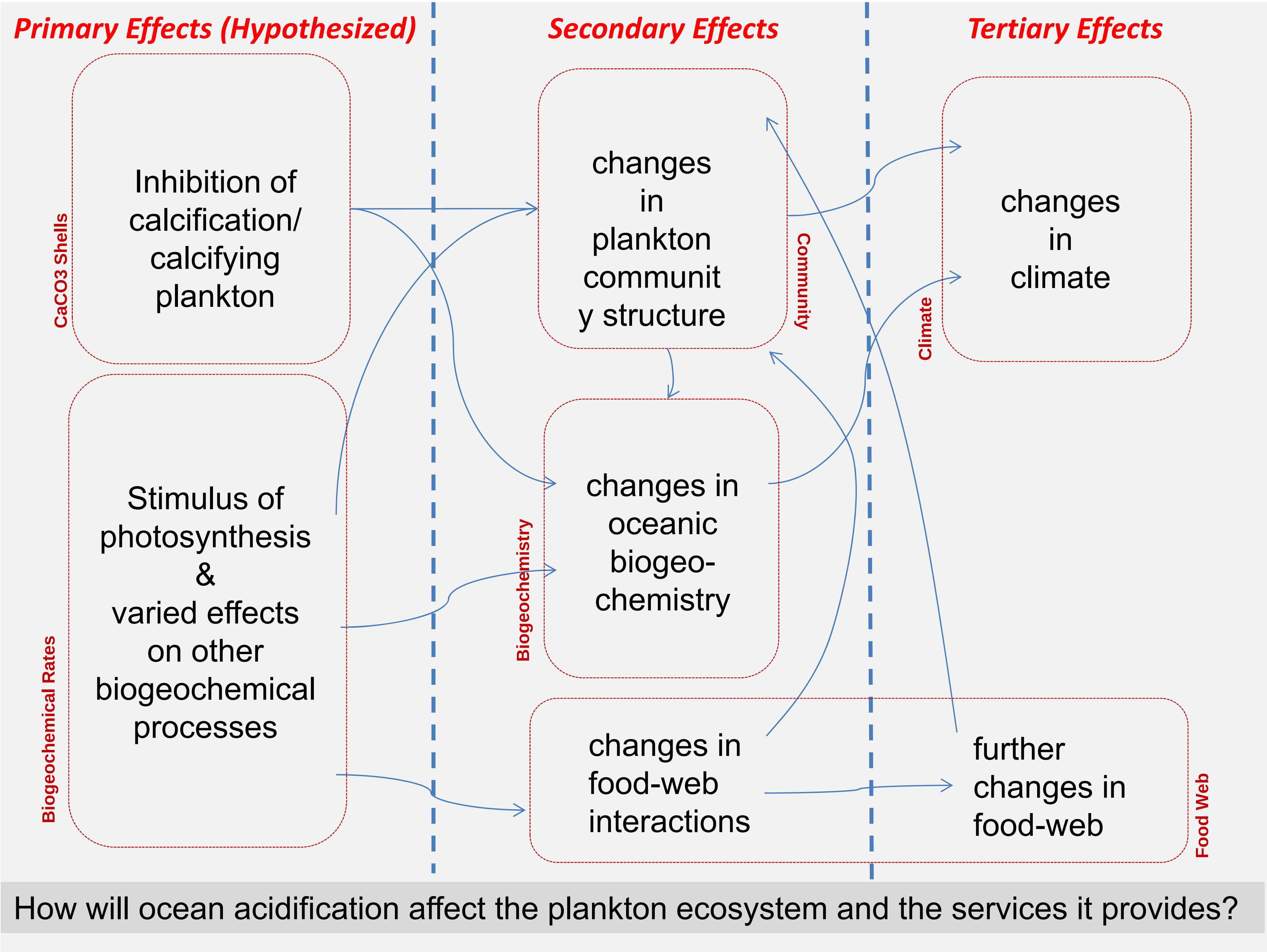


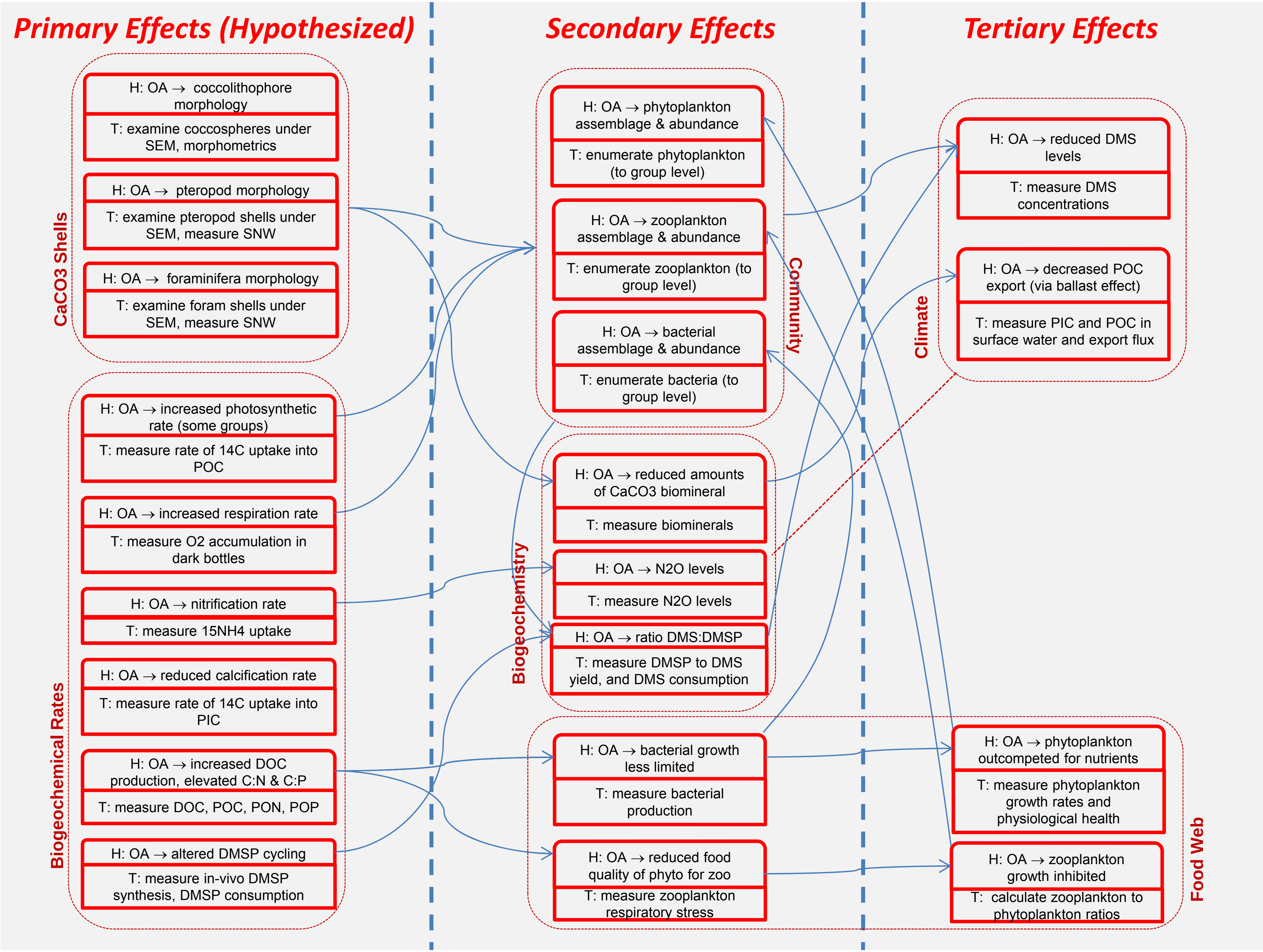
Beaufort *et al.* 2011 *Nature*



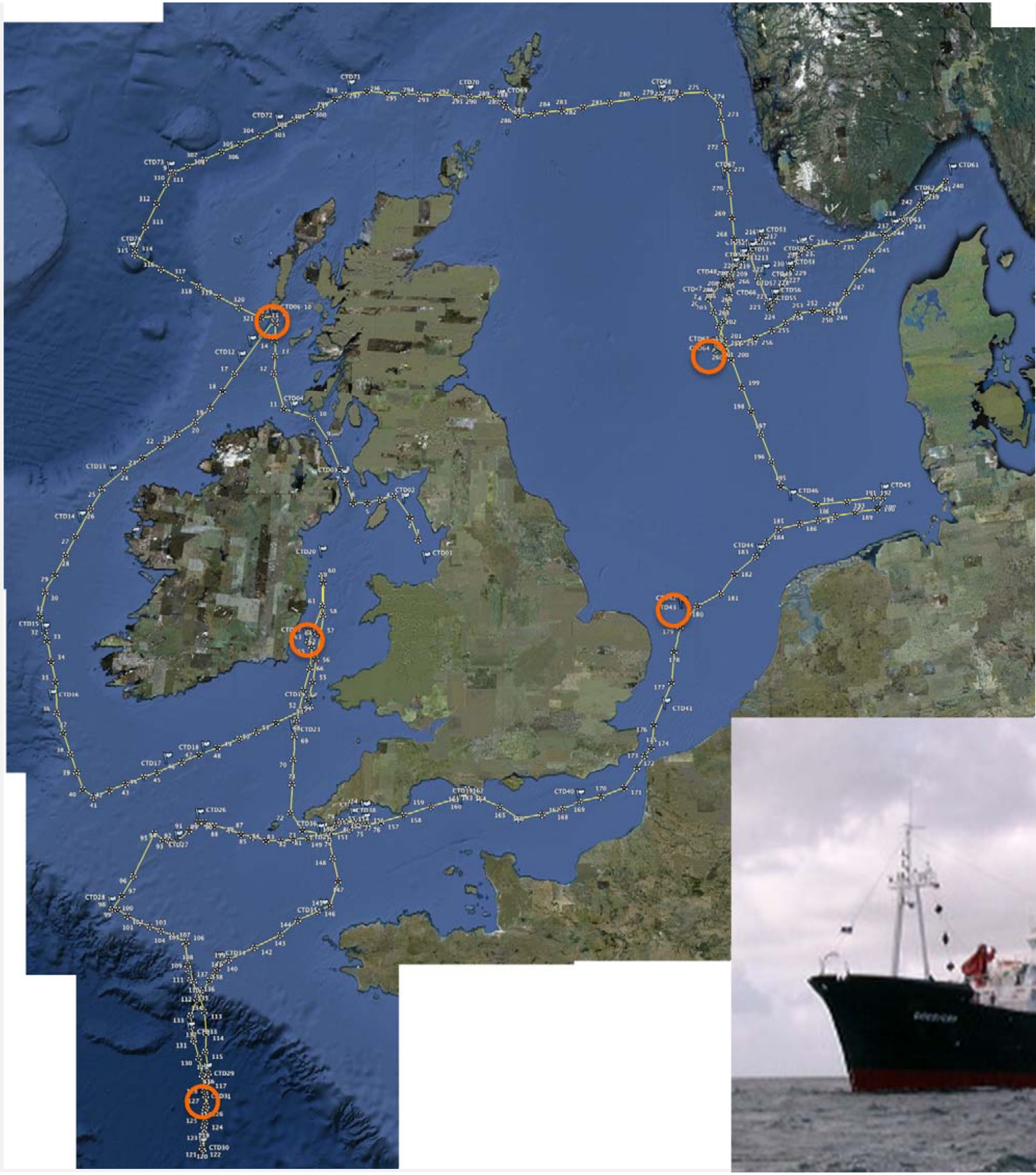


some geological and plankton data suggests strong impact of calcite saturation on coccolithophore calcification and ecology


Primary Effects (Hypothesized)
Secondary Effects
Tertiary Effects
CaCO3 Shells
Inhibition of calcification/ calcifying plankton
Biogeochemical Rates
Stimulus of photosynthesis & varied effects on other biogeochemical processes
changes in plankton communit y structure
Community
Biogeochemistry
changes in oceanic biogeo- chemistry
changes in food-web interactions
Climate
changes in climate
further changes in food-web
Food Web
How will ocean acidification affect the plankton ecosystem and the services it provides?



Primary Effects (Hypothesized)
Secondary Effects
Tertiary Effects
CaCO3 Shells
H: OA → coccolithophore morphology
T: examine coccospheres under SEM, morphometrics
H: OA → pteropod morphology
T: examine pteropod shells under SEM, measure SNW
H: OA → foraminifera morphology
T: examine foram shells under SEM, measure SNW
Biogeochemical Rates
H: OA → increased photosynthetic rate (some groups)
T: measure rate of 14C uptake into POC
H: OA → increased respiration rate
T: measure O2 accumulation in dark bottles
H: OA → nitrification rate
T: measure 15NH4 uptake
H: OA → reduced calcification rate
T: measure rate of 14C uptake into PIC
H: OA → increased DOC production, elevated C:N & C:P
T: measure DOC, POC, PON, POP
H: OA → altered DMSP cycling
T: measure in-vivo DMSP synthesis, DMSP consumption
Community
H: OA → phytoplankton assemblage & abundance
T: enumerate phytoplankton (to group level)
H: OA → zooplankton assemblage & abundance
T: enumerate zooplankton (to group level)
H: OA → bacterial assemblage & abundance
T: enumerate bacteria (to group level)
Biogeochemistry
H: OA → reduced amounts of CaCO3 biomineral
T: measure biominerals
H: OA → N2O levels
T: measure N2O levels
H: OA → ratio DMS:DMSP
T: measure DMSP to DMS yield, and DMS consumption
H: OA → bacterial growth less limited
T: measure bacterial production
H: OA → reduced food quality of phyto for zoo
T: measure zooplankton respiratory stress
Climate
H: OA → reduced DMS levels
T: measure DMS concentrations
H: OA → decreased POC export (via ballast effect)
T: measure PIC and POC in surface water and export flux
Food Web
H: OA → phytoplankton outcompeted for nutrients
T: measure phytoplankton growth rates and physiological health
H: OA → zooplankton growth inhibited
T: calculate zooplankton to phytoplankton ratios

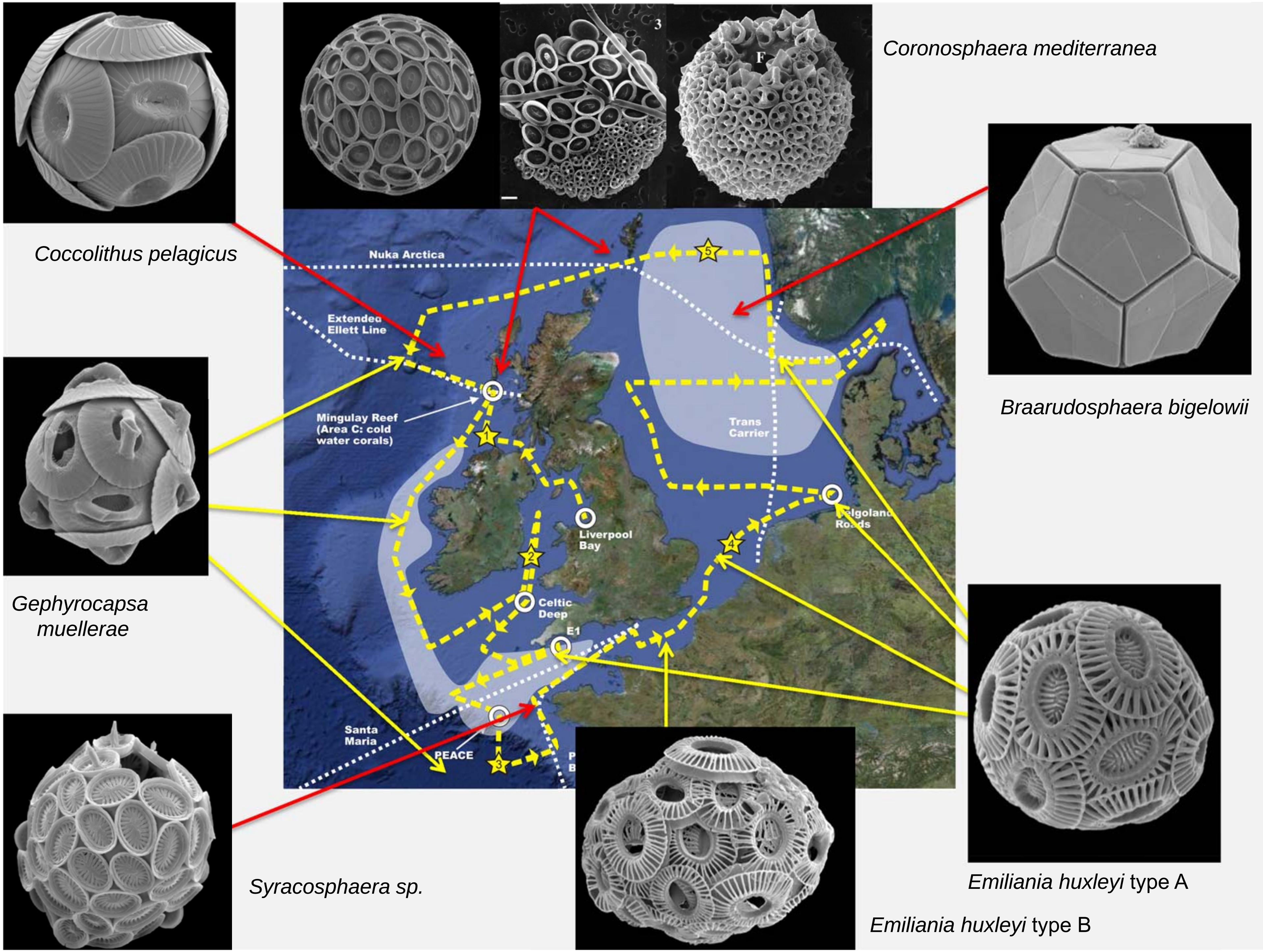


Cruise D366
June-July 2011

5 Bioassay experiments

72 CTD stations

320 Underway samples



Coronosphaera mediterranea
Coccolithus pelagicus
Braarudosphaera bigelowii
Gephyrocapsa muellerae
Syracosphaera sp.
Emiliania huxleyi type A
Emiliania huxleyi type B
Nuka Arctica
Extended Ellett Line
Mingulay Reef (Area C: cold water corals)
Trans Carrier
Liverpool Bay
Celtic Deep
E1
Santa Maria
PEACE

Cruise JR271

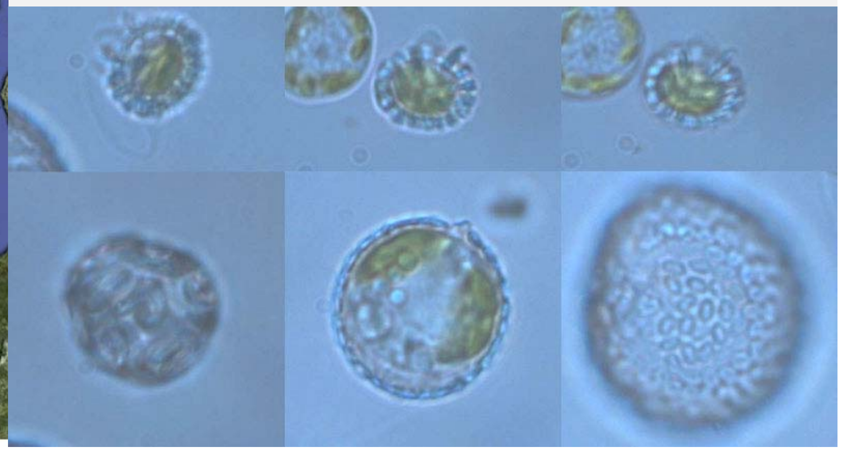
June-July 2012

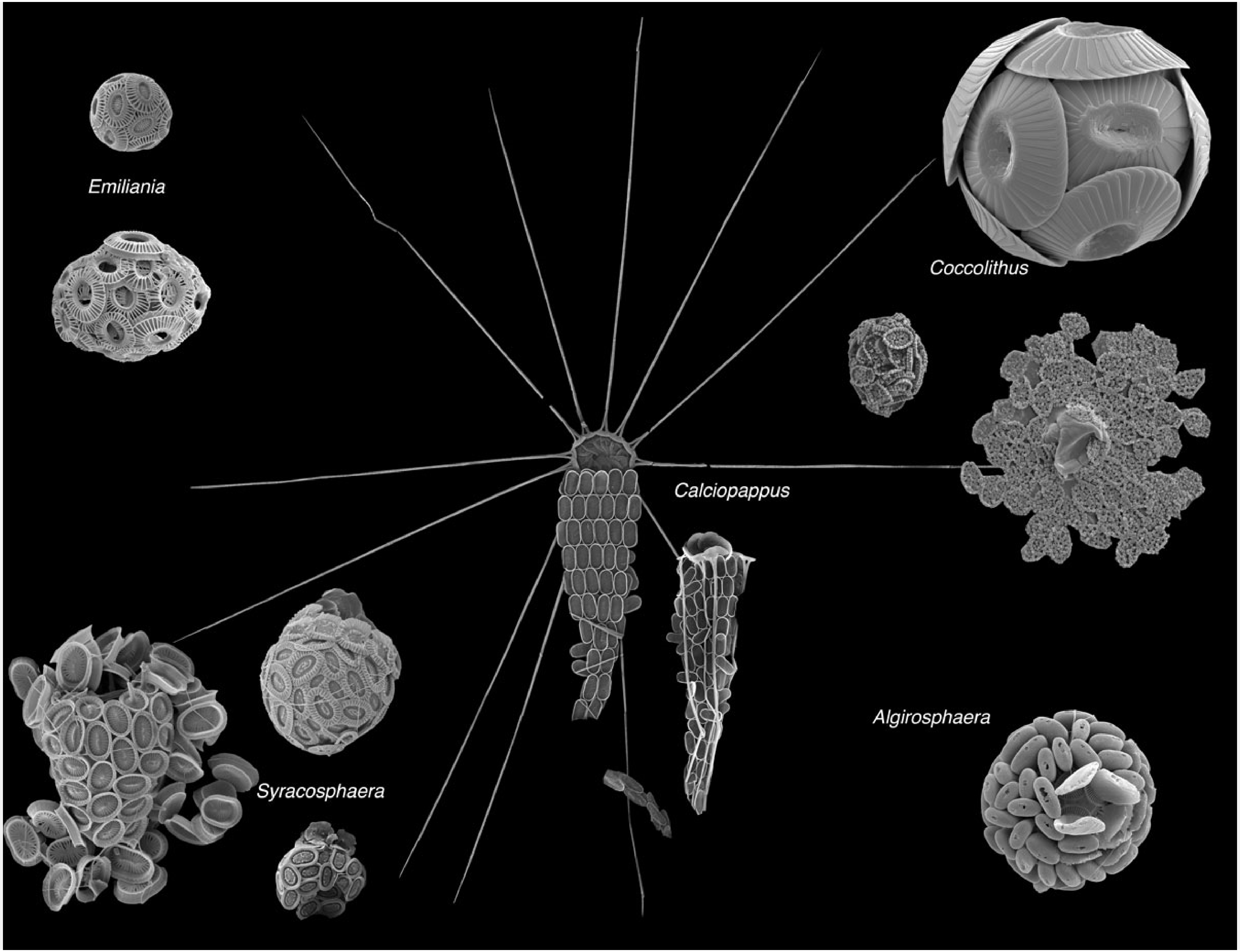
40 CTD stations (usually 6 depths)

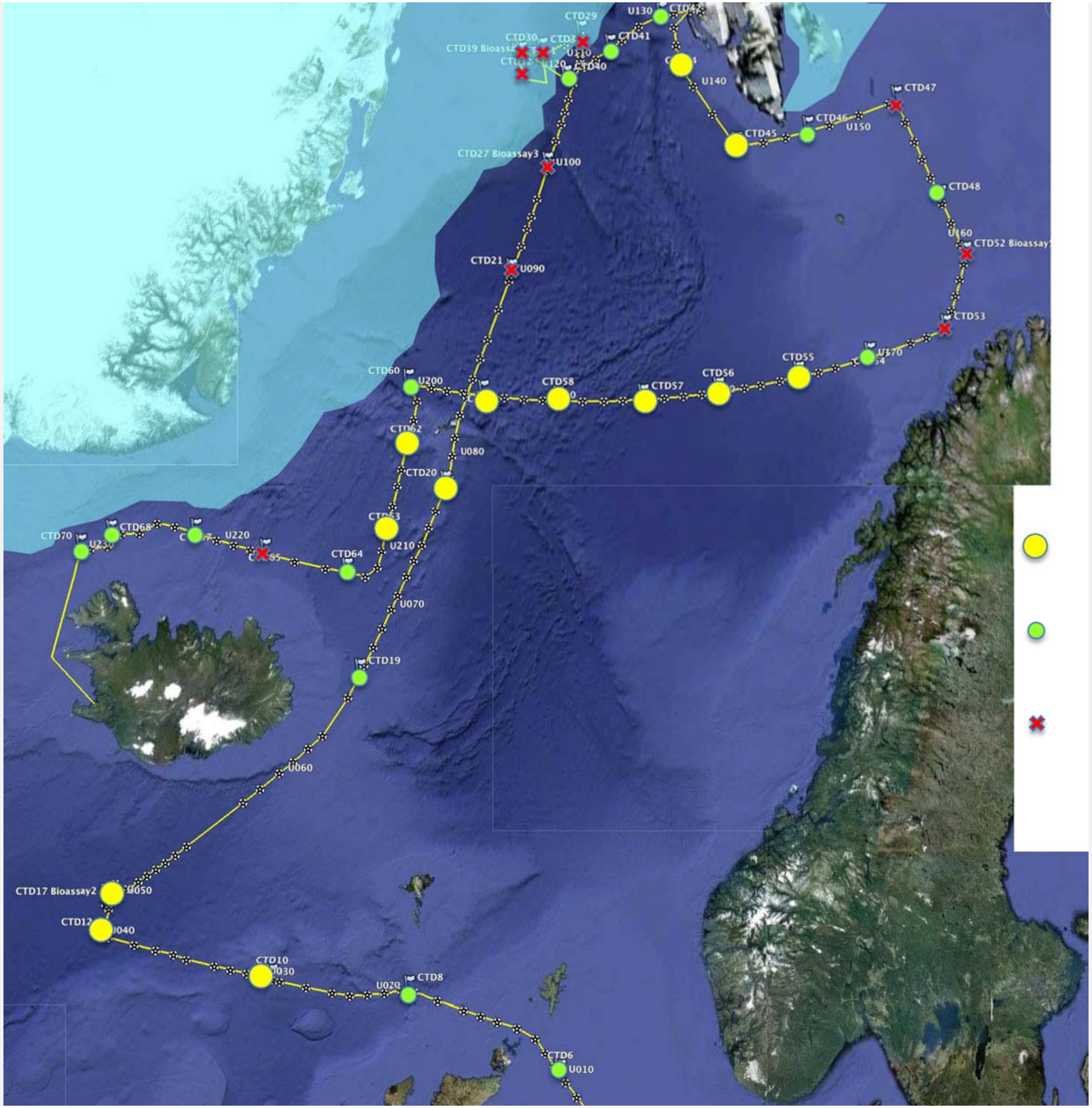
230 underway samples

5 bioassays (but coccos only in 1 & 2)

lots of ice




Emiliania
Coccolithus
Calciopappus
Algirosphaera
Syracosphaera

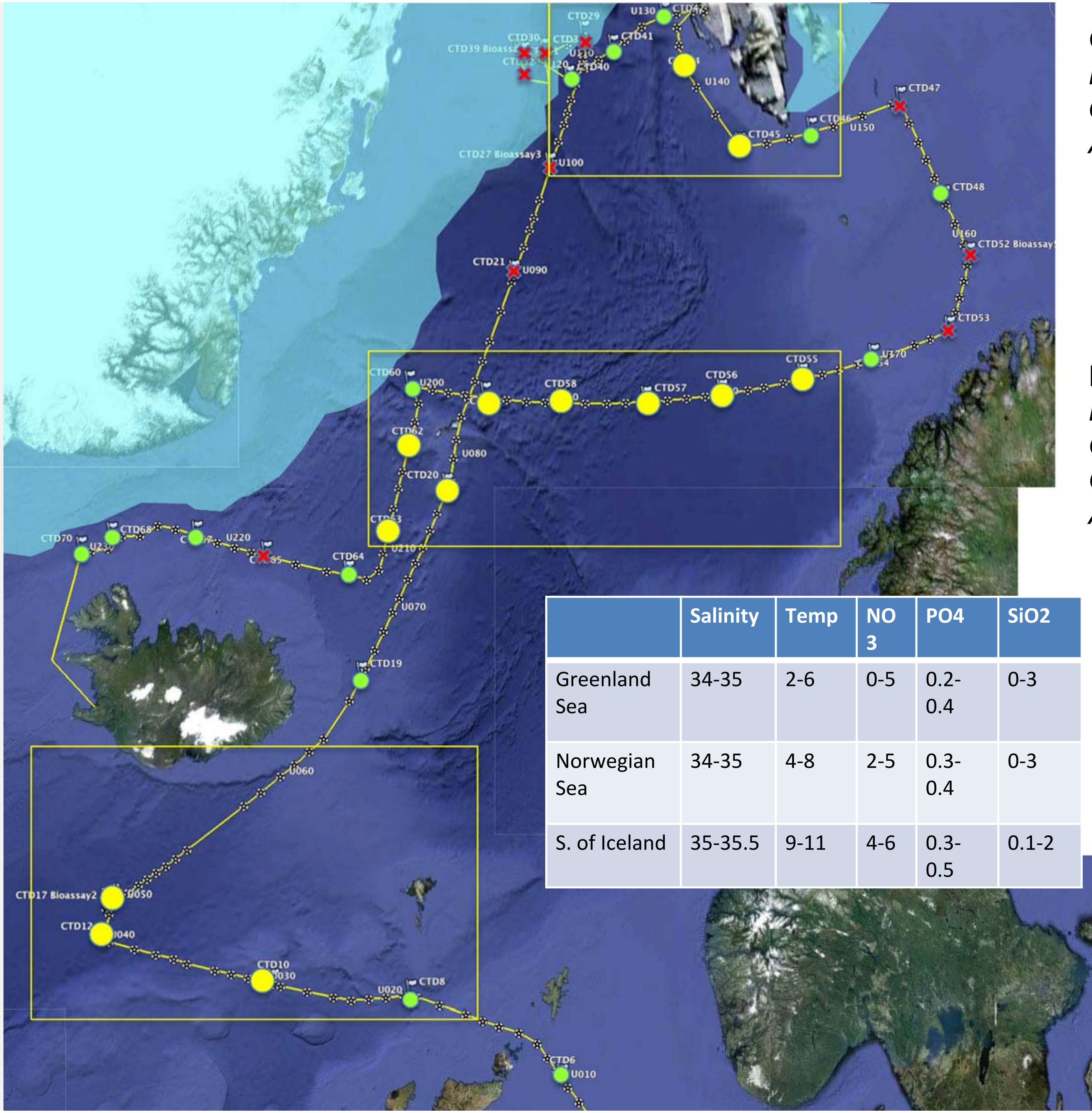


JR 271 coccolithophore abundance

>100,000 cells/l

10-100,000 cells/l

<10,000 cells/l

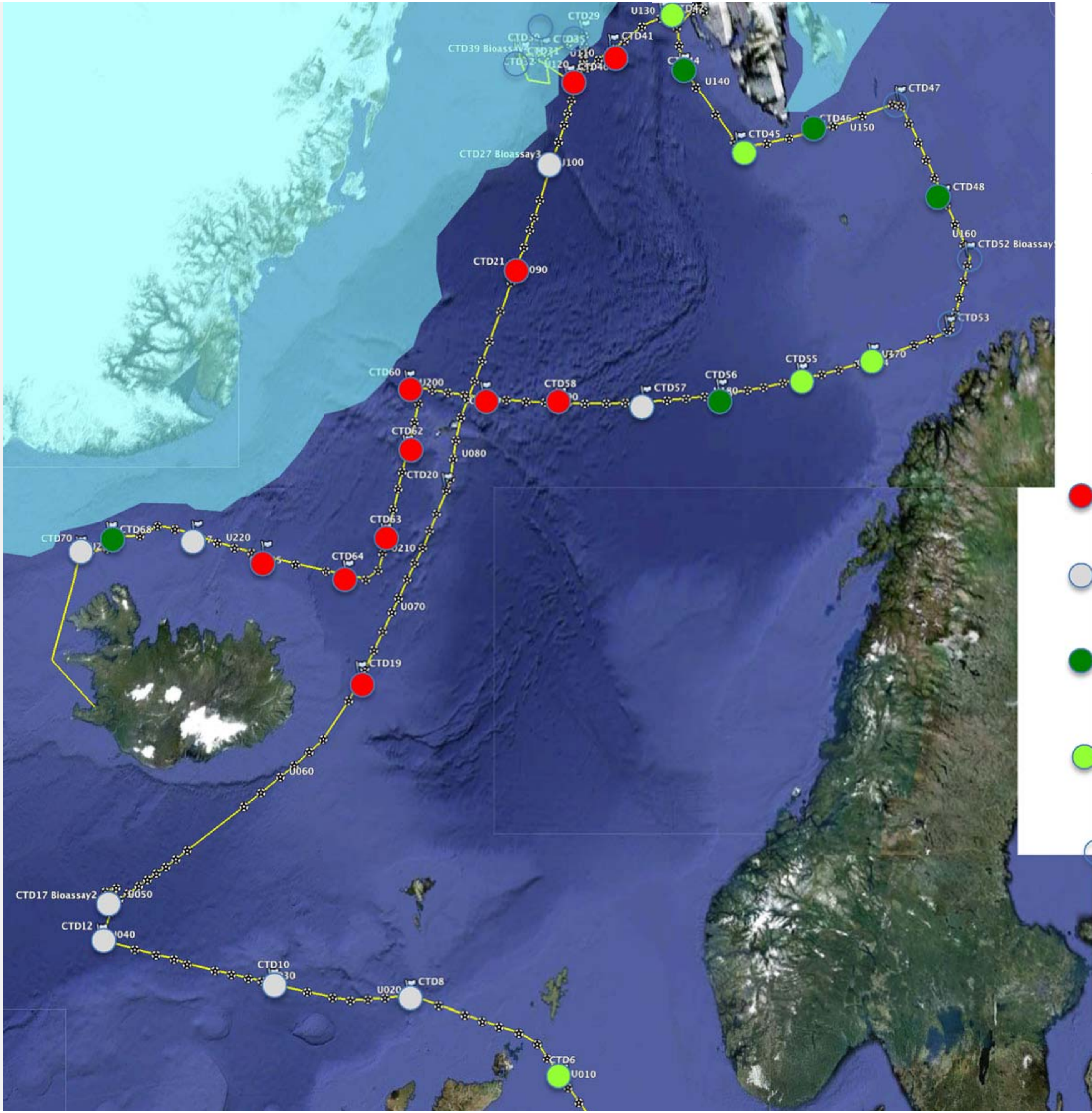


	Salinity	Temp	NO3	PO4	SiO2
Greenland Sea	34-35	2-6	0-5	0.2-0.4	0-3
Norwegian Sea	34-35	4-8	2-5	0.3-0.4	0-3
S. of Iceland	35-35.5	9-11	4-6	0.3-0.5	0.1-2

Greenland Sea
Emiliania
***Coccolithus* HOL**
Algirosphaera

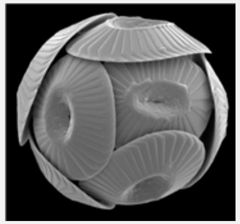
Norwegian Sea
Emiliania
Calciopappus
Coccolithus HET +HOL
Algirosphaera

South of Iceland
Emiliania
Calciopappus
Coccolithus HET
Syracosphaera



JR 271

Emiliania:Coccolithus



Ehux < 5x Cpel

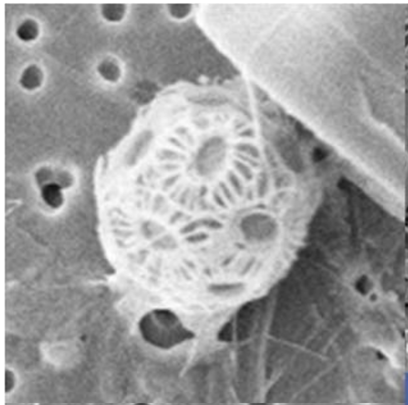
Ehux >5x Cpel

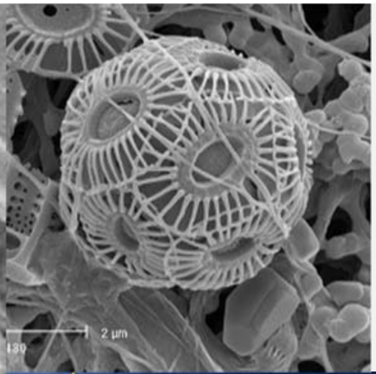
Ehux >50x Cpel

Ehux >500x Cpel

sample +/- barren

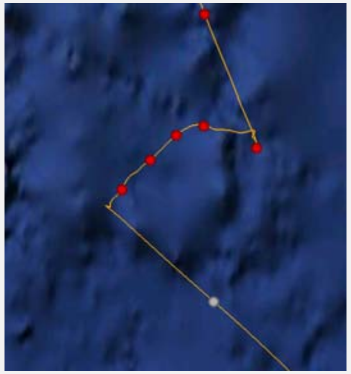
JR274 Antarctic
Jan-Feb 2013





Emiliania huxleyi

- Almost entirely type B/C (as predicted).
- Southerly limit rather sharp and crossed 4 times
- Some patchiness to N of South Georgia

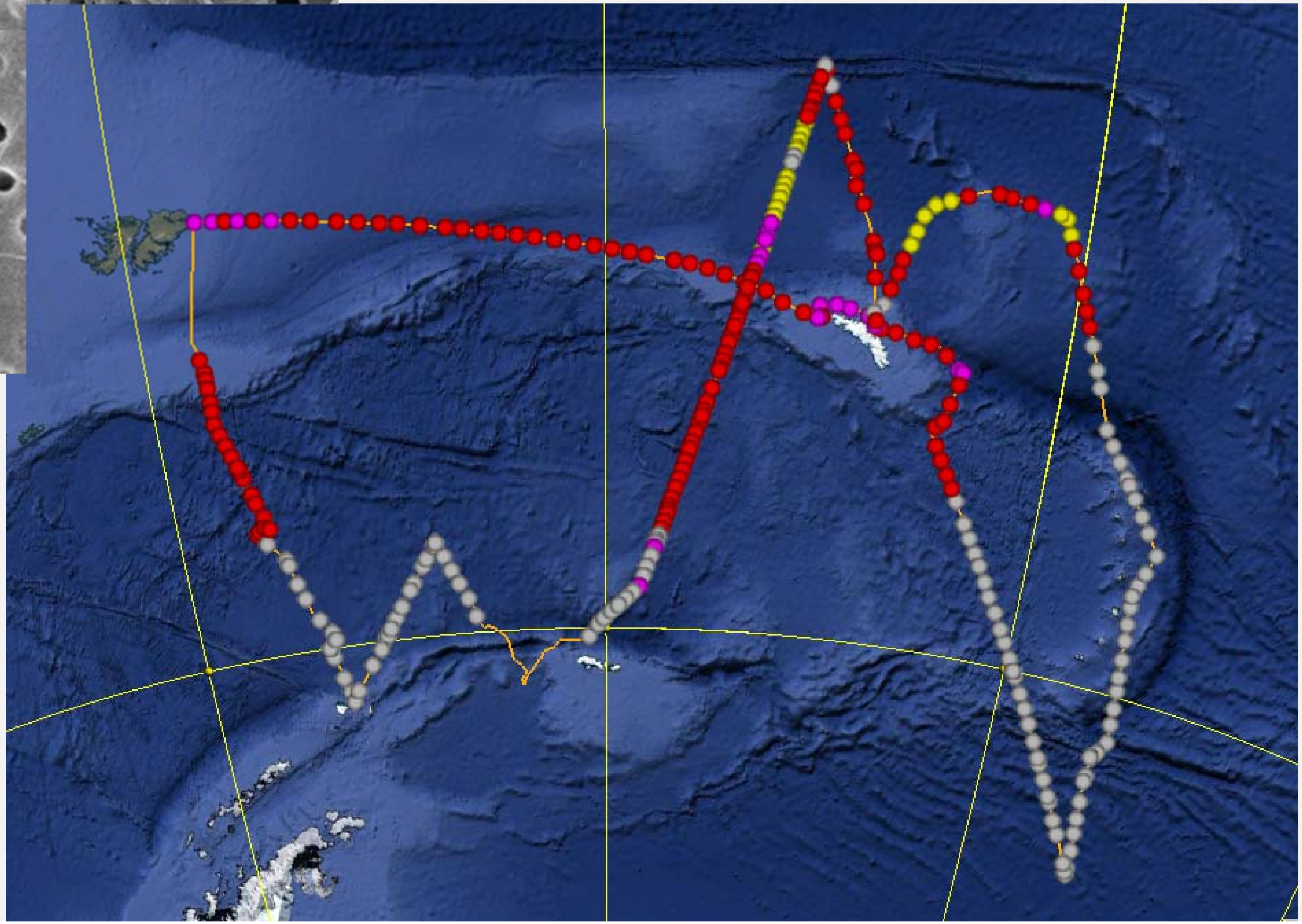


E. hux ab

E. hux rare

?etched relics

no Ehux



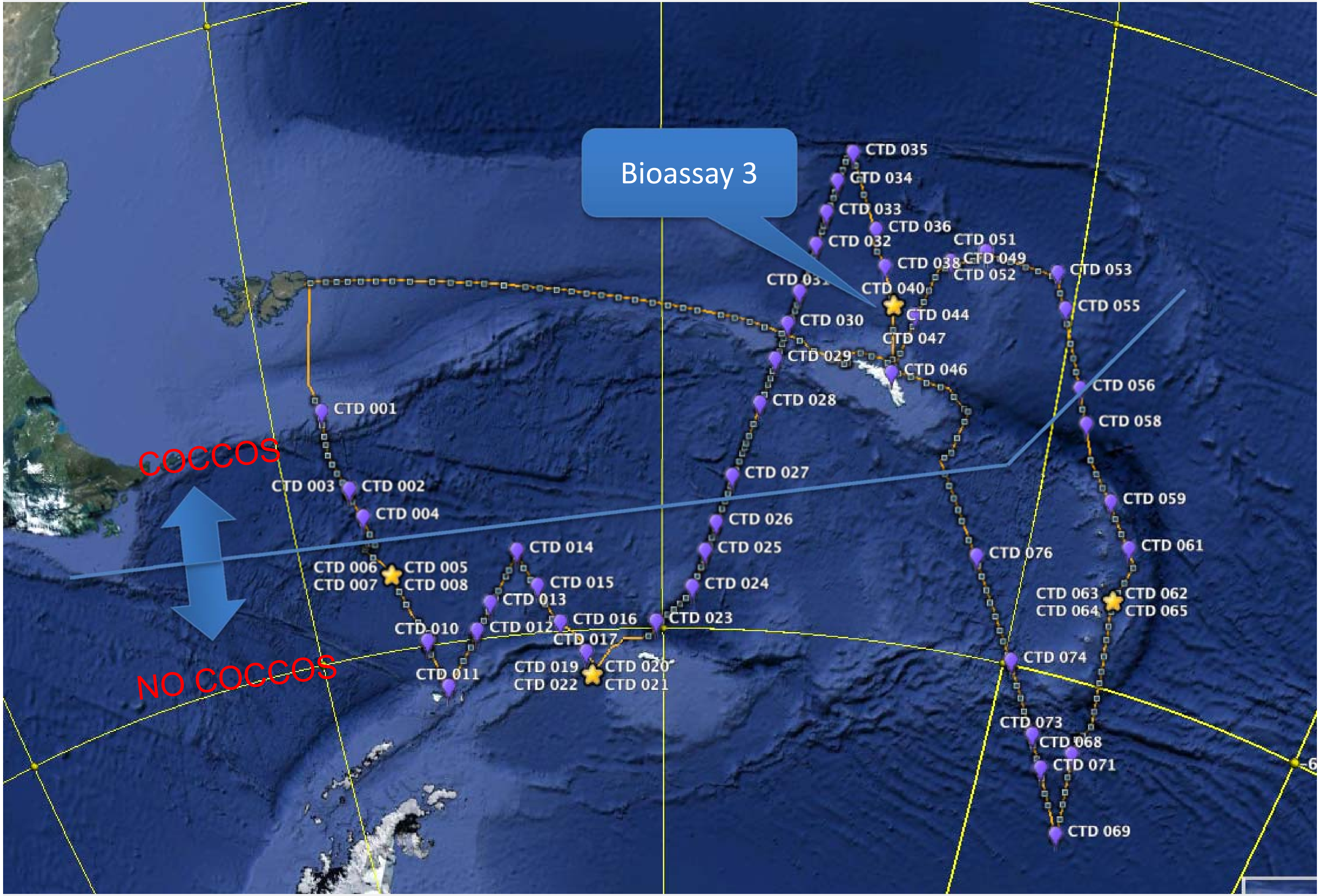
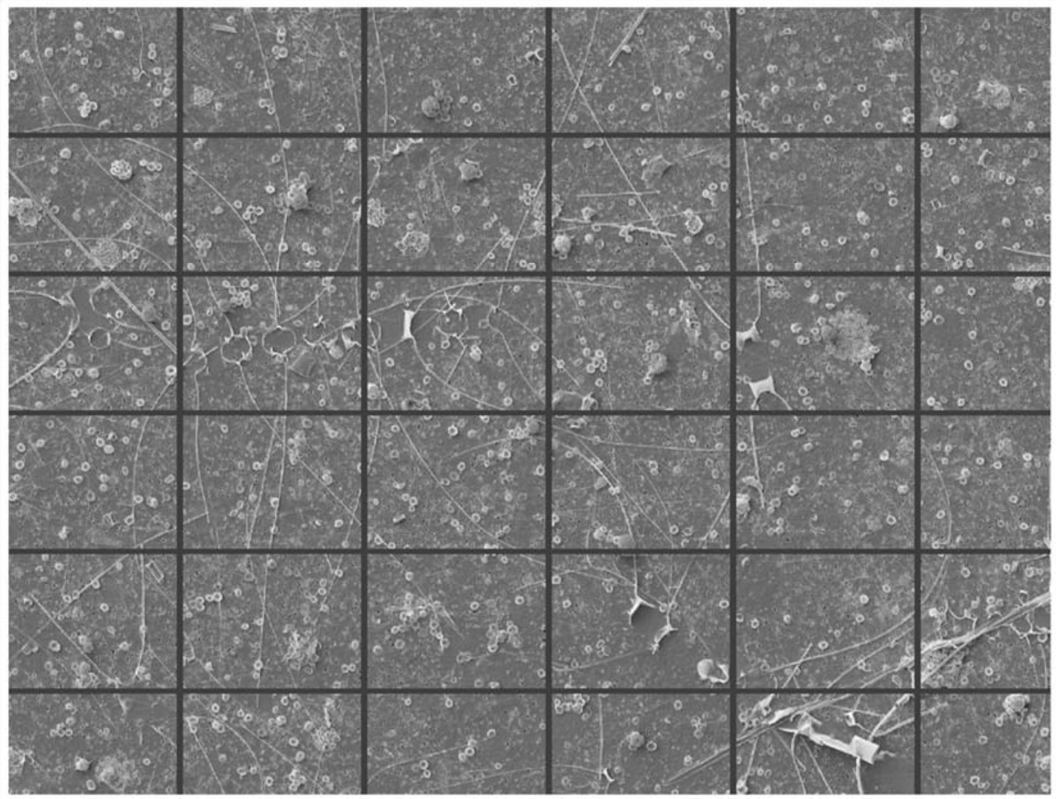
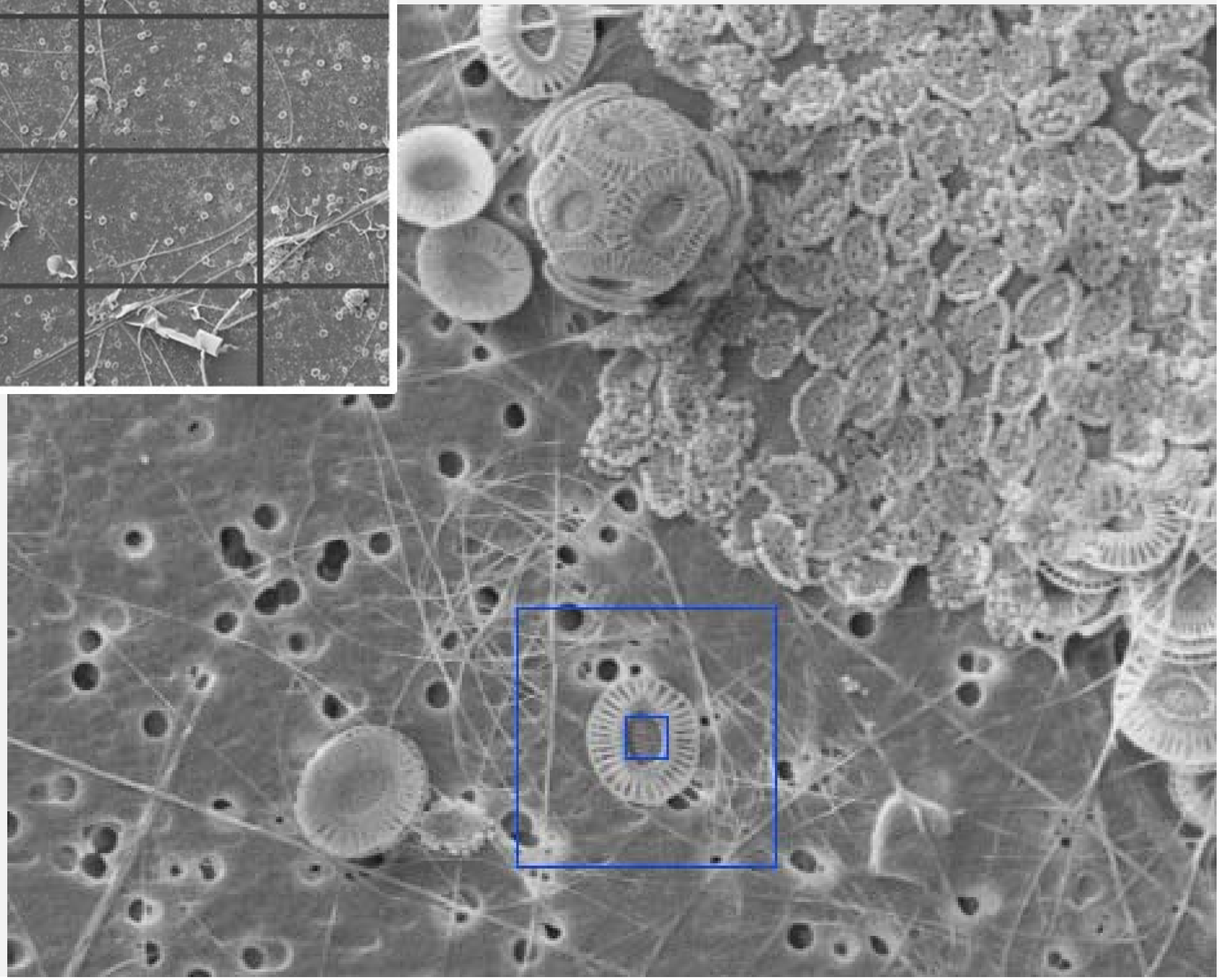

Bioassay 3
COCCOS
NO COCCOS
CTD 001
CTD 002
CTD 003
CTD 004
CTD 005
CTD 006
CTD 007
CTD 008
CTD 010
CTD 011
CTD 012
CTD 013
CTD 014
CTD 015
CTD 016
CTD 017
CTD 019
CTD 020
CTD 021
CTD 022
CTD 023
CTD 024
CTD 025
CTD 026
CTD 027
CTD 028
CTD 029
CTD 030
CTD 031
CTD 032
CTD 033
CTD 034
CTD 035
CTD 036
CTD 038
CTD 040
CTD 044
CTD 046
CTD 047
CTD 049
CTD 051
CTD 052
CTD 053
CTD 055
CTD 056
CTD 058
CTD 059
CTD 061
CTD 062
CTD 063
CTD 064
CTD 065
CTD 068
CTD 069
CTD 071
CTD 073
CTD 074
CTD 076

image collection

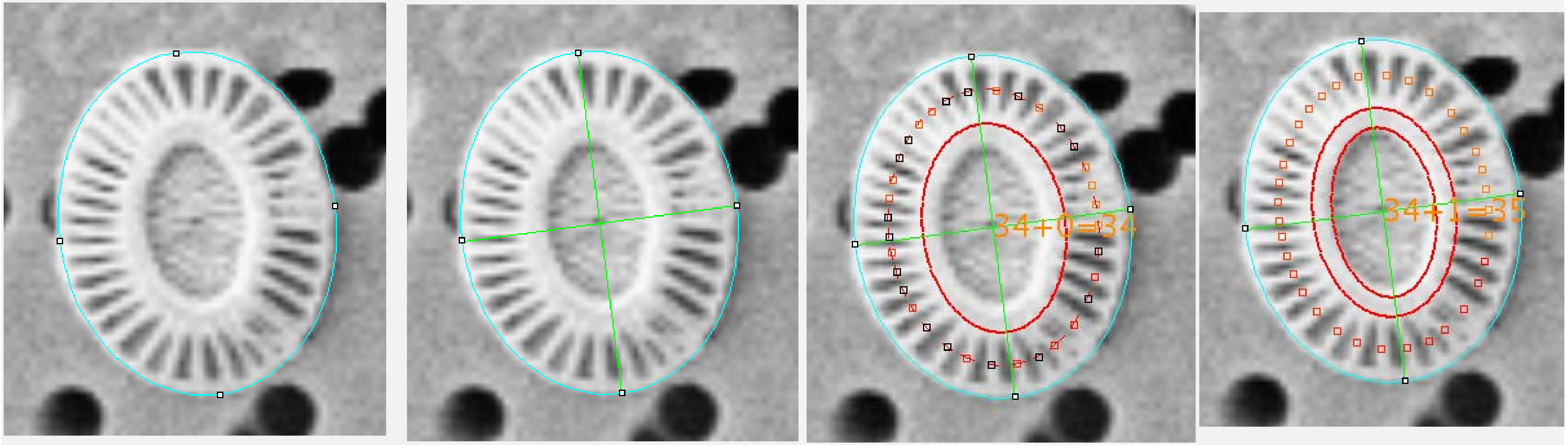




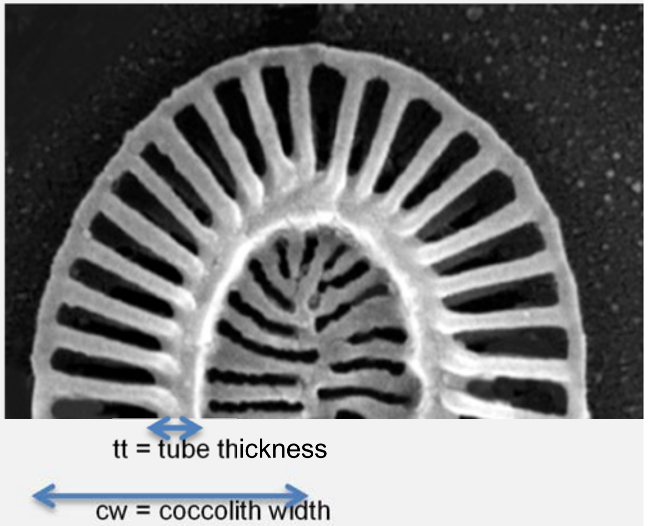
1. SEM automatically captures array of images overnight

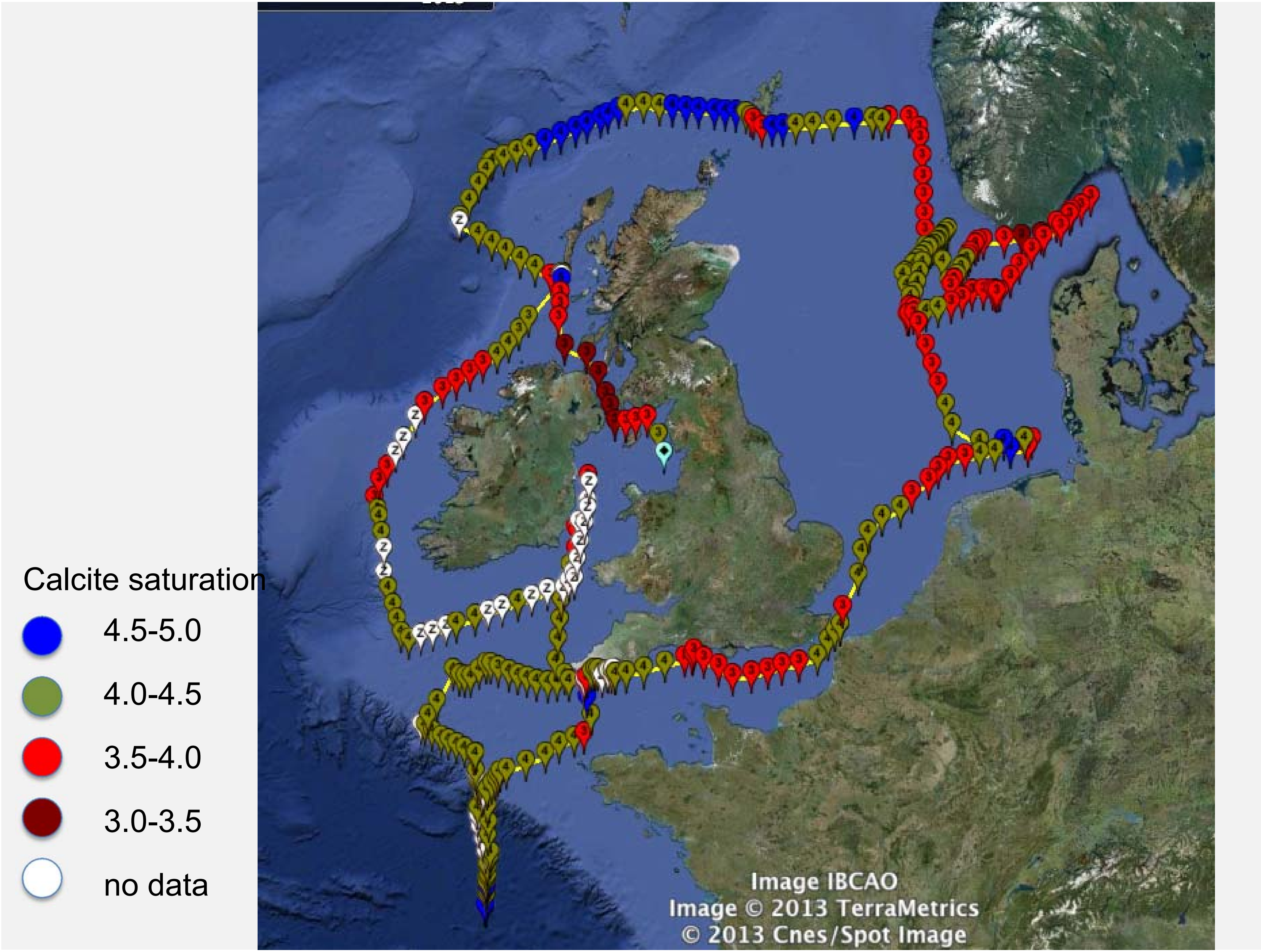
2. Individual specimens are collected using imageJ macros

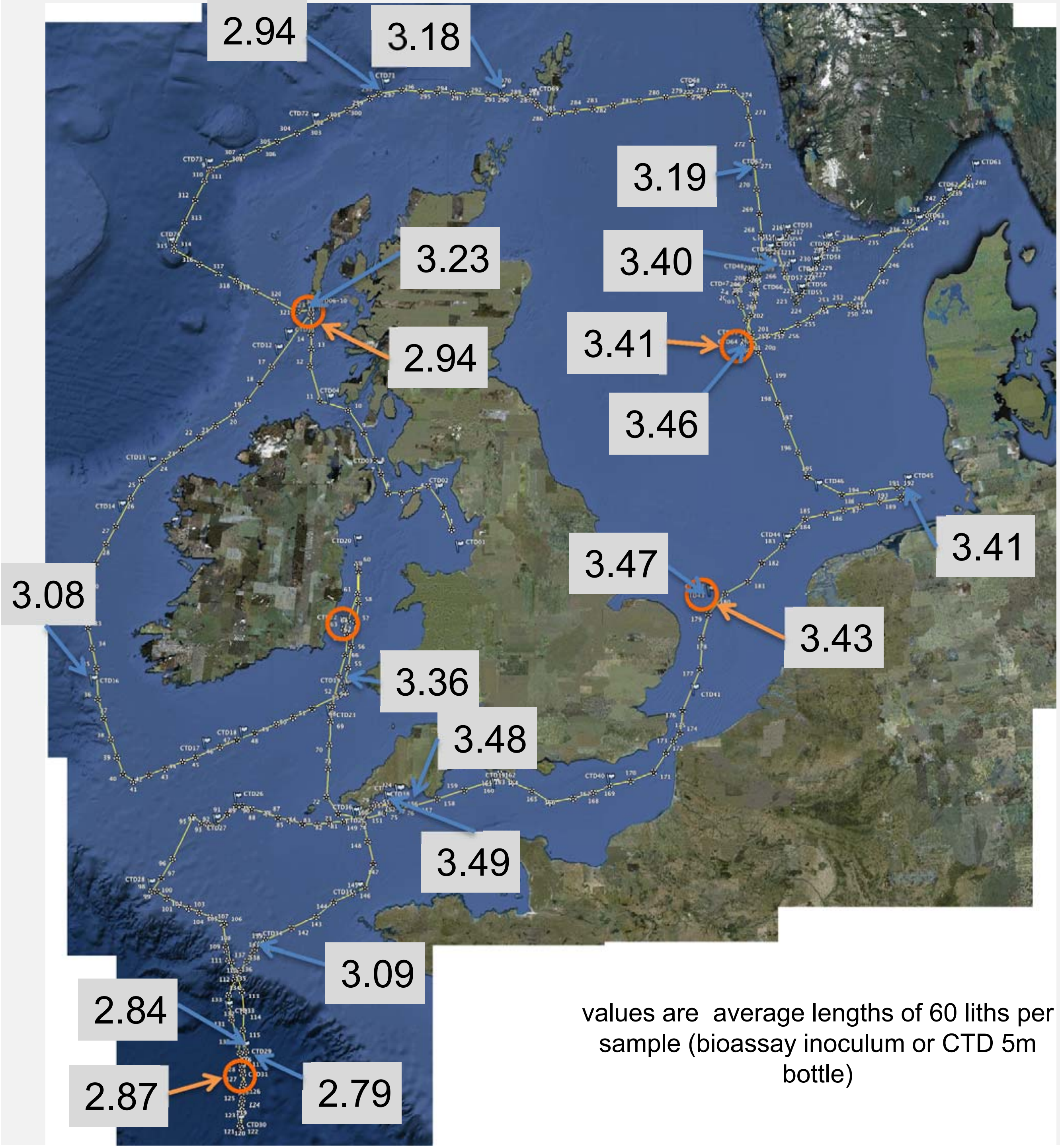
semi-automated coccolith measurement using ImageJ/FiJi



thickness of tube as proportion of coccolith width gives size-independent measure of degree of coccolith calcification



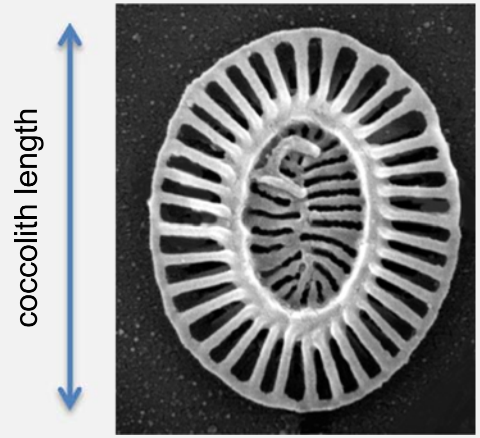

Calcite saturation
4.5-5.0
4.0-4.5
3.5-4.0
3.0-3.5
no data
Image IBCAO
Image © 2013 TerraMetrics
© 2013 Cnes/Spot Image



values are average lengths of 60 liths per sample (bioassay inoculum or CTD 5m bottle)

Emiliania huxleyi length variation

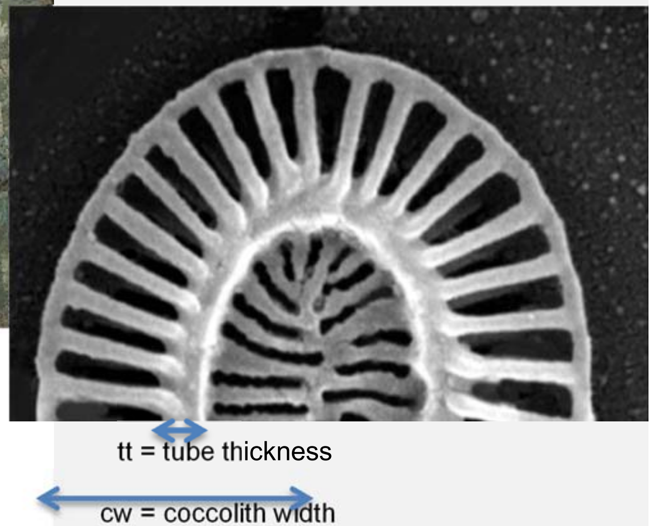
larger specimens in more neritic samples (Channel and North Sea)

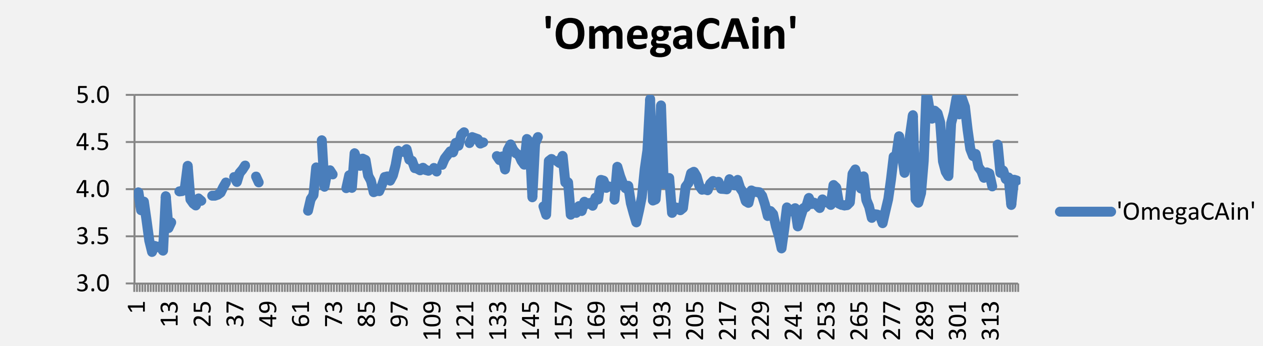


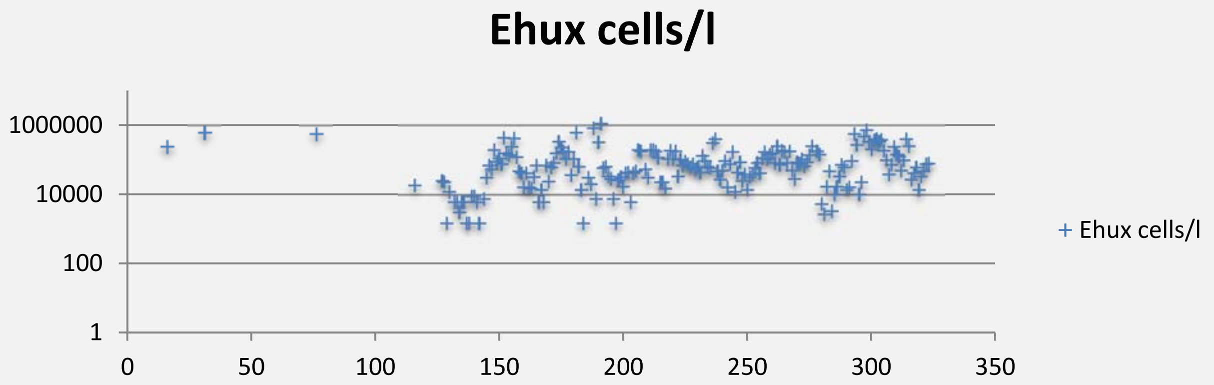
Emiliania huxleyi
degree of
calcification
variation

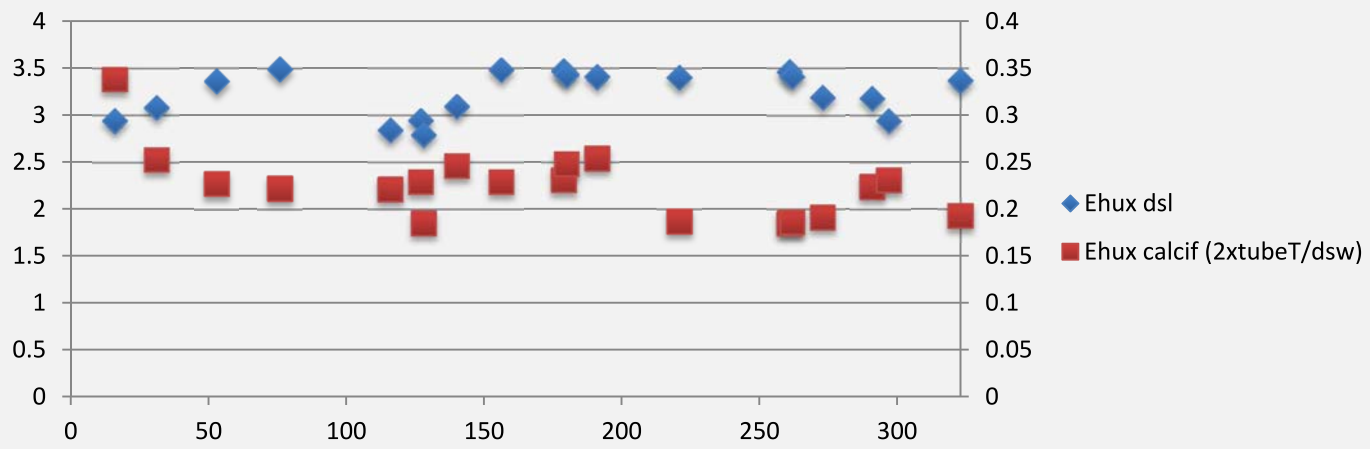
total variation is
low (0.18 to 0.25
except for
Bioassay 1), and
no obvious
pattern shown

values are tt/cw
(average of 60 liths)









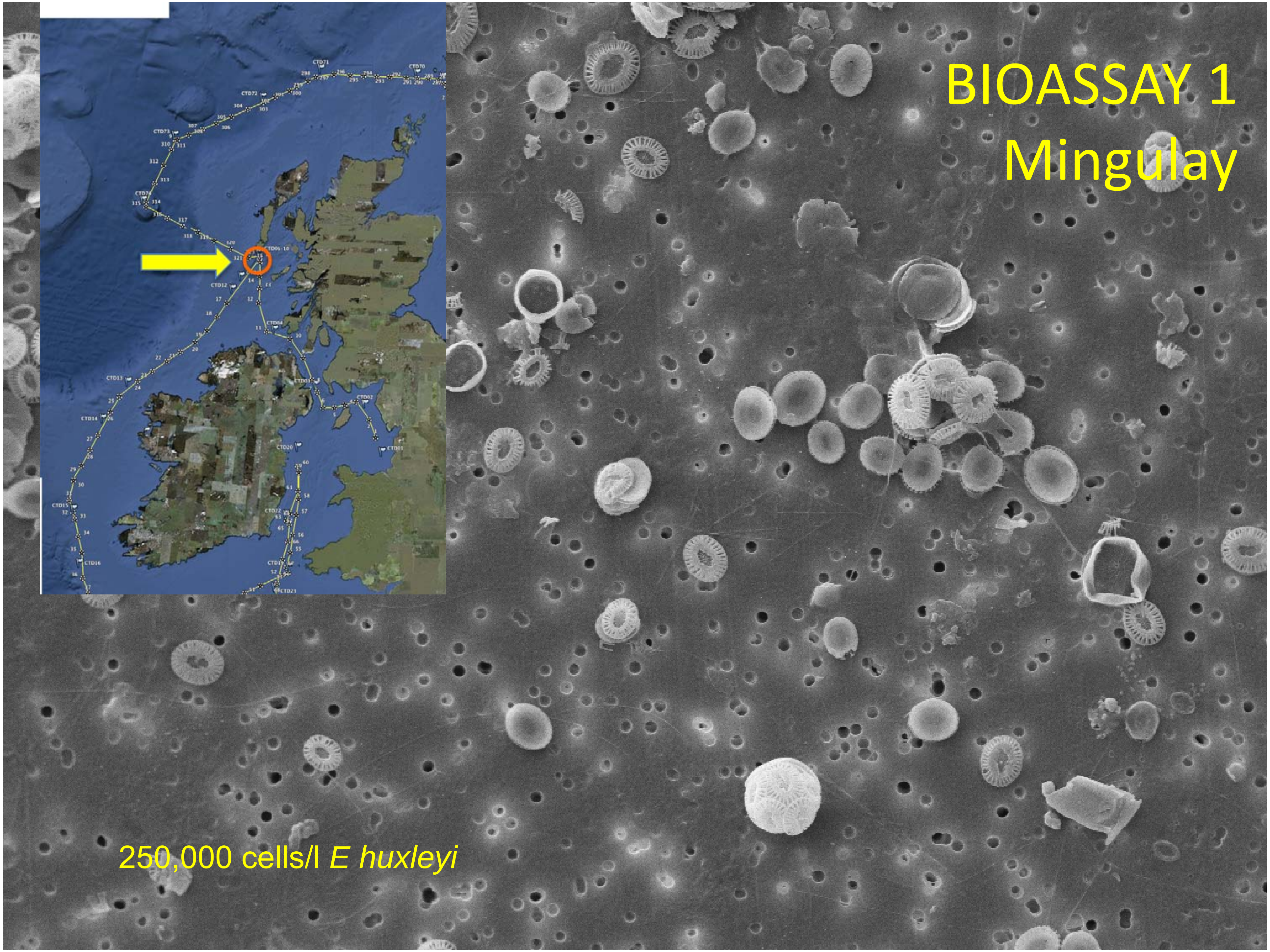
No obvious first order relationship of *E. huxleyi* abundance, size or degree of calcification with calcite saturation state

Bioassays

5 incubations each 4 days at four CO_2 levels
(380, 500, 750, 1000ppm)

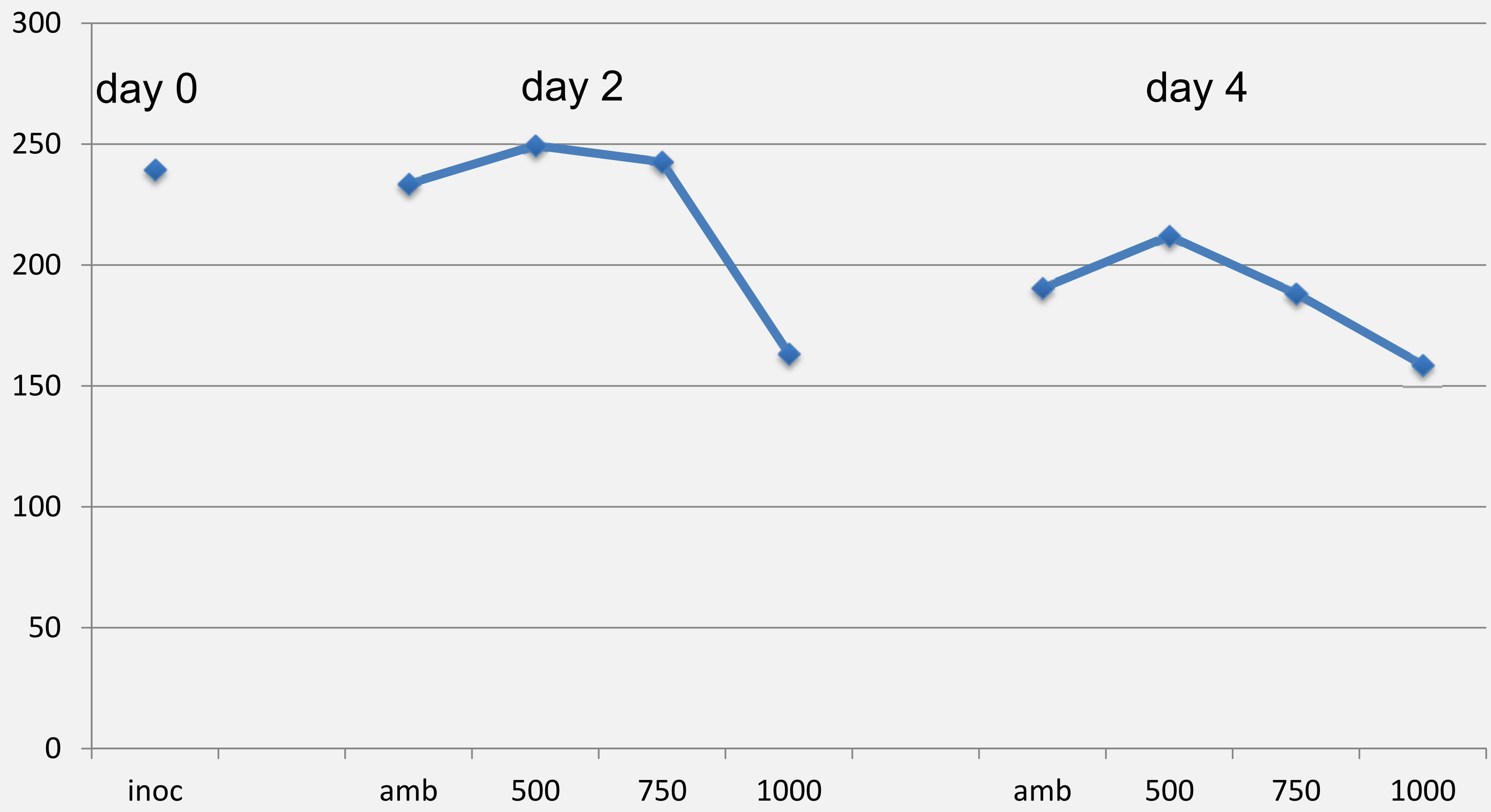
very extensive matrix of observations

BIOASSAY 1
Mingulay

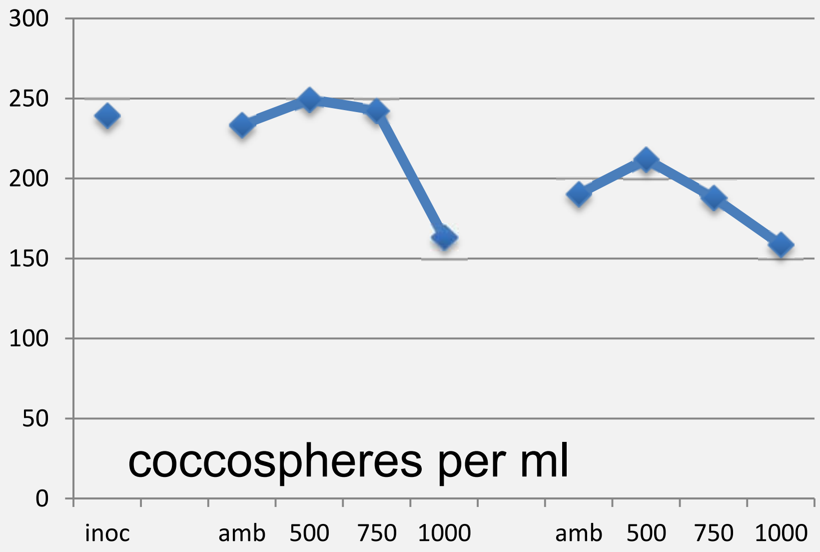


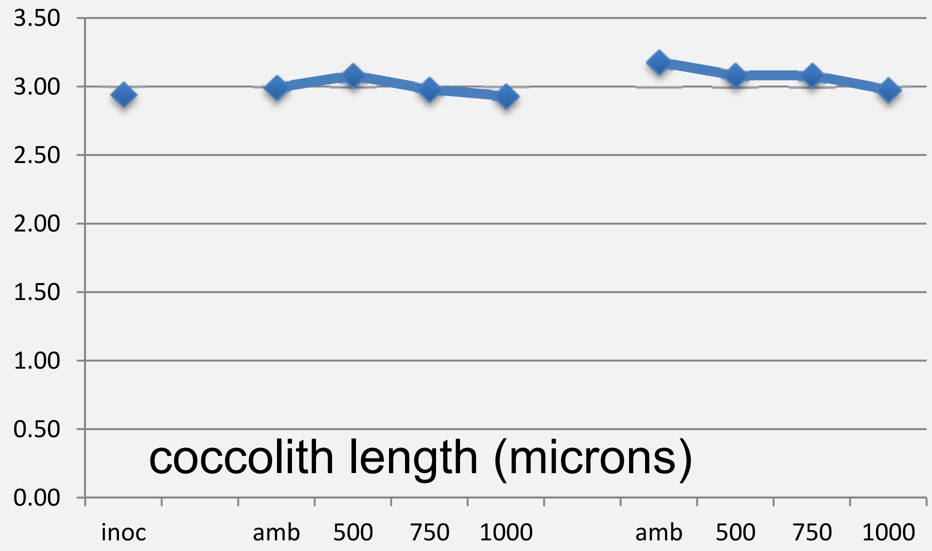
250,000 cells/l *E huxleyi*

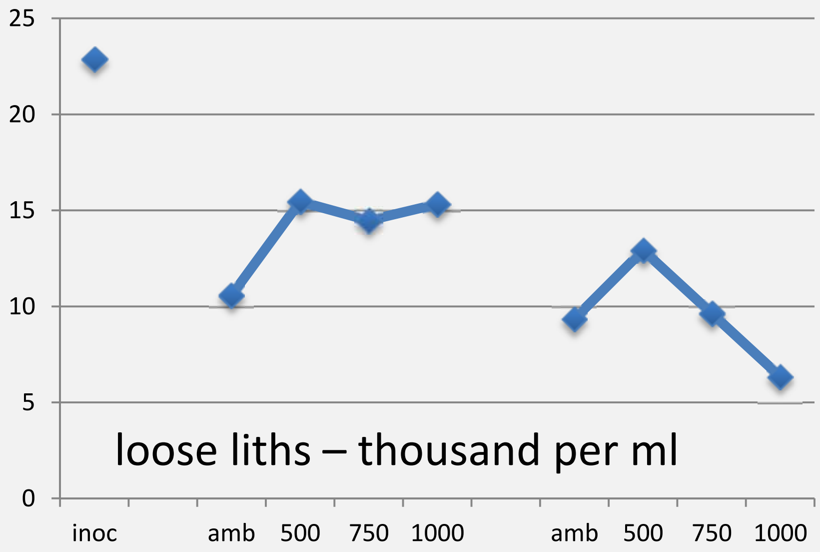
coccospheres/ml

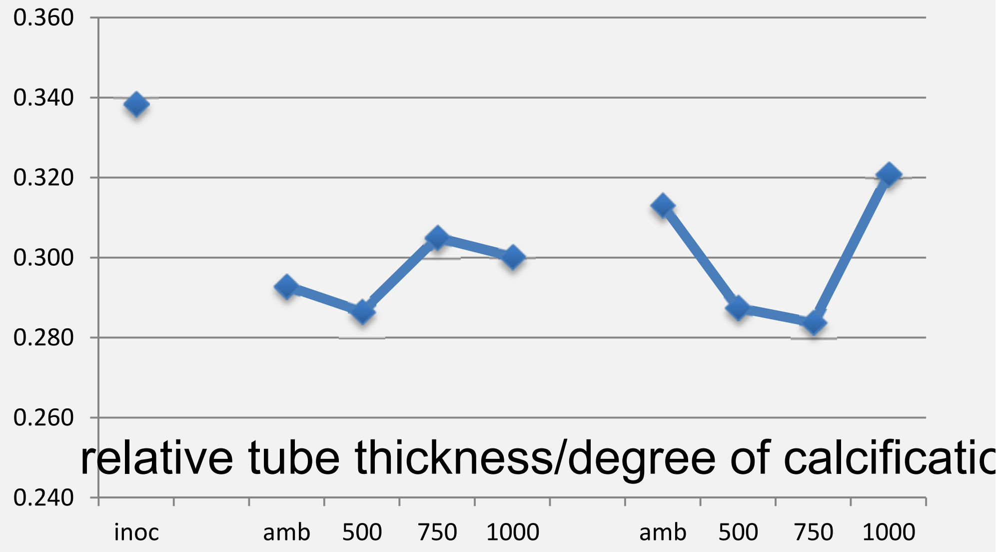


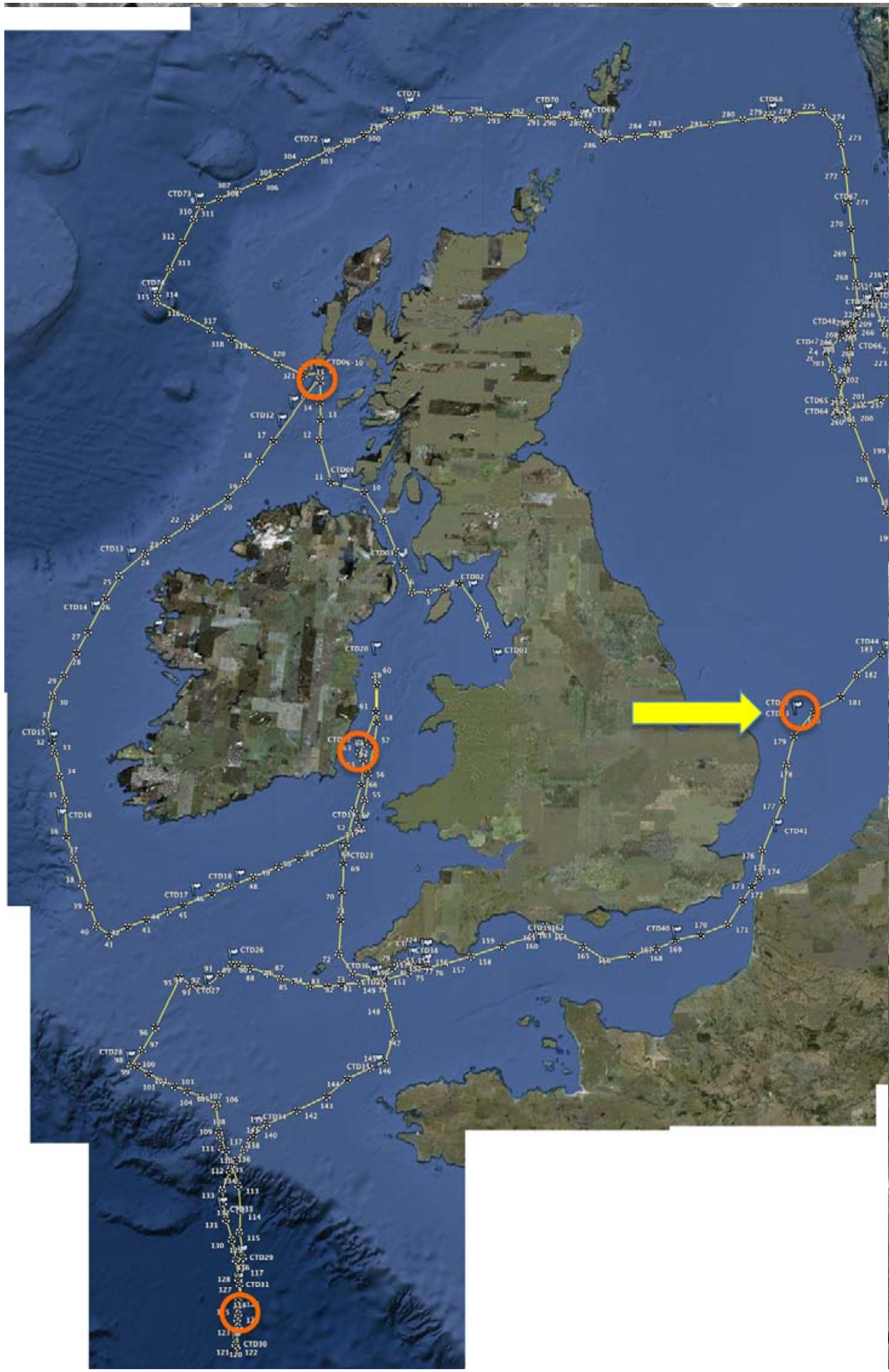
Bioassay 1 - Mingulay

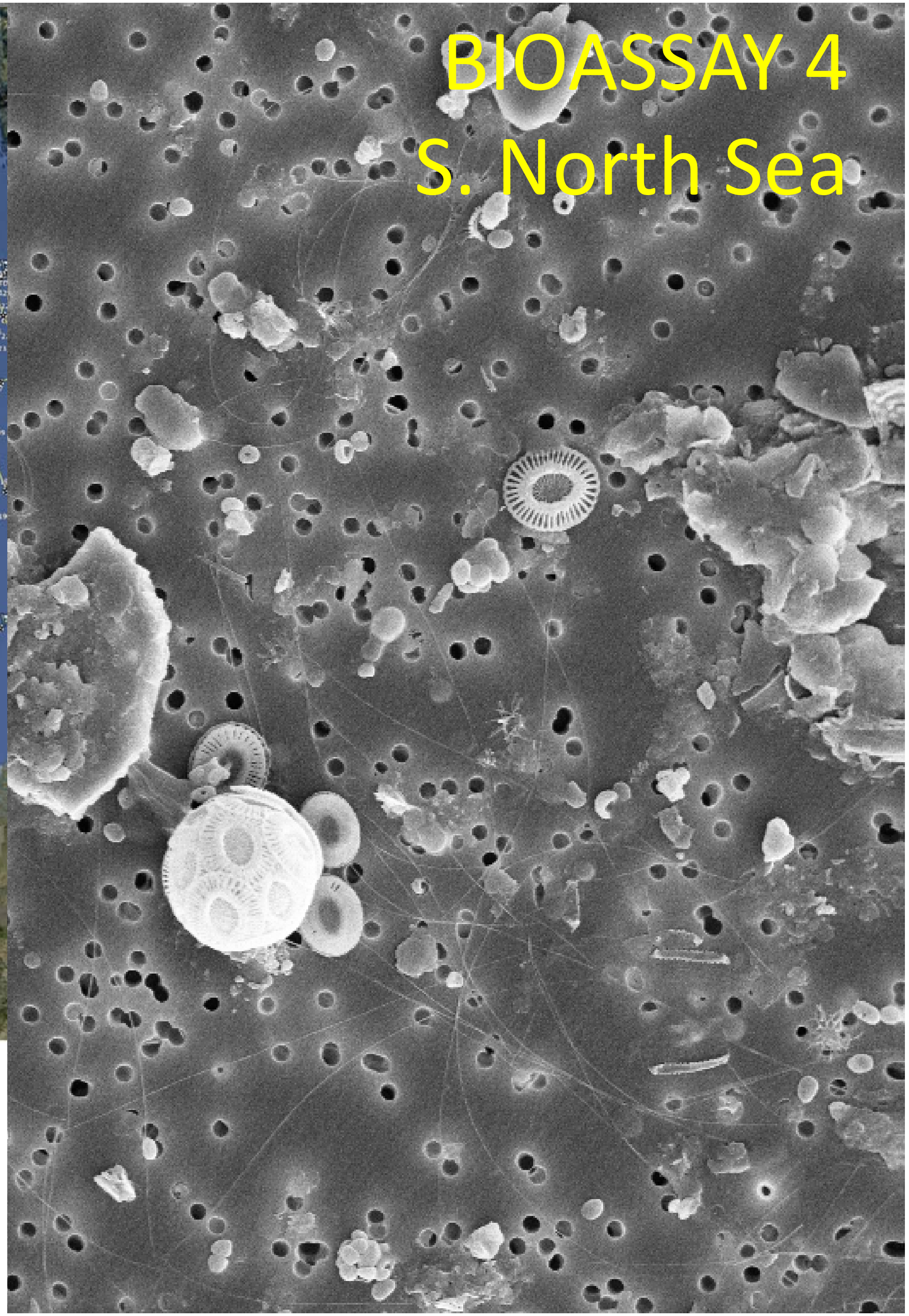




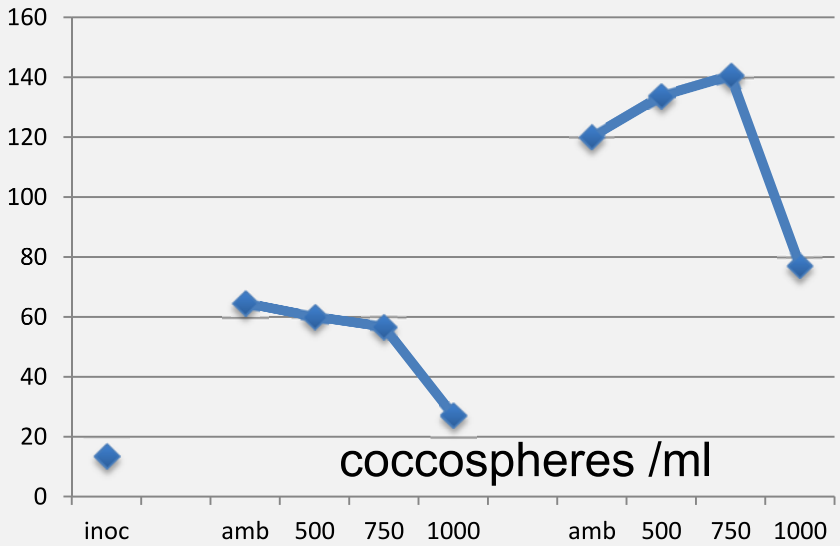


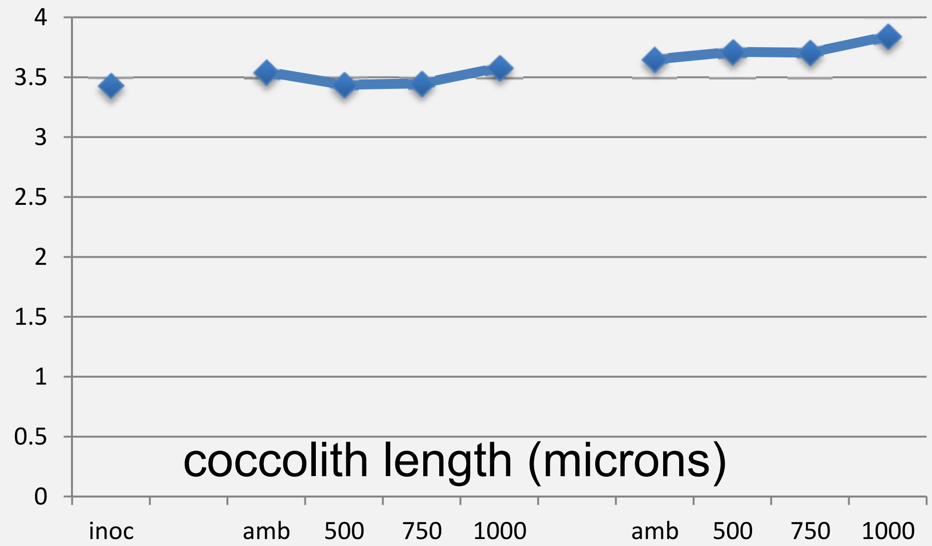


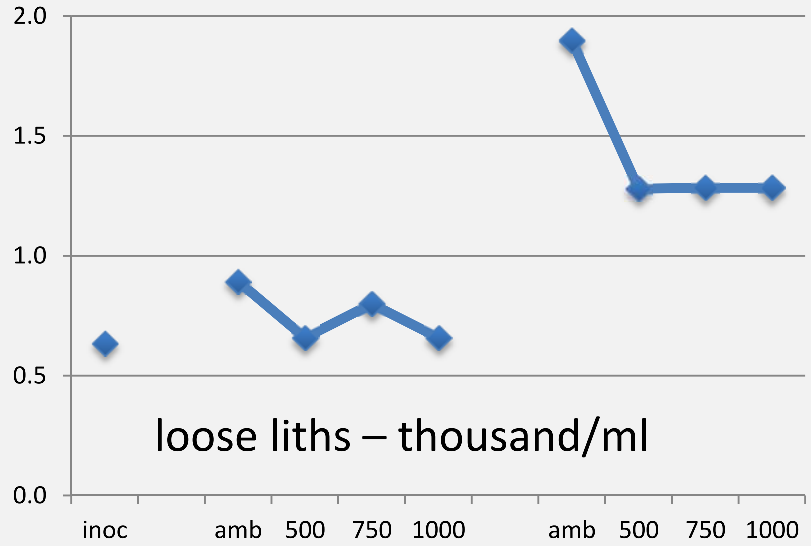


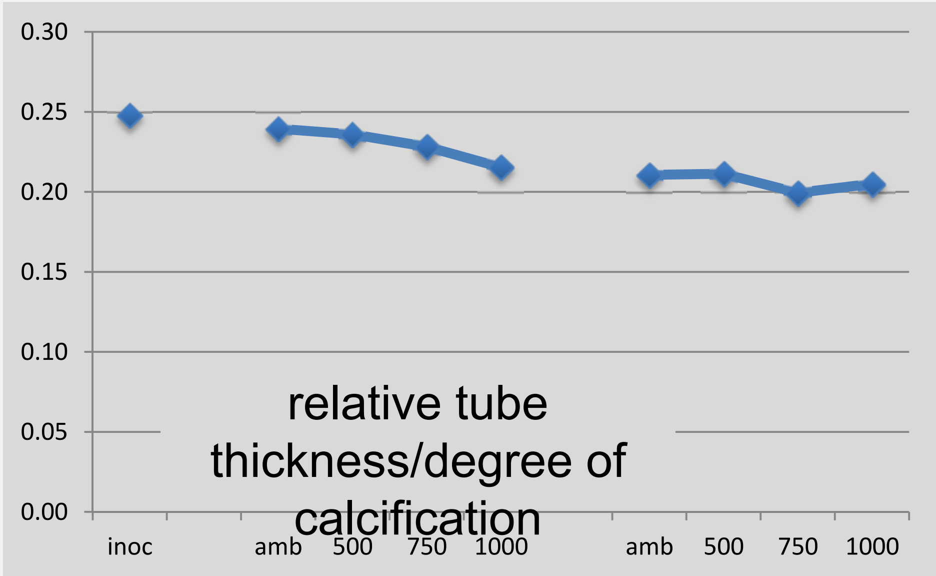

BIOASSAY 4
S. North Sea

Bioassay 4 – S. North Sea

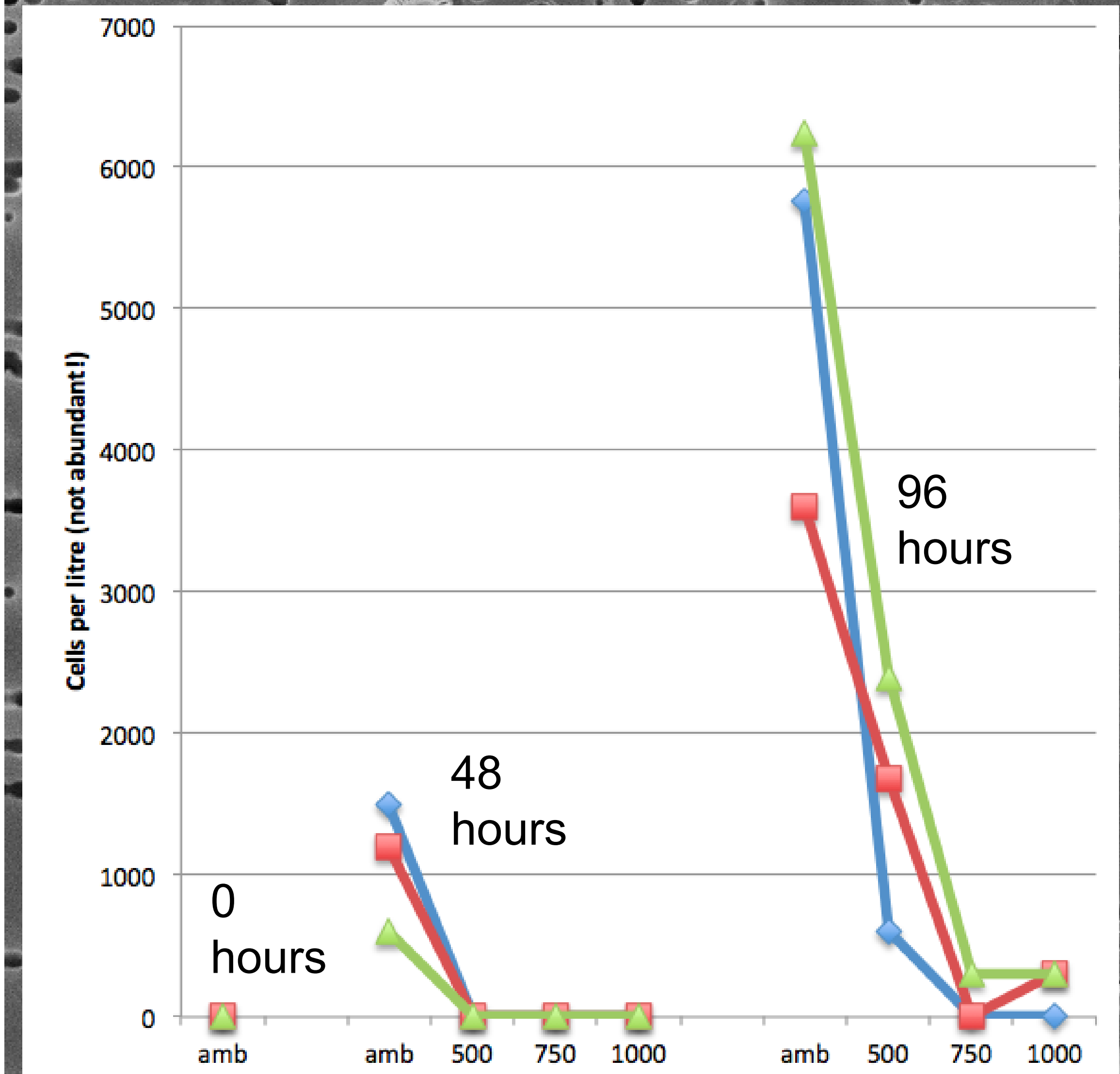




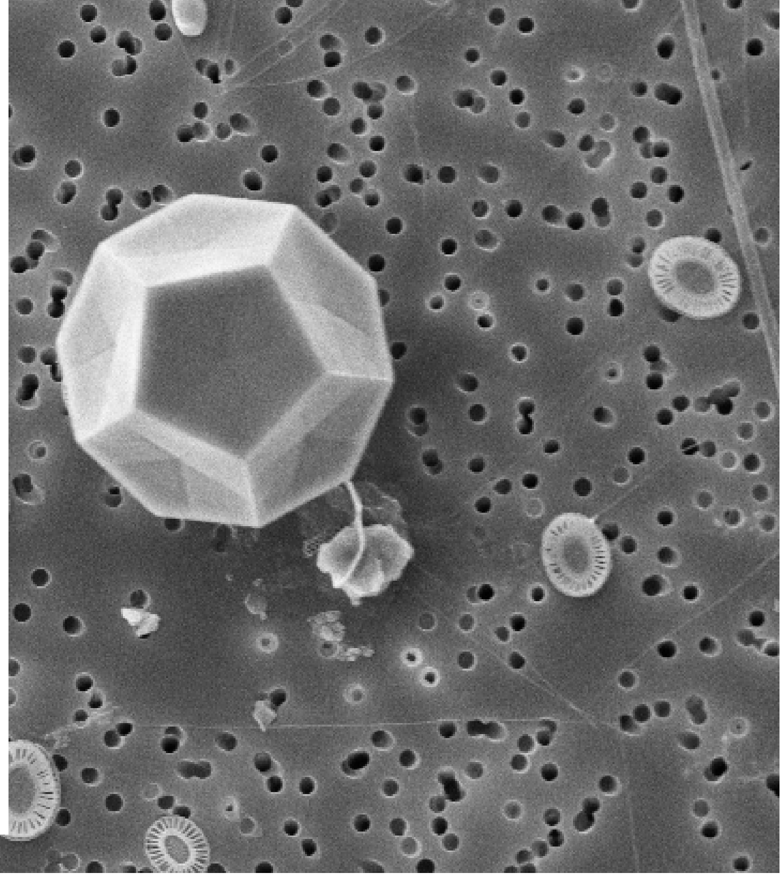




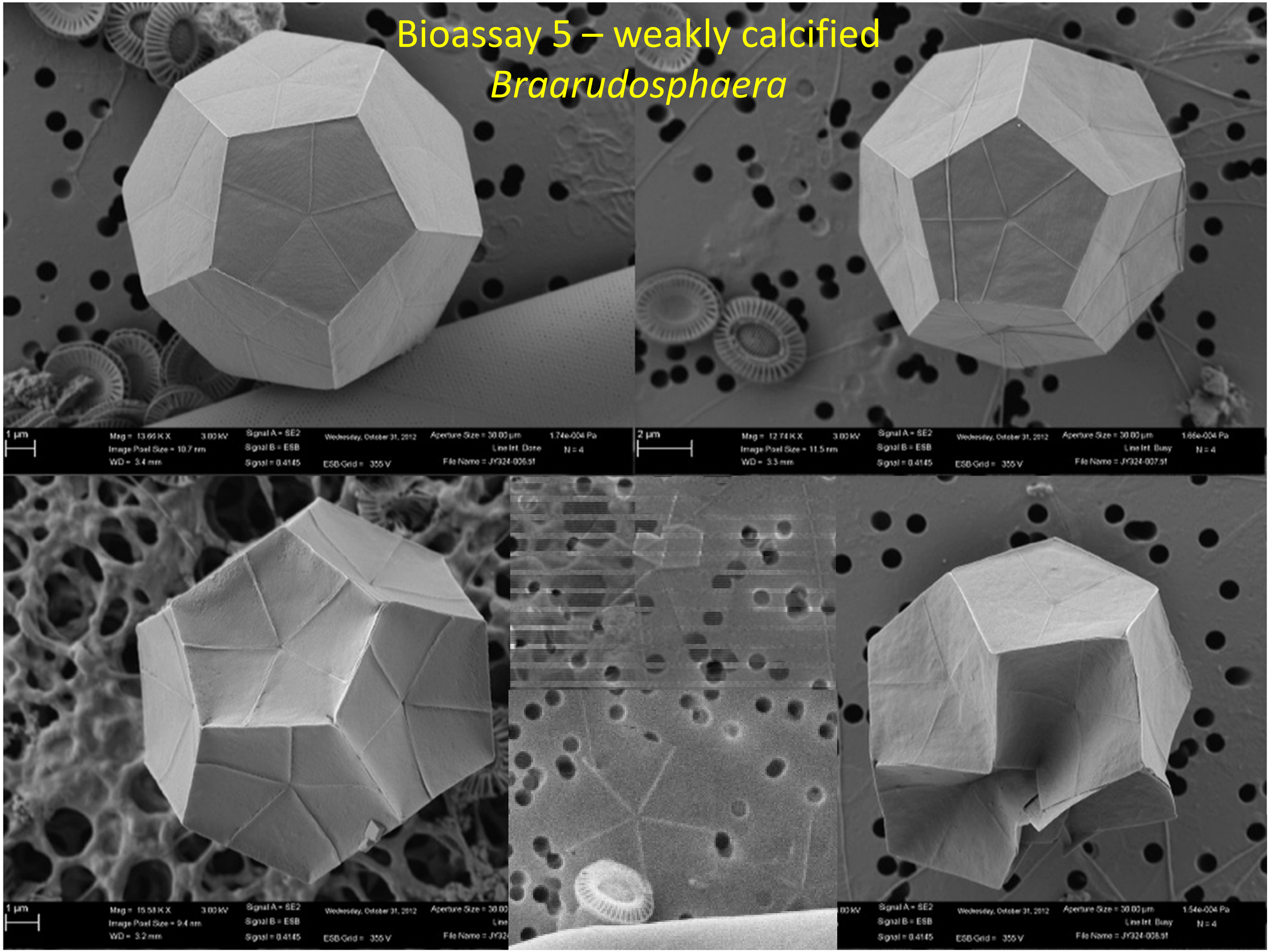
D366 - Bioassay 5 - North Sea

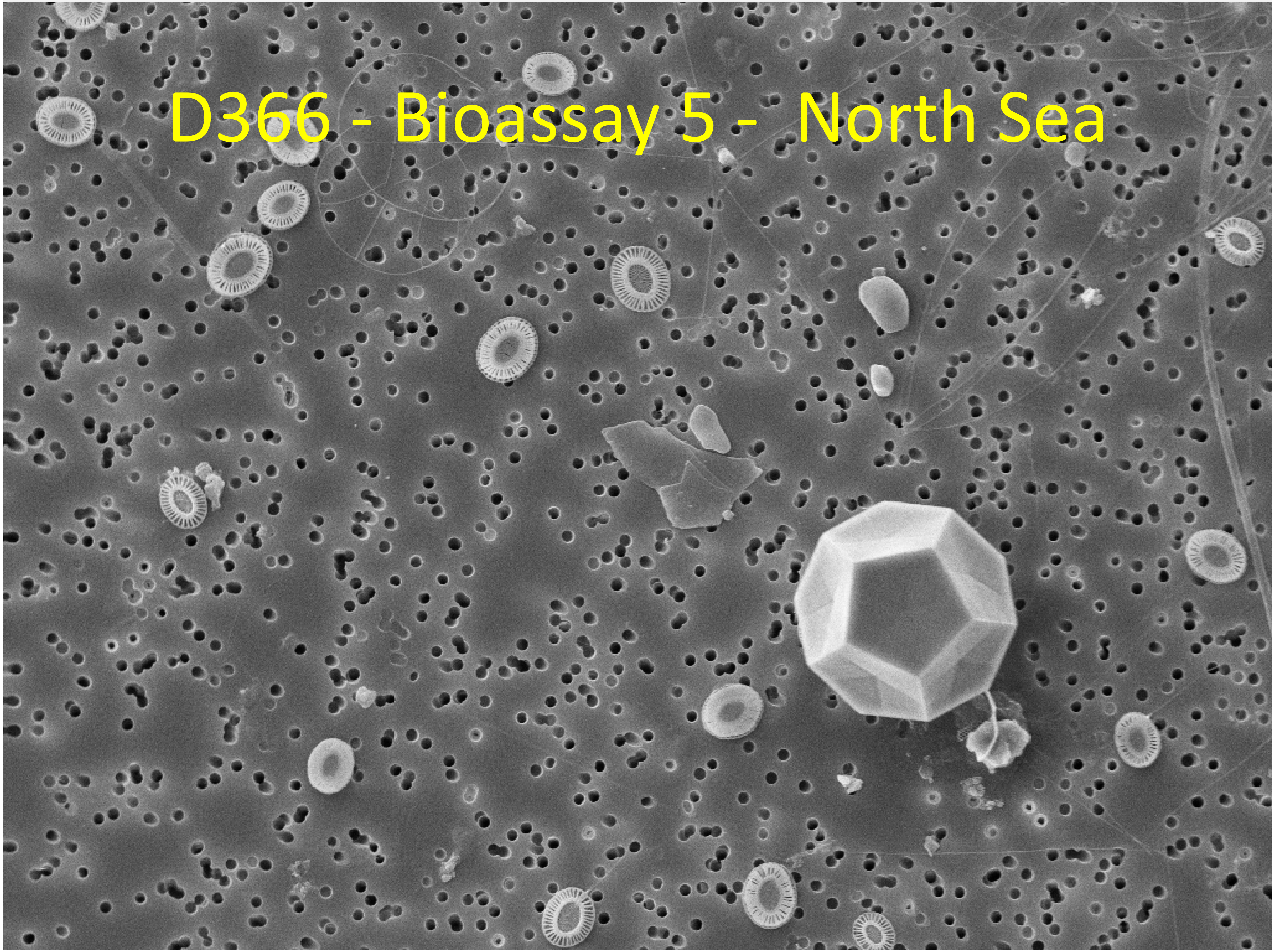


Braarudosphaera bigelowii
- growing population (low ab)
- only in low CO_2 treatments

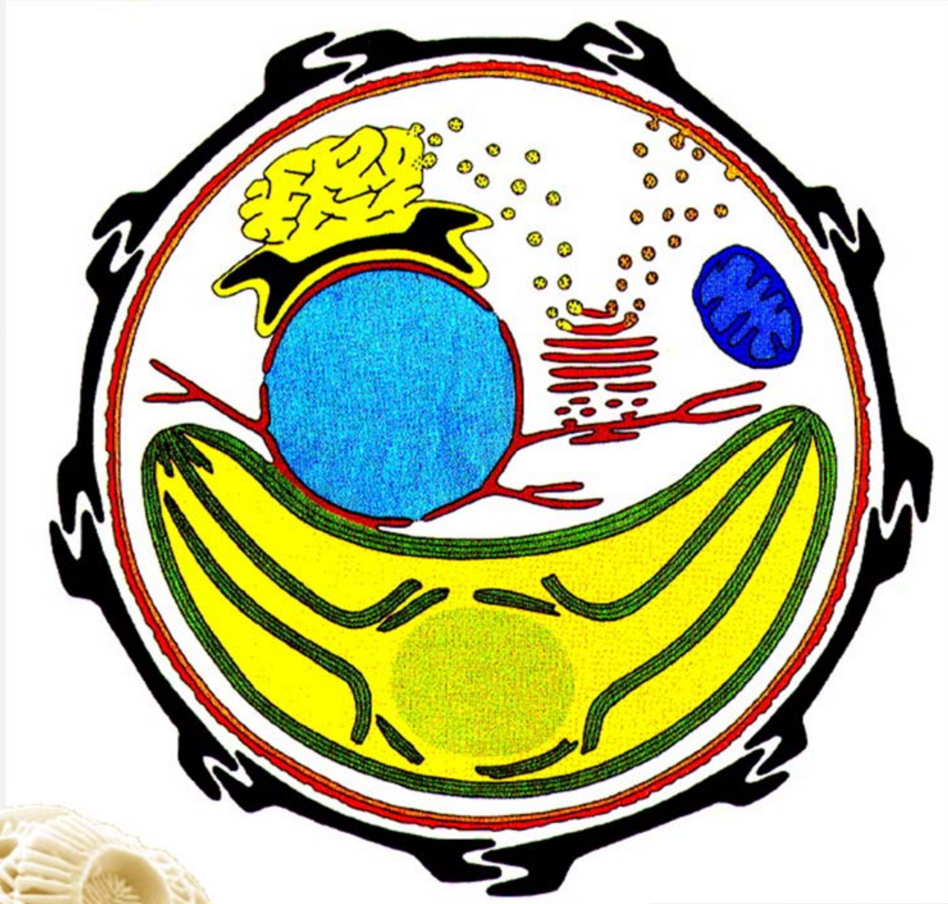


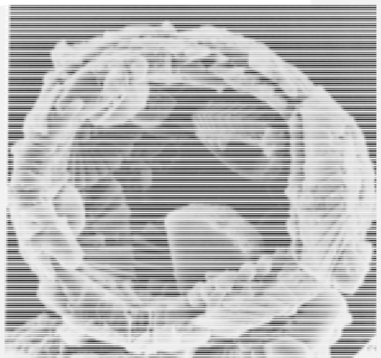
Bioassay 5 – weakly calcified *Braarudosphaera*




D366 - Bioassay 5 - North Sea

intracellular calcification

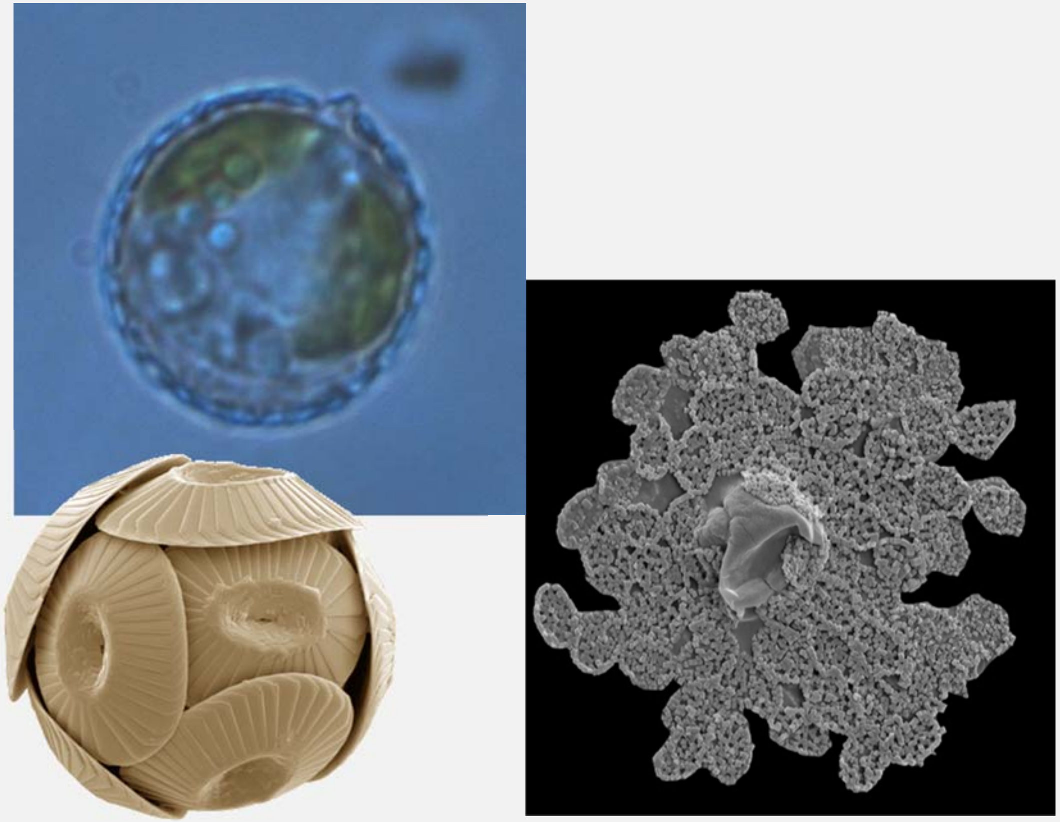




- Calcification inside vesicle deep within cell
- Transport of Ca^{2+} to vesicle
- Calcification from vesicle fluid not seawater
- Trace-element chemistry highly controlled
- Muted response to OA
- Shown by modern and fossil heterococcoliths

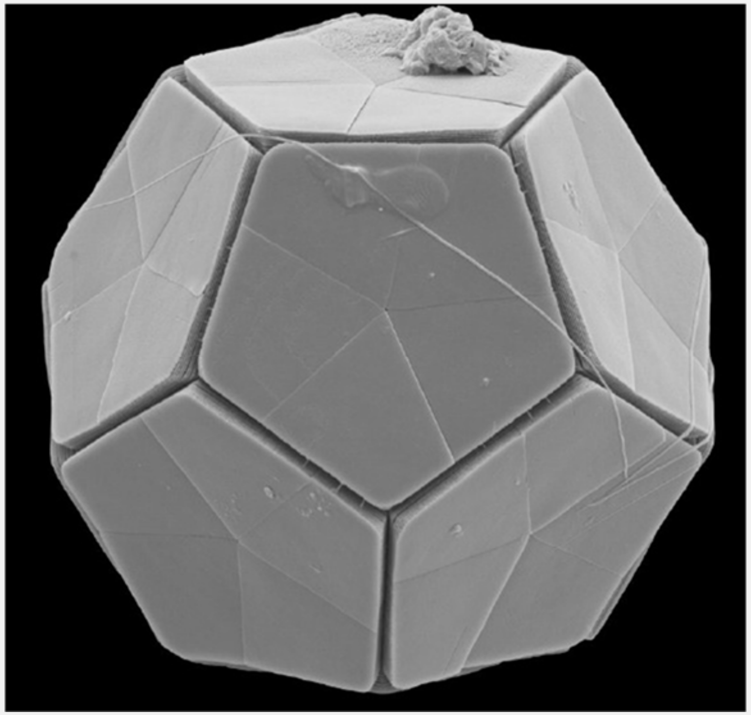
extra-cellular calcification

Holococcoliths,
observational evidence

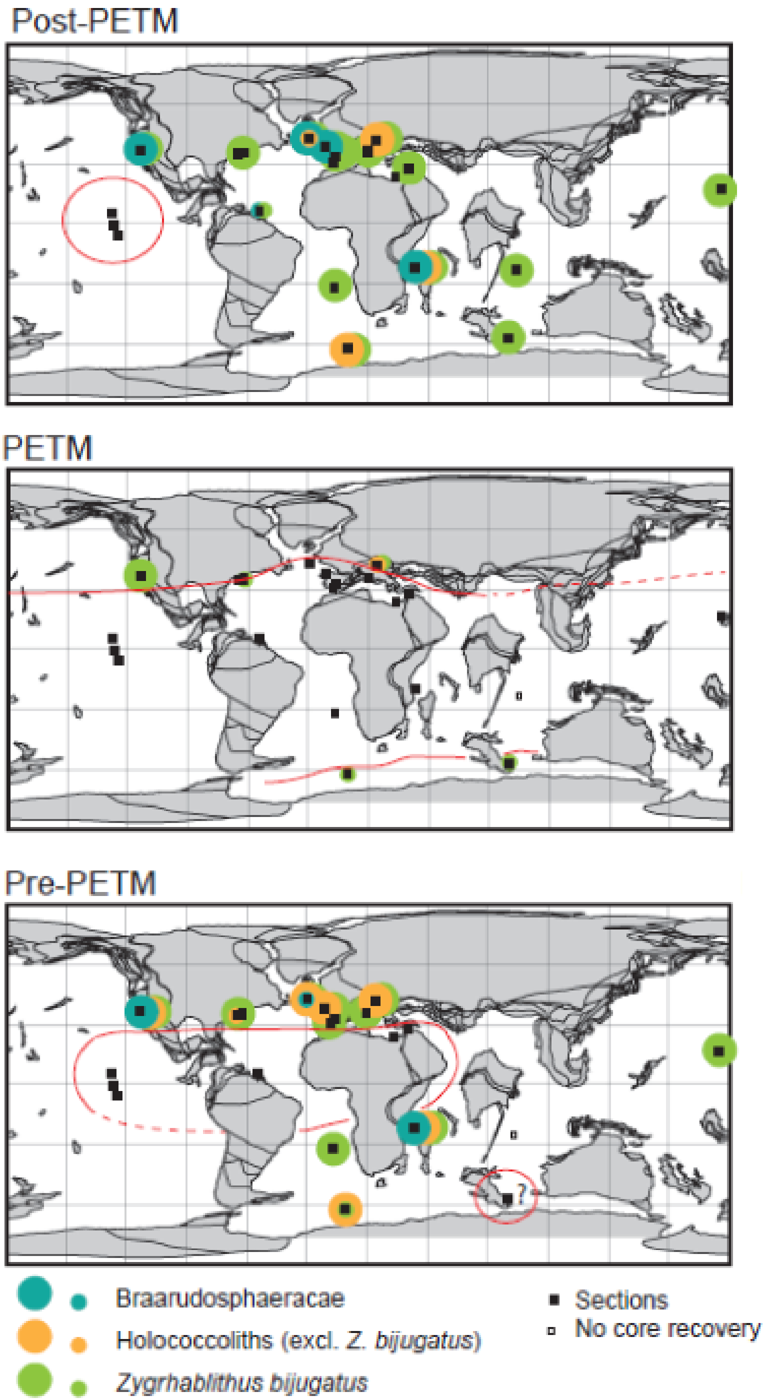


Coccolithus pelagicus - Holococcoliths

Braarudosphaera,
morphologically unfeasible

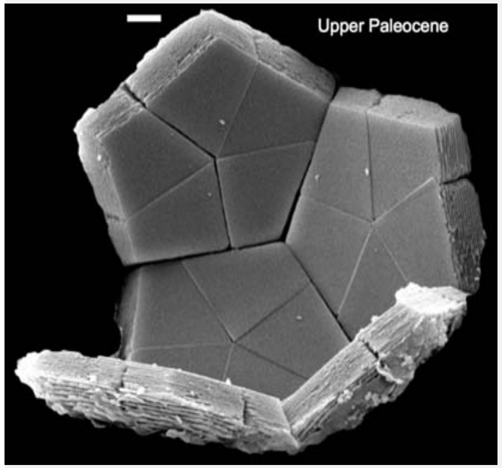


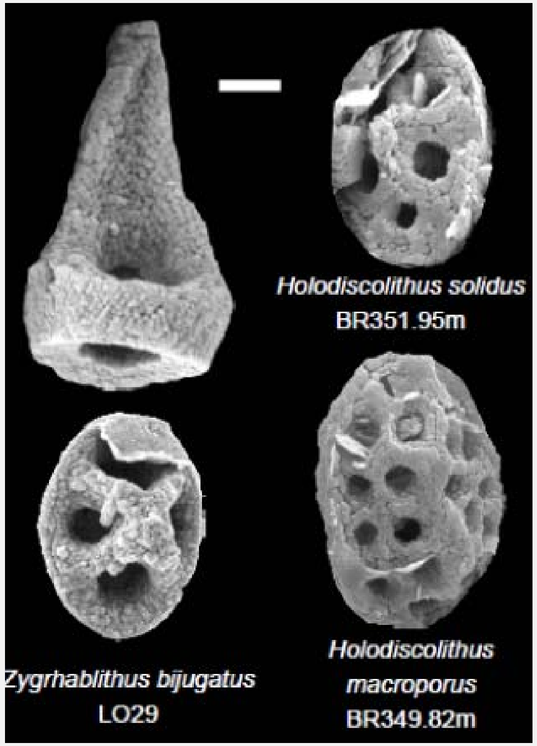
Braarudosphaera bigelowii



Geological evidence

- work in prep of Sam Gibbs & Paul Bown
- Holococcoliths and *Braarudosphaera* seem to be especially heavily affected by the Paleocene Eocene Thermal Maximum OA event



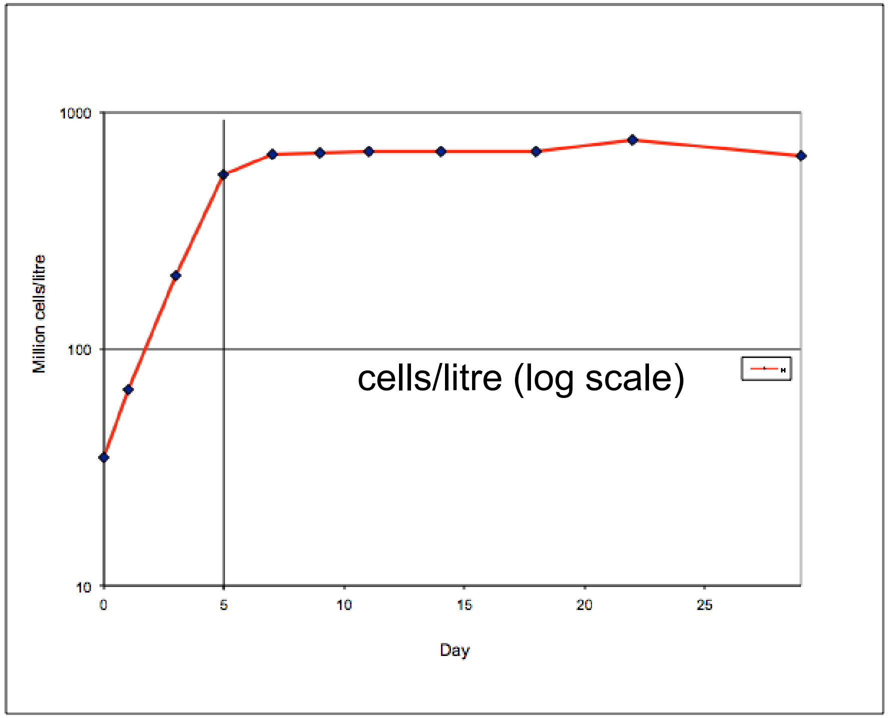


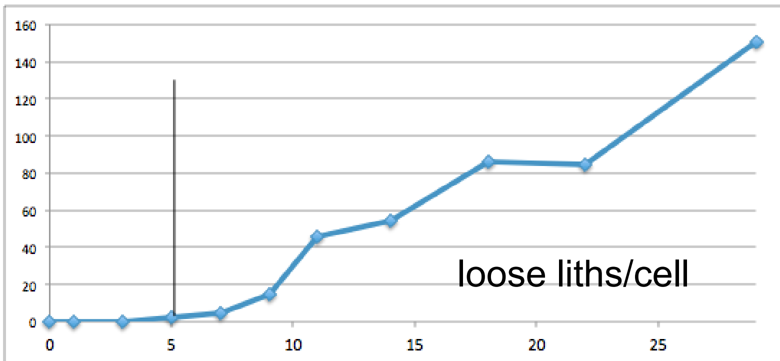
Summary

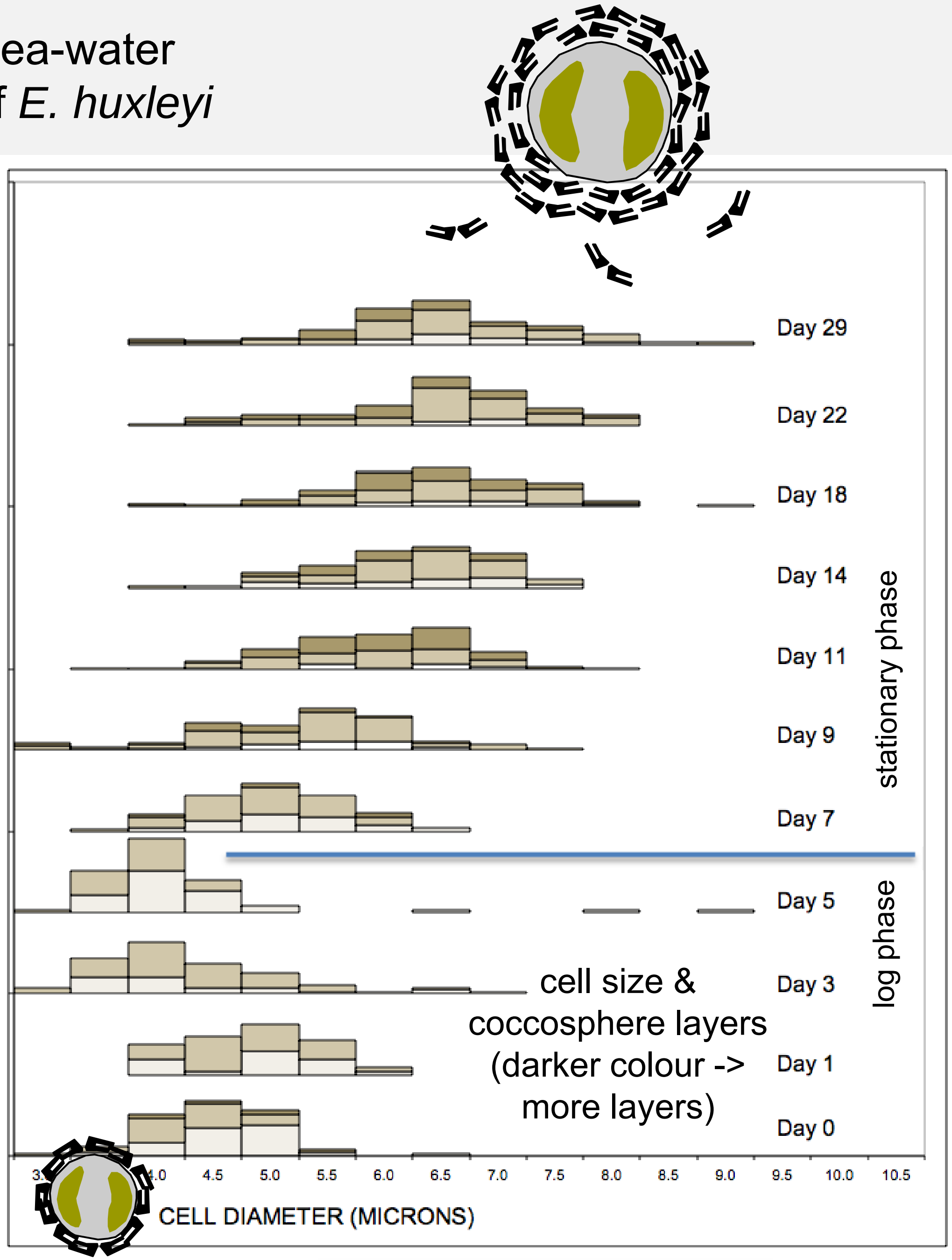
- Hypothesis that varying degree of carbonate saturation has a major effect on coccolithophore ecology and biogeography is not well-supported.
- Extra-cellular calcification may, however, be more vulnerable to changes in saturation state.

Batch culture

- take sterile nutrient enriched sea-water and add a few thousand cells of *E. huxleyi*







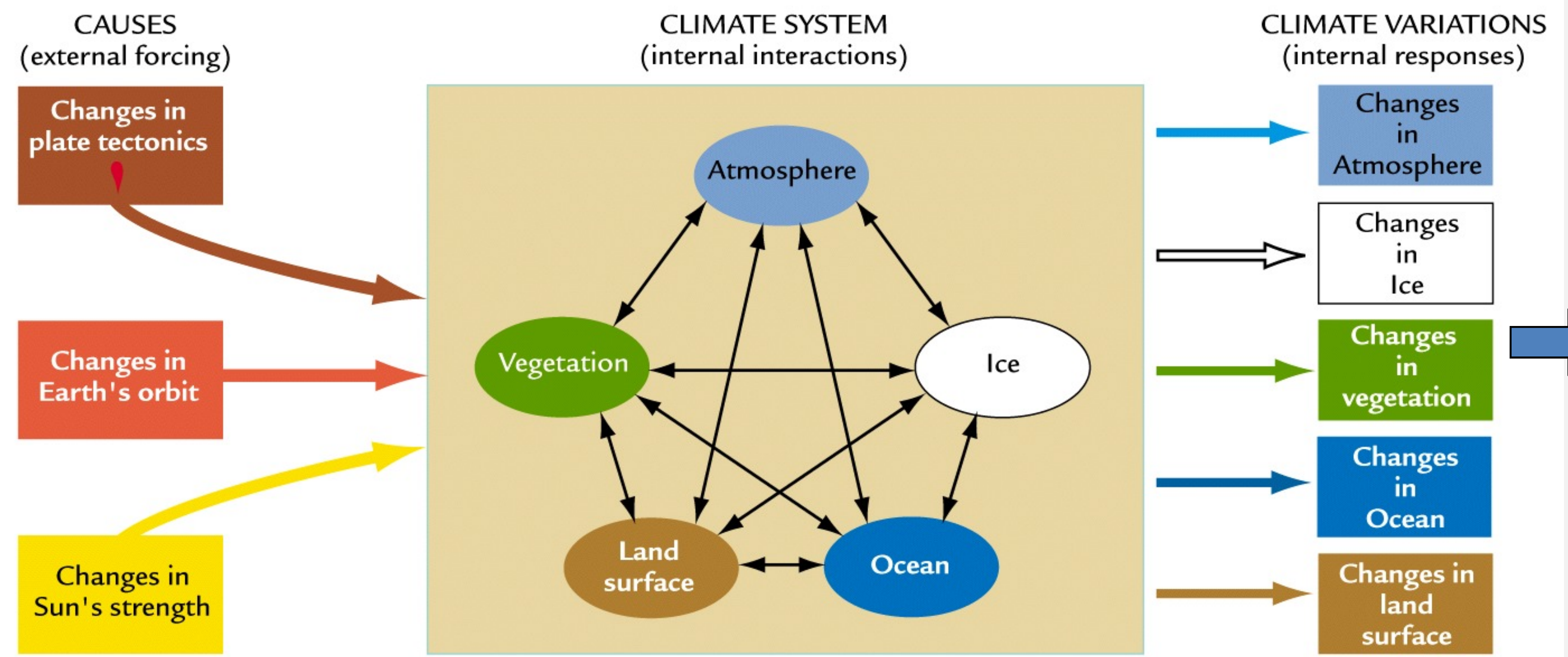
Cruise-based multi-factorial investigation of the impact of Ocean Acidification on the Pelagic Biosphere

Jeremy Young, Toby Tyrrell & many others

Summary

- 3 major cruises – with objective of developing major datasets to test multiple OA-related hypotheses
- Data synthesis commencing
- Collaboration welcome

Sea Surface Consortium UKOA



SIGNALS/PROXIES
changes in e.g.:

Organism physiology
(e.g. growth bands)

Faunal compositions

Carbonate chemistry

Sedimentation rates

Earth's climate system - geologist's perspective.

Typical problem is to relate changes in observed geological properties (e.g. changing coccolith assemblage) to external forcings.