OA impacts on benthic ecosystems :

From individuals to ecosystems and biogeochemistry

David Paterson on behalf of the benthic OA group

Physiology- impact on species function

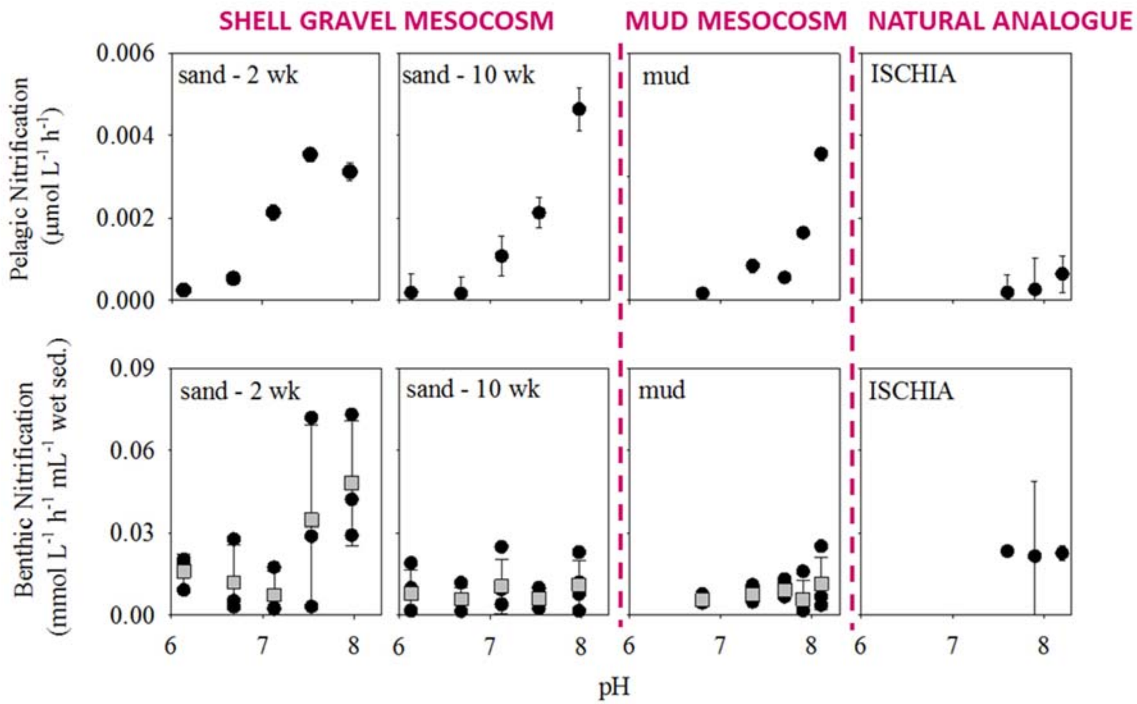
Change in spp and turnover

Species impact on other species (grazing, competition)

Species impacts on habitat (biotubation, stablisation, irregation)

Ecosystem function

CO_2 induces changes to pelagic but not benthic ammonia oxidation



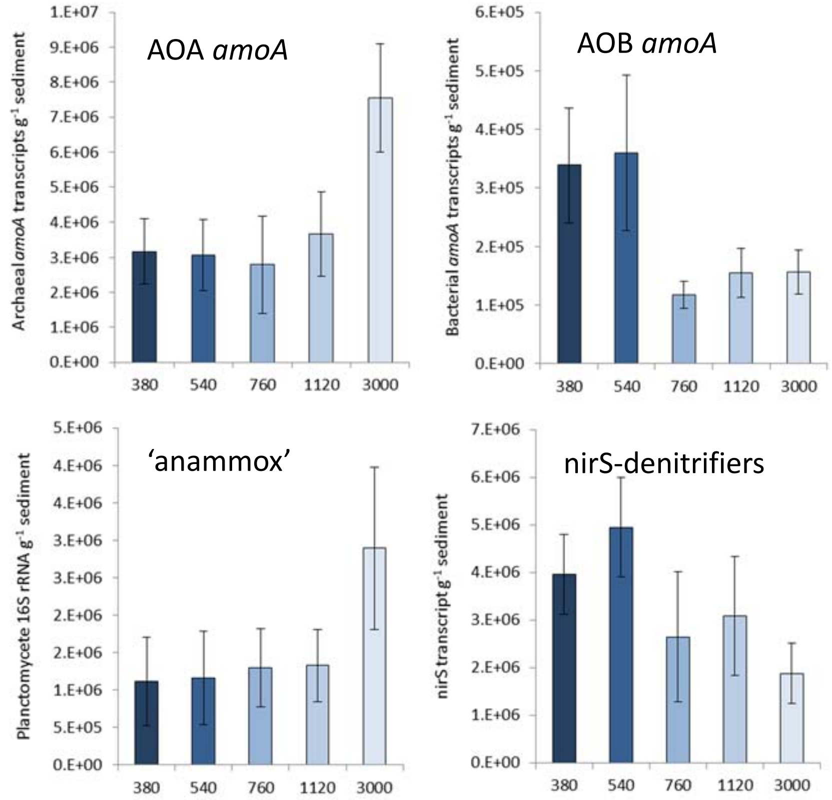
- Different nitrifier communities?
- Are benthic microbes already adapted to low pH?
- pH buffering capacity of sediments?

UK Ocean Acidification Research Programme

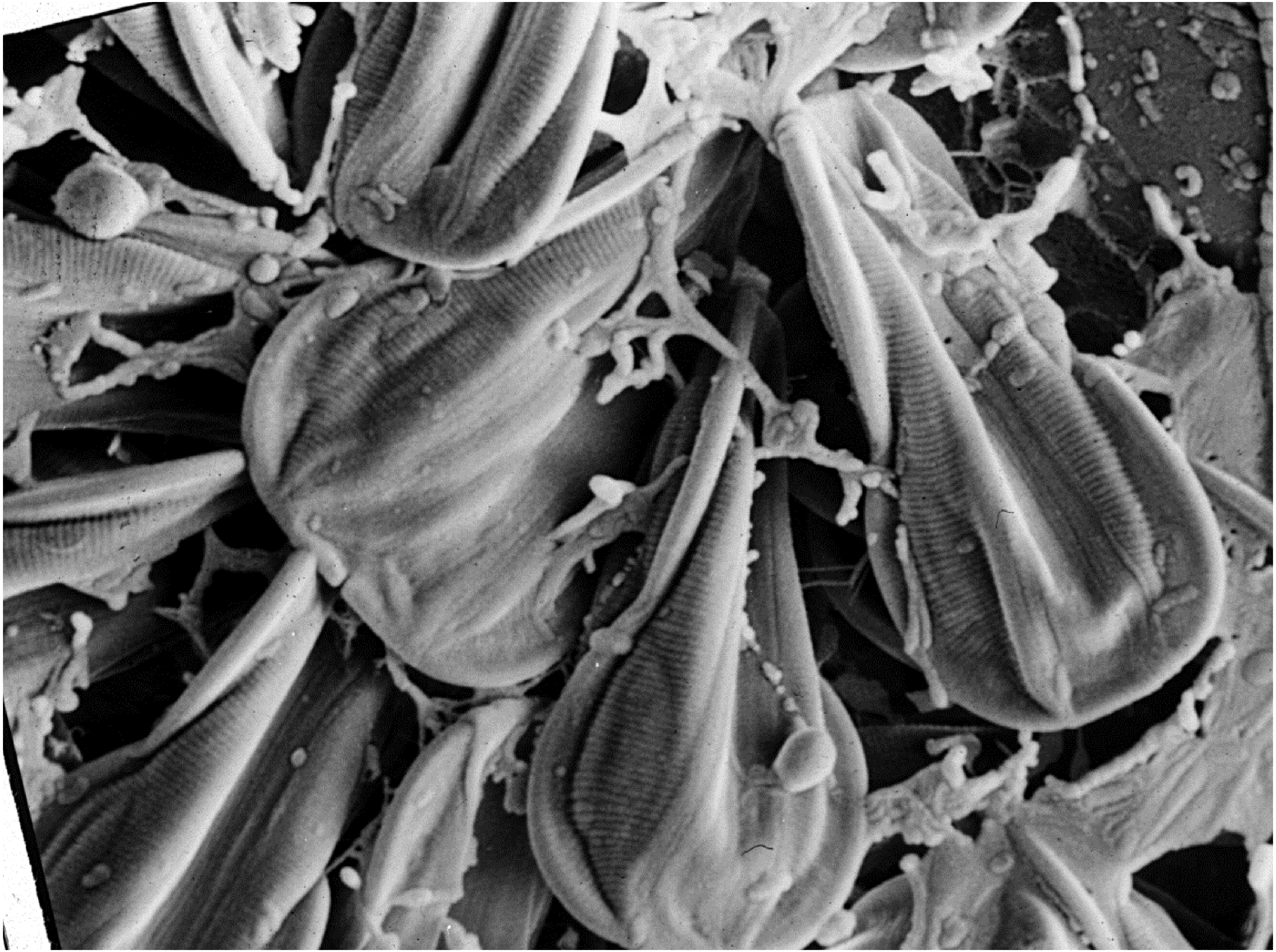
Tait et al. (in press) Estuaries and Coasts

OA alters balance of N cycling microbes in Arctic sediment

- Ammonia oxidation carried out by proteobacteria (AOB) and thaumarchaota (AOA)
- Decrease in 0.9 pH units increased abundance of AOA transcripts, but decrease of 0.4 pH units decreased AOB transcripts
- AOB more susceptible to OA than AOA?
- Decrease of 0.4 pH units also caused a decrease to nirS denitrification (coupled to AOB ammonia oxidation?)
- Decrease in 0.9 pH units resulted in an increase to known anammox bacteria
- Implications for nature and supply of N species from benthos to the pelagic?

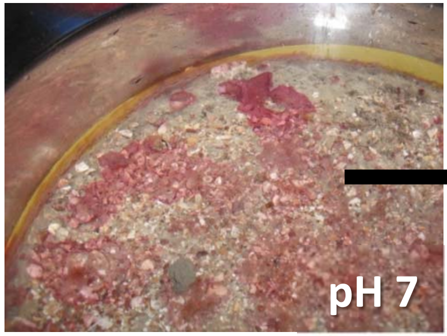


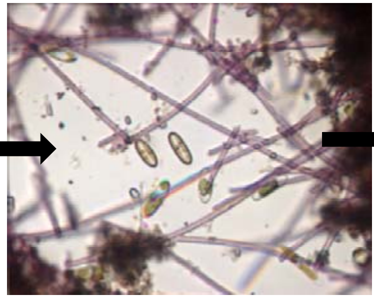
EPOCA

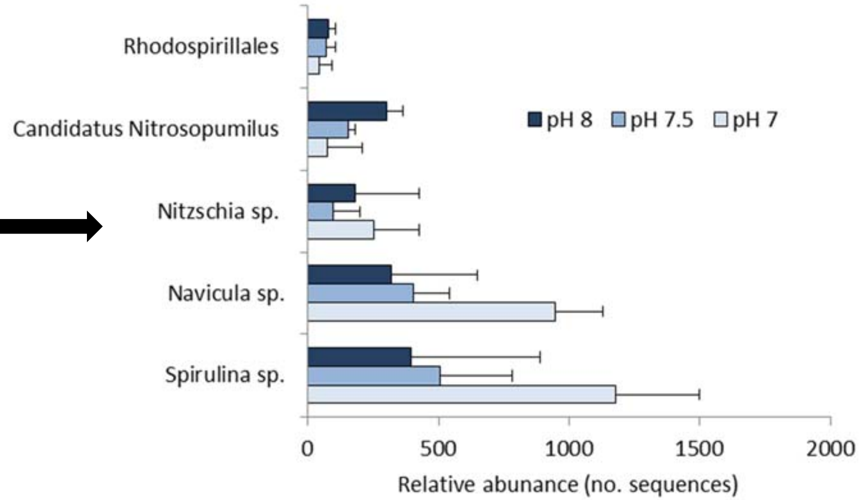


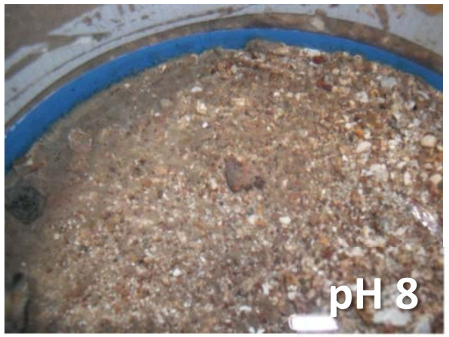
Tait et al. in prep.

CO_2 induces a bloom of microphytobenthos

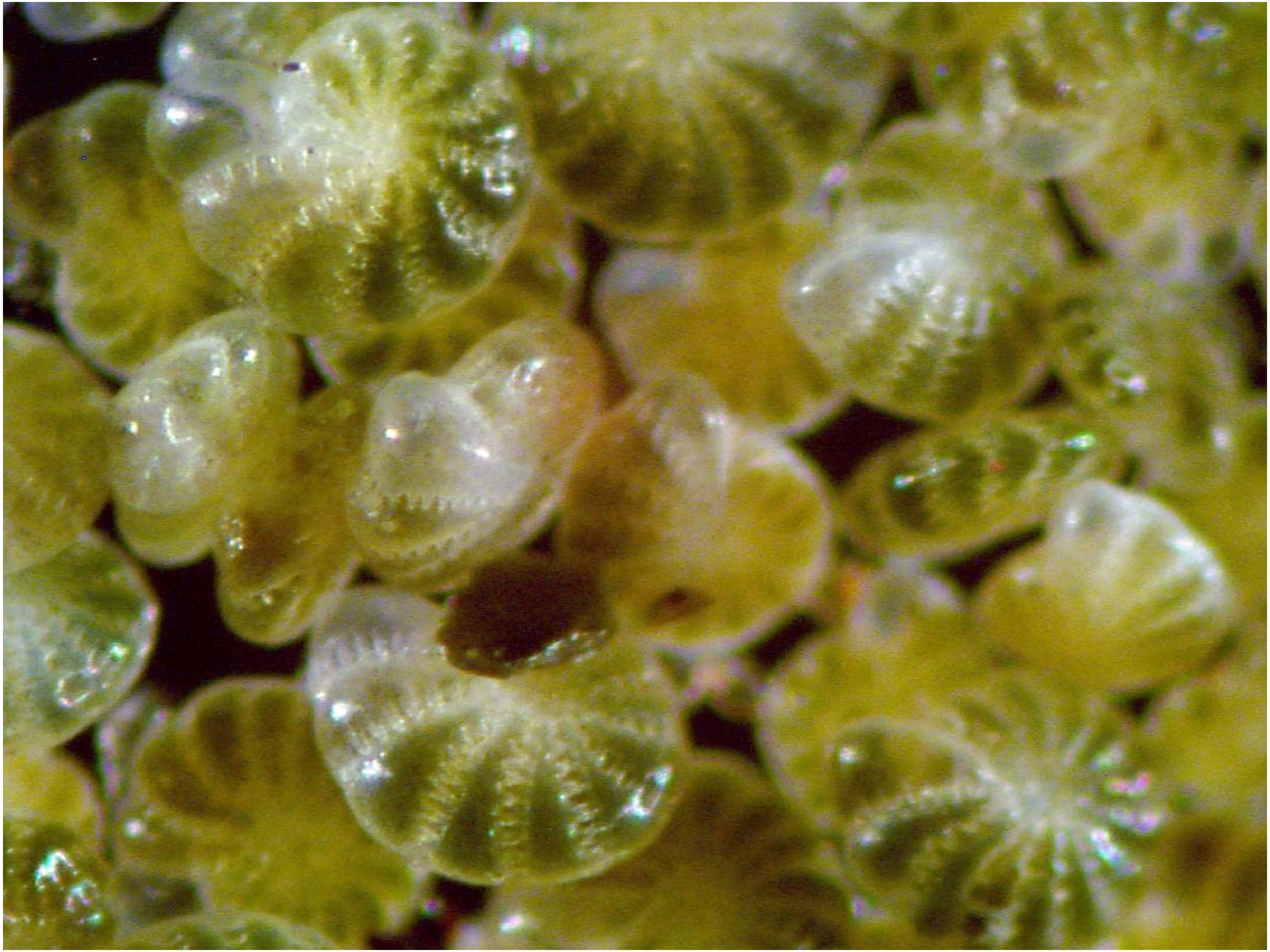








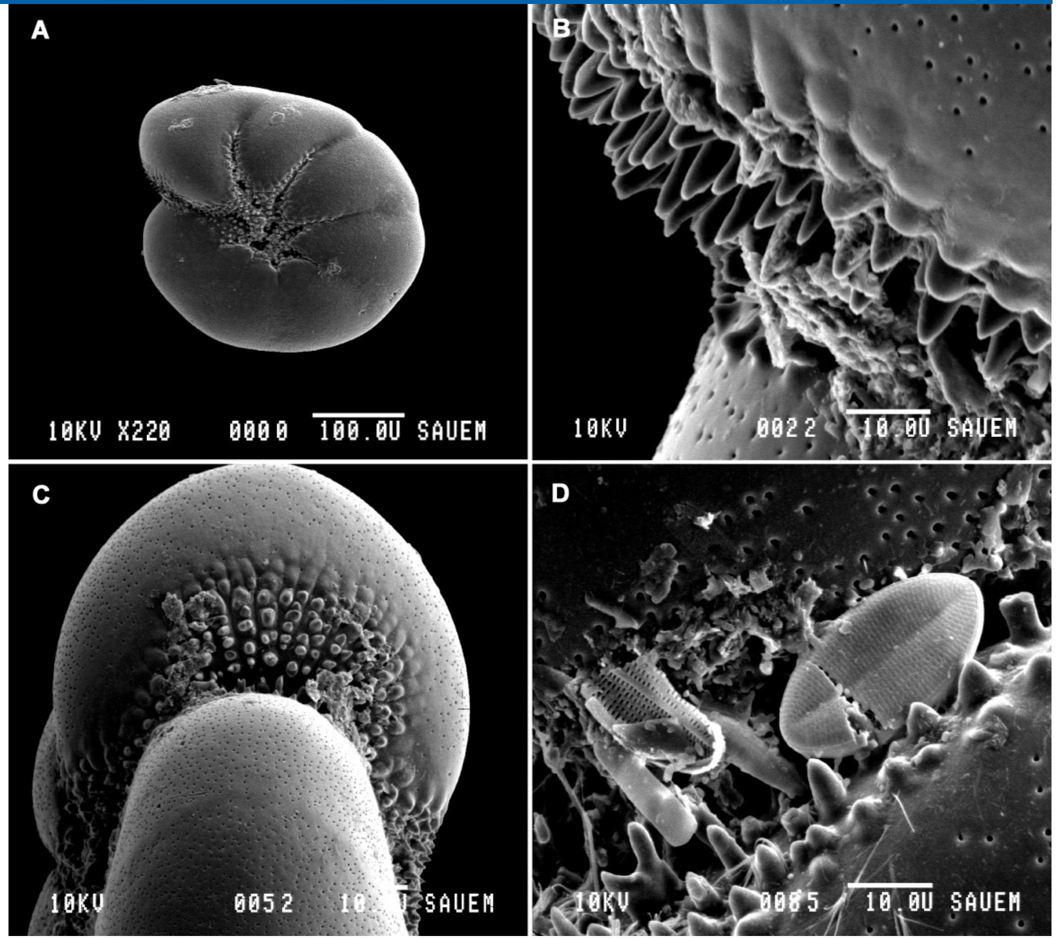
- CCS study using shell gravel
- Bloom of *Spirulina* and diatoms (predominantly *Navicula* sp. and *Nitzschia* sp.) appeared on top of sediments receiving seawater adjusted to pH 7 and 7.5
- Confirmed using in depth sequencing of active microbial community (16S rRNA 454 pyrosequencing)



Khanna, N., Godbold, J. A., Austin, W. E. N. & Paterson, D.
The impact of ocean acidification on the functional morphology of foraminifera. (submitted)

OA impacts on functional morphology:

- Test ornamentation of functional importance in breaking up aggregates of food and detritus
- Comparison of ornamentation in *Haynesina germanica* (dominant estuarine species) cultured under varying CO_2 concentrations
- 36 week exposure at either 380, 750 or 1000 ppm



Comparison of apertural regions and test surface between CO_2 treatments:

380 ppm | 750 ppm | 10000 ppm

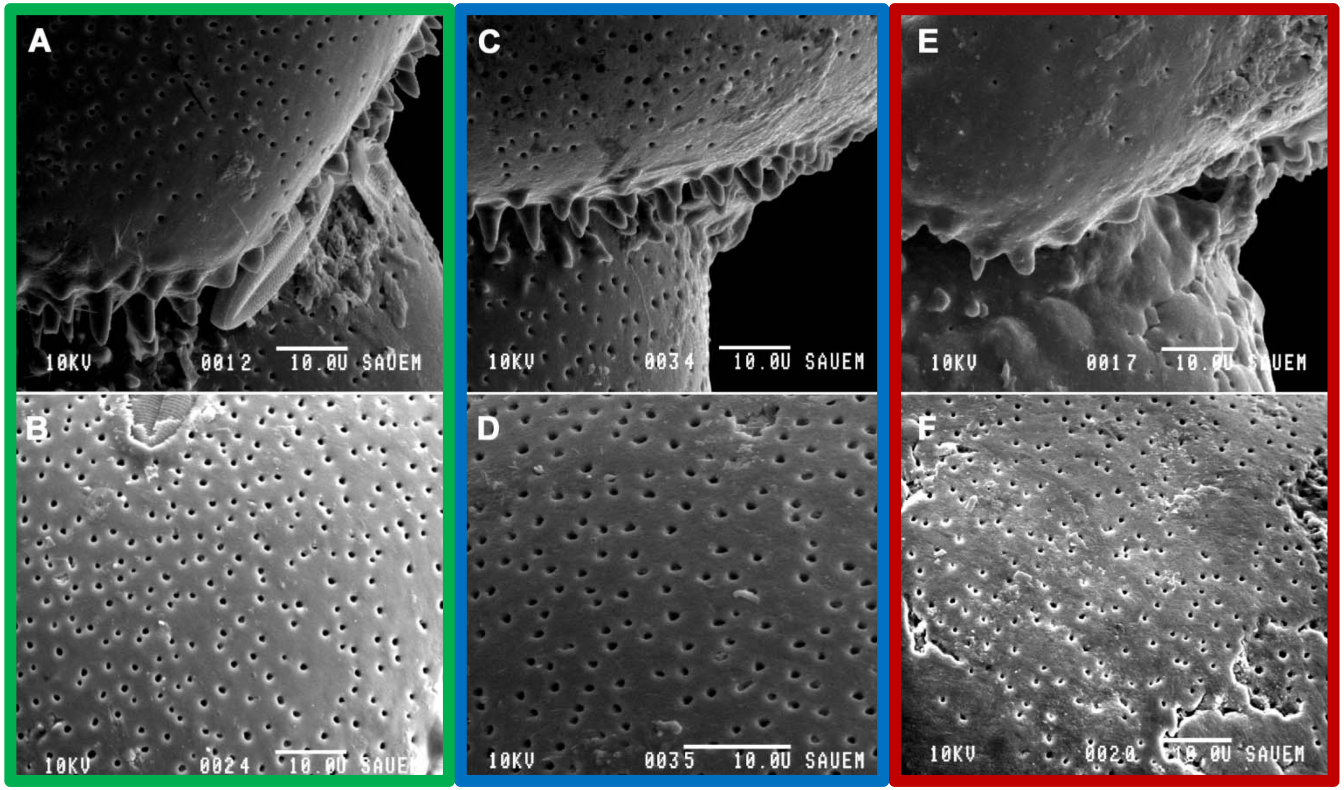
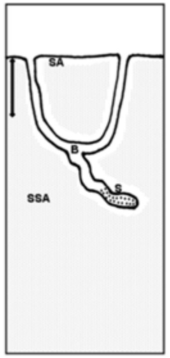
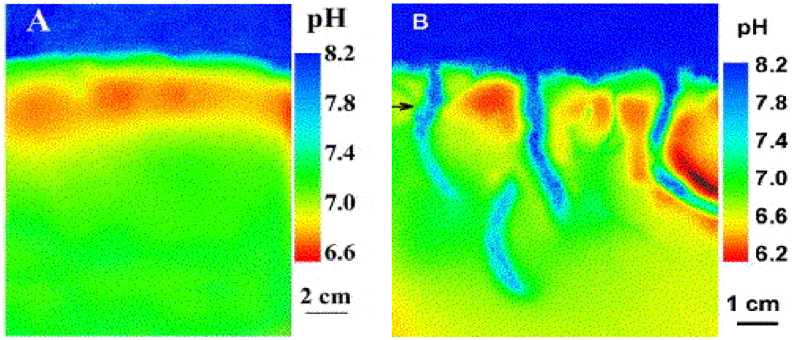


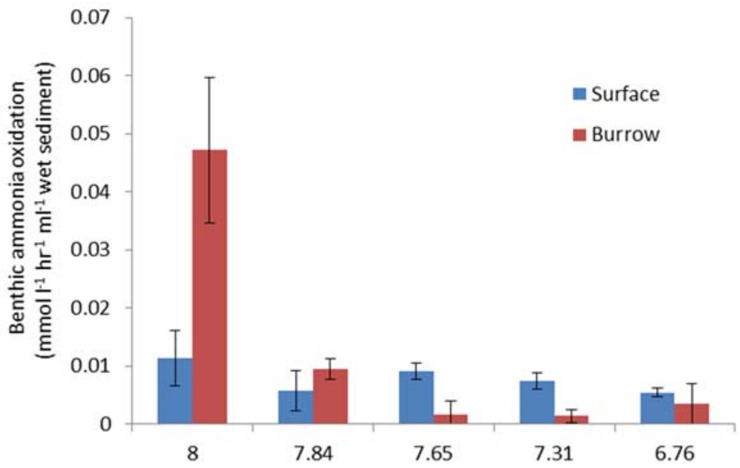

Image ©Susan Chambers MoS

Impacts of elevated CO_2 on ammonia oxidation in burrows of the mud shrimp *Upogebia deltaura*

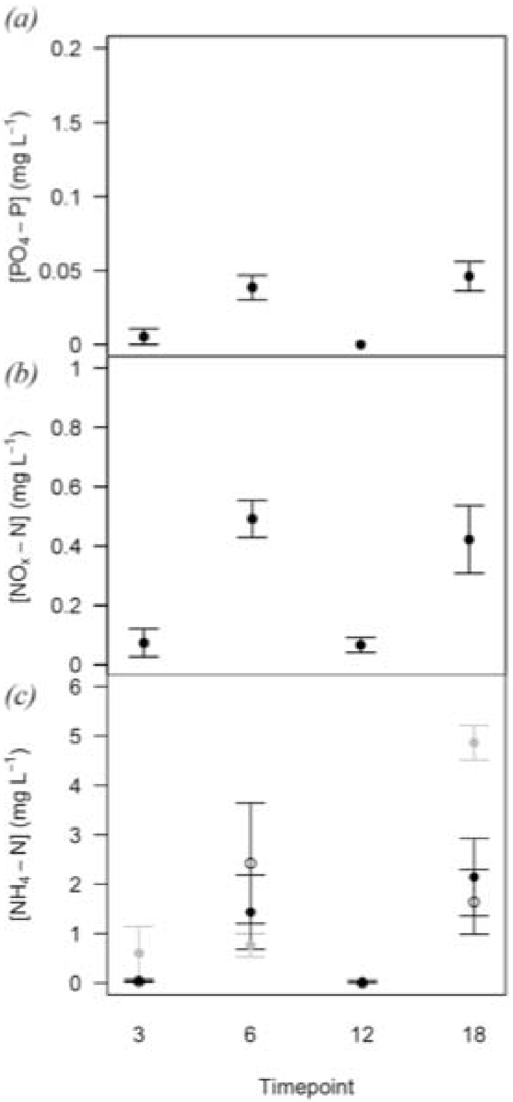




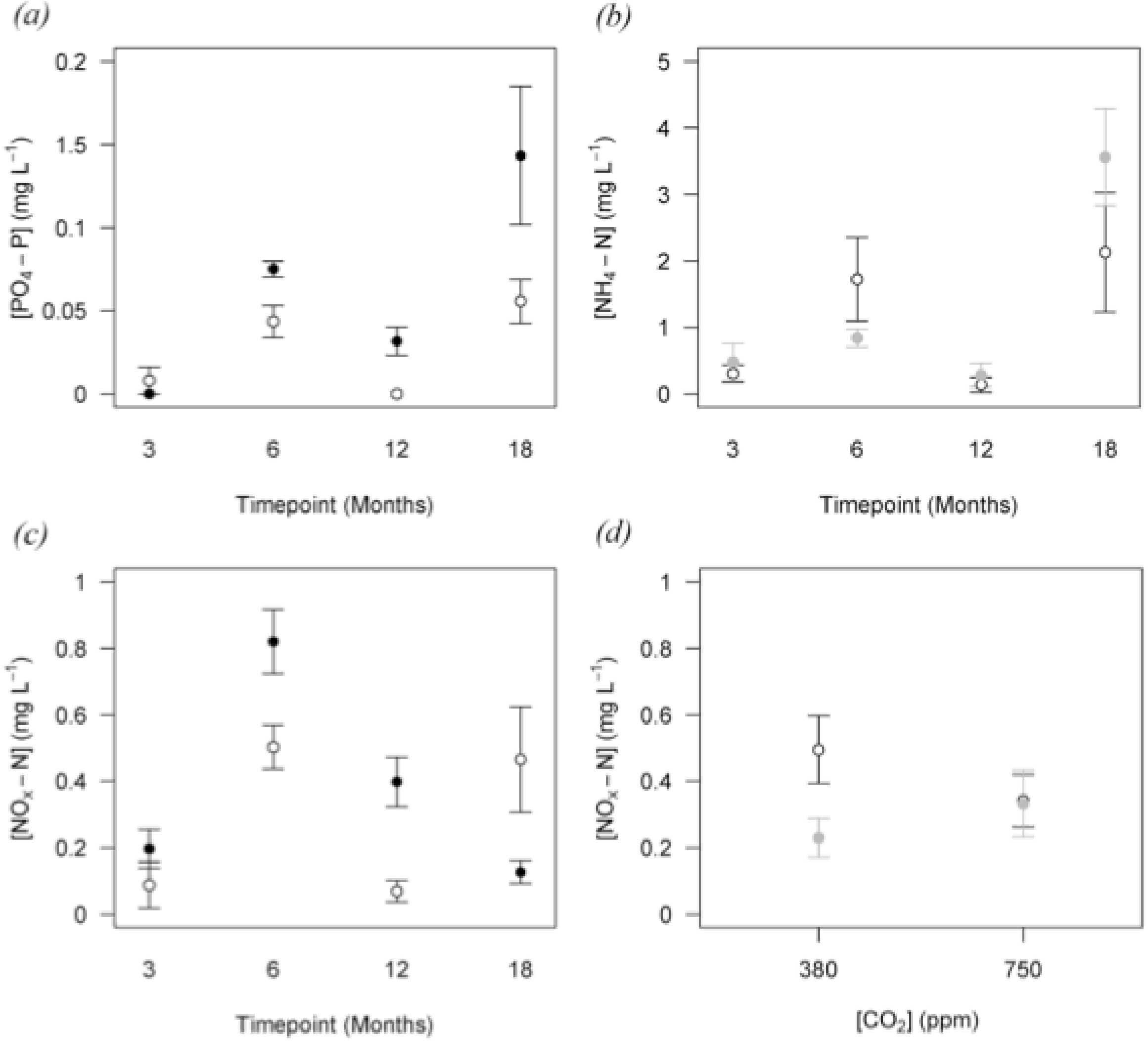
Zhu et al., 2006



- Higher rates of nitrification in burrows
- Elevated CO_2 has strong and significant effect on nitrification rates in burrow wall sediment but NOT in surface sediment
- Likely due to change in shrimp irrigation behaviour



Nereis virens; long-term incubation (542 days)



KEY FINDINGS

We find that the effects of warming, ocean acidification, and their interactions, are not detectable in the short-term, but manifest over time through changes in growth, bioturbation and bioirrigation behaviour which, in turn, affect nutrient generation.

These changes are intimately linked to species responses to seasonal variations in environmental conditions (temperature and photoperiod) that, depending upon timing, can either exacerbate or buffer the long-term directional effects of climatic forcing.


Searle
A
B
C
A
B
C
5 SALB
6 HUD

- Natalie Hicks, Ashleigh Currie,
- David Paterson, Emma Defew & Henrik Stahl

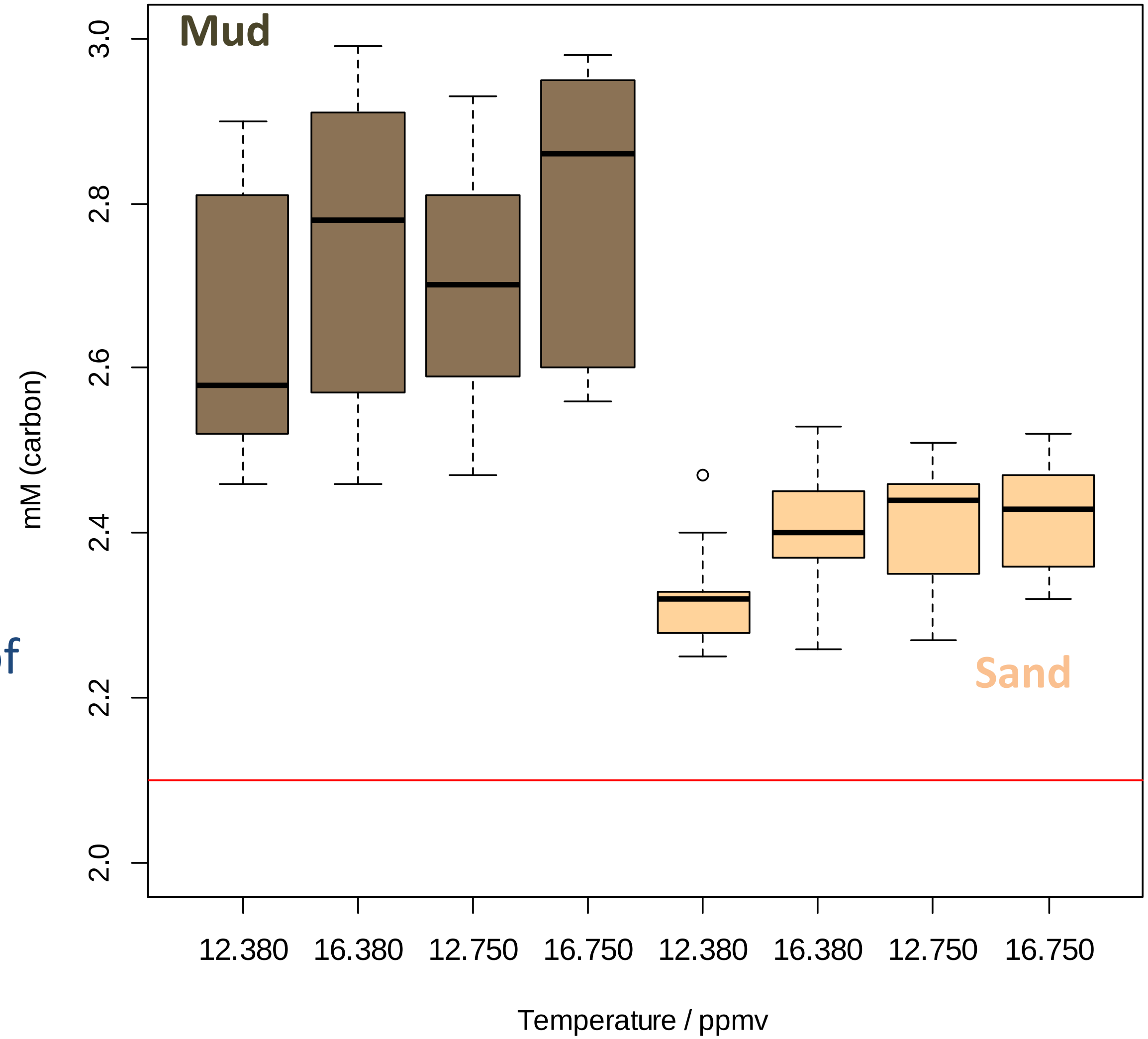
Elevated CO_2 and temperature alters benthic biogeochemistry in permeable and cohesive sediments

Sediment type dominates carbonate dynamics

Temperature is main driver

CO_2 effect noticeable at lower temperatures

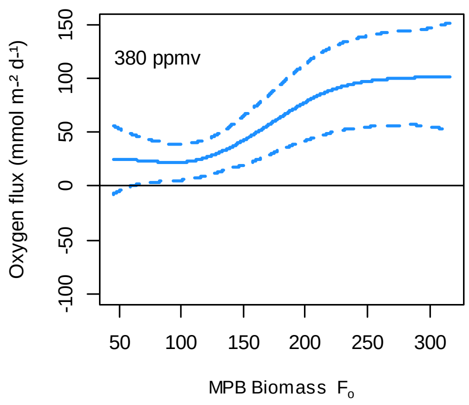
No additive/cumulative effect of Temp + CO_2 on carbonate system **(yet!)**

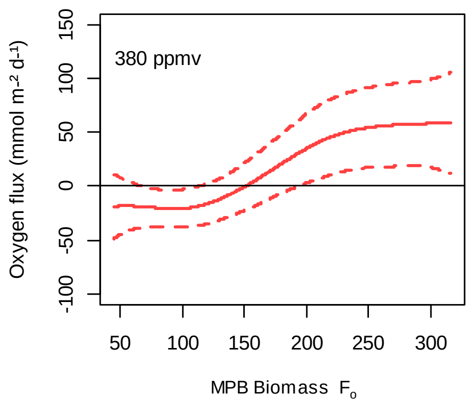


UK Ocean Acidification Research Programme

- Natalie Hicks, Ashleigh Currie,
- David Paterson, Emma Defew & Henrik Stahl

- Oxygen flux **dominated by temperature** in cohesive and permeable sediments
- **Single effect of CO_2 only marginally negative**
- This response **mediated by photosynthetic activity (MPB)** (CO_2 not significant in permeable sediments (light))
- However **interaction of CO_2 + Temp = reduced effect of Temp**





SUMMARY OF OXYGEN DYNAMICS

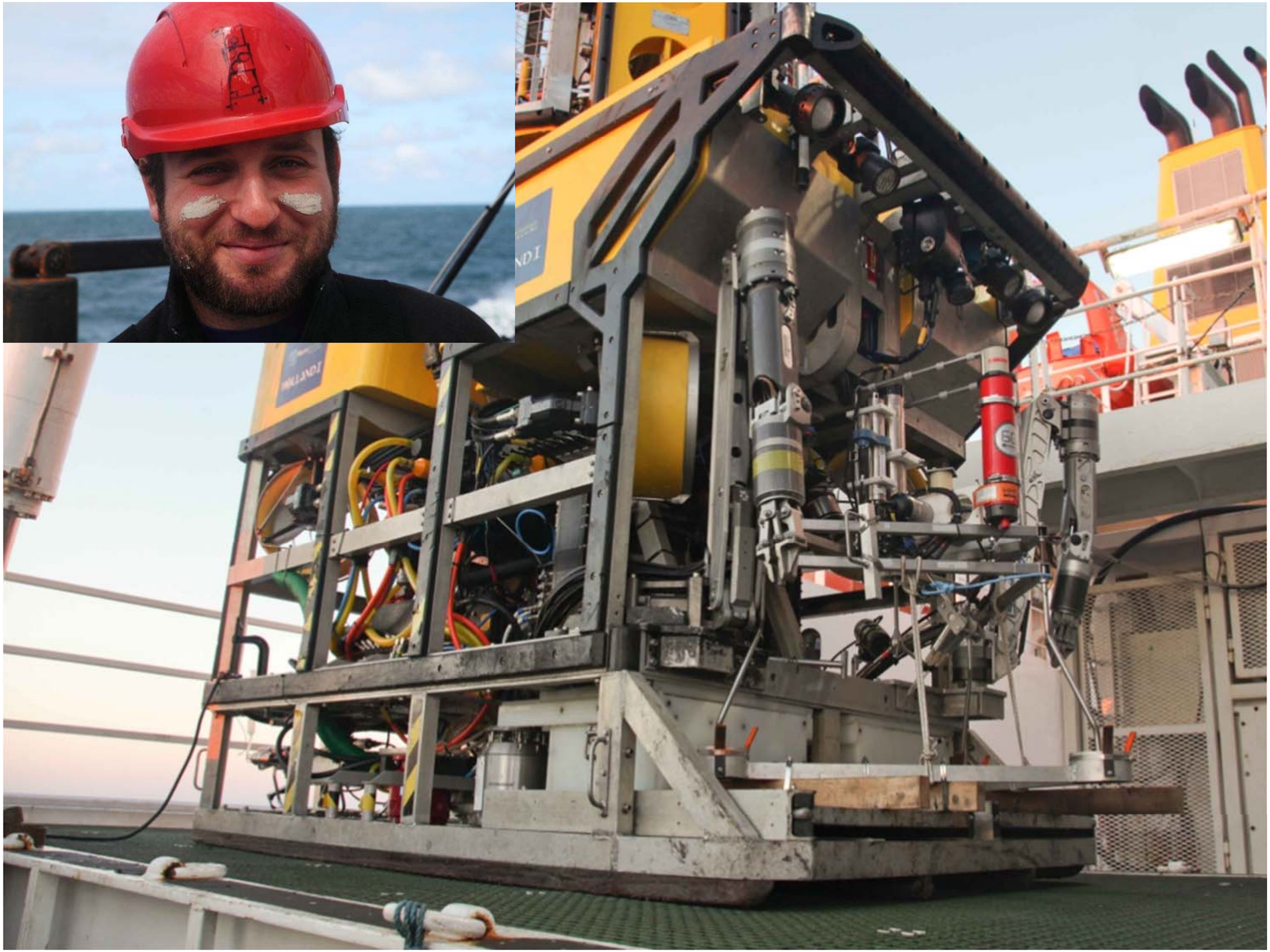
UK Ocean Acidification Research Programme

Murray Roberts
& cruise participants

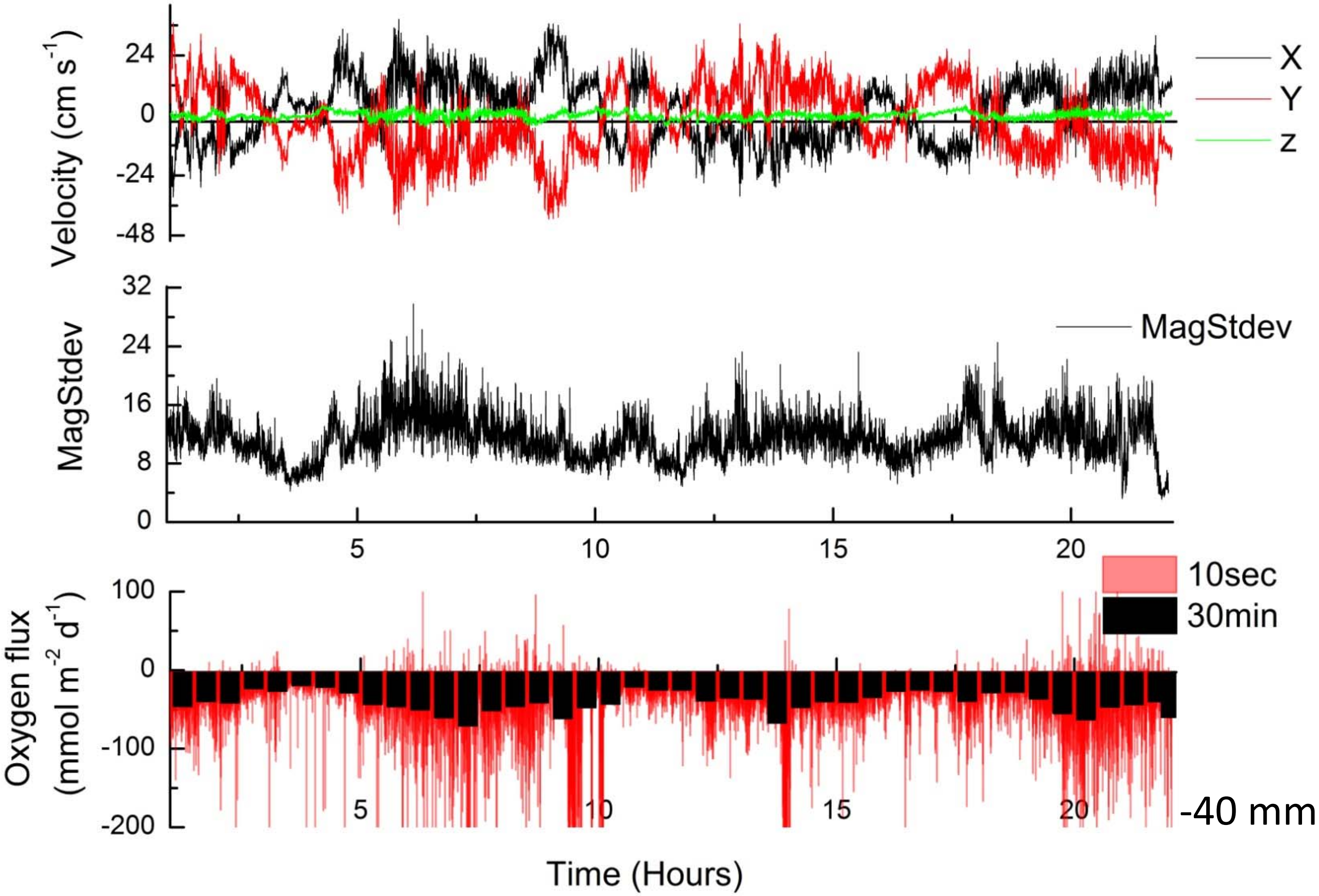
Changing Oceans

RRS James Cook 073

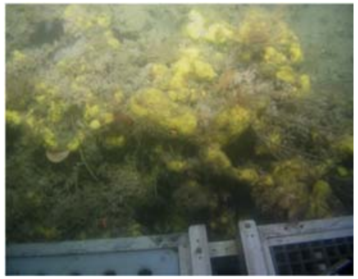
HERIOT WATT UNIVERSITY



Data: Karl Attard (University of Southern Denmark)

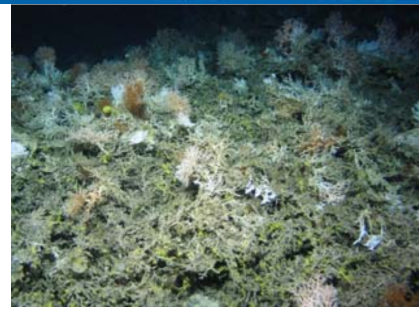


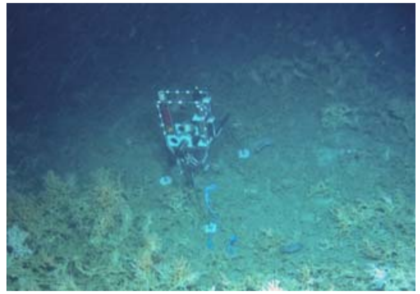
-40 mmol O_2 m^{-2} d^{-1}

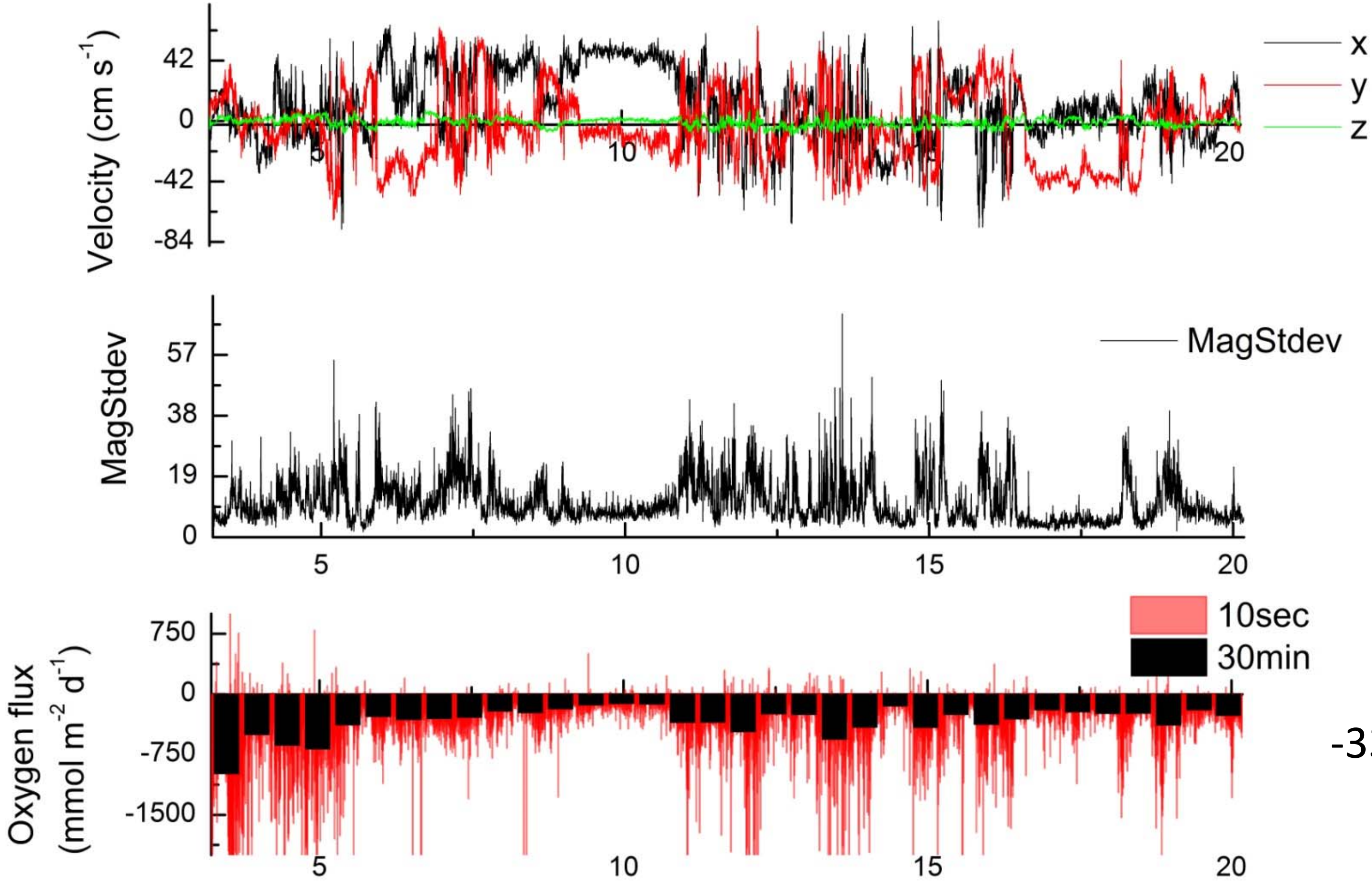


Deployment 1: Mingulay Reef

Data: Karl Attard (University of Southern Denmark)



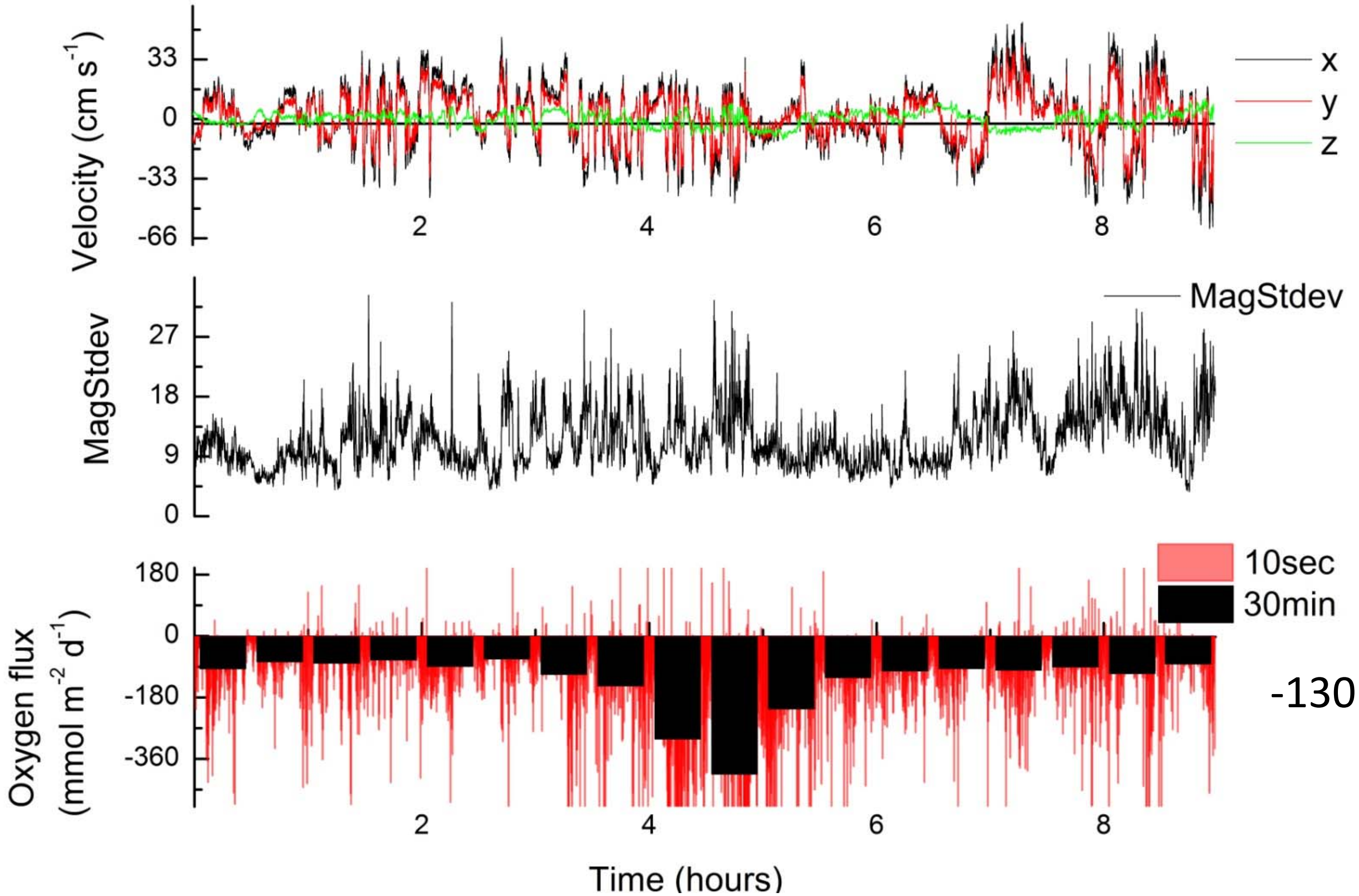


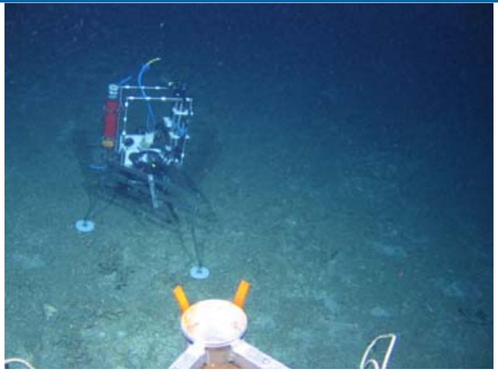


-330 mmol O_2 m^{-2} d^{-1}

Deployment 2: Rockall (on-mound)

Data: Karl Attard (University of Southern Denmark)





-130 mmol O_2 m^{-2} d^{-1}

Deployment 3: Rockall (off mound)

Data: Karl Attard (University of Southern Denmark)

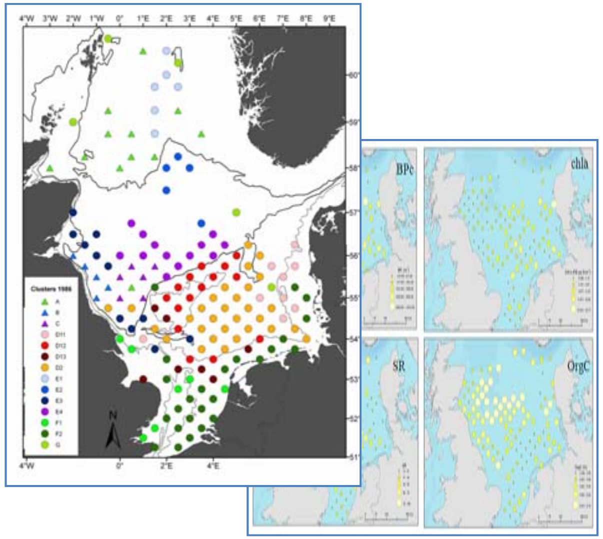
UK Ocean Acidification Research Programme

Scaling-up benthic function
Silvana Birchenough (CEFAS)

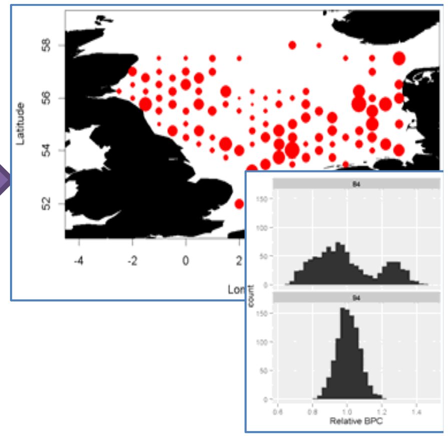
1. Species/habitats

Trait	Function
Size	Carbon storage
Feeding	Energy transfer
Bioturbation	Nutrient cycling
Habit	Energy transfer
Reproduction	Connectivity Energy export
Larval life	connectivity

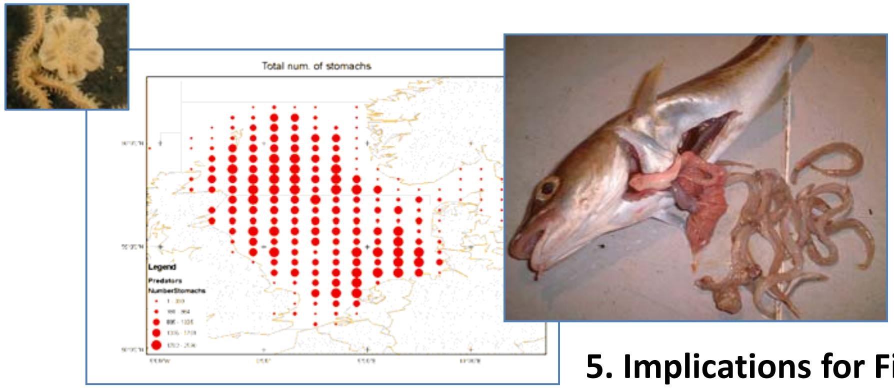
2. BTA to assess benthic function



3. Mapped benthic function



4. Regional modelling to look at OA responses



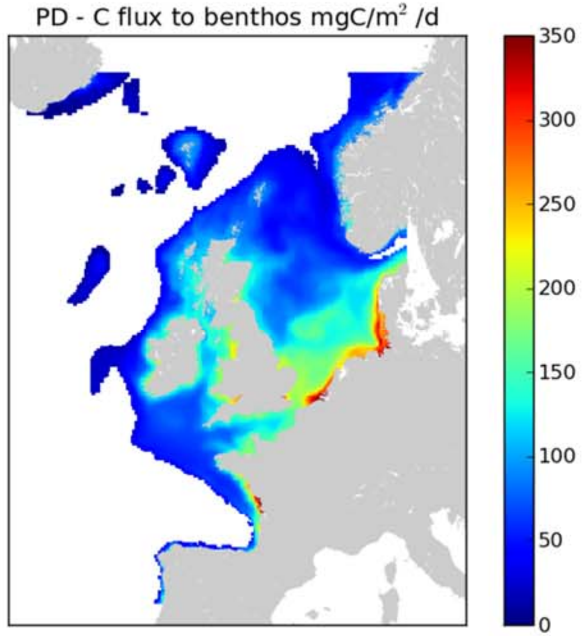
5. Implications for Fish/fisheries

6. Food for fish

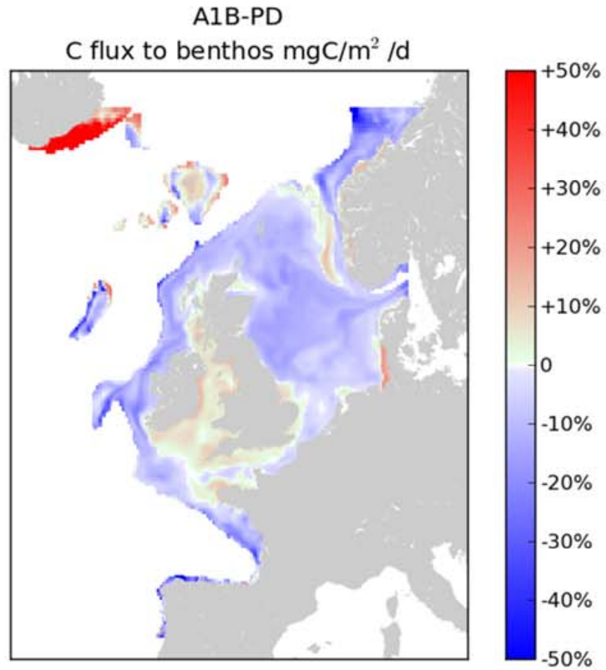
Jerry Blackford and Yuri Artioli

How might the food supply to the benthic system change?

Present day

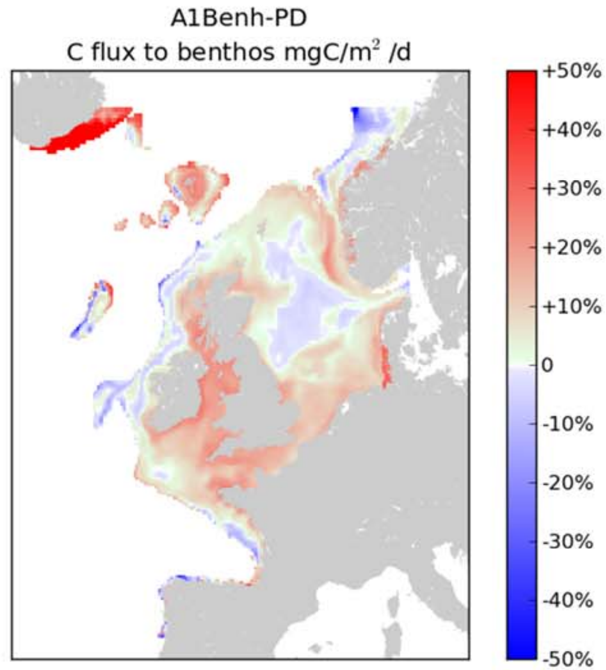


Climate Change



Impacts due to changing temperature, mixing and nutrient supply

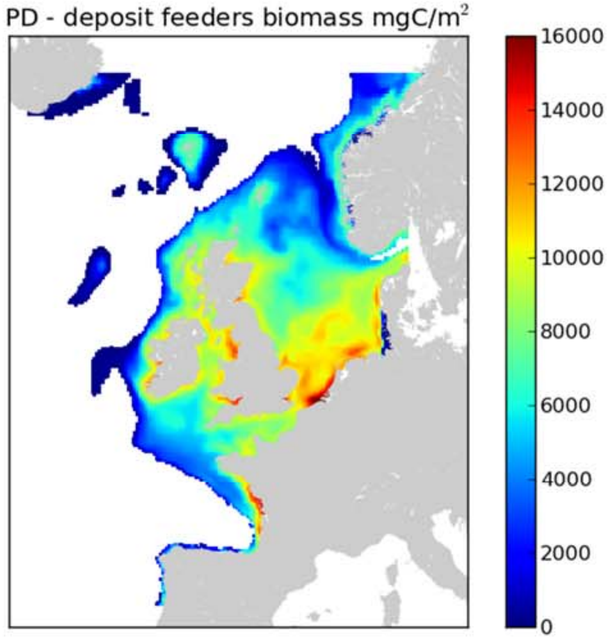
Climate Change
+ OA feedbacks



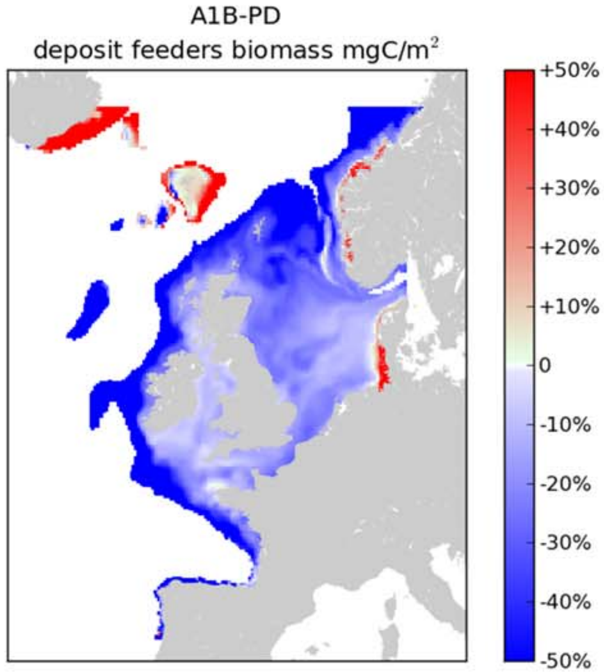
+ enhancement of primary production due to higher CO_2

…and for example deposit feeder biomass?

Present day

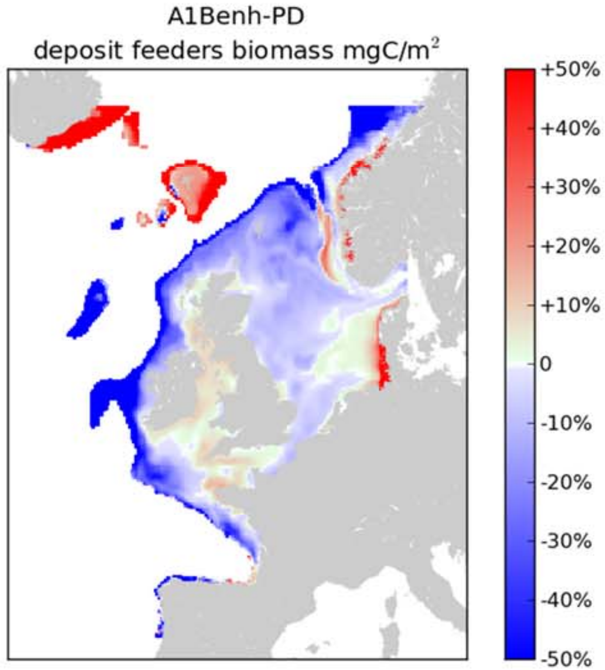


Climate Change



Decrease of 0 – 30%

Climate Change
+ OA feedbacks

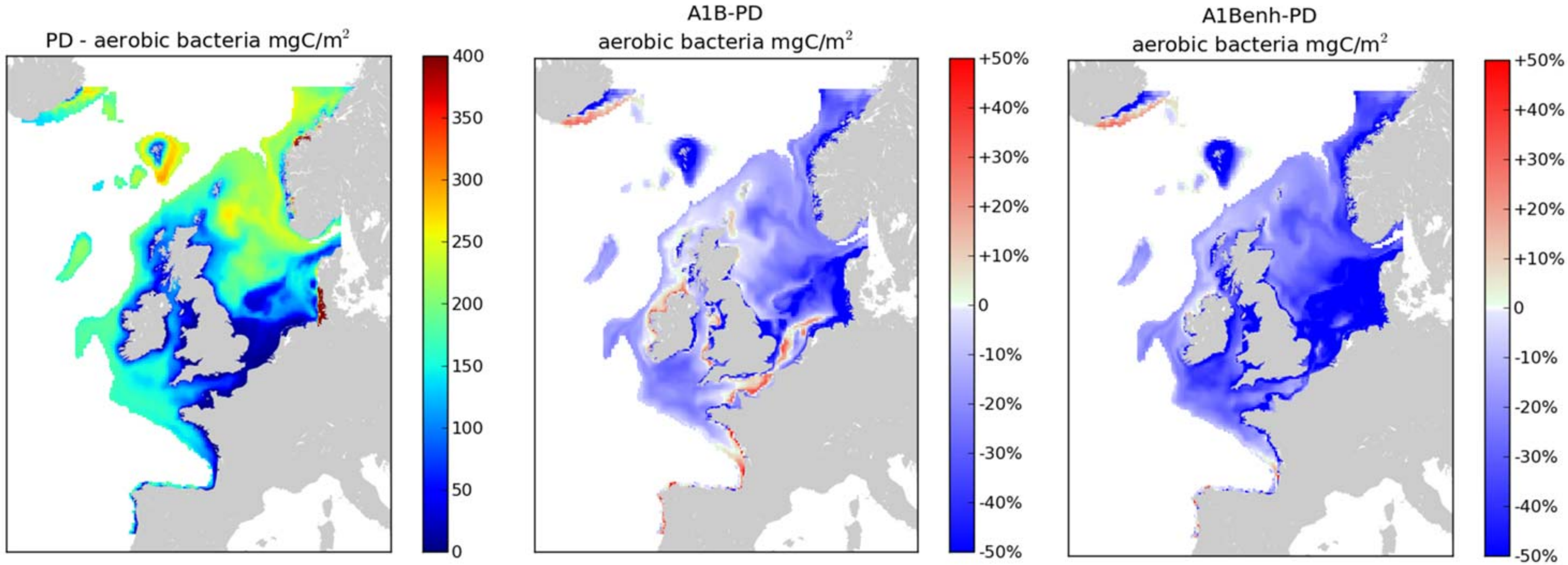


Increase of 10% to
decrease of 20%

Jerry Blackford and Yuri Artioli

…and for example aerobic bacteria biomass?

Present day | Climate Change + OA feedbacks | Climate Change



Increase of 10% to decrease of 30%

Decrease of 10-40%

Overall synthesis not yet completed
The entire benthic group

- Results suggest that impacts will and do occur ……
- Results are context dependant
- There are direct impacts of OA and temperature, interactions important and often temperature dominates
- Subtle indirect effects are prevalent (functional groups and processes)
- Modelled impacts were of the same order or less than inter-annual variability.
- The biggest data gaps are understanding how OA and T directly impact at the functional level, biogeochemistry now advancing supported by molecular analysis
- Require better discrimination of effects on varied functional groups and the benthic biogeochemical environment.