Plymouth Marine Laboratory

# UK CCSC

September 2007

# Marine Environmental Impacts

Jerry Blackford, Nancy Jones, Steve Widdicombe, Dave Lowe, Carol Turley, Andy Rees and others…

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# Modelling

## Regional scale impacts of distinct CO2 additions in the North Sea.

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**Abstract**
A coupled hydrodynamic – ecosystem – carbonate system model applied to the North West European shelf seas is used to simulate the consequences of distinct CO2 additions such as those that could arise from a failure of geological sequestration schemes. **The choice of leak scenario is guided by only a small number of available observations and requires several assumptions**; hence the simulations reported on are engineered to be **worse case scenarios**. **Only the most extreme scenarios are capable of producing perturbations that are likely to have environmental consequences beyond the immediate vicinity of a leak and these only in restricted areas**. We show that, given the available evidence, **the environmental impact of a sequestration leak is likely to be insignificant when compared to the expected impact from continued non-mitigated atmospheric CO2 emissions and the subsequent acidification of the marine system.** We also conclude that far more research, including both leak simulations and assessment of ecological impacts is necessary to fully understand the impact of CO2 additions to the marine system.

**Submitted to Marine Pollution bulletin, Under Review**

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# Scenarios

| Scenario | Site | Input duration days | Depth m† | Input concentration | Daily input per metre squared | | Daily input to model environment | | Total input | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | mmol .$m^{-3}.d^{-1}$ | Carbon $g.m^{-2}.d^{-1}$ | $CO_2$ $g.m^{-2}.d^{-1}$ | Carbon tonnes. $box^{-1}.d^{-1}$ | $CO_2$ tonnes. $box^{-1}.d^{-1}$ | Carbon tonnes | $CO_2$ tonnes |
| Seepage - low | North | 365 | 7.7 | 0.5 | 0.046 | 0.168 | 2.25 | 8.23 | 823 | 3018 |
| | South | 365 | 1.6 | 2.42 | | | | | | |
| Seepage - high | North | 365 | 7.7 | 50.0 | 4.6 | 16.8 | 225.0 | 823.0 | 82307 | 301791 |
| | South | 365 | 1.6 | 242.0 | | | | | | |
| Short term leak - low | North | 1 | 138.0 | 50.00 | 82.800 | 303.600 | 4057.2 | 14876.4 | 4057 | 14876 |
| | South | 1 | 28.5 | 242.00 | | | | | | |
| Short term leak - high | North | 1 | 138.0 | 500.00 | 828.000 | 3036.000 | 40572.0 | 148764.0 | 40572 | 148764 |
| | South | 1 | 28.5 | 2424.00 | | | | | | |
| Long term leak | North | 365 | 138.0 | 50.00 | 82.800 | 303.600 | 4057.2 | 14876.4 | 1480878 | 5429886 |
| | South | 365 | 28.5 | 242.00 | | | | | | |

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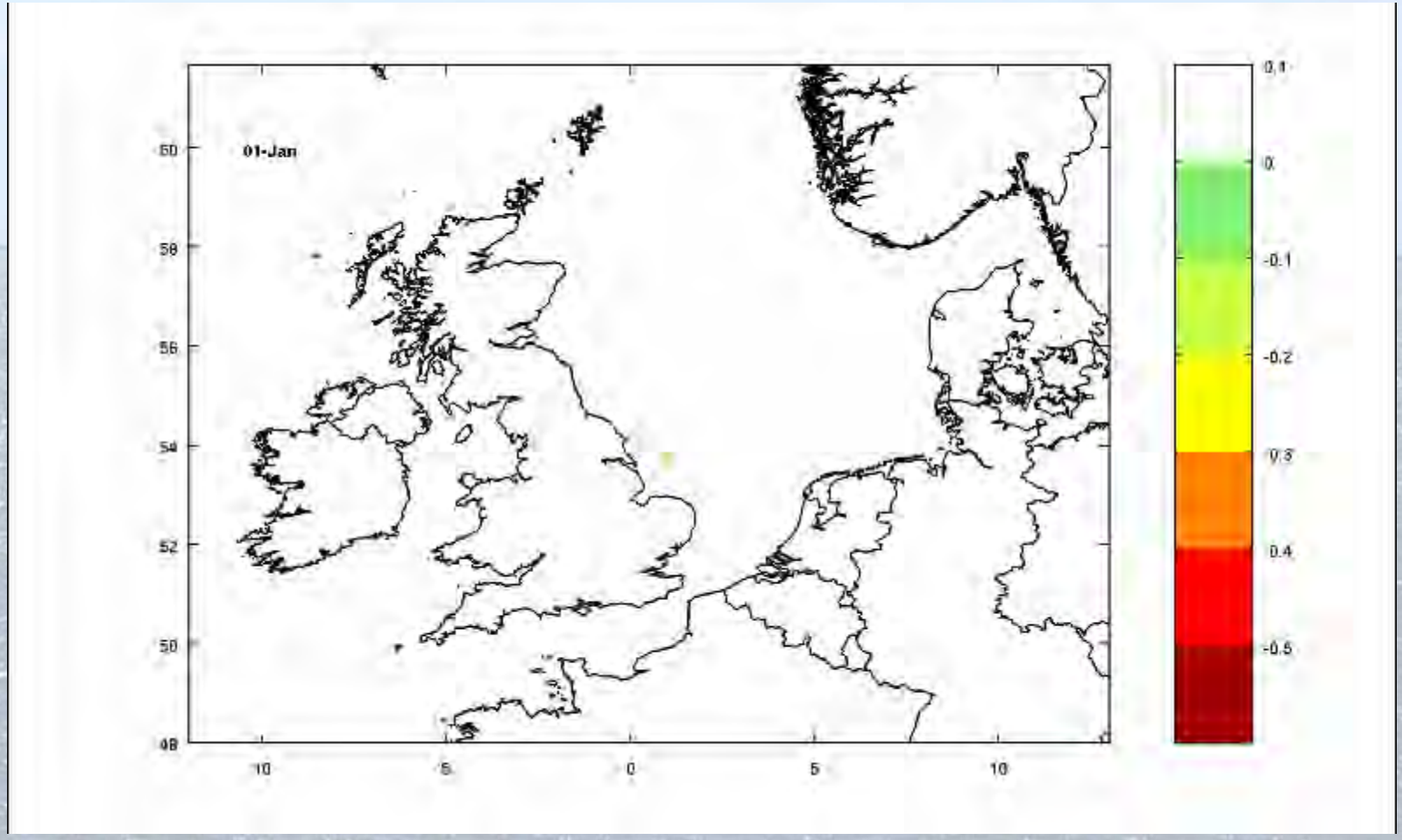
## Modelling leak scenarios: ok warning danger

OA



# Modelling

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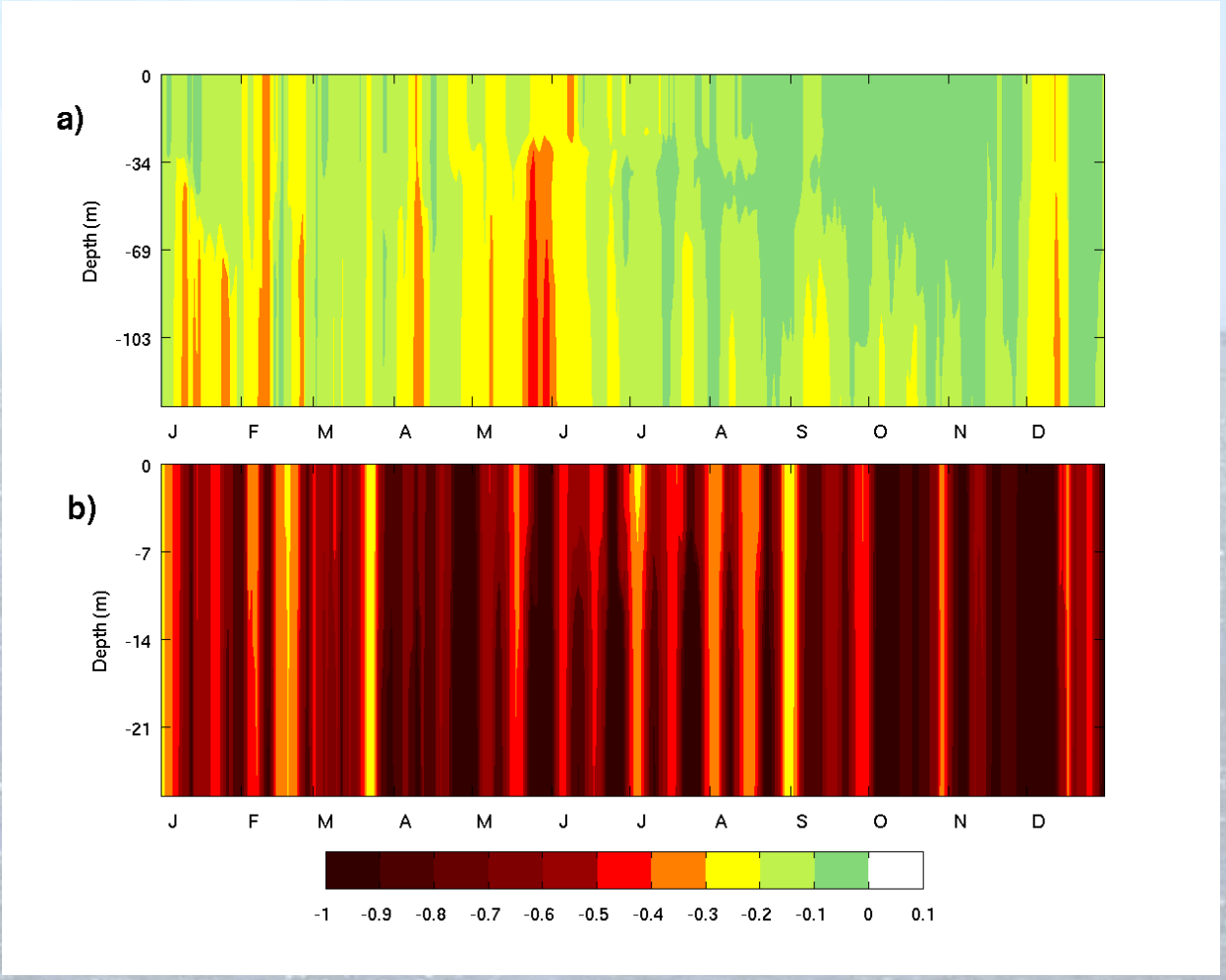
## Modelling leak scenarios:

ok | warning | danger

OA

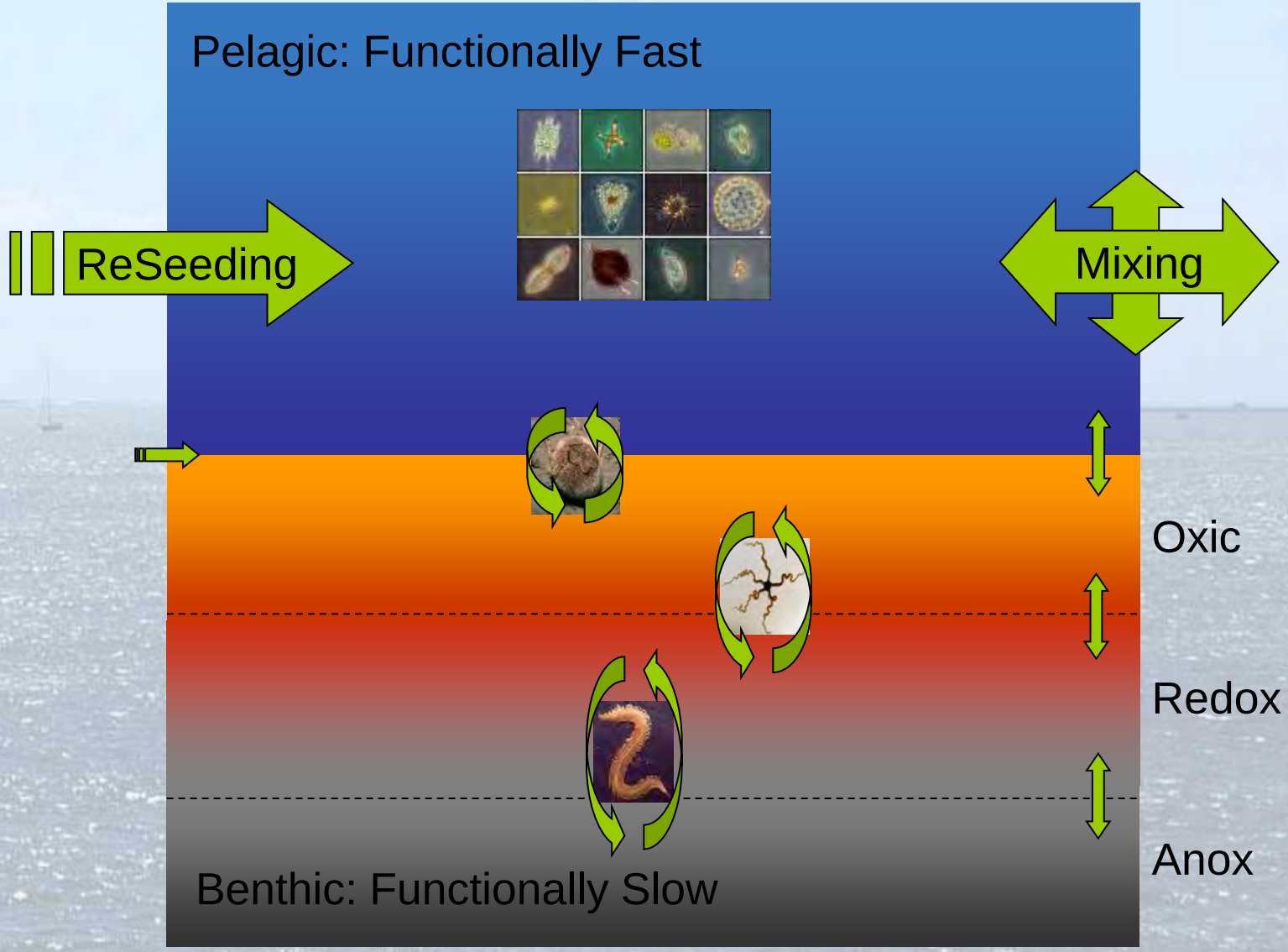



North Site

South Site

**Timing of leak relative to tidal cycle could be crucial**

# Modelling: Predicted sensitivities




**Recovery is a big issue for the benthic system, not the pelagic**

# Sediment Biogeochemical response.

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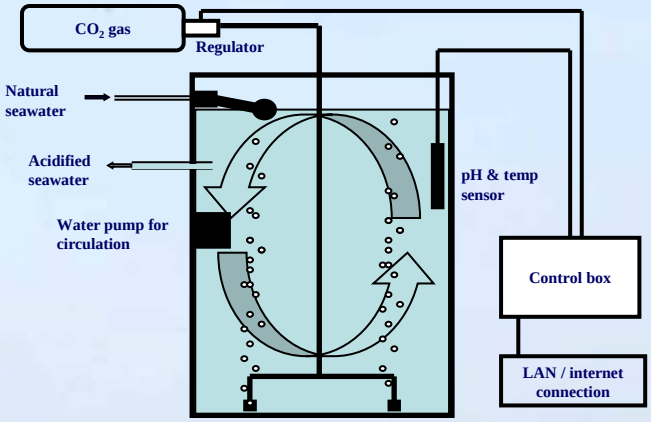
Impact of pH :

***Benthic diversity***
***Nutrient flux***
***Predator / prey interactions***




Impact of pH on a range of species:

***Psammechinus miliaris*** (Sea urchin, hard bottom)
***Strongylocentrotus droebachiensis*** (Sea urchin, hard bottom)
***Brissopsis lyrifera*** (Sea urchin, burrows in muddy sediment)
***Echinocardium cordatum*** (Sea urchin, burrows in sandy sediment)
***Ophiura ophiura*** (Brittlestar, sediment surface)
***Amphiura filiformis*** (Brittlestar, burrows in sediment)
***Nereis virens*** (Polychaete worm, burrows in sediment)
***Mytilus edulis*** *(Bivalve)*
***Callianassa subteranea*** (Burrowing shrimp)
***Upogebia deltuara*** (Burrowing shrimp)

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**Norwegian Institute for Water Research**

**4 pH treatments: 8.0, 7.3, 6.5 and 5.6**

**2 sediment types: Muddy silt and fine sand**

# pH and macrofaunal diversity

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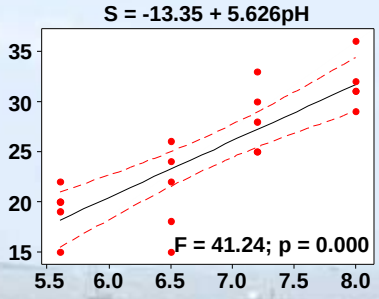
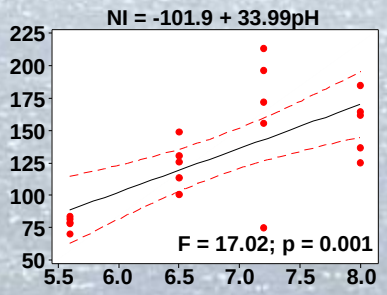
## Sand

### 2 weeks

**number of species**



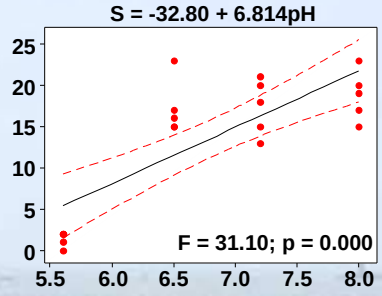

**number of indvs**

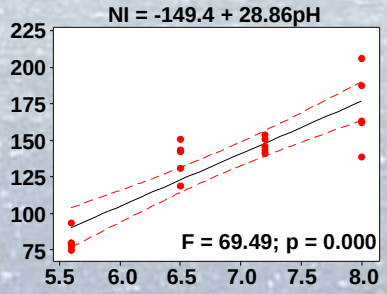



**evenness**

n.s.

### 20 weeks

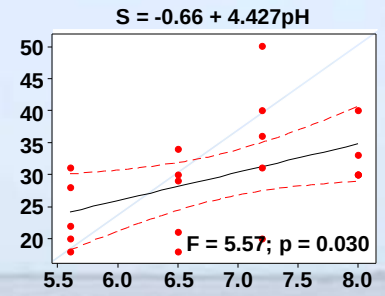


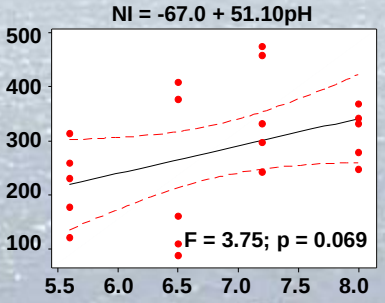




n.s.

## Mud

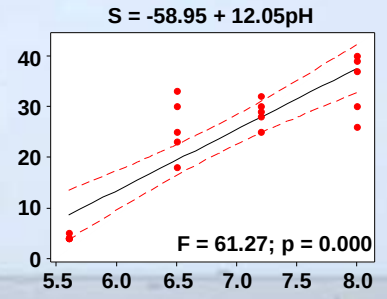
### 2 weeks

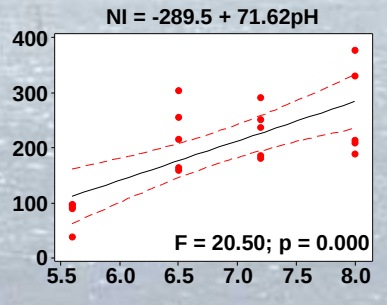


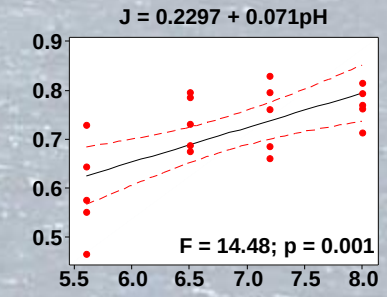




n.s.

### 20 weeks




**Biodiversity is impacted**

# pH and nutrient flux

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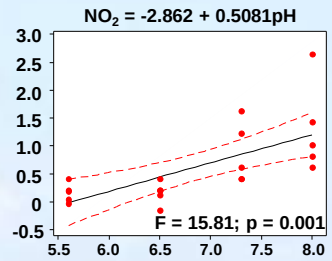
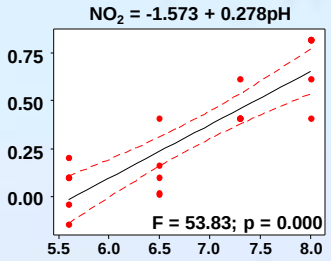
## Sand

### 2 weeks

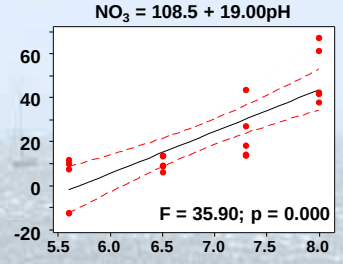
### 20 weeks

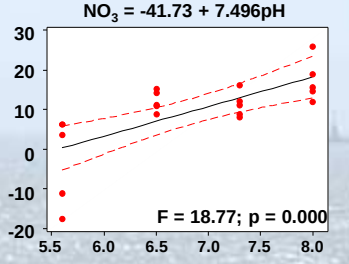
**Nitrite**



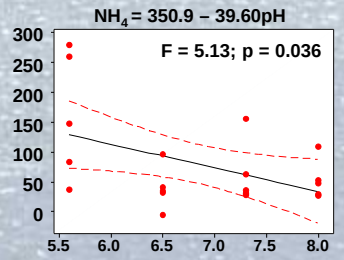



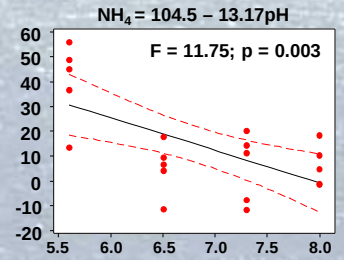

**Nitrate**



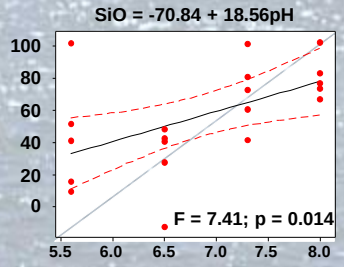



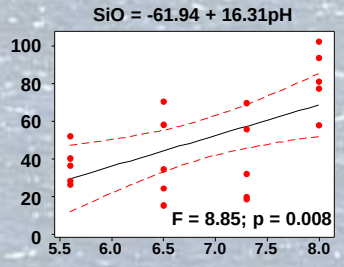

**Ammonium**




**Silicate**



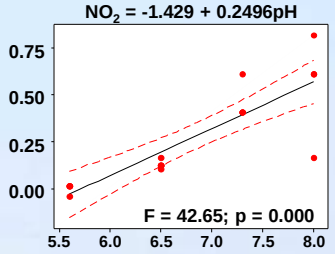

Seawater pH

## Mud

### 2 weeks

### 20 weeks

ns

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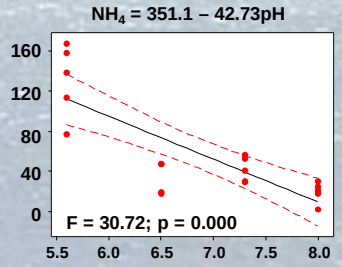


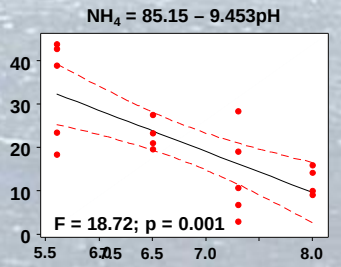


ns

ns

**Benthic function is affected**

Seawater pH

# Impact on Benthic Physiology

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## Impacts on Cellular Processes in Sediment Dwelling Echinoderms.

*Brissopsis lyrifera*

*Echinocardium cordatum*

*Ophiura ophiura*

*Amphiura filiformis*

**Muddy Sediments Surface Dwellers**

**Sandy Sediments Deeper Dwellers**

# Impact on Lysosomes

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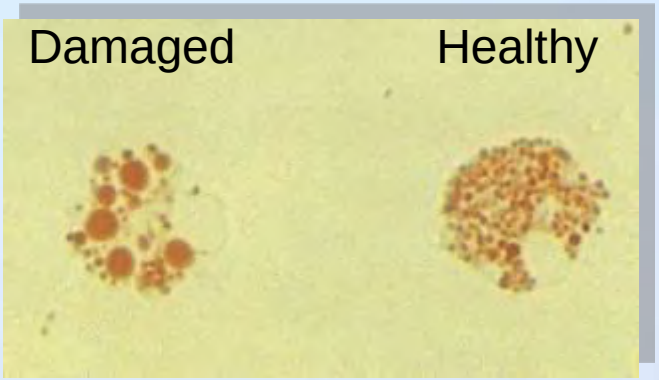
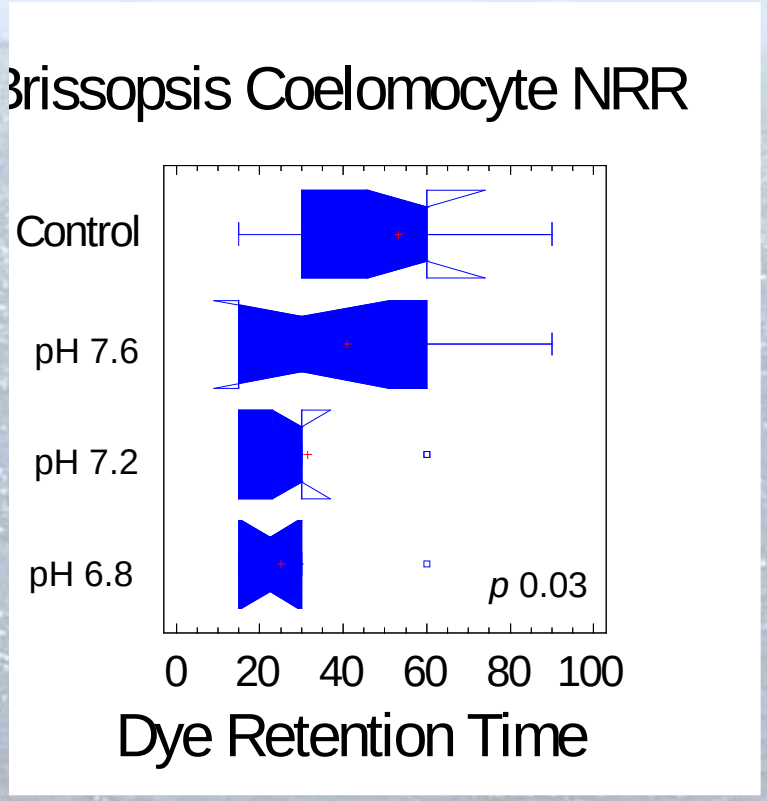
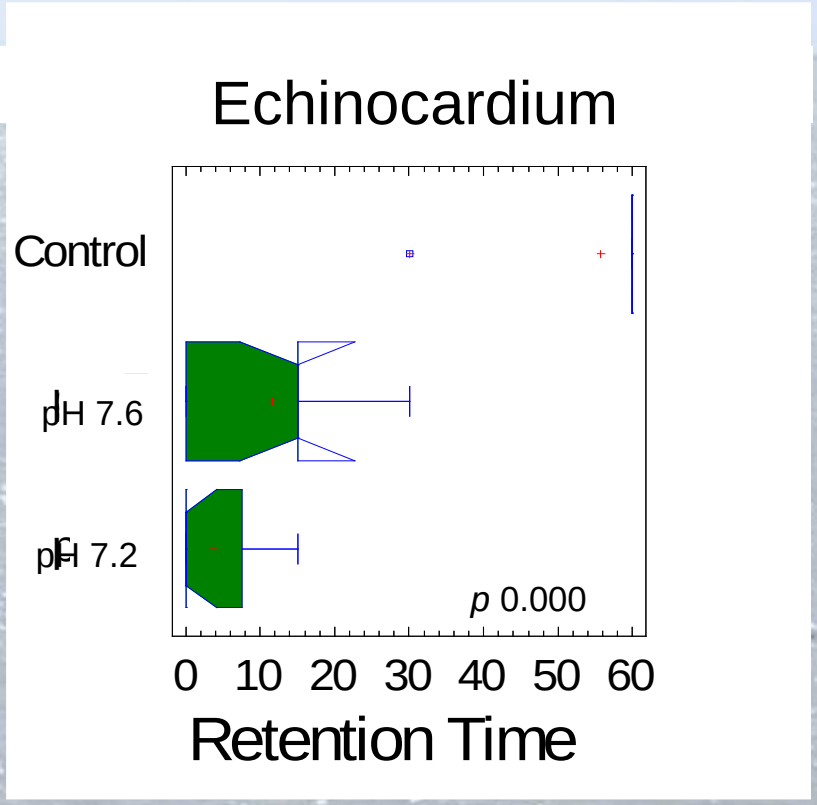
## Lysosomal Neutral Red Retention

**Damaged lysosomes exhibit pathological responses including enlargement and leakage – the greater the damage the faster the response**



# Impact on Gut Physiology

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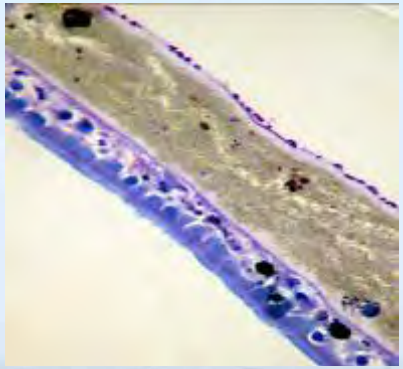
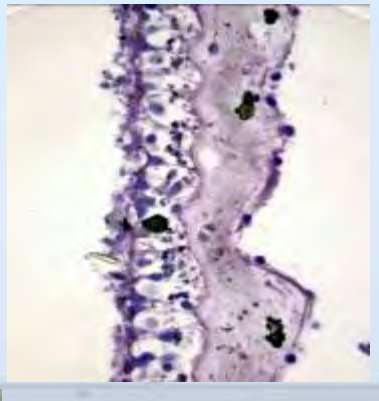
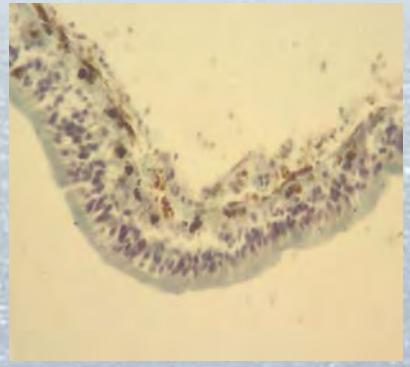
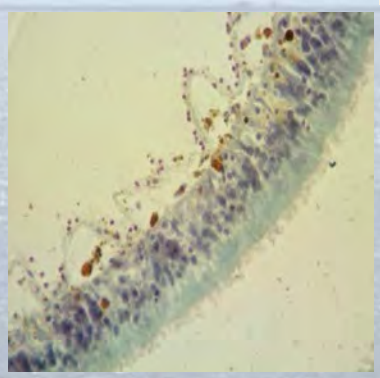
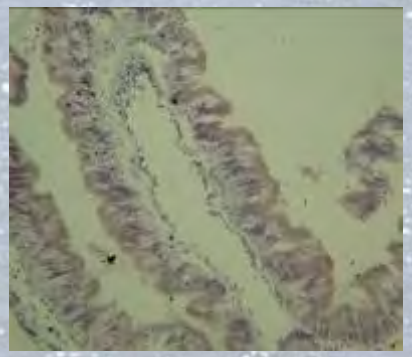
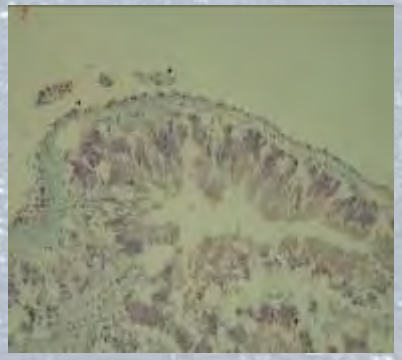
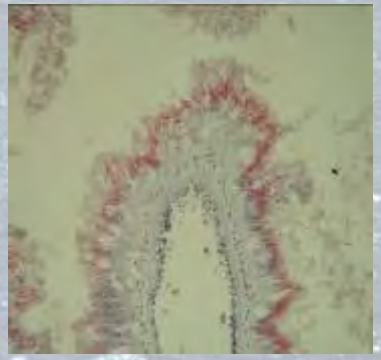
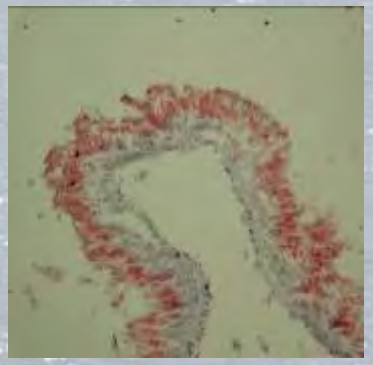
| | Control pH 8 | pH 7.6 | pH 7.2 | pH 6.8 |
|---|---|---|---|---|
| *Brissopsis* |  | | |  |
| *Echinocardium* |  | |  | |
| *Ophiura* |  |  |  |  |

# Impact on reproductive organs

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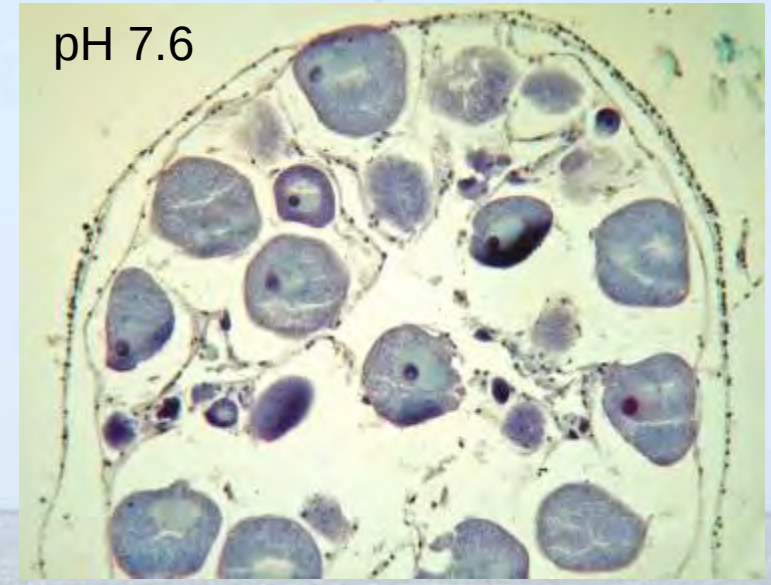



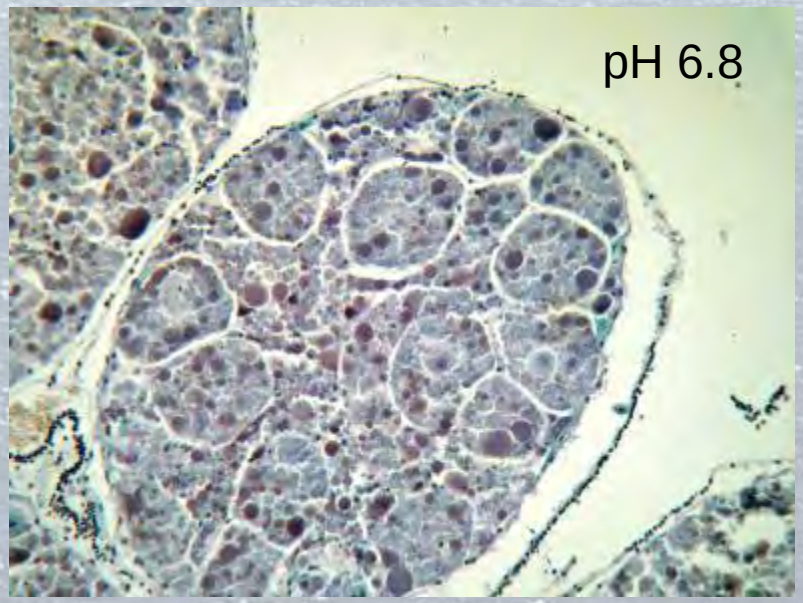

# Experiments: example

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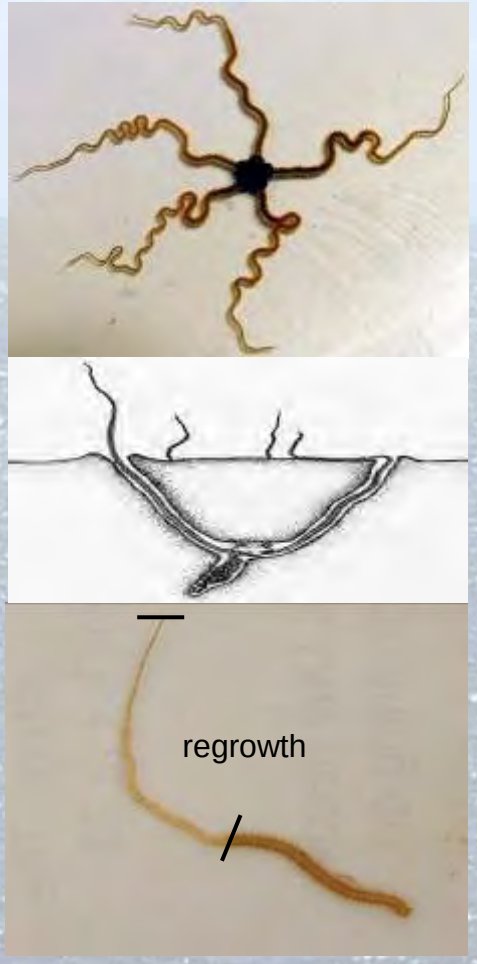
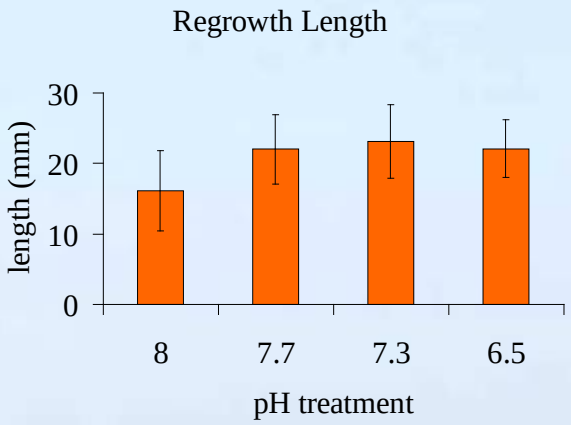
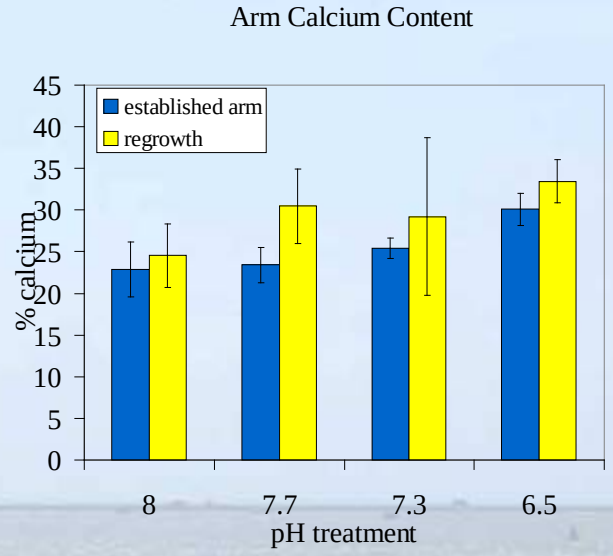
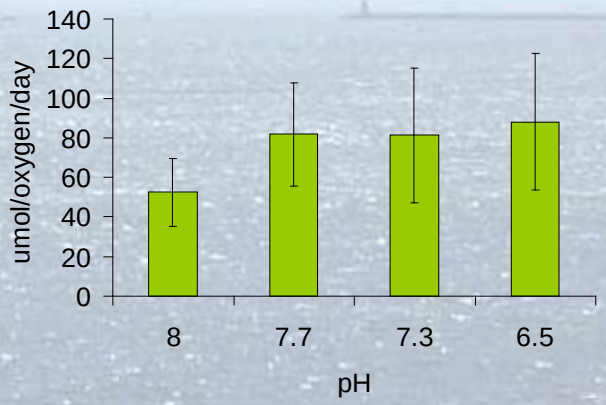
Arm regeneration in *Amphiura filiformis* at low pH

Hannah Wood




- 35 day exposure
- stress response

- Nutritional quality of regenerated arms ?
- Long term, slow onset exposures

# Policy & Communications

**Carol:** Presentation on CCS and OA to Jonathon Shaw (Minister for Marine, Landscape and Rural Affairs and Minister for the South East);Deborah Wells (Senior Private Secretary to Jonathon Shaw); Trevor Hutchings (Deputy Director, Fishing Industry Management Division - Defra), Diana Linskey (Deputy Director Marine Environment Division - Defra); Gail Clarke (Fishing Industry Management Division - Defra); Linda Gilroy (MP, Plymouth) during visit to PML - July 07

**Steve:** "Predicting the impact of seawater acidification on the marine environment" 2nd Meeting of the Scientific Group Intercessional Technical Working Group on CO2 Sequestration within the framework of the Convention on the Prevention of Marine Pollution by Dumping Wastes and Other Matter, 1972, Oslo, Norway 16th-20th April 2007

**Mel, Jerry, Steve:** "Ocean Acidification and Carbon Capture and Storage" Defra Policy 'Snapshot' presentation, London 21st May 2007.

**Steve:** "Predicting the impact of leakage on the North Sea ecosystem" Carbon Capture and Storage Association, Environmental Impact Assessment Workshop, London 23rd August 2007.

**Future**

**Carol:** Planned outreach activities in next 3 months: presentations at Royal Soc on CCS organised by institutes of Biology Chemistry and Physics and at a workshop in Bergen

**Jerry:** Carbon Transportation and Storage, London, 4th December. www.iom3.org.events/carbon

# Future Plans

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**Talking with BP** re sensible leakage scenarios.
Fine scale modelling, 1.8 km grid and ~50m

**Experiment: Impact of acidification on the uptake of metals by marine organisms**
In October 2007 an experiment will be conducted that addresses the following hypothesis:

**H0: Seawater acidification will not affect the bioaccumulation of metals in 4 different marine organisms.**

We will look at 2 elevated pH treatments plus controls. We will add organisms from 4 different taxa (annelid, mollusc, crustacean and echinoderm) to sediment from the Fal estuary which is naturally contaminated by metals. After a period of exposure we will analyse the organisms for metal bioaccumulation. Metals to be assessed are potentially:

**Ag, As, Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb, Zn.**