The potential impacts of leakage of CO_2 on benthic ecosystems

By

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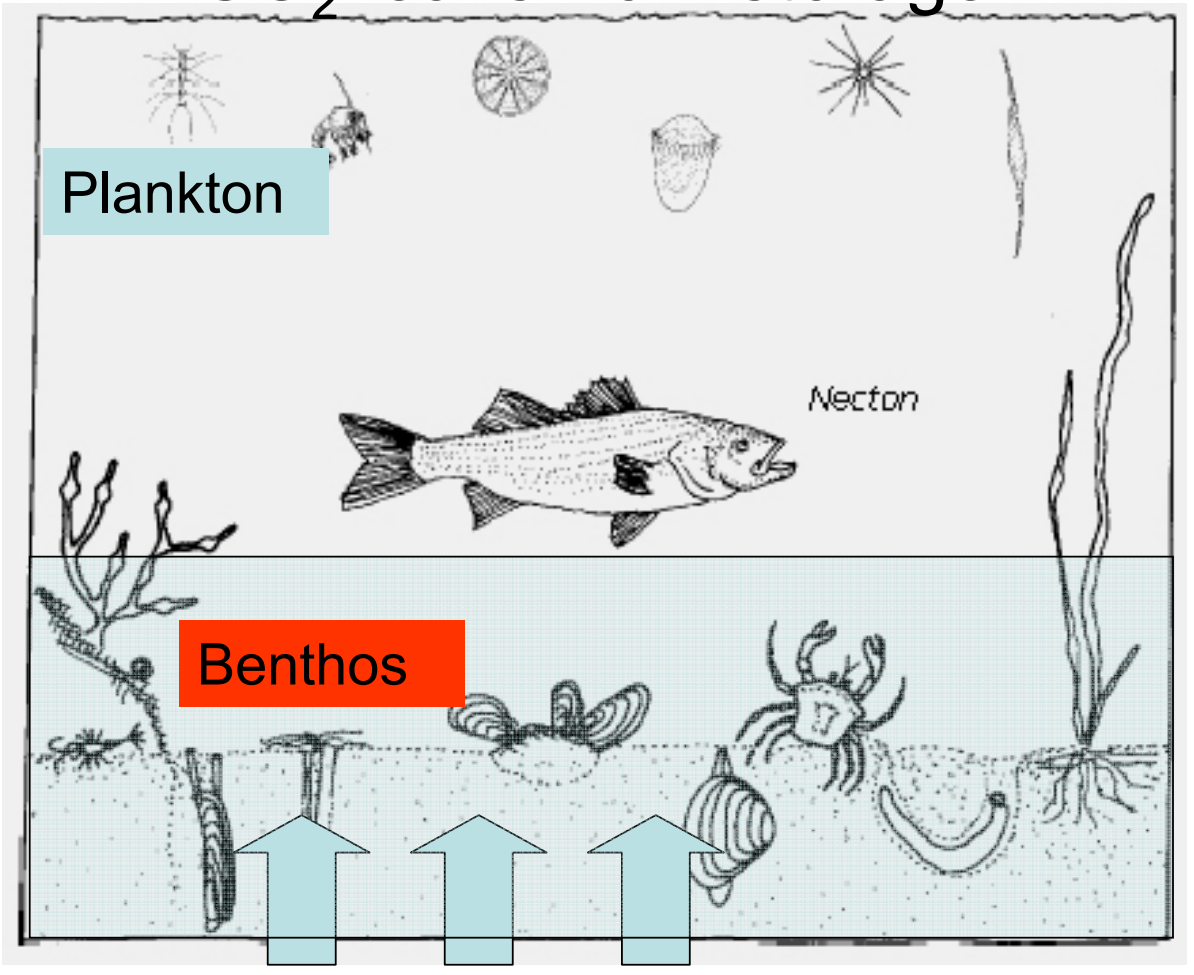
In producing this talk I have drawn freely on the work of my colleagues at PML particularly **Steve Widdicombe, Carol Turley Jerry Blackford**

What happens to the marine ecosystem if CO_2 leaks from storage?



Research at PML – Impact Experiments

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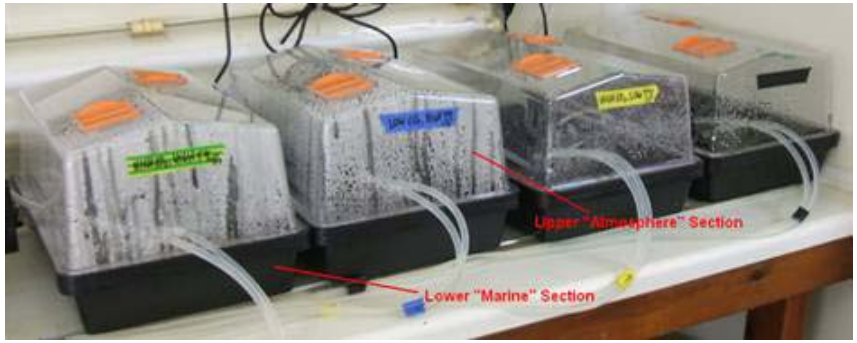
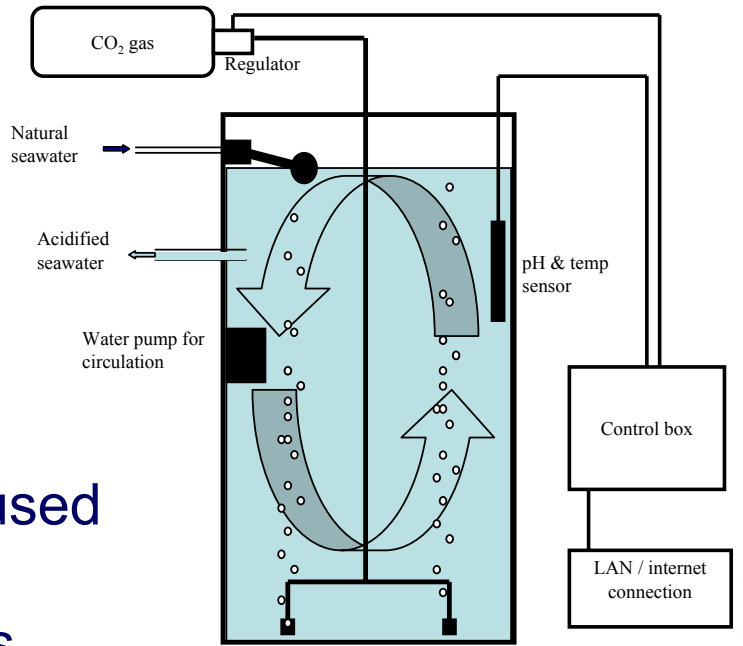


Small systems used for small organisms and larvae.

Findlay et al (in press *Aquatic Biology)*



Large systems successfully used to look at impacts of large organisms and sediment cores.

Widdicombe & Needham (2007) *Mar Ecol Prog Ser*

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Biodiversity experiment

The **Solbergstrand** Marine Research Station of the Norwegian Institute for Water Research (NIVA)

Large (7m x 4m) seawater basins

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Experimental setup

2 sediment types:
Mud and sandy

4 x pH levels:
Natural seawater (7.9), 7.3, 6.5 & 5.6

2 x length of exposure:
2 weeks & 20 weeks

Each treatment is replicated 5 times

After a 1 week acclimatisation.

2 week exposure samples taken 6th June 2005.

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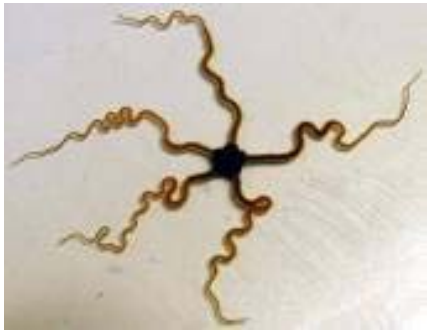
Impacts on individuals

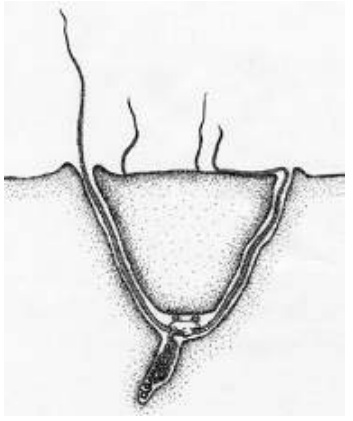
Energy consumed by an animal is divided between

- Respiration
- Growth
- Reproduction
- Repair
- Excretion

When animals are stressed, energy for respiration and repair increase at the expense of growth and reproduction. If an animal doesn't grow or reproduce……..

Whole Organism Physiology





Wood et al. *In press*. *Proceedings of the Royal Society B*.

*Examined t*he ability of the mud-living starfish to recover from damage in a range of pH regimes by removing an arm and following regrowth.

- **Lowered pH causes significant increase in respiratory rate**
- **Regrowth significantly longer at lowered pH**
- **pH significantly affects calcium content in arm regrowth; Regrown arms have significantly higher calcium content than established arms**

Impact on Animal Health – Immune Response

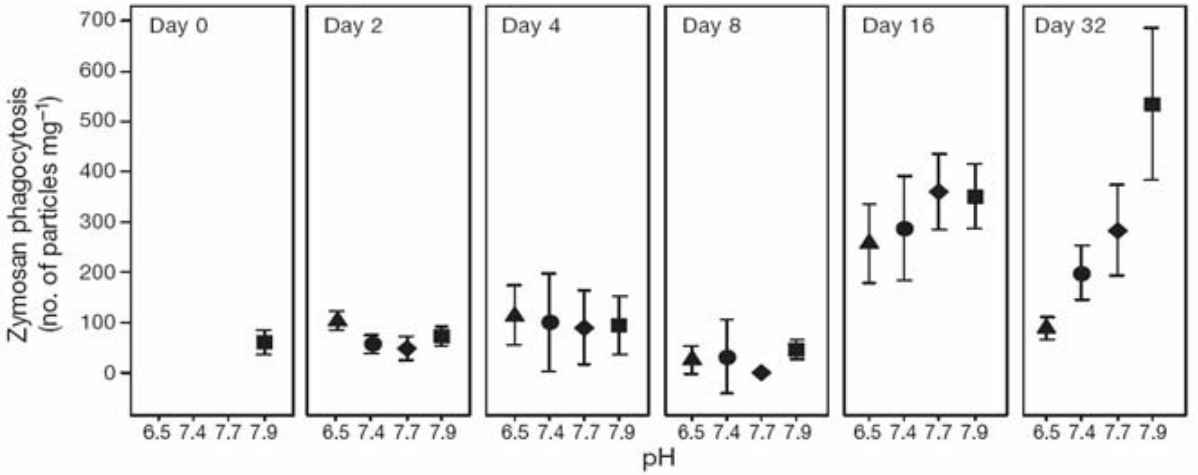
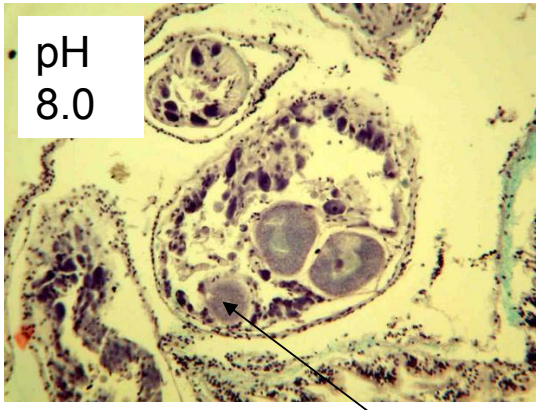
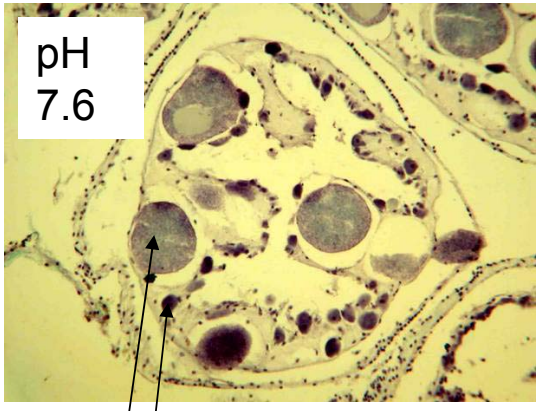


Fig. 1. *Mytilus edulis*. Number of phagocytosed zymosan particles (mean ± 95% CI; n = 10) per mg of haemolymph protein

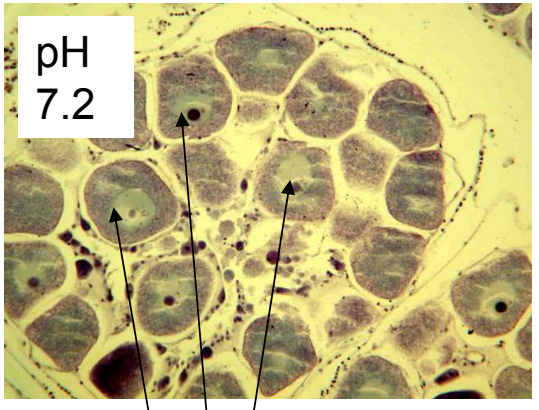
At reduced pH animals are less able to deal with pathogens; health declines and physiology compromised.

Brittle Star Eggs

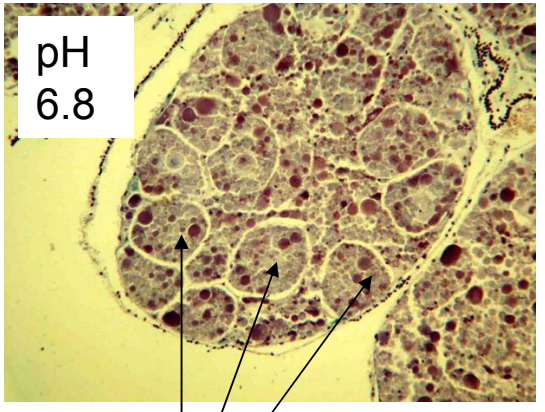




Developing eggs



Mature eggs



Degenerating eggs

Research and images from David Lowe

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With small decline in pH development accelerates; larger declines cause breakdown

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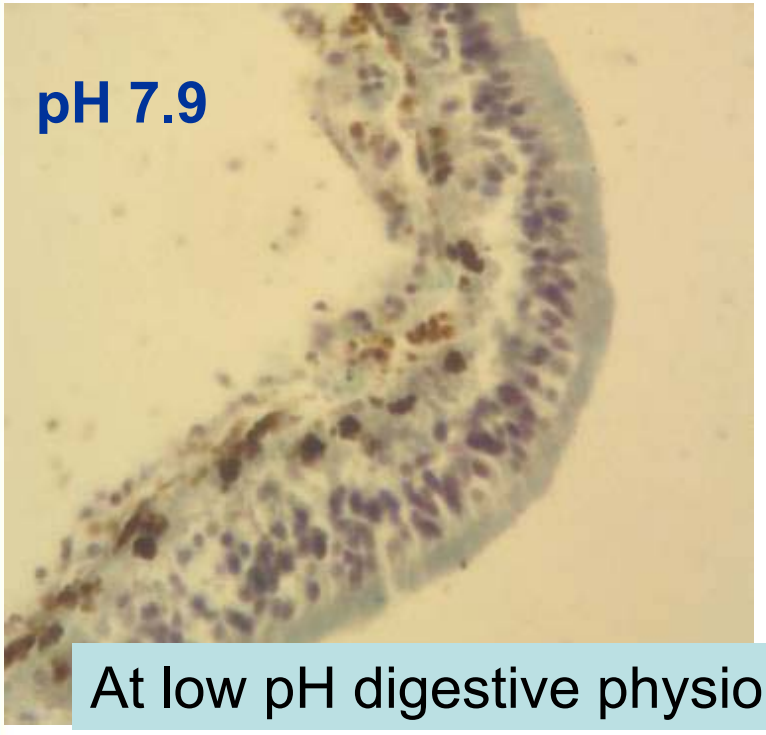
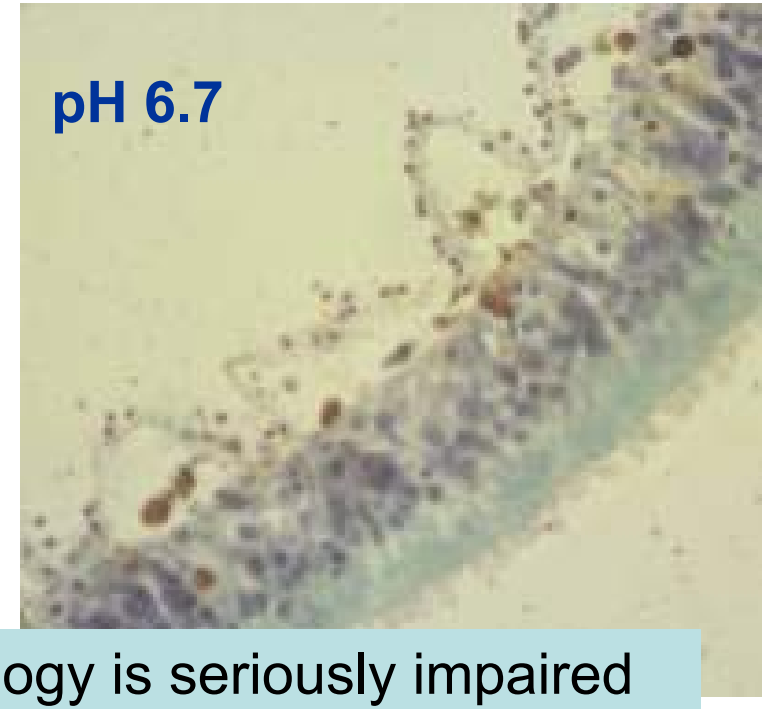
Effects of a reduction in pH on the intestinal epithelium in *Echinocardium cordatum*





At low pH digestive physiology is seriously impaired

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Summary

Experiments on physiology suggest animals are put under severe stress at low pH

If low growth poor reproduction and increased respiration are sustained long-term survival of a population is unlikely

After 2 weeks Muddy sediment

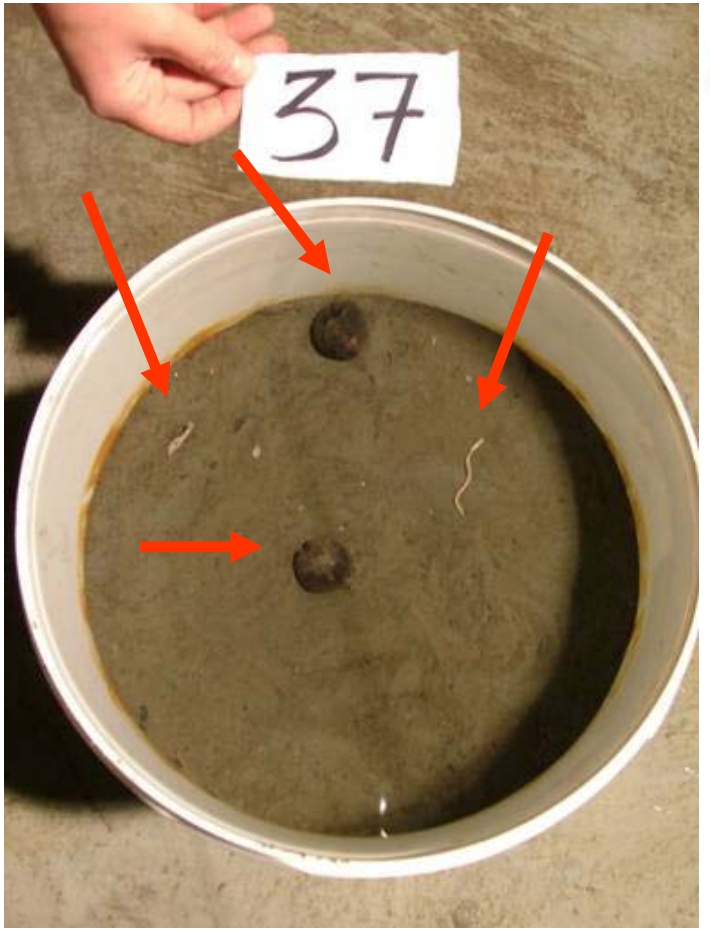
Control

pH 5.6 simulates a leak from storage

After 2 weeks
Sandy sediment

Control

pH 5.6



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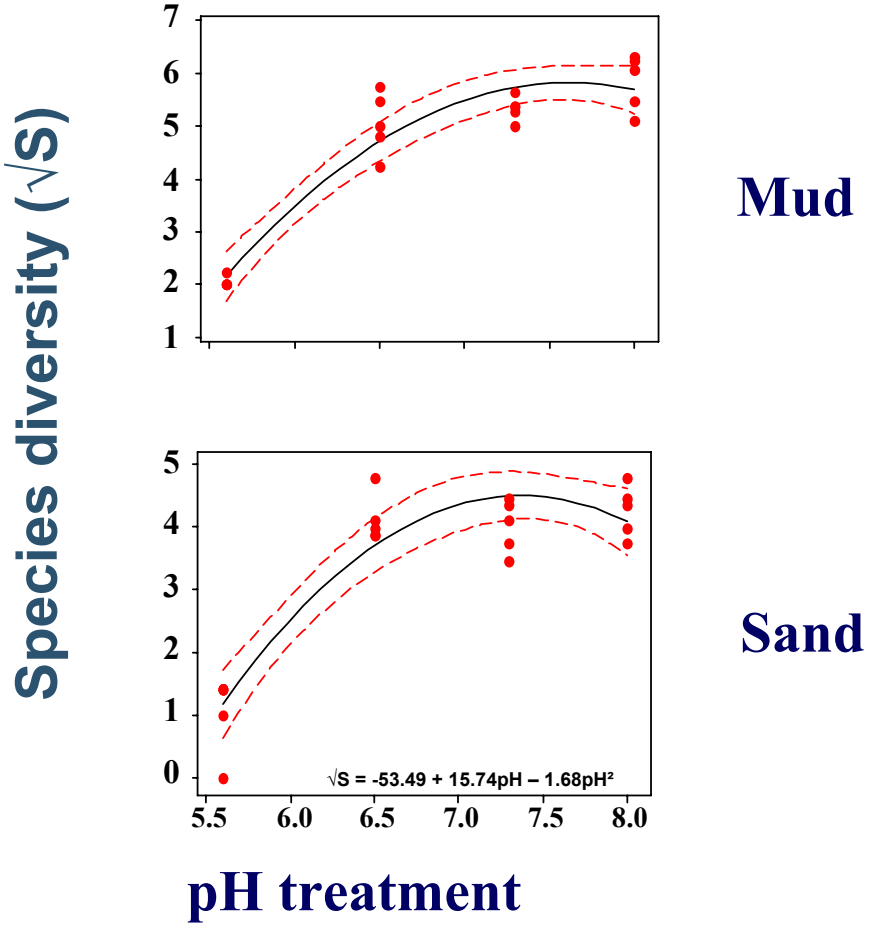
20 weeks exposure



Widdicombe et al. Submitted. *Mar. Ecol. Prog. Ser*

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Summary Communities

- Some species
  - Are killed directly
  - Change behaviour and are less able to feed and protect themselves from predators
  - Are less able to reproduce and their populations decline slowly
  - Prosper as a result of tolerance or reduced competition
- As a consequence
  - The composition and ecological function of seafloor communities changes.

Its not who you are ***its what you do*** that matters

- Some species have a bigger influence on ecosystem goods and services than others.
- Larger more mobiles animals usually have a greater impact than small static species.

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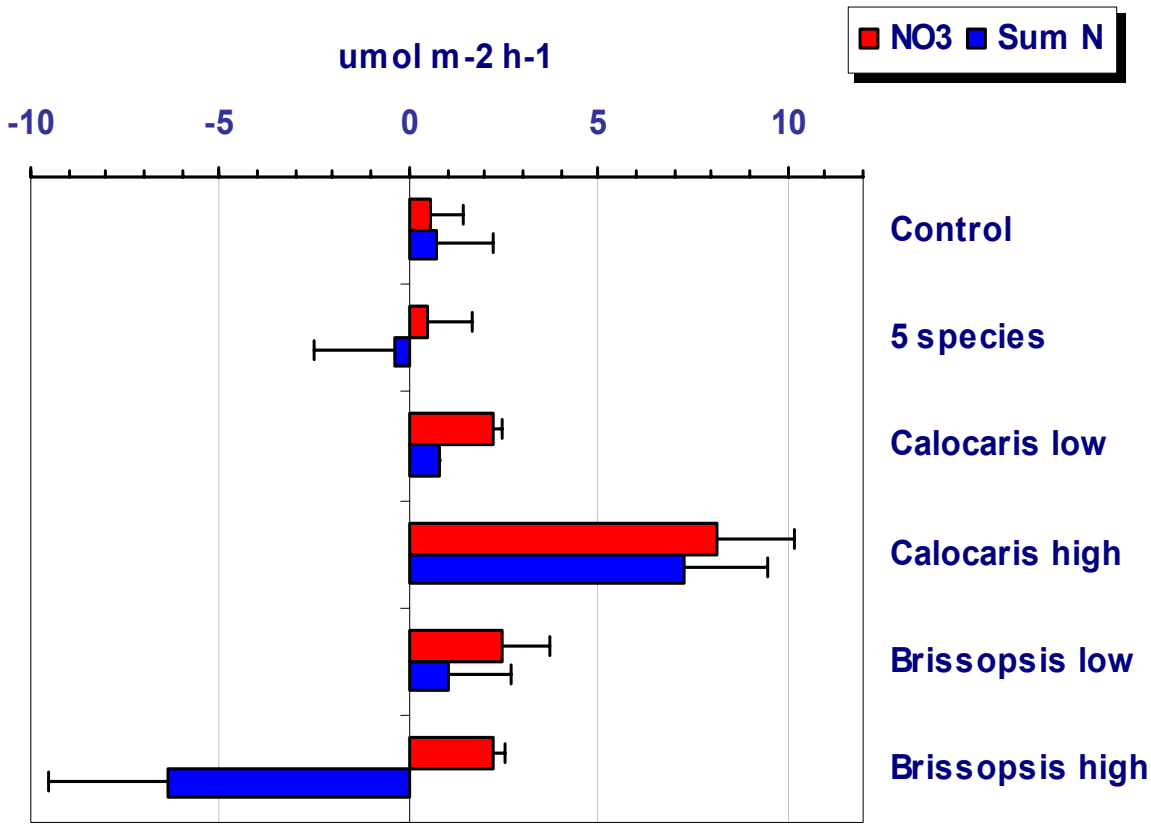

Not all species have the same effect on nutrient cycling:
***you need an appreciation of biology*.**

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If we change seafloor communities we run the risk of disrupting goods and services supplied to mankind

Examples include

- Food provision
- Bioremediation of waste
- Climate/gas regulation
- Nutrient cycling

Most legislation is written in terms of diversity but….

- Diversity can change without a change in ecological function e.g a number of small bodied species are lost
- Or
- Diversity can remain constant (or even increase) but ecological function might decline; eg if a large active species is replaced by a a number of small or inactive species.
- How do we frame new laws?

Impacts

Scale and persistence

Modelling leakage scenarios

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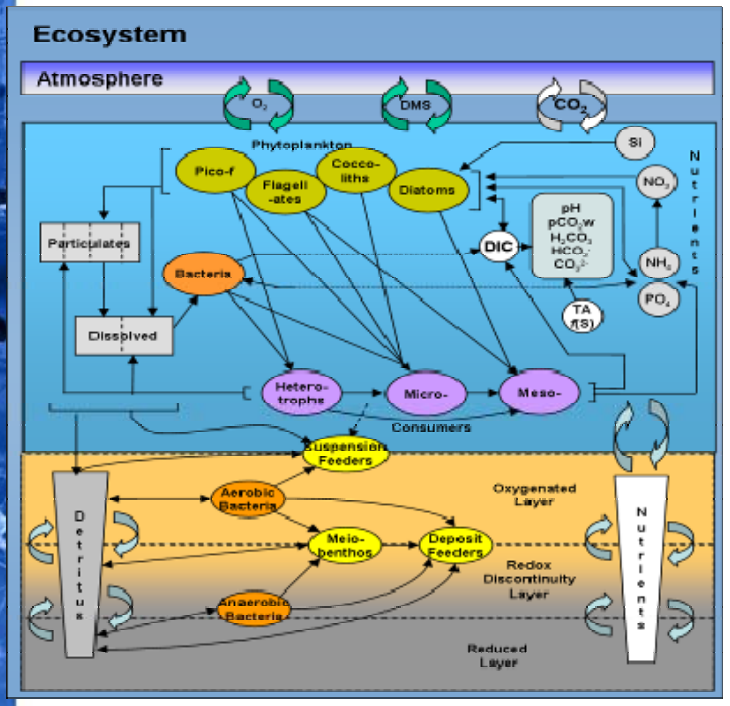

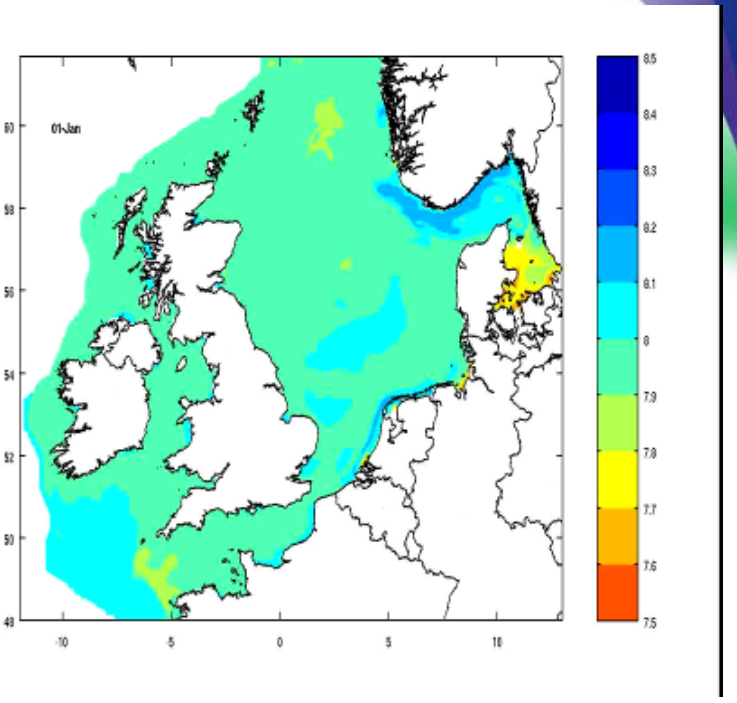

POLCOMS – ERSEM – Carbonate System Model (Blackford & Gilbert 2007)

- Comprehensive: Well evaluated model, biogeochemical functional complexity and coupled benthic system
- Flexible: Run with no or simplified ecology
- Strong research base in UK, run operationally by UKMO.

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Modelling CCS

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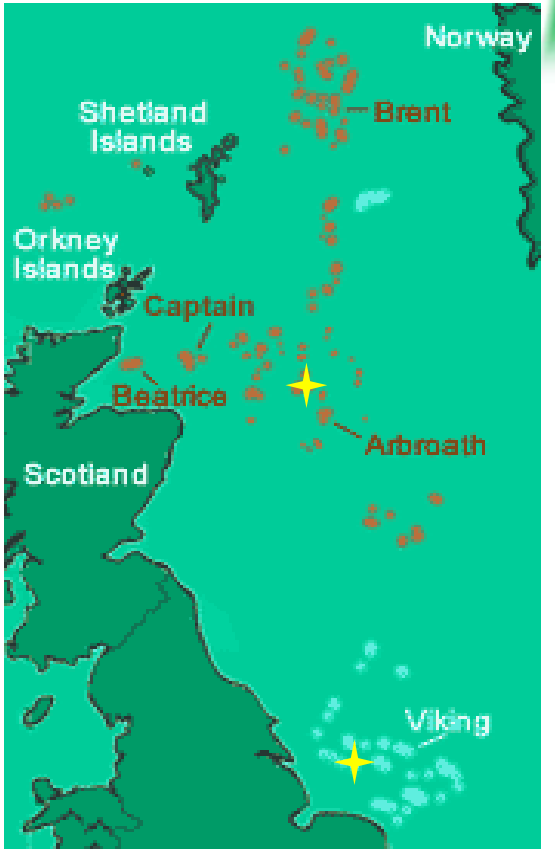
All modes of release were simulated at two sites,

North (57.75N, 1.00E), approximating to the Forties oil field
•water column depth of 138m
•strongly stratified during the summer

South (53.5N, 1.0E), representative of the Viking group of oilfields.
•depth of 28m
•mixed throughout the year.



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Modelling CCS leaks: Assumptions

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Scenarios:

1. Long term well head failure: We assume an unmitigatable fault in the well casing resulting in a catastrophic outgassing of ~5 million tonnes CO_2 over one year, five times the input rate at Sleipner, or 5 years worth of sequestered CO_2.

2. Pipeline fracture: We assume a fracture in a pipeline that persists for one day. We use an injection of 150 000 tonnes CO_2, approx 10 times a typical pipeline capacity and 50x the mean Sleipner injection.

i.e. worst case scenarios

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Long term 'well head' failure

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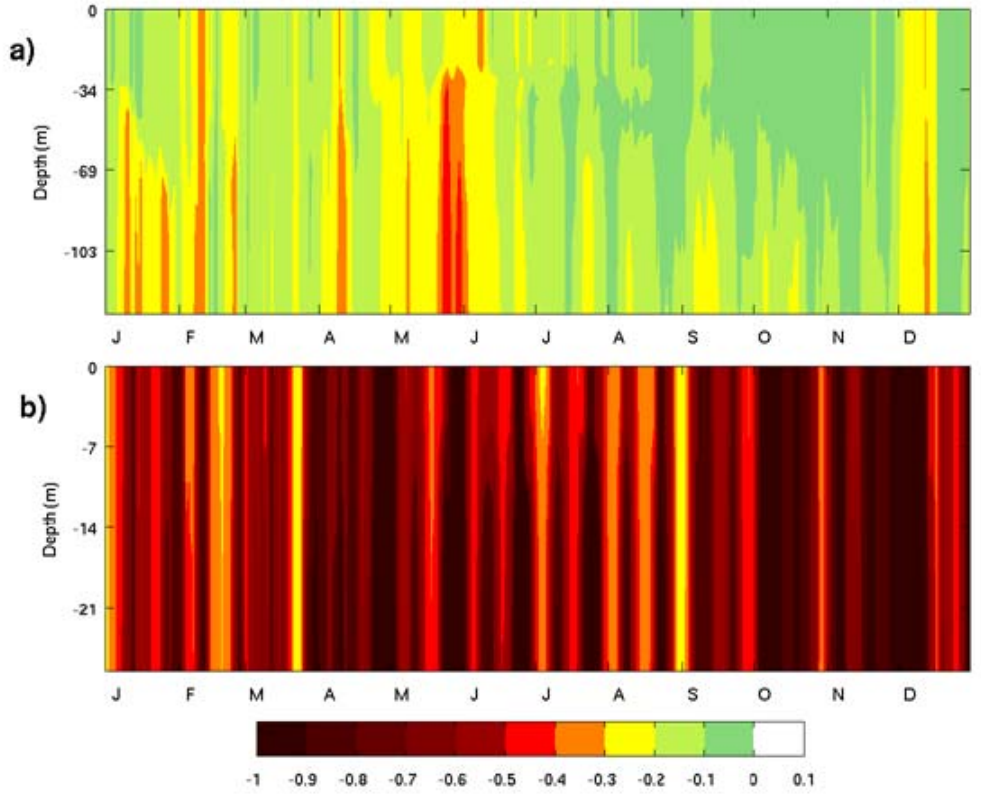
In situ perturbation at leak location (7x7 km^2 box)



ok

warning

danger

North Site

South Site

We need to develop fine scale (m) modelling of hydrodynamics and ecosystems

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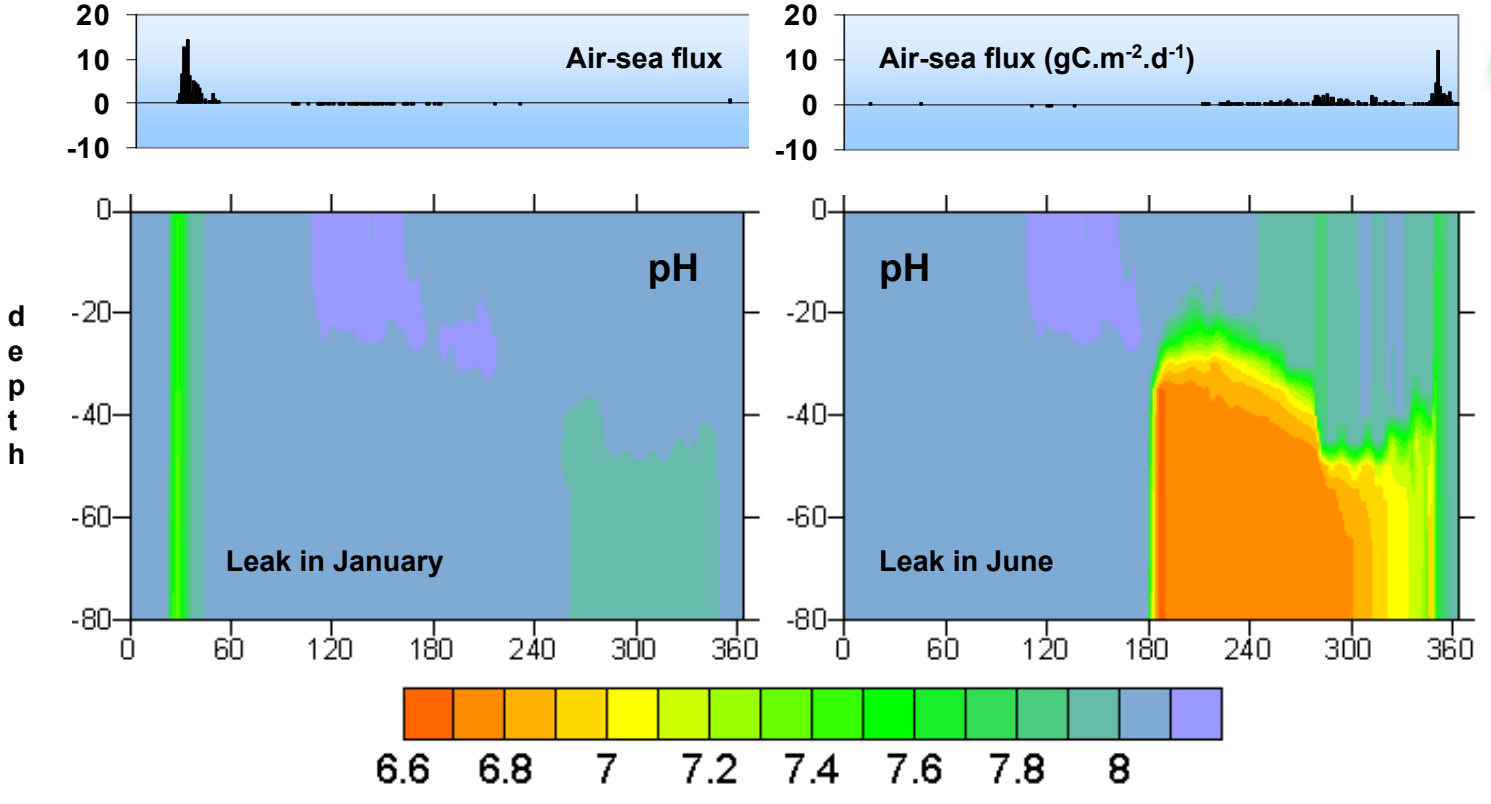
Speculative CO_2 leakage scenarios

Leaks of identical magnitude and duration, differ only in timing.



Summer stratified regions are at high risk.

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Impacts

- Depends on the size of the escape
- Depends on the location of the escape
  - Oceanographic conditions
- Depends on the time of year

Recovery: how quickly will the seafloor recover from a leak of CO_2

?

Ecological function will probably return before biodiversity

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Thank you.

"I don't know why I don't care about the bottom of the ocean, but I don't."

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