2nd Symposium on "The Ocean in a High-CO_2 World"

Predicting the impact of ocean acidification on benthic biodiversity: what can animal physiology tell us?

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S. Widdicombe & J.I. Spicer. 2008. Predicting the impact of Ocean acidification on benthic biodiversity: What can physiology tell us? *J. Exp. Mar. Biol. Ecol.* (doi.org/10.1016/j.jembe.2008.07.024)

6th – 9th October, Musée Océanographique, Monaco

Marine Biodiversity

- 29 non-symbiont animal phyla described so far.
- All but one has living representatives in the Ocean.
- All of these phyla have representatives in the benthos and most can be found in marine sediments.
- This incredible diversity or the marine ecosystem results from complex interactions between:

  the underlying *physical and environmental conditions* (e.g. depth, temperature, organic supply, granulometry…..)

  and *biological interactions* (e.g. predation, competition…..)

What has biodiversity every done for me?

The marine environment supports important “Goods and Services”:

- Nitrogen cycling
- Gas and climate regulation
- Food provision
- Waste disposal

The relationship between biodiversity and ecosystem function still poorly understood.

Biodiversity could be key for:

- Resilience and resistance
- Leisure and recreation
- Non-use benefits

What is “Biodiversity”?

Species diversity: The number of different species present

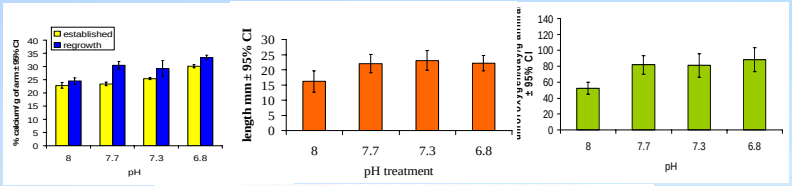
Taxonomic diversity: The phylogenetic relatedness of those species present

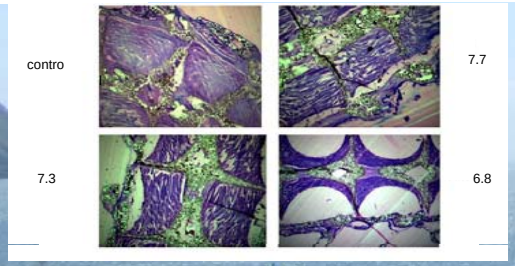
Functional diversity: The of different roles or functions performed within the ecosystem

What understanding does prediction require?

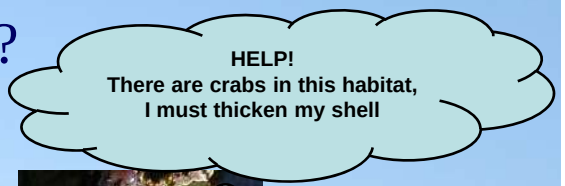
To predict the impact on biodiversity we need understand how OA will effect the survival and performance of individuals and the long-term sustainability of populations?

- The physiological and behavioural responses of organisms
- What traits make a species vulnerable or tolerant?
- Interactions with other environmental drivers e.g. temperature
- Will organisms have the time or ability to adapt?





Wood et al. (2008) Ocean Acidification may increase calcification rates- but at a cost *Proceedings of the Royal Society B* 275: 1767-1773



Chemical cue

Green Shore Crab

Carcinus maenas

Edible Periwinkle

Littorina littorea

Bibby et al (2007) Ocean acidification disrupts induced defences in the intertidal gastropod *Littorina littorea*. *Biology Letters* 3: 699-701

What understanding does prediction require?

Taxonomic and functional diversity:

Will OA selectively remove species from particular taxonomic or functional groups?

Is an organism's sensitivity to OA related to its:

- phylogeny?
- environment (deep v shallow; infaunal v epifauna)?
- reproductive strategy?
- reliance on calcium carbonate?

What understanding does prediction require?

Can sensitivity be predicted by phylogeny?

- Maintenance of extracellular pH is important for intracellular pH and the function of respiratory pigments.
- Some evidence that sensitivity to hypercapnia could be predicted by an organisms ability to compensate extracellular acidosis.
- Limited data would suggest that there could be an underlying phylogenetic pattern in compensatory ability.
- But the pattern is not clear cut and there could be a number of ecological factors that complicate the relationship.

Good or complete compensation




No or partial compensation





What understanding does prediction require?

Can sensitivity be predicted by ecology?

<u>Deep water v shallow water species</u>




- Pane & Barry (2007) compared the deep sea Tanner with the shallow water Dungeness crab.
- The Dungeness crab displayed compensated acidosis whilst the Tanner crab was largely uncompensated.
- Supports the idea that deep sea animals could be more vulnerable than shallow water animals.
- BUT, whilst a study of *Necora puber* (Spicer et al, 2007) supports this idea, data from a number of studies on the shallow water species *Callinectes sapidus* showed a considerable decrease in haemolymph pH.
  - Other shallow water organisms also show poor compensation.
  - More studies needed.


What understanding does prediction require?

Can sensitivity be predicted by ecology?

Infaunal v epifaunal

- CO_2 in sediment invariably higher than in the overlying water
- *Callianassa* can have a pH in its burrows as low as 6.3 (Torres et al 1977)
- CO_2 levels in *Arenicola* burrows as high as 4000ppm after 4 hours of tidal exposure (Toulmond 1973)
- Assumption than infaunal more tolerant than epifaunal animals
- Most studies conducted on epifaunal species
- No impact observed on the burrowing polychaete *Nereis virens* (Widdicombe & Needham 2007)
- *Amphiura* was seen to be affected by exposure to high CO_2 (Wood et al 2008)

- Need more data from comparative experiments on survival of hypercapnia by infaunal and epifaunal benthos

What understanding does prediction require?

Can sensitivity be predicted by ecology?

Reproductive strategy

- Some benthic species produce planktonic larvae whilst others employ direct benthic development.
- CO_2 in sediment invariably higher than in the overlying water.
- Could benthic larvae be better adapted to high CO_2 environments than planktonic larvae?
- Some evidence that larvae are very sensitive to high CO_2.
- But most studies have been conducted on planktonic, calcifying larvae (e.g. echinoderms and molluscs).
- Need more larval studies on a broader range of larval strategies.
  - What is the effect of body size?

What understanding does prediction require?

Taxonomic and functional diversity:

Will OA selectively remove species from particular taxonomic or functional groups?

Is an organism's sensitivity to OA related to its:

Underlying pattern	phylogeny?
Very likely	environment (deep v shallow; infaunal v epifauna)?
Possible	reproductive strategy?
Almost certainly	reliance on calcium carbonate?

Currently we must assume that species loss will be idiosyncratic and predictions for biodiversity will be difficult.

Where can future physiological studies help?

- Whole organism physiology: How will trade-offs effect long-term survival of individuals and populations?
- Are there physiological proxies or indicators of organism / species vulnerability?
- Understand the mechanisms by which OA can affect the biological interactions that structure communities and ecosystems.
- How will the numerous environmental drivers (pH, temperature, salinity, O_2, nutrients) interact to determine the abundance and distribution of species?
- What is the potential for individuals and species to adapt?

Thank you