Predicting the regional impacts of ocean acidification: Integrating sediment biodiversity and ecosystem function

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Introduction

• Understanding the potential impact of ocean acidification is necessary to support development of informed marine environmental policy
• Anticipated that OA will affect life history characteristics of individuals
• *Question: How to scale up impacts on individuals to impacts at community level?*
• Sensitivity to OA and functional importance of species
• Spatial heterogeneity – local stressors on local communities
• Focus on sediment biodiversity in the North Sea (Europe)
• Combine data with simulations to link spatial OA impacts on individual species and ecosystem function
Data – North Sea Benthos Survey 1986

- North Sea – Europe
  - 575,000 km²
  - Shallow ~40m
- 109 stations
- Benthic macrofaunal species abundance and biomass
- Species richness: 557 (13 to 106 at each station)
- Measures of Chl-a and TOC
- Indicators of bioturbation - controls the rate of organic matter decomposition
Linking individuals to community

At each station

Individual: \( BP_i = \log_{10}(Bi) \cdot Mi \cdot Ri \)

Population: \( BP_p = BP_i \cdot Ai \)

Community: \( BPC = \sum BP_p \)

\( BPC = \sum \log_{10}(Bi) \cdot Mi \cdot Ri \cdot Ai \)

Impact of Stressor Change individuals \((Ai, Bi, Ri, Mi)\). Recalculate BPC at community level

Each species
Abundance
Indiv. Biomass
Reworking
Mobility

Reworking
1 = epifauna
2 = surficial modifiers
3 = head–down / head-up feeders
4 = biodiffusers
5 = regenerators

Mobility
1 = in a fixed tube
2 = limited movement, sessile, not in tube
3 = slow movement through sediment
4 = free movement via burrow system

Adapted from Solan et al (2004)
Functional importance

- Functional importance: Proportional contribution to BPC
- Spatial variation: functional redundancy vs dominance of ‘functionally important’ species
- Just because a species is functionally important does not mean it is sensitive to OA
- What about sensitivity to OA?

<table>
<thead>
<tr>
<th>Species</th>
<th>No. stations &gt;30% to BPC</th>
<th>No. stations present (/ 109)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amphiura filiformis</td>
<td>28</td>
<td>79</td>
</tr>
<tr>
<td>Chamelea gallina</td>
<td>8</td>
<td>49</td>
</tr>
<tr>
<td>Echinocardium cordatum</td>
<td>4</td>
<td>61</td>
</tr>
<tr>
<td>Luniatia poliana</td>
<td>3</td>
<td>66</td>
</tr>
<tr>
<td>Mysella bidentata</td>
<td>3</td>
<td>73</td>
</tr>
<tr>
<td>Nephtys cirrosa</td>
<td>2</td>
<td>33</td>
</tr>
<tr>
<td>Ophelia borealis</td>
<td>1</td>
<td>54</td>
</tr>
<tr>
<td>Ophiura albida</td>
<td>1</td>
<td>61</td>
</tr>
<tr>
<td>Protodorvillea kefersteini</td>
<td>1</td>
<td>6</td>
</tr>
</tbody>
</table>

[Chl-a vs Chl-a diagrams showing redundancy and important species present]
Species Sensitivity to OA

- How likely will species be affected by OA?
- 557 species:
  - Lab experiments – limited range of species
- **Biological Traits Analysis** to estimate relative sensitivity to OA
- Determine Traits and Modalities (work in progress!)
- Set sensitivity of each Modality to OA (1 – 10)
- Score each species within Modality
- Combine score and sensitivity => relative sensitivity to OA of each species
- Higher the relative sensitivity, higher the probability that OA will impact species
- Same sensitivity at all sites

<table>
<thead>
<tr>
<th>Trait</th>
<th>Calcereous</th>
<th>Size</th>
<th>Bioturbation activity</th>
<th>Living habit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modality</td>
<td>TRUE</td>
<td>FALSE</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sensitivity</td>
<td>10</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Amph. fil.</td>
<td>1</td>
<td></td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Nephtys cirrosa</td>
<td>0</td>
<td></td>
<td></td>
<td>1</td>
</tr>
</tbody>
</table>

*Sensitivity values range from 0 to 10.*
Sensitivity vs Importance

Species
- Amphiura filiformis
- Chamelea gallina
- Echinocardium cordatum
- Echinocardium flavescens
- Echinocyamus pusillus
- Leptochiton asellus
- Levinsenius gracilis
- Lunatia poliana
- Magelona
- Mysella bidentata
- NEMERTEA
- Nephtys cirrosa
- Nephtys hombergii
- Nucula nitidosa
- Ophelia borealis
- Ophiura albida
- Protodorvillea kefersteini
- Scalibregma inflatum
Scaling up the impacts

Model: \[ BPC = \sum \log_{10}(Bi) \cdot Mi \cdot Ri \cdot Ai \]

Experimental evidence: R and / or M change under OA

OA affects some species more than others.

Given exposure to OA, probability that R and / or M changes given by Relative Sensitivity (BTA).

Direction of change unknown: 50% +- 1

Stochastic simulations

Each iteration:
For each species determine:
- Do R / M change?
- Which directions (+- 1)?
- Recalc. BPC
1000 iterations

Preliminary method and results
Need sensitivity of all species
Future scenario - scale probability of change to reflect magnitude of OA
Example results

- Range of values is indicator of impact of OA on community
- Shape indicates presence of important species
- Impact of OA given by combination of sensitivity and importance of species
Explore Spatial Impacts

= SD of relative BPC
Conclusions and future work

- Results are preliminary!
- Outline method for scaling up impacts on species to impacts on communities at a spatial scale
- Limitations:
  - Model is explanatory i.e. no ecological or temporal dynamics
  - Ignore changes to A and B
- But… first steps
- Future
  - Put all species into BTA
  - Need to scale probability of change to reflect magnitude of stressor – future scenarios
  - More life history characteristics
  - Include other ecosystem functions - not just bioturbation (OrgC and Chla)
Acknowledgements

- NERC / Defra / Decc
- UKOA Project symposium
- Julie Bremner (Cefas)
Thank you