Upscaling the impact of coastal hypoxia from species to ecosystem function. Bioturbation on the Black Sea Shelf.

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Coastal hypoxia

Breitburg et al, 2018

Soetart et al, 2000

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Coastal hypoxia

Breitburg et al, 2018

Soetart et al, 2000

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Question & Approach

Coastal Hypoxia

Macrobenthos

Macrobenthos

Hypoxia: from species to ecosystem
Habitat

Environmental Conditions (e.g. $T^\circ$, light, orgC, $[O_2]$) shape populations
Question & Approach

Functions

- Providing food, shelter
- Regulating erosion, eutrophication, carbon burial

Breitburg et al, 2018
Soetart et al, 2000
Question & Approach

Coastal Hypoxia \(\rightarrow\) Habitat \(\rightarrow\) Macrobenthos

Functions

Impact on biogeochemical cycling

Bioturbation

Bioirrigation

Breitburg et al., 2018

Soetart et al., 2000

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Question & Approach

Coastal Hypoxia → Habitat → Macrobenthos

Functions

Scales

km → mm
Question & Approach

Traits

Modalities of behavior:
- Mobility
- Feeding type
- ..
**Question & Approach**

- **Meta-Modelling**
  - Involve different models at different process scales
    - **Focus model**: Diagenetic model, 1D, 50cm of sediments
    - **General model**: Biogeochemical model, 500km the Black Sea
  - **Meta-Modelling**: To mimic the Focus model in the General Model

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Soetart et al, 2000
Results

Trait Mapping

Question & Approach

Results

- Trait Mapping
- Diagenetic Modelling

Conclusions
Results
Trait Mapping

Stations

August 1995
Wijsman et al., 1999
~30 stations

May 2016
~15 stations

August 2017
~7 stations

Queiros et al., 2015
A. Capet (MAST, Uliège)
Results
Trait Mapping

Species

VanVeen Grabs

Allita Succinea

Mytilus Galloprovincialis

Abundance and biomass of dominant macrobenthic species
### Results

**Trait Mapping**

#### Traits

- Method of sediments reworking
- Propensity to move through the sediment
- Max sediment dwelling depth
- Feeding mechanisms
- Diet
- Larval development mechanisms
- Propagule dispersal
- Larval type
- Degree of attachment
- Relative adult mobility
- Adult life habit
- Maximum adult size
- Tolerance to disturbance

#### Modalities

<table>
<thead>
<tr>
<th>Trait</th>
<th>Modalities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Method of sediments reworking</td>
<td>(1) Epifauna that bioturbate at the sediment-water interface,</td>
</tr>
<tr>
<td></td>
<td>(2) surficial modifiers (&lt;1-2 cm)</td>
</tr>
<tr>
<td>(Reworking mode: Ri)</td>
<td>(3) upward/downward conveyors that actively transport sediment to/from the sediment surface</td>
</tr>
<tr>
<td></td>
<td>(4) Biodiffusors</td>
</tr>
<tr>
<td>Propensity to move through the sedimentary matrix</td>
<td>(1) in a fixed tube</td>
</tr>
<tr>
<td>(Mobility : Mi)</td>
<td>(2) limited movement, sessile, but not in a tube</td>
</tr>
<tr>
<td></td>
<td>(3) slow movement</td>
</tr>
<tr>
<td></td>
<td>(4) free movement via burrow system</td>
</tr>
</tbody>
</table>
Results

Trait Mapping

In-Situ
Median Grain Size
Silt Content
OrgC, TotN

Model (3D GHER-BAMHBI)

Physics:
Temperature
Salinity
Age of bottom waters
Bottom stress

Biogeochemistry:
Hypoxia / Oxygen
OrgC rain / sed. content
PAR

Environ.
Queiros et al, 2015

A. Capet (MAST, Uliège) Hypoxia: from species to ecosystem
Results
Trait Mapping

Stations

Traits

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<tr>
<th>Species</th>
<th>Feeding Mechanisms</th>
<th>Adult Longevity</th>
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<tr>
<td>Mya arenaria</td>
<td>SF 2 DF 1 GB 0</td>
<td>&lt;2 2-5 &gt;5</td>
</tr>
<tr>
<td>Mytilus galloprovincialis</td>
<td>3 0 0</td>
<td>0 1 3</td>
</tr>
<tr>
<td>Nerela rava</td>
<td>0 0 3</td>
<td>3 0 0</td>
</tr>
<tr>
<td>Terebellides stromeli</td>
<td>0 3 0</td>
<td>0 0 3</td>
</tr>
<tr>
<td>Lagis koreni</td>
<td>0 3 0</td>
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Species

Environ.
Results
Trait Mapping

Species

Stations

Traits

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<td>SF: 2, DF: 1, GB: 0</td>
<td>Age: 1, 3</td>
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<tr>
<td>Mytilius galloprovincialis</td>
<td>SF: 3, DF: 0, GB: 0</td>
<td>Age: 1, 3</td>
</tr>
<tr>
<td>Nerelrava</td>
<td>SF: 0, DF: 3, GB: 3</td>
<td>Age: 0, 0</td>
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<td>Age: 0, 3</td>
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A. Capet (MAST, Uliège) Hypoxia: from species to ecosystem 4/10
Results

Trait Mapping

Multiple Linear Regression

\[ f(\text{Age}_{\text{std}}, \text{oxy}_{\text{av}}, \text{depth}, \text{oxy}_{\text{std}}, \text{H}_{\text{index}}) \]

\[ R^2 = 0.7938, \quad \text{Adjusted } R^2 = 0.7446 \]

\[ \text{Mi}_4: \text{free movement, burrower} \]

\[ +\text{DEPTH} \]
Results
Trait Mapping

\[ f(Age_{\text{std}}, oxy_{\text{std}}, \text{depth}) \]
\[ R^2 = 0.41, \text{Adjusted } R^2 = 0.3428 \]

Ri1: Epifauna

Age_{\text{std}} (in days)

Oxy_{\text{std}} (in mmol/m^3)
Results

Trait Mapping

Bioturbation Community Potential ($BP_c$)

$$BP_c = \sum_{i=1}^{n \text{ species}} \sqrt{\text{Biomass}_i \cdot \text{Mobility}_i \cdot \text{Reworking}_i}$$

Solan et al, 2004
Results
Diagenetic Modelling

1 Question & Approach

2 Results
- Trait Mapping
- Diagenetic Modelling

3 Conclusions
Results

Diagenetic Modelling

Capet et al, 2016

Region 1 23,7.10³ km²; 15-57m
- $D_C$: 25 mmolC/m²/d
- Oxic: 18.3%
- Denit.: 5.9%
- Anox.: 76.0%

Region 2 33,9.10³ km²; 26-109m
- $D_C$: 9.8 mmolC/m²/d
- Oxic: 41.8%
- Denit.: 6.3%
- Anox.: 51.9%

Region 3 21,4.10³ km²; 46-120m
- $D_C$: 4.3 mmolC/m²/d
- Oxic: 68.8%
- Denit.: 5.1%
- Anox.: 26.1%
Results

Diagenetic Modelling

Denitrification ratio as a function of:
- Benthic respiration
- Bottom oxygen concentration
Results

Diagenetic Modelling

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Hypoxia : from species to ecosystem
Results
Diagenetic Modelling

A. Capet (MAST, Uliège)

Hypoxia: from species to ecosystem

Region 1: 23.7 x 10^6 km²; 15-57m
- Dissolved Oxygen (DO): 25 mmol/Kg
- Oxidation: 18.3%
- Denitrification: 1.9%
- Anoxia: 76.0%

Region 2: 33.9 x 10^6 km²; 26-109m
- DO: 9.8 mmol/Kg
- Oxidation: 41.3%
- Denitrification: 6.3%
- Anoxia: 51.9%

Region 3: 21.4 x 10^6 km²; 46-120m
- DO: 4.3 mmol/Kg
- Oxidation: 68.8%
- Denitrification: 5.1%
- Anoxia: 25.1%
Conclusions

- Sediments are a nightmare for marine modellers..
Conclusions

- Sediments are a nightmare for marine modellers..
- .. but should be considered to resolve shelf biogeochemistry
Conclusions

- Sediments are a nightmare for marine modellers..
- .. but should be considered to resolve shelf biogeochemistry
- We propose a methodology to do so in large scale oceanic models
Conclusions

Thank for your attention

(BenthOx)

(2016-2020)