Ecological risk of treated ballast water: a mesocosm experiment

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Outline

• Introduction
• Background of mesocosm testing
• Research questions
• Preliminary results from pilot study
• Test result summary
• Conclusions
Ecological risk of discharge ballast water that use active substances (G9)

- Modelling with MAMPEC-BW
- WET Toxicity testing with:
  - “algae”
  - “crustacean”
  - “fish”

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Assessment factors
GESAMP 38th meeting (PNEC general)

- Lowest short-term L(E)C50 from 1-2 fresh/marine species from one or two trophic levels
- Lowest short-term L(E)C50 from 3 fresh/marine species representing three trophic levels
- Lowest short-term L(E)C50 from 3 fresh/marine species representing three trophic levels + 2 additional marine species, or 1 chronic NOEC from fresh/marine species but not algae
- 2 chronic NOEC from fresh/marine species including algae representing two trophic levels
- 3 chronic NOEC from fresh/marine species including algae representing three trophic levels

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Assessment factors

• Experimental ecosystems
  – Realistic semi-natural conditions
  – Reduce uncertainty in extrapolation to complex multi-species studies

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Experimental ecosystems challenges for treated ballast water

• How to discriminate between effects caused by replacement of water and effects of toxic substances?

• How predictive are toxicity test results (i.e. bioassays) for effects of treated ballast water on ecosystems?

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Set-up of the mesocosm experiment

- Eight tanks of 5 m³ each
- Sediment layer & Water fraction
- Stable community of:
  - micro-flora
  - invertebrates
- Static systems
- Continuous aeration
- Similar water quality conditions

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Dosing of treated ballast water

Replacement of 10% water volume by 3 types of treated ballast water

DAY -5  →  BW-d5  →  BW-d5  →  Control

DAY -1  →  BW-d1  →  BW-d1  →  Control

DAY 0  →  BW-d0  →  BW-d0  →  Control

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Chemistry at start of exposure

H₂O₂

PAA

Treatment

concentration H₂O₂ (mg/l)

concentration PAA (mg/l)

bw = discharge ballast water
mc = mesocosm +10% bw

Control
BW-d5
BW-d1
BW-d0

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Toxicity testing

Bacteria toxicity test
10% of discharge samples

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Bacteria</th>
<th>Rotifer</th>
<th>Algae</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
</tr>
<tr>
<td>BW-d5</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
</tr>
<tr>
<td>BW-d1</td>
<td>NO</td>
<td>NO</td>
<td>YES</td>
</tr>
<tr>
<td>BW-d0</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
</tr>
</tbody>
</table>

Rotifer toxicity test
10% of discharge samples

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Bacteria</th>
<th>Rotifer</th>
<th>Algae</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
</tr>
<tr>
<td>BW-d5</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
</tr>
<tr>
<td>BW-d1</td>
<td>NO</td>
<td>NO</td>
<td>YES</td>
</tr>
<tr>
<td>BW-d0</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
</tr>
</tbody>
</table>

Algal toxicity test
10% of discharge samples

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Bacteria</th>
<th>Rotifer</th>
<th>Algae</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
</tr>
<tr>
<td>BW-d5</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
</tr>
<tr>
<td>BW-d1</td>
<td>NO</td>
<td>NO</td>
<td>YES</td>
</tr>
<tr>
<td>BW-d0</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
</tr>
</tbody>
</table>
Measurements & Analysis

• Water quality parameters
  – pH, oxygen, salinity, temperature, turbidity
  – TOC, DOC, POC, hardness
  – Nutrients (NH4, NO3, NO2, PO4, SiO2)
  – Weather conditions

• Zooplankton

• Phytoplankton
  – Biomass as chlorophyll-a
  – Community, periphyton

• Benthic organisms
  – Mudshrimps, lug worms,

• Invertebrates
  – Cockles, breadcrumb sponges, periwinkles, mussels

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Phytoplankton

Total Chlorophyll-a (µg/l)

-42 -28 -14 0 14 28 42 56 70

5 10 15

Control BW-d5 BW-d1 BW-d0

daynr.

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Zooplankton

Copepod (calanoid)

Copepod (harpacticoid)

Daynr.

Daynr.

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Bivalves

Bivalvia

Cockle (juveniles)

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Macro-invertebrates

Corophium volutator

Microdeutopus gryllotalpa

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Macro-invertebrates

Polydora ciliata

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Control</th>
<th>BW-d5</th>
<th>BW-d1</th>
<th>BW-d0</th>
</tr>
</thead>
<tbody>
<tr>
<td>count</td>
<td>0</td>
<td>10</td>
<td>5</td>
<td>0</td>
</tr>
</tbody>
</table>

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## Summary

<table>
<thead>
<tr>
<th>Control versus →</th>
<th>BW-d5</th>
<th>BW-d1</th>
<th>BW-d0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bacteria test</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Algae test</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rotifer test</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Chlorophyll-a</td>
<td>C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Copepod (calanoid)</td>
<td>N</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Copepod (harpacticoid)</td>
<td>N</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bivalvia larvae</td>
<td>N</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cockles (juveniles)</td>
<td>N</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corophium volutator</td>
<td>N</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Microdeutopus grylotalpa</td>
<td>N</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Polydora ciliate</td>
<td>N</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Halichondria panicea</td>
<td>G</td>
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<tr>
<td>Mytilus edulis</td>
<td>G</td>
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</tr>
<tr>
<td>Ctenodrilus serratus</td>
<td>N</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cockles (adults)</td>
<td>N</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oligochaeta sp.</td>
<td>N</td>
<td></td>
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</tr>
<tr>
<td>TOC</td>
<td>C</td>
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<td></td>
</tr>
<tr>
<td>DOC</td>
<td>C</td>
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<tr>
<td>Acidity</td>
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<td>Oxygen</td>
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<tr>
<td>Ortho-phosphate</td>
<td>C</td>
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<tr>
<td>Littorina littorea</td>
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</tr>
<tr>
<td>Arenicola marina</td>
<td>N</td>
<td></td>
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</tr>
<tr>
<td>Ammonium</td>
<td>C</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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Conclusions

• How to discriminate between effects caused by replacement of water and effects of toxic substances?
  – Replacement of water with no active substances is not free from effects.
  – However, the level of toxic substances present in the treated water corresponded with the amount of effects.

• How predictive are toxicity test results (i.e. bioassays) for effects of treated ballast water on ecosystems?
  – Effects seen in bioassays are not directly copied in mesocosms.
    • results might be affected by physical characteristics like pH, oxygen, DOC, N/P.
  – However, high risk indicated by the toxicity tests corresponded with high level of disturbances of the ecosystem.

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