Biomarker response distributions as tool to validate environmental risk and to monitor early effects of emerging pollutants in Arctic species or ‘Biomarker Bridges’

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Abstract

- Environmental management of the southern Barents Sea in Norway will be **risk based**
- The state of the environment will be controlled through monitoring of **environmental indicators**
- Important that assessment schemes are **coherent**!
  - i.e. that information from risk assessment and field monitoring can be evaluated in relation to the same established set of environmental standards and discharge requirements
Abstract

- Preventive environmental management requires the use of technology and practice to proactively avoid damage by the oil industry operators.

- It will require the capacity:
  - to make early diagnosis of subtle anthropogenic effects
  - detect possible changes in:
    - populations of ecological indicator species
    - eco-fisheries parameters

- Regional environmental management of the southern Barents Sea should take into account specific regional characteristics.

  - assessments and monitoring should be based on species and conditions of the region rather than on generic eco-toxicological model species.
Abstract

- We think that assessment of environmental sensitivity in the region can partly be accomplished through a set of representative ecological indicator species for which sensitivity distributions can be established in relation to relevant known stressors (e.g. oil).

- This can be applied both to the end-points of fitness.

- And to early diagnosis parameters at low levels of biological organization in the selected ecological indicator species.

- This concept integrates predictive risk assessment and monitoring.
Abstract

- This presentation will focus on
  - principles for establishment of sensitivity distributions related to the early diagnosis parameters – ‘Biomarker response distributions’
  - their state of development
  - applicability as integrated approach to risk assessment and bio-monitoring of known (oily) discharges combined with emerging pollutants
  - inclusion of Arctic / Barents Sea species
Acceptable Risk

Unacceptable Risk

How can we monitor this in the field?

the risk assessment procedure is based on chemical discharge data

the validation is based on biological response parameters (biomarkers)

chemical/biological integration!

Species Sensitivity Distributions used is Environmental Risk Assessment

Risk = f(Potentially Affected Fraction of species)

Concentration of toxic compounds
Terms & assumptions

- **Biomarkers** measure exposure to pollutants and give an assessment of the health status of individual animals.

- Health condition in an ecosystem is reflected by the health condition in a representative subset of organisms in the ecosystem.

  - By measuring the health status of a range of species representing different phylogenies and feeding types, we can use a weight of evidence approach to envisage the ecological consequences of pollutant exposures.

Experimental basis - Chronic oil exposures of fish and invertebrates

<table>
<thead>
<tr>
<th>Biomarkers</th>
<th>Fitness</th>
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Commonly used environmental goal:
PAF \leq 0.05 (5%)
Data: Biomarkers for Genotoxic stress

**Fish**
Cod, sheepshead minnows

**Invertebrates**
Shrimps, mussels, scallops and sea urchins

**DNA adducts**
Measured in samples of the liver by the $^{32}\text{P}$-postlabelling technique using thin layer chromatography (TLC)

**DNA strand breaks**
Measured in 'blood' cells of bivalves and sea urchins by the comet assay and in hepatopancreas of shrimps by the alkaline unwinding assay

**Principle for Construction of a Biomarker Response Distribution (BRD) for oil:**
Building the “biomarker bridge”
The Lowest Observed Effect Concentration for Genotoxic stress
establish a biomarker response distribution based on these results

LOECs for Genotoxic stress in the experiments

Concentration THC (µg/L)
Genotoxic Biomarker Response Distribution (BRD) vs Risk curve (chronic SSD)
The biomarkers for Genotoxic stress can contribute to early warning signals for effects predicted by the risk curve - in a suite of biomarkers.
Other biomarker results

• Genotoxic stress markers were used as example of how a Biomarker Response Distribution can be constructed

• Other biomarkers were measured in the same experiments...

• representing different kinds of exposures and effects
  
  - PAH metabolites
  - Oxidative stress (GST, catalase, TOSC)
  - Lysosomal membrane stability
PAH metabolites - BRD

- Cod - study A
- Cod - study B
- Sheepshead minnow – study A
- Sheepshead minnow – study B

Combined risk curve
5% level
Oxidative stress - BRD

NB! Biomarker LOEC determined by absolute deviation from control (+/-)
Lysosomal membrane stability - BRD

- Sea urchin - study A
- Shrimp - study A
- Shrimp - study B
- Scallop - study A

Concentration THC

Potentially affected fraction of species

Concentration THC
The "Biomarker Bridge" curve

The relationship between risk and biomarker responses in relation to fraction of affected species

The "Bridges" help to set a scale of severity for biomarkers when used as early warning environmental indicators related to risk in a risk based management.

Biomarker signals: Fraction of biota with observed Genotoxic stress

(shrimp/mussel/sea urchin/cod/carp)
State of development

- "Bridges" that link environmental risk and biomarkers have been constructed

- For further development of the tool
  - need data for more species to establish generic robust BRDs (~15 species)
  - need data for a broader range of environmental stress to cover possible emerging pollutants
  - need data for Arctic / Barents Sea species for regional application

✓ Several ongoing and planned projects will generate relevant data for model- and Barents Sea species
### Species & types of stress

#### Emerging pollutants

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<thead>
<tr>
<th>Type of Biomarkers</th>
<th>Biotransformed metabolic stressors</th>
<th>General toxic stress</th>
<th>Oxidative stress</th>
<th>Genotoxic stress</th>
<th>Endocrine disruptive stress</th>
<th>Immuno-toxic stress</th>
<th>Histo-logical changes</th>
<th>Fitness related effects</th>
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<tbody>
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<td>Animal species</td>
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<td>Fish Arctic</td>
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<td>Wolffish (spotted)</td>
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<td>Model fish</td>
<td>Sheepshead minnow</td>
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<td>Model invert</td>
<td>Mussel</td>
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<td>Invert. Arctic</td>
<td>Icelandic scallop</td>
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<td>Invert. Arctic</td>
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<td>Invert. Arctic</td>
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<td>Invert. Arctic</td>
<td>Calanus sp.</td>
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<td>Gammarus wilkitzkii</td>
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- By including different kinds of stress indicators, the tool can be applicable to detect biological responses to emerging pollutants.
Concluding remarks

- Predictive Risk Assessment and Biomarker based monitoring (in caged organisms) are currently in use to assess risk and effects in water column organisms in the Norwegian sector of the North Sea.

- The ”Biomarker Bridge” tool can:
  - integrate such predictive Risk Assessment with Biomonitoring to obtain coherent assessment schemes
    - this implies an integration of (predicted) chemical constituents of oily discharges (e.g. produced water) to biological responses (in-situ)
  - provide early indication of Emerging Pollutants as Biomarker response signals deviate from the predicted
  - contribute to facilitate Environmental Indicators for the Risk based Environmental management of the Barents Sea and other Arctic waters
Acknowledgements

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  - the Research Council of Norway for funding the project

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  - Thank you for your attention!