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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Based on project funded by the Research Council of Norway
with additional data from industry project BioSea I (Total & Eni)

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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 !
  - ie. 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

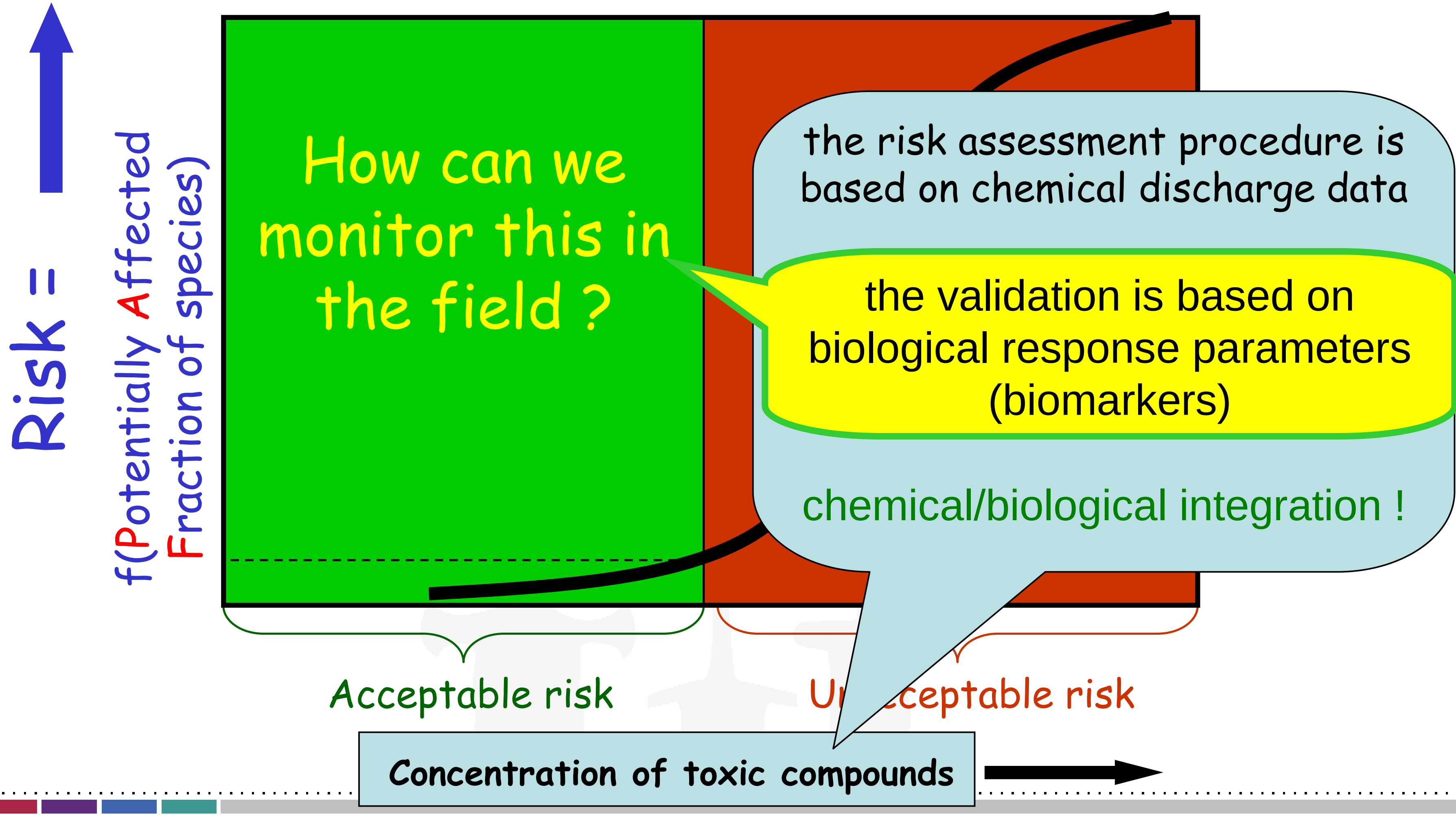
Abstract

- 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

Species Sensitivity Distributions used is Environmental Risk Assessment



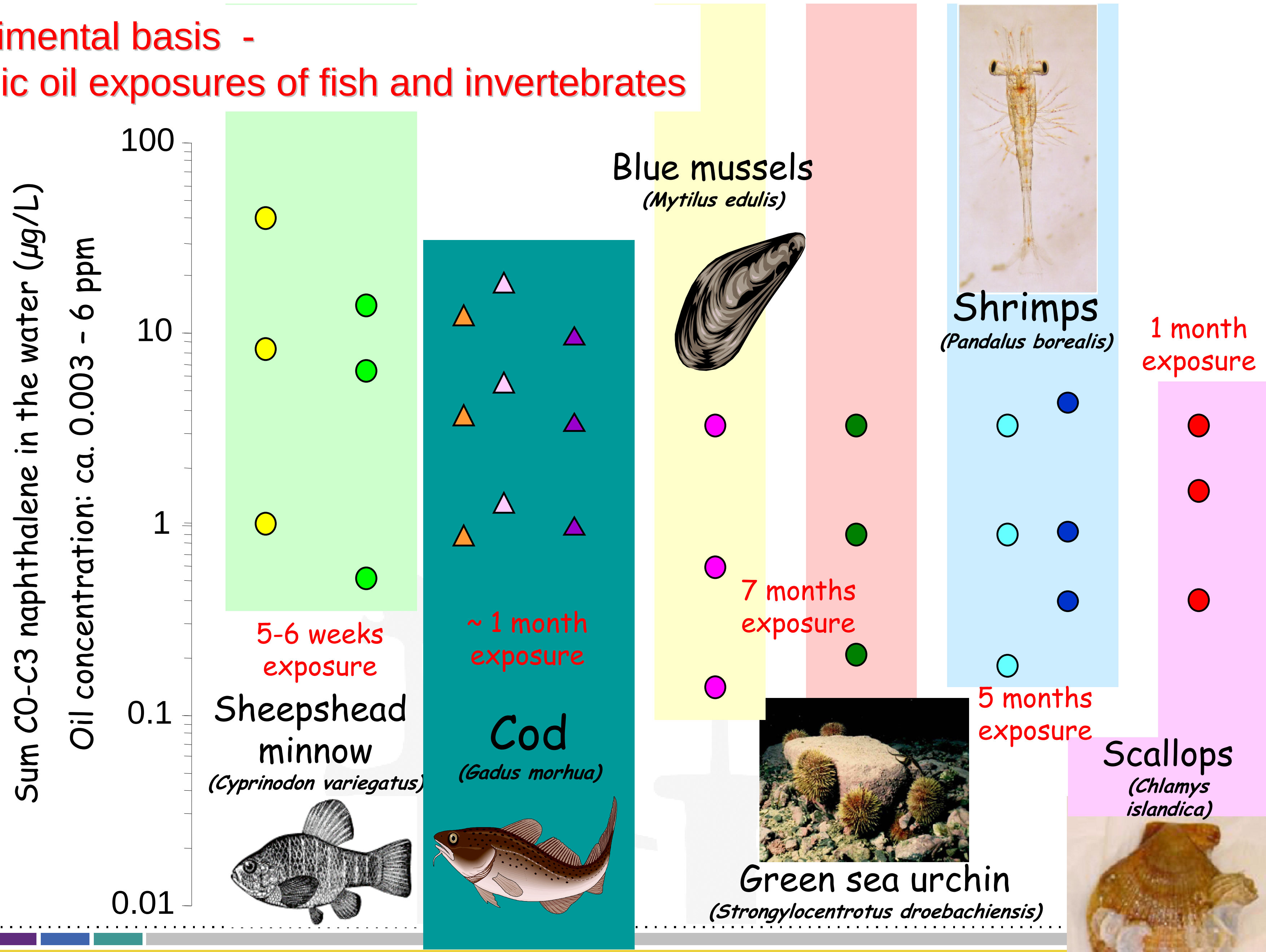
Terms & assumptions

- 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 concequences of pollutant exposures

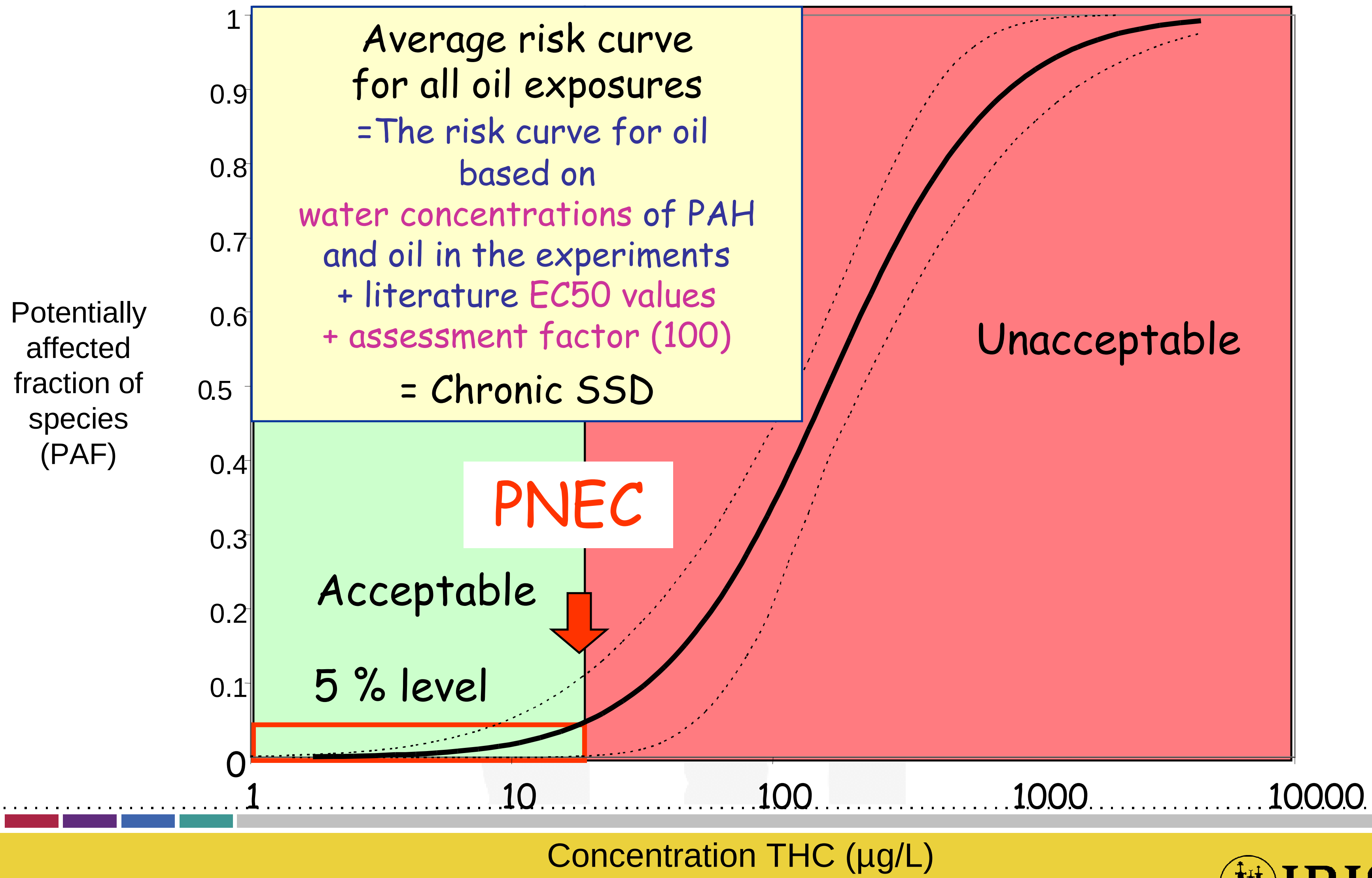
  - Depledge & Galloway, *Front Ecol Environ* 2005; 3(5): 251-258.

Experimental basis -
Chronic oil exposures of fish and invertebrates



Biomarkers	X	X	X	X	X	X
Fitness	X		X		X	

Commonly used environmental goal:
PAF ≤ 0.05 (5%)



Principle for Construction of a Biomarker Response Distribution (BRD) for oil: Building the "biomarker bridge"

Data: Biomarkers for Genotoxic stress

Fish
Cod, sheepshead minnows

DNA adducts

Measured in samples of the liver

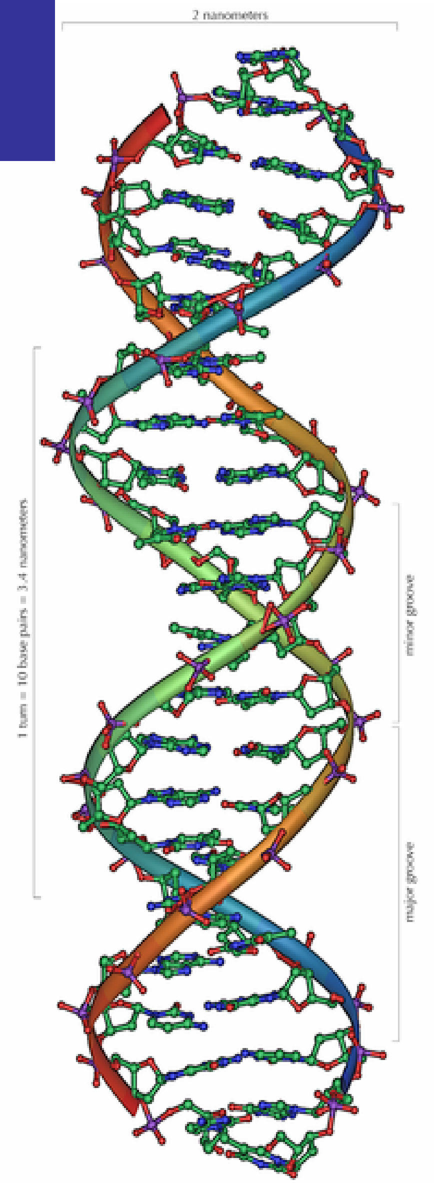
by the ^{32}P-postlabelling technique using thin layer chromatography (TLC)

Invertebrates
Shrimps, mussels, scallops and sea urchins

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



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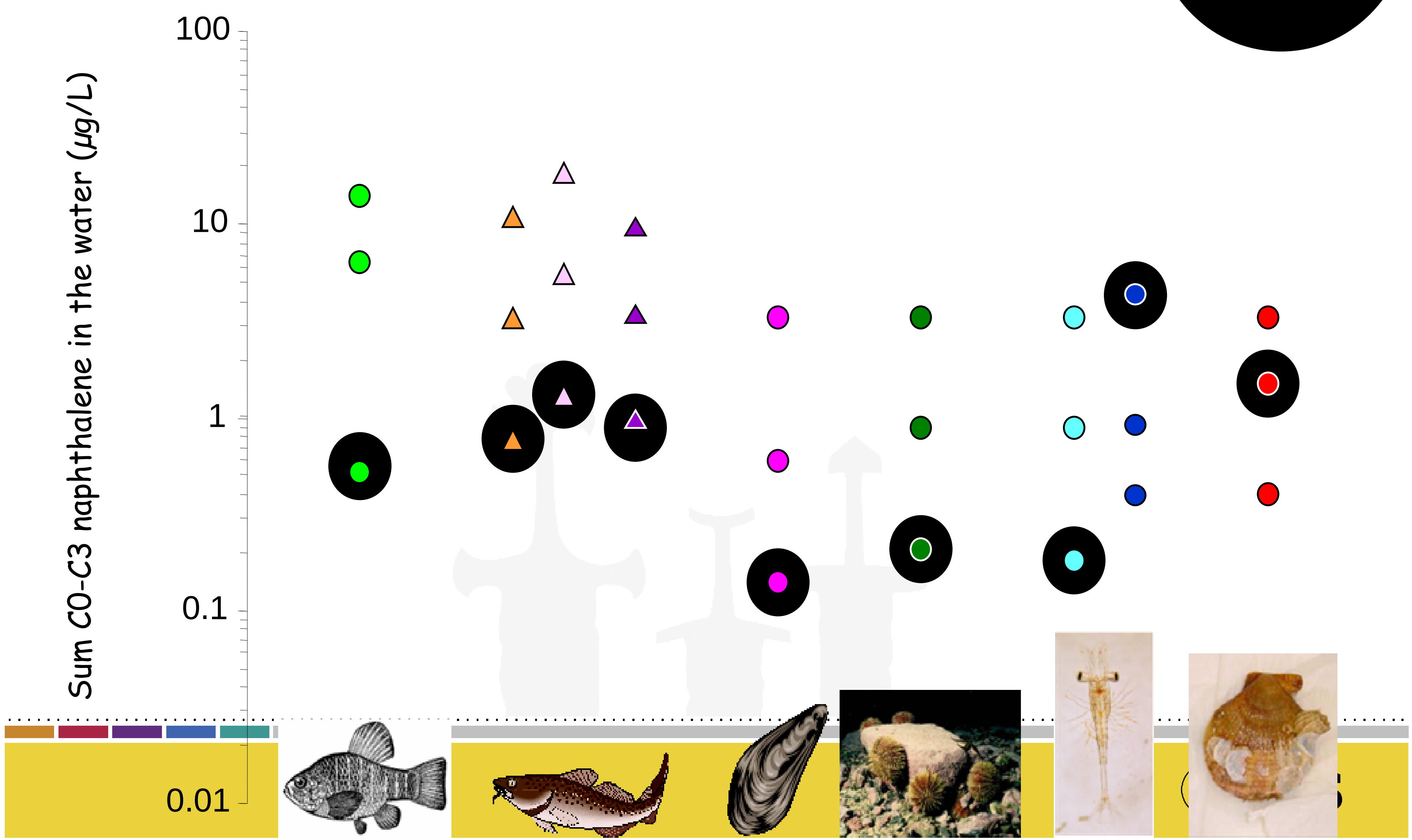
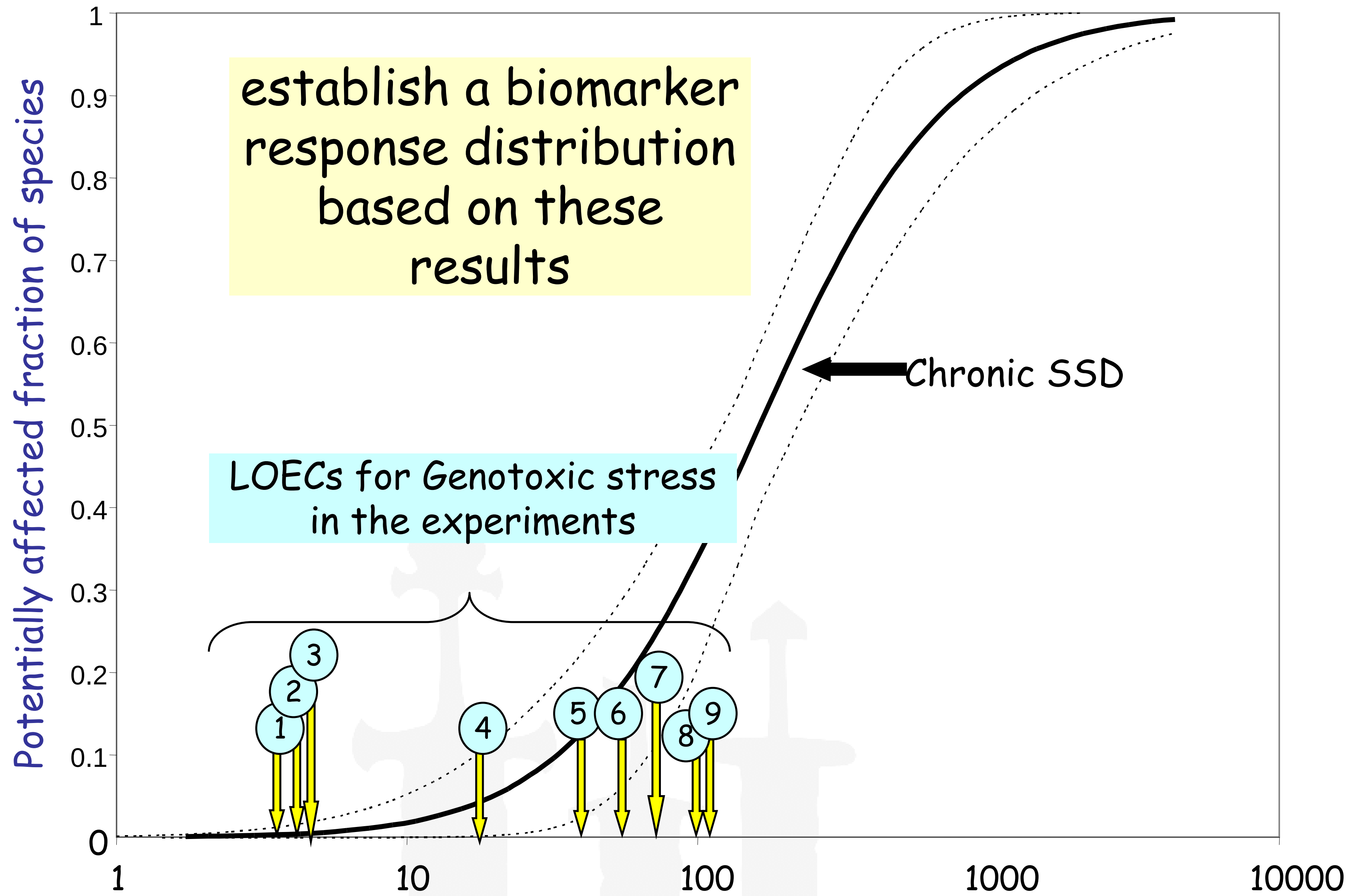
The Lowest Observed Effect Concentration for Genotoxic stress

LOEC





Concentration THC (μg/L)

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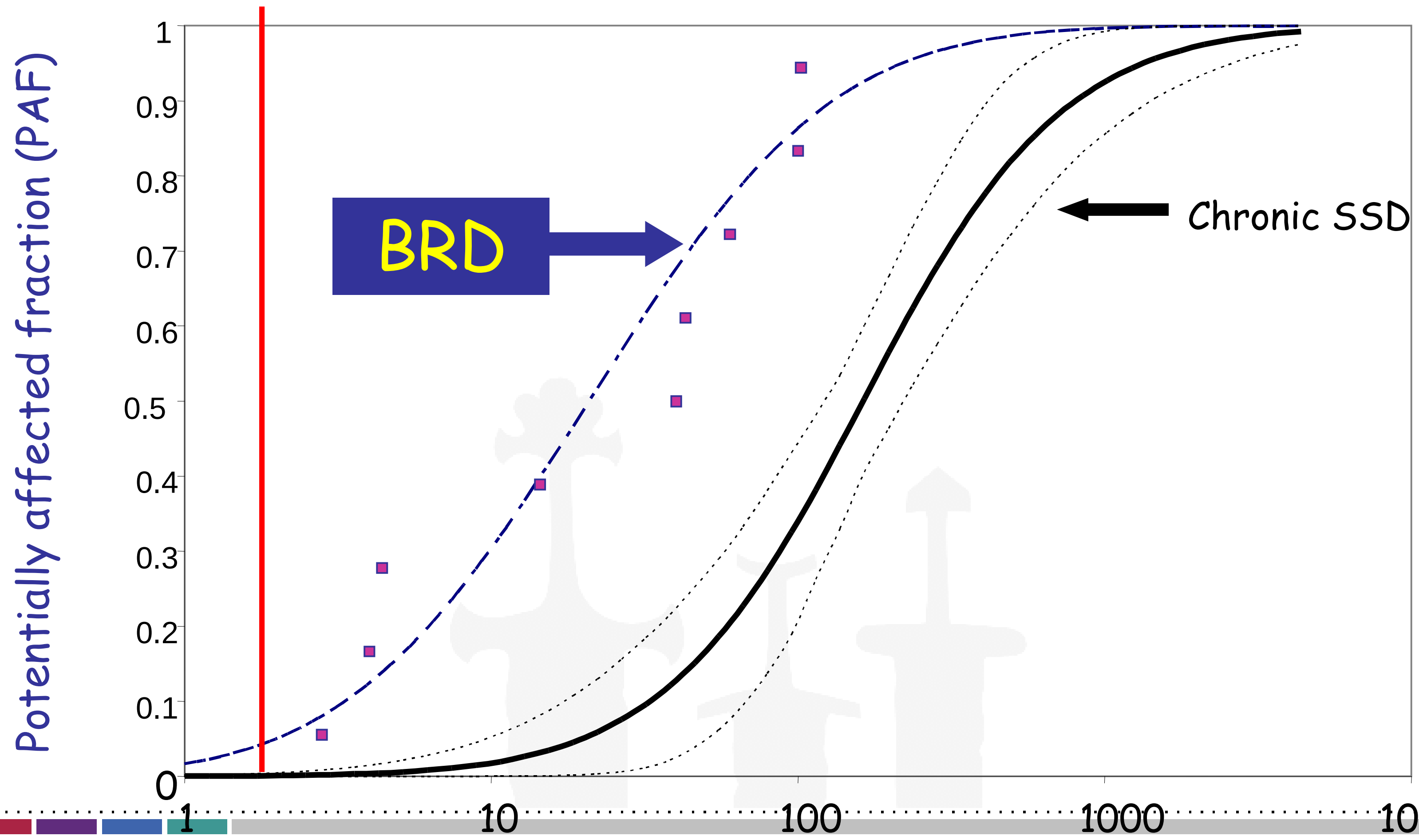
Genotoxic Biomarker Response Distribution (BRD)
vs
Risk curve (chronic SSD)



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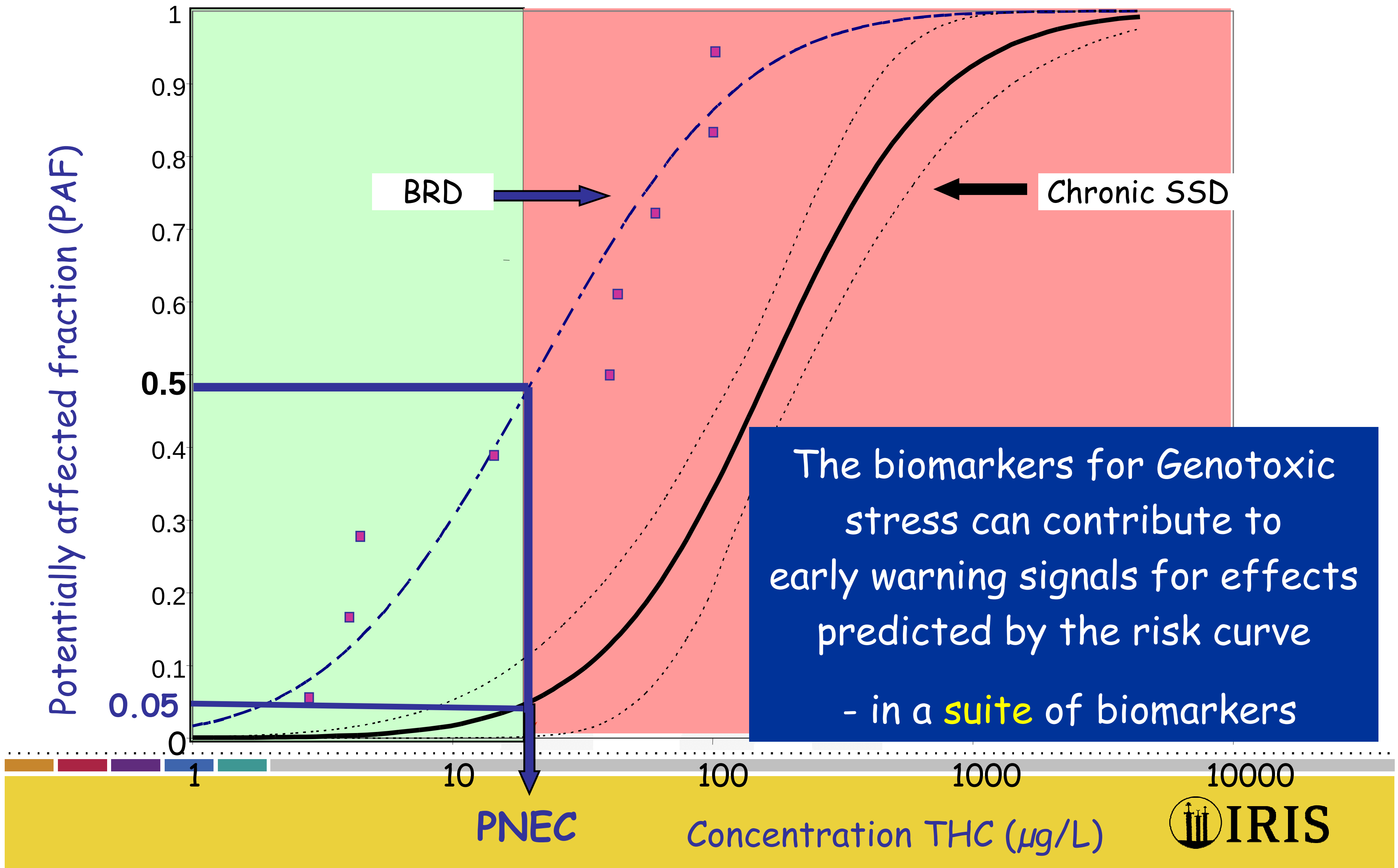

Potentially affected fraction (PAF)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.05
0
1
10
100
1000
10000
BRD
Chronic SSD
PNEC
Concentration THC (µg/L)
The biomarkers for Genotoxic stress can contribute to early warning signals for effects predicted by the risk curve
- in a suite of biomarkers
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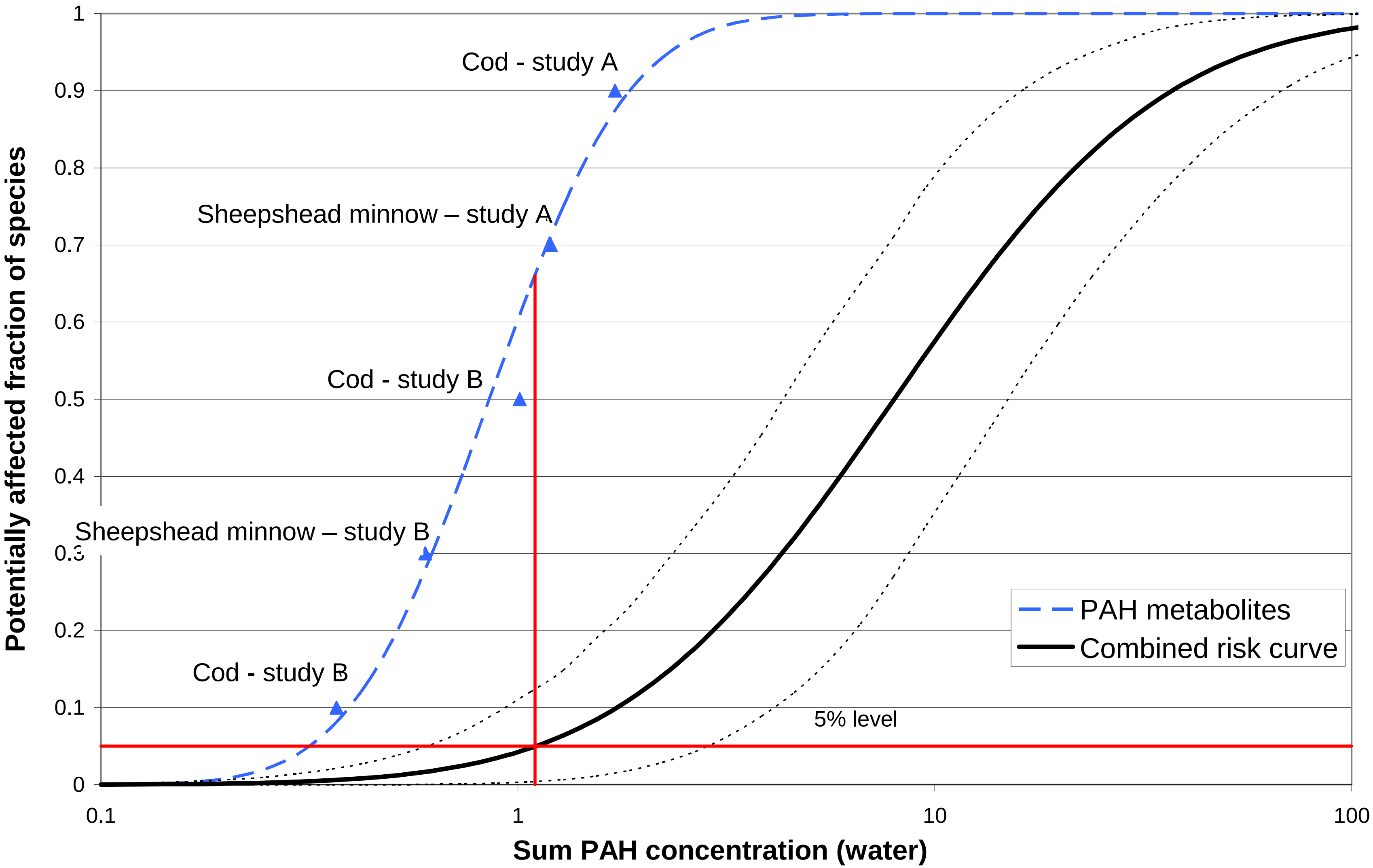
Other biomarker results

- Genotoxic stress markes 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



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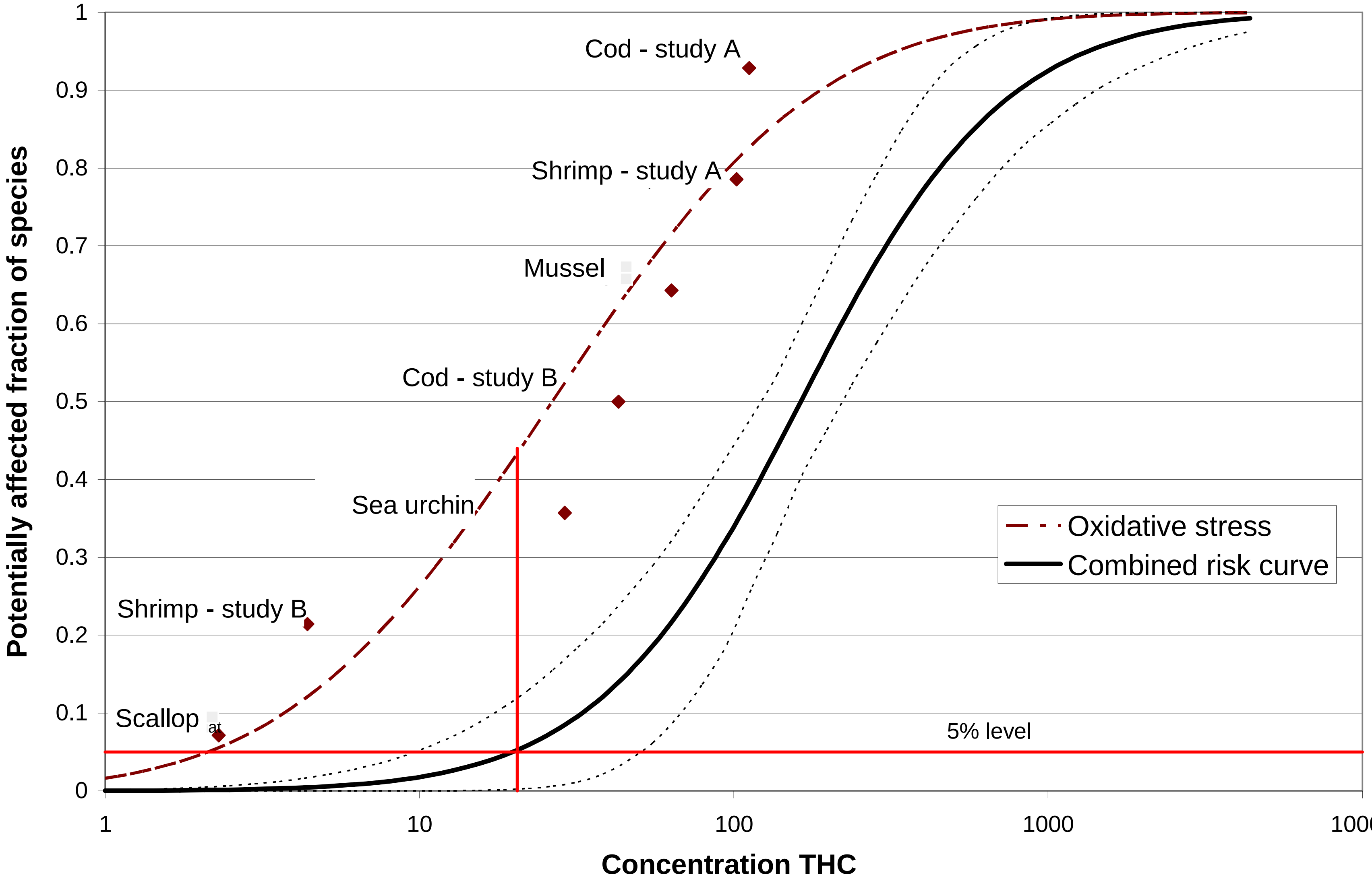
Oxidative stress - BRD



NB! Biomarker LOEC determined by absolute deviation from control (+ / -)

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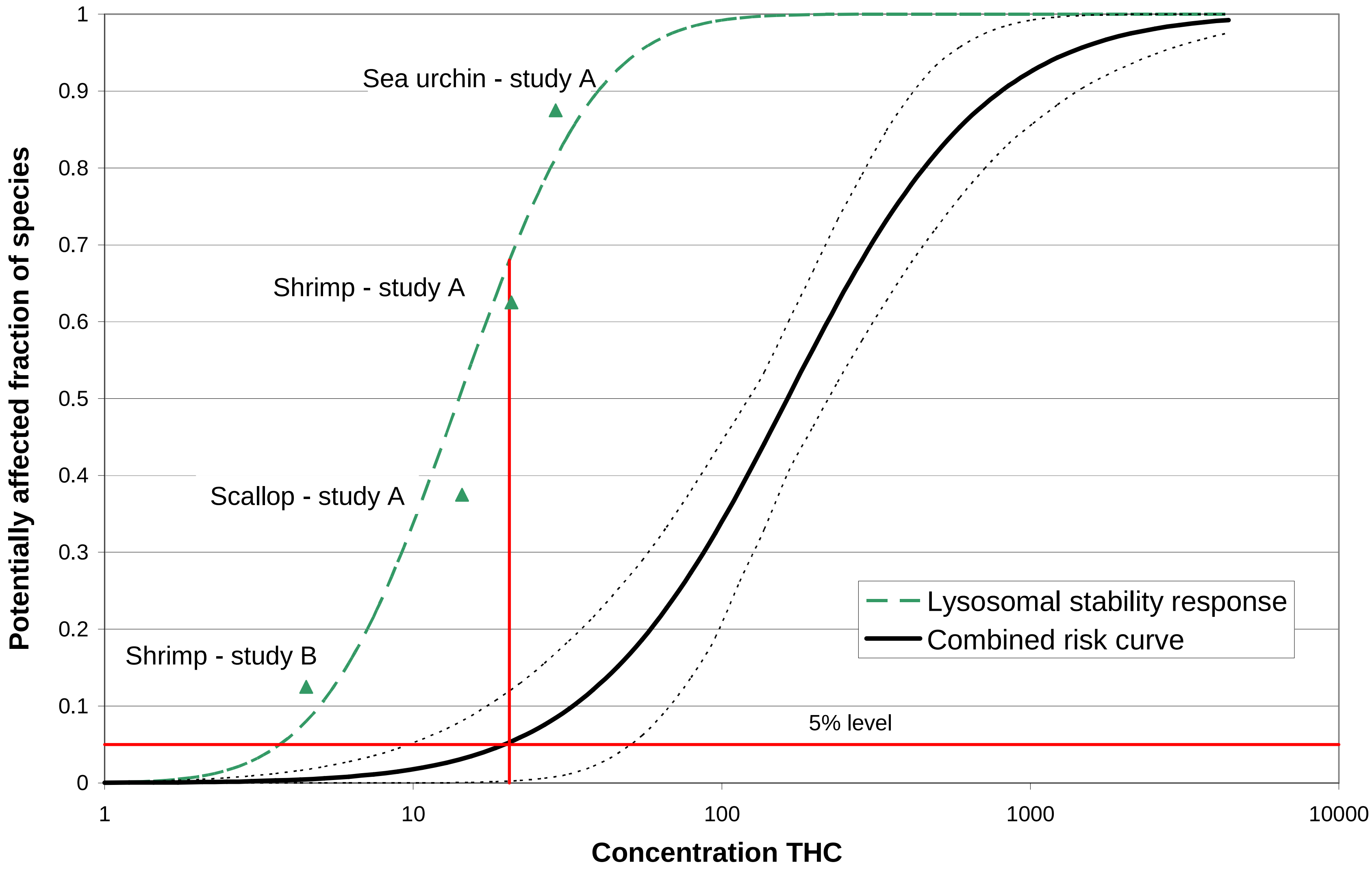
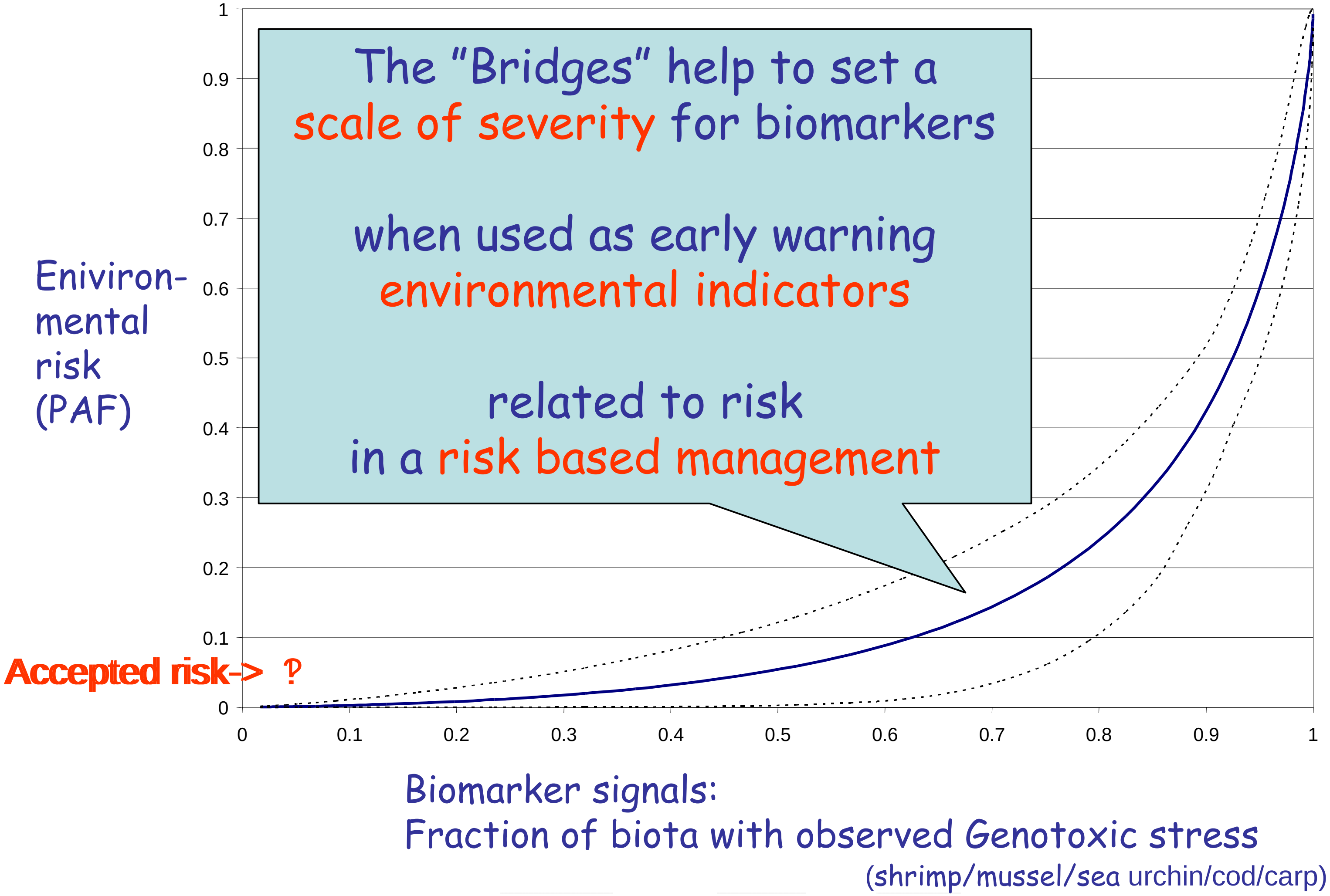
Lysosomal membrane stability - BRD



The "Biomarker Bridge" curve

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



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

Data existing or under way

	Type of Biomarkers / Animal species	Biotransformed metabolic stressors	General toxic stress	Oxi-dative stress	Geno-toxic stress	Endocrine disruptive stress	Immuno-toxic stress	Histo-logical changes	Fitness related effects
fish Arctic	Atlantic cod								
fish Arctic	Wolffish (spotted)								
fish Arctic	Polar cod								
fish Arctic	Capelin								
fish Arctic	Herring								
fish Arctic	Halibut								
model fish	Sheepshead minnow								
model fish	Zebra fish								
model fish	Turbot								
model invert.	Mussel								
invert. Arctic	Icelandic scallop								
invert. Arctic	Sea urchin								
invert. Arctic	Northern shrimp								
invert. Arctic	Calanus sp.								
invert. Arctic	Gammarus wilkitzkii								

➢ By including different kinds of stress indicators, the tool can be applicable to detect biological responses to emerging pollutants

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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 co-herent 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 an other Arctic waters

Acknowledgements

- We would like to thank
  - the Research Council of Norway for funding the project
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    which made it possible to construct
    these pilot Biomarker Response Distributions

  - Thank you for your attention!

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