Main challenges for the use of biomarkers towards a sustainable management for the marine environment protection

Challenges related to the linking of impact prognostics (predictions) and diagnostic monitoring tools. Challenges in balancing environmental cost contra benefit.

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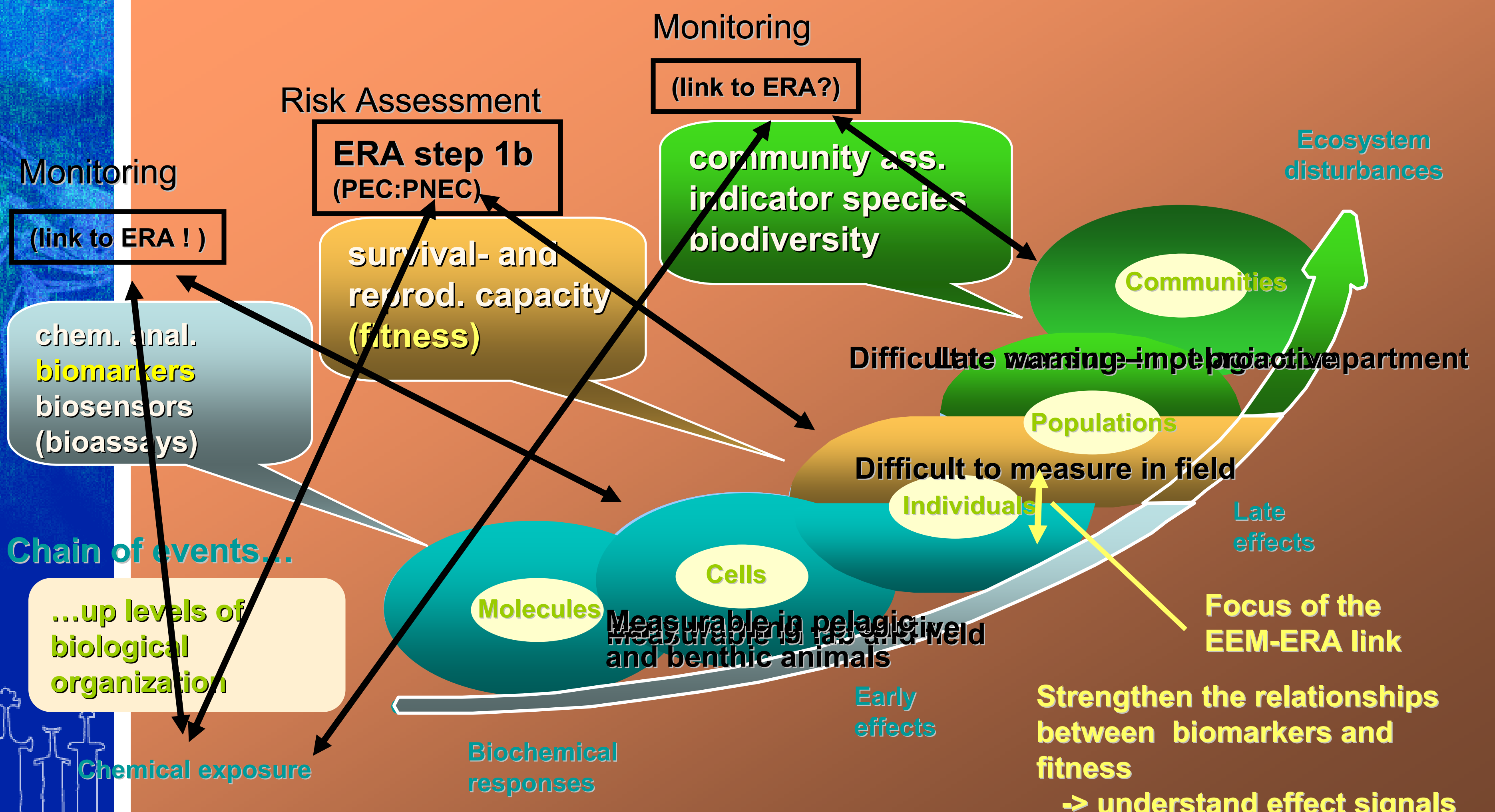
Linking of impact prognostics (predictions) and diagnostic monitoring tools

- Integration of Biomarkers in ERA
  - Motivation
  - Approach
  - Solutions
  - Challenges

Integration of Biomarkers in ERA

Motivation and Approach



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Integration of Biomarkers in ERA

EEM – ERA link

- Approach
  - Build a 'Biomarker Bridge'
    - Why?
      - enables field monitoring of accepted biological effect levels determined by risk assessment
    - How?
      - strengthen the relationships between biomarkers and fitness (lab studies)
    - Additional benefit!
      - this will improve understanding of biomarker signals -> contributes to interpretation basis for biomarkers
  - Alternative approach:
    fully unite 'Test endpoint' to 'Assessment endpoint' (=Biomarkers)
    - Realistic alternative?
      - Ecological relevance of biomarker responses remains to be fully defined
  - Definition of threshold levels and criteria to quantify ecological relevance must be established for biomarkers !

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Integration of Biomarkers in ERA

Challenges

- The correlations between fitness and biomarkers are not necessarily based on causal relationships !
  - Only some of the links between biomarkers and fitness effects are well known and understood in a mechanistic way
  - Same dilemma as in human health research
- To overcome this problem
  - There is a need for sufficient amount of data to be able establish statistical relationships or 'weight of evidence' to determine the relevance of biomarkers in relation to fitness and ecological effects
  - An advantage before human health research is that we can be more experimental !

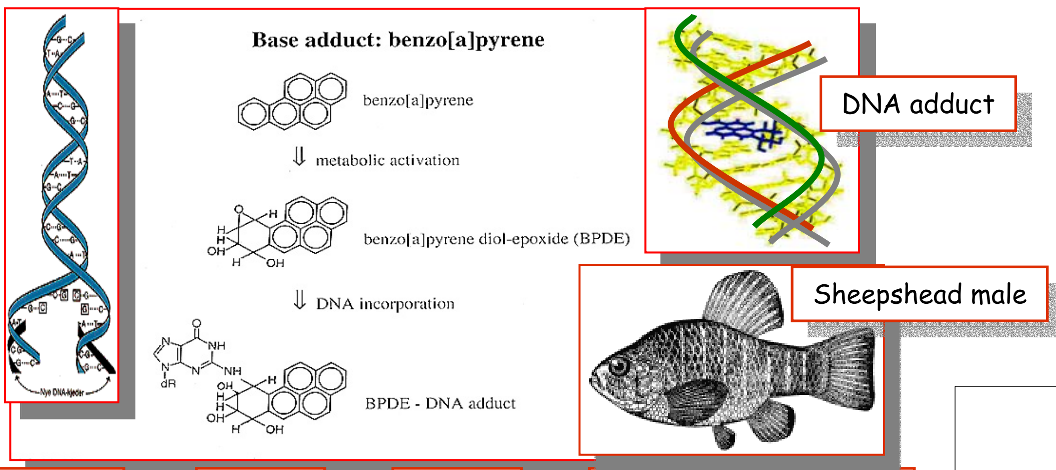
Integration of Biomarkers in ERA

- Solutions
  - Building the 'Biomarker bridge'
    - Two examples:
      - Vertebrate
        - » Fish (sheepshead minnow – *Cyprinodon variegatus*)
      - Invertebrate
        - » Crustacea (Northern shrimp – *Pandalus borealis*)

Building of the 'Biomarker bridge'

Correlations fitness and biomarkers (example):

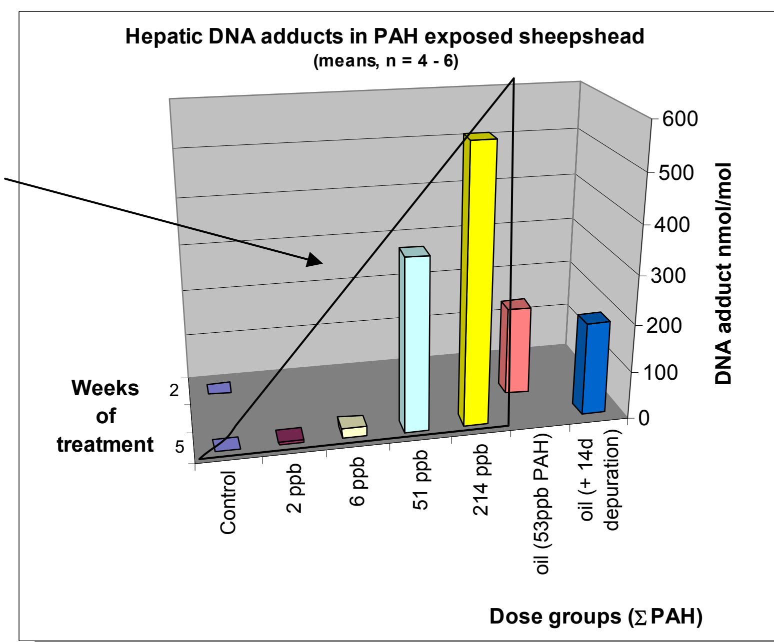
Lab. Effect study exposure of fish



Biomarker:
Benzo[a]pyrene
DNA adduct

0 | 2 ppb | 6 ppb | 51 ppb | 214 ppb

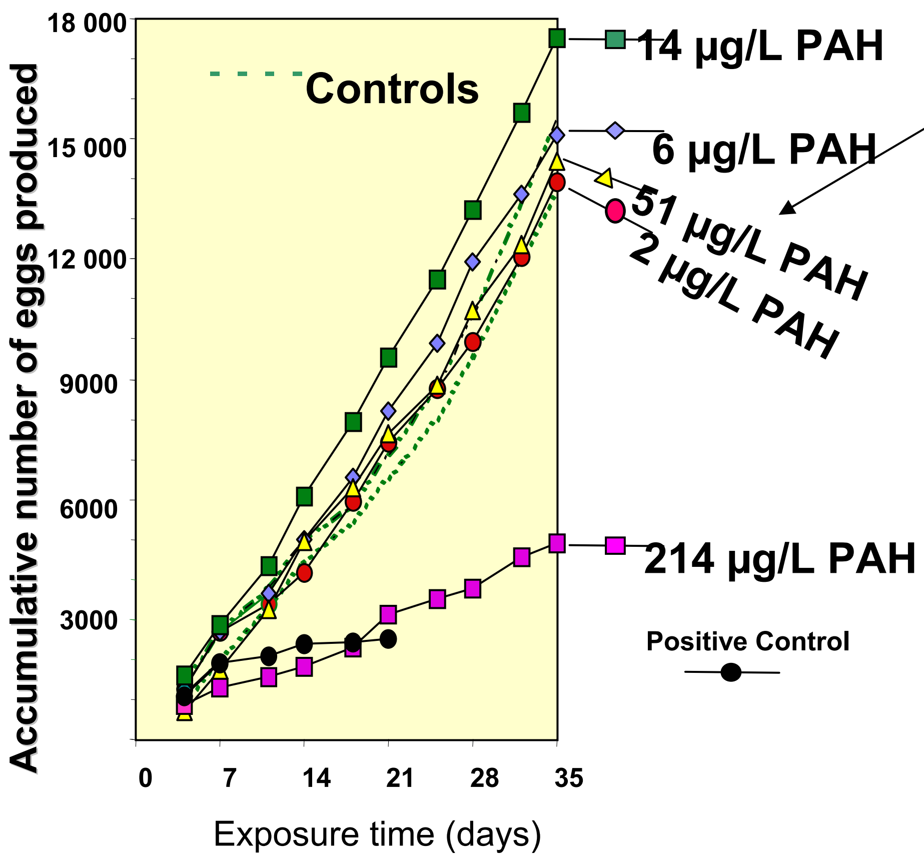
Increasing PAH dose (ppb in water) /
increasing biomarker effect (adducts in liver)



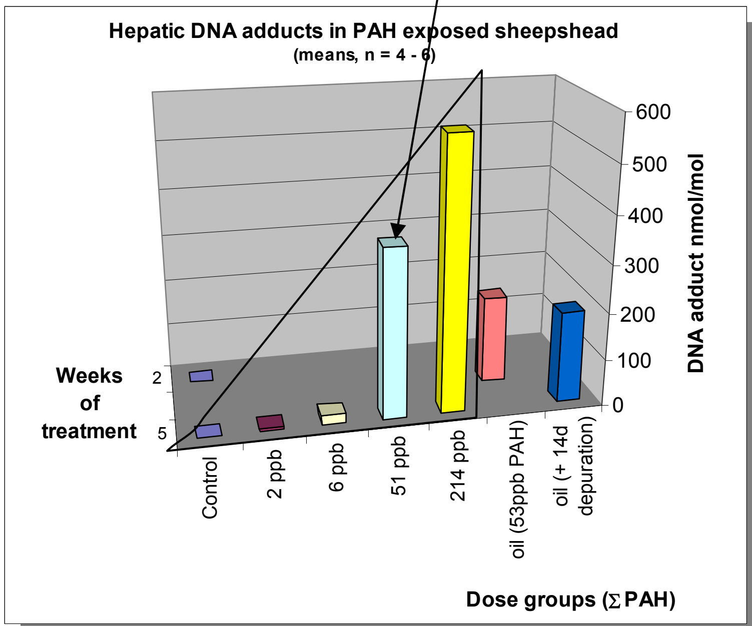
(data & ill. J. Beyer)

Building of the 'Biomarker bridge'

Fitness: reproductive output (as fecundity)
coherent with to biomarker values



- Egg production 'NOEC'
  (51 ug/L PAH)
- corresponds to
- a DNA adduct level
  of approximately 300 nmol/mol



(data & ill. R.K. Bechmann & J. Beyer)

Building of the 'Biomarker bridge'
PROOF "Validation" - experiments

- **ERA effect validation & Biomarker responses**

	Effect validation	Biomarker responses
Invertebrates	**Oil dispersions - sensitive life stage test**	**Oil dispersions – sensitive life stage test**
	(PROOF – RF-AM) **Drilling Discharges - field experiment**	**Drilling Discharges - lab experiment** **Drilling Discharges - field experiment**
Fish	(PROOF-IMR)	**Alkylated Phenols - lab. Experiment**
	Oil disp. / sim.PW - lab. experiment	**Oil disp. / sim.PW - lab. experiment**
	Produced Water - field experiment	**Produced Water - field experiment**

Practical connections to:

ERMS **PROOF**

BioSea JIP **WCM - OLF**

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Building of the 'Biomarker bridge'

PROOF "Validation" - experiments

- **ERA effect validation & Biomarker responses**

	Effect validation	Biomarker responses
Invertebrates	**Oil dispersions - sensitive life stage test**	**Oil dispersions – sensitive life stage test**
	(PROOF)	**Drilling Discharges - lab experiment**
Fish		

Crustacean & mollusk (& echinoderm): North Sea dispersed oil

survival offspring

mollusks: exposed parents / exposed larvae;
crustaceans: exposed as embryos / as larvae

Practical connections to:

ERMS **PROOF**

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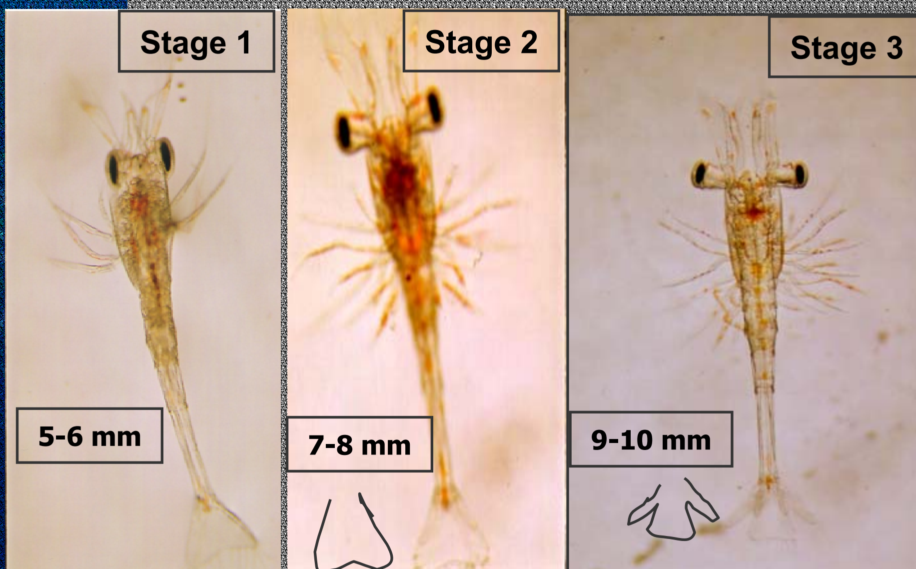
Building of the 'Biomarker bridge
Early life stage mortality - Northern shrimp

Bodil K. Larsen



- significant mortality when exposed as embryo & larvae
- dose dependent mortality when exposed as embryo
- significantly higher mortality in 0.09 ppm
- embryo exposure most severe

Building of the 'Biomarker bridge'
PROOF "Validation" - experiments

- **ERA effect validation & Biomarker responses**

	Effect validation	Biomarker responses
Invertebrates	**Oil dispersions - sensitive life stage test**	**Oil dispersions – sensitive life stage test**
	(PROOF – RF-AM)	**Drilling D harges - lab e nt**
	Drilling Discharges - fi	**Drilling**
Fish		

Crustacean & Mollusks
N.Sea oil exposure

Chemical burden & Biomarkers
(1 month exposure)

GST, Catalase, TOSC
Larvae: Comet (M), Alk.Unw. (C)

Practical connections to:

ERMS

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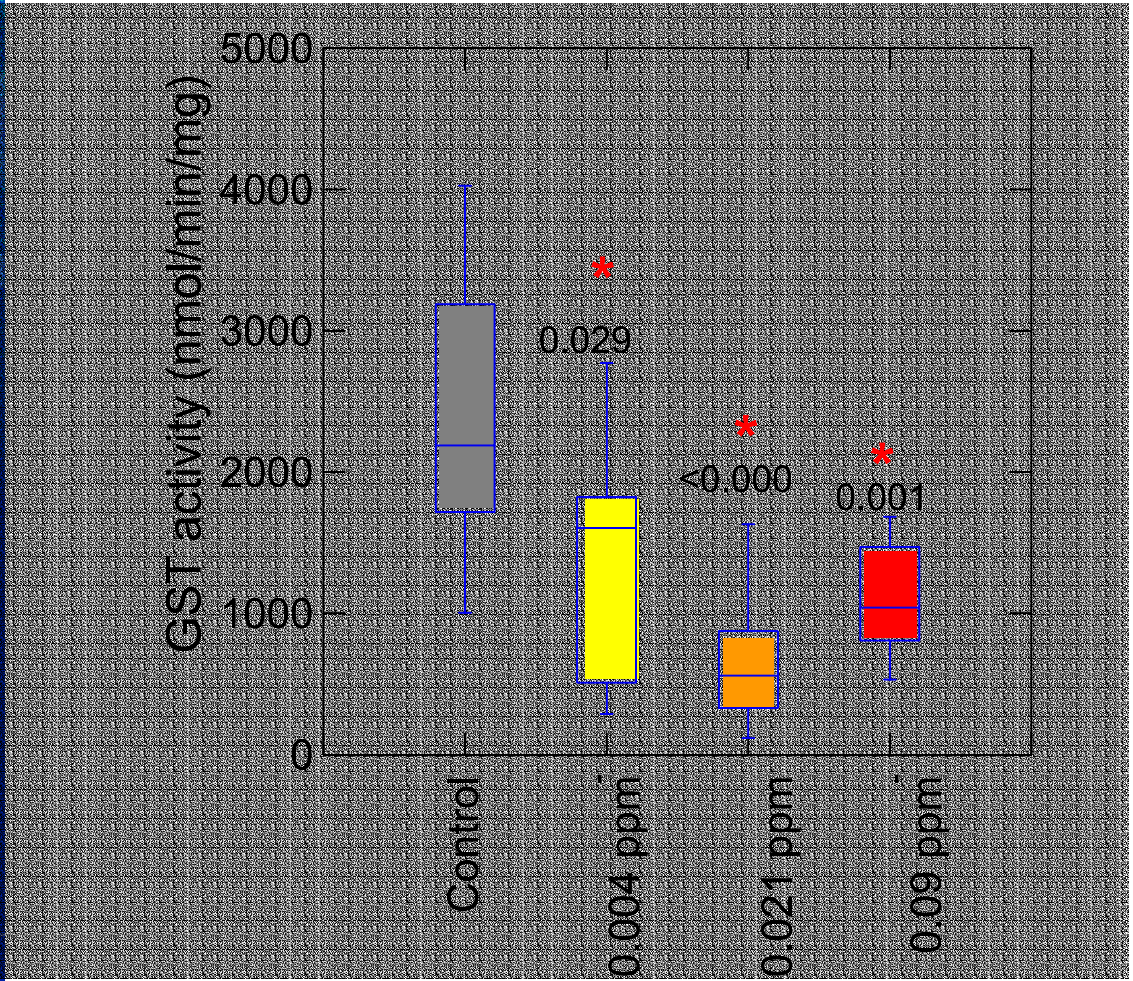
Building of the 'Biomarker bridge
Example of Biomarker in shrimp: Glutathione S-Transferase (GST)

Bodil K. Larsen



- other biomarkers measured for other projects in the same exposure
- joint evaluation of a larger biomarker set
- ->

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Building of the ’Biomarker bridge

Example of conclusion based on joint evaluation

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shrimp biomarkers :

- GST: Responds to oil exposure, although response pattern is probably not linear, rather U-shaped.
- Lysosomal stability: Works very well.
- Alkaline unwinding: Works well, but the sensitivity is not clear.
- Catalase: Large variability, bell-shaped response.
- TOSC: Large variability, small non-significant changes

Integration of Biomarkers in ERA
Use of the results…

- Compare (validate!) the PNEC values currently used in ERA by comparison with the found NOEC levels
  - based on organism health and fitness parameters
- Biomarker values associated with these NOEC levels can be established as threshold level signals
  - "Biomarker NOECs"
- Then these biomarkers
  can be used in Environmental Effect Monitoring (EEM)
  after field validation (QA, etc.→)
  - linked to Environmental Risk Assessment (ERA) !

Other Challenges

New frontiers of oil & gas industry…

- Research...
  - adapt methods and tools to the new frontiers
    - deep-sea and Arctic
    - other geographical areas
  - adapt methods
    - from North Sea & laboratory conditions
  - develop tools (ERA, EEM)
    - based on the existing ones

    another example:
    'tropicalisation of ERMS'

An example:
Blood diagnostics

…with biomarkers in deep-sea sea stars (Girassol - Total Cold Water project)

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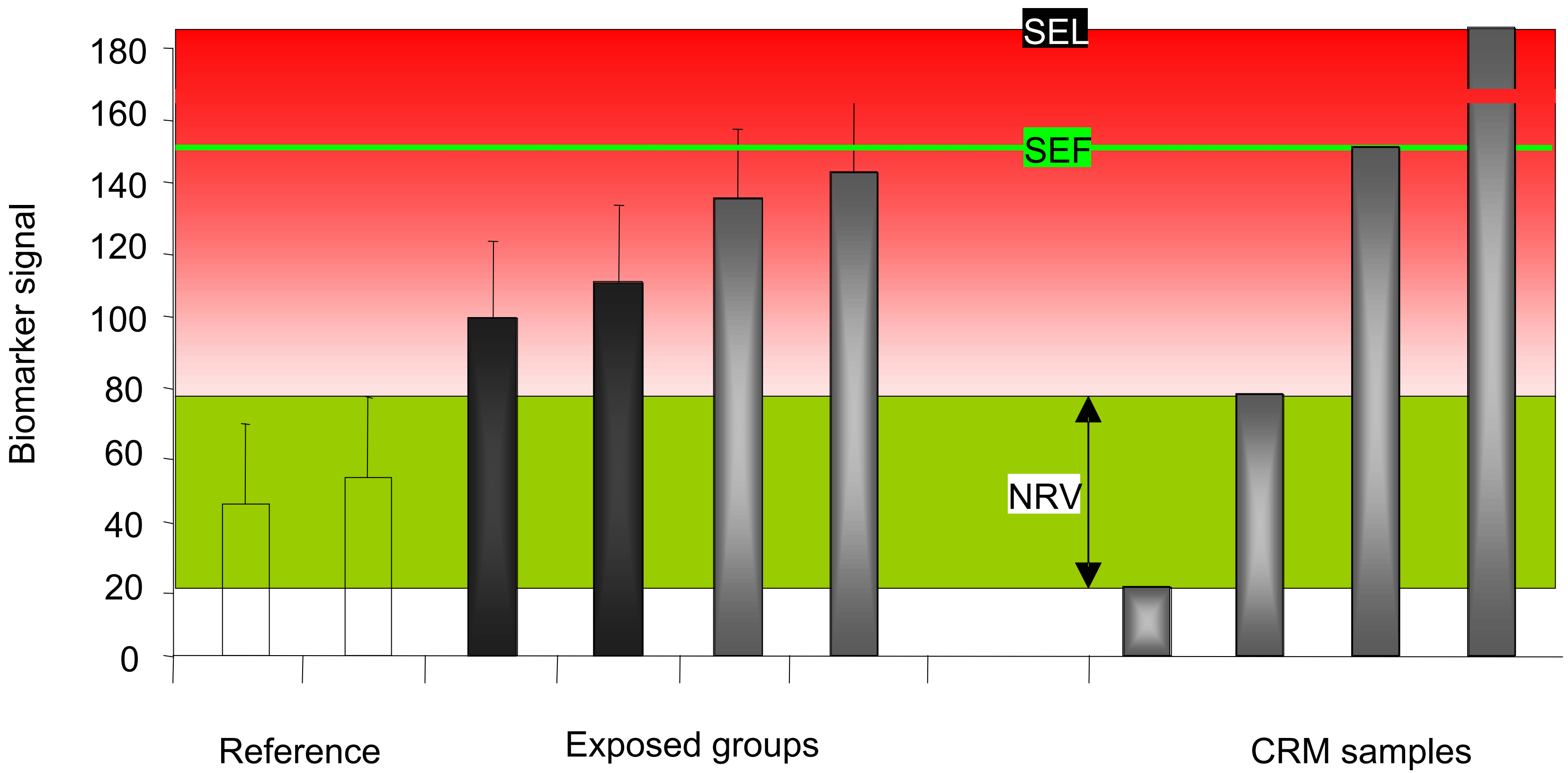
Interpretation – different aspects

- Standardization
- Analytical variance
- Other QA aspects
- Spanning the scales
- Determination of threshold levels
- Combination of information

Biomarker interpretation basis



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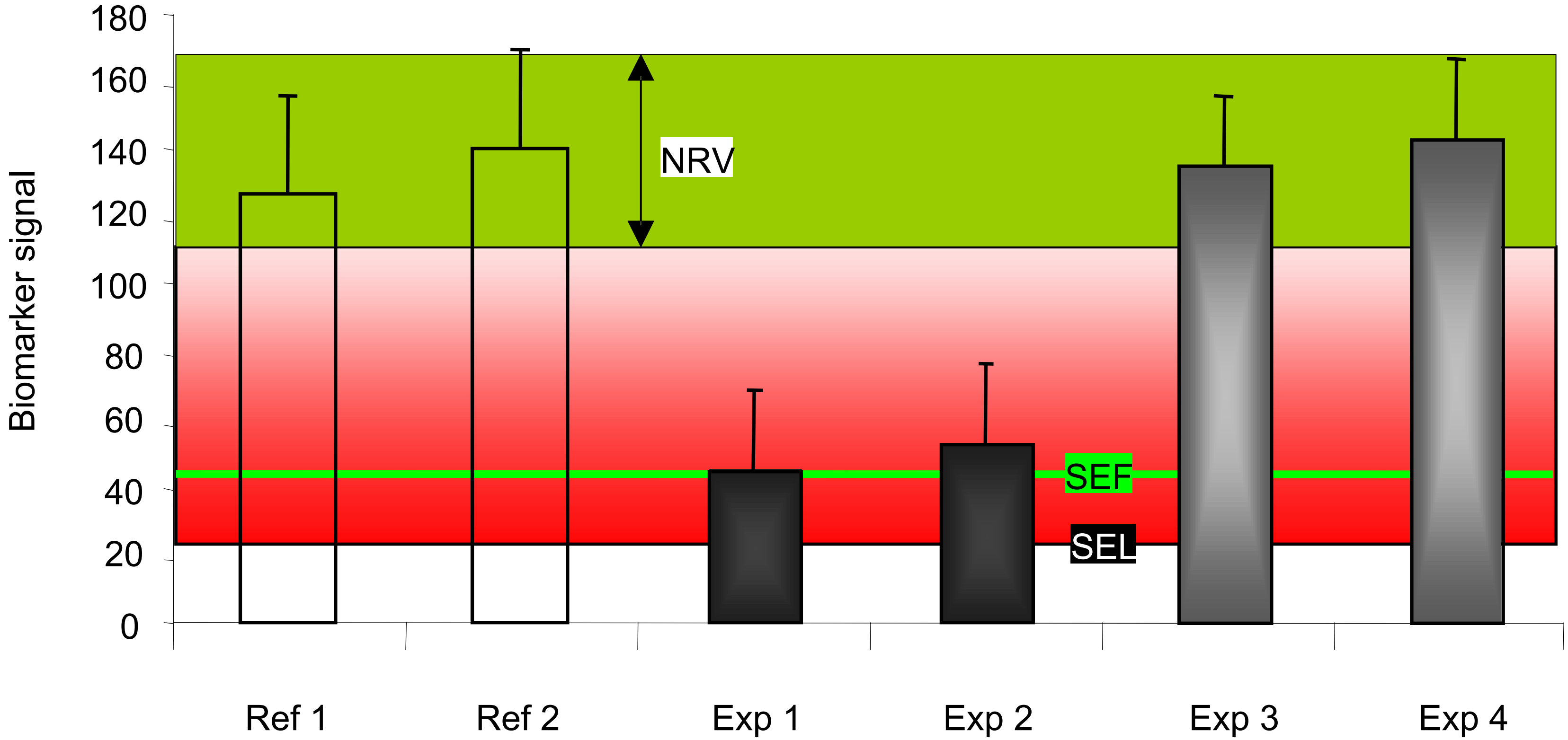
Biomarker interpretation basis



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Optimizing the biomarker approach

- Stepwise EEM !
  - Environmentally relevant and cost efficient
    - 1.step Screening
      - Simple techniques
      - On-board analyses
    - 2.step Effect cause and severity
        - » (dependant on results of 1.step)
      - Follow-up investigations (e.g. the North Sea DNA adduct case)
        - » Application of additional adequate biomarkers
        - » Chemical analysis
        - » Population or community investigations
  - Combination with classical methods

Decision support –

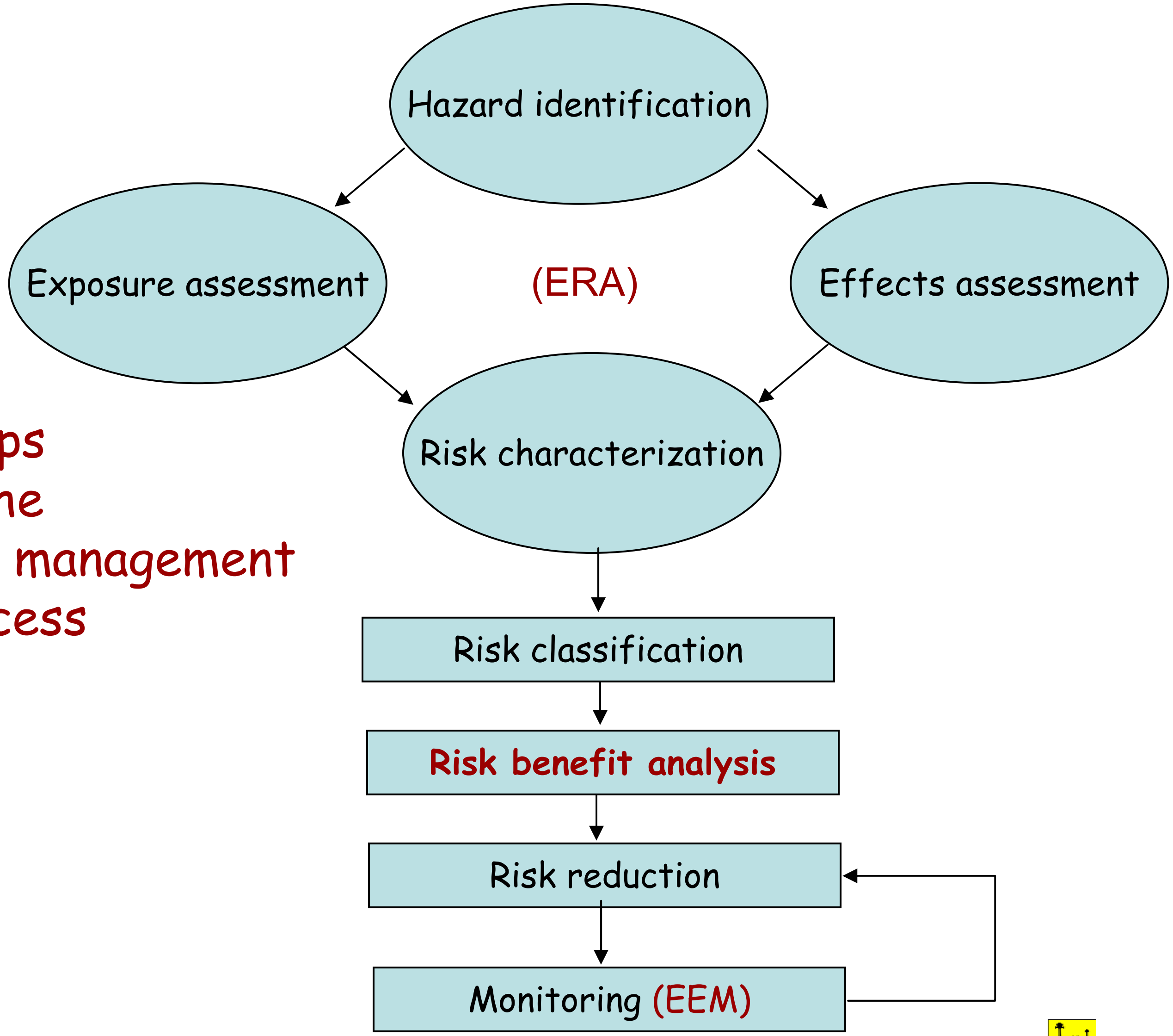
Balancing environmental cost / benefit

- Poorly developed
  - In Norway:
  - The zero harmful effects discharge sets a regulatory / politically based environmental goal
    - Which strongly influences the decisions
  - In Oil contingency planning :
    - Net Environmental Benefit Analysis (NEBA)
  - Environmental cost / benefit (='Risk benefit') needs to be developed further and integrated with ERA and EEM in the total Risk Management process ->

Balancing environmental cost / benefit

Decision making in Risk Management

- Steps in the risk management process



Summary of Main challenges

- For the further use of biomarkers towards a sustainable management for the marine environment protection following challenges must be met
  - Biomarkers and ERA must be integrated ('Biomarker bridge')
  - Definition of threshold levels and criteria to quantify ecological relevance must be established for biomarkers
  - Adapt the methods to the new frontiers of the oil & gas industry
  - QA: the biomarker protocols must be standardized and the modes of interpretation biomarker results must be harmonized
  - Optimize the biomarker approach to a stepwise EEM
  - Balance the environmental cost / benefit in the Risk management process