Biodetectors Workshop, Sorrento, Italy, April 2017

SIMONI (SMART INTEGRATED MONITORING): A NOVEL BIOANALYTICAL STRATEGY FOR WATER QUALITY ASSESSMENT

Ron van der Oost

waterOnet

Outline

- Micropolutant risks: substances or effects?
- Effect-based water quality monitoring
- SIMONI 1.2 model & effect-based trigger values
- Future of regular water quality monitoring..?

Effects or substances?

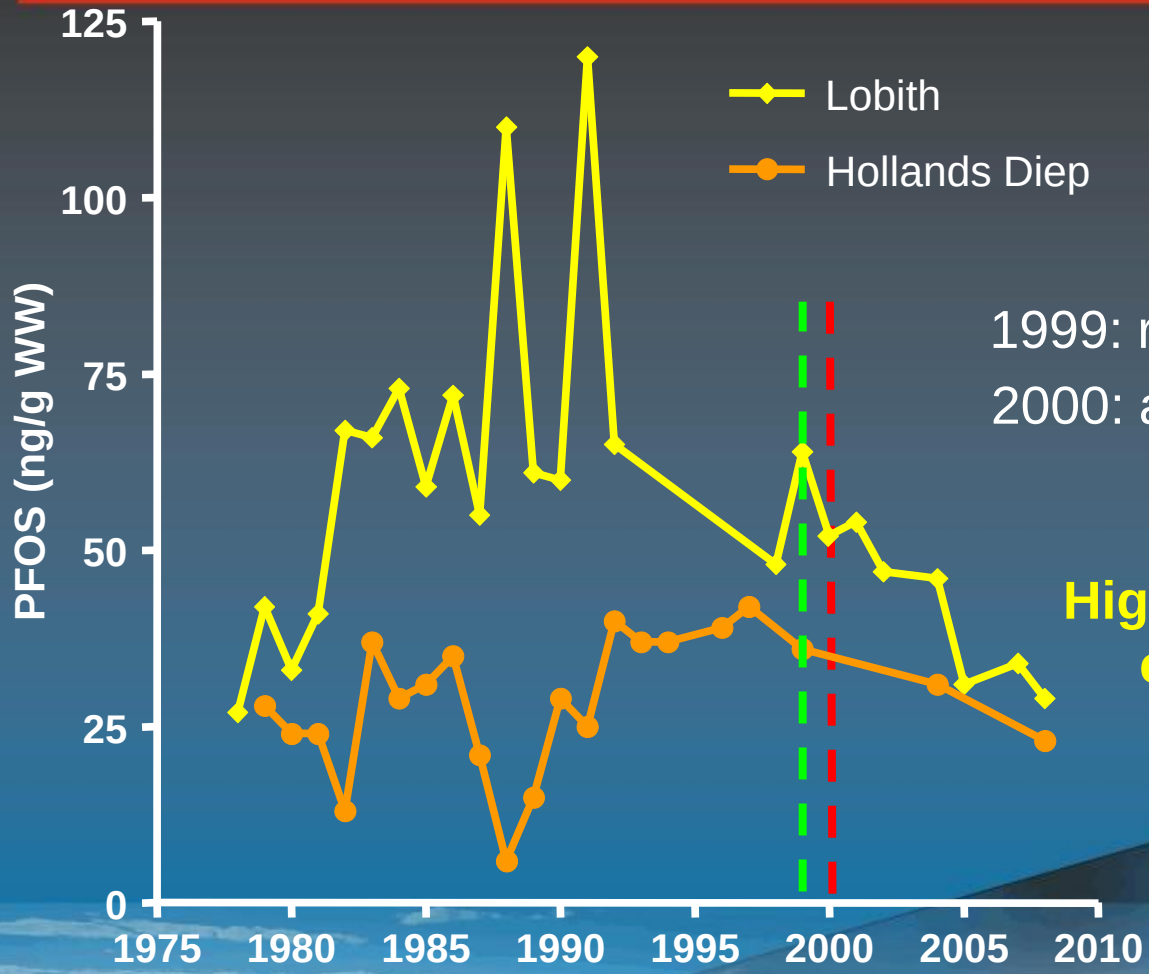
No one else has more...

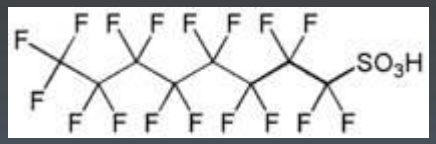
129,318,840 ORGANIC AND INORGANIC SUBSTANCES TO DATE

A global team of scientists is continually adding substance information from the world's disclosed chemistry to the CAS REGISTRY℠, the gold standard for chemical substance information.

www.cas.org

PFOS in eel (historical sample bank)





1999: routine analytical methods

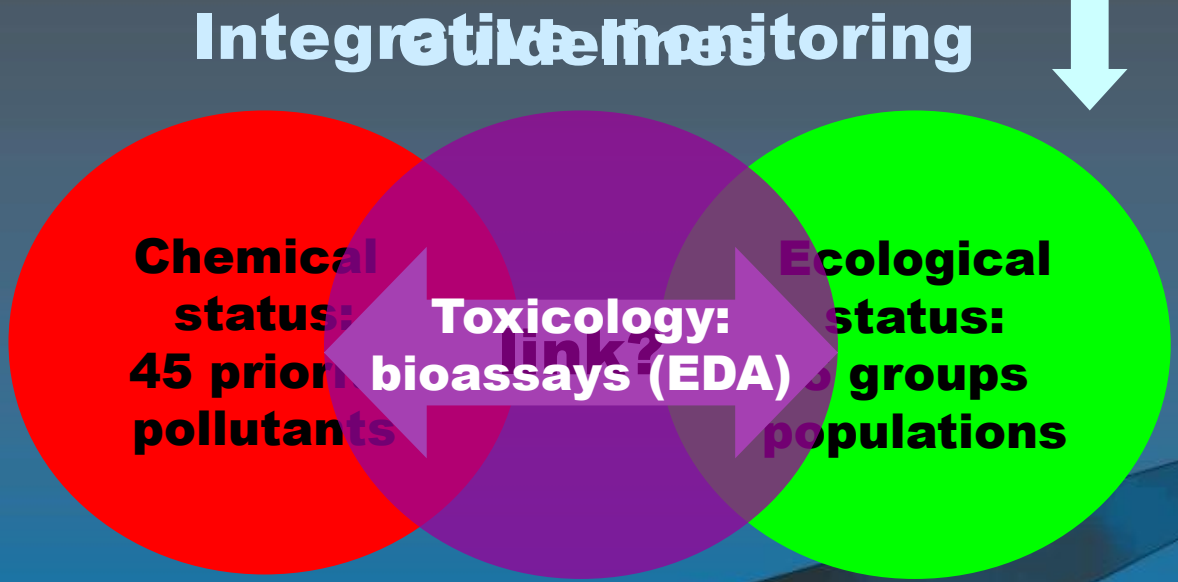
2000: alternatives available

Highest risks occurred when compound was not yet measured..!

Kwadijk et al., 2010

WFD monitoring

Non-chemical factors: habitat, hydromorphology microbiology, predation, etc



Monitoring effects or substances..?

Bioanalytical tools:

- ☺ Limited amount of assays can give a cost-effective and reliable risk assessment
- ☹ Low substance specificity
- ☺ Bioavailability included
- ☺ Mixture toxicity included
- ☺ Metabolites included
- ☺ Unknown substances included
- ☹ Chronic exposure is difficult and expensive
- ☹ No accepted classification available
- ☹ Biomagnification not included
- ☺ No effects ☞ no worries

….

Dick de Zwart (RIVM, Netherlands)

Chemical analyses:

- ☹ Search for a needle in a haystack: obligatory analysis of more then 200 substances in drinking water
- ☹ Many analyses are yet impossible (e.g. matrix effects)
- ☹ Not enough toxicity data available for risk assessment (ERA)
- ☹ No information on bioavailability
- ☹ No information on mixture toxicity
- ☺ Direct comparison to substance-directed legal guidelines
- ☹ Low concentrations ☞ still worries
- ☹ Surrogate security and accuracy

….

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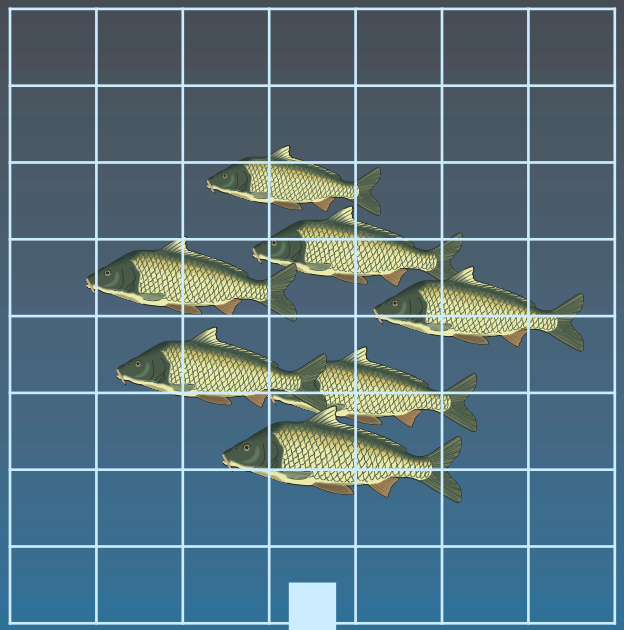
Effect-based water quality monitoring

Passive sampling



Biomarkers:
Biochemical changes

Bioassays

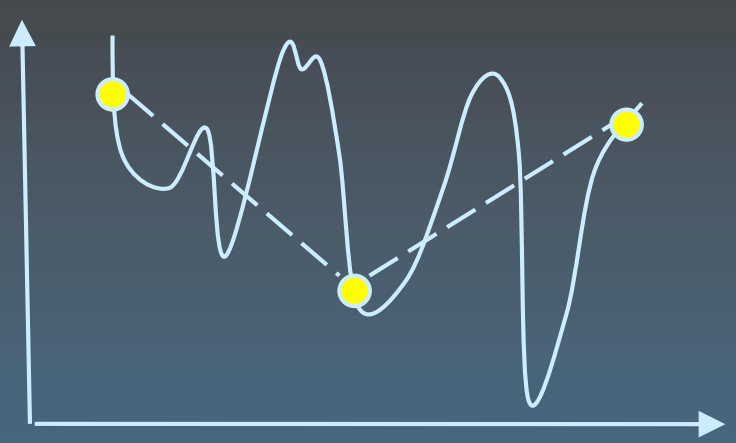
Smart monitoring

Alternative (WFD) monitoring methods:

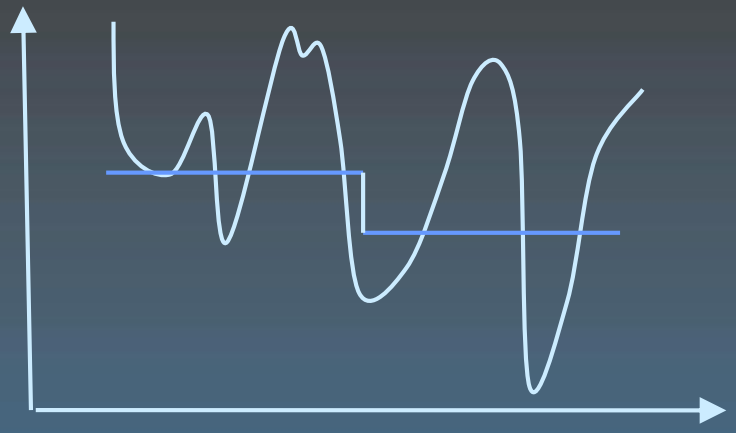
- Passive sampling: time-weighted average
- Integrated monitoring: chemistry, biology & toxicology
- Toxicity screening: Identification hazards and ‘hot spots’
- Risk analysis: identify relevant toxic substances (EDA)

Goal: better information on water quality for less €!

Passive sampling: time integration



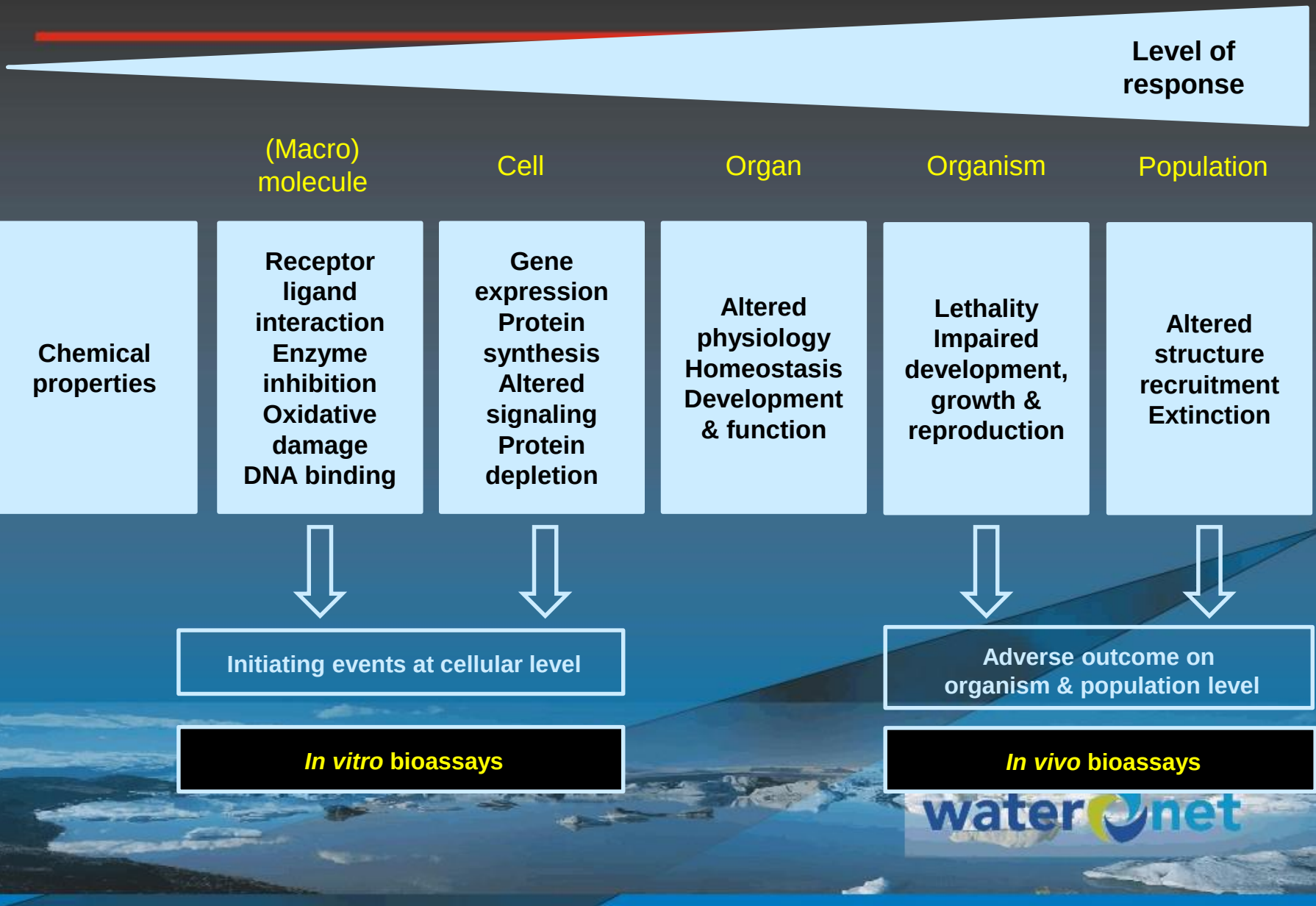
Grabsamples



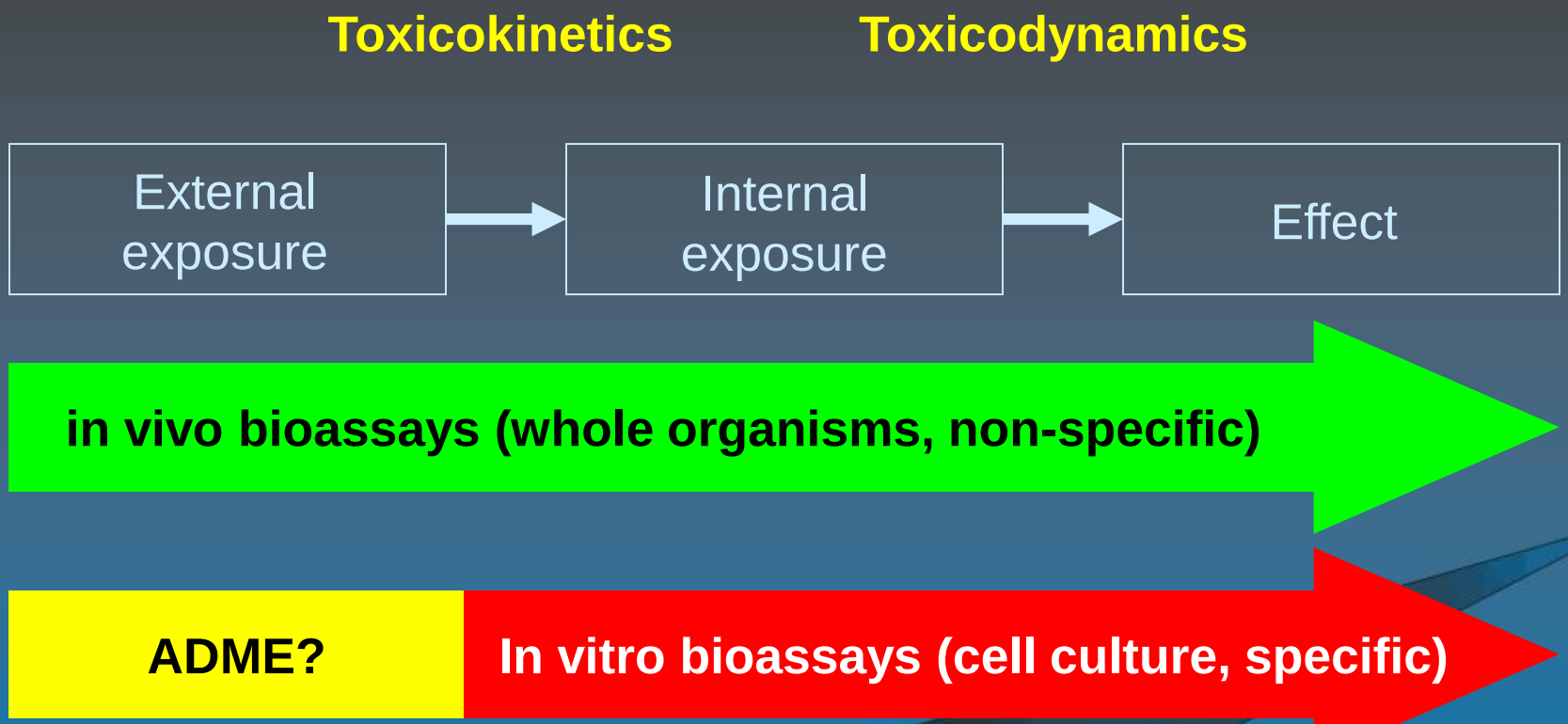
Passive sampling

- Grabsamples are ‘snapshots’
- PS is better for trends & time weighed average
- Lower sampling frequencies needed with PS

Adverse Outcome Pathways (AOP)



Relevance of observed toxicity



A: passive samplers

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Convince regulators & policy makers

- Select validated high-throughput bioassays
- Design effect-based trigger values!
- Design a clear strategy for regulators
- Demonstrate that effect monitoring can be cheaper than chemical analyses
- Explain uncertainties of the approaches

- Realistic approach: no ostrich behaviour ("if we don't measure it, we don't have a problem…")

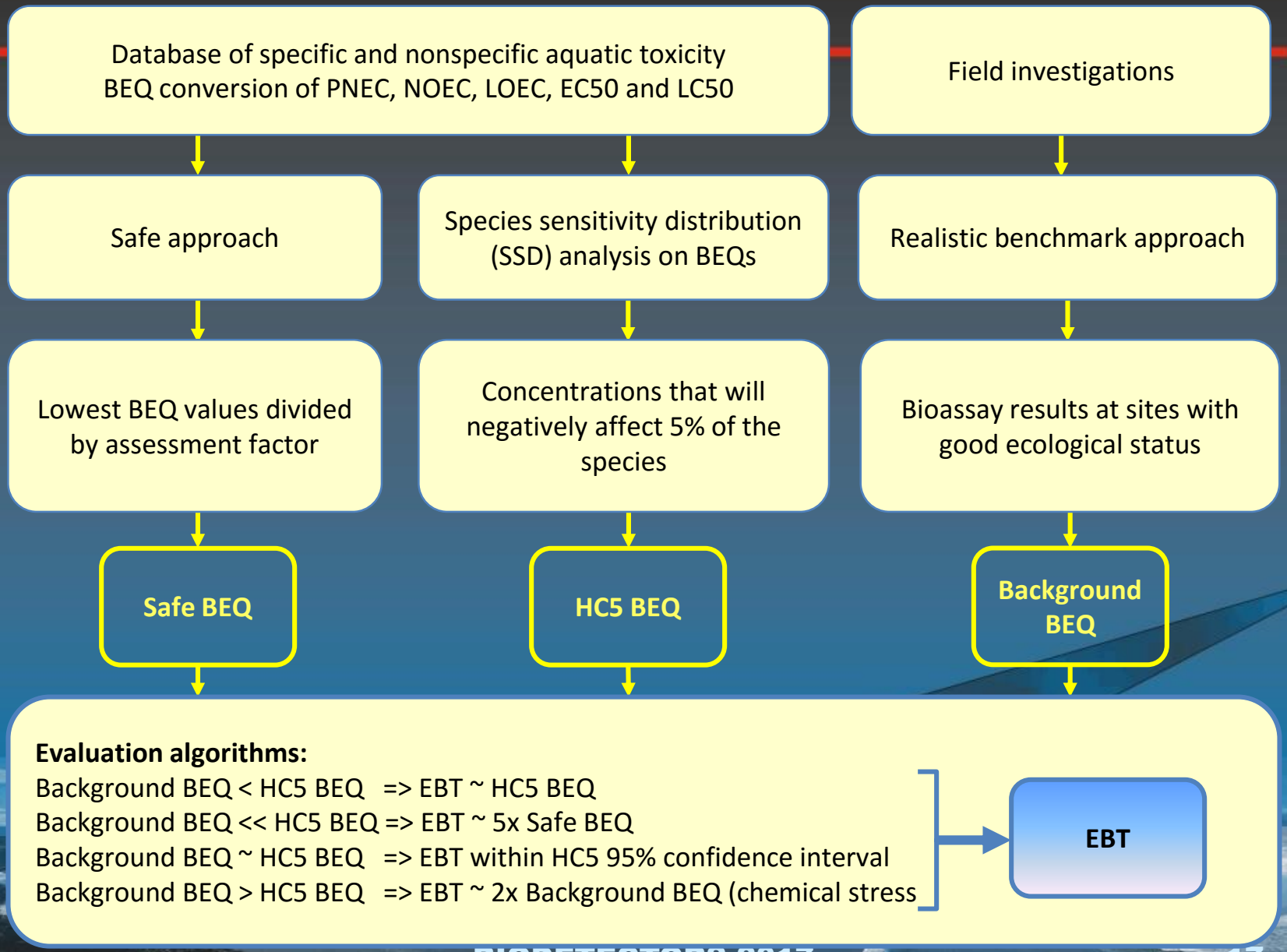
Selection toxicological endpoints SIMONI

- In situ toxicity (water):
  - Daphnids: mortality (1 week)
- General toxicity (concentrated extracts)
  - cel culture: cytotoxicity
  - Bacteria: luminescence
  - Algae: growth inhibition
  - Daphnids: mortality (immobilisation)
- Specific toxicity (concentrated extracts)
  - Endocrine disruption: ER, anti-AR, GR
  - Xenobiotics metabolism (DR, PXR)
  - PAH toxicity
  - Lipid metabolism: PPAR
  - Antibiotics activity (5 classes)
- Reactive toxicity (concentrated extracts)
  - Genotoxicity
  - Oxidative stress

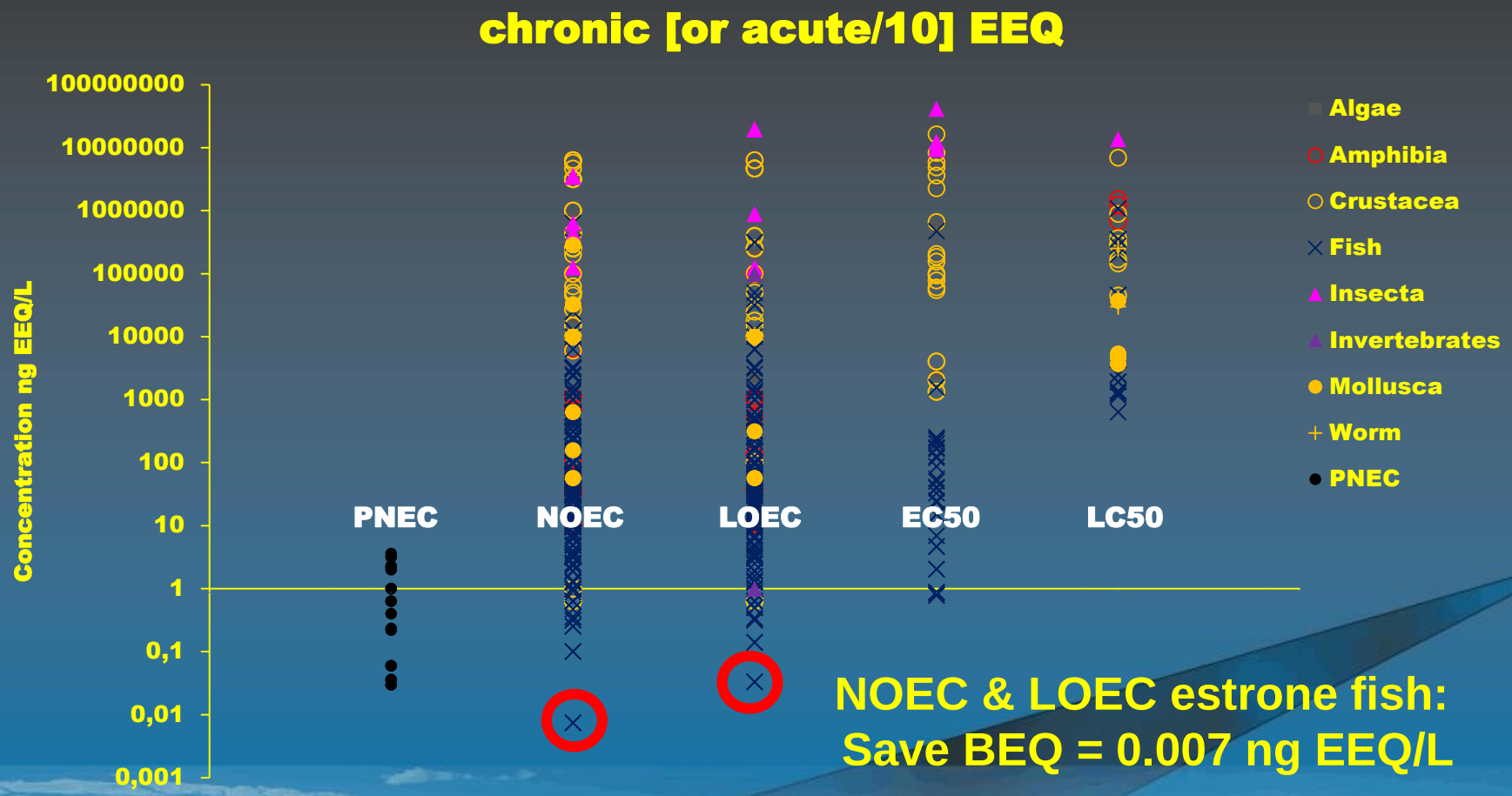
SIMONI assumptions for trigger values

- Trigger values based upon chronic toxicity (or acute/10)
- Compounds selected for trigger value development relative effect potency (REP) >0.001 bioassay reference
- All adverse effects considered for trigger values:
  - Not only effects related to the endpoint mechanism
  - Not restricted to growth, reproduction and mortality
- Water concentrations ⟶ bioanalytical equivalents (BEQ)

Effect-based trigger values SIMONI



Safe BEQ: estrogenic EQ toxicity data

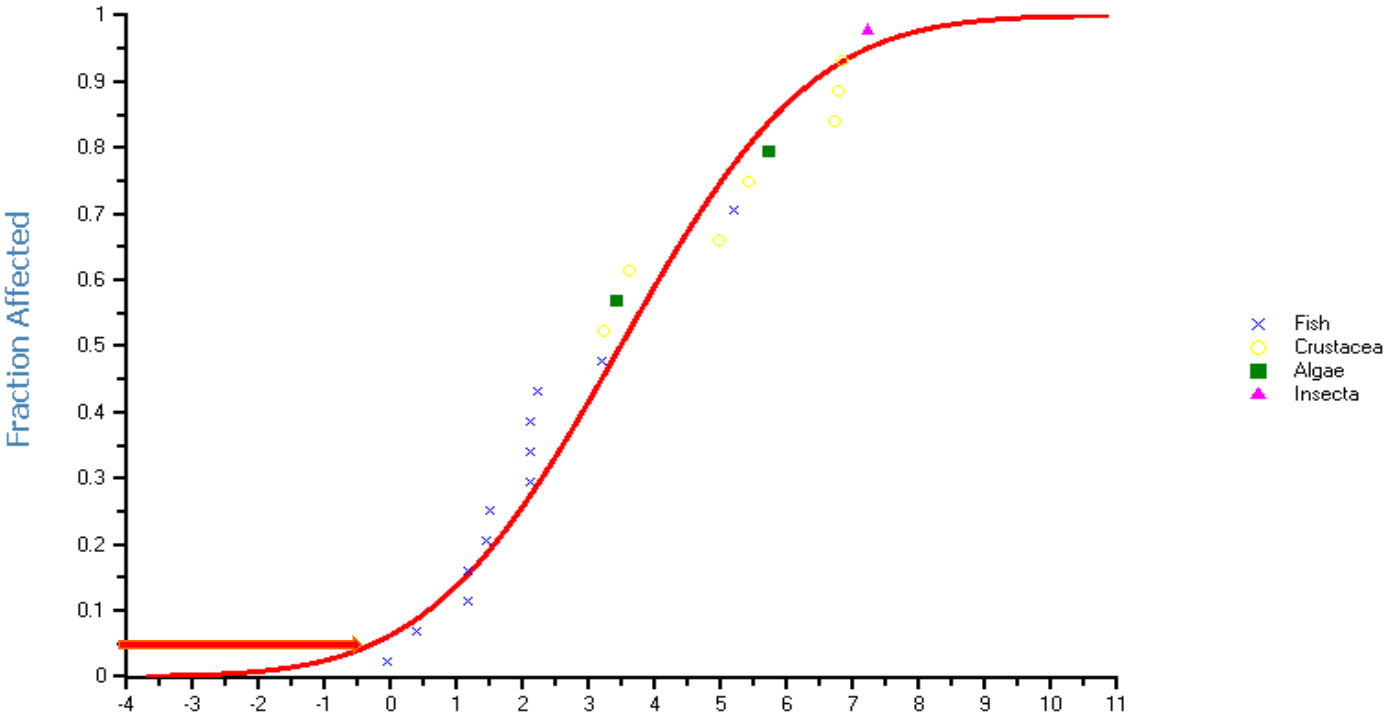


NOEC & LOEC estrone fish:
Save BEQ = 0.007 ng EEQ/L

Sileno, 2015

HC5 BEQ: species sensitivity distribution

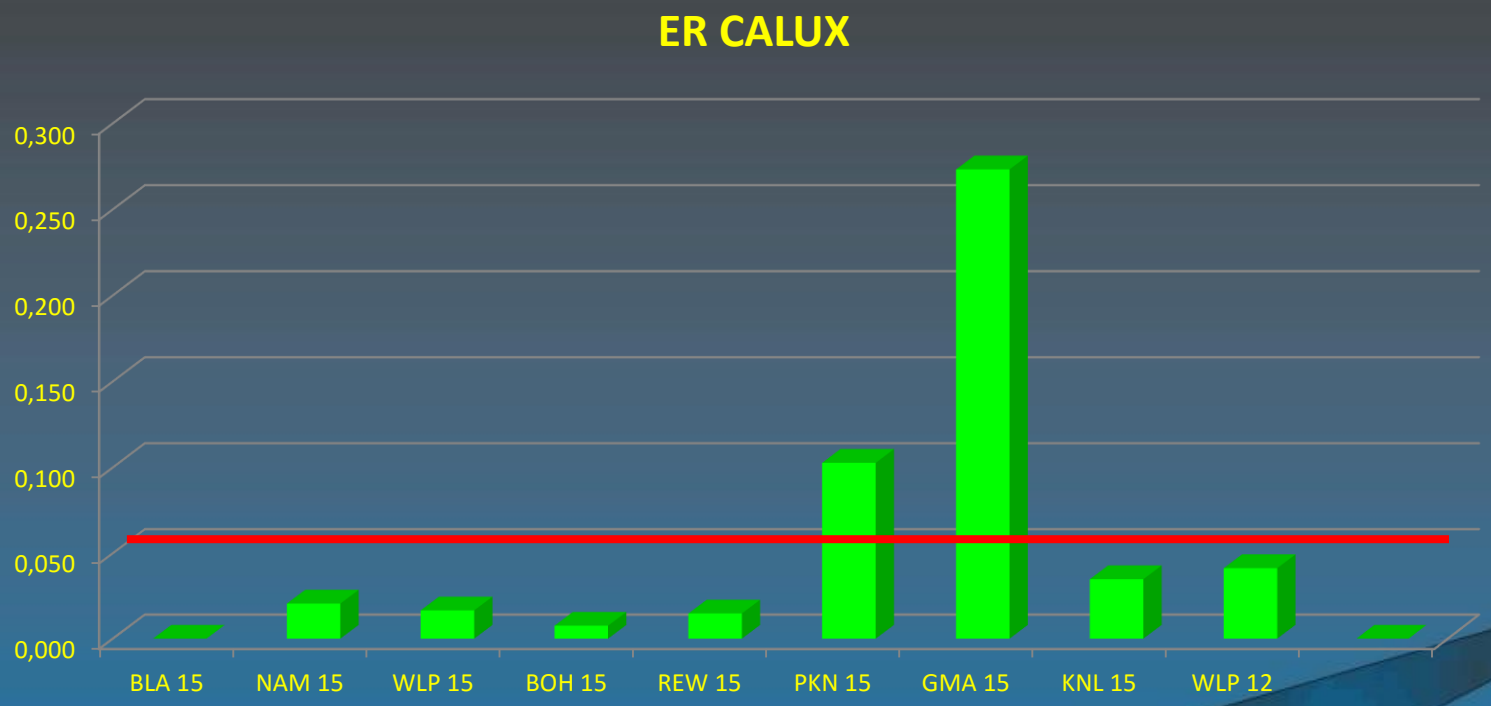
Estrogenic compounds: chronic EC50 EEQs



HC5 BEQ (hazard to 5% organisms) = 0.5 ng EEQ/L

Sileno, 2015

Background BEQ: responses clean sites



Average activity at sites with good ecological status:
Background BEQ = 0.06 ng EEQ/L

Sileno, 2015

Evaluation estrogenic EBT (ER CALUX)

Safe BEQ:	**0.007 EEQ/L**
HC5 BEQ:	**0.52 EEQ/L**
Background BEQ:	**0.06 EEQ/L**

EBT = 0.5 EEQ/L

Jarosova et al., 2014: EBT = 0.2-0.4 EEQ/L

Kunz et al., 2015: EBT = 0.4 EEQ/L

Sileno, 2015

Effect-based trigger values *in vitro*

Endpoints	Bioassays	Safe BEQ	HC5 BEQ	Background BEQ	EBT
Estrogenic	ERa CALUX (ng EEQ/L)	0.0066	0.52 (0,02-5.4)	0,06	0.5
Anti-androgenic	anti-AR CALUX (µg F1EQ/L)	0.00005	0.13 (0.05-0.27)	5	25
Dioxin and dioxin-like	DR CALUX (pg BEQ/L)	0.4	137 (15-736)	13	50
Glucocorticoid	GR CALUX (ng DEQ/L)	20	2145 (116-14311)	<1.2	100
PPARγ receptor	PPARγ CALUX (ng REQ/L)	0.00014	0.3 (0.002-6.9)	4	10
Reactive PAHs	PAH CALUX (ng BEQ/L)	0.04	47 (2-368)	63	150
Oxidative stress	Nrf2 CALUX (µg CEQ/L)	0.000006	0.034 (0.008-0.11)	4	10
Pregnane X	PXR CALUX (ng N1EQ/L)	0.000004	0.008 (0.002-0.024)	1,5	3
Antibiotics RIKILT WaterSCAN	Aminoglycosides (ng N2EQ/L)	300	33222 (1546-219614)	<90	500
	Macrolides & β-Lactam (ng PEQ/L)	1.8	98 (13-470)	<1.4	50
	Sulphonamides (ng SEQ/L)	10	67037 (24675-148222)	4.6	100
	Tetracyclines (ng OEQ/L)	170	27275 (8292-68544)	<22	250
	Quinolones (ng F2EQ/L)	5.3	8759 (2197-26050)	<44	100

Ecological Key Factor Toxicity

both bad

HIGH RISK

ROUTINE SCREENING

CUSTOMIZED INVESTIGATION

Chemistry (KRW+)

msPAFchemical

bad & good

good & bad

POTENTIAL RISK?

Advanced chemistry: msPAF for more new substances

Toxicology: in vivo bioassays TIE & EDA

Biology KRW+ (msPAF ecology)

Toxicology (bioassays)

> Trigger values?

Tocicity traffic light

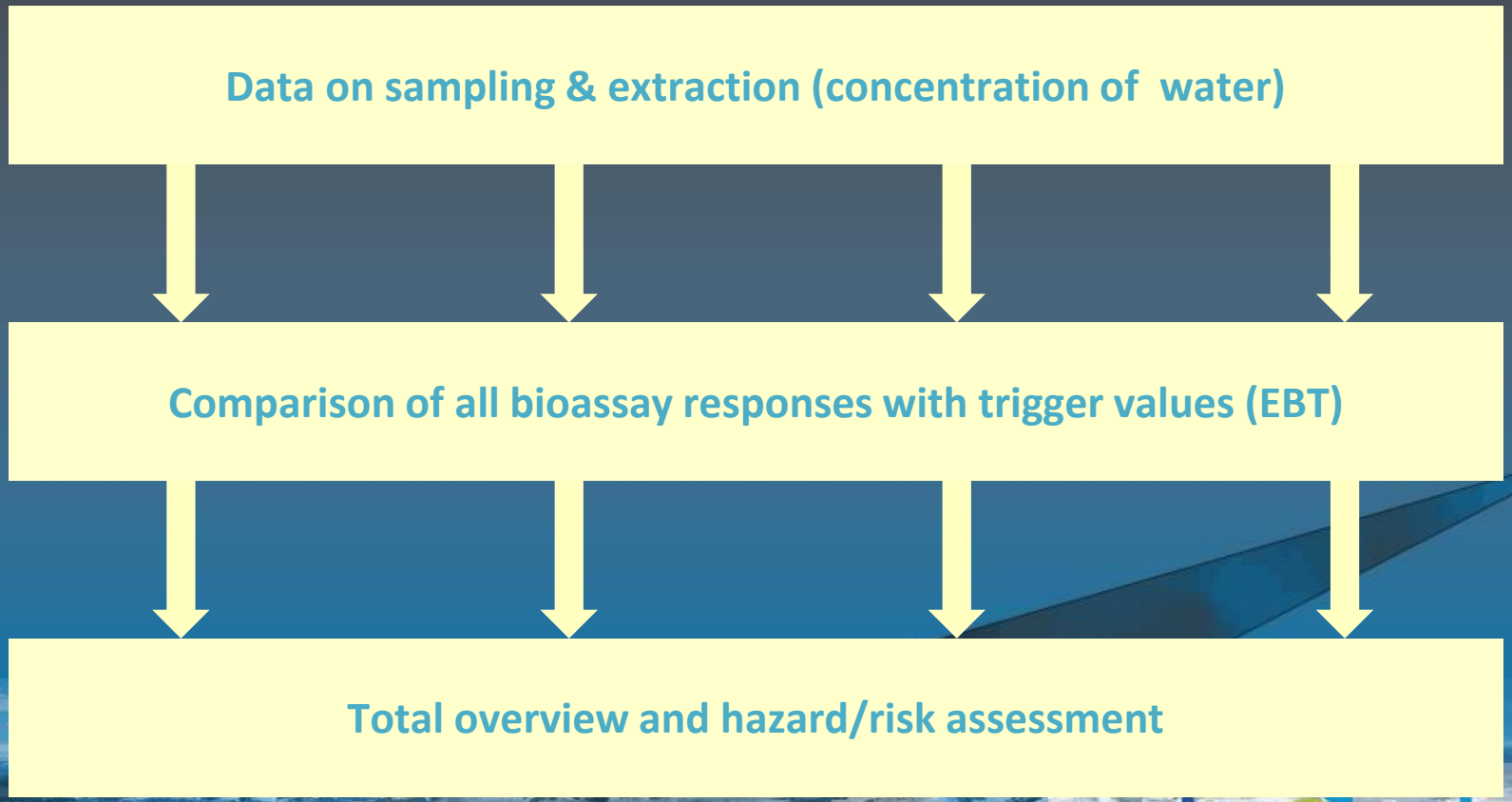
Passive and/or grabsampling

both good

LOW RISK

SIMONI – effect-based risk assessment

Van der Oost et al., ET&C, in press (parts 1&2)

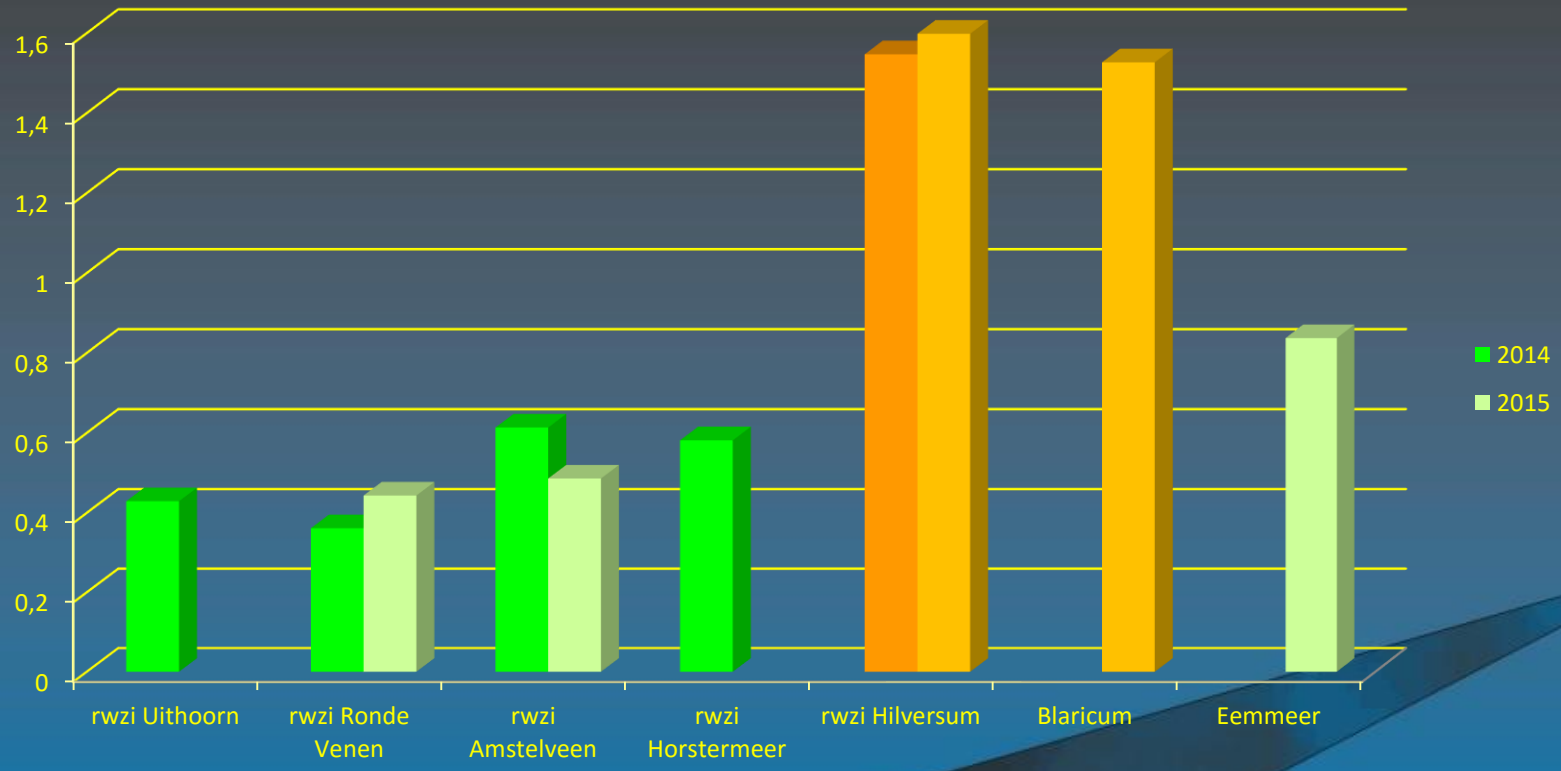


SIMONI 1.2: hotspots micropollutant risk

Risk = Σ [(bioassay response/EBT)*bioassay weight] / 0,5*total weight

Highest ecological risks [score >1] in greenhouse areas (pesticide emission)

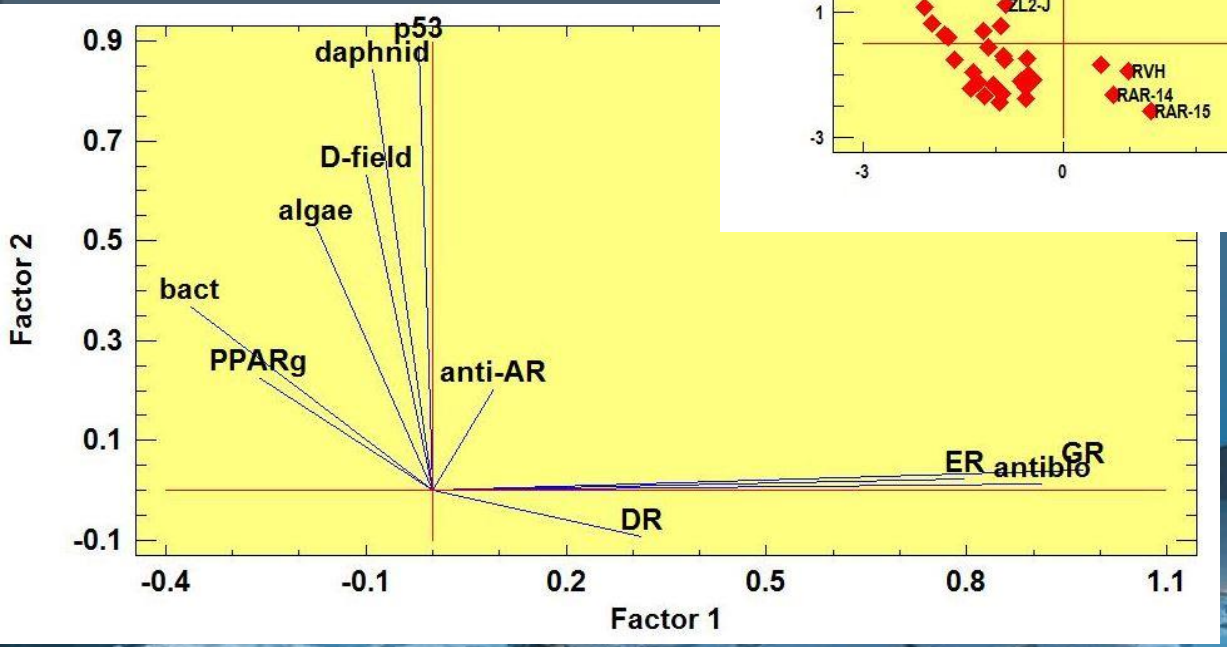
SIMONI 1.2: risks of wwtp emissions

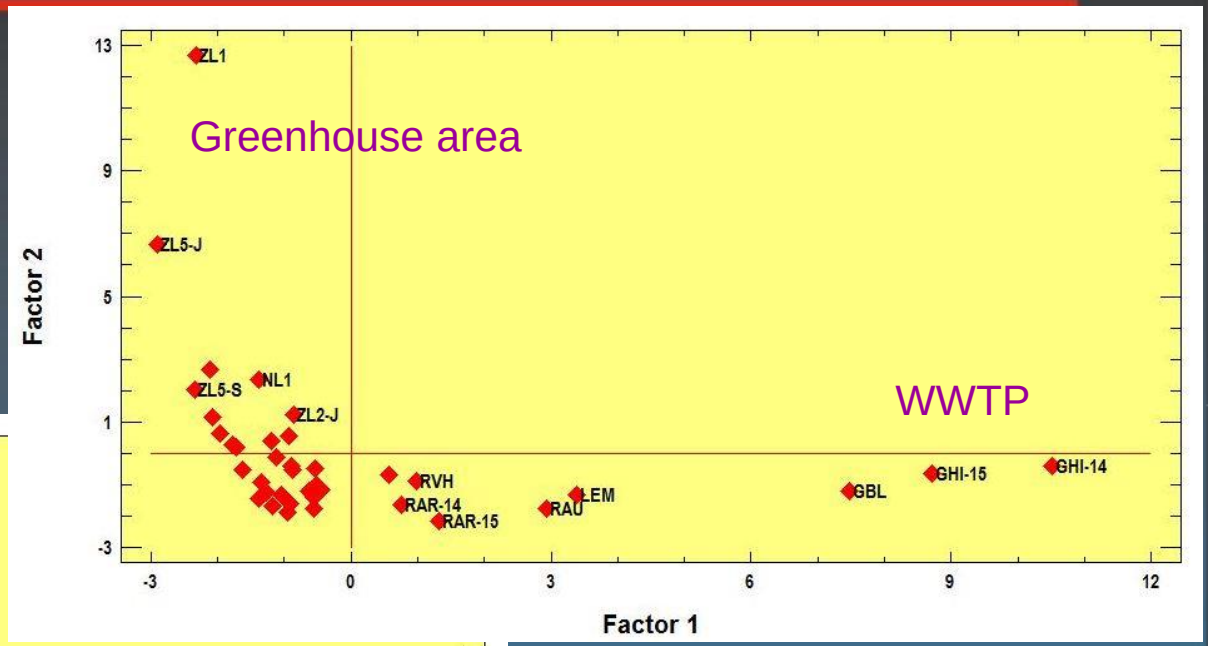


Highest ecological risk [score >1] at undiluted wwtp emissions

Statistics: Factor analysis (PCA)

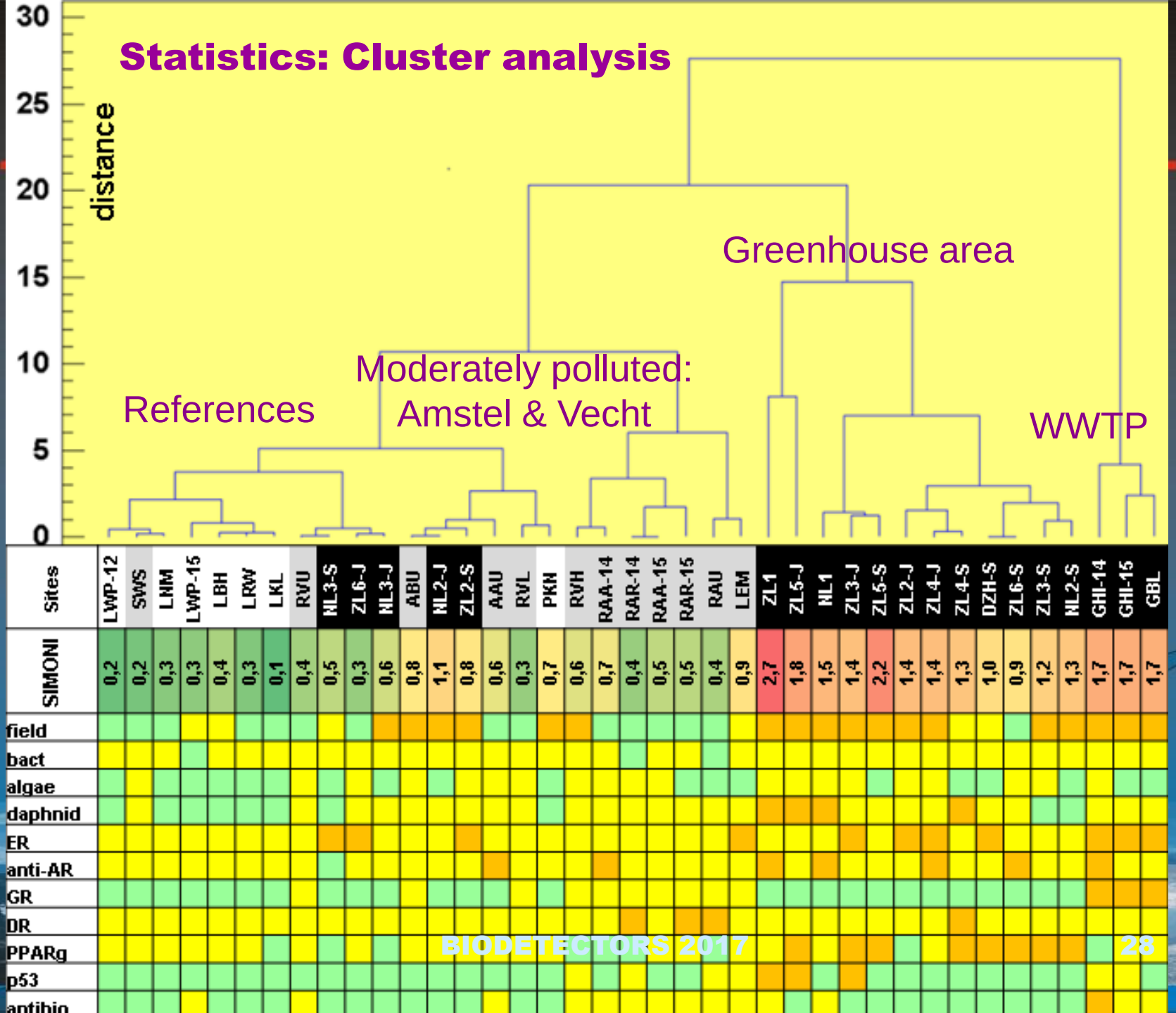
Factor loadings



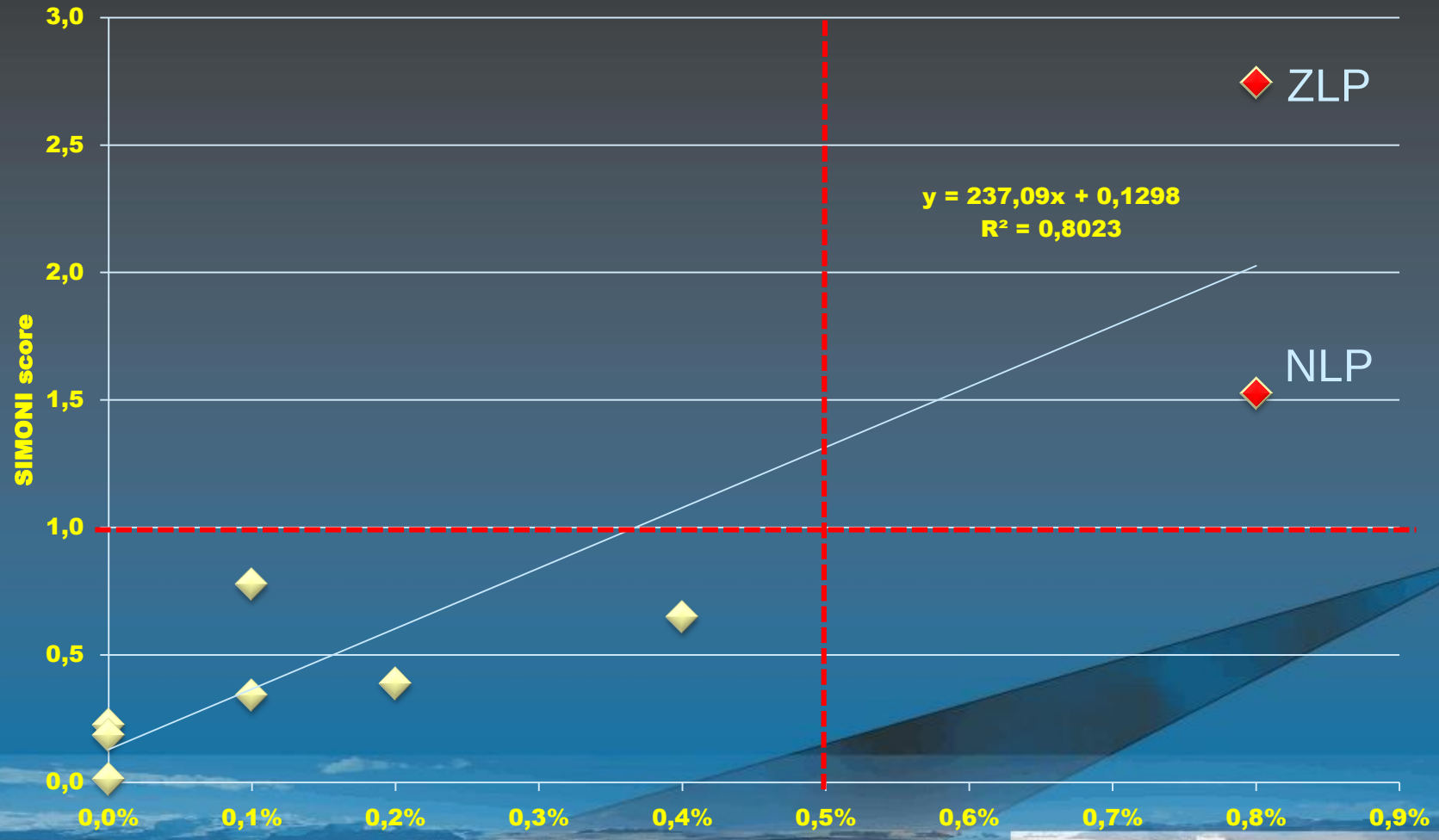


Sites scatter plot

Statistics: Cluster analysis



Waternet 2012: SIMONI vs. msPAF



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The near future..?

both bad

HIGH RISK

SCREENING

CUSTOMIZED INVESTIGATION

Chemistry (KRW+)

msPAFchemical

bad & good

good & bad

POTENTIAL RISK?

Advanced chemistry: msPAF for more new substances

Toxicology: in vivo bioassays TIE & EDA

Biology KRW+ (msPAF ecology)

Toxicology (bioassays)

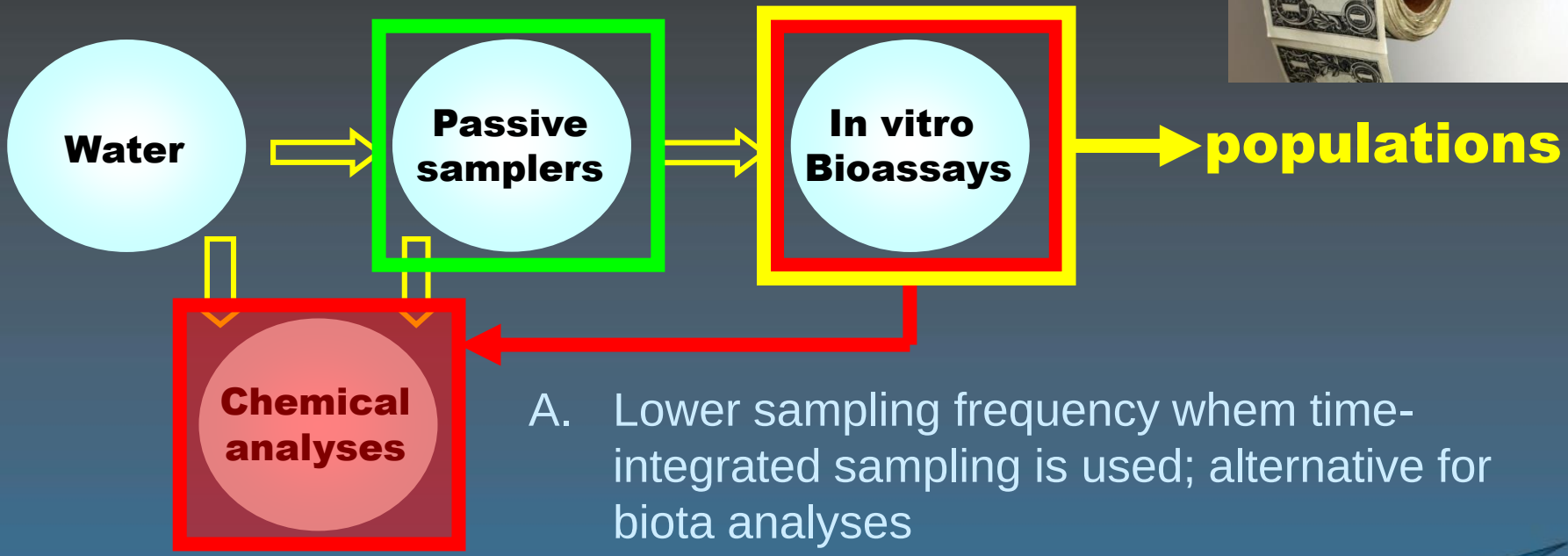
> Trigger values?

Passive and/or grabsampling

both good

LOW RISK

Cost reductions on monitoring



A. Lower sampling frequency whem time-integrated sampling is used; alternative for biota analyses

B. Only advanced chemical analyses after responses in tox-screening

C. Bioassay screening and innovative DNA testing to reduce costs for ecological research

Cost reductions on monitoring

- WFD chemical monitoring
  - 12x grabsamples (each month)
  - Chemical analyses of 45 priority pollutants
  - Costs around €40,000

- SIMONI 1.2
  - 2x passive sampling (different seasons)
  - Chemical analyses of metals & nutrients
  - Toxicological analyses with 5 non-specific & 10 specific bioassays
  - Costs around €7,000
  - Additional risk analysis only at sites with potential risk!

Uncertainties SIMONI vs. WFD?

SIMONI

- Bioassays or biomarkers
  - No (sensitive) response to all pollutants
- Passive sampling
  - Not all compounds accumulate in samplers

Uncertainties of combination?

Different mixture

WFD

- Grab sampling
  - Snapshot; variation and no information on bioavailability
  - No information on >100,000 other chemicals in water cycle

What do we need…?

- Optimisation of bioassay selection and trigger values (UvA)
- Improved quantification of effects in passive sampler extracts
- Design of more ‘simple’ bioassays for effect measurement
- Design of less expensive EDA/TIE (HT-EDA)
- Support fom other (EU) countries to use the SIMONI framework

Paradigm shift: substances → effects!

Thanks!

Research & Innovation Steering Group

Bianca, Giulia, Maria, Laura & Thao

New perspectives