Diagnosis of field impacts of chemicals from monitoring and experimental data.

SASAqS conference, 29 June 2015

Paul van den Brink

Wageningen University and Alterra

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The use of indices to assess water quality

- The structural composition of a community can give an indication of the intensity of impact resulting from different factors or stressors on that community
- Kolkwitz and Marson 1902
  - Saprobic index
  - Oligosaprobic – Polysaprobic
- Many indices nowadays
  - SASS5
  - a valid, rapid and robust assessment methodology

- Specific index is the holy grail of environmental management

Question: what is impacting my system?

SETAC PRESS

Environmental Toxicology and Chemistry, Vol. 24, No. 4, pp. 954–965, 2005

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ANALYZING EFFECTS OF PESTICIDES ON INVERTEBRATE COMMUNITIES IN STREAMS

MATTHIAS LIESS* and PETER CARSTEN VON DER OHE
UFZ—Centre for Environmental Research, Permoserstrasse 15, D-04318 Leipzig, Germany

(*Received* 1 *December* 2003; *Accepted* 25 *September* 2004)

Abstract—The aim of this investigation was to find patterns in aquatic invertebrate community composition that are related to the effects of pesticides. Investigations were carried out in 20 central European streams. To reduce the site-specific variation of community descriptors due to environmental factors other than pesticides, species were classified and grouped according to their vulnerability to pesticides. They were classified as species at risk (SPEAR) and species not at risk (SPEnotAR). Ecological traits used to define these groups were sensitivity to toxicants, generation time, migration ability, and presence of aquatic stages during time of maximum pesticide application. Results showed that measured pesticide concentrations of 1 : 10 of the acute 48-h median lethal concentration (LC50) of *Daphnia magna* led to a short- and long-term reduction of abundance and number of SPEAR and a corresponding increase in SPEnotAR. Concentrations of 1 : 100 of the acute 48-h LC50 of *D. magna* correlated with a long-term change of community composition. However, number and abundance of SPEAR in disturbed stream sections are increased greatly when undisturbed stream sections are present in upstream reaches. This positive influence compensated for the negative effect of high concentrations of pesticides through recolonization. The results emphasize the importance of considering ecological traits and recolonization processes on the landscape level for ecotoxicological risk assessment.

Keywords—Field effect Pesticides Recovery Cumulative risk assessment

Question: what is impacting my system?

- Pesticides: SPEcies At Risk (SPEAR) index
- A taxon is regarded as 'at risk' only if it is
  - Relatively sensitive to pesticides
  - Has a low recovery potential

- $SPEARpesticides = \frac{\sum_{i=1}^{n} Log\,(x_i+1)*y}{\sum_{i=1}^{n} Log\,(x_i+1)} * 100$
  - n = # of taxa
  - x_i is the abundance of the taxon i and
  - y = 1 if taxon is 'at risk', or 0 if not

SPEAR index

PNAS PNAS PNAS PNAS

Pesticides reduce regional biodiversity of stream invertebrates

Mikhail A. Beketov[a,1], Ben J. Kefford[b], Ralf B. Schäfer[c], and Matthias Liess[a]

[a]Department of System Ecotoxicology, Helmholtz Centre for Environmental Research - UFZ, 04318 Leipzig, Germany; [b]Centre for Environmental Sustainability, School of the Environment, University of Technology Sydney, Sydney, NSW 2007, Australia; and [c]Quantitative Landscape Ecology, Institute for Environmental Sciences, University of Koblenz-Landau, 76829 Landau, Germany

Edited by David Pimentel, Cornell University, Ithaca, NY, and accepted by the Editorial Board May 13, 2013 (received for review March 25, 2013)

The biodiversity crisis is one of the greates manity, but our understanding of the driver after decades of studies and regulation effo whether to what degree and at what con ricultural pesticides cause regional-scale spe the effects of pesticides on the regional t invertebrates in Europe (Germany and Franc ern Victoria). Pesticides caused statistically both the species and family richness in both taxa up to 42% of the recorded taxonom the effects in Europe were detected at con legislation considers environmentally prote ecological risk assessment of pesticides fa biodiversity, and new approaches linking e ogy are needed.

environmental impacts | environmental risk asses plant protection products | macroinvertebrates |

ELSEVIER

Available online at www.sciencedirect.com

Science of the Total Environment 382 (2007) 272–285

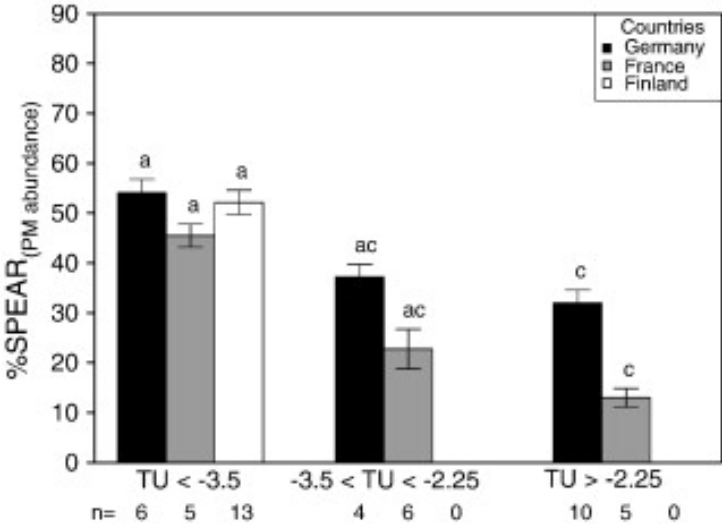
www.elsevier.com/locate/scitotenv

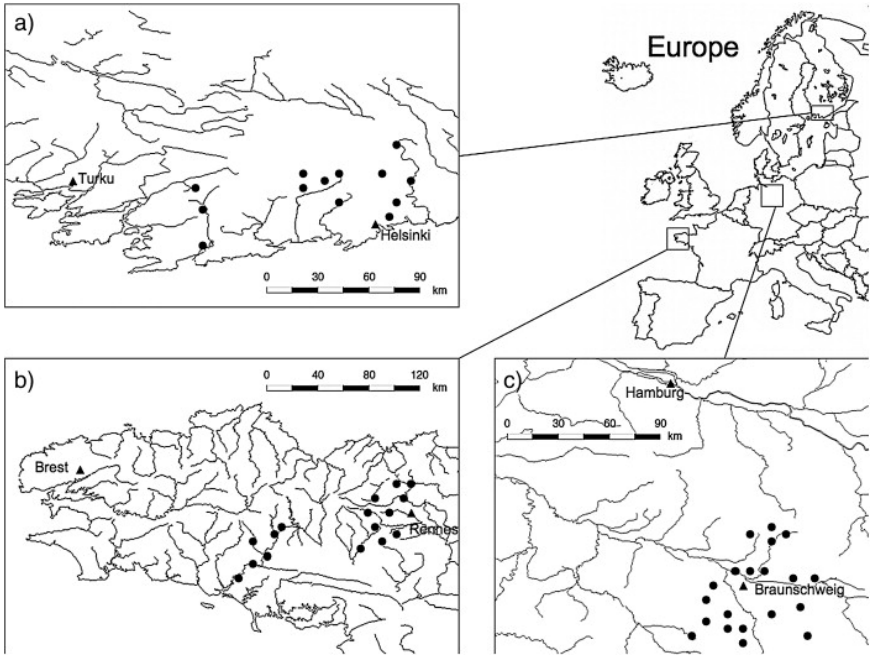
Effects of pesticides on community structure and ecosystem functions in agricultural streams of three biogeographical regions in Europe

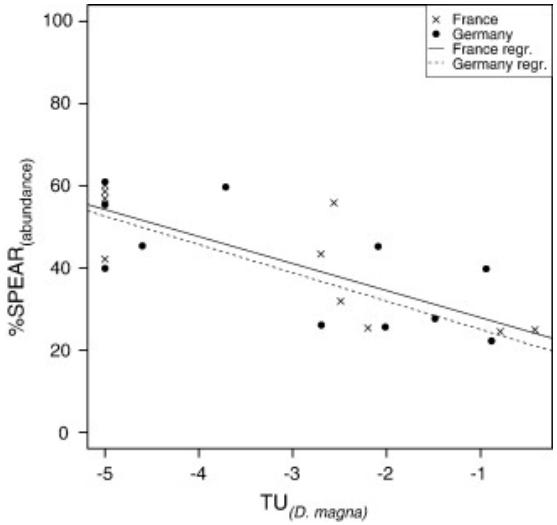
Ralf Bernhard Schäfer [a,b,*], Thierry Caquet [c], Katri Siimes [d], Ralf Mueller [e], Laurent Lagadic [c], Matthias Liess [a]

SPEAR index

- Invertebrate samples taken in three countries in Europe → $SPEAR_{pesticide}$
- Also pesticides measured and recalculated to $TU_{daphnia}$







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SPEAR index

- SI: DE and FR

	Site groups		
	Uncontaminated (TU < –4)	Slightly contaminated (–4 < TU < –2)	Highly contaminated (TU > –2)
Parameter	Mean	Mean	Mean
TU	–4.86	–2.59	–0.94
Temperature, °C	12.08	12.99	13.05
pH	7.12	7.45	7.79
Ammonium, mg/L	0.06	0.07	0.13
Nitrite, mg/L	0.10	0.11	0.15
Nitrate, mg/L	11.06	13.89	20.73
Orthophosphate, mg/L	0.26	0.84	0.39
Oxygen, %	10.15	10.24	10.62
Velocity, m/s	0.29	0.23	0.19
Width, m	2.07	2.01	1.48
Wood, %	11.80	17.21	11.48
Free substrate, %	54.08	60.35	66.49
Allochthonous leaves, %	11.25	6.98	5.04
Stoniness, share	0.68	0.96	0.26
Hardness, °dH	5.64	12.37	20.87
Conductivity, µS/cm at 25 °C	446	612	944
Submersed plants, %	16.13	11.06	8.63
Immersed plants, %	5.00	2.79	6.38
Filamentous algae, %	0.25	1.60	1.98

Mean values and SDs are given for each contamination category and for the entire dataset.

SPEAR index

Science of the Total Environment 505 (2015) 565–572

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Short Communication

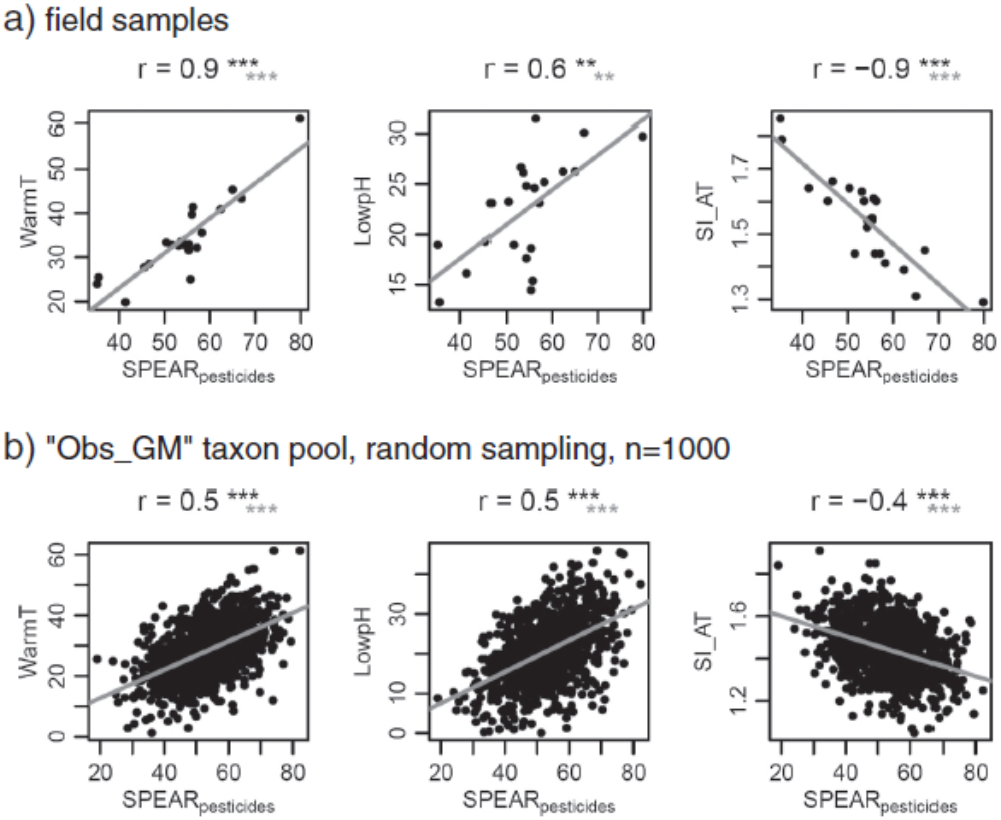
How stressor specific are trait-based ecological indices for ecosystem management?

Nele Schuwirth *, Mira Kattwinkel, Christian Stamm

Eawag: Swiss Federal Institute of Aquatic Science and Technology, 8600 Dübendorf, Switzerland

HIGHLIGHTS

- Trait-based indices can help river managers to identify relevant stressors.
- We test how stressor specific such indices are by analysing the sensitivity of taxa.
- We quantify inherent correlations between indices with Monte-Carlo simulations.
- We demonstrate how to clearly distinguish these from correlations between stressors.
- Inherent correlation of indices increases with decreasing biodiversity.



- Indices
  - $SPEAR_{pesticides}$
  - Temperature
  - Flow velocity
  - pH stress

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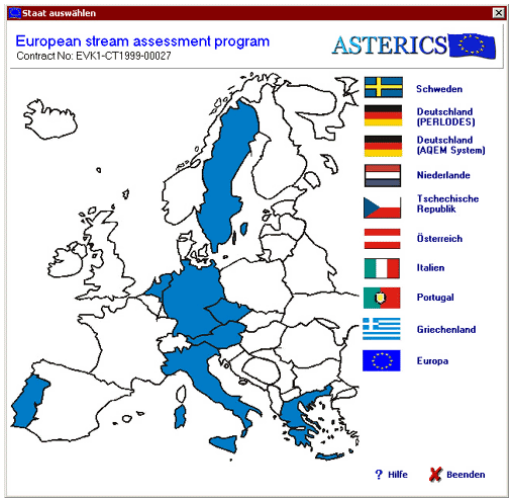
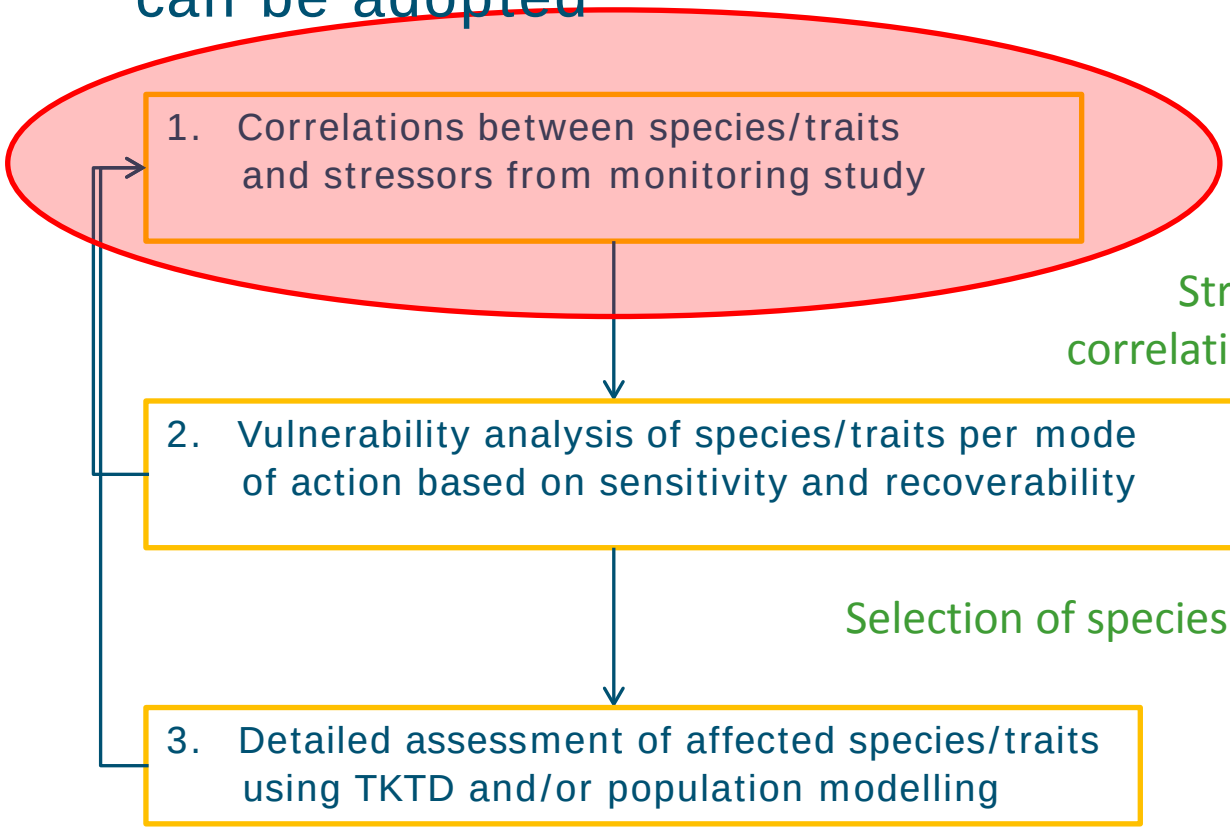
SPEAR index

- ASTERICS (version 4.0.4)
  - calculates the ecological status of rivers based on benthic invertebrate taxa lists
  - Water Framework Directive
  - 83 indices for general water quality + $SPEAR_{pesticide}$
  - 1063 species used for correlation (662 ±328)
  - Correlations between indices and $SPEAR_{pesticide}$
    - P < 0.001 63%
    - P < 0.01 70%
    - P < 0.05 80%



Diagnosis of field impacts of chemicals

- Problem: correlation in field data cannot be avoided
- But a more holistic view including all possible stressors can be adopted



Multivariate analysis or correlation analysis

Stressors x and y have a significant correlation with invertebrate community

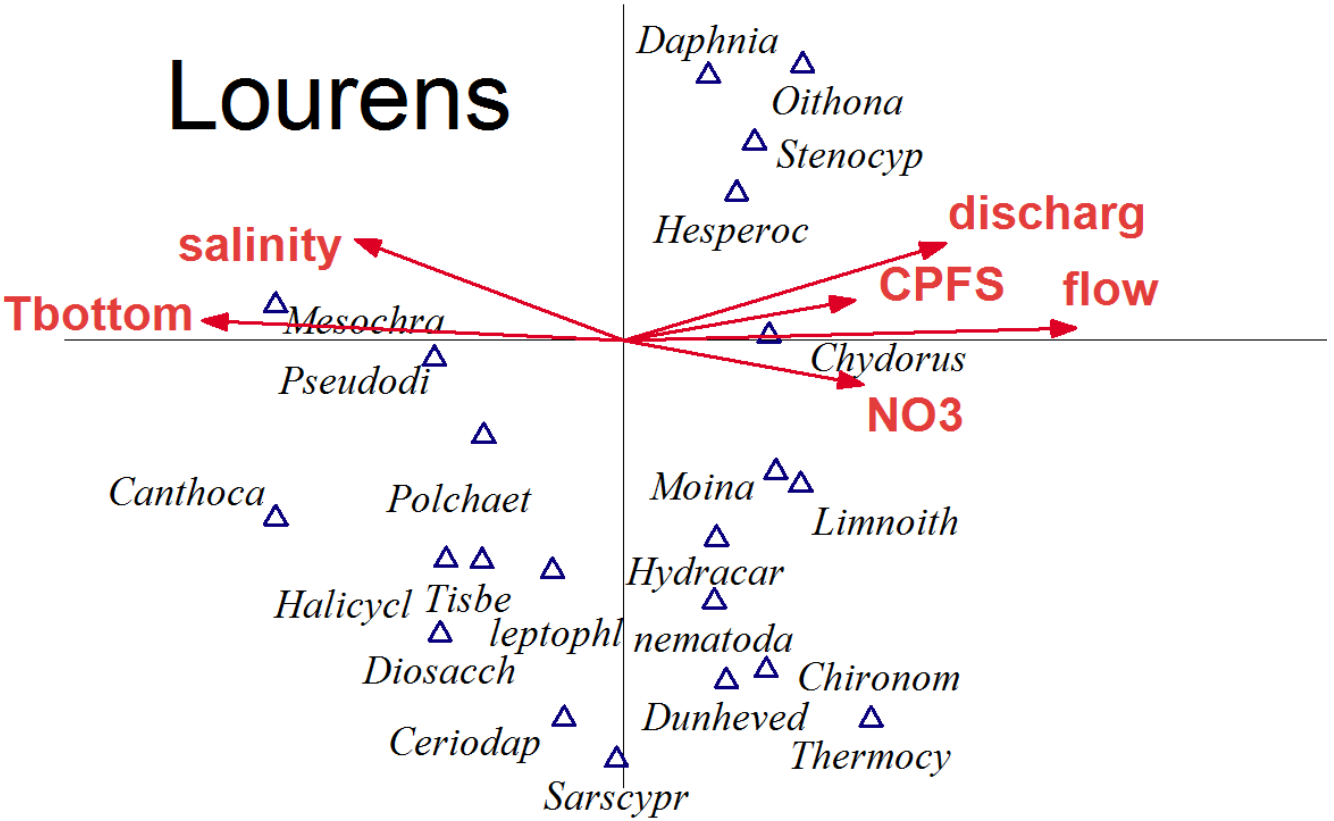
Which species/traits are likely to be influenced?

Selection of species for which causality makes sense

In depth analysis of expected response

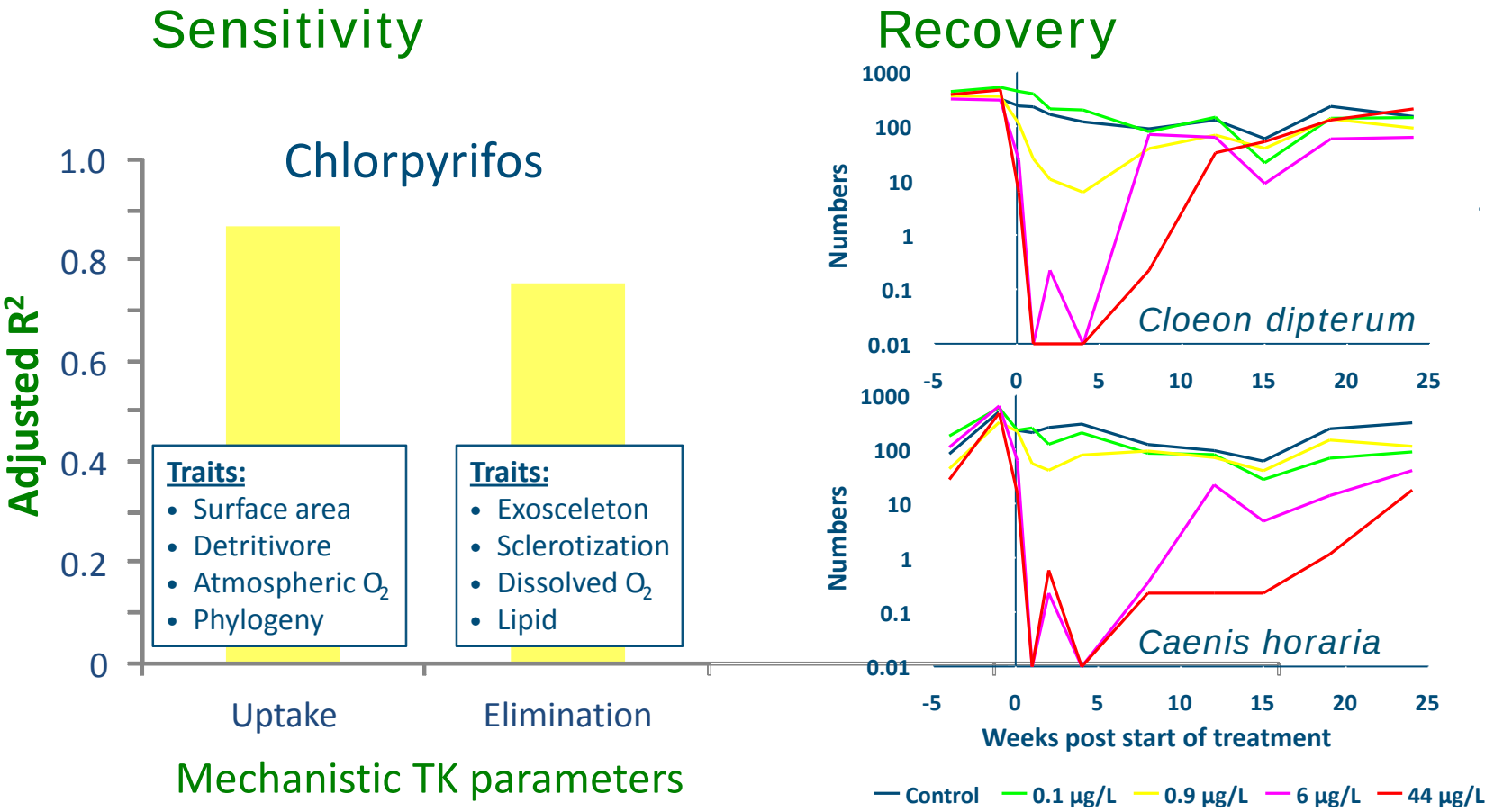
1. Corr. between biology and stressors

Environmental variables, pesticide pollution and meiofaunal community structure in two contrasting temporarily open/ closed False Bay estuaries



1. Corr. between biology and stressors

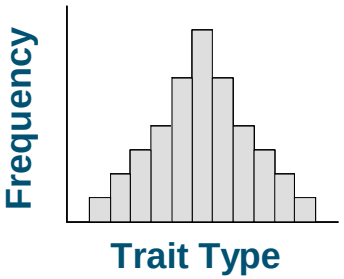
- Traits determine vulnerability



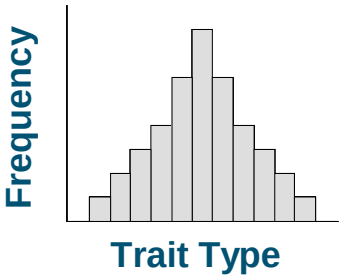
Rubach et al., 2012
Van den Brink et al., 1996

1. Corr. between biology and stressors

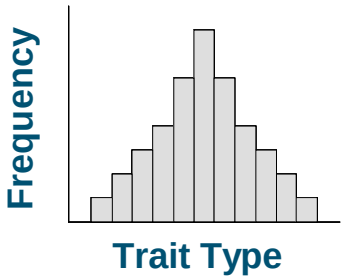
Reference site



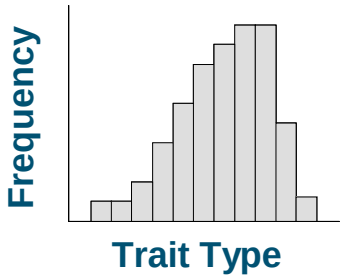
No environmental impact
at reference site
Traits frequency unchanged



Stressed site



Environmental Stressor Filtering
at test site
Traits that provides resistance or
resilience to stressor are favoured



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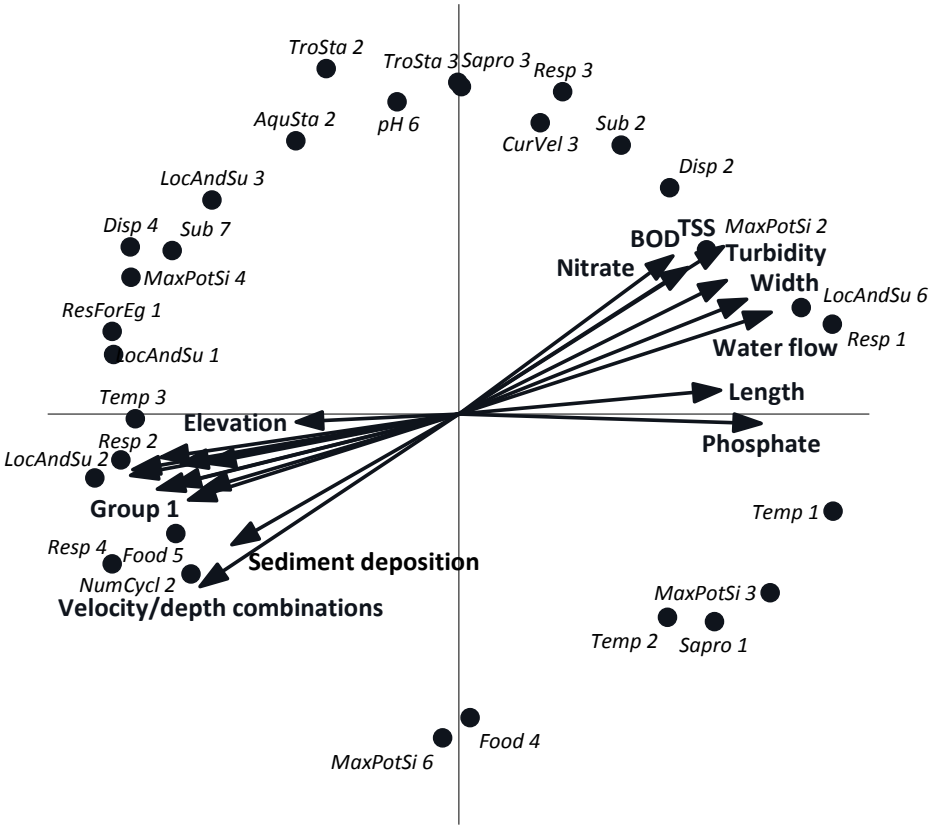
Culp et al., 2011

1. Corr. between biology and stressors

Environmental Management (2015) 56:260–269
DOI 10.1007/s00267-015-0489-x

Assessment of Ecological Quality of the Tajan River in Iran Using a Multimetric Macroinvertebrate Index and Species Traits

Group 1 constitutes of the habitat parameters bank vegetative protection, epifaunal substrate/available cover, embeddedness, channel flow status, channel alteration, frequency of riffles, bank stability, riparian vegetative zone width as well as the sum of all habitat parameters.



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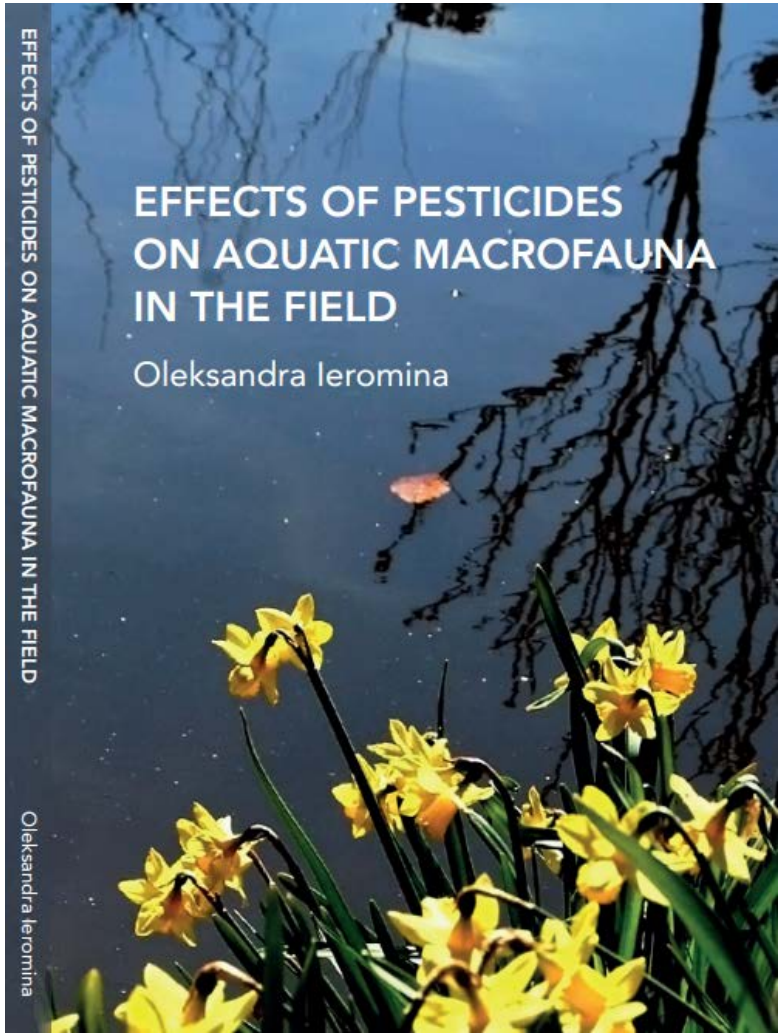
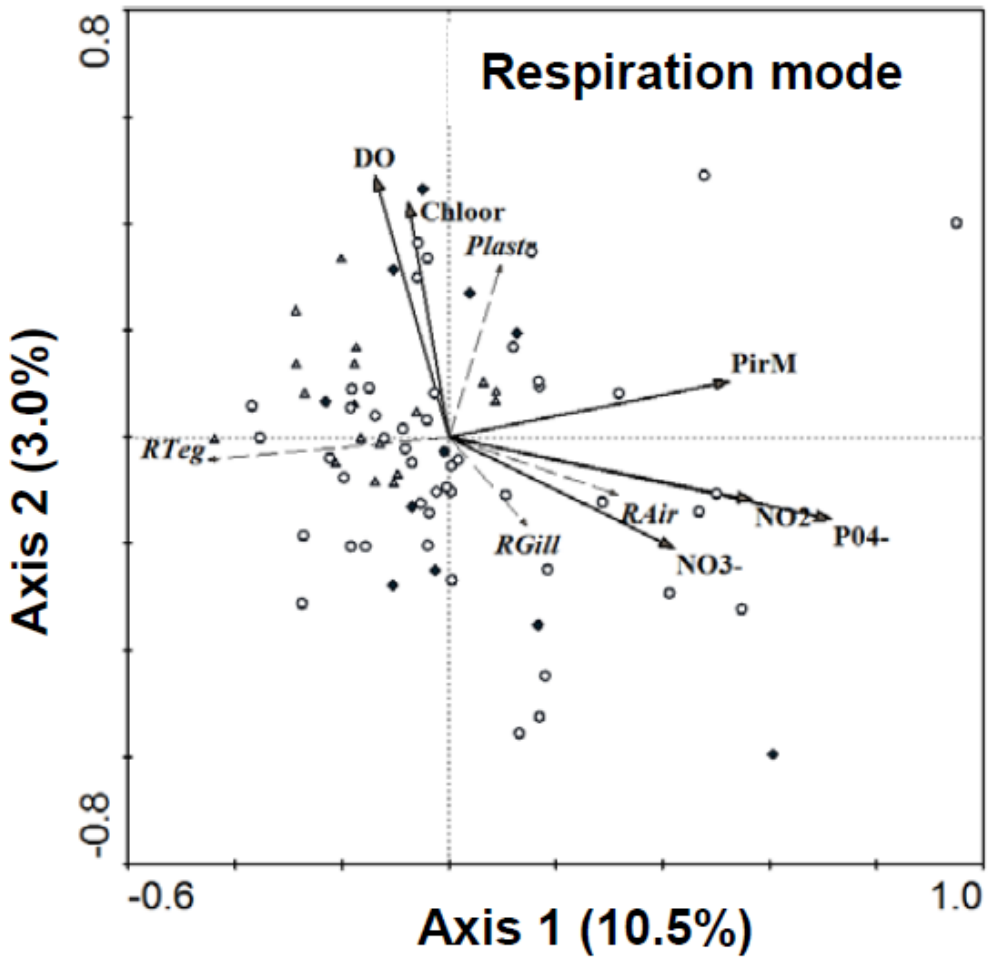
1. Corr. between biology and stressors





Traits: Gill, aerial, plastron, tegument respiration

Chem.: Chlorprofam, pirimiphos-methyl

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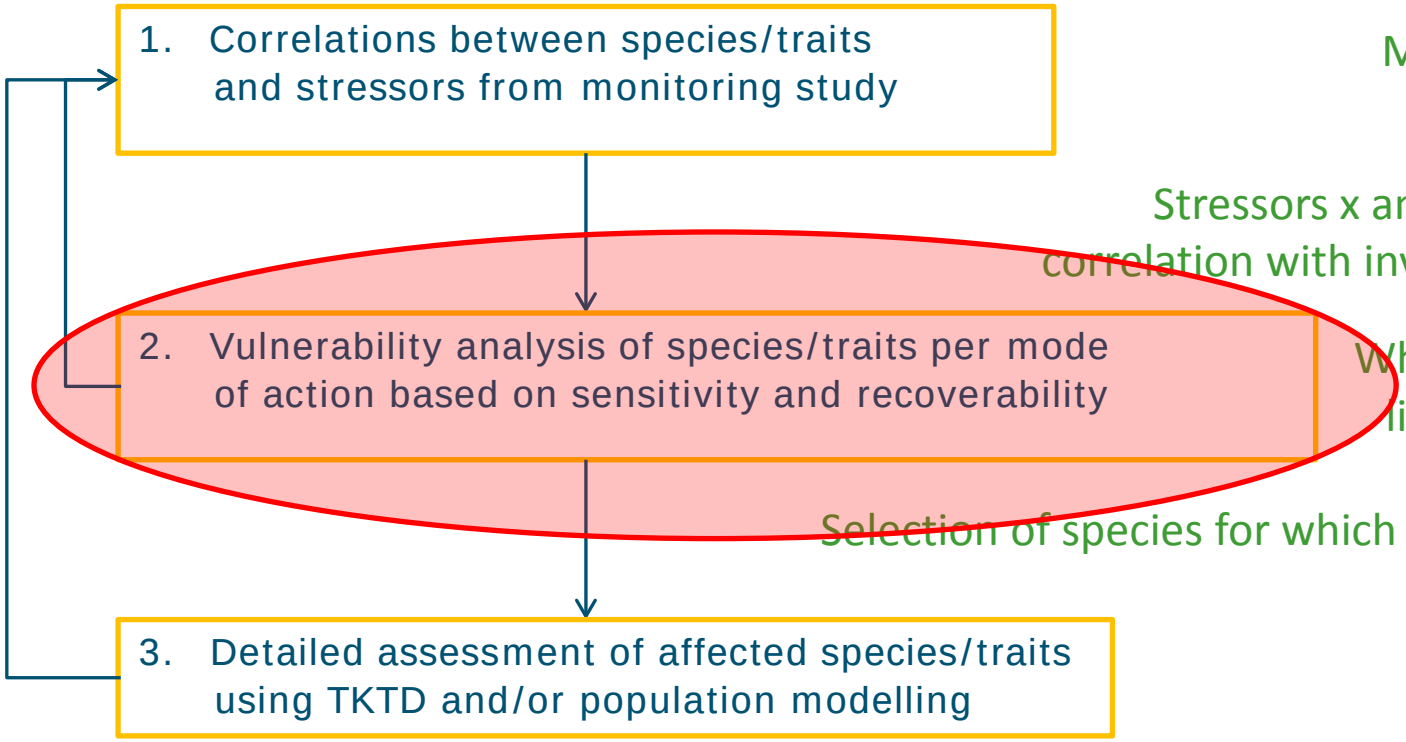
Diagnosis of field impacts of chemicals



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In depth analysis of expected response

2. Vulnerability analysis

- Pesticides

SETAC PRESS

Environmental Toxicology and Chemistry, Vol. 9999, No. 9999, pp. 1–11, 2015

Printed in the USA

Environmental Toxicology

EVALUATING AQUATIC INVERTEBRATE VULNERABILITY TO INSECTICIDES BASED ON INTRINSIC SENSITIVITY, BIOLOGICAL TRAITS, AND TOXIC MODE OF ACTION

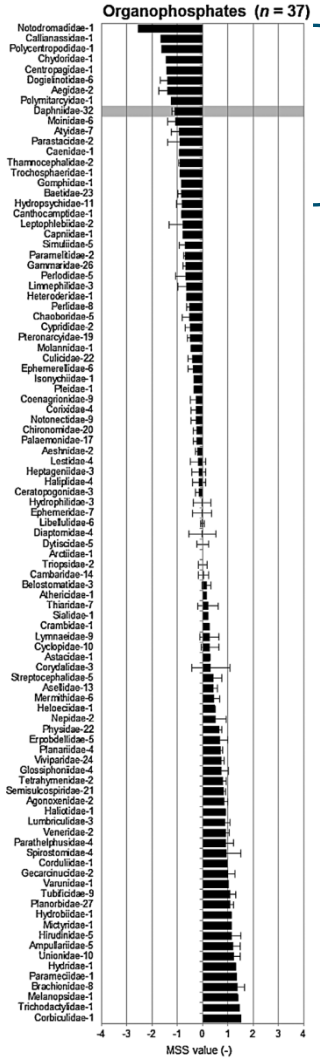
ANDREU RICO*† and PAUL J. VAN DEN BRINK†‡

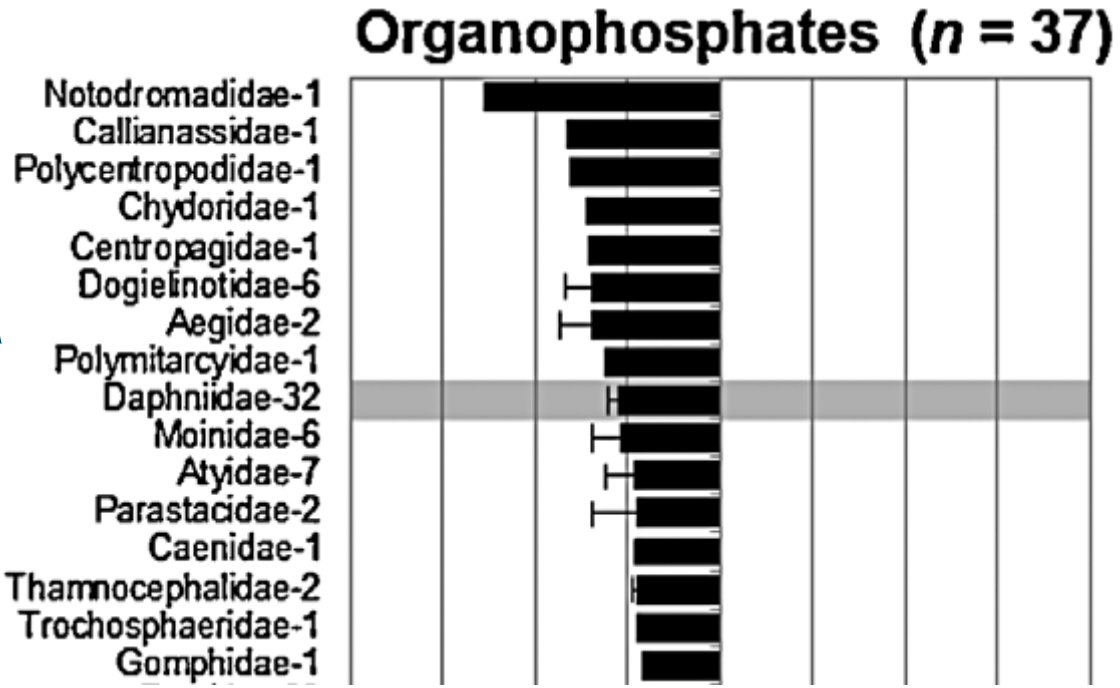
†Alterra, Wageningen University and Research Centre, Wageningen, The Netherlands

‡Department of Aquatic Ecology and Water Quality Management, Wageningen University, Wageningen University and Research Centre, Wageningen, The Netherlands

(Submitted 23 January 2015; Returned for Revision 17 March 2015; Accepted 3 April 2015)

2. Vulnerability analysis





$$RelSens = -0.2 - 0.2 \cdot Size + 0.3 \cdot Scle - 1.0 \cdot Arth$$

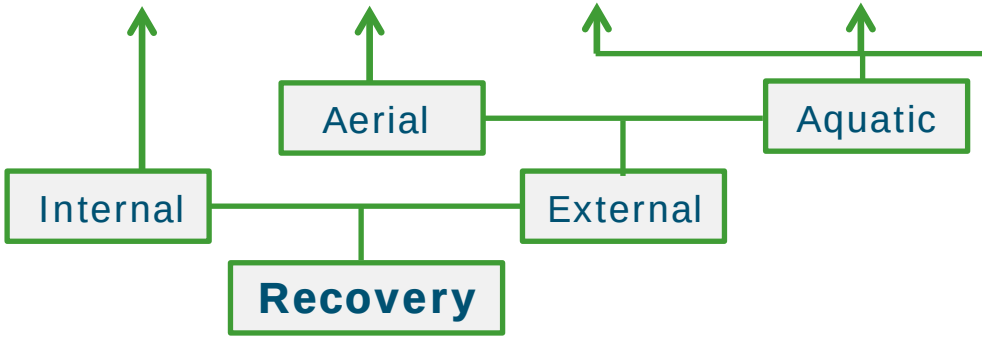
$$(r^2 = 0.5;\ p < 0.001)$$

2. Vulnerability analysis

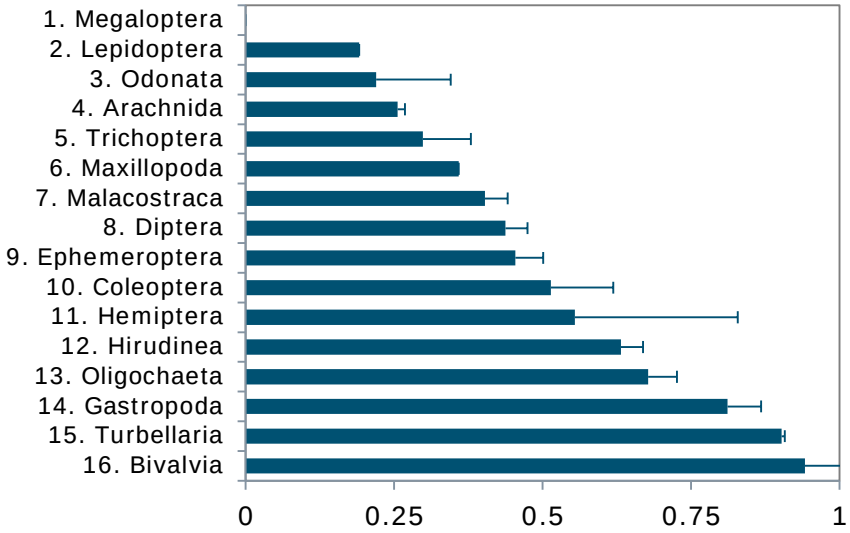
- Invertebrate Vulnerability Index:

$$RelSens = -0.2 - 0.2 \cdot Size + 0.3 \cdot Scle - 1.0 \cdot Arth$$

$$IVI = (RelSens \cdot 0.46) + (Volti \cdot 0.26) + (Fly \cdot 0.14) + (Drift \cdot 0.05) + (Crawl \cdot 0.04) + (Swim \cdot 0.04)$$



Averaged IVI for different class/orders for pyrethroids



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2. Vulnerability analysis

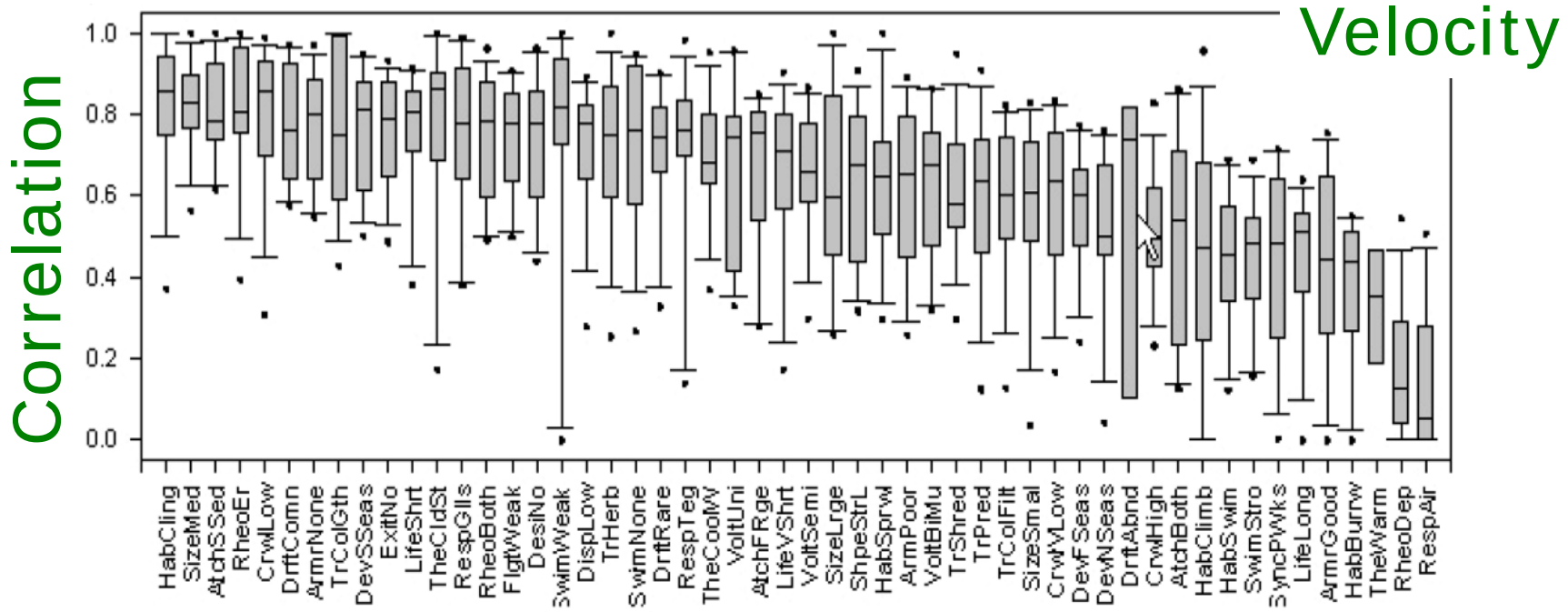
Trait patterns of aquatic insects across gradients of flow-related factors: a multivariate analysis of Canadian national data

Nelli Horrigan and Donald J. Baird

Can. J. Fish. Aquat. Sci. 65: 670–680 (2008) doi:10.1139/F07-191

- Evaluate relationships between taxon traits and three flow-related variables (velocity, T and DO)
- 13 independently collected Canadian data sets
- To develop a flow bioassessment metric irrespective of geographical region

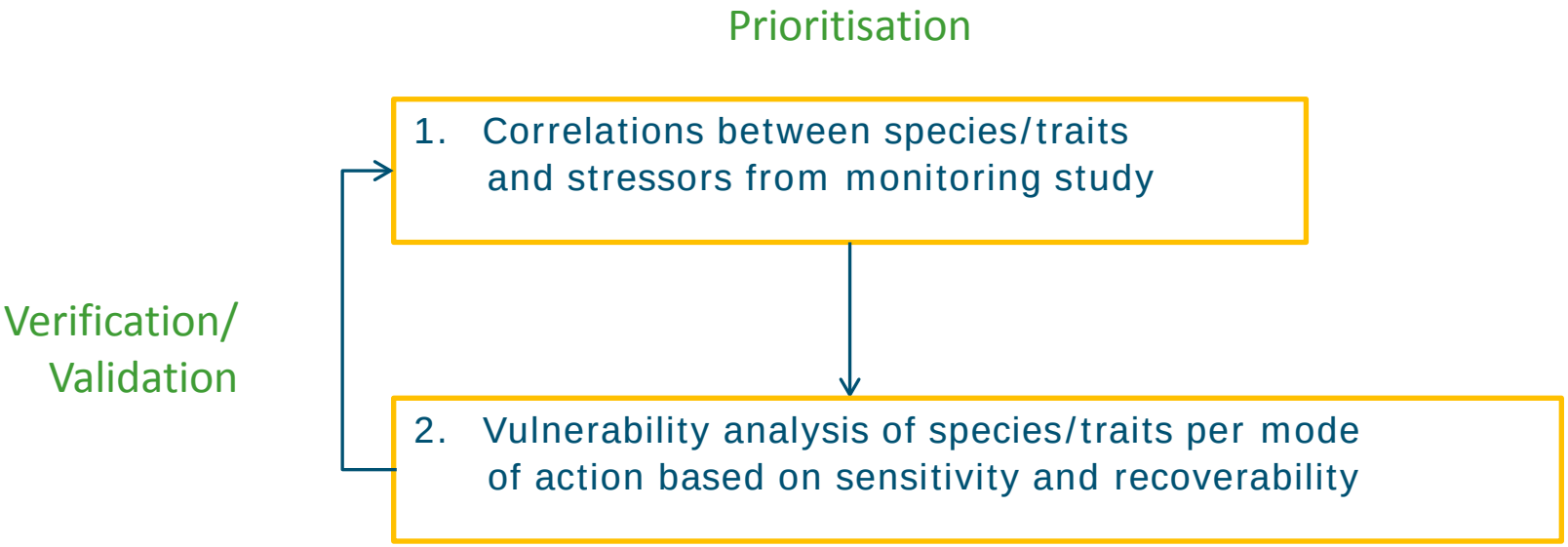
2. Vulnerability analysis



- Traits related to flow
  - Low crawling rate
  - Common occurrence in drift
  - Short adult life span
  - Erosional rheophily
  - Medium size at maturity
  - Cold thermal preference

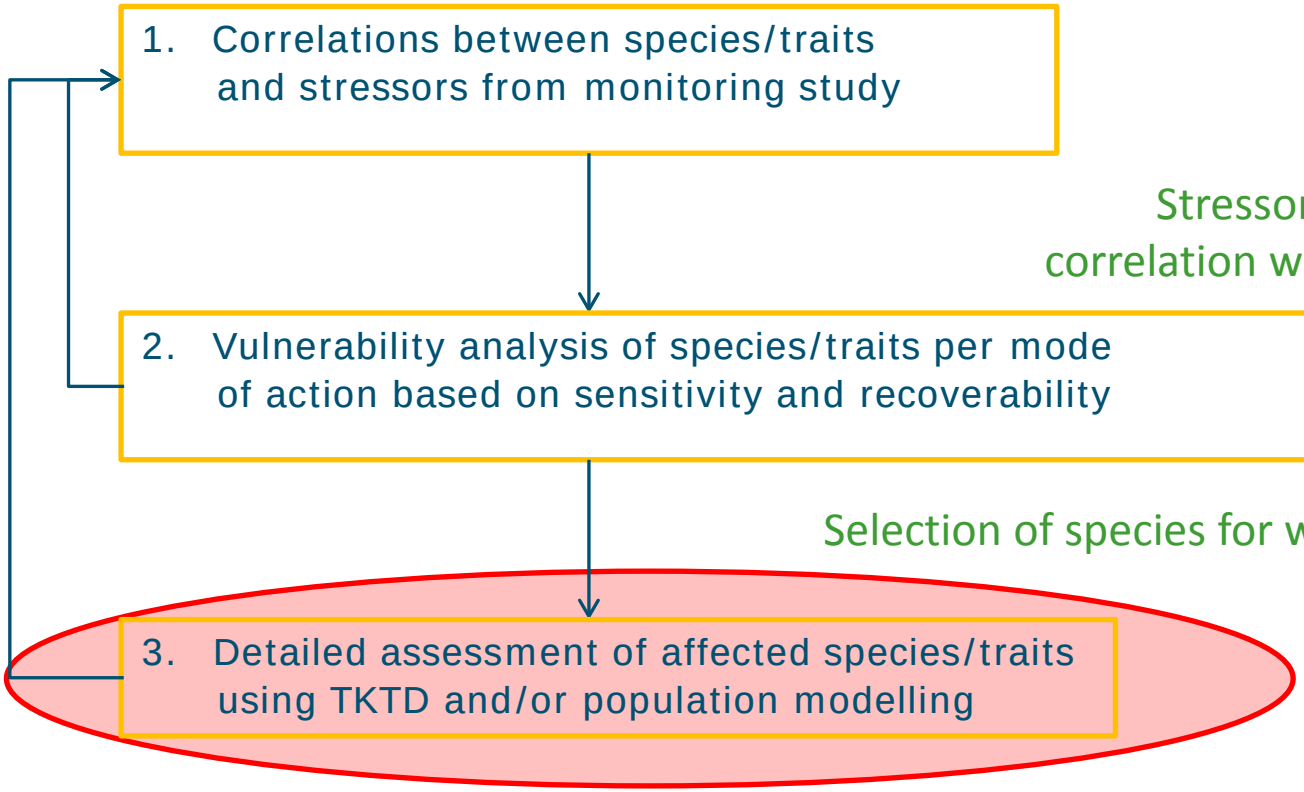
Diagnosis of field impacts of chemicals

- The circle of diagnosis
  - Selection of species/traits and chemicals
  - Hypotheses
  - Very specific vulnerability indicators
  - Verification/validation



Very specific indicators based on external data

Diagnosis of field impacts of chemicals



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3. Detailed assessment using models

SETAC PRESS

Environmental Toxicology and Chemistry, Vol. 26, No. 10, pp. 2226–2236, 2007

Printed in the USA
0730-7268/07 $12.00 + .00

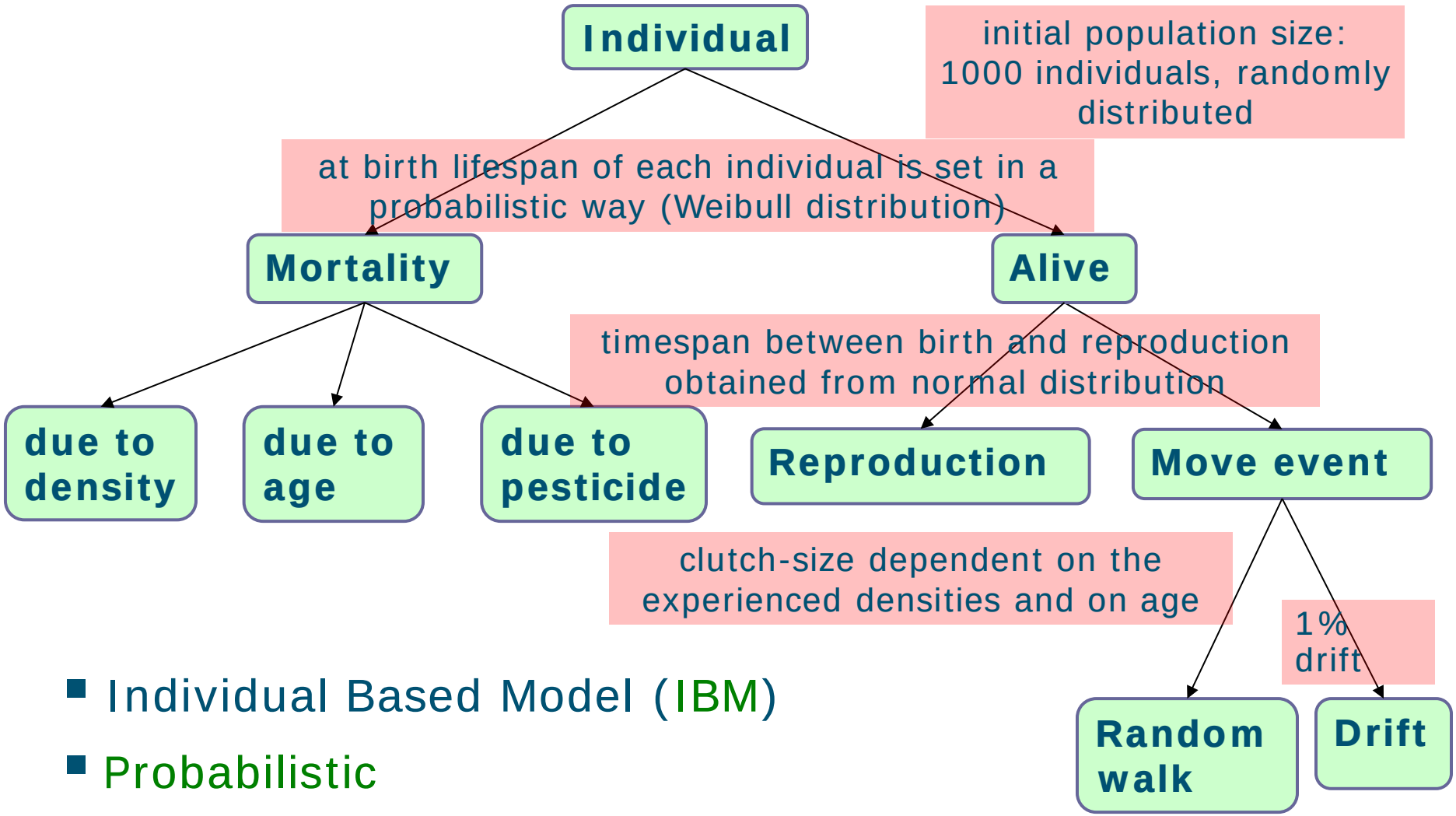
AN INDIVIDUAL-BASED APPROACH TO MODEL SPATIAL POPULATION DYNAMICS OF INVERTEBRATES IN AQUATIC ECOSYSTEMS AFTER PESTICIDE CONTAMINATION

PAUL J. VAN DEN BRINK,*†‡ J.M. (HANS) BAVECO,† JANA VERBOOM,† and FRED HEIMBACH§
†Alterra, Wageningen University and Research Centre, P.O. Box 47, 6700 AA Wageningen, The Netherlands
‡Wageningen University, Department of Aquatic Ecology and Water Quality Management, Wageningen University and Research Centre, P.O. Box 8080, 6700 DD Wageningen, The Netherlands
§Bayer CropScience, Alfred-Nobel-Straße 50, 40789 Monheim, Germany

(*Received* 10 *January* 2007; *Accepted* 30 *April* 2007)

- MASTEP: Metapopulation model for Assessing Spatial and Temporal Effects of Pesticides
- *Asellus aquaticus*, *Gammarus pulex*, *Chironomus riparius*, mayflies (*Cloeon dipterum*/*Baetis* sp.)

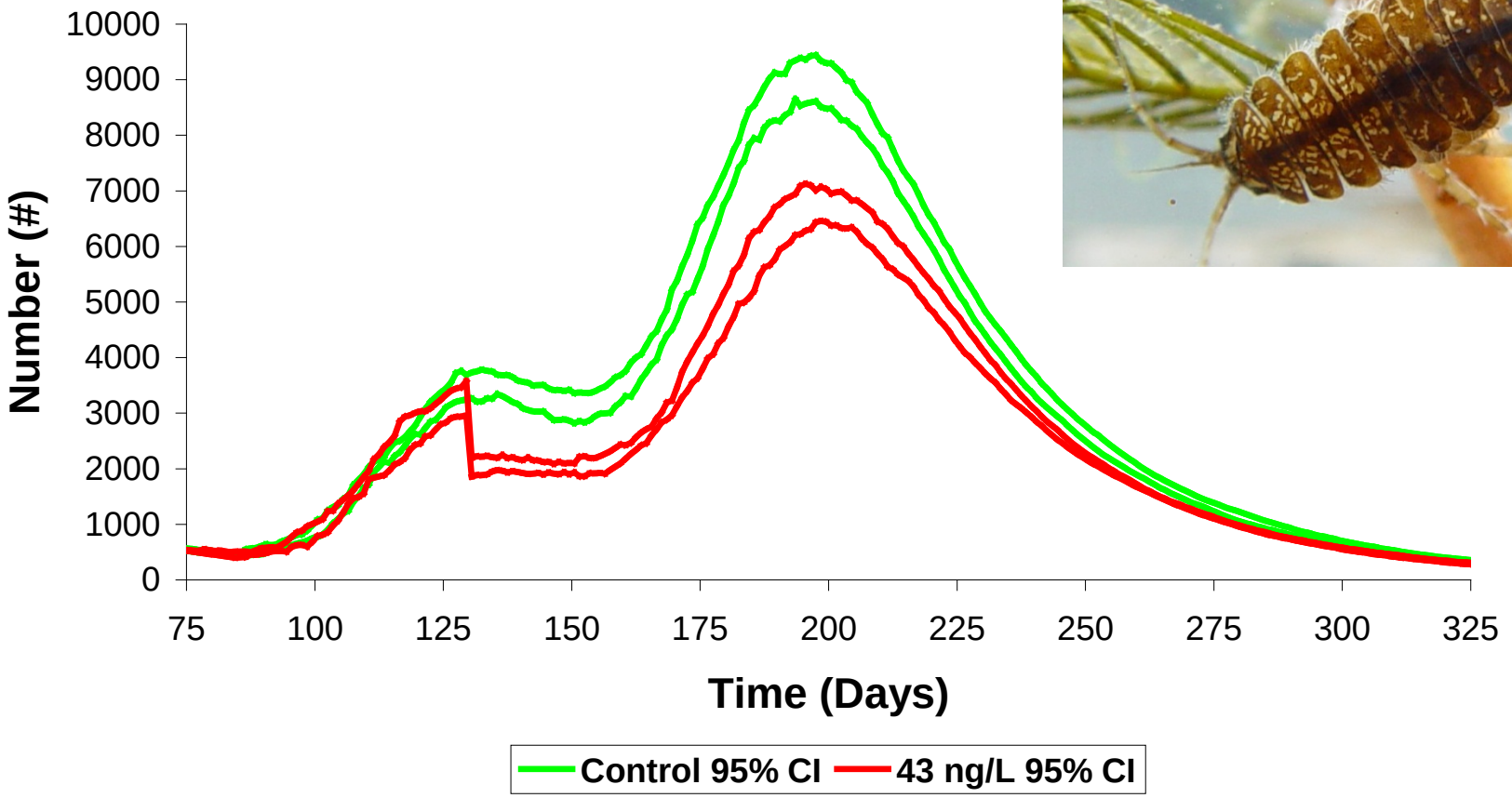
3. Detailed assessment using models



- Individual Based Model (IBM)
- Probabilistic

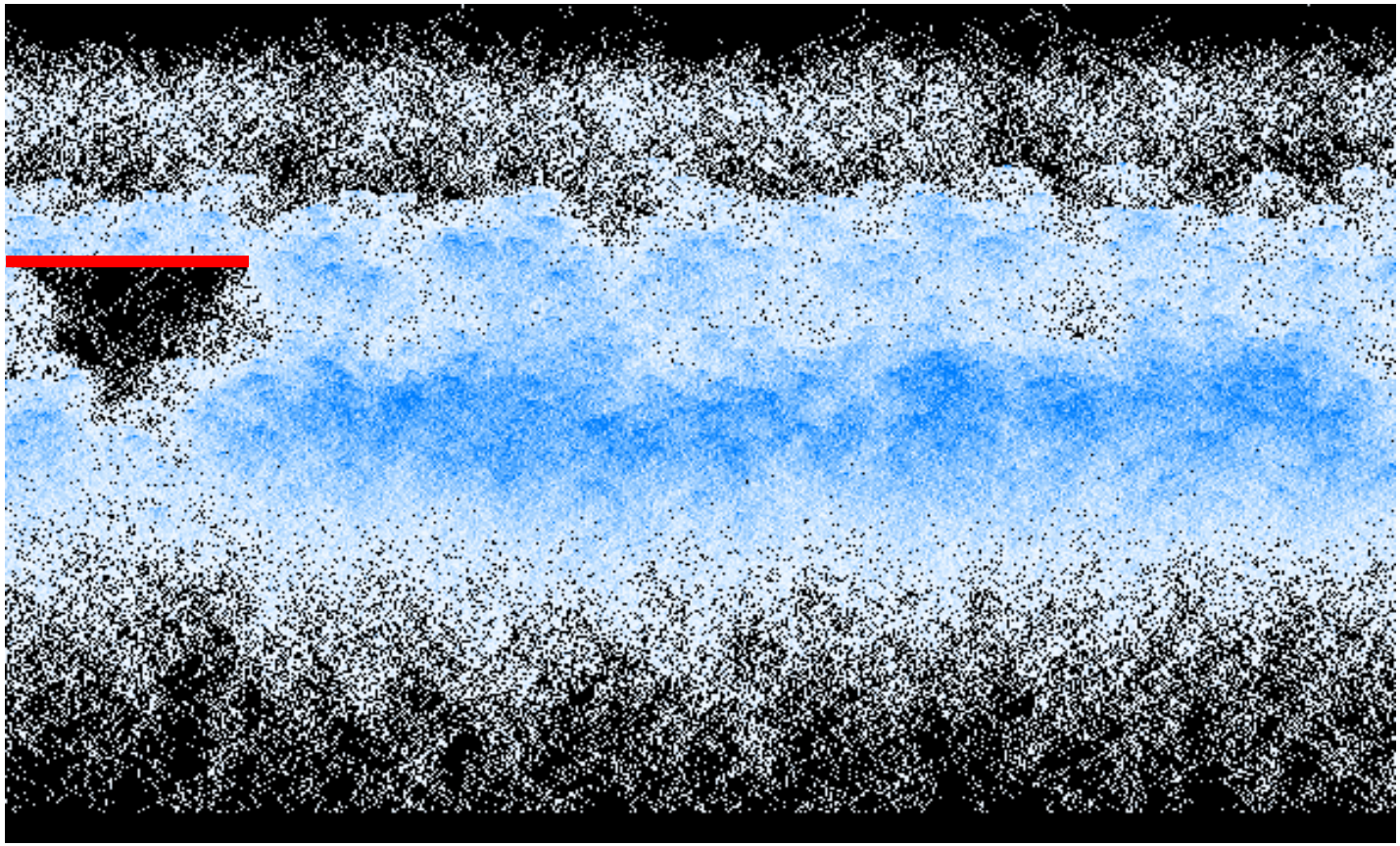
3. Detailed assessment using models

- Pond: *Asellus aquaticus*



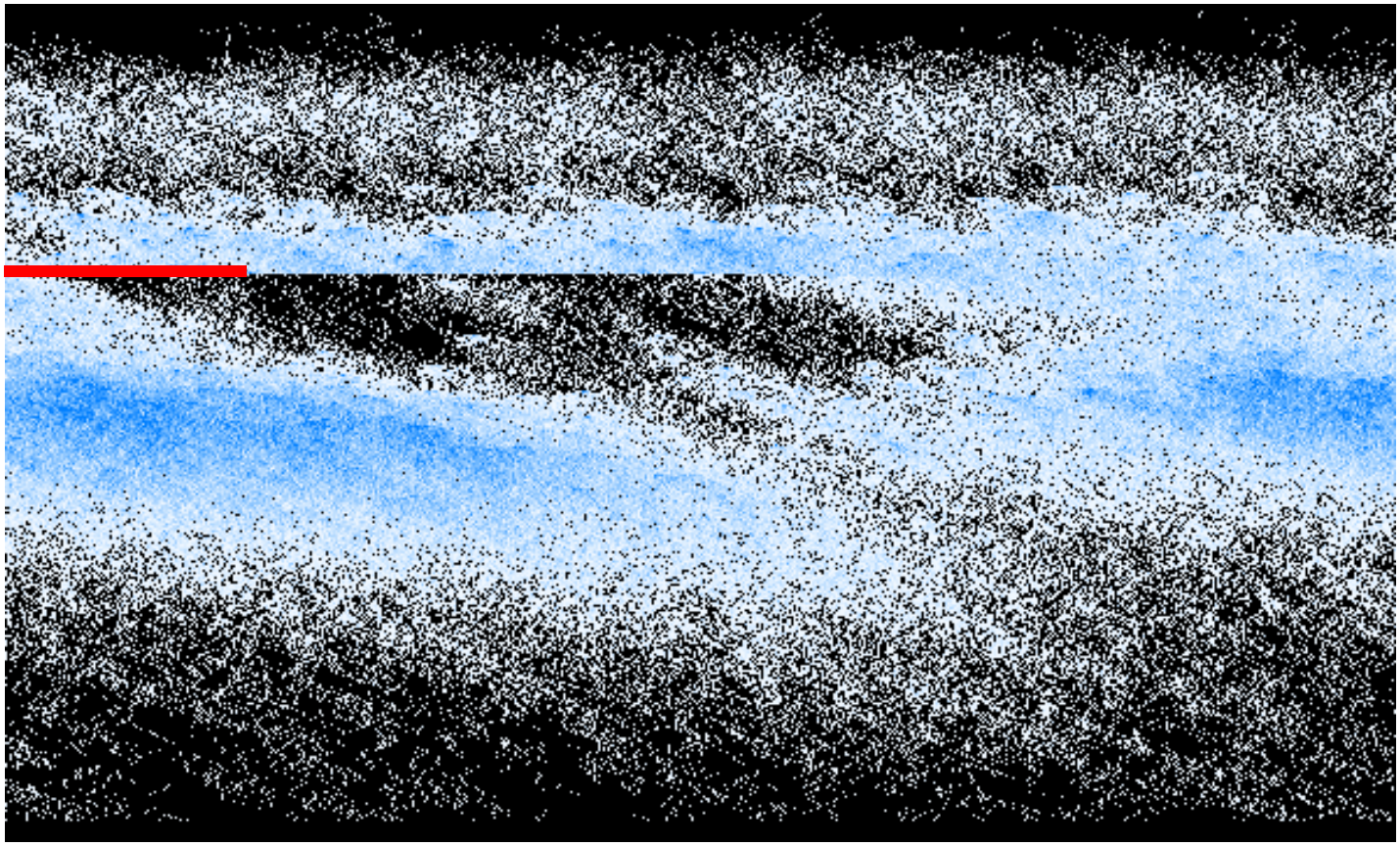
3. Detailed assessment using models

- Ditch: *Asellus aquaticus*



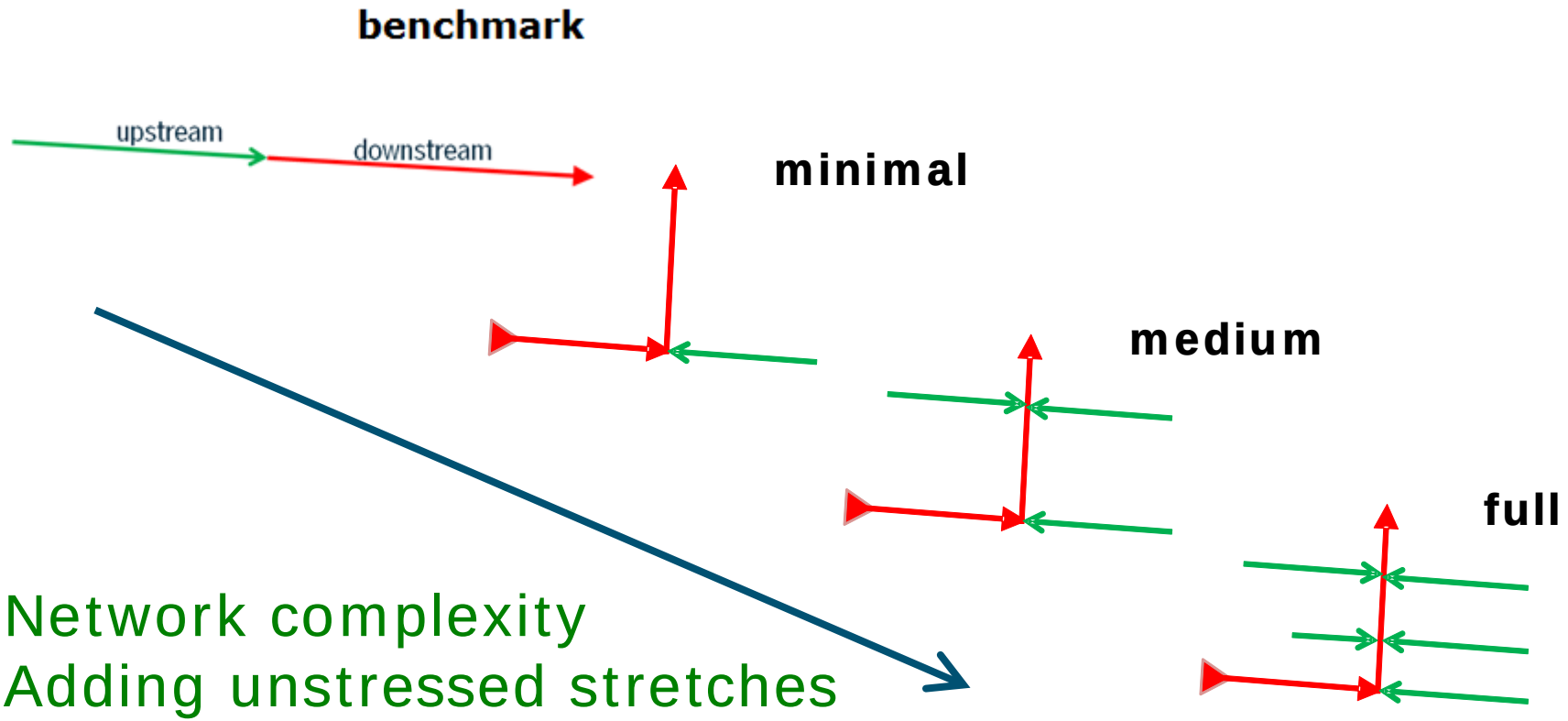
3. Detailed assessment using models

- Stream: *Asellus aquaticus*



3. Detailed assessment using models

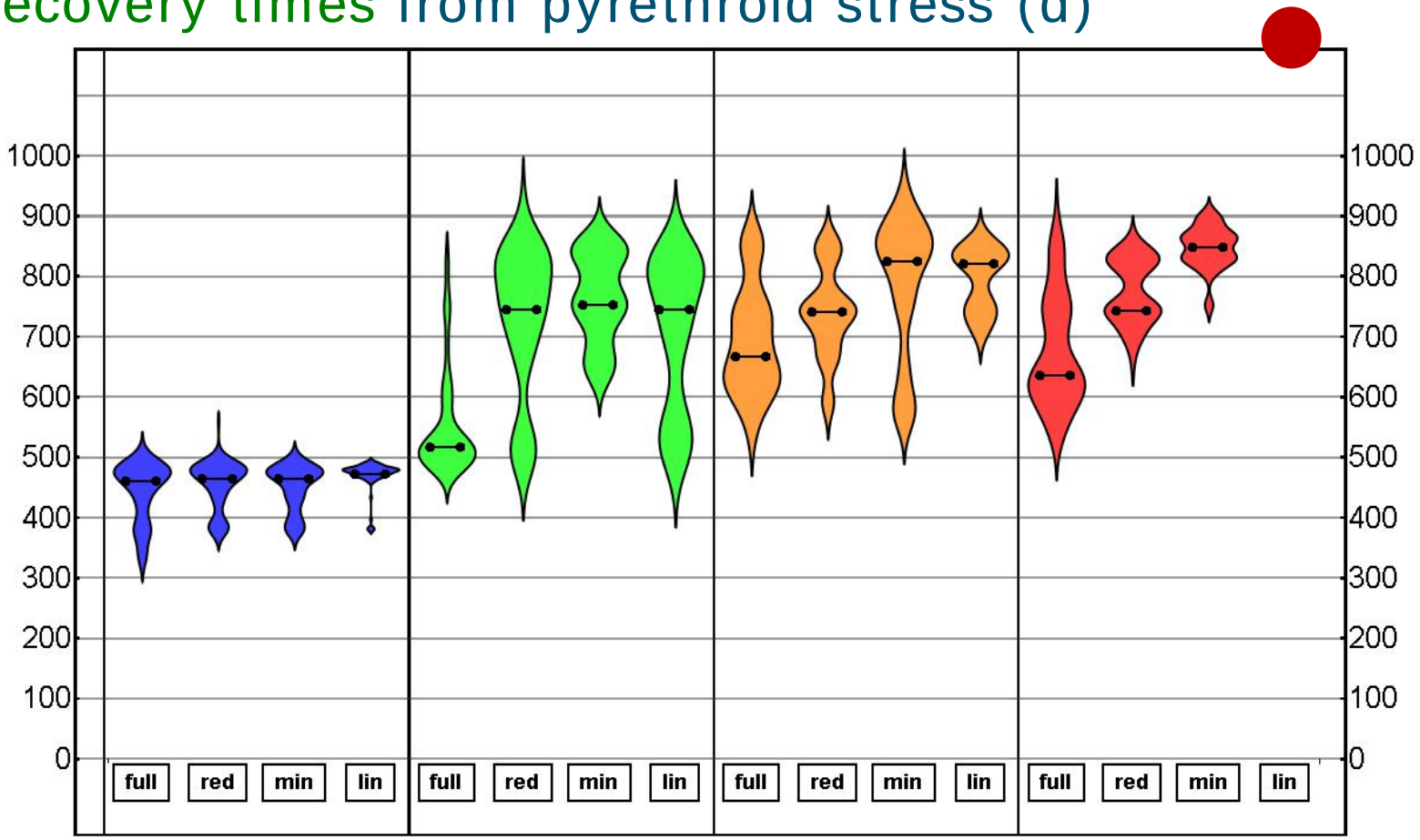
- Upscaling of modelling framework to connected waterways level (beyond the ditch, stream or pond)



Focks et al., 2013

3. Detailed assessment using models

- Recovery times from pyrethroid stress (d)



3. Detailed assessment using models

- More upscaling → network of 137 ditches

A: spray drift

B: no direct input

C: spray drift

D: no direct input

E: no direct input

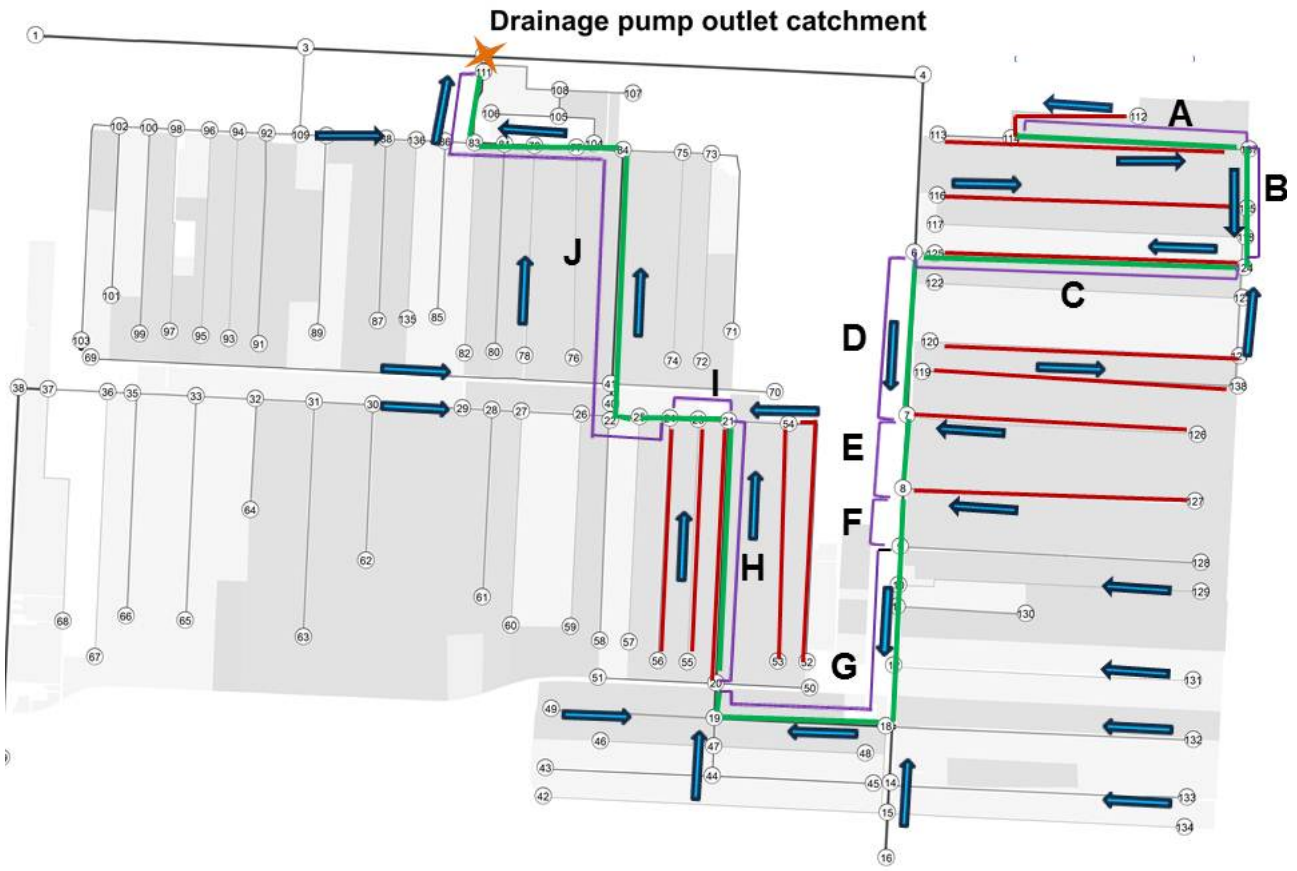
F: no direct input

G: no direct input

H: spray drift

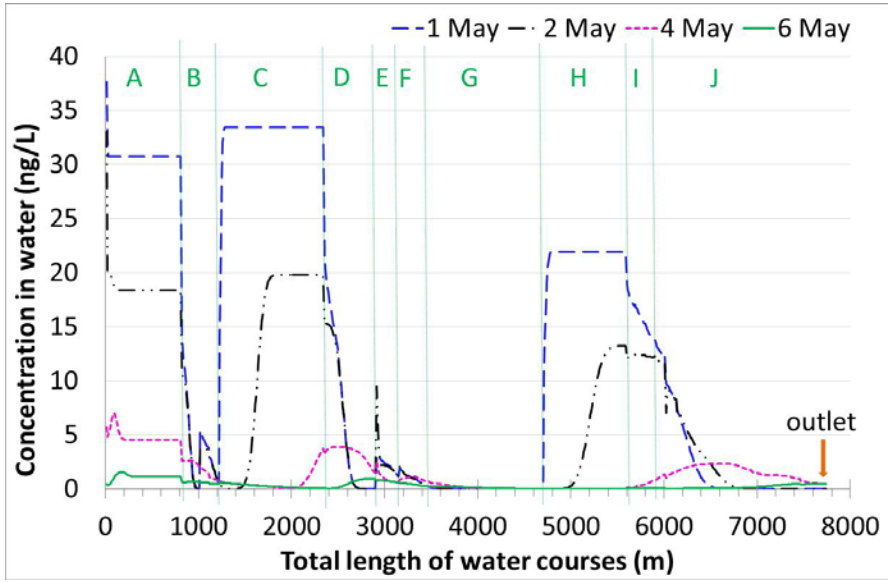
I: no direct input

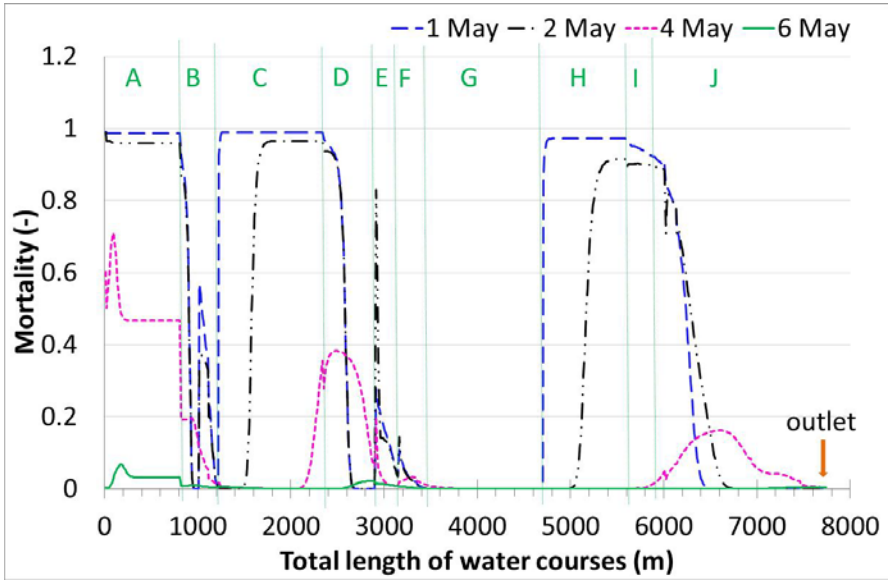
J: no direct input



3. Detailed assessment using models

- Concentrations of lambda-cyhalothrin and mortality probability

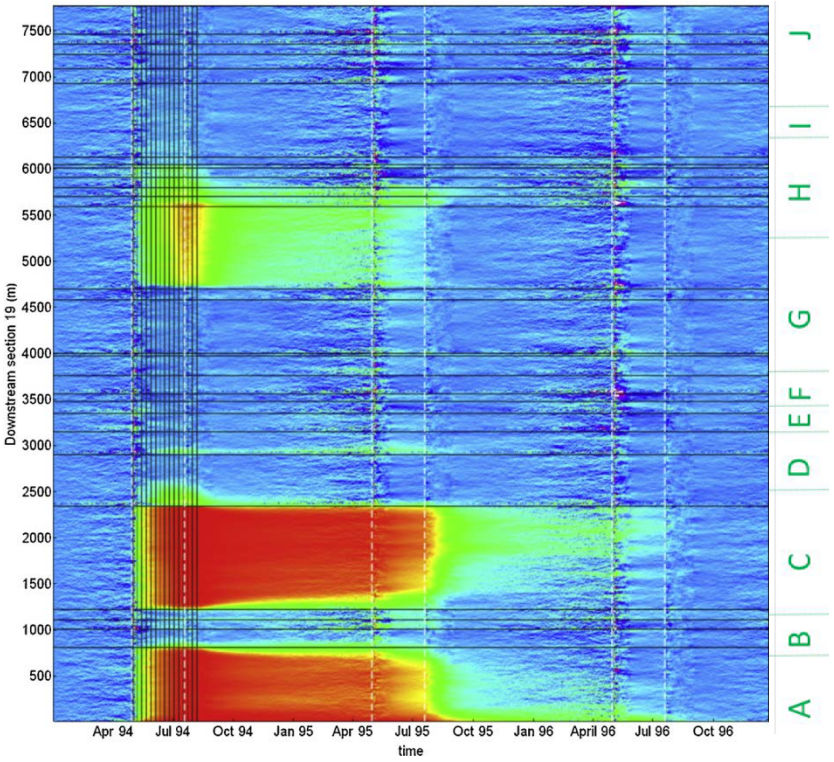




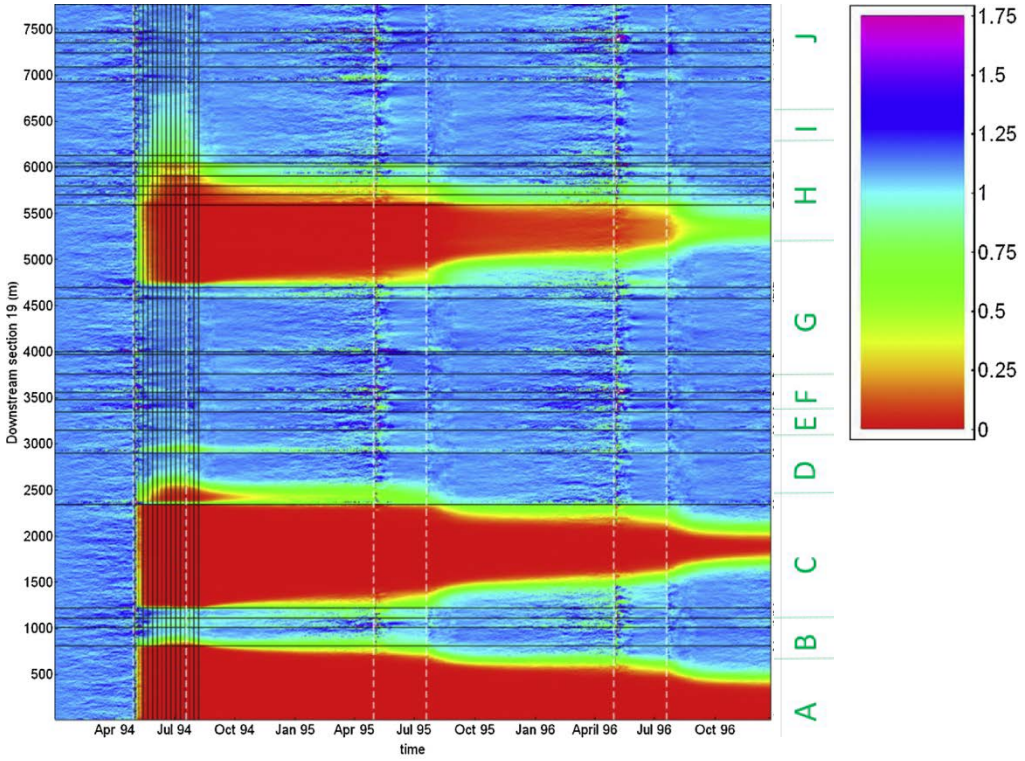
3. Detailed assessment using models

- Numbers relative to untreated runs

Low sensitivity



High sensitivity



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Conclusions / outlook

- Modelling
  - Increasing the complexity of the water network (functional connectivity) affects the effects and recovery times → increases realism
- Indices
  - Try to avoid collinearity of stress factors
  - Have to be very specific (I made an attempt but is this possible?)
  - More effort should be made in combining experimental and monitoring data
  - Ecological modelling could be included in monitoring programmes, especially for charismatic / important species (e.g. fish)

Thanks!

Questions?