What can we learn from landscape eco(toxico)logy for regulatory ecological risk assessment?

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Quantitative Landscape Ecology

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Aims of pesticide risk assessment

- Regulation EC 1107/2009 repealing EC 91/414: no unacceptable effects on environment, ecosystems and biodiversity

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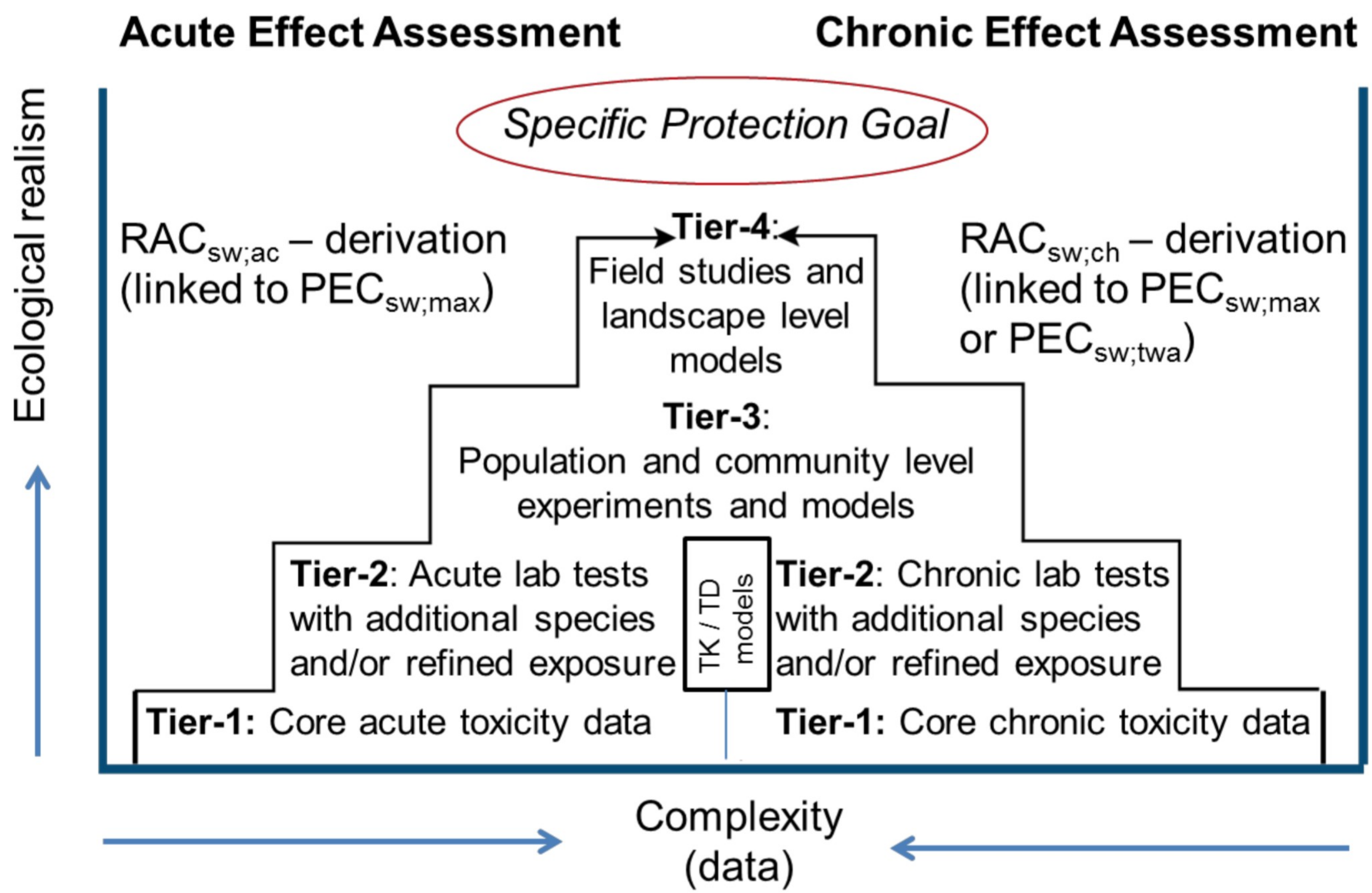

EFSA 2013

Aims of pesticide risk assessment

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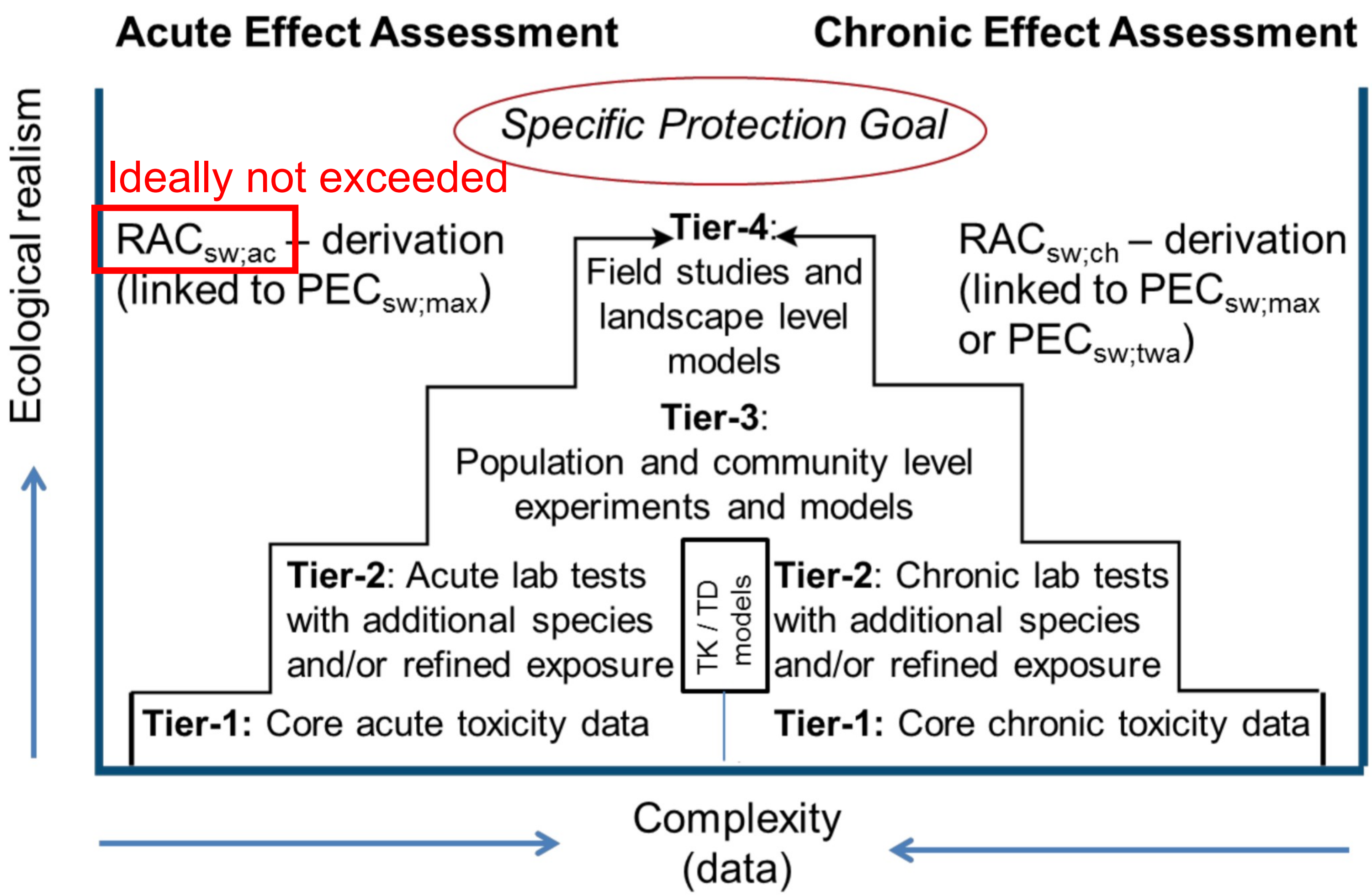
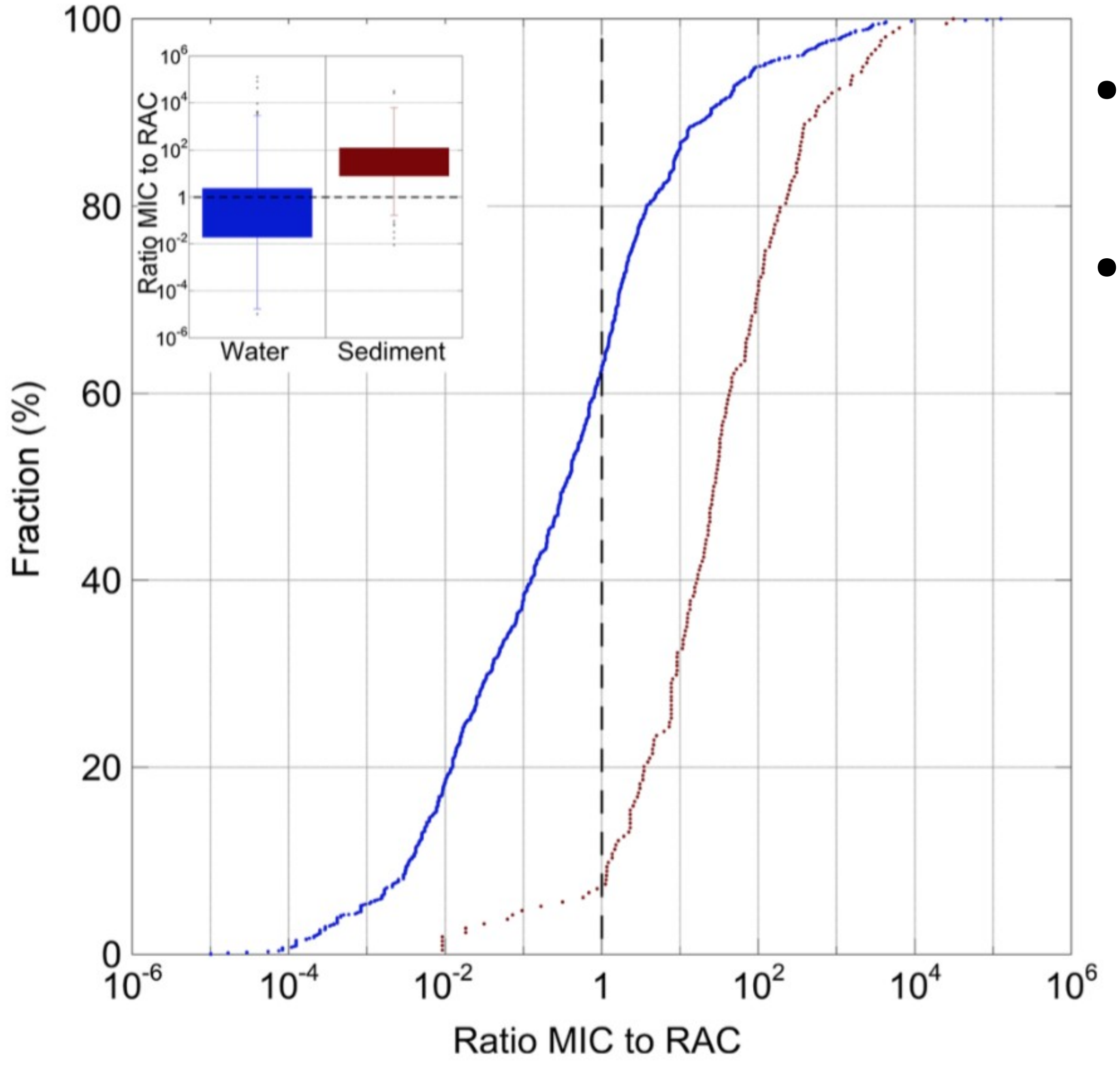


EFSA 2013

RACs are frequently exceeded

- Meta-analysis of EU insecticide concentrations (165 studies)



- ~ 40% exceedance of RAC_{SW}
- Exceedance in 55% of sites (n = 385)

Stehle & Schulz 2015 *Environ Sci Pollut Res*

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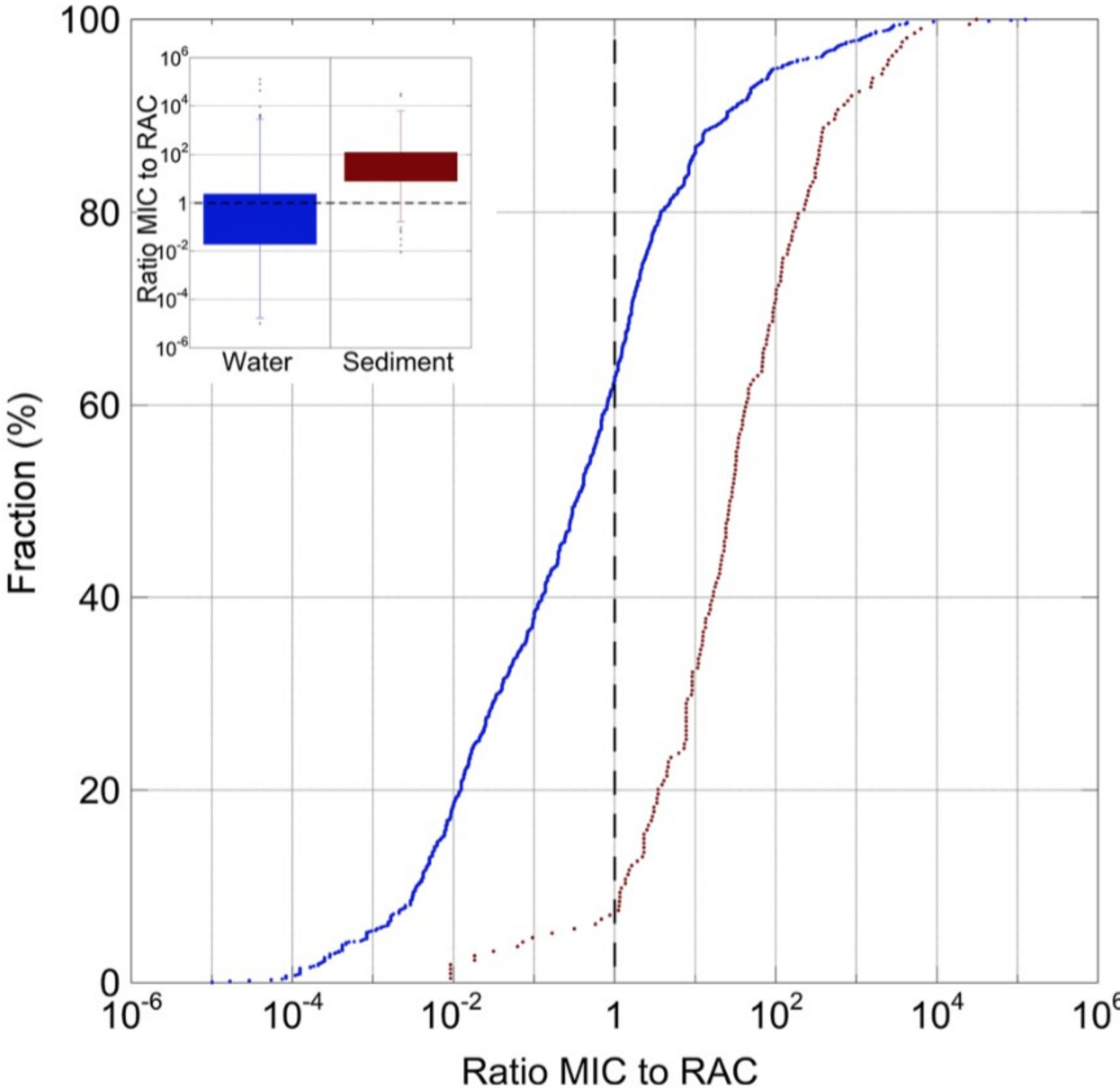

- ~ 40% exceedance of RAC_{SW}
- Exceedance in 55% of sites (n = 385)

- Analysis of German monitoring data
- Exceedance in 25% of sites (n = 3049)

Stehle & Schulz 2015 *Environ Sci Pollut Res*

Reasons for RAC exceedance

- Non-compliance with risk mitigation conditions
  → Unlikely given the magnitude of exceedances?

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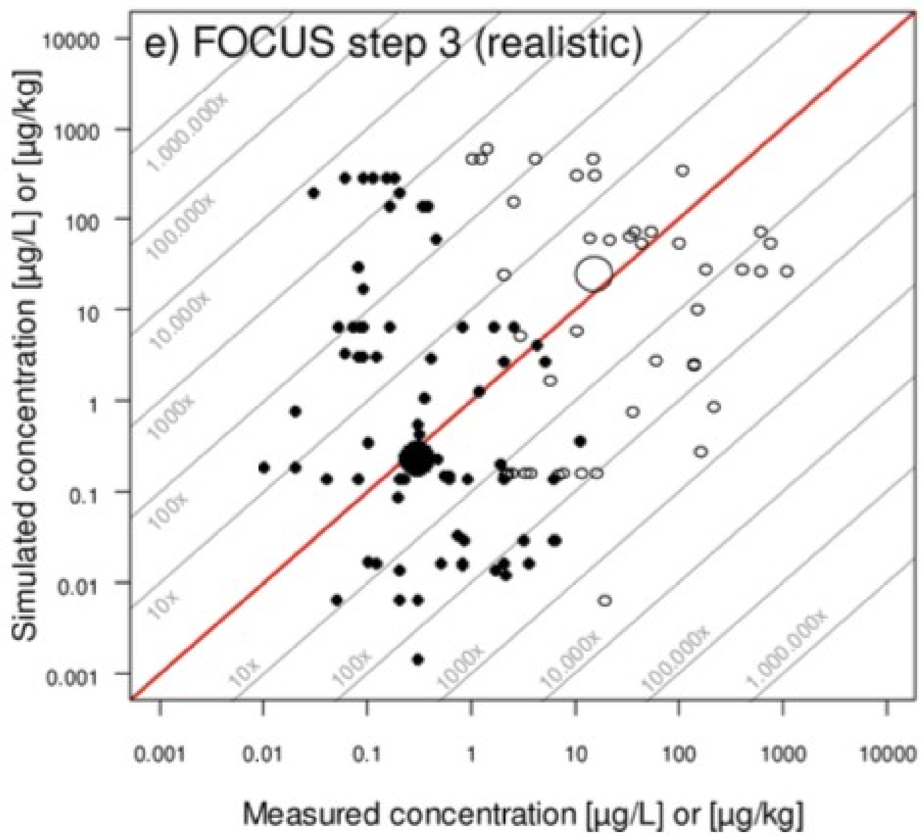
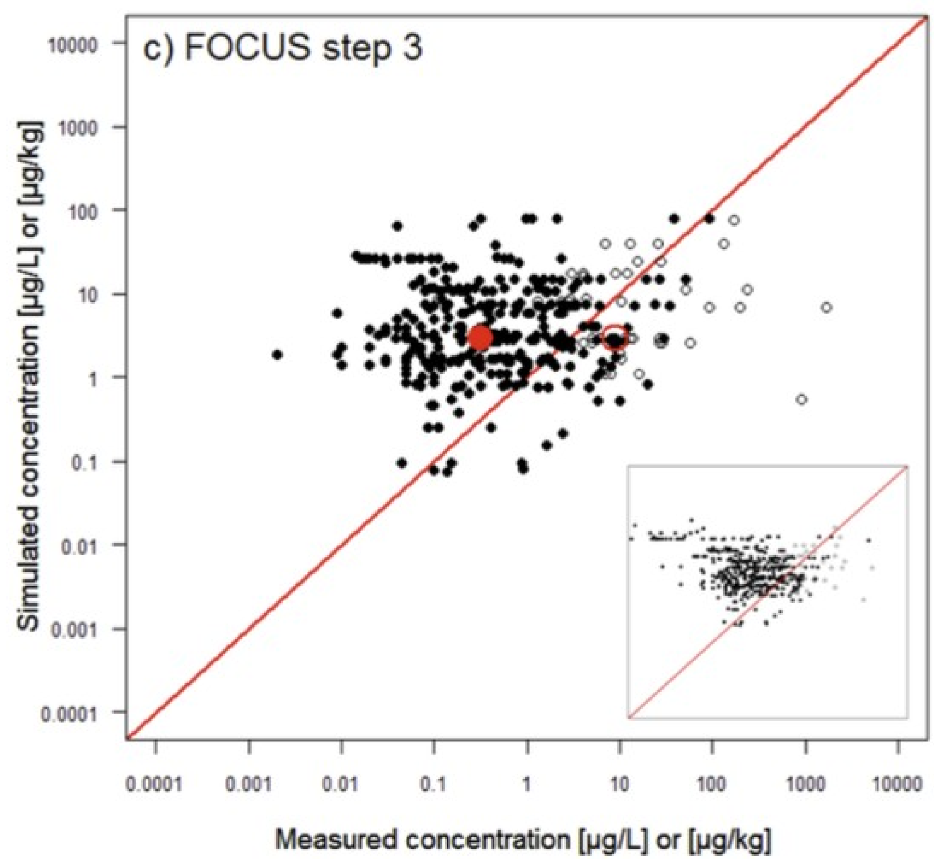
- Unreliable exposure characterisation?

42% underprediction for insecticides



Knäbel et al. 2012 *Environ Sci Technol*

13% underprediction for fungicides

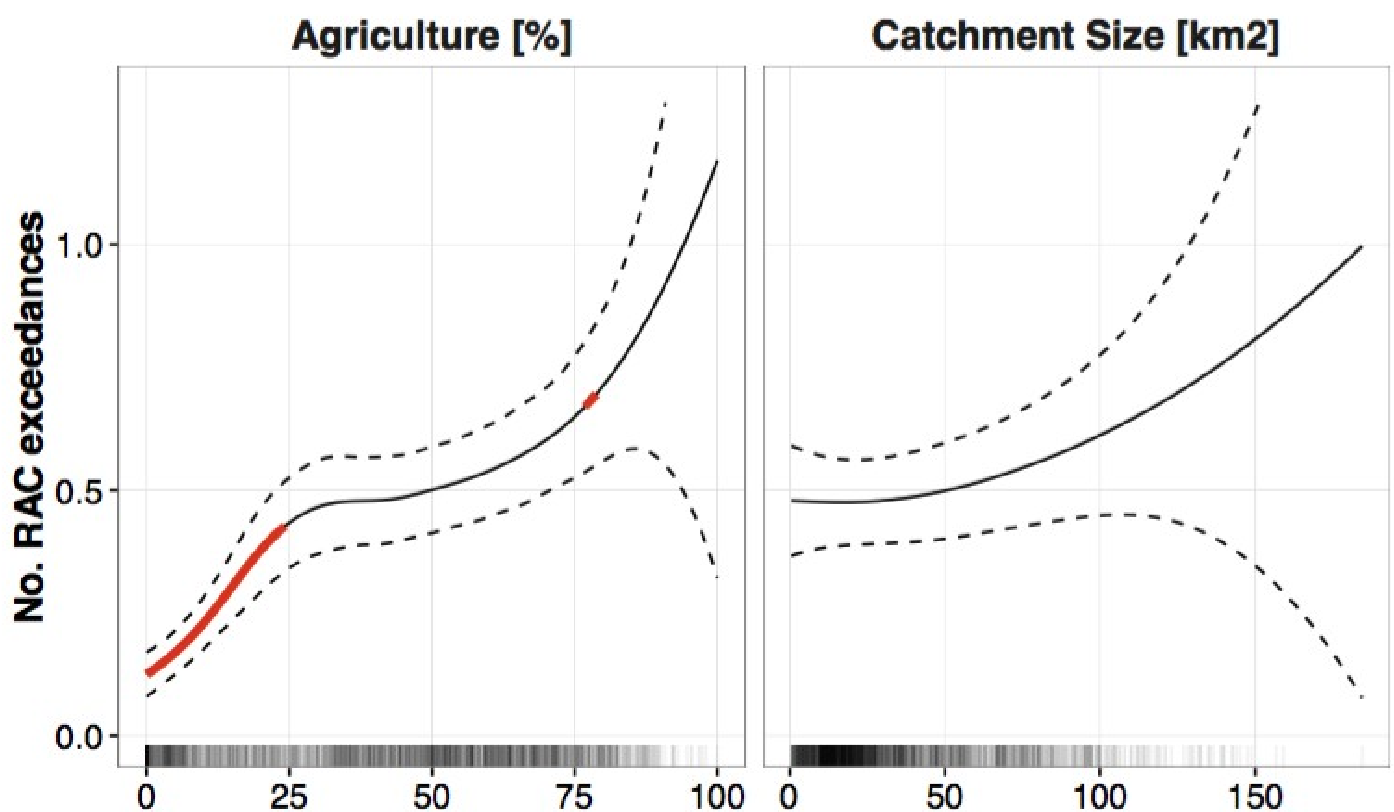


Knäbel et al. 2014 *Environ Sci Technol*

Reasons for RAC exceedance

- Non-compliance with risk mitigation conditions → Unlikely given the magnitude of exceedances?
- Unreliable exposure characterisation?
- Landscape influences level of RAC exceedance

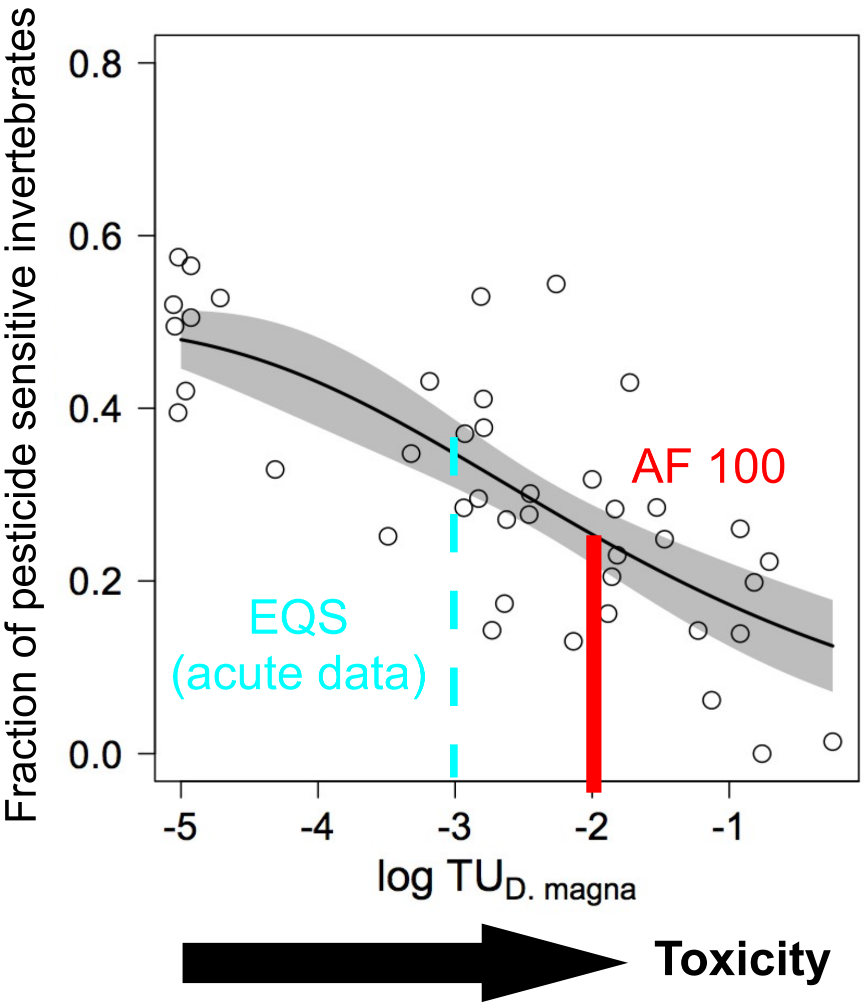
- Analysis of German monitoring data
- 42,200 grab samples, all-season



Szöcs et al. 2016 *Environ Sci Technol* under review

Is the current approach protective?

Meta-analysis: 8 field studies with 111 water bodies



Schäfer et al. 2012 *Environ Sci Technol*

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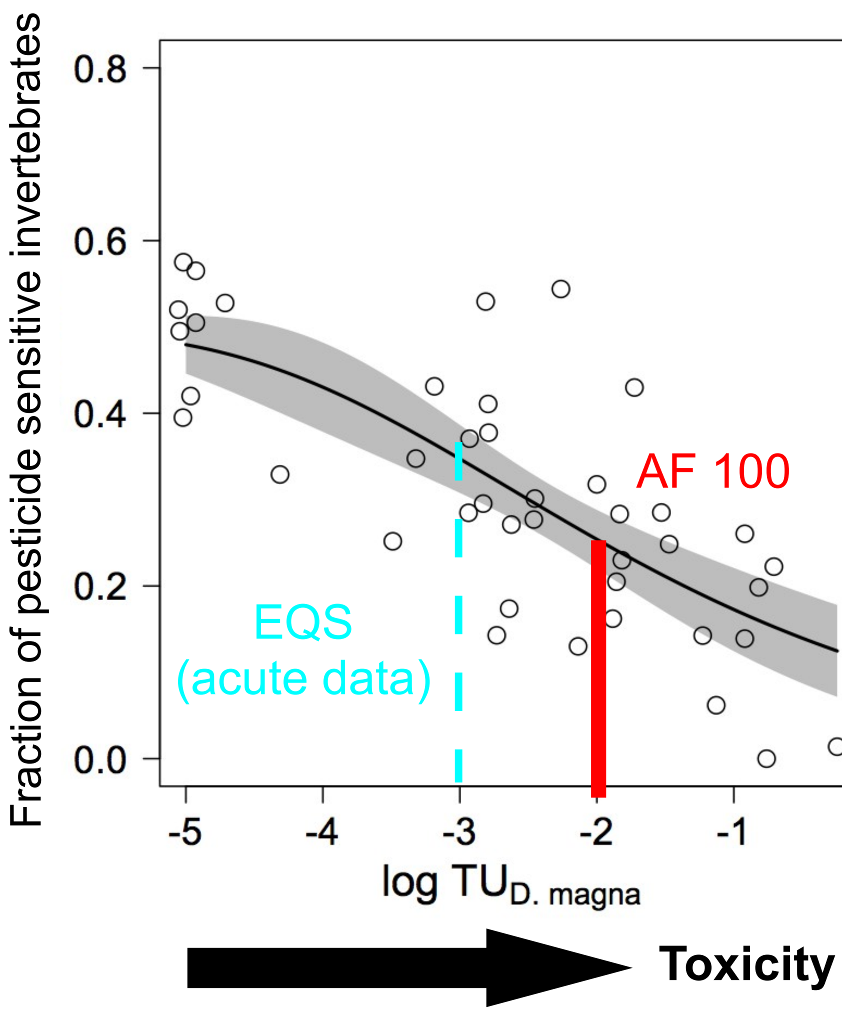
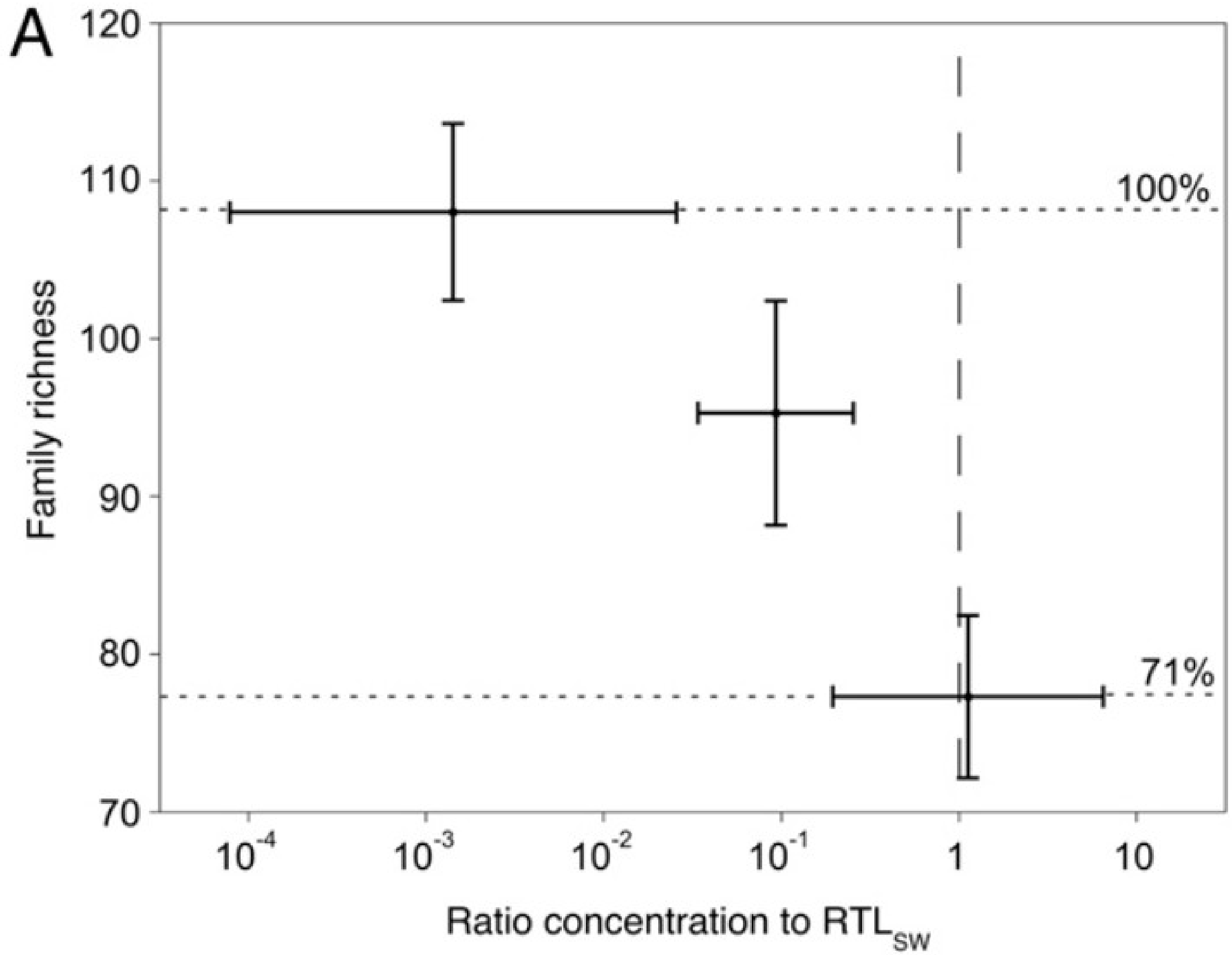


AFs of Uniform principles not always protective

Schäfer et al. 2012 *Environ Sci Technol*

Is the current approach protective?

Re-analysis of field study data from South-East Australia and France (Beketov *et al.* 2013 PNAS)



Stehle & Schulz 2015 *PNAS*

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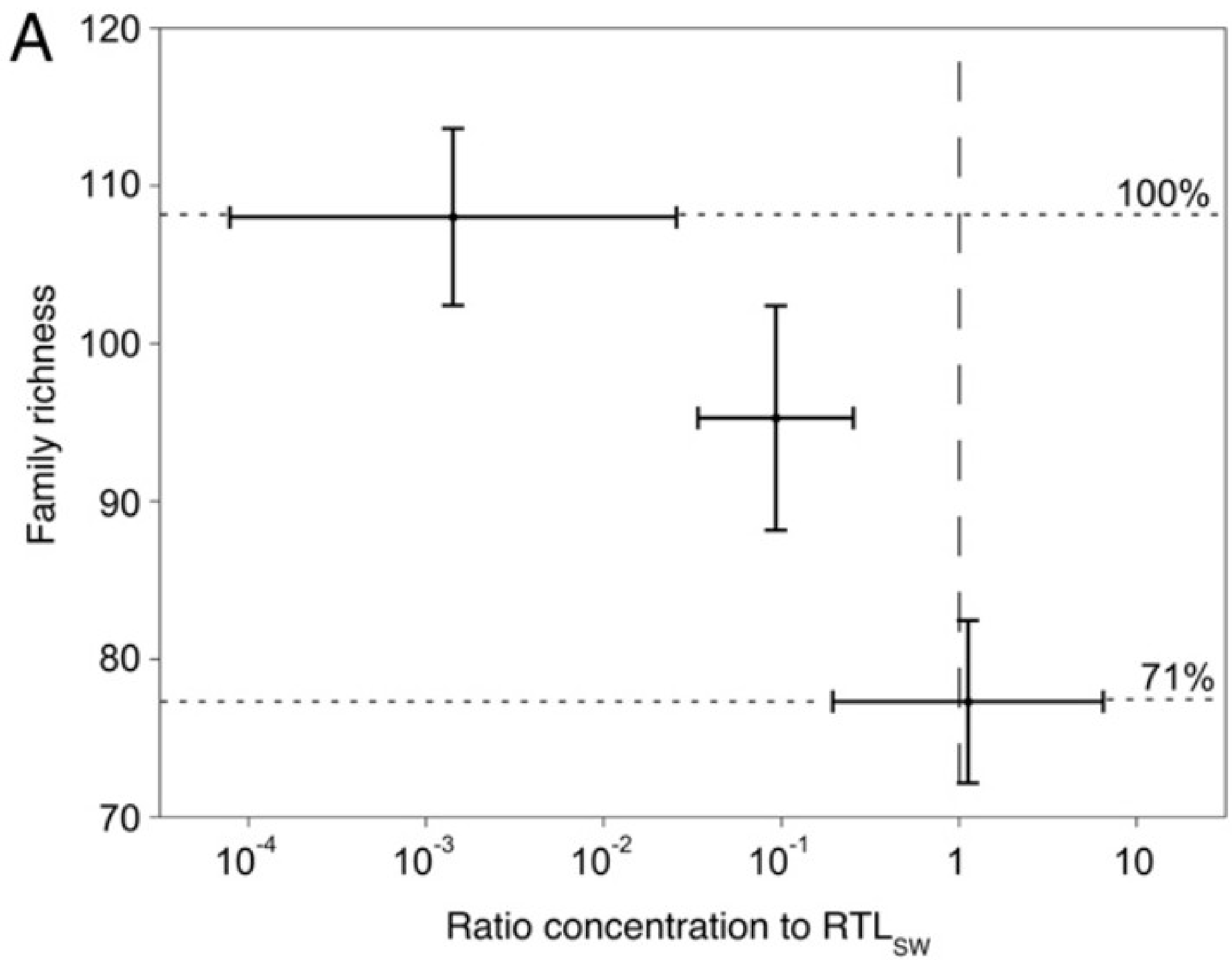
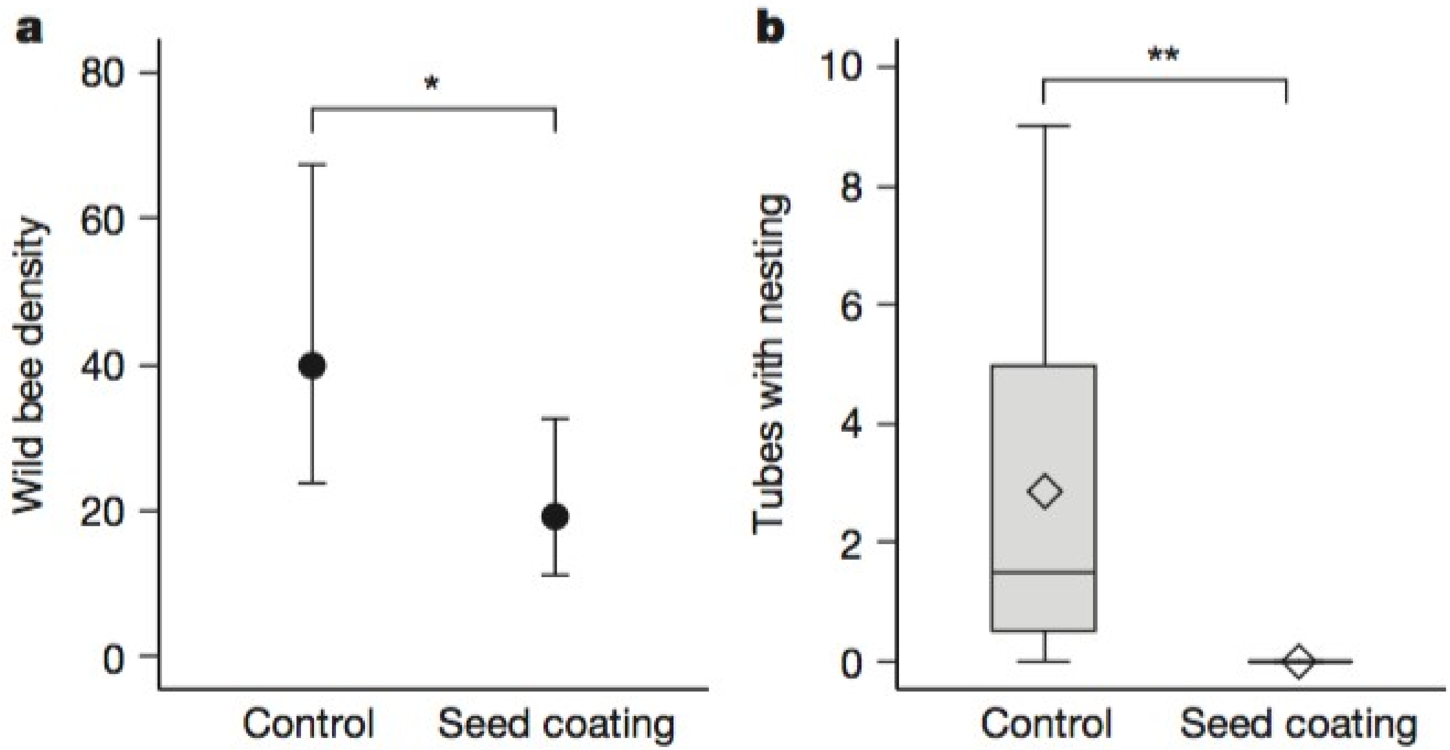


➡ 30% loss of invertebrate biodiversity at RAC

Stehle & Schulz 2015 *PNAS*

Is the current approach protective?

Blind field study with 8 paired sites (control – treatment with pyrethroid and neonicotinoid)



Rundlöf *et al.* 2015 *Nature*

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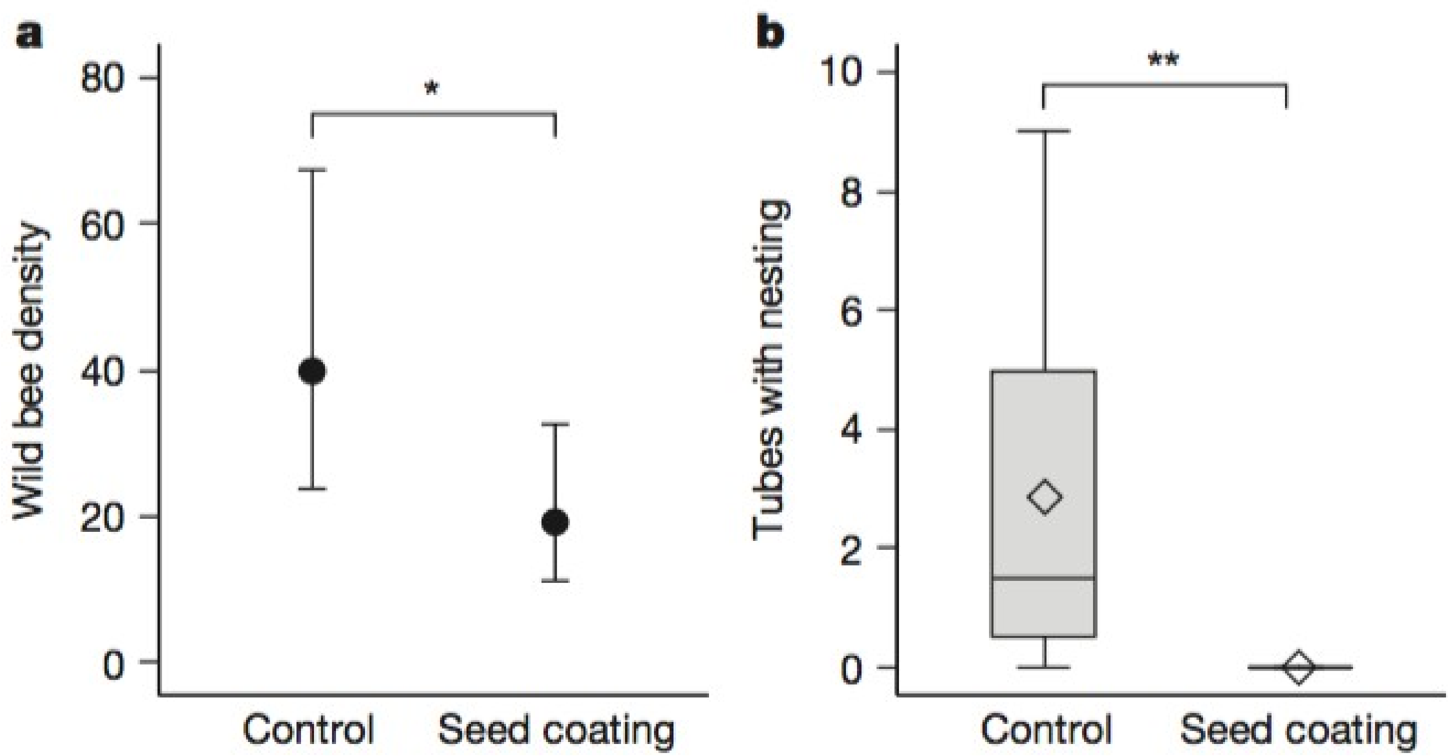


Rundlöf *et al.* 2015 *Nature*

➡ Pollinators not sufficiently protected?

Reasons for incomplete protectiveness

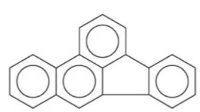
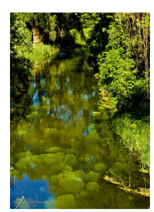
- Discrepancy between effect thresholds of model systems and field studies found for pesticides, ionizing chemicals, and metals (Schäfer 2014 *ET&C,* Liess and Beketov *2011 Ecotoxicology)*
  → pond mesocosms unlikely protective for streams

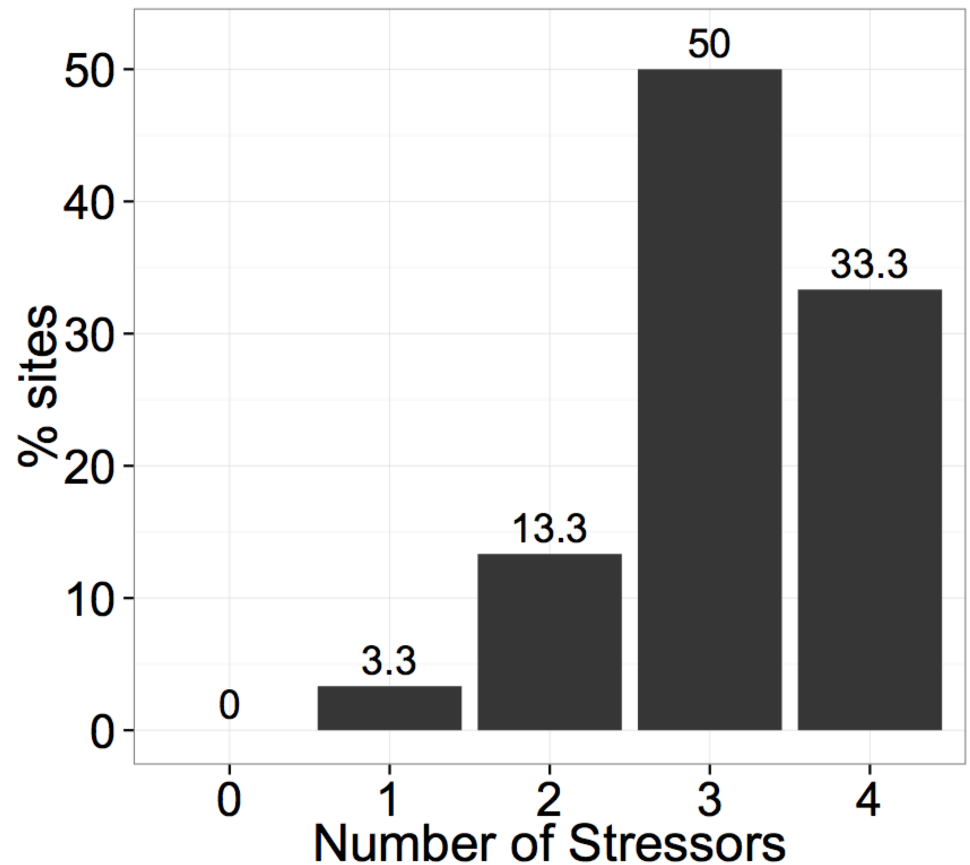
Reasons for incomplete protectiveness

- Discrepancy between effect thresholds of model systems and field studies found for pesticides, ionizing chemicals, and metals (Schäfer 2014 *ET&C*, Liess and Beketov *2011 Ecotoxicology)*
- Multiple stressors

- Analysis of German monitoring data for 4 stressors





Schäfer et al. 2016 *Freshw. Biol.* in press

Reasons for incomplete protectiveness

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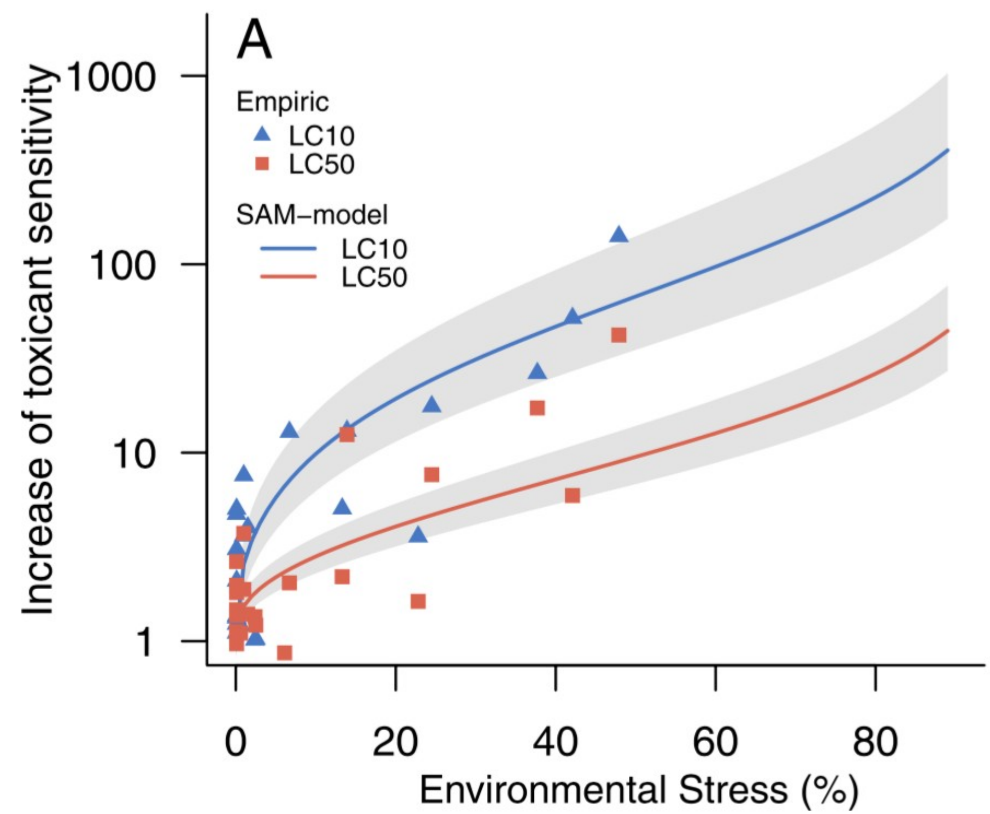
- Multiple stressors

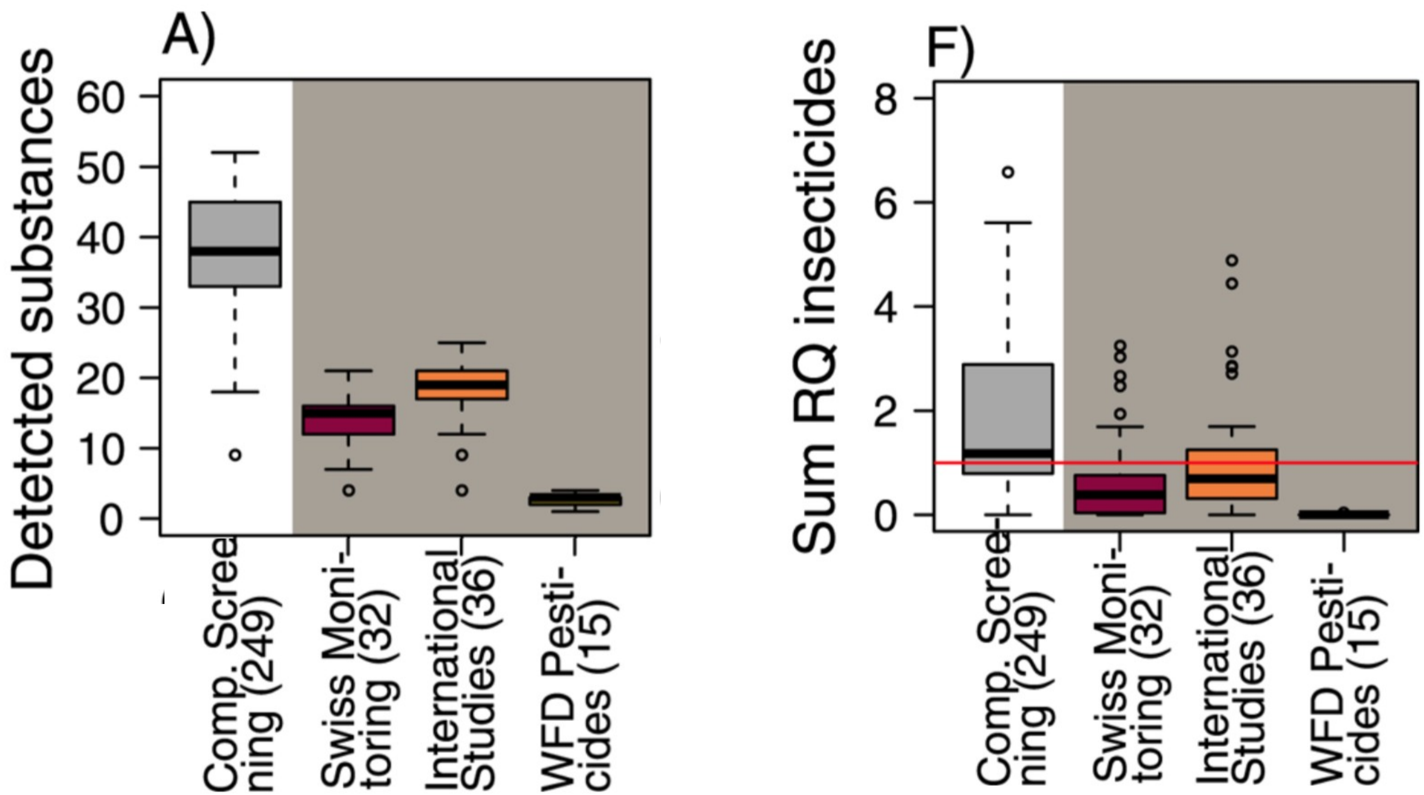
- Meta-Analysis of stressor pairs (env. stressor & chemical) with complete dose-response curves (n = 23)



Liess et al. 2016 *Sci. Rep.*

Reasons for incomplete protectiveness

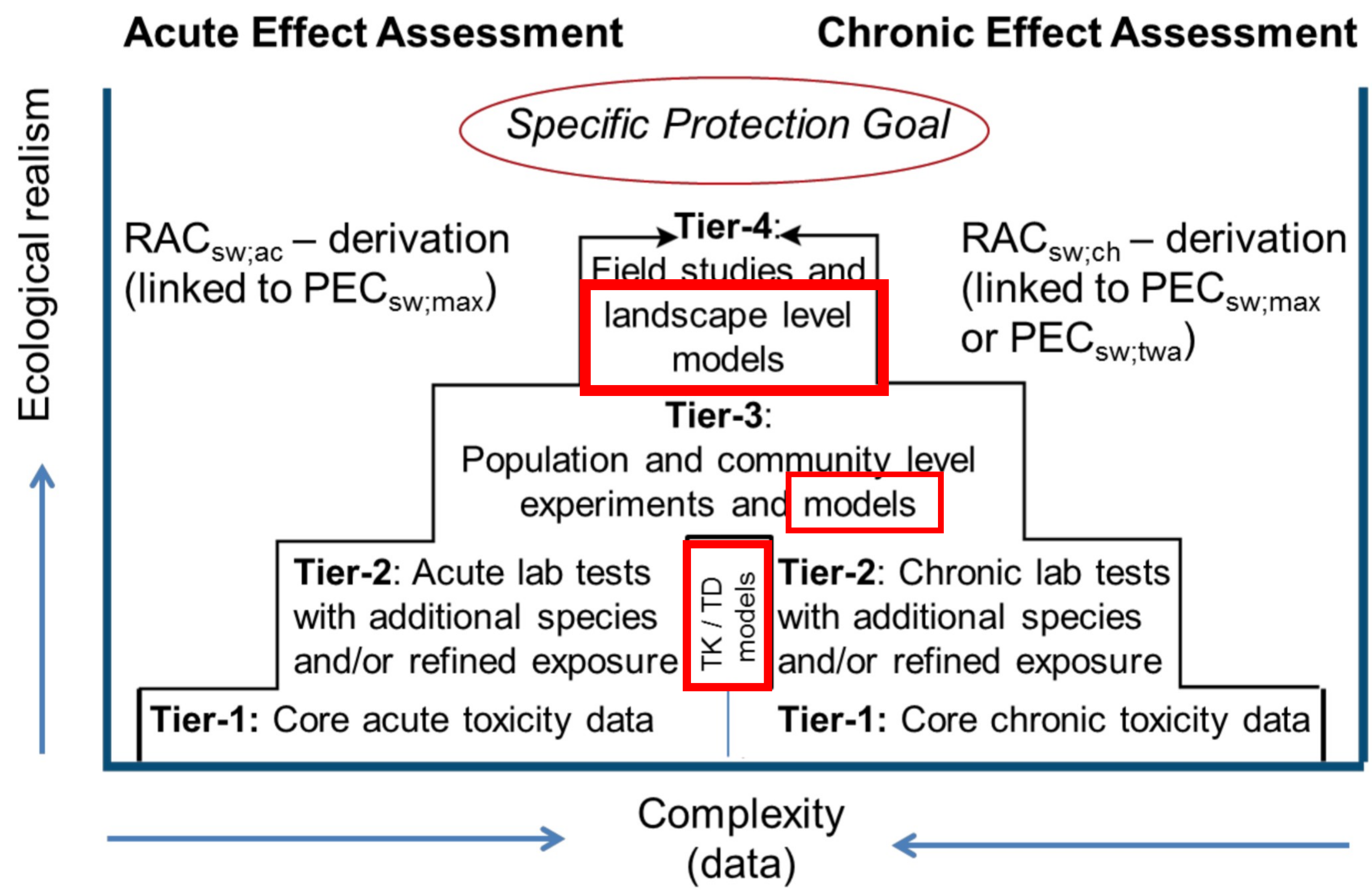
- Discrepancy between effect thresholds of model systems and field studies found for pesticides, ionizing chemicals, and metals (Schäfer 2014 *ET&C,* Liess and Beketov *2011 Ecotoxicology*)
- Multiple stressors
- Mixture toxicity



Moschet et al. 2014 *Environ Sci Technol*

Improving prospective risk assessment

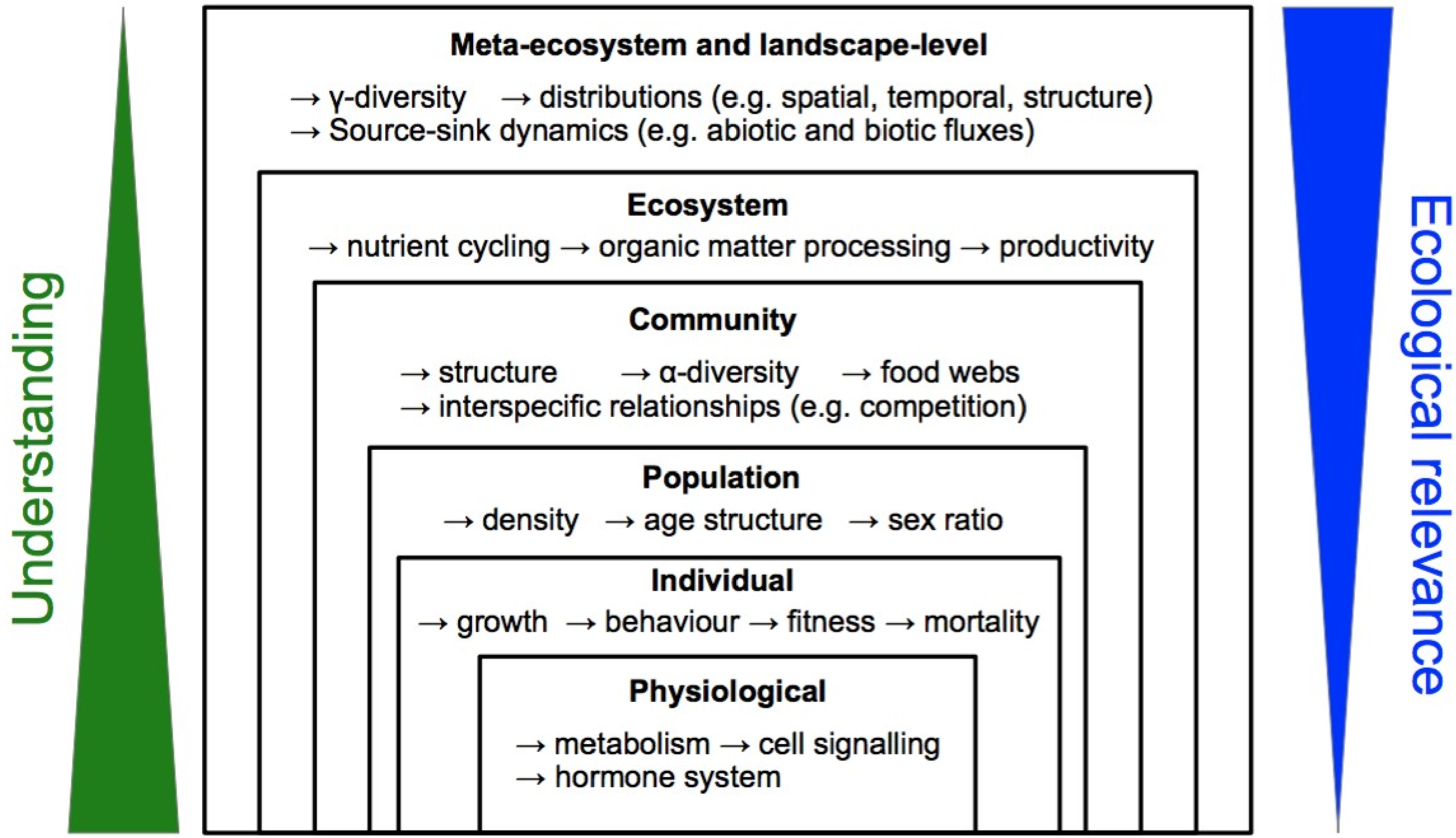
- Refining risk assessment via modelling?



EFSA 2013

Refining via modelling?

- Understanding of processes decreases with complexity
  e.g. 6 competing biodiversity theories McGill 2010 *Ecol. Letters*
  12 mathematical models for community assembly Presley et al. 2010 *Oikos*



Schäfer & Bundschuh 2016 *in press*

Refining via modelling?

Example: Models for effects of Bt maize on non-target butterflies

Flowering Maize

Peacock butterfly (Inachis)

Journal of Applied Ecology

Journal of Applied Ecology 2012, **49**, 29–37 doi: 10.1111/j.1365-2664.2011.02083.x

Estimating the effects of Cry1F *Bt*-maize pollen on non-target Lepidoptera using a mathematical model of exposure

Refining via modelling?

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Peacock butterfly (Inachis)

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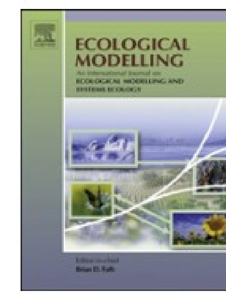

Increased mortality is predicted of *Inachis io* larvae caused by Bt-maize pollen in European farmland

Refining via modelling?

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Flowering Maize

Peacock butterfly (Inachis)

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Ecological Modelling 268 (2013) 103–122

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Letter to the Editor

No evidence requiring change in the risk assessment of *Inachis io* larvae

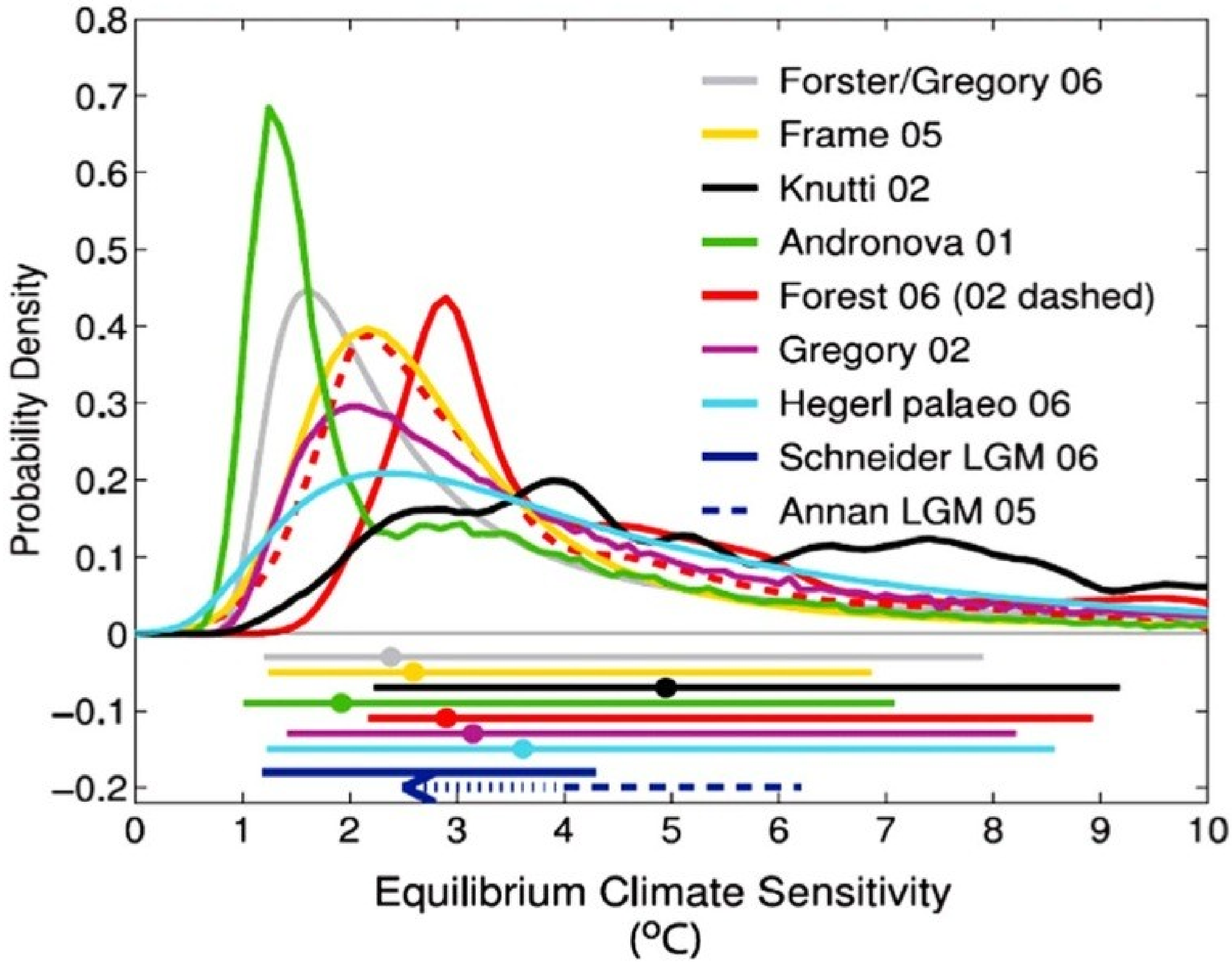
CrossMark

1. The use of data by Holst et al.

1.1. Pollen deposition on host plants

Refining via modelling?

Example: Climate models prediction for doubling of CO_2



➡ High uncertainty despite decades of development

Foley 2010 *Progr. Physical Geogr.*

Refining via modelling?

- High risk of bias and uncertainty of models increases with level of complexity → Not suitable to derive precise regulatory thresholds for communities and biodiversity

Refining via modelling?

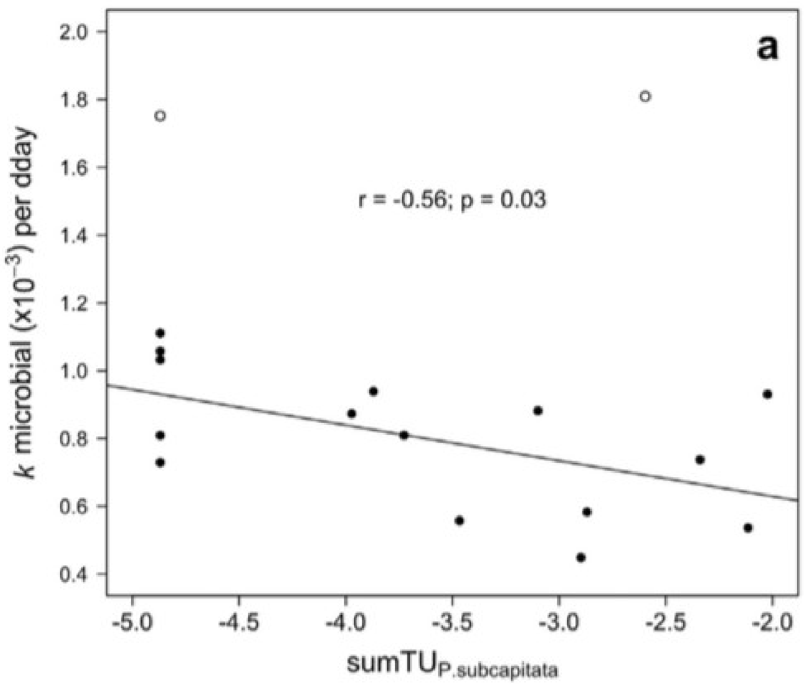
- High risk of bias and uncertainty of models increases with level of complexity → Not suitable to derive precise regulatory thresholds for communities and biodiversity

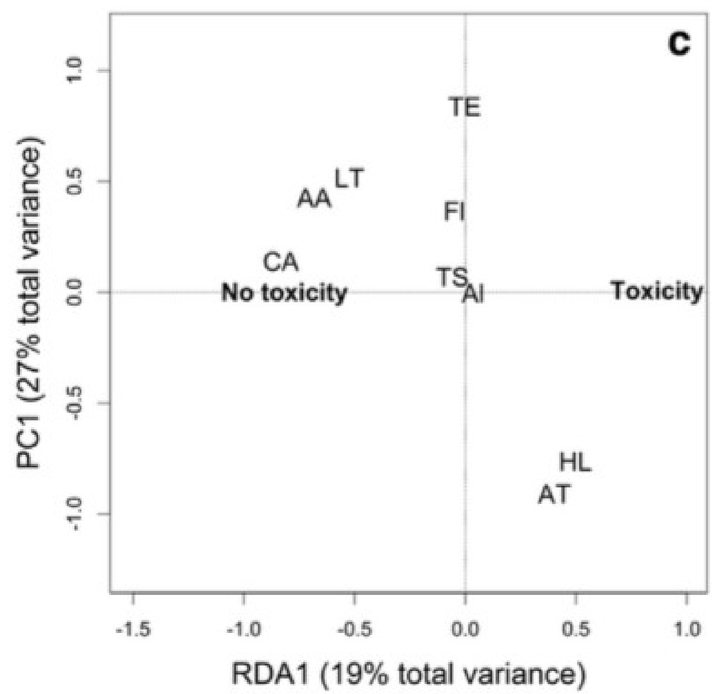
- Nevertheless, models can be useful to:
  - identify research gaps
  - explore scenarios (e.g. multiple stressors)
  - test hypotheses and understand patterns
  - estimate regulatory thresholds for individuals (e.g. TK-TD) and populations, where community-processes are largely irrelevant

Improving prospective risk assessment

- Include all relevant receptors

Aquatic hyphomycetes?
Reduction in ecosystem functioning (microbial decomposition) along fungicide toxicity gradient, toxic effect confirmed in laboratory





Fernandez et al. 2015 *Sci. Tot. Environ.*

Improving retrospective risk assessment

- Post-registration monitoring

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Wouldn't this be extremely costly?

Improving retrospective risk assessment

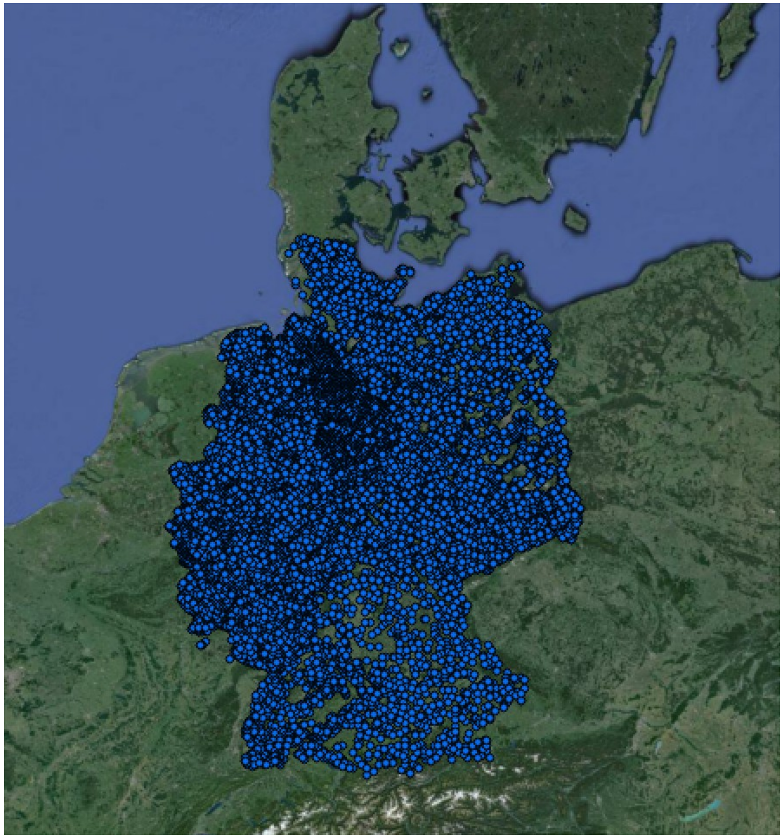
- Post-registration monitoring

Wouldn't this be extremely costly?

➡ Join forces with other programs

Demonstration farms for integrated plant protection

Biological & chemical monitoring networks for WFD



Integrating regulatory frameworks?

- Pesticides are managed prospectively in authorisation and retrospectively in Water Framework Directive
- Protection goals vary and could be more specific
- RACs and EQS (and pesticides considered) can differ between member states

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- Protection goals vary and could be more specific
- RACs and EQS (and pesticides considered) can differ between member states

➡ Water body-type specific protection goals?

➡ Harmonise and improve consistency

"To minimize risks of negative impacts on humans and the environment, the most stringent restriction in all legislations should be adopted."

Brack et al. 2016 *Sci. Tot. Environ. in press*

Conclusions

- Risk assessment does not stand reality check (frequent RAC exceedances)
- Current approach not fully protective
- Models no panacea
- Field-relevance requires field observation
- Integration with WFD may fix several shortcomings

Thank you!

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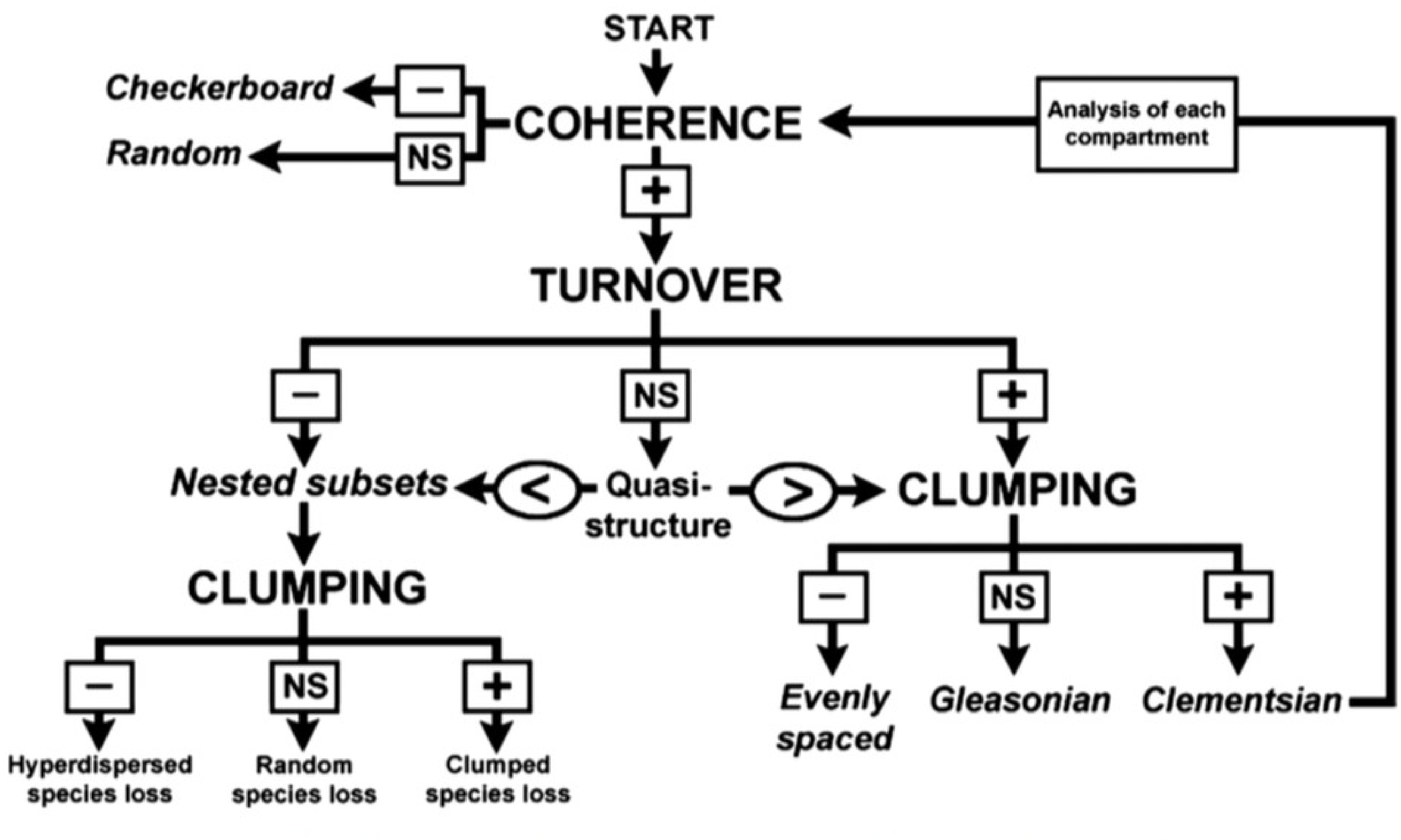
Mathematical underpinning for pesticide effects on community assembly unclear

12 mathematical models for explaining community assembly



Presley et al. 2010 *Oikos*

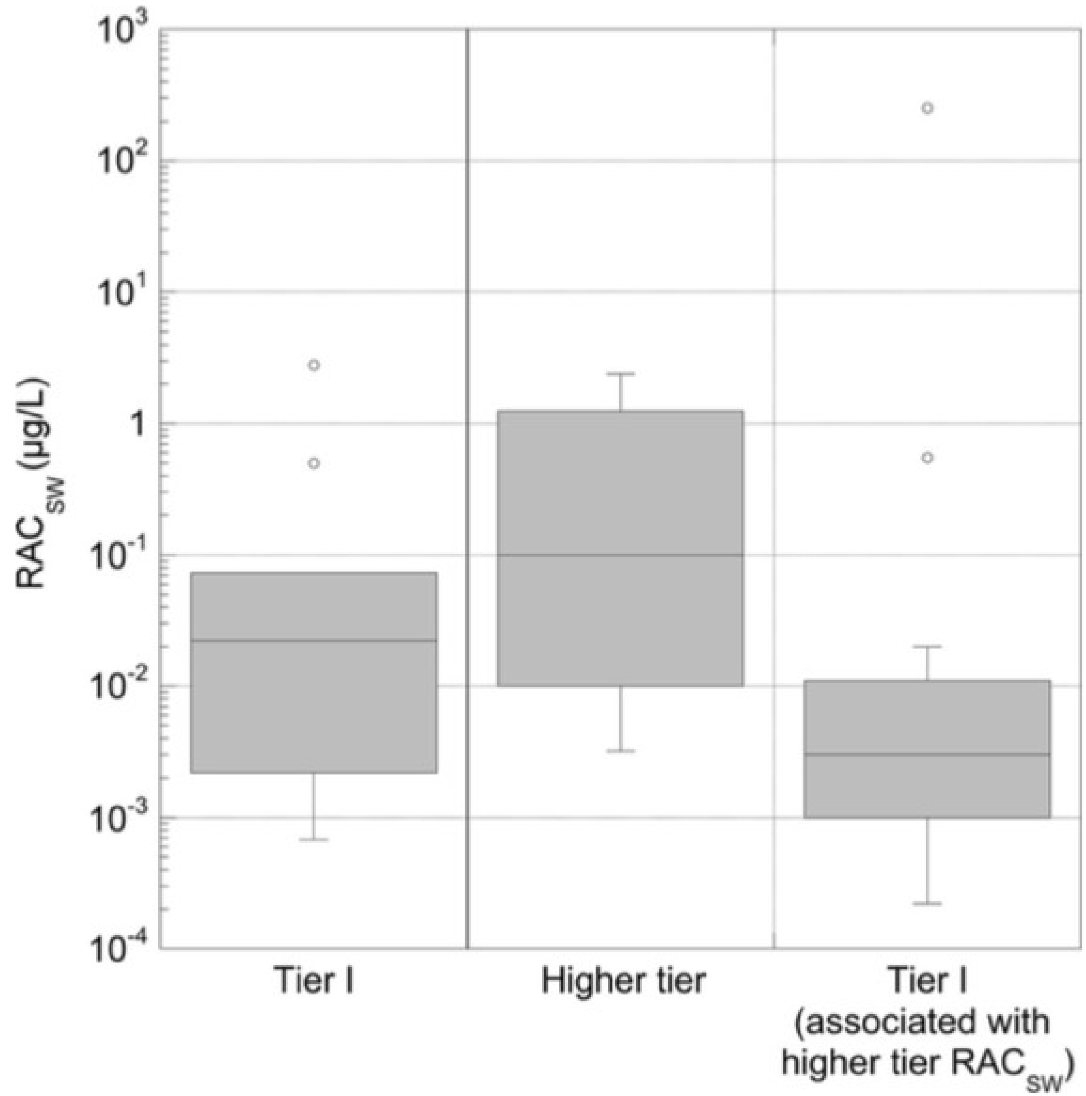
Mathematical underpinning for pesticide effects on biodiversity unclear

Six prominent unified biodiversity theories

Unified theory	Key references	Input parameters	Math	Spatial model	Assertion 1 Intraspecific spatial	Assertion 2 Interspecific variation in global abundance	Assertion 3 Interspecific independence
Continuum	(Gauch & Whittaker 1972; Hengeveld *et al.* 1979; Coleman *et al.* 1982; McGill & Collins 2003)	S, N_{max}~, σ~, A	Probability theory (analytical)	Density surface (aggregate)	Peak and tail	N_{max} and σ are sampled from distribution (input)	Each peak is located according to a Poisson process (random wrt other species)
Neutral	(Caswell 1976; Hubbell & Foster 1986; Bell 2000, 2001; Hubbell 2001)	S or Θ, N, m	Birth–death (analytical) + Lattice (simulation)	Lattice (individual)	Dispersal-limited	Metacommunity processes create logseries regional abundances (derived)	Each lattice cell can be populated by any species
Metapopulation	(Hanski & Gyllenberg 1997)	S, A~, w~	Levins metapopulation differential equation (analytical)	Probability present|A (aggregate)	Incidence	Density of species w_i is sampled from loguniform distribution (input)	Presence of one species on a patch is modelled independent of any other species allowing simple summation
Generalized Fractal	(Harte *et al.* 1999; Green *et al.* 2003; Storch *et al.* 2008)	S, l_i~, D_i~	Hierarchical division (simulation)	Spatially explicit (aggregate)	Hierchically clumped	Each species is modelled with four nested levels of multiplication of a uniformly distributed random variables approaching a central limit theorem like situation (derived)	Each species is modelled and placed in space independent of other species allowing simple summation
Clustered Poisson	(Plotkin & Muller-Landau 2002; Plotkin *et al.* 2002; Morlon *et al.* 2008)	S, N, aggregation parameters	Neyman–Scott process	Point process (individual)	Explicitly aggregated	Regional species abundance distribution is specified (various used) (input)	Each species is its own clustered Poisson process without reference to other species, allowing simple summation
MaxEnt	(Harte *et al.* 2005; Pueyo *et al.* 2007; Harte 2008)	S, A, N, E	MaxEnt (analytical)	Not spatially explicit (aggregate)	Derived exponential P	MaxEnt plus a constraint on total abundance gives a logseries SAD (derived)	$P_i(n\|A)$ is independent of other species, allowing simple summation

McGill 2010 *Ecol. Letters*

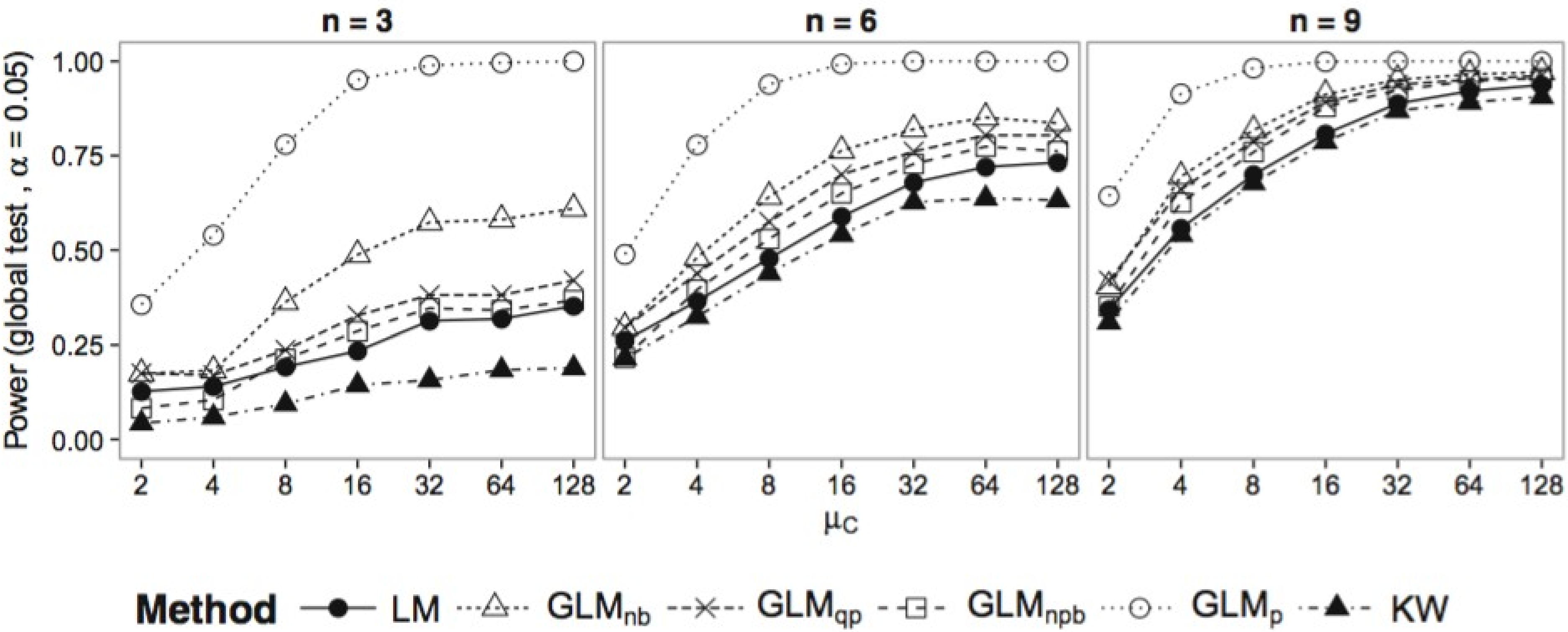
Past mesocosm studies increased RAC more than an order of magnitude



Stehle & Schulz 2015 *Environ Sci Pollut Res*

Mesocosm studies would require about 9 replicates for reliable power, but would still not capture rare taxa that are important for ecosystem functions

Mouillot et al. 2013 *PLOS Biology*



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