Modelling chemical effects on community and ecosystem level

Udo Hommen, 24.10.2018

Copied from R. Pastorok and D. Preziosi 2013 (presentation at Modelink-workshop)
Painted by Dana Schoof, a 6-year old in Seattle, WA
Modelling chemical effects on community and ecosystem level

Outline

Introduction

Available tools

Why looking on community and ecosystem level?

Exampe 1

AQUATOX / CASM

Reason 1

Exampe 2

STREAM:com

Reason 2

Example 3

IBC-grass

Reason 3

Challenges

Summary

Use in regulatory RA

Reason 1

Reason 2

Reason 3

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SETAC Europe 13th Special Science Symposium
Extrapolation of Effects Across Biological Levels:
Challenges to Implement Scientific Approaches in Regulation
23–24 October 2018 | Brussels, Belgium

Fraunhofer IME
Modelling chemical effects on community and ecosystem level
Definitions for this presentation

**Community** = group or association of populations of two or more different species occupying the same geographical area and in a particular time, also known as a biocoenosis (https://en.wikipedia.org)

**Ecosystem** = community plus environment (habitat, abiotic factors)
Why consider community and ecosystem level?

SETAC workshop (Solomon et al. 2008): “In ecological risk assessment, the target for protection may often be the community. It is recognized that not all populations can be tested and protected, and by maintaining biodiversity at the community level it is assumed that ecosystem structure and function are maintained.”

Now: The target for protection is usually the population: “For earthworms, enchytraeids, microarthropods, macrodetritivores …, nematodes, molluscs …, small effects (10 < 35%) up to months on abundance/biomass of populations are tolerable. (EFSA PPR 2017).
Why consider community and ecosystem level?

- **Direct effects** on one population can have indirect effects on other populations
  - **Top-down**
  - **Bottom-up**

Example: *Effects of chlorpyrifos on microcosm food web*

Modified from Baird et al. (2001)
Why consider community and ecosystem level?

- Direct effects on one population can have **indirect effects** on other populations
  - Top-down
  - Bottom-up
- Species interactions can affect **vulnerability** (sensitivity and recovery)

Example: *Competition with less sensitive copepods inhibits recovery of daphnids after short-term exposure to insecticide*

See also Foit et al. (2012)
Why consider community and ecosystem level?

- Direct effects on one population can have **indirect effects** on other populations
  - Top-down
  - Bottom-up
- Species interactions can affect **vulnerability** (sensitivity and recovery)
- **Ecosystem services** might depend on communities rather than single populations
  - e.g. provision of fresh water, primary production, nutrient cycling
Why ecosystem models if we have model ecosystems?

See presentation by M. Vighi
Why ecosystem models if we have model ecosystems?

- Complex and expensive studies: At least screening would be useful.
- Case study character!
  - location, community composition, season, exposure profile
- In addition to extrapolation / prediction
  - Analytical tool to understand effects within food webs and ecosystems
Extrapolation across biological levels: From single species tests to community level effects

- **Ecological scenario**: Habitat, Abiotic factors, Community structure, Location, Time

- **Exposure**: Substance properties & use => PECs

- **Organism level effects**: Survival, Growth, Reproduction, ... NOECs, ECx, TKTD

- **Species ecology**: Life cycle characteristics, Dependencies on environmental factors

- **Community level response**

- **Population level response**: Growth rate, Mean abundance, Recovery time, Extinction risk

Extrapolation of Effects Across Biological Levels: Challenges to Implement Scientific Approaches in Regulation, 23-24 October 2018, Brussels, Belgium
Ecosystem modelling for chemical risk assessment – not really new

- Standard Water Column Model **SWACOM**
- Differential equation system for 19 species of 4 trophic levels plus nutrients, light and temperature
- Modelling toxic effects by changing parameter values
AQUATOX: Linking water quality and aquatic life

- Free available software: https://www.epa.gov/ceam/aquatox
- Long history of development and refinements, starting in the 1970ies
- Recent version 3.1, released in 2014
- Peer reviewed 2003 (Release 2) and 2008 (Release 3)
- Very well documented (website, manuals, reports, course material)
- Not a specific model, more a tool box and parameter library
- Integrates fate, accumulation and effects
- More than 70 publications on worldwide applications of AQUATOX covering different generic and site specific ecosystems and different stressors including different types of chemicals
Example: AQUATOX to derive PNECs for river Po, Italy
Gredelj et al. (2018)

Copied from Gredelj et al. 2018, doi.org/10.1016/j.envint.2018.06.017
Comparing PNEC derived via AF, SSD and AQUATOX

$\text{PNEC}_{\text{AQUATOX}}$ up to 100x larger than $\text{PNEC}_{\text{SSD}}$ but once also much lower

Based on Gredelj et al. 2018, doi.org/10.1016/j.envint.2018.06.017
Example: Predicting effects of thiametoxam in a generic pond (Bartell et al. 2018)

• Aim: to provide rapid preliminary or screening-level risk assessments and identify circumstances for more detailed assessments

• Simulating the daily production of 49 populations in generic Midwestern farm pond

• Intention was to produce plausible magnitudes and temporal patterns of baseline biomass

• Risk-assessment endpoints
  • changes in biomass of populations
  • alterations in community structure for primary producers, zooplankton, invertebrates, fish

**CASM: Comprehensive Aquatic System Model**

Bartell et al. (2000)
Example: Predicting effects of thiametoxam in a generic pond (Bartell et al. 2018)

- Exposure across 6 regional scenarios rarely exceed the identified population-specific NOEC values
- No effects on populations and communities
- Use of exposure multiplication factors to find effect threshold (e.g. 10 % 10% reduction in benthic invertebrate community similarity
- Margins of safety: 10 - >100
Example: **STREAM:com**  
Gergs et al. (in prep.): CEFIC LRI ECO26

**Differences compared to n CASM example**
- Site specific and spatially explicit
- Population dynamics emerges from individual behaviour
- More sophisticated TK-TD modelling
- Consideration of parameter uncertainty

Copied from Gergs et al. 2018, see also *poster 14*
Example runs for lethal effects of an insecticide in Vichtbach FOCUS PECs multiplied by factor 270 to demonstrate effects

Based on Gergs 2018, see also poster 14
A terrestrial example: Herbicide effects on plants

IBC-grass: Reeg et al. (2017, 2018)

• Individual-based and spatially explicit model, which accounts for inter- as well as intraspecific competition between plant individuals.

• IBC-grass was tested with experimental data in order to estimate its suitability to extrapolate individual level effects to community level impacts for non-target terrestrial plants.

Copied from Reeg et al. 2017 & 2018, see poster 11

http://deacademic.com/pictures/dewiki/66/Bl%C3%BChstreifen_002.jpg
Community and population level effects

Community level

Population level

Copied from Reeg et al. 2018, see also poster 11
Disadvantages

Van den Brink et al. in Solomon et al. (2008):
“The primary disadvantage of ecosystem-based models is their complexity and associated uncertainty. In addition, they are poorly amenable to validation (Baird et al. 2001), often lack sufficient data, and may not account for a wide range of nonmodeled interactions (e.g., those resulting from pheromonal, gustatory, olfactory, physical, mechanical, or behavioral interactions) in the real world (Health Council of The Netherlands 1997).

... and their results are too difficult to communicate for application in generic risk assessment.”
Challenges
1. Complexity - Parameterisation

• Many species – many parameters – many endpoints
• However, it seems to be possible (see examples!)
• Do not expect perfect fits for all populations
• Example Streambugs parameter calibration using Bayesian interference on stream mesocosm experiment with Thiacloprid


Copied from Kattwinkel et al. (2016)
Challenges
2. Validation – lack of data

Mesocosm data

Modelled

Control

Relative abundance [%]

Time [d]

0 20 40 60 80 100

100 90 80 70 60 50 40 30 20 10 0

Treatment

Relative abundance [%]

Time [d]

0 20 40 60 80 100

100 90 80 70 60 50 40 30 20 10 0

Measured

Monitoring data

Modelled

Feeding trait

Simulated and field trait community composition for an upland stream section.

Habitat trait

Measured

Filter feeders
Gatherers
Grazers
Shredders

Akal
Argyll
Lithall
Pelai
Phytal
Particulor organic matter
Psammal

Copied from poster 14 by Gergs et al.

Simulated and stream mesocosm dynamics of amphipods and isopods in a control system and upon chlorpyrifos exposure.
Challenges

3. Communication – documentation

- Confidence in a model depends on transparent documentation of the model, its parameterisation, its behaviour and the demonstration of its ability to predict observations, not used for calibration

- TRACE (TRAnsparent and Comprehensive Ecological modelling documentation)
  Grimm et al. (2014): Documentation of model development including model testing

- Scientific Opinion on Good Modelling Practice.
  EFSA PPR (2014) : Covers also the use of the model in a specific risk assessment, e.g. the environmental scenario

- See also poster 12 by Amelie Schmolke

Copied from Grimm et al. (2014)
Challenges
4. Define environmental scenarios

For prospective risk assessments (e.g. ppp, REACH)

- Set up a generic scenario or select real ecosystems?
- What is a representative community / ecosystem for prospective risk assessment?
- Which are the populations / groups to consider in the model?
- Which temporal and spatial scales?

- Example: Can we ‘ecologize’ the FOCUS exposure scenarios?

Rico et al. 2016
Challenges

5. How to use model outputs in regulatory risk assessment

Assume a model is ‘fit for purpose’ …

Three levels of use:

1. Supplementary tool to analyse tier 3 studies
   • Testing of hypotheses => output not directly used for risk assessment

2. Extrapolation from mesocosms / field tests to other conditions
   • Use similar endpoint as from the study

3. Prediction across biological levels to effects in community / ecosystem context
   • Models allow to calculate many types of outputs
   • Stay close to specific protection goals and assessment endpoints used in comparable experiments if possible
   • Offer options to the risk manager…
Summary

Why looking on community and ecosystem level?

Why use ecosystem models?

To dos

‘Validation’ based on different types of information

‘Validation’ based on different types of information

Tools are there

Use and explore them!

Good documentation of model development and testing

Define ecological scenarios

Analysis of community level studies

Extrapolation from community level experiments

Prediction of effects in ecosystem context

Assessment endpoints should fit regulatory needs (e.g. SPGs)

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Indirect effects can be relevant!

Sensitivity and recovery can be affected!

Ecosystem services can depend on community function!

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References


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