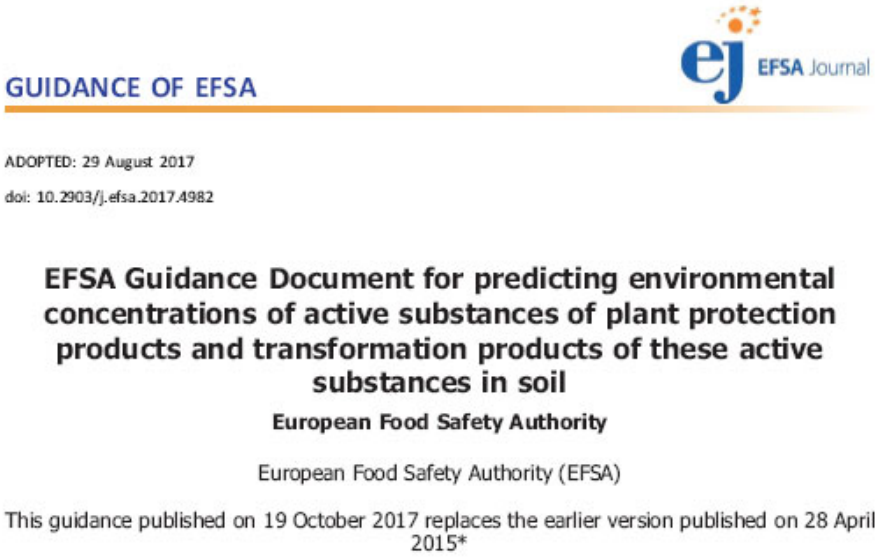
Linking exposure and effect models for soil risk assessment

– a potential tool to answer burning questions in soil risk assessment

T.G. Preuss, C. Oberdoerster, S. Oberdoerster, A. Gergs

Upcoming changes



GUIDANCE OF EFSA

EFSA Journal

ADOPTED: 29 August 2017

doi: 10.2903/j.efsa.2017.4982

EFSA Guidance Document for predicting environmental concentrations of active substances of plant protection products and transformation products of these active substances in soil

European Food Safety Authority

European Food Safety Authority (EFSA)

This guidance published on 19 October 2017 replaces the earlier version published on 28 April 2015*

New PECsoil guidance: More conservative exposure estimation, e.g. Soil layer (0-1 cm), wash-off, soil bulk density, PEC_liquid

SCIENTIFIC OPINION

EFSA Journal

ADOPTED: 15 December 2016

doi: 10.2903/j.efsa.2017.4690

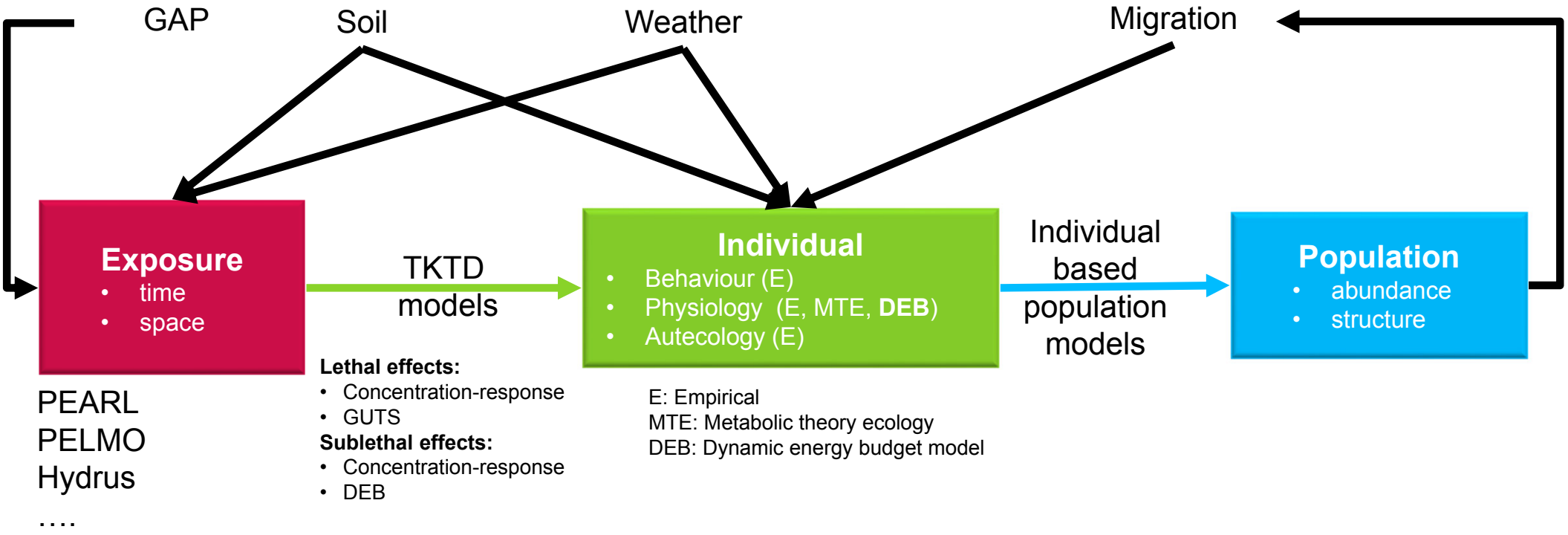
Scientific Opinion addressing the state of the science on risk assessment of plant protection products for in-soil organisms

EFSA Panel on Plant Protection Products and their Residues (PPR), Colin Ockleford, Paulien Adriaanse, Philippe Berny, Theodorus Brock, Sabine Duquesne, Sandro Grilli, Antonio F Hernandez-Jerez, Susanne Hougaard Bennekou, Michael Klein, Thomas Kuhl, Ryszard Laskowski, Kyriaki Machera, Olavi Pelkonen, Silvia Pieper, Michael Stemmer, Ingvar Sundh, Ivana Teodorovic, Aaldrik Tiktak, Chris J. Topping, Gerrit Wolterink, Peter Craig, Frank de Jong, Barbara Manachini, Paulo Sousa, Klaus Swarowsky, Domenica Auteri, Maria Arena and Smith Rob

Exposure profiles vary in both time and space. For these reasons, the following research needs are proposed:

- Reliable models of **movement for endogenic earthworms**, within the soil profile;
- Dynamic models of exposure providing soil and pore-water concentrations at all relevant soil depths and varying with time;
- **TK/TD models** capable of linking toxicological effects to internal body concentrations in time;
- Ideally, these three combined components would be integrated into the system model used to develop the population-modelling ‘surrogate reference tier’.

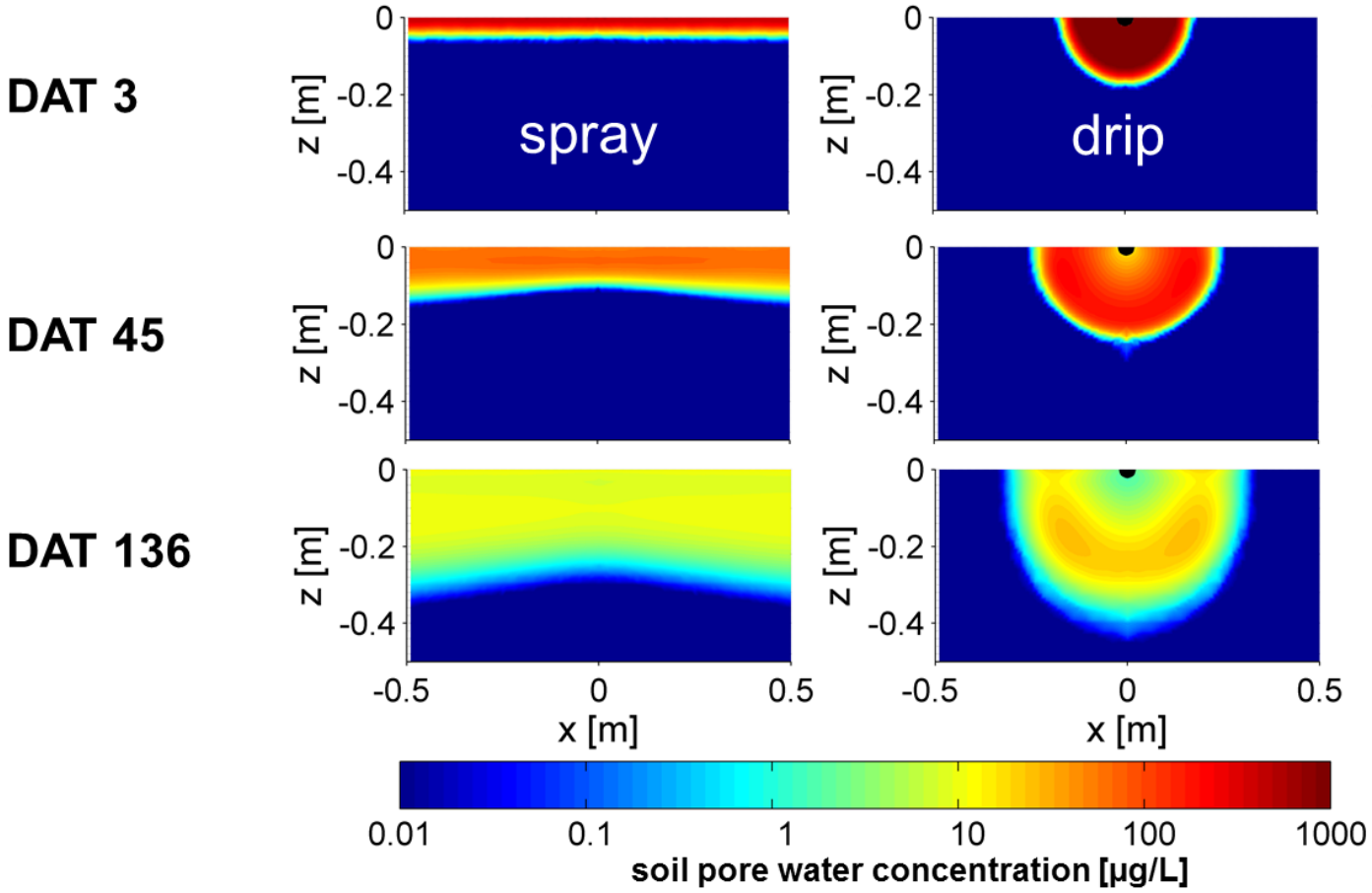
A modular approach



Each modules themselves should be validated for the purpose used!

Exposure modules

Problem homogenous vs heterogenous exposure



Increasing complexity in application technologies:

- band application
- precision farming

- seed treatment
- drip applications

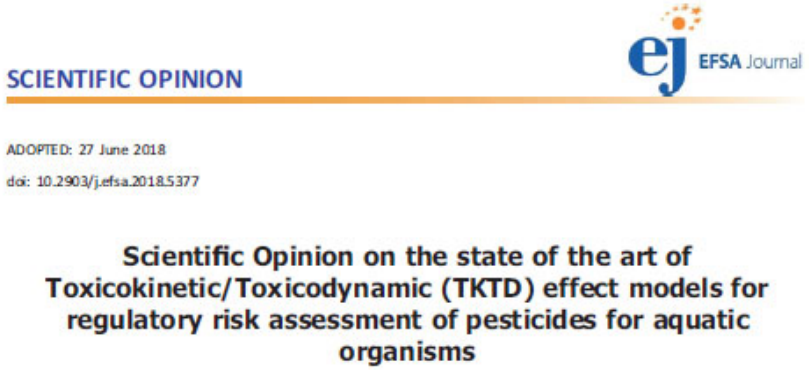
TKTD modules – linking exposure and effects

Lethal effects ➔ GUTS

- generic model no species specific data needed
- calibration method standardised to get reliable compound specific parameters (EFSA SO TKTD models, 2018)

Sublethal effects ➔ DEB

- species specific parameterisation needed (Add my pet database)
- calibration method standardised to get reliable compound specific parameters (DEB Community)



SCIENTIFIC OPINION

EFSA Journal

ADOPTED: 27 June 2018

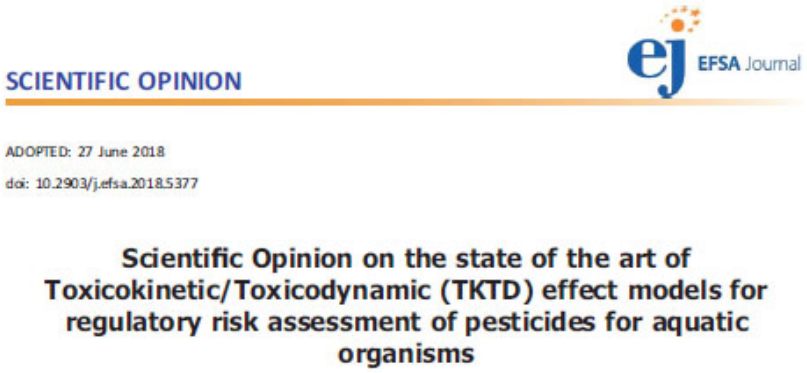
doi: 10.2903/j.efsa.2018.5377

Scientific Opinion on the state of the art of Toxicokinetic/Toxicodynamic (TKTD) effect models for regulatory risk assessment of pesticides for aquatic organisms

The current state of science in the GUTS framework is sufficient to facilitate the use of these models in the aquatic risk assessment for pesticides ….

The physiological DEB part … needs to be evaluated separately from the TKTD part and this should be done ahead of submission … for regulatory use (e.g. **by a group of experts at EU level**).

TKTD modules – linking exposure and effects


SCIENTIFIC OPINION

EFSA Journal

ADOPTED: 27 June 2018

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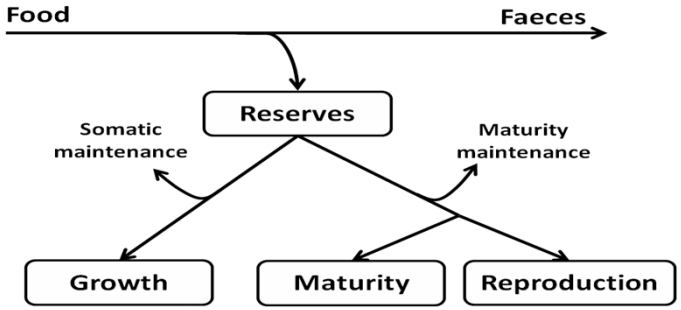
Scientific Opinion on the state of the art of Toxicokinetic/Toxicodynamic (TKTD) effect models for regulatory risk assessment of pesticides for aquatic organisms

The physiological DEB part … needs to be evaluated **by a group of experts at EU level**…

Species specific DEB Models available in the Add my Pet database



Earthworms:

Eisenia fetida
Lumbricus terrestris
Dendrobaena octaedra
Octolasion cyaneum
Aporrectodea longa

Springtails:

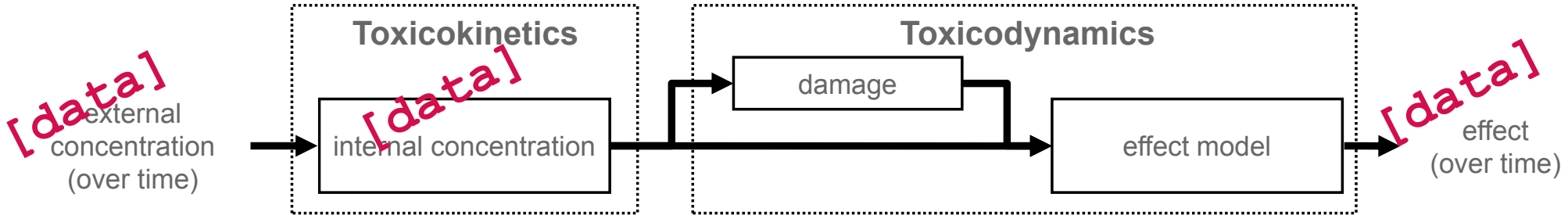
Folsomia candida
Isotoma viridis
Tomocerus minor
Entomobrya nivalis
Orchesella cincta
Lepidocyrtus cyaneus

Mites:

Rhizoglyphus_robini

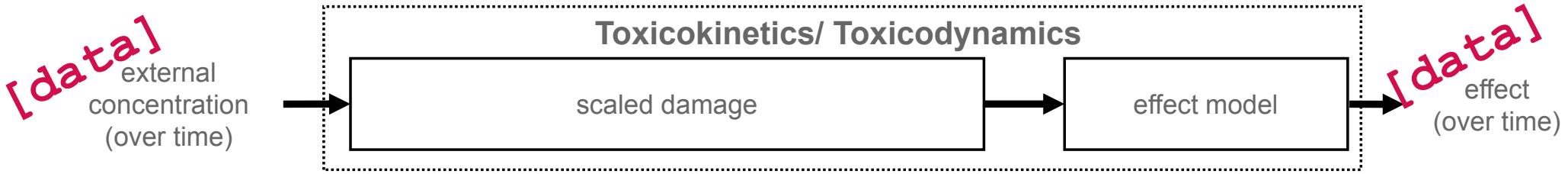
Dose metrics

TKTD modules



- Measured kinetics
- QSAR prediction
- prediction by physiological base toxicokinetic models

Scaled damage



Behaviour module

Spatial heterogenous exposure translate for soil organism which moves into the soil column into temporal heterogenous exposure.

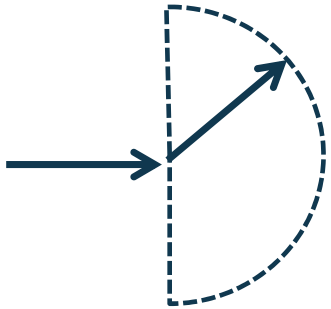
Therefore realistic estimation of movement behaviour under different environmental conditions is key!

➔ Currently no standard module available

Movement models

Earthworms

E. fetida
(Johnston et al., 2014a)



Random movement:
- Direction: -90 to 90 °
- Step length: 5 cm/day

L. terrestris
(Johnston et al., 2018)

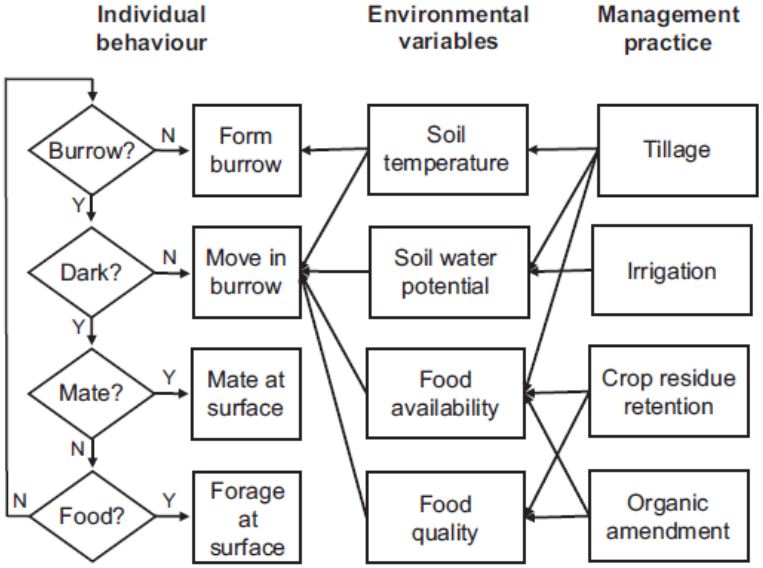


FIGURE 2 Conceptual model of *Lumbricus terrestris* individual behaviour per hourly time step in EEEworm. Behavioural rules in the diamond and square boxes are described fully in the text. If individuals do not already inhabit a burrow, they will prioritise burrow formation above all other behaviours. During dark hours, individuals mate and forage at the soil surface. Adults prioritise searching for a mate (if required: every 3 months for sperm transfer) in neighbouring burrows before foraging on plant litter. During light hours, individuals are largely inactive in their burrows but can move to optimise their position in the burrow according to prevailing environmental conditions. Different management practices affect different environmental variables in the soil profile, which also affect individual energy budgets

A. caliginosa
(Johnston et al., 2014b)

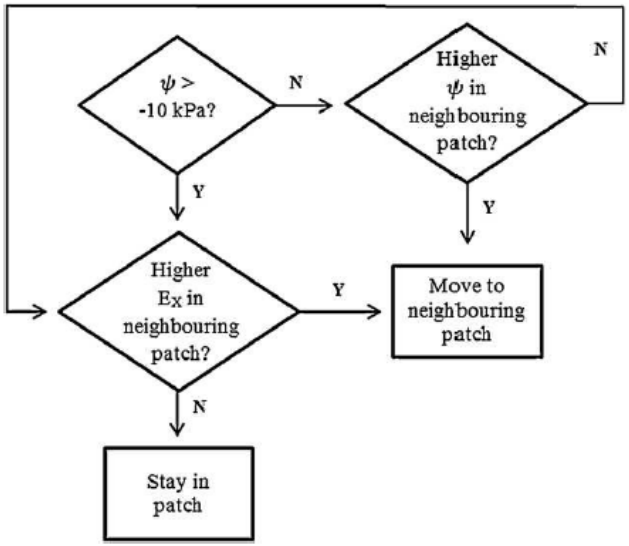


Fig. 5. Conceptual model of earthworm (*Aporrectodea caliginosa*) movement in the individual based model, where ψ represents soil water potential and E_x the energy content of food. Diamonds indicate decision points and rectangles are processes per daily time-step.

Movement model
Collembola - Roeben et al. 2013

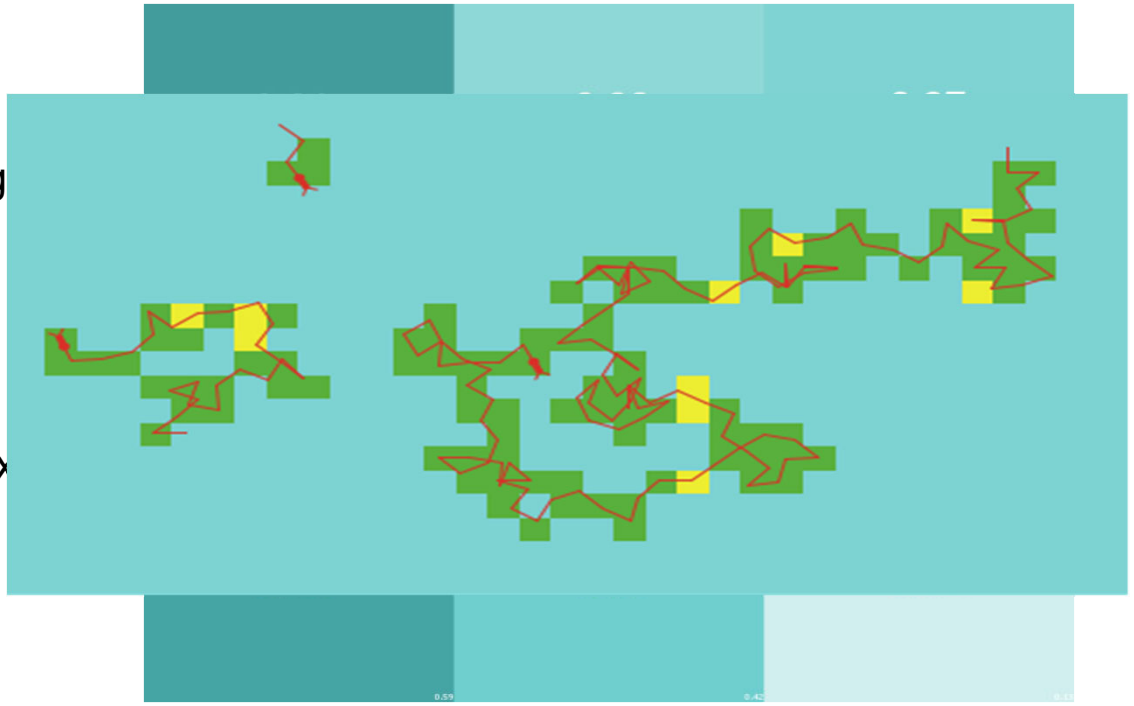
Movement

Patch-by-patch movement

- Distance [cm] drawn from a lognormal distribution[12)]
- Through scaling (patch 1x1cm) and iteration moving paths per day can be recorded

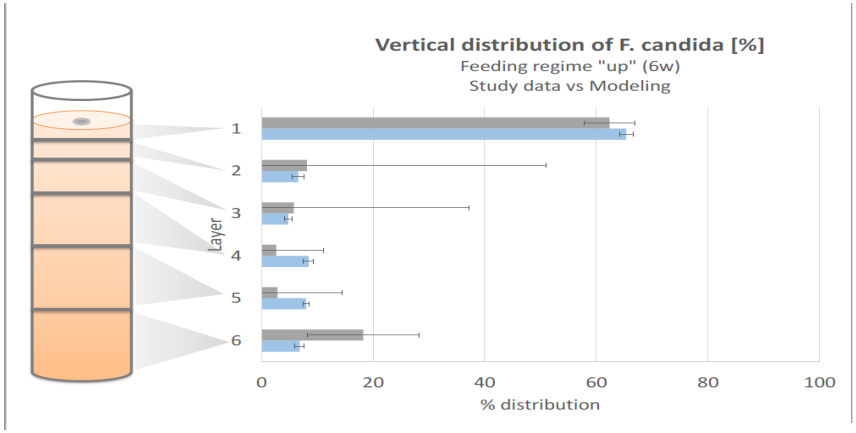
Decision making

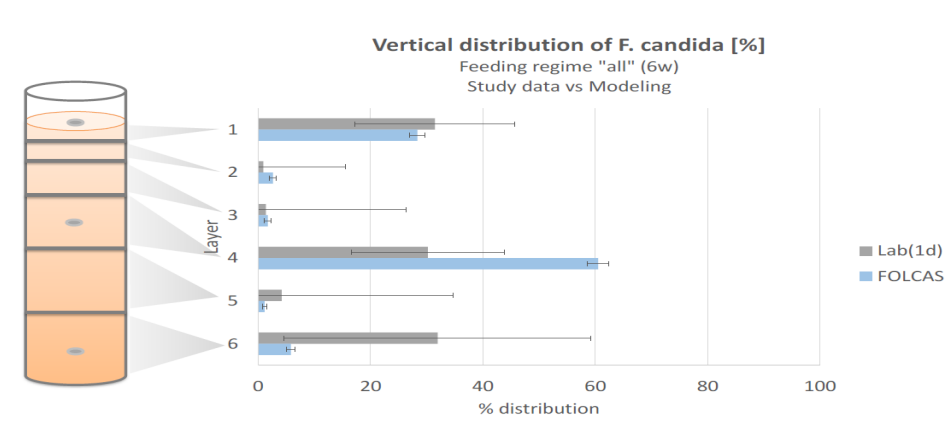
- Probability for attraction ‘p-ges’
  - // Organic matter content (15x)[10,13)], Temperature (3x soilair (1x)[9)] and pH (1x)[11)]
  - // 70% patch with highest attraction (probability) is chosen

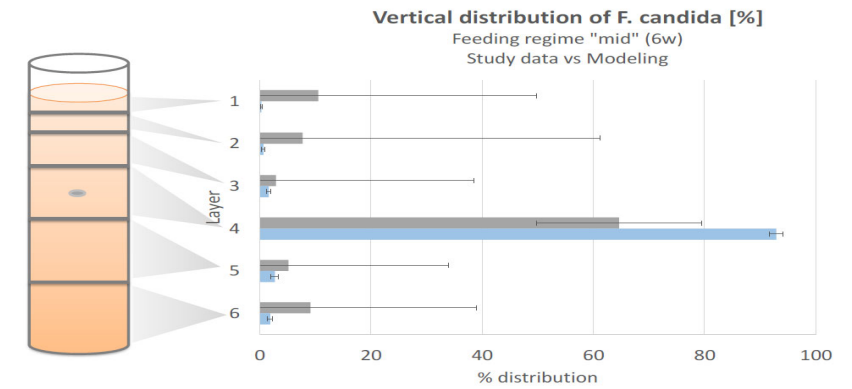


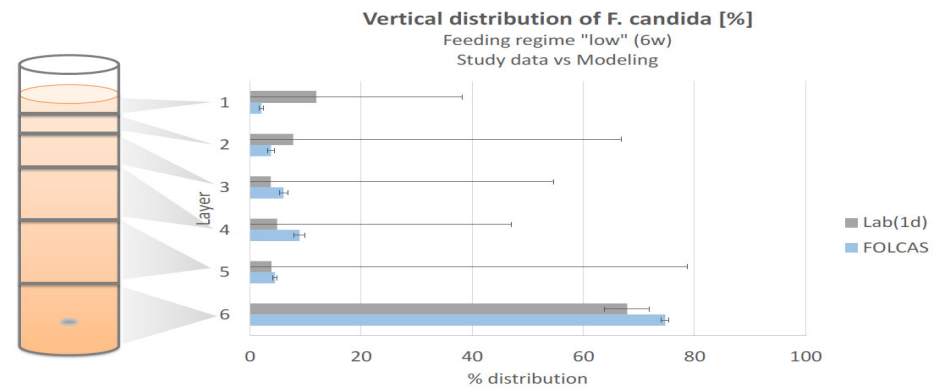
Testing movement models

Example FOLCAS Roeben et al. 2018



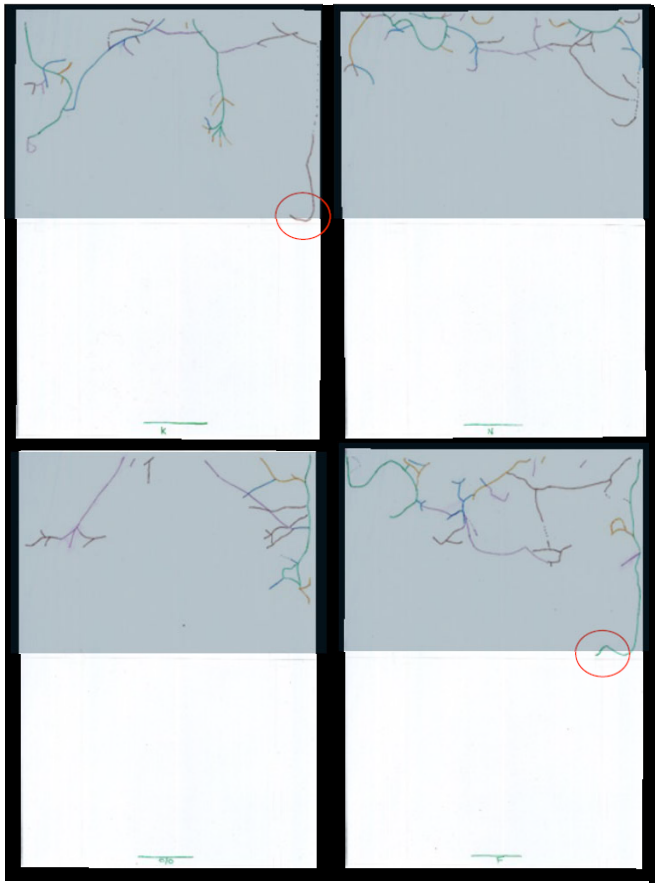






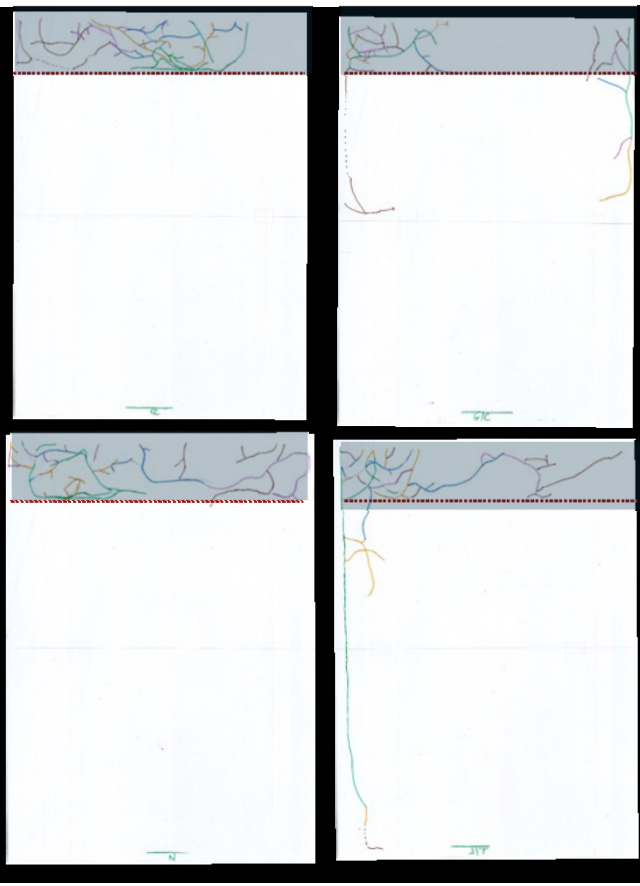
Testing movement models

Example Earthworms – cooperation BAYER and INRA ongoing



50% OM-rich soil
[0-15 cm] TOP
50% OM-poor soi
[15-30 cm] BOTTOM

A caliginosa did not burrow that deep and only encountered twice the OM-poor soil (and then avoid it, see the red circles)



5 cm of OM-very rich soil
[0-5 cm] TOP
35 cm OM-poor soil
[15-30 cm] BOTTOM

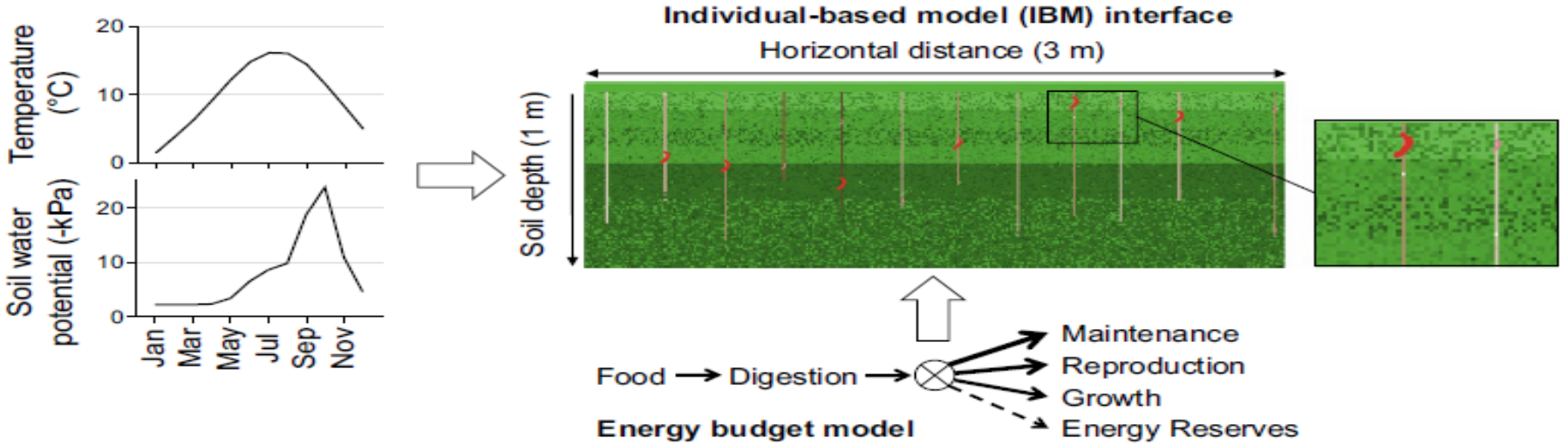
A caliginosa mainly stay in the first layer (see the red dotted line)

Experiments conducted Y. Capowiez

Behaviour model

Example Earthworm

Application of the behaviour of *L. terrestris* simulated with Johnston model (Johnston, 2018) and the exposure calculated with PEARL



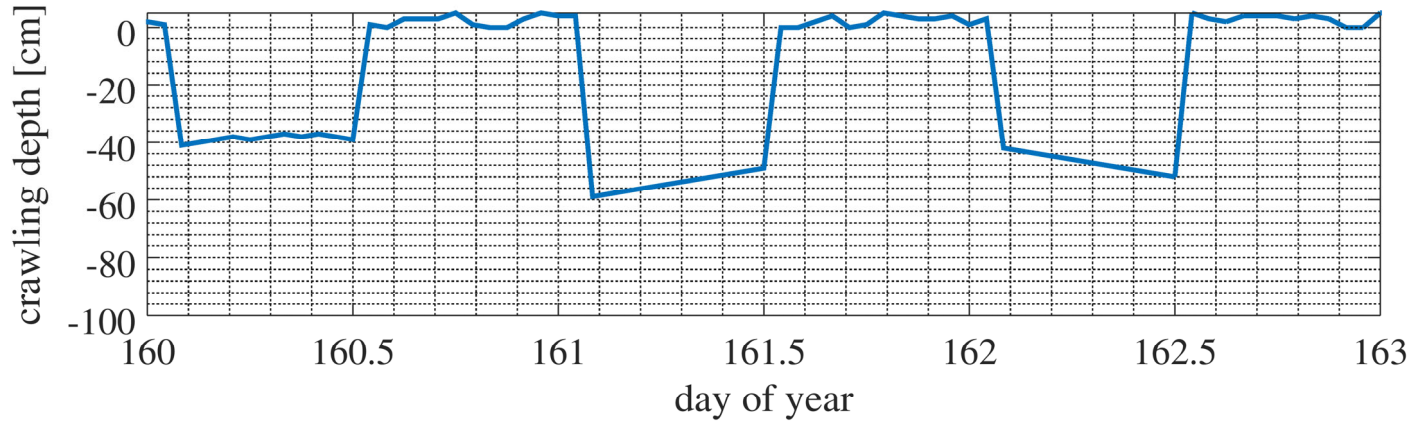
Exposure → Concentration-response → Individual → individual based population model → Population

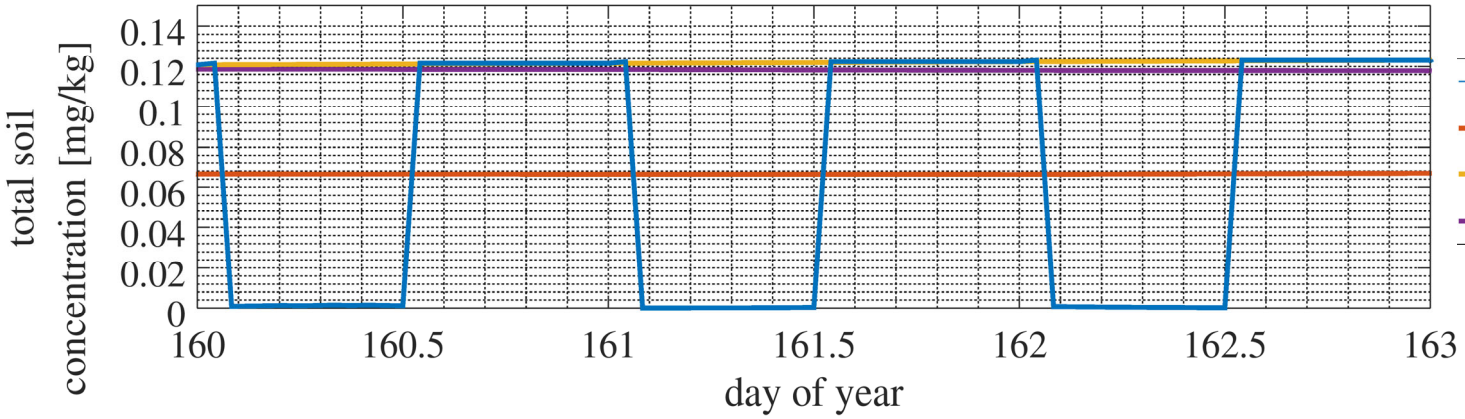
PEARL

Metabolic scaling theory

Behaviour model

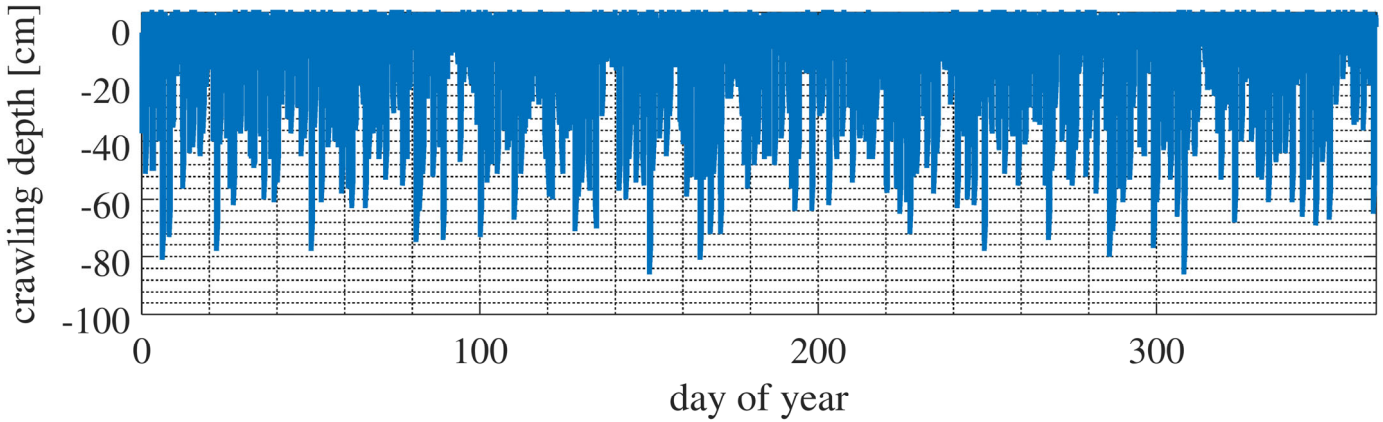
Example Earthworm



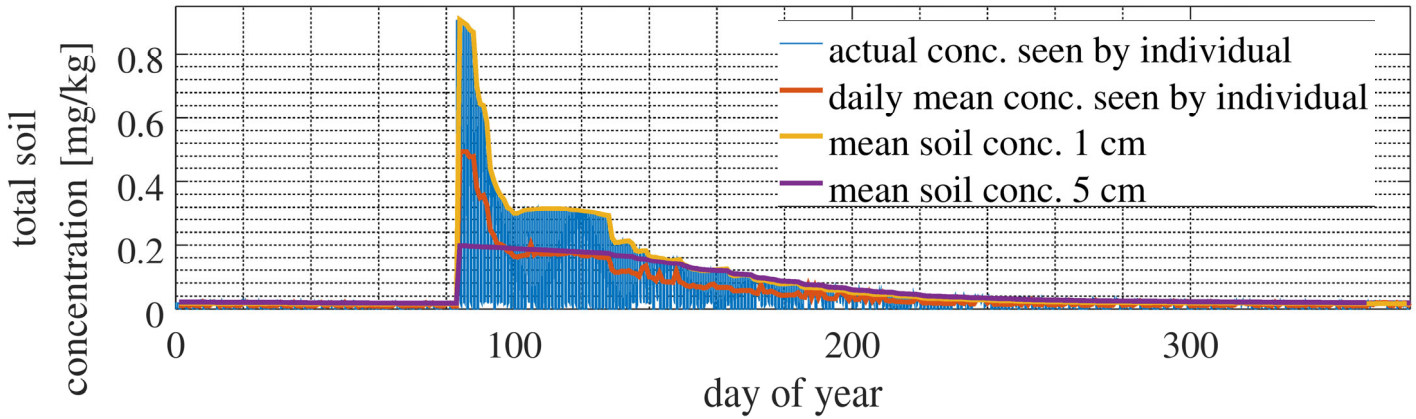


Behaviour model

Example Earthworm



Earthworm (*L. terrestris*) movement from Johnston (2018) model



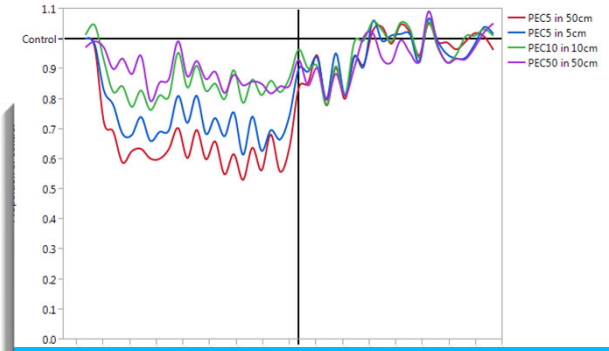
Related (total) soil concentrations from FOCUS PEARL calculations

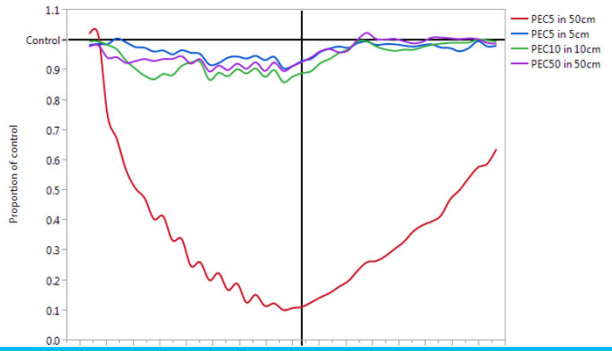
Linking exposure and effects

Example Earthworms – Thorbek & Johnston (2017)

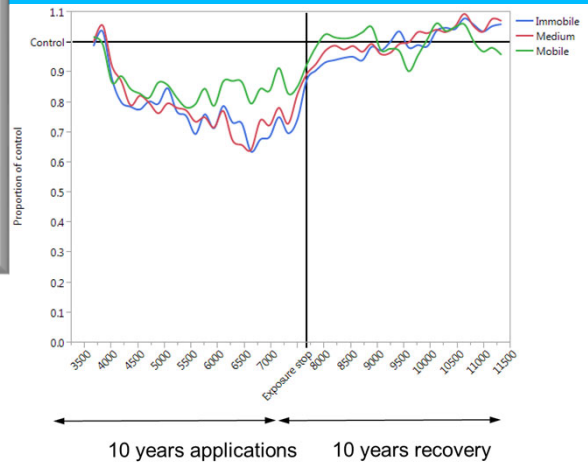
L. terrestris *A. caliginosa*

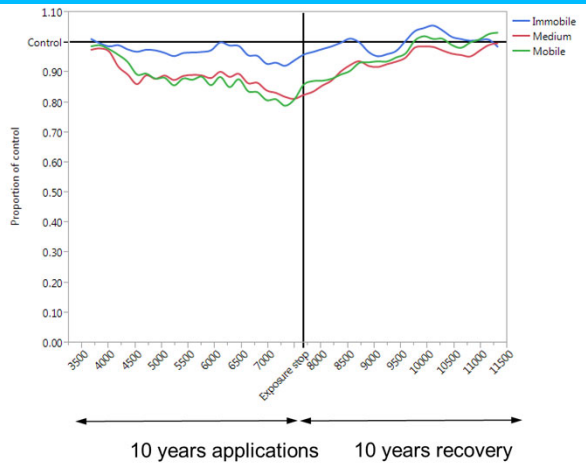
Simplified exposure scenarios





FOCUS scenarios



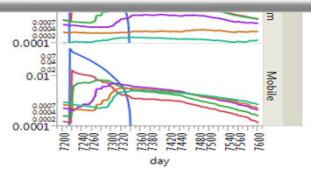


0.1333 mg/kg

Current RA:

- Worst case-exposure scenario is different for different species
- Results differ markedly between simplified exposure and FOCUS scenarios

➔ Since no worst-case can be defined risk assessment should be conducted as realistic as possible



Results
I. FOCUS Scenarios

FOCUS Scenarios

1. FOCUS scenarios
   - Châteaudun
   - Hamburg
   - Piacenza
   - Porto
2. 2 different crops
   - Sugarbeet
   - Wintercereals
3. c = 0.652 [kg/ha]
   - c ≙ EC_{50} (Châteaudun + Piacenza)
   - application 14 d after emergence
4. reproduction inhibition
   - FOLCAS

	1 Sugarbeet	2 Wintercereals
1 Châteaudun	16.07 %	36.11 %
2 Hamburg	31.91 %	21.95 %
3 Piacenza	23.08 %	47.06 %
4 Porto	32.05 %	5.45 %

Exposure → Concentration-response → Individual → Population

PEARL — Empirical — individual based population model

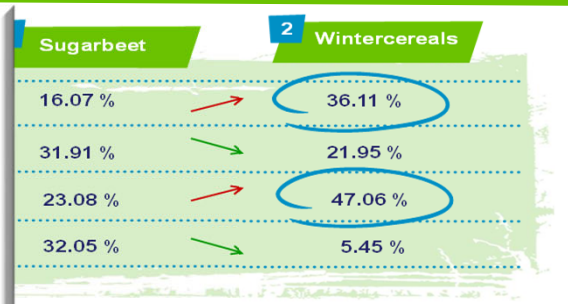
Results
I. FOCUS Scenarios

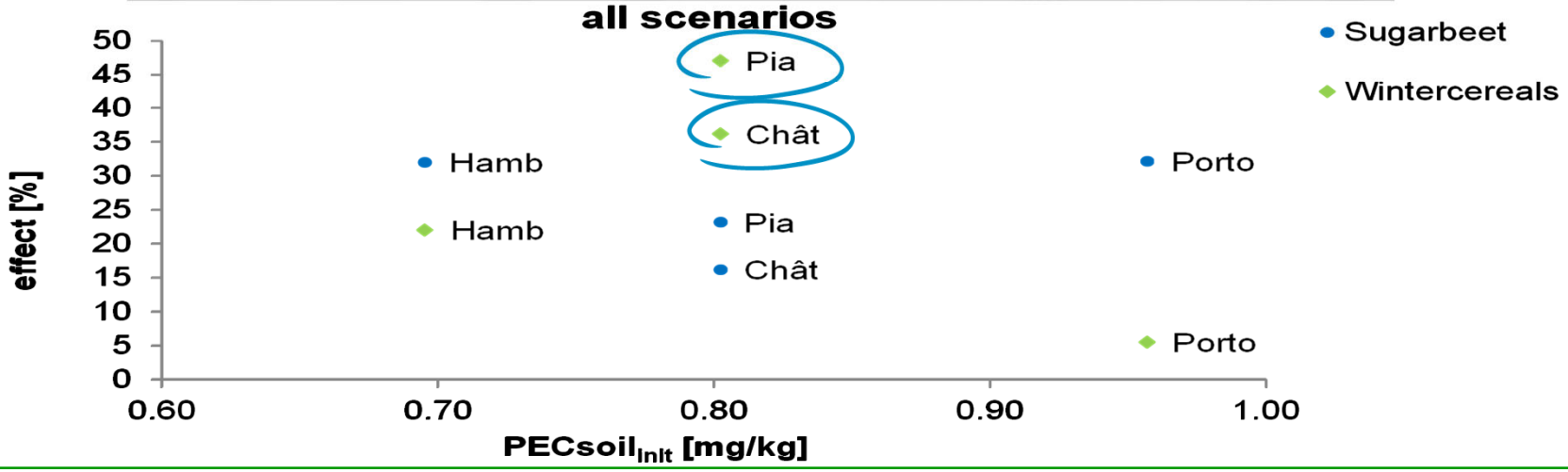
FOCUS Scenarios

- C
- H
- P
- P

➢ Scenario and crop selection influence the extent of the effect on collembolan populations

➢ No correlation of effects with PECsoil

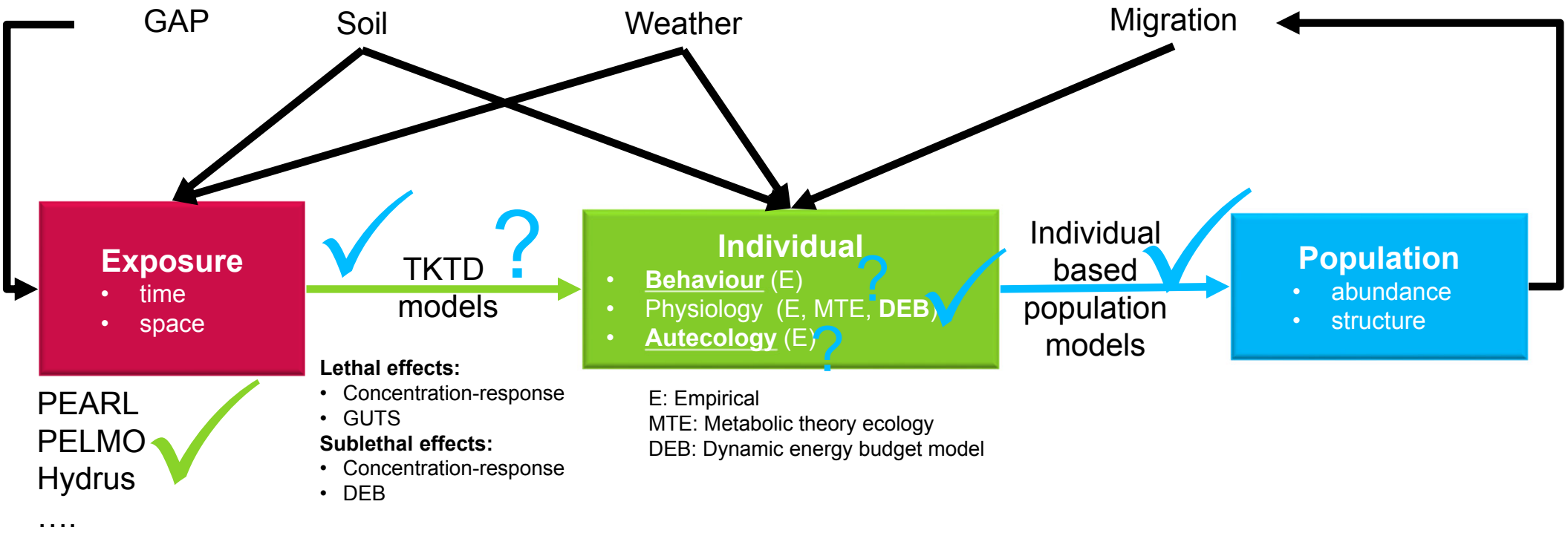




→ No correlation between PECsoil$_{init}$ and observed maximum effect

RWTH AACHEN UNIVERSITY

A modular approach



Each modules themselves should be validated for the purpose used!

Conclusion

- Exposure of soil organism emerge from spatial exposure pattern and movement behaviour
  - Effects differ markedly between simplified exposure and detailed calculated scenarios
  - Since no worst-case can be defined risk assessment should be conducted as realistic as possible
- Integrated risk assessment of using a modular model approach to link exposure and effect models will allow a conservative risk assessment and thereby reducing the uncertainty of our current approach
  - In future we might not have political discussions about 1 or 5 cm depth (for neither being a scientific rational)
  - Instead we will discuss things which are measurable and have a true and realistic distribution (e.g. the behaviour of earthworms, dynamics of OC in the soil scenario)
- A lot of tools are already available, some well tested, some already accepted in regulatory frameworks
  - Let use this tools in a modular approach and focus future research on the missing parts (for this question it is autecology and behaviour of soil organisms)

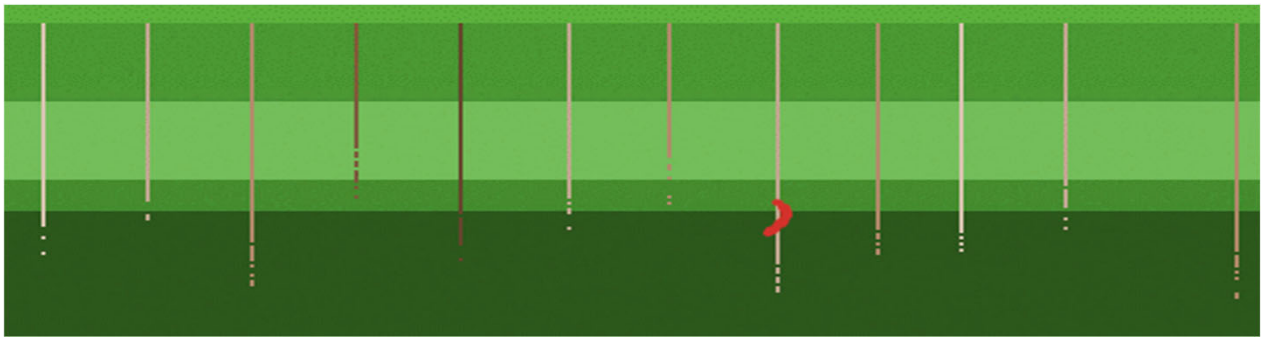
Thank you!

Bye-Bye

Behaviour model

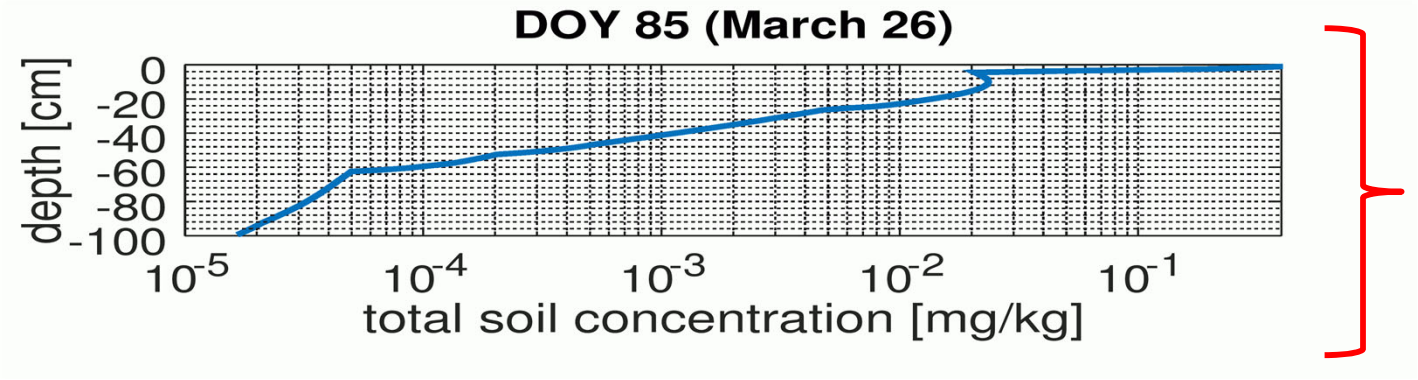
Example Earthworm

One day of life of *L. terrestris* in Châteaudun…



Earthworm movement simulated by **Johnston (2018)** model, environmental conditions (soil temperature, moisture, OM) taken from depth profile of FOCUS PEARL calculations

To which soil concentrations of Imidacloprid (1 x 117 g/ha, March 25) is one individual exposed during one season?



Simulated (total) **soil concentration profiles** taken from **FOCUS PEARL** calculations:
Imidacloprid, 1 x 117 g/ha at March 25 (DOY 84) in sugar beet