

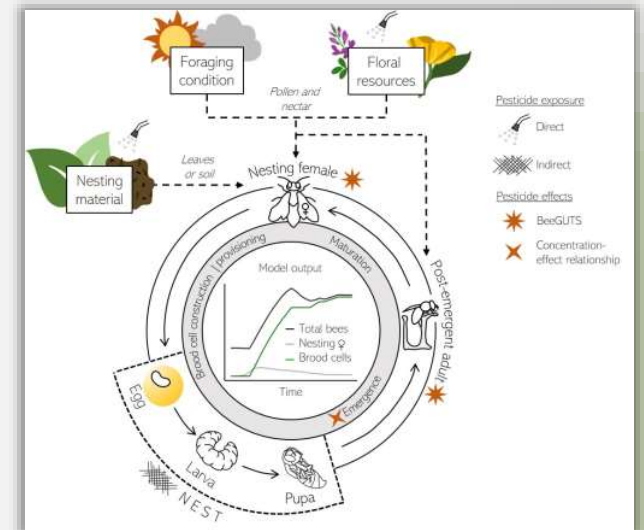
SolBeePop (Amelie Schmolke, RIFCON)



SolBeePop_{ecotox}

A Population Model for Solitary Bees

Amelie Schmolke



SolBeePop_{ecotox}: Population model for solitary bees

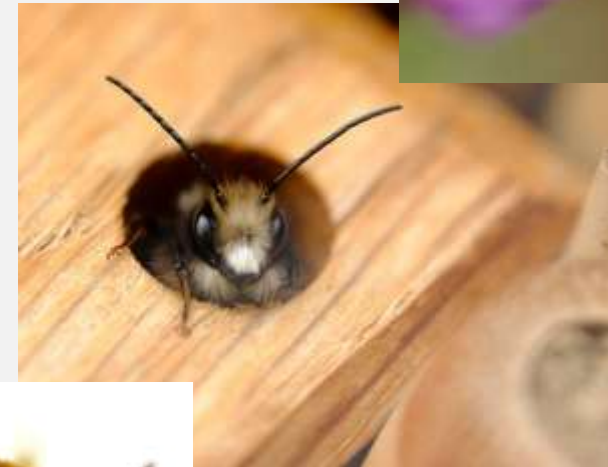
- Individual-based model captures **solitary bee life cycle** and represents populations managed for pollination as well as wild populations
- Representation of **multiple bee species**: species-specific **biological traits** correspond to model input parameters
- Inclusion of **multiple relevant pesticide exposure routes**: direct spray, pollen, nectar, and nesting materials



SolBeePop_{ecotox}: Population model for solitary bees

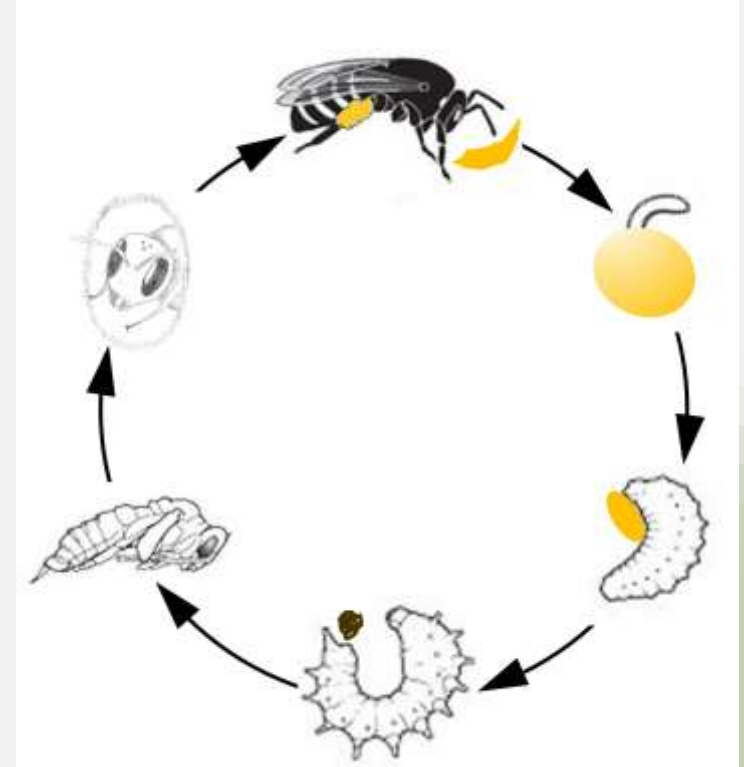
Overview of the presentation

1. Solitary bees
2. Model concept
3. Model data requirements and outputs
4. Model implementation
5. Model performance assessment
6. Example application
7. SolBeePop_{ecotox} and ERA



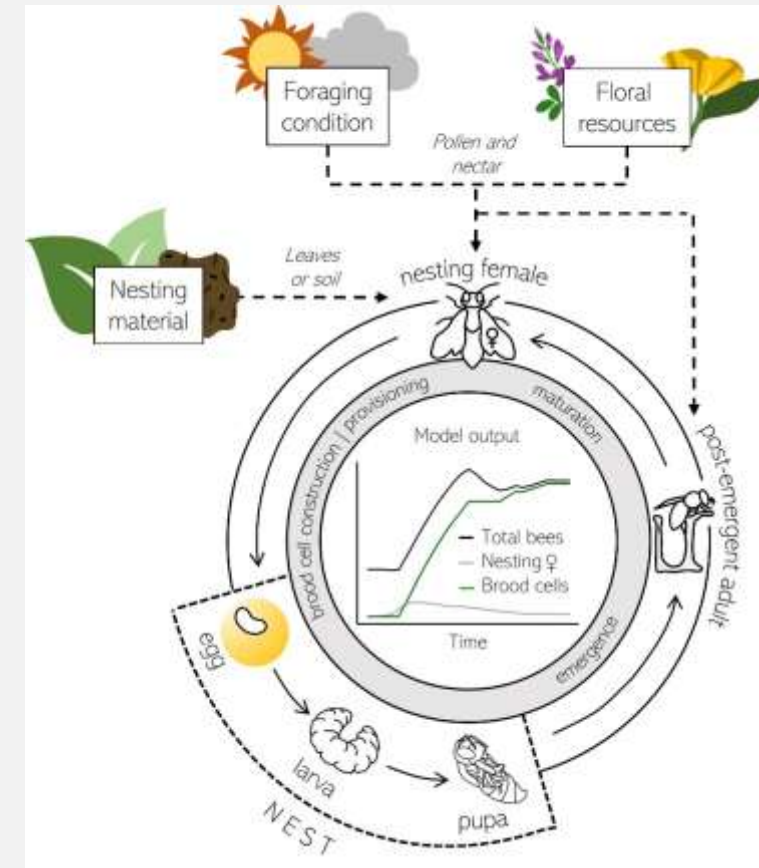
1. Solitary bees

- More than **20.000 species of bees (Apoidea)** described worldwide
- Among those, “**solitary bees**” summarize a diverse of non-social species (>75% of species)
- Distinct **life-history** (excluding brood parasites):
 - Each female bee reproduces and cares alone for her offspring
 - Females build nests with separate brood cells for each offspring
 - Cells are provisioned with food for the entire development
 - Developing bees can remain dormant in the nest over extended time periods
- Important **pollinators** of crops and native plant communities
- Due to their ecology, they may be **exposed to pesticides** in agricultural landscapes



2. SolBeePop: Concept

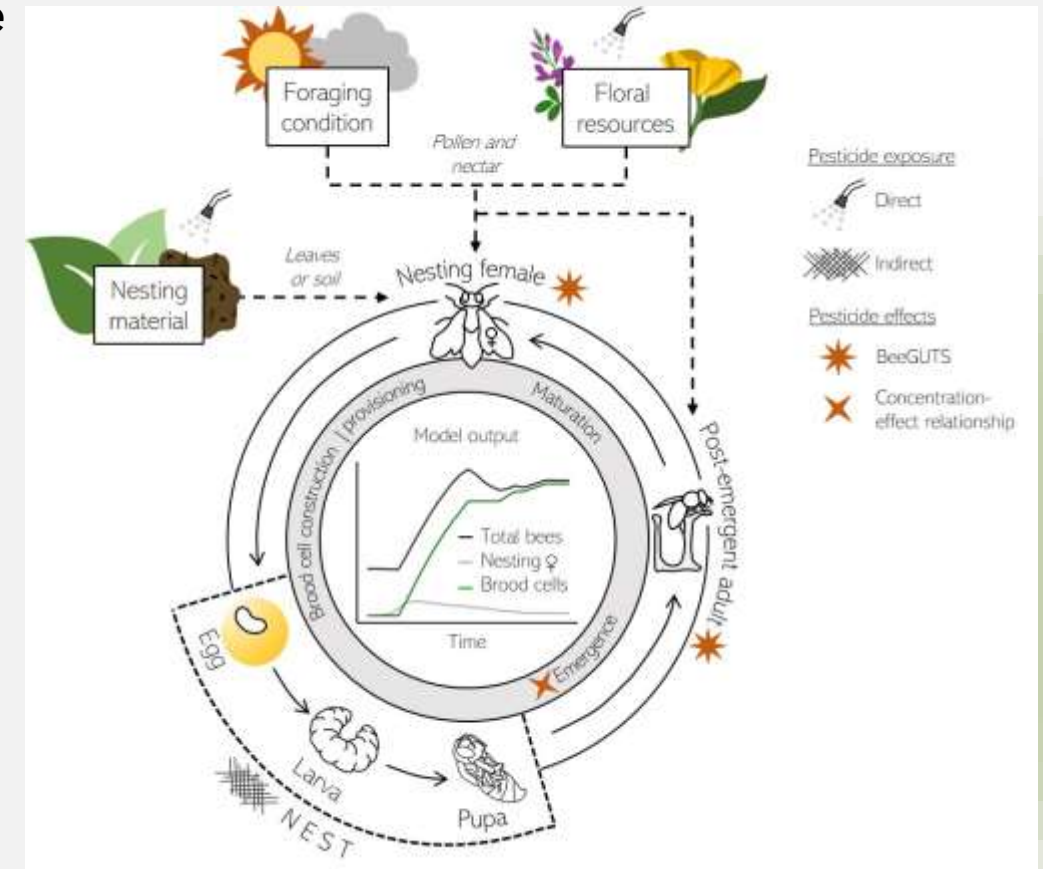
- **Individual-based model** including **stochasticity** (processes reflecting outcome distributions)
- **Life history**
 - Sequential brood cell production by nesting females
 - Developmental time and voltinism
- **Density dependence** can be simulated through limitation of suitable nesting resources
- **External drivers** defined by daily input time series:
 - weather conditions
 - floral resource availability from (treated) crops and other sources, e.g., natural/mixed flower communities



Schmolke, A., Galic, N., & Hinarejos, S. (2023).
J Appl Ecol, 60, 2573–2585.
DOI: 10.1111/1365-2664.14541

2. SolBeePop_{ecotox}: Concept

- **Exposures** defined via separate daily input time series for each route:
 - **direct spray**
 - residues in **nectar** from crop / exposed floral resources
 - residues in **pollen** from crop / exposed floral resources
 - residues in **soil** used for nesting or brood cell partitions
 - residues on **leaves** used for brood cell lining and/or partitions
- **Effects** in in-nest life stages and adults:
 - Larvae: **concentration-response** function for survival applied at time of emergence
 - Post-emergent females: **daily mortality** with BeeGUTS*



Schmolke A, Galic N, Roeben V, Preuss TG, Miles M, Hinarejos S. 2024. Environ Toxicol Chem. DOI: 10.1002/etc.5990

*Baas J, Goussen B, Miles M, Preuss TG, Roessink I. 2022. Environ Toxicol Chem. 41(9):2193–2201. DOI: 10.1002/etc.5423

3. SolBeePop_{ecotox}: Data requirements

Ecological traits (species-specific)

- Traits include, e.g., post-emergent female life span, phenology, brood production, composition of provision (pollen:nectar), pre-emergence development times, survival rates, sex ratio, body size, consumption rates
- Compiled for mason and orchard bees (*Osmia bicornis*, *O. lignaria*, *O. cornuta*, *O. cornifrons*), the alkali bee *Nomia melanderi*, the hoary squash bee *Eucera pruinosa*, and the leafcutter bee *Megachile rotundata*

Environmental factors (specific to scenario)

- Weather data, e.g., precipitation, temperature, sunshine / irradiation, wind
- Phenology of floral resources particularly of exposed crops
- Consideration of landscape composition possible



Megachile rotundata
Picture from usda.gov



Osmia lignaria
Picture from usda.gov



Eucera (Peonapis) pruinosa
Picture by Ilona Loser - wikimedia



Nomia melanderi
Picture by Mark Harrison, Seattle Times

3. SolBeePop_{ecotox}: Data requirements

Exposure (specific to each pesticide)

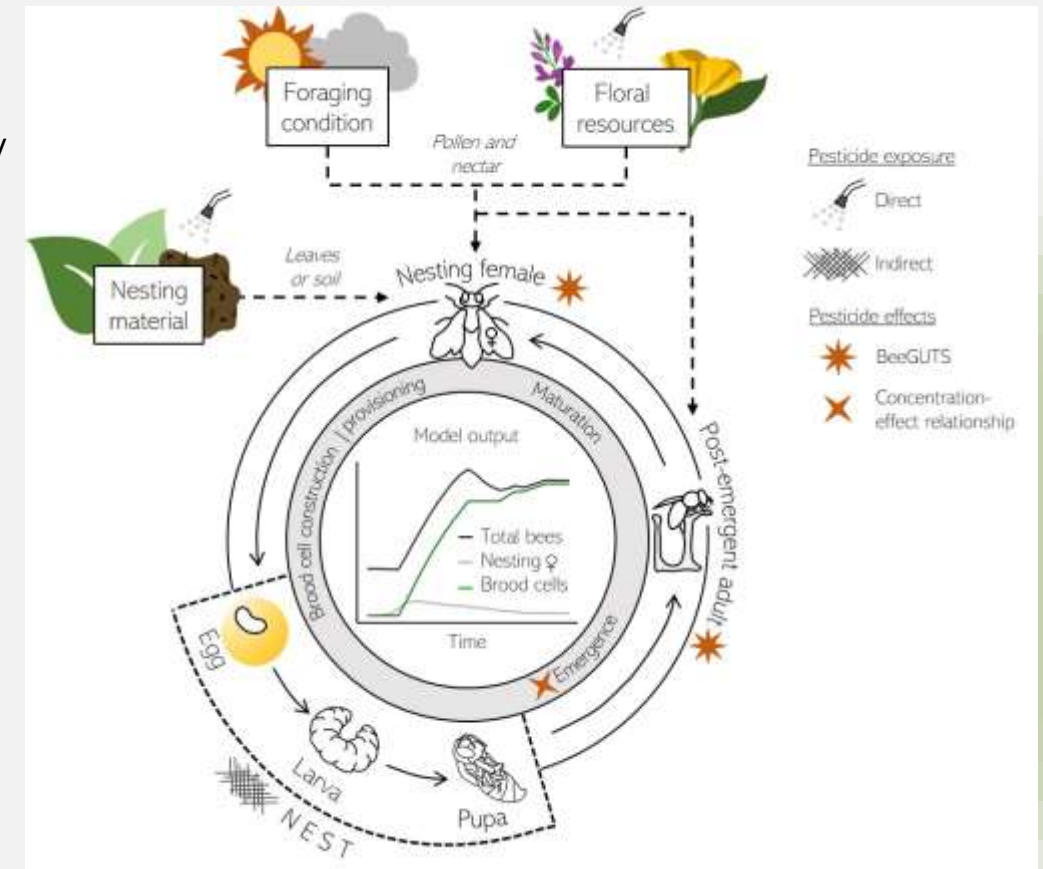
- Single pesticide simulated: application type, rate and timing
- Residues in pollen and nectar (separate daily time series)
- Residues in relevant nesting matrix (soil or leaves)
- Transfer rate of compound from nesting material to bees (adult and developing)
 - Currently very limited data available, but the impact of different assumptions can be tested with the model

Effects (specific to the combination of pesticide and species)

- GUTS parameters: (Bee)GUTS calibrated to laboratory toxicity data (adults)
- Dose-response parameters for larval toxicity

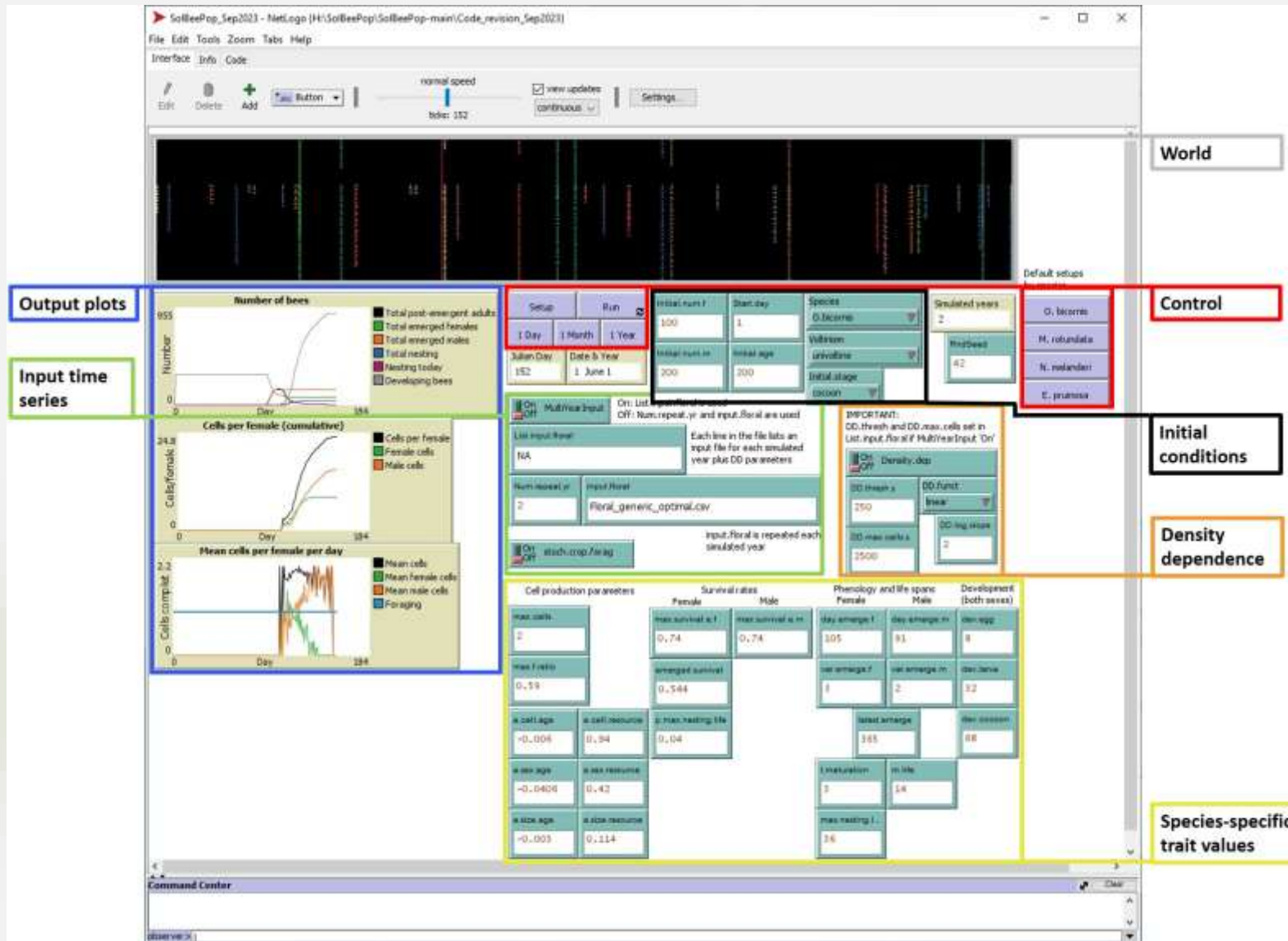
3. SolBeePop_{ecotox}: Outputs

- **Daily output series**
 - Numbers of individuals per life stage and sex
 - Number of brood cells produced per female bee (female / male offspring)
 - Number of dead bees (per life stage) due to exposure
- **Population-level effect sizes**
 - Separate simulations for controls (no exposure) and treatment (with exposure)
 - Calculation (post-processing) from outputs of the two simulations (or simulation sets)
 - Effect sizes can be calculated for any day (date)
 - Comparison to measurements in (semi-)field studies
 - Long-term analysis of (wild) populations



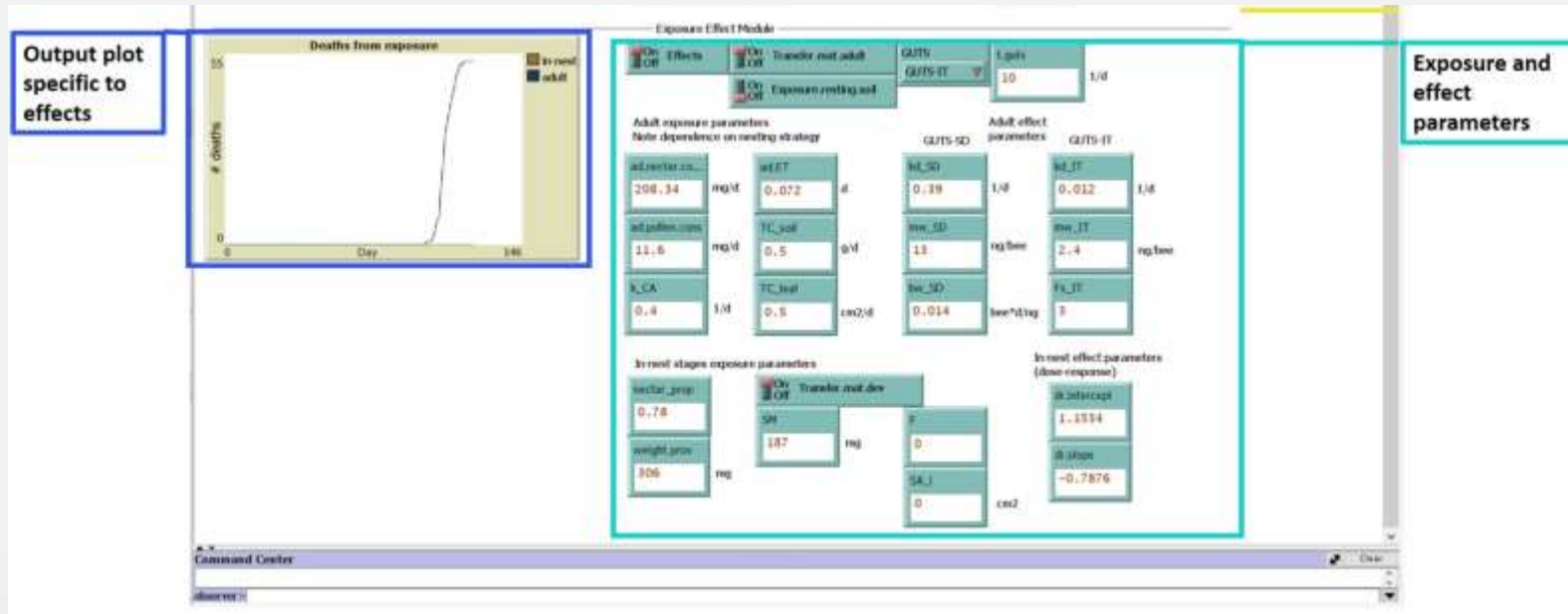
Schmolke A, Galic N, Roeben V, Preuss TG, Miles M, Hinarejos S. 2024. Environ Toxicol Chem. DOI: 10.1002/etc.5990

4. SolBeePop_{ecotox}: Implementation / Interface



- Implementation in NetLogo version 6
- Input file defines environmental conditions: generated outside of model
- All parameters can be set on the interface
- Presets available for 4 species
- Outputs require post-processing

4. SolBeePop_{ecotox}: Implementation / Interface



- Exposure and effect module can be switched on or off
- Exposure and effect definitions from input / parameter settings
- Input file: exposure time series need to be added (outside of model)
- Effect parameters are specific to pesticide
- Model code publicly available:
<https://doi.org/10.5281/zenodo.15323914>

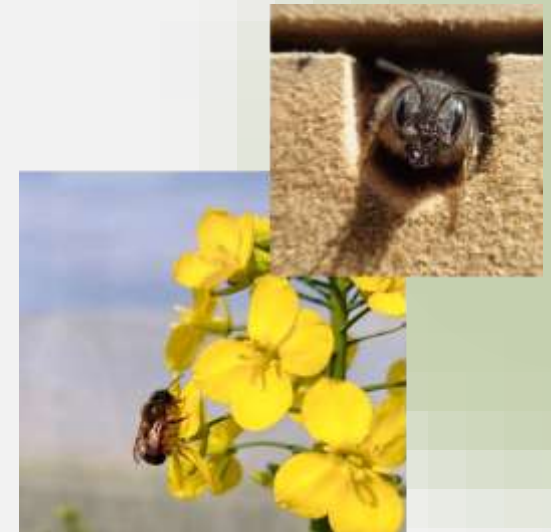
5. SolBeePop_{ecotox}: Assessing model performance

Data from two semi-field (tunnel) studies conducted with *Osmia bicornis*

- Mesh tunnel set up over a portion of a crop field
- *O. bicornis* cocoons introduced at nest boxes at onset of oilseed rape flowering
- Number of females in nest boxes and brood cell production monitored
- Controls (6 replicates) and (positive control) treatments with 75 g a.i./ha dimethoate spray application (during bee flight activity; 3 replicates)
 - Dimethoate application restricted to experimental mesh tunnels
- Studies conducted in two different years in the same region

Simulations with SolBeePop_{ecotox}

- **Calibration** of SolBeePop_{ecotox} to the **untreated controls**
- Simulation of **effects** from dimethoate using **honey bee toxicity** parameters

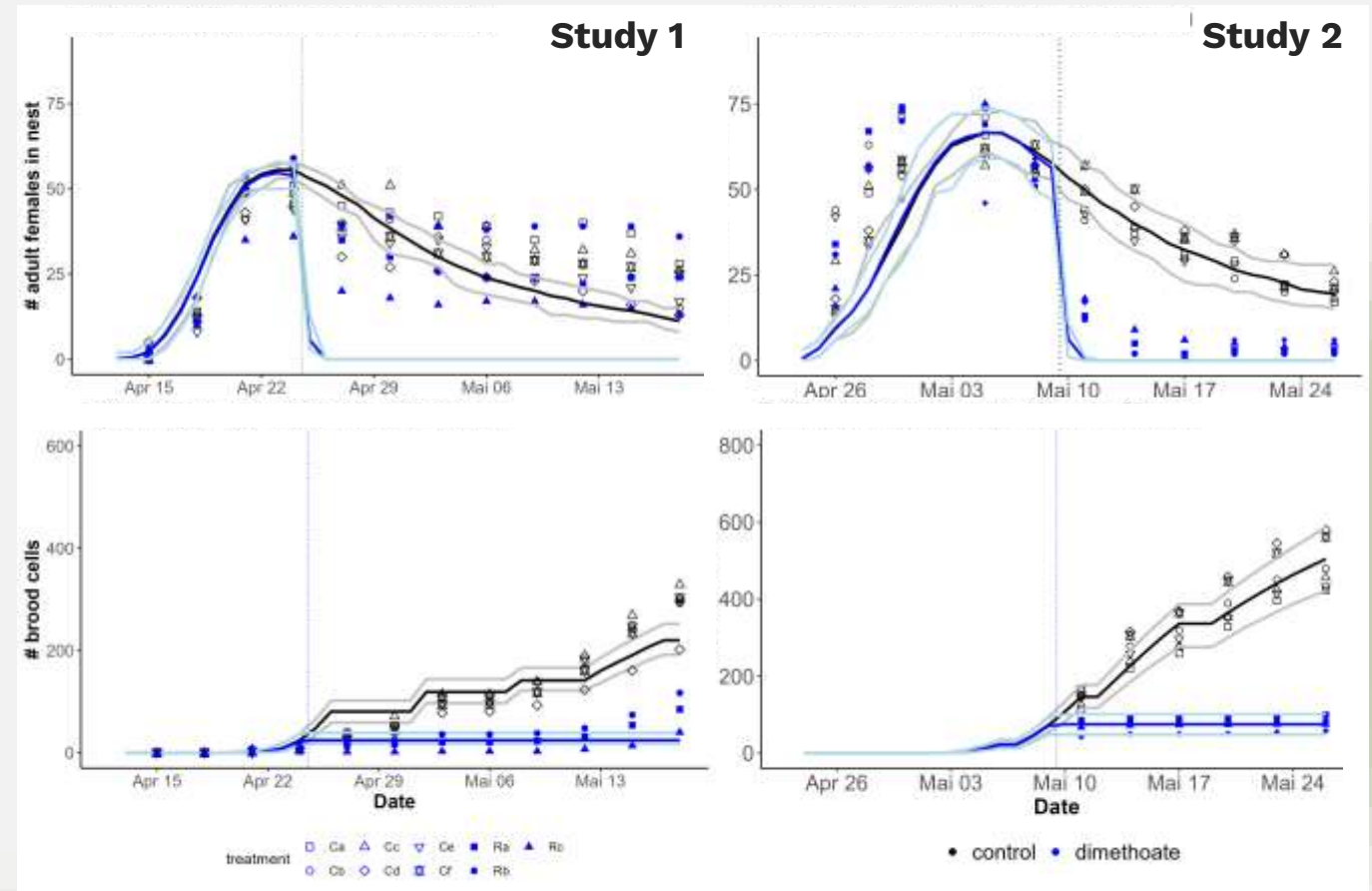


Osmia bicornis
Pictures by Olaf Klein

5. SolBeePop_{ecotox}: Assessing model performance

Observations (dots) and simulations (lines) of *O. bicornis* semi-field studies

- Simulation of **controls** captures the dynamics observed in the semi-field studies
- Observed **effects** of dimethoate can be represented by the model using honey bee toxicity data (and no further model calibration)



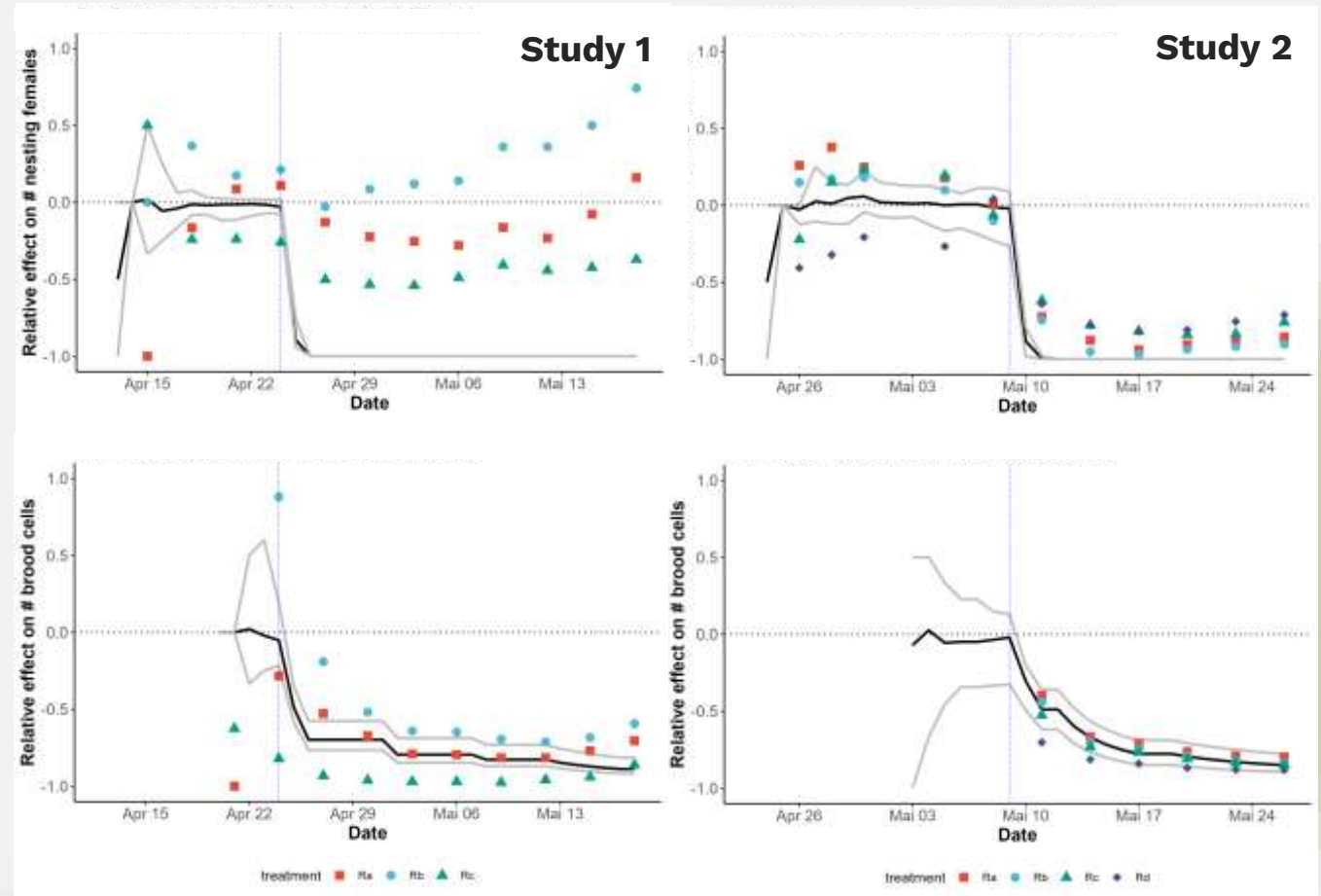
Untreated controls

Dimethoate treatments

5. SolBeePop_{ecotox}: Assessing model performance

Relative effect:
Observations (dots) and
simulations (lines)
of *O. bicornis* semi-field studies

- Effects relative to control presented for the same data and simulations



6. SolBeePop_{ecotox}: Extrapolating to untested species

Simulation of hypothetical semi-field studies

- **Soil-nesting** solitary bee species are not amenable to testing, but the majority of solitary bees are soil-nesting
- Simulation of semi-field studies with the alkali bee, ***Nomia melanderi***, and the hoary squash bee, ***Eucera pruinosa***
- Scenarios with **temporal shifts** between bee emergence and application
- Example for application of the model for predictions relevant in environmental risk assessments



Eucera (Peponapis) pruinosa
Picture by Ilona Loser - wikimedia



Nomia melanderi
Picture by Mark Harrison, Seattle Times

6. SolBeePop_{ecotox}: Extrapolating to untested species

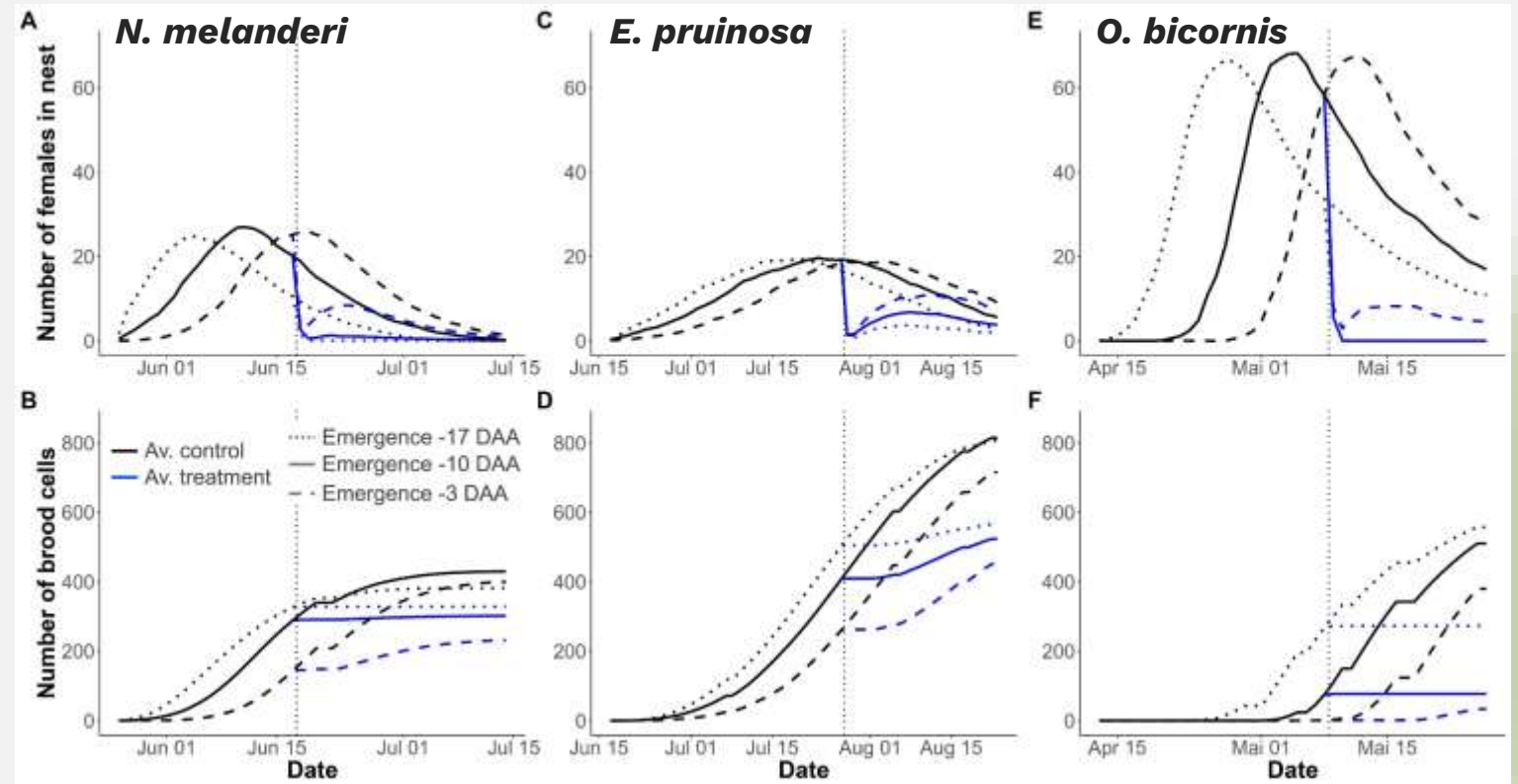
Simulations of **untreated controls**

Dimethoate treatment simulations:

100% of post-emergent females exposed

Temporal scenarios:

- 17 days prior to treatment (dotted line)
- 10 days prior to treatment (solid line; corresponds to *O. bicornis* semi-field studies)
- 3 days prior to treatment (dashed line)



7. SolBeePop_{ecotox} and Environmental Risk Assessment

- Model applicable to simulate **specific study designs** (e.g., semi-field or field studies)
- Control simulations (without treatment) and with pesticide exposure can be compared to determine **population-level effect sizes**
 - Exposures can be specified according to different exposure routes
 - Exposures can vary in time, i.e., pesticide dissipation, multiple applications, etc. can be simulated
 - Exposure multiplication factors can be applied to estimate a margin of safety
- The model can be used to **extrapolate to untested conditions / scenarios**
 - Scenarios with untested exposure levels, temporal patterns or exposure in the landscape
 - Across bee species with different ecological traits
 - Different study designs

7. SolBeePop_{ecotox} and Environmental Risk Assessment

Open questions and model improvements

- Simulation of **wild populations** (simulations of multiple years and bee generations)
 - Definition scenarios necessary including the temporal horizon of simulations
 - Most relevant for specific protection goals: assessing relevant population-level effect sizes over multiple generations / years
 - Simulation of multiple species with different life history traits to address diversity in bee species
- **Evaluation** of the model with **different compounds and species** should be conducted
- Use in a specific **risk assessments** is needed
- **Independent review** of the model: SolBeePop_{ecotox} is currently under review by the EFSA working group “Effect models in environmental risk assessment”

Thank You

Co-developers of SolBeePop_{ecotox}

Silvia Hinarejos, Nika Galic,
Vanessa Roeben, Thomas G.
Preuss, Mark Miles



SolBeePop publications

Schmolke, A., Galic, N., & Hinarejos, S. (2023). SolBeePop: A model of solitary bee populations in agricultural landscapes. *Journal of Applied Ecology*, 60, 2573–2585. <https://doi.org/10.1111/1365-2664.14541>

Schmolke, A., Galic, N., Roeben, V., Preuss, T. G., Miles, M., & Hinarejos, S. (2024). SolBeePopecotox: A Population Model for Pesticide Risk Assessments of Solitary Bees. *Environmental Toxicology and Chemistry*, 43, 2645–2661.

<https://doi.org/10.1002/etc.5990>

Schmolke, A., Galic, N., & Hinarejos, S. (2025). Landscapes from the bee perspective: An application of SolBeePop to field study data. *Food and Ecological Systems Modelling Journal*, 6, e149273.

<https://doi.org/10.3897/fmj.6.149273>

SolBeePop_{ecotox} code and files

Schmolke, A. (2025). *SolBeePop/SolBeePop: V2.1.0* (Version v2.1.0) [Dataset]. Zenodo. <https://doi.org/10.5281/zenodo.15323914>

- or -

<https://github.com/SolBeePop/SolBeePop>