Testing the BEEHAVE landscape module – complexity comes at a price

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Objectives

- The worry about the decline of the honeybee population has intensified the need for mechanistic tools that can explain and predict the interactive effects of plant protection products and other stressors on the bees.
- The honeybee colony model BEEHAVE (Becher et al., 2014) has been discussed as a potentially promising tool for modelling ecologically relevant scenarios.
- According to the evaluation by the European Food Safety Agency (EFSA), some properties of the BEEHAVE model need to be more complex in order to fulfill the requirements to be used in ecological risk assessment.
- One of those properties is the representation of the landscape, which should include *detailed spatial and temporal field data from defined study sites in Europe, and the contribution of these data to pollen, nectar and water availability, pesticide contamination and foraging behavior*. (EFSA, 2016)
- In this poster presentation, we compare a simp EZ4 two patch scenario against a complex landscape approach in BEEHAVE.

Model input for the landscape

To parametrize a specific nectar source, the following parameters need to be known:

- Distance to hive
- Gathering time for pollen
- Quantity of pollen
- Gathering time for nectar
- **Quantity of nectar**
- **Sugar concentration of the nectar**

To parametrize the full landscape for one study, this information is needed for each m² of the landscape for each nectar and pollen source

The complex landscape – why is it so complex?

Nectar availability is difficult to define

- Nectar production per plant depends on weather conditions: in sunny weather, sugar values can be 2-3 times higher than in cool weather (Farkas, 2007)
- Multiple sampling on the same day stimulates a higher nectar production (see graph below): does this mean that plants also produce more nectar when they are visited multiple times by the bees?

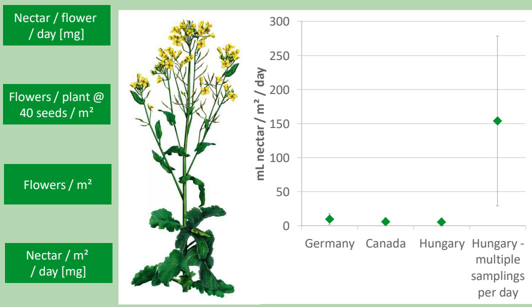
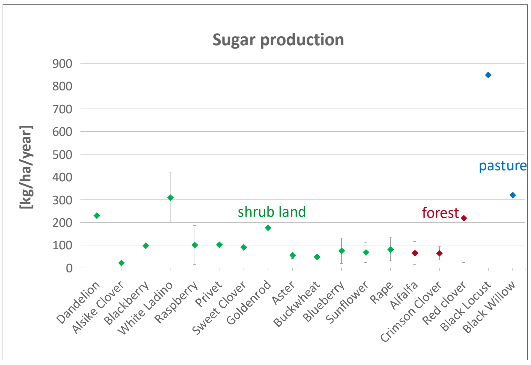


Figure: For oilseed rape, the reported values of nectar per area per day depend on the sampling time and interval.

Information about field studies is often insufficient

- For each of the LULC types, we tried to find the corresponding information on nectar availability (quality and quantity).
- The LULC types can be sorted into categories (see table below).
- Most of the area was covered with Forest and Grassland / Pasture / Hay.
- For the dominant cover, the least information on nectar / sugar production was available from literature (see graph below).

	Average of 12 Study Apiaries		
Land Use Category	1 mile radius	3 mile radius	5 mile radius
Corn	2,50%	3,10%	2,70%
Soybean	3,30%	4,50%	4,40%
Other Crops	0,90%	0,70%	0,60%
Developed, Open Space	6,00%	5,70%	5,30%
Developed, Low-High Intensity	3,00%	2,70%	2,30%
Forest	44,40%	45,70%	47,80%
Grassland/Pasture/Hay	38,80%	36,10%	35,20%
Water/Barren/Shrub/Wetland	1,10%	1,50%	1,60%



BEEHAVE parameterization: simple two-patch scenario

The field study

We are using the results of a field study conducted following EPA guidelines.

1. Location: North Carolina
2. Surrounding: hives were placed in sites that lacked extensive acreages of crops treated with pesticides / that lacked crops in general
3. Winter mortality: out of 24 controls, only 8 survived the winter
4. Duration: May 2014 – April 2015, 9 observation dates
5. Exposure: Supply of artificial nectar diets (sucrose solution) during a 42-day period; exposed to an insecticide

BEEHAVE parametrization

- Initial conditions:
  - Mean initial values are taken from the data of the feeding study
  - All counted adult bees are assumed to be nurses (suggested by the initial number of brood)
- Weather data was included using information on maximum daily temperature (>15°C) and sunshine hours from the location
- **Food:**
  - We parametrized a two-patch scenario: one patch represents the feeder, one patch the background nectar availability.
  - We included a basic variability in background food: available from February – October.
  - Amount of nectar was the most sensitive parameter: nectar sugar concentration and distance to hive were fixed (0.5 % and 2.2 km).
  - We followed two paths for the parametrization:
    A. Find the background nectar availability to match the control mortality
    → Scenario Low food
    A. Find the background food availability to match the control colony dynamics over time
    → Scenario High food

Simulations

- After control parametrization, we simulated the toxicant exposure through artificial nectar using effect parameters from laboratory studies:
  - Acute forager contact LD50: 40 ng / bee
  - Acute forager oral LC50: 2 ng / bee

Results

- When the model matches the winter mortality, the predictions for numbers of adults are much too low.
- When the model matches the numbers of adults, winter mortality is 0%.
- In both scenarios, the predictions for the treatments are over protective

→ **for this case study, the exact definition of the background food availability is irrelevant.**

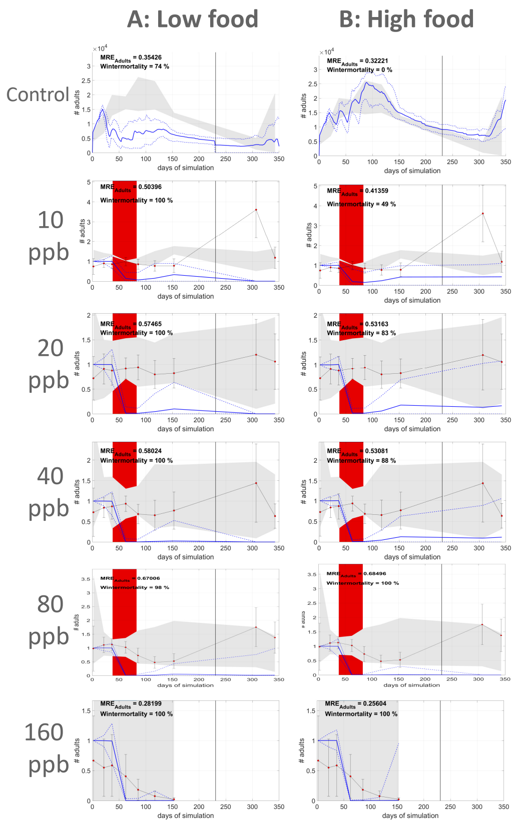


Figure: The starting day of the simulation is the 15th of May; the vertical black line represents the 31st of December. The control graphs show variability of the control data (grey shade), the mean model prediction of 300 runs (solid blue line) and the maximum and minimum simulation (dashed blue line). In the graphs for the treatments, the grey area is the data variability, normalized to the mean of the treatment. The red dots are the data, normalized to the control mean, and the blue line is the mean model simulation, normalized to the control model simulation.
The MRE is the mean relative deviation of the mean model to the mean observation.

Conclusions

- **For this field study, the information on nectar availability was insufficient for a detailed parametrization of the landscape.**
  → **More detailed information on nectar availability is needed so the EFSA requirements for bee modelling can be met. This conclusion is not limited to the BEEHAVE model, but to all bee models.**
- **The simulation studies showed that for this case study, a detailed landscape parametrization is not needed: the predictions for toxicity are nearly identical for the two different background food levels.**

References
Becher, M. A., Grimm, V., Thorbek, P., Horn, J., Kennedy, P. J. and Osborne, J. L. (2014), BEEHAVE: a systems model of honeybee colony dynamics and foraging to explore multifactorial causes of colony failure. J Appl Ecol, 51: 470–482
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EZ1 Title options:
I think we need BEEHAVE and maybe complexity in the title, in case someone is looking for this poster based on the title

1) Evaluating the options for the BEEHAVE landscape module - complexity comes at a price
2) The BEEHAVE landscape module - is complexity the solution?
zie; 25.04.2017

EZ4 How to refer to BEEHAVE ecotox?
zie; 01.05.2017