A review of honeybee models and a short introduction to the new integrated colony model BEEHAVE

Volker Grimm
Presentation based on project: Honeybee population dynamics: integrating the effects of factors within the hive and in the landscape (Rothamsted Research, UK, 2009-2013). Co-funded by BBSRC (88%) and Syngenta (12%)

Matthias Becher*, Pete Kennedy*, Jenny Swain, Judy Pell, Juliet Osborne*: Rothamsted Research, UK
  *Current address: University of Exeter

Dave Chandler, Sally Hilton: University of Warwick

Pernille Thorbek: Syngenta

Volker Grimm: UFZ
Grimm V, Becher MA, Kennedy PJ, Thorbek P, Osborne J. 
Ecological modeling for pesticide risk assessment of honeybees and other pollinators. In: Fischer D, Moriarty T. 

Becher MA, Thorbek P, Kennedy PJ, Osborne J, Grimm V. 
Towards a systems approach for understanding honeybee decline: a stock-taking and synthesis of existing models. 

Becher MA, Thorbek P, Kennedy PJ, Grimm V, Osborne J. 
<BEEHAVE: an integrated model of honeybees dynamics>. To be submitted to Journal of Applied Ecology (within next 4 weeks)
Three categories of models:

1. Within-hive colony dynamics (8)
2. Varroa mite population dynamics within hives (11)
3. Foraging (12)
1. Within-hive colony dynamics

Most important models:

- BEEPOP (deGrandi-Hoffmann et al. 1989): beekeeping management
- HoPoMo (Schmickl and Crailsheim 2007): science (drivers, feedbacks)
- Khoury et al. (2011): Impact of forager mortality on colony development
2. Varroa mite population dynamics

Most important models:
- Martin (1998): understand varroa effects on honeybees, beekeeping management
3. Foraging

Most important models: hard to tell

- Most models use "energetic efficiency" as basis for foraging decisions
- None of the models linked to colony dynamics, explicit landscape structure and dynamics, or pollen collection
## Representation of stressors

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Conclusions from review

- Model **testing, validation, and analysis** of most models was very limited
  - No clear separation of **imposed** and **emergent** dynamics
  - No clear indication of how much **calibration** was involved
  - Limited or no **sensitivity analysis**
- For foraging models, a **benchmark** test exist: the Seeley et al. (1991) feeder experiment
Conclusions from review

- **Well-tested building blocks** exist in existing models.
- A model that would allow **integrating stressors** within and outside the hive does not yet exist.
- Colony structure and important **feedback loops** need to be included (e.g., "age of first foraging").
- **Egg-laying rate, weather, colony structure, and availability of nectar and pollen** should drive the dynamics.
BEEHAVE: developed by Matthias Becher
Colony module (in-hive, daily time steps):
- Similar to BEEPOP
- Feedbacks: brood care, amount of honey and pollen
- Consumption of nectar and pollen

Varroa module (daily time steps):
- Similar to Martin (2001)
- Transmits either deformed wing or acute paralysis virus

Foraging module (minutes):
- Driven by energetic efficiency
- Can be linked to heterogeneous and dynamics landscape
- Includes pollen collection
Automated calculation of:
- number of patches
- distance to apiary
- area of patch
- chance to find the patch
- crop type (colour)
Implemented in **NetLogo** (free software platform)

Documented in **ODD** format (ca. 40 pages)

User **manual** and **guided tour** exist (ca. 60 pages)

Extensive **testing** (debug code, consistency tests, visual output)

**Validation:**
- Age of first foraging, lifespan
- Number of reproductive cycles of varroa in a year
- Seeley's feeder experiment
Colony Module

- Structure of in-hive cohorts & drones

Foraging Module

- Feeders & flower patches
  - Quantity of nectar/pollen
  - Distance to colony

Varroa Module

- Healthy & infected mites

Beekeeping

- Honey harvest
- Feeding
- Varroa treatment

Further Input Fields

- Flower patches
- Colony stores
- Egg-laying

Run Buttons & Output-Plots
1st Example Scenario

NO VARROA

N initial bees: 10000

2 patches:

- Distance: 1500 m 500 m
- Nectar concentration: 1.5 mol/l 1.5 mol/l
- Pollen (max): 1 kg/day 1 kg/day

Nectar flow:

Daily foraging period based on real weather:
1st Example Scenario

N adult workers (10 colonies) - no varroa – flower patches at 500 & 1500 m

10 surviving colonies
2nd Example Scenario

N adult workers (10 colonies) - with varroa and DWV
– flower patches at 500 & 1500 m

5 surviving colonies
3rd Example Scenario

N adult workers (10 colonies) - with varroa and DWV
– flower patches at 250 & 1500 m

8 surviving colonies
3rd Example Scenario

N adult workers (10 colonies) - with varroa and DWV – close flower patch: 250, 500 & 1000m

First combination of foraging AND Varroa model:
Improved food availability can compensate loss of diseased bees
No varroa – nectar feeder at 1000 m - sugar concentration 1.0/1.5 mol/l – double mortality per foraging trip for 30 days (equivalent to increase in forager mortality from ca. 15 to 30%) (similar to Khoury/Henry scenario)
BEEHAVE: to do list

Get it published as soon as possible

- Designed so that others can test and use it
- Offer training courses, workshops

2 PhD students currently working on

- Multiple stressors, landscape structure and dynamics (Juliane Horn, UFZ)
- Specific pesticide module (Jack Rumkee, Univ. Exeter/Syngenta)

From one to many colonies
Summary

• Three types of models (within-hive, varroa, foraging)
• Well-tested modules exist, but no integrated model
• BEEHAVE: first attempt to link within-hive dynamics to foraging in heterogeneous and dynamic landscape
• BEEHAVE (or refinements) would be suitable for regulatory risk assessment
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Steve Martin
Peter Neumann
Thomas Schmickl
Foragers:

- Foraging
- Resting
- Searching
- Collect nectar/pollen
- Dancing
- Unloading
- Leaving hive?
- Experienced?
- Good patch?
- Dying?
- Found a patch?
- Abandon patch? Stop foraging?

# repetitions depending on weather conditions