Agent-based model of foraging beehaviour

UvA CLS ABM 2024 - **Group 5**
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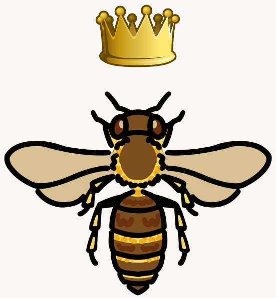
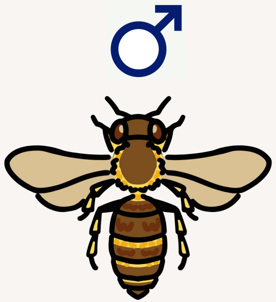
1. Introduction



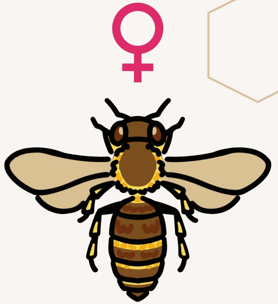
Queen

- 1 queen bee
- Lay eggs, mostly



Drone

- 10%-15% of population
- Pass their genes (and that's it)



Worker

- 80%-90% of population
- Can't mate, but do **everything** else
- Care about brood
- Guard the nest
- **Forage for resources**

Eusociality: division of labour into reproductive and non-reproductive groups

Polyethism: functional specialization of non-reproductive individuals

Goal & motivation

Polyethism

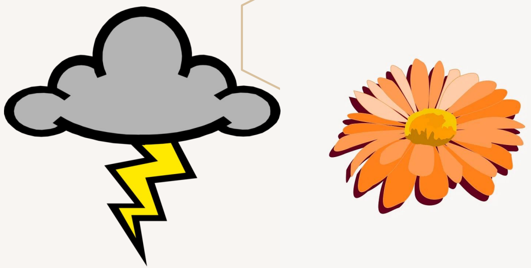
- correlated with age (young bees stay in nest, old bees forage)
- adaptive based on colonies needs
- in this work: changing **weather conditions** and varying **resource sparsity**

Interactions:

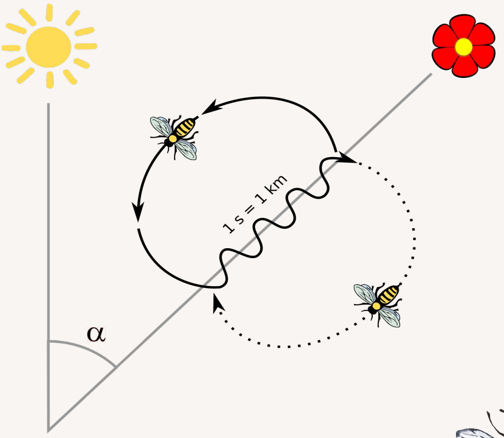
- bees are attracted to flowers from which they gather nectar
- pheromonal exchange, antennae touching
- **waggle dance**

Why ABM?

- applied to other eusocial species (ants, meerkats)
- bees don’t have global information
- emergence of complex behaviour (colony task adaptation) arises from local interactions



Key factors in our work: **weather** and **resource density**



Waggle dance

1.

2. Model & Approach

Literature review

Drawbacks

- complexity
- focus
- implementation

Theory

1. **Beck et. Al**: *The effect of forager loss on honeybee workers temporal polyethism and social network structure* (2023)
2. **J. Devillers**: *In silico bees* (CRC press, 2014)
3. **B. Johnson**: *Division of labor in honeybees: form, function, and proximate mechanisms* (2010)
4. **T. Seele**: *The Wisdom of the Hive: the social physiology of honey bee colonies* (Harvard University Press, (2009)
5. **N. Calderone**: *Proximate mechanisms of age polyethism in the honey bee, Apis mellifera L* (1998)

Models

1. **BeeKeeper**: *PhD model* (2021)
2. **Toward a Complete Agent-Based Model of a Honeybee Colony** (2018)
3. **Bee++**: *An Object-Oriented, Agent-Based Simulator for Honey Bee Colonies* (2017)
4. **BEEHAVE**: *a systems model of honeybee colony dynamics and foraging to explore multifactorial causes of colony failure* (2014)
5. **HoPoMo**: *A model of honeybee intracolonial population dynamics and resource management* (2007)

Own model

Forager Bees

- Sensitive to weather events
- **Field of vision**,
- Current task
- Speed
- ...

Beehive

- Position
- Radius
- Nectar
- No. of young bees

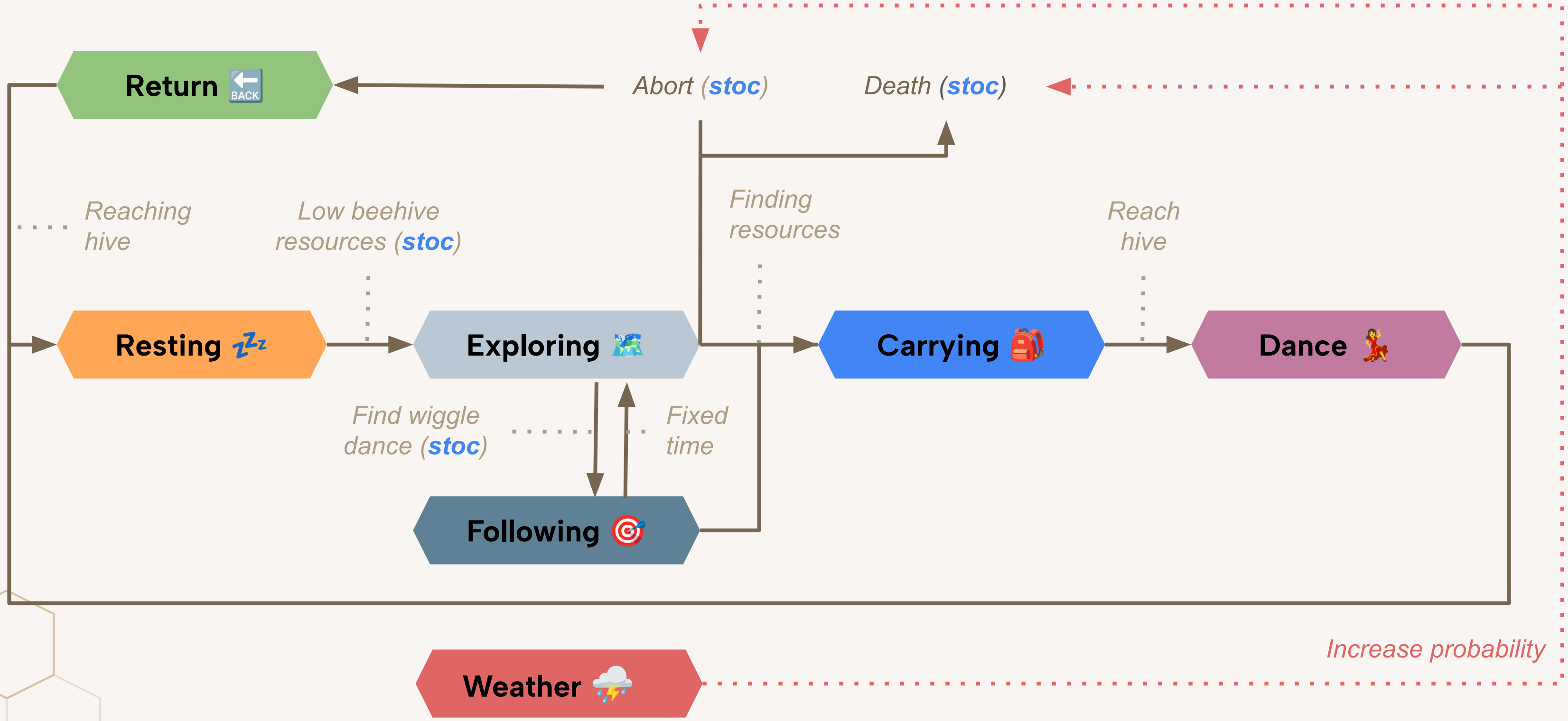
Key aspects

- Continuous space
- Metropolis algorithm *(novel)*
- Weather events

Resources

- Position
- Quantity
- Radius
- Persistence

Bee state evolution and weather impact



3. Experiments

Experiments

Baseline Assessment

1. Weather conditions

Storm rate impact on bees & bee task distribution.

2. Resource density

Resource density impact on bee task distribution.

Weather conditions

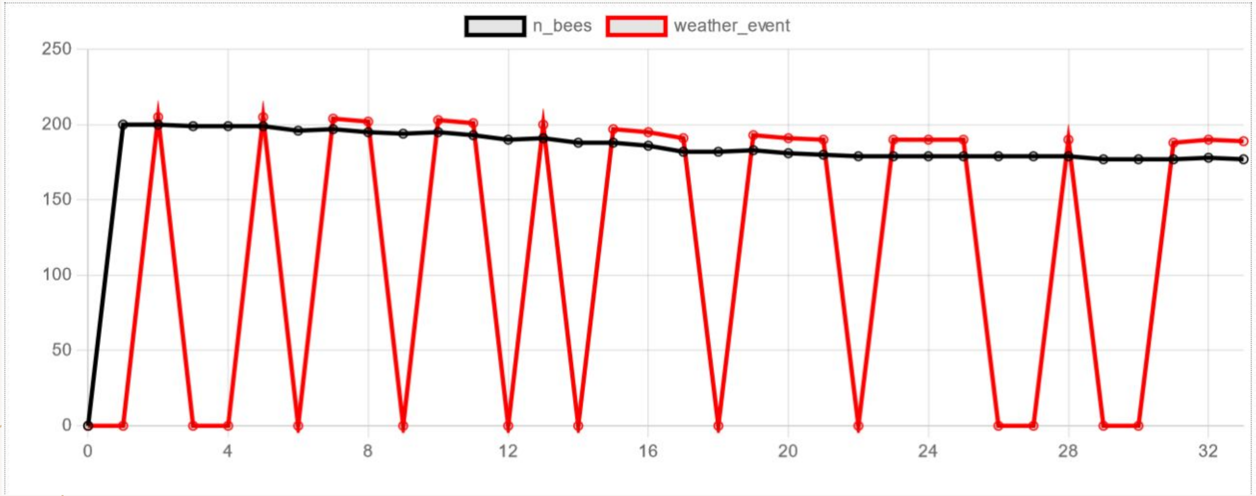
Description

Storm rate impact on bees & bee task distribution.

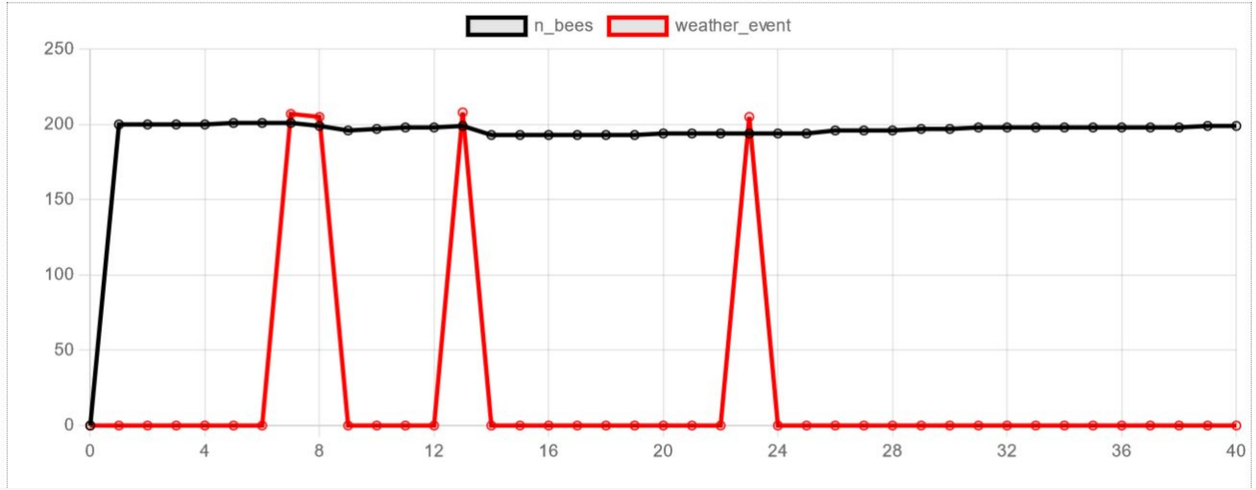
Storms
- Storm probability
- Storm duration

Hypothesis

As weather event kills off bees that are outside the hive, we expect the states of bees to change in order to adapt to the storm.



⬆️ Probability
⬆️ Duration



⬇️ Probability
⬇️ Duration

Resource density

Description

Resource density impact on task distribution.

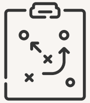
Resources
- Spread
- Quantity

Hypothesis

Bees will dynamically shift their roles in order to optimize resource collection and hive maintenance

Dense

Sparse

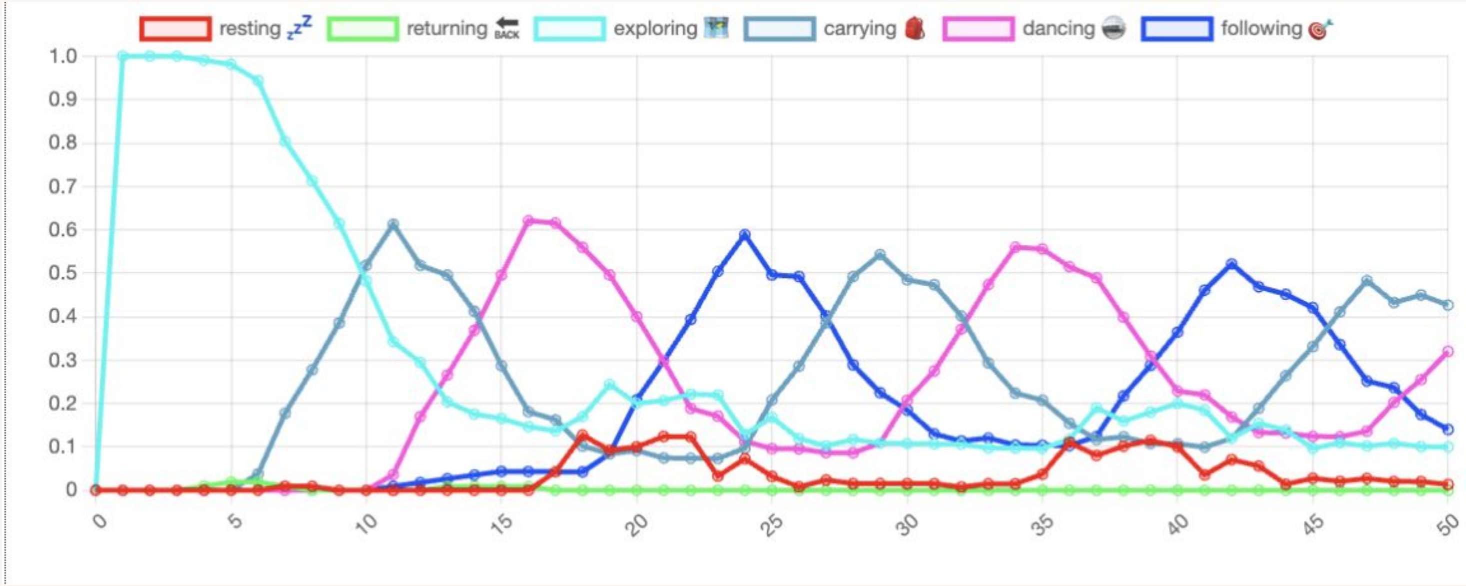


4. Results


resting
returning
exploring
carrying
dancing
following

1. Baseline & Parameter validation

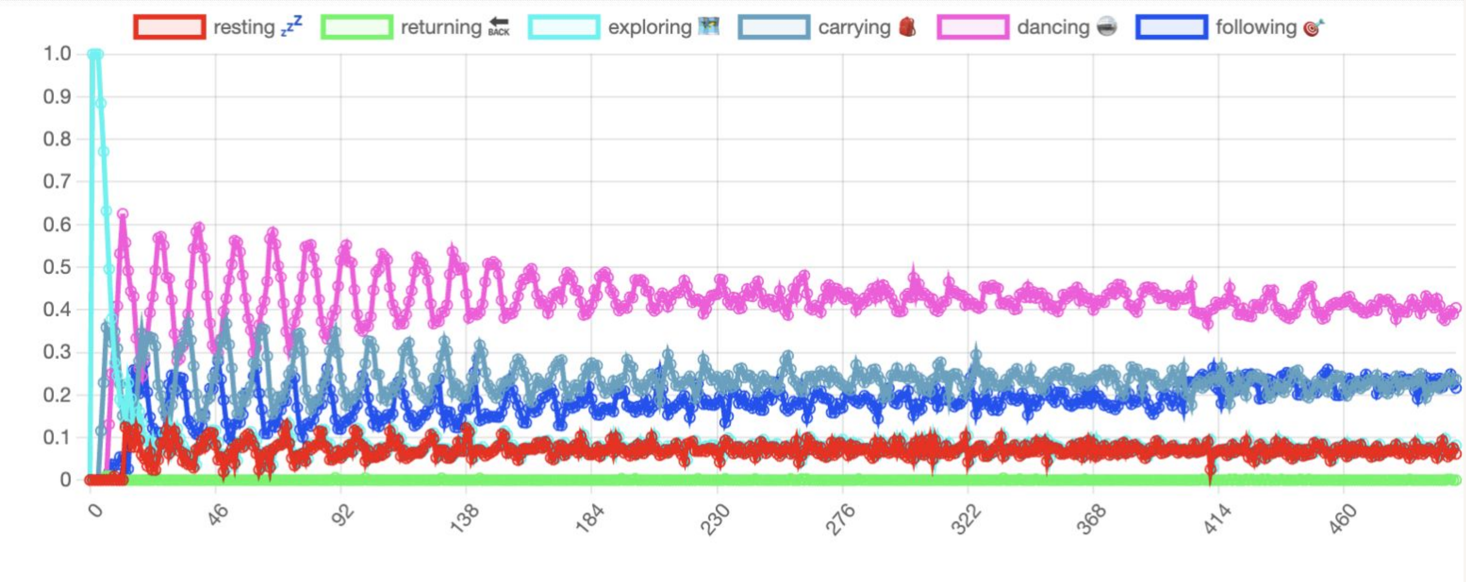
Bee State proportions through time during simulation



We find: Baseline with reasonable colony-level oscillatory behavior from individual rules

1. Baseline & Parameter validation

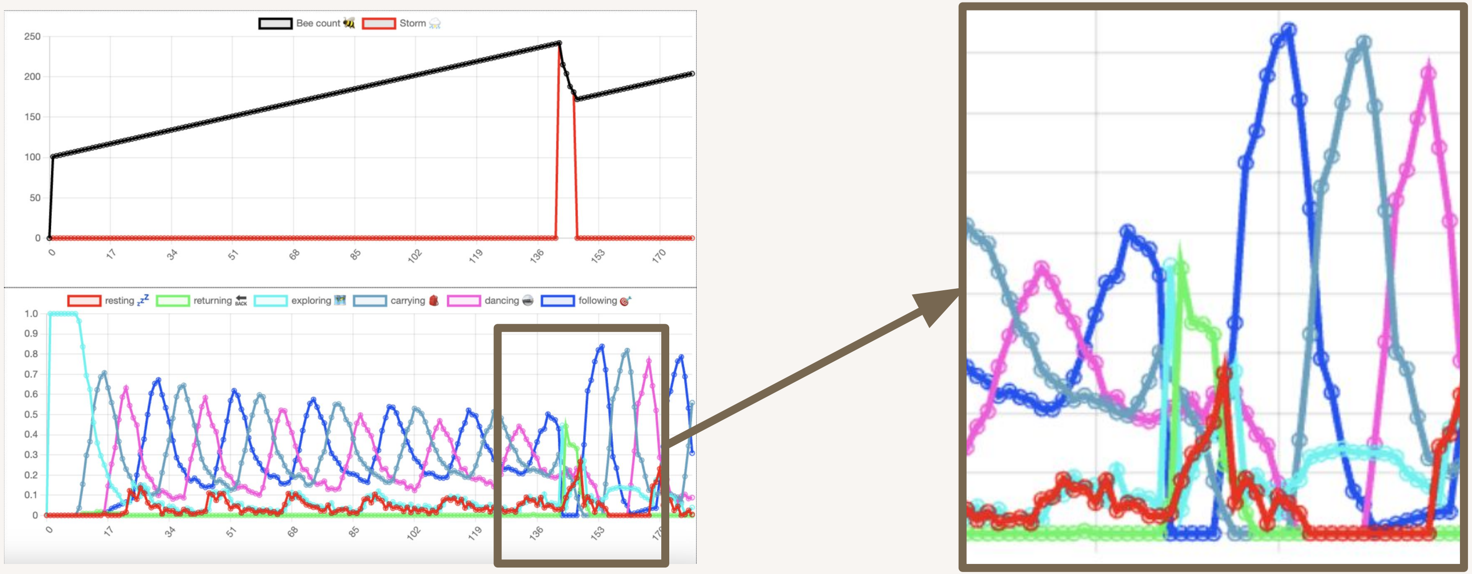
Bee State proportions through time during simulation (extended)



We find: Oscillations converge due to stochasticity

2. Introduction of storm events

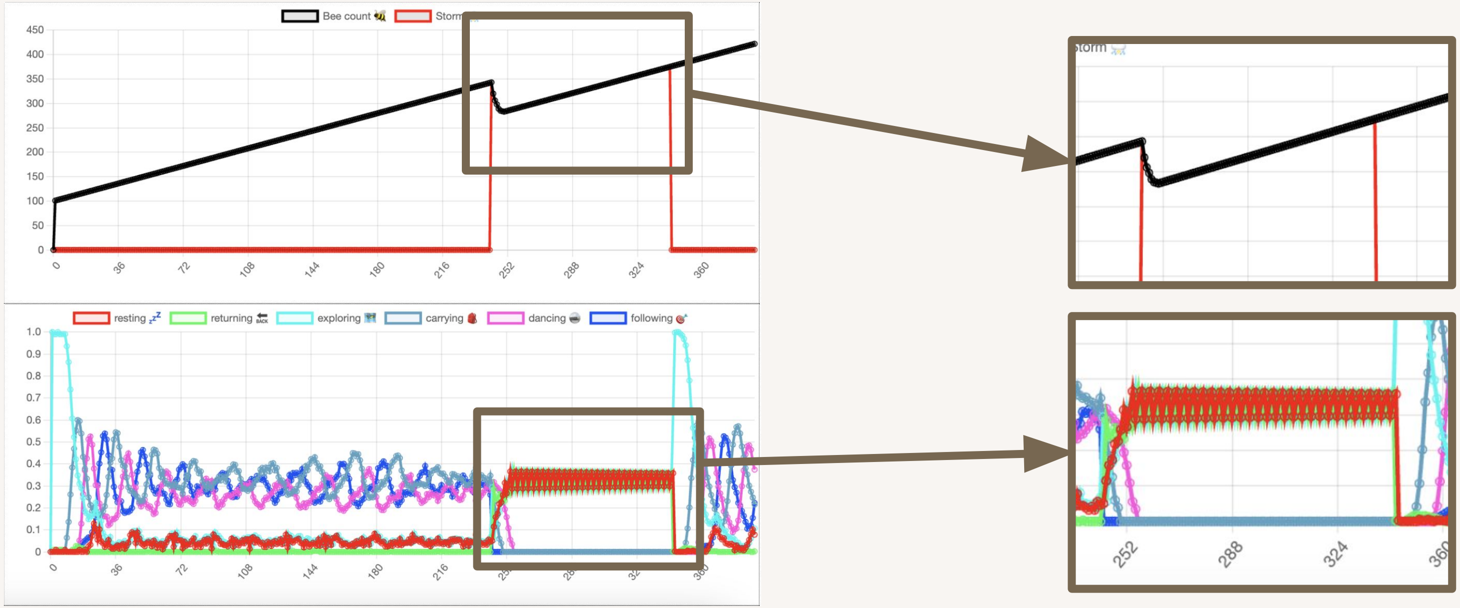
Bee population and state proportions through time



We find: Storm events reset population oscillation dynamics due to survival strategy of individual bees

2. Introduction of storm events

Bee population and state proportions through time



We find: Storm events reset population oscillation dynamics due to survival strategy of individual bees

5. Conclusions

& Future Works

Thank you! Questions?

Bee parameters

```
FIELD_OF_VIEW = 20                 # 20 (in m) TODO: calibrate further using real data
STARVATION_SPEED = 1/(60*60*24)    # within 1 day (in rate/s)
MAX_AGE = (60*60*24*7*6)           # within 6 weeks (in s)
P_DEATH_BY_STORM = 1/(60*60)       # on average within 1 hour (probability) TODO: calibrate further
SPEED = 5                          # 5 (in m/s)
PERCEIVE_AS_LOW_FOOD = 2           # 2 (in kg) TODO: calibrate further
DANCING_TIME = 60                  # 1 minute (in s) TODO: calibrate further
P_FOLLOW_WIGGLE_DANCE = 1          # 100% (probability) TODO: calibrate further
P_ABORT_EXPLORING = 1/(60*60)      # on average within 1 hour (probability) TODO: calibrate further
P_ABORT_FOLLOWING = 1/(60*60)      # on average within 1 hour (probability) TODO: calibrate further
STORM_ABORT_FACTOR = 10            # 10 times more likely to abort during storm TODO: calibrate further
CARRYING_CAPACITY = 0.001          # 1g (in kg) TODO: calibrate further
GATHERING_RATE = 0.0001            # 0.1g/s (kg/s) TODO: calibrate further
```