Symmetry breaking in collective honeybee foraging: *A simulation study*

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Introduction

Symmetry breaking is the phenomenon that the numbers of foragers exploiting two equally profitable food sources will diverge. This phenomenon has been investigated in ants [1,4,5], but hardly in honeybees. It is even not clear whether in honeybees symmetry breaking can occur [3, p.190]. We present results of an individual-oriented simulation model showing that under specific circumstances symmetry breaking in the numbers of honeybee workers exploiting two or four identical nectar sources can occur. We studied factors that influence the occurrence of symmetry breaking, which include: size of the forager pool, number of bees initially exploiting the sources, and size of the flower patch. This study is part of an ongoing study which aims at developing an individual-oriented simulation model capturing the necessary and sufficient behavioural rules to generate the collective foraging patterns observed in bees [for details see 2,6,7].

Asymmetry decreases with scouting probability

Emergence of asymmetry through the haphazard occurrence of differences in detection times of food sources. These differences result in a different recruitment rate for each of the four sources.

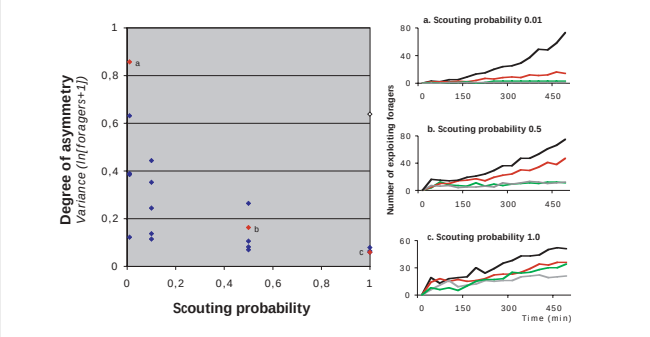

Fig. 1 **Degree of asymmetry for four different scouting probabilities. For each probability five runs have been made, each with a different seed for the random number generator. All runs were made with a forager pool of 200 bees, a patch size of 40 for all sources and with no experienced bees exploiting the sources.**
At the right: three example results of forager patterns, showing along the vertical axis the number of different foragers visiting each of the four sources during each half hour. Set-up: four identical sources at 400 m from the hive

Asymmetry decreases with number of initial exploiters

Emergence of symmetry breaking happens through the haphazard occurrence of differences in inspection times, which results in a different recruitment rate for each of the four sources.
Stability of asymmetry: After an initial sharp increase, the net rate of recruitment for each source decreases due to the diminishing pool of potential recruits and becomes zero when all bees are employed foragers. Therefore, with a limited pool of worker bees the initial divergence will stabilise.

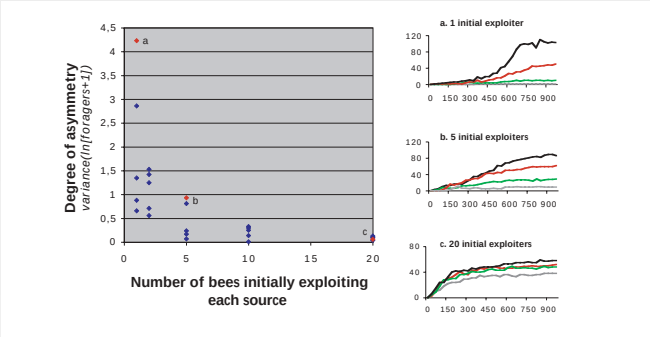

Fig. 2 **Degree of asymmetry for five different starting conditions: The number of bees initially exploiting each source is set to 1, 2, 5, 10 or 20. For each setting five runs have been made, each with a different seed for the random number generator. All runs were made with a forager pool of 200 bees, a patch size of 40 for all sources and with scouting probability set to zero. Set-up: four identical sources at 400 m from the hive.**

Asymmetry depends on patch size and potential forager pool

Emergence of symmetry breaking happens through the haphazard occurrence of differences in numbers of dance followers and subsequent success in finding the advertised source by these recruits. This results in diverging rates of the positive feedback recruitment processes.
With small-sized patches a stable symmetric distribution of foragers arises, due to the negative feedback through interference at the food sources. When food patches are large the foragers do not experience interference and chance may give the work force of one source a recruitment boost: an asymmetric distribution arises.
Stability of asymmetry: see above.

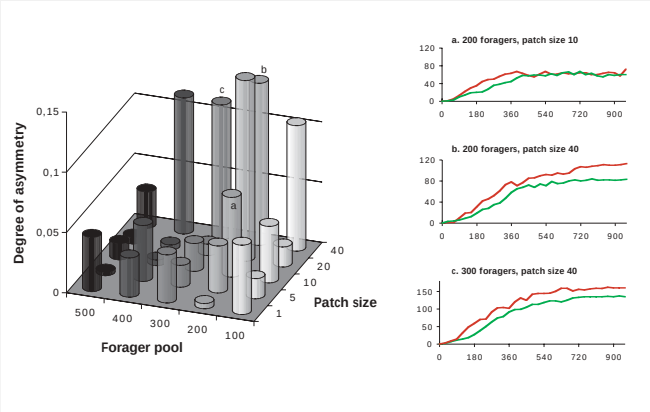

Fig. 3 **Degree of asymmetry for 25 different parameter settings. Forager pool varies from 100 to 500, patch size varies from 1 to 40. For each setting one run has been made. Set-up: two identical sources at 400 m from the hive**

Conclusions

1. **Symmetry breaking in collectively foraging honey bees can arise through self-organisation.**
2. **Emergence of symmetry breaking depends on: size of the forager pool, the scouting probability, the number of bees initially exploiting the sources, the size of the flower patches**
3. **These predictions will be empirically tested by the second author.**

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