Honeybees show tipping points

May 16 2014, by Denis Paiste

Bees cluster on the hand of Bernardo Niño, senior research technologist in Grozinger Lab at Penn State. Credit: Bernardo Niño.

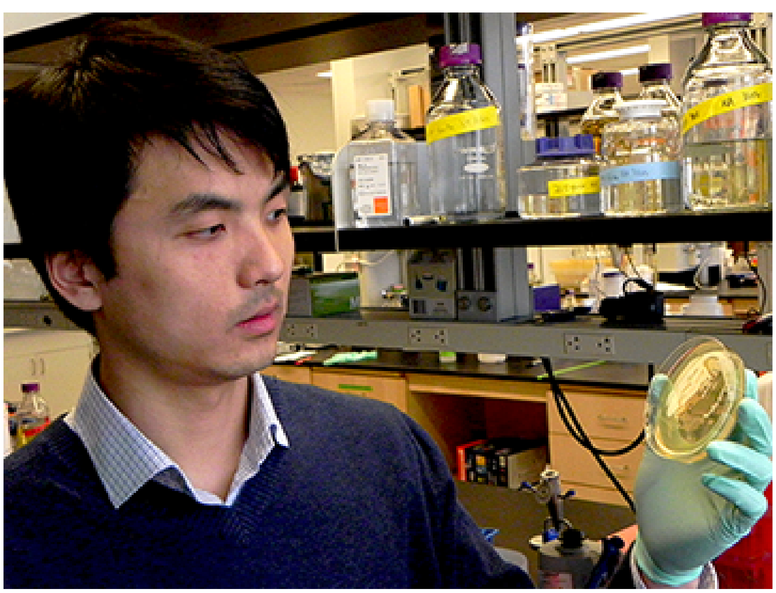
Parasites, lack of food, cold snaps, pesticides, and poor management all can stress honeybee colonies, making it difficult to pin their collapse on a single source. However, in controlled field tests, honeybee colonies show evidence of Allee effects (a positive correlation between population size and individual fitness) and tipping points that are early warning indicators of collapse, MIT physics graduate student Lei Dai says.

"We are seeing a global decline of honeybees and this is a serious problem because they are important for pollination of plants and crops, so people are trying to understand the dynamics of honeybee colonies," Dai says.

Dai's work with the Gore Lab at MIT established early warning signals for population collapse in the yeast, Saccharomyces cerevisiae. Dai was the lead author on two papers establishing the theoretical and experimental findings.

In an isolated living system like the yeast colony, Dai and colleagues found that when the population got small enough it reached a tipping point where it could not survive. "What we named as the tipping point is the threshold condition when the population would definitely go extinct," Dai says. It is accompanied by a phenomenon called critical slowing down, which increases both the time and space needed for recovery.

"We see that fluctuations become bigger and more correlated before the populations go extinct which, we think, is a pretty generic phenomenon before biological transitions," Dai says.



Lei Dai studies cooperative populations including bees and yeast. Credit: Denis Paiste, Materials Processing Center

Dai's honeybee research is in collaboration with Christina Grozinger, a professor of entomology and director of the Center for Pollinator Research at Pennsylvania State University, and her beekeeping technician, Bernardo Niño. Field studies took place from spring through fall 2013, and the researchers are working on a paper to report their results. Dai helped to design the experiment.

The key similarity between the bees and the yeast is that they are cooperative populations. Yeast convert sucrose to other sugars they can more readily consume and share the bulk of their production with other yeast; bee colonies are dependent on adult bees to forage for food and return to the hive to share it with the immature and worker bees that stay inside the hive. For bees, researchers draw a distinction between the colony, which means the social grouping, and the hive, which means the colony inside its box.

The yeast carry an enzyme that produces good sugars for them, and they share most of the goods with other yeast cells. "This cooperation leads to what we call bistability in the population, so when the environment is good, they can always grow up, they can survive. But when the environment is bad, then they could have two scenarios, survival or extinction," Dai explains.

In nature, an organism may thrive at an intermediate population size but fail when that population grows too small. This phenomenon is called a strong Allee effect and can be triggered by different biological mechanisms in different populations. "In the honeybees, it's basically the adult bees having a positive influence on the brood," Dai says.

Positive interactions between the members of the population lead to these threshold effects such as Allee effects or bistability, explains Jeff Gore, the Latham Family Career Development Assistant Professor of Physics at MIT. "When a population has these positive interactions, these positive feedback loops, then it can display these sudden transitions, these tipping points leading to collapse."

Honeybee hives under study. Credit: Bernardo Niño.

Researchers measure the effect of shocks to a population, which are called perturbations, such as reducing food availability. Resilience is a measure of how successfully a population can bounce back to a steady state from the shock.

In the field studies, researchers stressed the honeybee colony by limiting the available food. "We had evidence that there is this critical threshold for survival and also increasing the stress, we observed that honeybees became less resilient," Dai says.

"We proposed a very simple mathematical model together with the field data people collected at Penn State, and we observed that indeed that there is an Allee effect in honeybee dynamics. If you only have very few bees to start with, then the colony is going to collapse. Otherwise the colony is doing fine; they will survive. They will grow up over summer and survive the winter, like a yearly cycle," Dai says.

Dai, 27, is a fifth year graduate student, and he expects to finish his thesis by the end of this summer and get his PhD in the fall. He will go on to an appointment as a postdoc associate at the University of California at Los Angeles, with a joint appointment under James Lloyd Smith, an associate professor of ecology and evolutionary biology, and Ren Sun, a professor of molecular and medical pharmacology. Sun studies RNA viruses such as influenza and hepatitis C. "It's a direction that I would like to pursue in my post-doc, which is the ecology and evolution of infectious diseases, and in particular, I would like to study the evolution of RNA viruses," Dai says. "Given the rapid advances of sequencing technologies, there is a lot of data coming out in that area, so I think it would be exciting to combine theory with the data.

More information: 1. "Slower recovery in space before collapse of connected populations. "Lei Dai, et al. *Nature* 496, 355–358 (18 April 2013) DOI: 10.1038/nature12071 . Received 04 November 2012 Accepted 15 March 2013 Published online 10 April 2013

2. The paper "Generic Indicators for Loss of Resilience Before a Tipping Point Leading to Population Collapse" is available online: www.gorelab.org/Science-2012-Dai-1175-7.pdf

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