Unpacking chaos to protect coffee: Study untangles the ecological dynamics of ants in Puerto Rico

August 11 2025

Ivette Perfecto, University of Michigan professor in the School for Environment and Sustainability, points to a nest of Solenopsis invicta, a species of ant that lives on a coffee farm in Puerto Rico. Credit: University of Michigan

To help manage agricultural practices with fewer or no pesticides, University of Michigan researchers say they need to understand how ecological systems work on agricultural lands.

Now, U-M researchers John Vandermeer and Ivette Perfecto have used two ecological theories to describe a tangle of interactions between three ant species and a recently introduced fly that preys on one of the ant species.

Their work on a coffee farm in Puerto Rico shows that the interaction between the ants and the predator fly creates chaotic patterns—chaos in the classical sense, in that natural populations are subjected to fluctuations depending on the interactions of organisms within a system.

These chaotic patterns mean that any one of the four insect species could be dominant at any point in time. Understanding which ants may be dominant over time may help farmers use the ants to manage pests on their farms. Their study is published in the *Proceedings of the National Academy of Sciences*.

"Two of the three ant species we studied are really important agents of biological control of two of the important pests in coffee," said Vandermeer, U-M professor of ecology and evolutionary biology.

"We would like, or a farmer would like, to be able to predict when the ants are going to be there, and when they're not going to be there. And it turns out that that kind of prediction is going to be pretty difficult."

For three decades, Vandermeer and Perfecto, a professor at the U-M School for Environment and Sustainability, have been studying ant interactions in the coffee farm's agricultural setting. Their goal is to help transform how agriculture is done—but to do so, we need to first understand the ecology of agricultural systems, they say.

"We believe that the current international agricultural system with its use of pesticides and chemicals is not contributing to the welfare of anybody, especially the farmers, and is actually contributing quite a bit to global climate change," Vandermeer said.

"We take the position that in order to incorporate the rules of ecology into the development of new forms of agriculture, we need to understand what those rules are and how those rules work."

In the tropics, ants are dominant, Vandermeer says, and often involved in agriculture as agents of controlling pests. But using an ant species to control pests can be complicated: the dominance of the ant being used as a biological control depends on what other species of ants—as well as other types of insects—there are in the system.

In this system, Vandermeer and Perfecto examined two types of ecological behavior: intransitive loop cyclic behavior and predator-mediated coexistence. Intransitive loop cyclic behavior means that if there's a group of three ant species, Ant A might be dominant over Ant B, Ant B might dominate Ant C, but Ant C could dominate Ant A.

When a predator is thrown into the mix, these dynamics become even more complicated. Among the three species of ants that Vandermeer and Perfecto study, one species is dominant. But the recently introduced fly preys upon the dominant ant.

This predator-prey relationship not only affects the dominant ant, it has downstream effects on the other two ant species, allowing any of the four species to become the dominant species at different points of time. This is an example of predator-mediated coexistence.

The waxing and waning of the predator fly and its ant target, as well as the change of dominance in the ant species, are called oscillations. By overlapping and modeling these two oscillating ecological principles, the researchers could examine how the principles introduce chaos into the system.

The results are ... chaotic. But by plotting both of these oscillating behaviors, the researchers were able to see that at certain times, the whole system looked like a predator-prey cycle, and at other times, the system looked like an intransitive loop oscillation.

This could mean—in theory—the researchers could get a window into when each insect species was going to be the dominant species.

"The good news is that the chaotic patterns of the insects are really very interesting from an inherent intellectual sense. The bad news is that it's not really as simple as it might seem to base agricultural practices on ecological principles, because the ecological principles themselves are way more complicated than simply finding a poison that kills the pests," Vandermeer said.

"What we're uncovering, we think, over the past 30 years or so are some of those complications that come out if you're serious about putting ecology into the fundamental operations of the agricultural system."

More information: Perfecto, Ivette, Keystone predator and keystone intransitivity and the rescue of a competitively subdominant species, *Proceedings of the National Academy of Sciences* (2025). DOI: 10.1073/pnas.2421005122. doi.org/10.1073/pnas.2421005122

Provided by University of Michigan

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