Ants and Avalanches: Insects on Coffee Plants Follow Widespread Natural Tendency

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This photo shows an Azteca ant tending green coffee scale. Credit: Ivette Perfecto

Ever since a forward-thinking trio of physicists identified the phenomenon known as self-organized criticality---a mechanism by which complexity arises in nature---scientists have been applying its concepts to everything from economics to avalanches.

Now, researchers at the University of Michigan and the University of Toledo have shown that clusters of ant nests on a coffee farm in Mexico also adhere to the model. Their work, which has implications for controlling coffee pests, appears in the Jan. 24 issue of the journal *Nature*.

The basic idea of self-organized criticality often is illustrated with a sand pile. As you trickle sand onto the cone-shaped pile, the cone grows and grows until it reaches a "state of criticality" where it stops growing. Add more sand, and the grains just slide down the sides in mini-avalanches.

"What physicists have done---both mathematically and physically---is look at how many grains of sand actually fall with each avalanche," said John Vandermeer, the Margaret Davis Collegiate Professor of Ecology and Evolutionary Biology and one of the *Nature* paper's authors. "What they find is that most avalanches involve one or two sand grains, and relatively few avalanches involve hundreds of sand grains." Such a pattern---with small versions of a phenomenon being more common than big ones---characterizes what's known as a power law, a sort of fingerprint of systems that exhibit self-organized criticality.

What do avalanches have to do with ants" Vandermeer and co-author Ivette Perfecto, a professor at the U-M School of Natural Resources and Environment, have been studying ants and other associated insects in a 45-hectare (111-acre) plot on an organic coffee farm in southwestern Mexico for three years and wondered whether the spatial distribution patterns they observed could be explained through the concept of criticality. With Stacy Philpott, then a U-M graduate student and now an assistant professor of ecology at the University of Toledo, they set out to examine the system in detail.

The ants, Azteca instabilis, have a natural history like that of many other ants. A queen establishes a colony in a tree, and once the colony reaches a certain size it splits and a satellite nest is established in a neighboring tree. Over time, you'd expect the ants to spread to every tree on the farm, but that's not the case.

"The ants only occupy about three percent of the trees," Vandermeer said. "But once you find them, you find them in clumps."

How to explain the clumpiness?

"Normally when you have an animal or plant that's distributed in patches like that, you tend to think that there's some kind of underlying habitat variable that's responsible," Vandermeer said. But on the coffee farm, the habitat is about as uniform as a habitat can be, as trees are deliberately planted in a grid pattern. So the non-uniform distribution of ant colonies must be due to something other than habitat---something inherent in the biology of the ants.

Combining computer modeling with field observations, the researchers came up with a scenario that explains the spatial patterns as a case of criticality.

As the ant colonies spread from tree to tree, local clusters develop, but the clusters don't expand indefinitely, all because of another insect with a sinister name: the decapitating fly. The parasitic fly lays its egg on the thorax of an ant; the egg hatches and the fly larva migrates into the ant's head capsule where it feasts on the contents. Then the ant's head falls off and the new adult fly emerges. Unfortunately for the ants, the bigger their clusters, the easier it is for the flies to find their colonies.

"So it's the fly that maintains the ants' spatial distribution," Perfecto said. Looking at the frequencies of various sizes of clumps, the researchers found the telltale power law relationship, the hallmark of criticality.

Their understanding of the system has implications for controlling coffee pests, such as green coffee scale (Coccus viridis), a flat, featureless insect that lives on coffee bushes. On some bushes, Azteca ants protect the scale insects from predators and parasites and in return collect honeydew, a sweet, sticky liquid the scale secretes.

One of the green coffee scale's mortal enemies is a beetle whose adult and larval forms both feed on it. "When an adult beetle comes to eat the scale insects, the ants vigorously defend the scales against attack," Vandermeer said. "So within these clusters, the beetle can't eat its prey." The adult beetle, that is. The larval beetles evade the ants with waxy secretions on their backs that gum up the ants' mouthparts.

Not only are beetle larvae able to polish off plenty of green coffee scale, they also get an inadvertent assist from the ants. In the course of shooing off parasitic wasps that attack scale, the ants also scare away bugs that parasitize beetle larvae.

"So we have a situation where the beetle is the main predator of the scale insects, which are pests on the coffee, and that beetle would go extinct if not for the patchy distribution of ants, because the larvae can only survive with the ants, and the adults can only survive without them," Vandermeer said. "The farmers see the ants protecting the scale insects and want to eliminate them. But what we've discovered is that the ant, by forming these clusters, is a key component to maintaining the main scale insect predator in the system."

Source: University of Michigan

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