Helpful interactions can keep societies stable

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Mutualistic interactions abound in nature, yet classical ecology models predicted they shouldn't. With a new approach, biologists from Penn clarify what the old predictions missed. Credit: Erol Akçay

For half a century, scientists who have developed models of how ecological communities function have arrived at an unsettling conclusion. Their models' predictions—seen as classic tenets of community ecology—suggested that mutualistic interactions between species, such as the relationship between plants and pollinators, would lead to unstable ecosystems.

"In one of these classic theories," says Erol Akçay, an assistant professor of biology at Penn, "it says that if you have a lot of these mutualistic interactions, where if you increase the abundance of one species it will lead to an increase in the other, things tend to go out of equilibrium."

In a paper published this week in *Nature Ecology and Evolution*, Akçay and Jimmy Qian, a 2019 Penn graduate who worked in Akçay's lab when he was a student, challenge those assumptions. Their work shows that mutualism is compatible with stable communities and that the balance of mutualism with other types of interactions, including competitive and exploitative, plays determinative roles in the makeup, size, and stability of those communities.

"We argue that mutualisms are not inherently destabilizing," says Qian, now a medical student at Stanford University. "It's all about the balance of how much mutualism there is and how unique those mutualistic benefits are."

As an undergraduate, Qian worked with Akçay for more than two years on projects related to health and medicine. The current project emerged from initial attempts to model the community dynamics of a human microbiome.

"As we started reading the literature and building models, we realized there were questions in microbiome ecology that were generalizable to community ecology as a whole, which is where this paper ended up," says Qian.

Specifically, the researchers started looking more closely at the seminal work of Robert May, a renowned ecologist and physicist who argued that larger, more complex communities tend to be less stable. Stability in these models is a measurement of how likely a system is to return to an equilibrium if nudged away from it. For example, a stable community could withstand a disease reducing numbers of one of its species and come out the other side of the infection with its same species composition intact.

In earlier studies, scientists showed that mutualistic interactions had destabilizing effects on communities and thus must only play a small role in ecosystems, alongside interactions that are either competitive or exploitative, like a predator-prey dynamic.

Yet one needn't look further than a coral reef or rainforest to see that the world is full of complex ecosystems. And from plant-pollinator interactions to human-microbiome relationships, mutualistic interactions also abound. So Akçay and Qian decided to dig deeper to see what these earlier models may have missed when it came to mutualism and ecosystem stability.

One thing they noticed was that earlier studies had assumed mutualistic interactions benefited the species involved in a linear fashion, without any saturation point. But in reality, the benefits of mutualism have a limit. For example, says Akçay, if you have more bees in an ecosystem, plants might get pollinated more and might produce more fruits. "But at some point," he says, "if the area is filled with bees and the plants are all pollinated, the plants will be limited by something else."

In addition to including this saturation point, Akçay and Qian attempted to make their new model more closely mimic the natural world by allowing the ecosystem to assemble gradually, adding species in a sequential manner. The classical models, in contrast, assumed that all the species came together in one fell swoop and then reached equilibrium.

"Of course, real communities don't assemble that way," says Akçay.

Their sequential assembly technique also allowed them to measure a different type of stability from the internal stability normally measured in these models, which they call external stability, or the ability of a community to resist invasion by a new species.

In their model, each time they added a species they would randomly assign it an interaction type—mutualistic, exploitative, or competitive—with all the other species in the community.

Their findings support the intuitive notion that mutualistic interactions have a place in a stable society.

"It's really the balance of the different interaction types between species that governs the community dynamics and stability," Qian says.

In their model, more mutualisms did not mean less internal stability, in contrast to what the classic models predicted. And mutualisms enhanced external stability in their analysis.

"So, they are actually more stable in an external sense because they are more resistant to invasions from outside," says Akçay. "And the reason is blindingly obvious in retrospect. If you have a community where most of the species are helping each other, each species will be abundant. If you are at this tiny population size and are trying to invade this community, it will be hard because your competitors are thriving."

While the new model is relatively simple and has room to be refined, Akçay and Qian say the results seem to be part of a shift in the community ecology field toward understanding that positive interactions in communities don't necessarily unsettle communities.

"These old, classical ecology questions still have legs," Akçay says.

More information: Jimmy J. Qian et al, The balance of interaction types determines the assembly and stability of ecological communities, *Nature Ecology & Evolution* (2020). DOI: 10.1038/s41559-020-1121-x

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