From bees to coral reefs: How humans impact partnerships in the natural world

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By harassing bees and other flower visitors, invasive Argentine ants prevent insects from pollinating the flowers of this Californian cactus (*Ferocactus viridescens*), which is now endangered. Credit: John Ludka

Mutually beneficial partnerships among species may play highly important but vastly underrecognized roles in keeping the Earth's ecosystems running, a group of evolutionary biologists suggests in a study.

The authors present evidence that human impacts may be forcing these mutualist systems down unprecedented evolutionary paths.

"With global climate change, evolutionary change can happen very rapidly, over a few years," said Judith Bronstein, a professor of ecology and evolutionary biology at the UA's College of Science and senior author on the paper. "That can be a good thing or a bad thing, we don't know, but people need to start looking at those effects."

In an effort to distill out common traits underlying biological partnerships and to develop a set of lessons to guide future research and conservation efforts, the researchers sifted through almost 200 research studies on the effects of global change on mutualisms, or interactions between organisms that benefit both partners.

Experts from several fields joined forces in this study and published their conclusions in Ecology Letters, one of the most influential journals in the field of ecology.

Many plants depend on animals to disperse their seeds. Where habitat destruction or other human-caused activity drives these species out of ecosystems, seeds stay right where the fruiting tree dropped them, as with this Copa Palm. Credit: Patricia Alvarez

"The alarmist view is that if you disrupt an interaction, you lose the interaction, you lose the community, and, ultimately, the ecosystem," Bronstein said. "We are trying to challenge people to make that explicit and to figure out whether their data support that. We need to ask, 'What is the range of possible things that can happen?'"

"It is not all doom-and-gloom," lead author E. Toby Kiers added. "There are clear cases in which mutualisms show a surprising ability to adapt to global change."

Even though the study of mutualistic relationships in nature is young, biologists have already discovered that every species is in one way or another involved in one or more partnerships, sometimes hundreds.

Some examples of mutualisms are well known from high-school biology textbooks, such as the fig wasp, which ensures the fig tree's propagation by pollinating its flowers and whose larvae get to use the fig fruit as a safe – and delicious – nursery in return.

Others are less obvious, but crucial for the health and functioning of entire ecosystems. Corals, for example, the tiny polyps they are, could never build their reef structures – massive hubs of marine biodiversity – without the help of microscopic algae living in their tissues. The algae, called zooxanthellae, use sunlight to make nutrients and help the polyps build their calcareous skeleton.

Despite the importance of mutualisms for ecosystems worldwide, Kiers, an evolutionary biologist at the Free University of Amsterdam, pointed out "there is a gaping hole in the current science, namely the ways that humans are disrupting the evolution of mutualisms."

Bronstein has observed a tendency to look at species interactions in the face of human-caused change in ways that are too simplistic.

"The idea of co-extinction has received a lot of press, meaning that if you lose one species, the other will invariably vanish, too. It's certainly a risk, especially if the mutualism is highly specific in the sense that one cannot exist without the other. But there are very, very few relationships that are that specific and vulnerable."

Kiers added that in contrast to co-extinction, small changes or shifts in mutualistic relationships are the most ubiquitous and possibly the most potent global disruptions.

"Unfortunately, because they are more subtle, these processes are harder to see and rarely discussed," she said.

The authors argue that because every species is involved directly or indirectly in mutualistic partnerships and mutualists act as key players in global carbon and nutrient cycles, pollination and seed dispersal, the breakdown of those relationships could accelerate and worsen effects of global change on biodiversity loss and ecosystem disruption.

Bronstein pointed to pollination, a type of mutualism that has received "90 percent of the attention, because there is absolutely no doubt that plants are flowering earlier due to global climate change."

"This is causing a lot of concern," she said, "because it means that at the time the flowers open, their pollinators may not yet be around. That would mean that pollination of these plants would fail. While that is definitely a possibility and there is some good evidence for it in some situations, it is not the only thing that can happen when pollination gets disrupted. For example, there are known cases in which pollinators have been lost from an island through overhunting, and the plants have evolved traits that allow them to be pollinated by other animals."

Seed dispersal is another example. Many plants rely on mammals

catching their fruit in their fur and carrying them to new habitats. Where large mammals were forced out of an ecosystem through habitat destruction or hunting, the plants were found to evolve smaller and smaller fruit that could be carried by smaller mammals or birds.

As different as the relationship between a flower and a bee may seem from coral polyps that cultivate microbes in their tissue, Bronstein and her co-workers identified certain recurring themes.

For example, how a mutualistic relationships plays out depends a lot on its ecological setting, Bronstein explained.

"Many species of ants milk aphids for the highly nutritious honeydew they produce. In return, the ants protect them from predators and parasites. But if the ants get starved for protein, they will eat the aphids, very readily. So the effect the ants have on the aphids ranges from highly beneficial to detrimental. To assess any mutualistic relationship, you have to know its context."

The authors identify three scenarios that can happen over the course of evolutionary timeframes when mutualist relationships are disrupted by human doing, regardless of their specific nature: a switch to new partners, a shift from mutual benefit to antagonism or abandonment of the interaction.

"If one or both of the groups that were interacting come into contact with new partners and adapt to them, as in the example of flowers adapting to new pollinators, the mutualistic interaction persitsts, just with different partners," Bronstein explained.

How humans shape their environment can drastically change a mutual interaction: One of nature's most widespread and important mutualisms is between tree roots and certain fungi in the soil. The fungi help the

plant grow by providing nutrients such as nitrogen and phosphorus to them, while the plant pays them back in carbohydrates.

"What happens when we dump a lot of nitrogen fertilizer into the system?" Bronstein said. "The plants no longer need their fungi and sever their connections with them. The fungi don't have an option and potentially just die or adapt to a more parasitic lifestyle. But what will happen if at some point in the future we stop using the fertilizer?"

"In the light of human-caused change, we have reason to be concerned about this, especially given the importance of these fungi to global carbon sequestration."

Kiers pointed to laboratory scale experiments suggesting that rapid evolutionary change can happen in very short timeframes.

"We have this wealth of knowledge from experiments looking at evolution on a short scale," she said. "Scientists have shown that it is possible for organisms to evolve in the lab. There is a lot to learn from these rapid evolution studies and it is time we start applying them to real world."

"There is an important message here," Bronstein added. "Throughout evolutionary history, habitats have changed enormously. Species have changed over these evolutionary time scales, but interactions have as well, and we expect this to continue. Our findings show that it is probably not enough to try and protect species on an individual level. We need to broaden our focus and start preserving mutualisms in the context of their ecosystems."

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