Theory of oscillations may explain biological mysteries

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Connect one pendulum to another with a spring, and in time the motions of the two swinging levers will become coordinated.This behavior of coupled oscillators---long a fascination of physicists and mathematicians---also can help biologists seeking to understand such questions as why some locations overflow with plants and animals while others are bereft, University of Michigan theoretical ecologist John Vandermeer maintains.

In the cover article for the December issue of the journal *BioScience*, Vandermeer summarizes theoretical work he has done over the past decade, leading to his conclusion that ecologists seeking to understand complex interactions in nature should pay closer attention to coupled oscillations.

The basic idea of oscillating populations is not new to ecology.

"We know that any predator-prey system, say lions and zebras for example, shows oscillations," said Vandermeer, who is the Margaret Davis Collegiate Professor of Ecology and Evolutionary Biology. "If there are lots of lions preying on zebras, numbers of zebras decline; then because zebras are scarce, lions starve and their numbers dwindle, allowing the zebra population to build up again. You see this oscillation, changing on a regular basis from lots of predators with few prey to lots of prey with few predators. The pattern is like waves or pulsations."

What gets interesting is when two independently oscillating systems, such as lions preying on zebras and cheetahs preying on impalas, become connected through the invasion of a third predator---leopards, for instance.

"When they become connected, the situation is very much like connecting two springs together---the ups and downs get into regular patterns." In the case of lions, cheetahs and leopards, bringing leopards into the system causes lion and cheetah populations to oscillate in phase with each other----peaking and declining at the same time. That works to the leopard's advantage---when both lion and cheetah populations are low, leopards can pounce on the plentiful prey. But then lions and cheetahs increase again, eventually building up their numbers and combined competitive strength enough to drive out the leopards---at least until the next low point in the lions' and cheetahs' population cycles.

Predator-prey systems can also become coupled when a new prey species invades and competes for resources with prey species in two previously unconnected predator-prey systems. For example, an extremely fast antelope might begin competing with zebras and impalas for food. Even though neither lion nor cheetah is fast enough to prey on the new antelope, the antelope's activity links the previously unconnected lion-zebra and cheetah-impala pairs. In such a case, the ups and downs of the two original prey species are thrown into chaotic but coordinated patterns, Vandermeer said.

"That's what's known as coordinated chaos---a phenomenon that occurs in some physical systems, such as lasers, but hadn't been pointed out in ecology before." By oscillating out of phase with the other two grazers---zebras and impalas---the antelope can coexist with them, prospering when their numbers are low.

Considering such scenarios with the aid of mathematical simulations such as Vandermeer's can help address questions biologists have wrestled with for decades, such as how species that appear to be exploiting the same resources can coexist and why some predator-prey systems are particularly resistant to invaders.

"In the past, ecologists have taken a traditional Newtonian view of the world, where everything comes into a nice equilibrium," Vandermeer said. "But oscillations sometimes destroy that equilibrium. What I'm suggesting is that we ecologists need to acknowledge the inherent oscillation in consumer-resource systems, such as predator-prey, herbivore-plant and parasite-host systems, and start approaching these old ecological issues in terms of coupled oscillators."

Source: University of Michigan

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