

Rising carbon dioxide levels pose a previously unrecognized threat to monarch butterflies

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Researcher Leslie Decker with a monarch butterfly in a University of Michigan laboratory. Credit: Austin Thomason/Michigan Photography

A new study conducted at the University of Michigan reveals a previously unrecognized threat to monarch butterflies: Mounting levels

of atmospheric carbon dioxide reduce the medicinal properties of milkweed plants that protect the iconic insects from disease.

Milkweed leaves contain bitter toxins that help monarchs ward off predators and parasites, and the plant is the sole food of [monarch caterpillars](#). In a multi-year experiment at the U-M Biological Station, researchers grew four milkweed species with varying levels of those protective compounds, which are called cardenolides.

Half the [plants](#) were grown under normal carbon dioxide levels, and half of them were bathed, from dawn to dusk, in nearly twice that amount. Then the plants were fed to hundreds of monarch caterpillars.

The study showed that the most protective of the four milkweed species lost its medicinal properties when grown under elevated CO₂, resulting in a steep decline in the monarch's ability to tolerate a common parasite, as well as a lifespan reduction of one week.

The study looked solely at how elevated carbon dioxide levels alter plant chemistry and how those changes, in turn, affect interactions between monarchs and their parasites. It did not examine the climate-altering effects of the heat-trapping gas emitted when fossil fuels are burned.

"We discovered a previously unrecognized, indirect mechanism by which ongoing environmental change—in this case, rising levels of atmospheric CO₂—can act on disease in monarch butterflies," said Leslie Decker, first author of the study, which is scheduled for publication July 10 in the journal *Ecology Letters*.

"Our results emphasize that global environmental change may influence parasite-host interactions through changes in the medicinal properties of plants," said Decker, who conducted the research for her doctoral dissertation in the U-M Department of Ecology and Evolutionary

Biology. She is now a postdoctoral researcher at Stanford University.

U-M ecologist Mark Hunter, Decker's dissertation adviser and co-author of the *Ecology Letters* paper, said findings of the monarch study have broad implications. Many animals, including humans, use chemicals in the environment to help them control parasites and diseases. Aspirin, digitalis, Taxol and many other drugs originally came from plants.

"If elevated carbon dioxide reduces the concentration of medicines in plants that monarchs use, it could be changing the concentration of drugs for all animals that self-medicate, including humans," said Hunter, who has studied monarchs at the U-M Biological Station, at the northern tip of Michigan's Lower Peninsula, for more than a decade.

"When we play Russian roulette with the concentration of atmospheric gases, we are playing Russian roulette with our ability to find new medicines in nature," he said.

Earlier work in Hunter's lab had shown that some species of milkweed produce lower cardenolide levels when grown under elevated carbon dioxide. That finding caught the attention of Decker, who with Hunter designed a follow-up study to look at the potential impact of rising CO₂ on the disease susceptibility of monarchs in the future.

They created an experimental system that allowed them to manipulate and measure all the key links in the chain: carbon dioxide levels, toxin concentrations in milkweed leaves, infection by parasites, and monarch susceptibility to those [parasites](#). The fieldwork was conducted in 2014 and 2015.

Inside 40 growth chambers on a hilltop at the Biological Station, they exposed milkweed plants to two different carbon dioxide levels. Twenty chambers were maintained at current global CO₂ concentrations of

around 400 parts per million, and 20 chambers received 760 ppm of CO₂, a level that could be reached well before the end of the century if the burning of fossil fuels continues unabated.

The four milkweed species differed in their levels of protective cardenolide compounds. The most protective species was *Asclepias curassavica*, commonly known as tropical milkweed. The chamber-raised plants were fed to monarch caterpillars, and each caterpillar got a steady diet of a single milkweed species with known carbon dioxide exposure.

Three-day-old caterpillars were also infected with carefully controlled doses of a common monarch parasite that is distantly related to the malaria pathogen. *Ophryocystis elektroscirrha* is a protozoan that shortens adult monarch lifespan, impedes its ability to fly and reduces the number of offspring it produces.

Over about two weeks' time, the infected caterpillars grew to a length of about 2 inches, with striking yellow, white and black bands. Then they pupated inside a hard-shelled chrysalis for about 10 days before emerging as orange-and-black butterflies.

At their Biological Station lab, Decker and Hunter raised hundreds of adult monarchs. The lifespan of each individual—in Michigan, monarch butterflies typically live for about a month—was recorded, and the number of parasitic spores on each carcass was counted.

Piecing together all this data, the researchers were able to determine how changes in [atmospheric carbon dioxide](#) levels altered toxin concentrations in the four milkweed species and, in turn, how exposure to those plants affected the monarch's lifespan and disease susceptibility.

The largest declines in parasite tolerance and butterfly lifespan occurred

in monarchs that fed on *A. curassavica*, a milkweed species in which cardenolide production declined by nearly 25 percent when grown under elevated CO₂.

In caterpillars that fed on *A. curassavica* milkweed grown under elevated CO₂, tolerance to the parasite declined by a whopping 77 percent when compared to caterpillars that fed on *A. curassavica* grown under ambient-level CO₂.

Monarchs that fed on *A. curassavica* grown under elevated CO₂ suffered a reduction in lifespan of seven days due to parasitic infection. Parasites reduced mean lifespan by only two days for monarchs that ate *A. curassavica* grown under ambient CO₂ levels.

"We've been able to show that a medicinal [milkweed](#) species loses its protective abilities under elevated [carbon dioxide](#)," Decker said. "Our results suggest that rising CO₂ will reduce the tolerance of [monarch butterflies](#) to their common parasite and will increase parasite virulence."

In recent years, monarch populations have been declining rapidly. Most discussions of the monarch butterfly's plight focus on habitat loss: logging of trees in the Mexican forest where monarchs spend the winter, as well as the loss of wild [milkweed plants](#) that sustain them during their annual migration across North America.

"Habitat loss, problems during migration and climate change all contribute to monarch declines," Hunter said. "Unfortunately, our results add to that list and suggest that parasite-infected monarchs will become steadily sicker if atmospheric concentrations of CO₂ continue to rise."

Provided by University of Michigan

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