Plants' defensive responses have downstream effects on nearby ecosystems

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Typical river reach on the Merrill & Ring Tree Farm, Olympic Peninsula, Washington. Credit: Sara Jackrel

Chemical changes that occur in tree leaves after being attacked by insects and mammals can impact nearby streams, which rely on fallen plant material as a food source, report scientists from the University of Chicago Department of Ecology and Evolution. The study, published March 17 in the journal *Proceedings of the Royal Society B*, shows how interactions between terrestrial and aquatic ecosystems are an essential part of understanding ecological responses to climate change.

Graduate student Sara Jackrel and Timothy Wootton, PhD, professor in the Department of Ecology and Evolution, simulated herbivory, or the activity of insects eating leaves, on red alder trees in a forest on the Olympic Peninsula in Washington state. Their research showed caterpillars ate fewer leaves from the stressed trees than those that were left alone. Leaves from these stressed trees also decomposed much more slowly when submerged in nearby streams, and further results suggest that the trees funneled a valuable nutritional resource away from the leaves as a defensive response to animal attacks.

"Terrestrial herbivory could have innumerable effects on leaf chemistry, and our simulation had a very strong effect in streams," said Jackrel, the study's lead author. "The tree's response to herbivory had a cascading effect across an ecosystem boundary, into another trophic level entirely. The important finding was making that indirect link from a terrestrial system into an aquatic system."

Plants generate many defensive responses to being attacked by insects and other animals. Some produce tannins and compounds that are toxic or taste bad to discourage herbivores from eating them. Others may even release chemicals that attract predators for the particular insect attacking the plant.

Insects and microbe decomposers that live in streams depend on a variety of nutritionally diverse leaf litter as a food sources. They play no direct role in the interactions between trees and their herbivores, but the new study shows how the composition of those leaves is shaped by their activity,

Leaf pack deployment system for red alder trees to test decomposition in water (with branches of red alder hanging over the river and a fallen green leaf of a red alder lying on the stream bed). Credit: Sara Jackrel

During her fieldwork, Jackrel mimicked the activity of caterpillars by systematically punching holes in the alder leaves with an office hole punch. She also painted the leaves with methyl jasmonate, a chemical that trees release under stress, to enhance the defensive response to the hole punches. Some trees were fertilized with phosphorus, while others were not.

Jackrel then buried packages of leaves and placed others underwater in a stream to test how quickly they decomposed in both soil and water. Caterpillars were also allowed to feed on treated and untreated leaves to test their preferences.

Leaves from trees that received both fertilizer and the herbivory treatment decomposed the most slowly. Caterpillars and aquatic insects ate fewer of these leaves than those from untreated trees as well.

Nitrogen levels were also much lower in the treated leaves. Insects value nitrogen as a nutrient, and the study results suggest that trees alter nitrogen levels to deter them from eating more leaves, perhaps by storing it the trunk or roots.

Understanding how trees' defensive responses to natural herbivores impact nearby streams will help scientists better predict the effects of climate change and other human activity like logging and agriculture.

"With climate change, insect communities are going to change," Jackrel said. "So understanding fundamentally how these communities naturally affect leaf chemistry, and how that might affect stream systems, is a critical reference to have. Then we can work to predict how climate change, along with other anthropogenic changes, might be affecting aquatic systems."

More information: "Cascading effects of induced terrestrial plant defences on aquatic and terrestrial ecosystem function," *Proceedings of the Royal Society B*, rspb.royalsocietypublishing.or … .1098/rspb.2014.2522

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