

Science

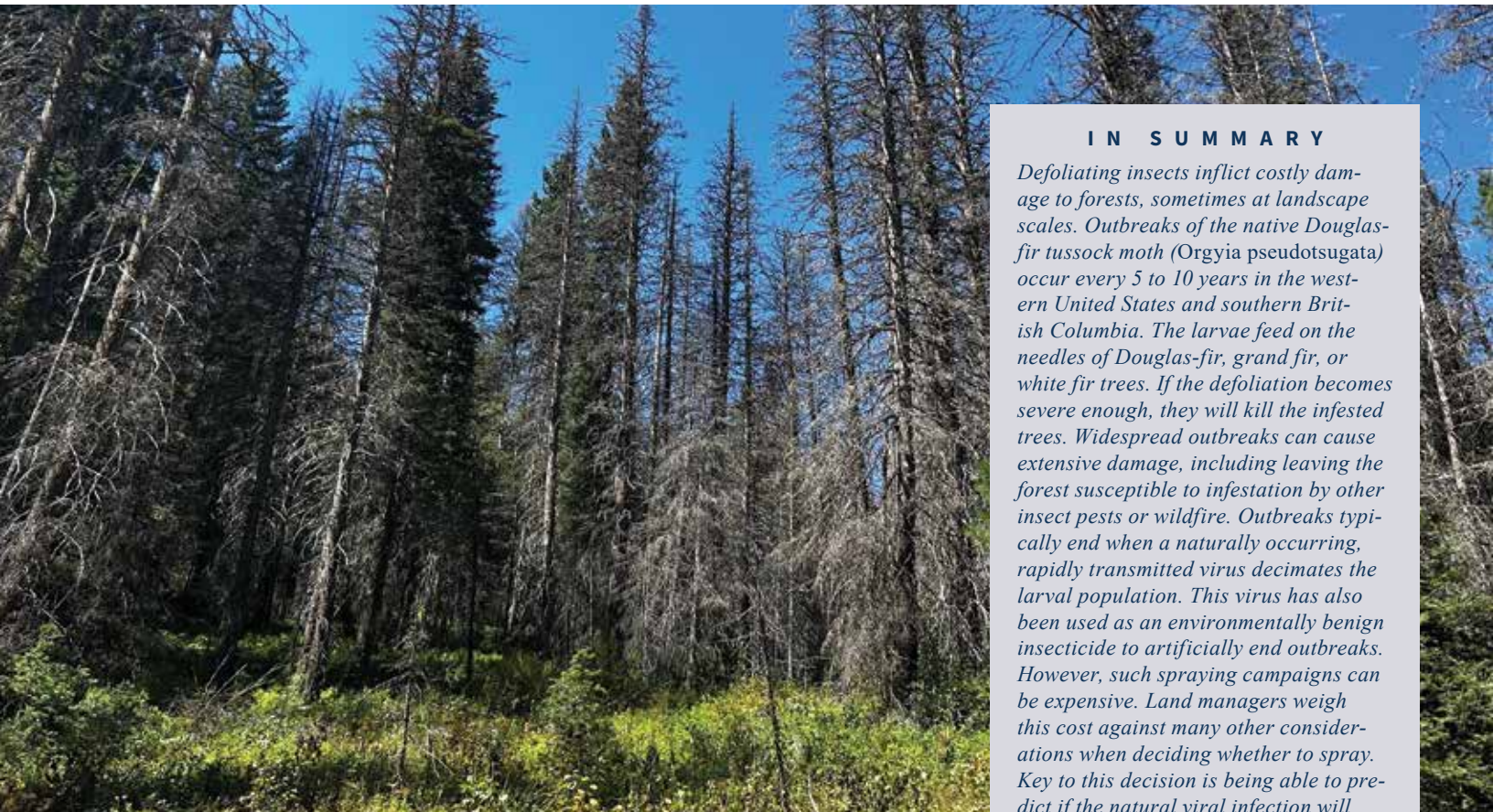
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"Science affects the way we think together."
Lewis Thomas

The Very Prickly Caterpillar: Navigating Douglas-fir Tussock Moth Outbreaks



Trees defoliated by Douglas-fir tussock moth caterpillars at Sage Hen Creek Campground in the Boise National Forest. USDA Forest Service photo by Nicole Green.

Nestled under a shady canopy of Douglas-fir and grand fir, Sage Hen Creek Campground in the Boise National Forest with its hiking trails, beautiful reservoir, and excellent huckleberry picking, is popular in the summer.

In 2018 and 2019, visitors to the campground observed many unhealthy or dead trees. Alarming signs were posted in the area:

WARNING: DO NOT TOUCH DOUGLAS-FIR TUSSOCK MOTH CATERPILLARS

HUCKLEBERRY PICKERS PLEASE WEAR LONG-SLEEVED SHIRTS AND GLOVES

The culprit was a native insect (*Orgyia pseudotsugata*) that is visually striking in its caterpillar phase, with a brightly colored body and large, horn-like tufts on either side of its head. These caterpillars hatch in the spring and

IN SUMMARY

Defoliating insects inflict costly damage to forests, sometimes at landscape scales. Outbreaks of the native Douglas-fir tussock moth (*Orgyia pseudotsugata*) occur every 5 to 10 years in the western United States and southern British Columbia. The larvae feed on the needles of Douglas-fir, grand fir, or white fir trees. If the defoliation becomes severe enough, they will kill the infested trees. Widespread outbreaks can cause extensive damage, including leaving the forest susceptible to infestation by other insect pests or wildfire. Outbreaks typically end when a naturally occurring, rapidly transmitted virus decimates the larval population. This virus has also been used as an environmentally benign insecticide to artificially end outbreaks. However, such spraying campaigns can be expensive. Land managers weigh this cost against many other considerations when deciding whether to spray. Key to this decision is being able to predict if the natural viral infection will act quickly enough to stop the outbreak ahead of substantial defoliation.

Research scientist Carlos Polivka and collaborators at the University of Chicago developed a tool that models the virus and its transmission through a Douglas-fir tussock moth population, predicting the time course of the viral infection. This helps land managers determine if they should intervene or if the natural viral infection will soon take care of the outbreak.



A Douglas-fir tussock moth caterpillar. Contact with the caterpillar hairs can cause humans to develop a skin rash. Photo by William M. Ciesla/Bugwood.org.

feed voraciously on Douglas-fir, grand fir, or white fir needles.

The caterpillars are covered with tiny hairs that can produce an allergic reaction in humans. Symptoms can resemble those of hay fever, but more intense reactions, such as welt-like rashes, may also occur.

Connie Mehmel, a retired USDA Forest Service entomologist, used to get itchy eyes when exposed to the caterpillars. “Different people react in different ways. I try not to let them get on my bare skin. If you’re ever walking through an area that is experiencing an outbreak, you better keep walking,” she said.

The consequences of a Douglas-fir tussock moth outbreak can spiral far beyond spoiling a hike or picnic plans. “They can really

defoliate a tree from top to bottom in a matter of a few weeks, and when that happens it can kill the tree. About every 10 years you’ll see an outbreak somewhere, sometimes happening over a large area. Those big, extensive ones are rare, but they can do a lot of damage,” said Mehmel.

An outbreak in the early 1970s provides a case in point. In 1972, tussock moths began spreading rampantly, and by 1974 they had defoliated over 1.2 million acres in Oregon, Washington, Idaho, and parts of Montana.

“That was the biggest outbreak on record, with very, very heavy tree mortality. Some areas had to be closed because you could hardly get through the woods with the number of caterpillars that were out there. The public was very much in favor of spraying because the caterpillars were so disruptive,” recalled Mehmel. “Unfortunately, DDT was the only insecticide we had at the time that was effective against tussock moths, but it had been banned 2 years earlier.”

In a nod to public pressure, the U.S. Environmental Protection Agency made an exception to the DDT ban and granted a one-time use. The resulting operation in 1974—treating hundreds of thousands of acres, including parts of the Umatilla and Wallowa-Whitman National Forests—was the largest aerial spraying of DDT in the United States.

Mehmel says there were some lessons from the decision. “That same year, the outbreak collapsed on its own. So, all that DDT was sprayed without being necessary. But something positive did come out of it, which was the conclusion that we don’t want this to happen again. The Forest Service began investing in research into alternative pesticides.”

An Applied Science Partnership

Carlos Polivka, a scientist with the USDA Forest Service Pacific Northwest Research Station, began studying Douglas-fir tussock moths more than a decade ago through a serendipitous path. The research lab where he works in Wenatchee, Washington, was also where Mehmel worked. At lunch in the break room one day, Polivka asked Mehmel about her insect work. She told him about the Douglas-fir tussock moth and how the quest for control options had led to the identification of a natural virus that afflicts tussock moths. Because the virus targets only tussock moths and often leads to local population collapse, it offered a safe and effective alternative to DDT. In fact, the virus

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Defoliation from Douglas-fir tussock moth caterpillars in the Boise National Forest. USDA Forest Service photo by Nicole Green.



KEY FINDINGS

- The virus registered for use as a biological insecticide under the name TM Biocontrol-1 is just as infectious, and hence effective, against Douglas-fir tussock moth larvae as the naturally occurring form of the virus.
- The virus does not persist in the environment for long periods. This implies that high, late-season infection rates are due to successive rounds of transmission among individual caterpillars, not long-term persistence of the virus.
- Small-scale interactions taking place on individual Douglas-fir branches between the moth larvae and the infectious particles of the virus are not sufficient to explain the population-level spread of the virus. Other factors in the environment may play a role.

was being used as a pesticide spray under the name TM Biocontrol-1.¹

Polivka realized that research could help address some nagging knowledge gaps about this virus. As Mehmel explained, there were some tricky nuances to iron out. “Any time you use a biological control agent, the timing has to be right. The virus is sensitive to wind, and heat, and UV [ultraviolet] radiation. There’s a lot to finesse if you are going to be using a virus as an insecticide,” she said.

At the time, there was also concern about the potency of TM Biocontrol-1—that its effectiveness might be diminished through long-term storage and that wild strains of the virus might be more virulent.

Polivka and his team set up experiments in which they monitored a lab population of insects while also doing a field study of the virus in the wild. “To study the virus in the field, we would take regular collections of insects once a week, pulling them off the trees and immediately quarantining them. And then we would see how many of those individuals were infected, which would allow us to calculate the infection rate for that week,” he said.

It’s readily apparent when a caterpillar has been infected. “It’s pretty gross, actually,” said Polivka. “It takes about 7 to 10 days for an infection to run its course, but the first thing it does is perforate the gut lining of the caterpillar, and the insides begin to break down. Once that happens, the caterpillar bursts open onto the foliage. We refer to that as the ‘splatterpillar phase.’ The liquid inside

the dead larva contaminates the foliage for the next one to come along and eat it.”

This is how the virus spreads through the population. “It causes one caterpillar after another to die, which will eventually cause the population to collapse. Once that happens, we usually don’t see them again for another 10 years or so,” said Mehmel.

Predicting the Outcomes of Insect-Virus Interactions

Polivka’s work led to discoveries that have alleviated long-standing questions about the use of the virus as a biological control agent.

“Our results suggested that concerns about the efficacy of the TM Biocontrol-1 strain of the virus compared to the wild virus were unfounded. We did find that the two strains are different, but those differences are not biologically significant. The transmission rates and decay rates of TM Biocontrol-1 and the wild virus are very similar,” he said.

In other words, Polivka’s work suggests that storing TM Biocontrol-1 does not degrade its effectiveness. This is a relief because large quantities of the biocontrol virus are kept in cold storage. “The biocontrol virus is very

expensive to produce,” said Mehmel. “And it has not been produced for quite some time because we have a lot of it right now. So, we need to be able to store it, potentially for a long time.”

Polivka’s research also revealed a new understanding about how the virus behaves. He determined that the virus does not survive in the environment for long periods but decays rapidly on the foliage. This suggests that high, late-season infection rates are due to successive rounds of transmission, not long-term persistence of the virus. His team’s work also suggests that spraying later growth stages of tussock moths with lower amounts of virus might be more effective in controlling the population.

In a later study, Polivka and his colleagues tested the mechanism behind the transmission of the virus to the insect host to understand how the viral infection spreads. Does it all depend on close contact between the individual insect and the infectious viral particles, or are there larger influences at play? Their work showed that those small-scale interactions between caterpillar and virus are not enough to explain the population-level spread of the tussock moth virus. More research is underway to explain these dynamics more fully, but Polivka and his team suggest that other environmental factors might play important roles.

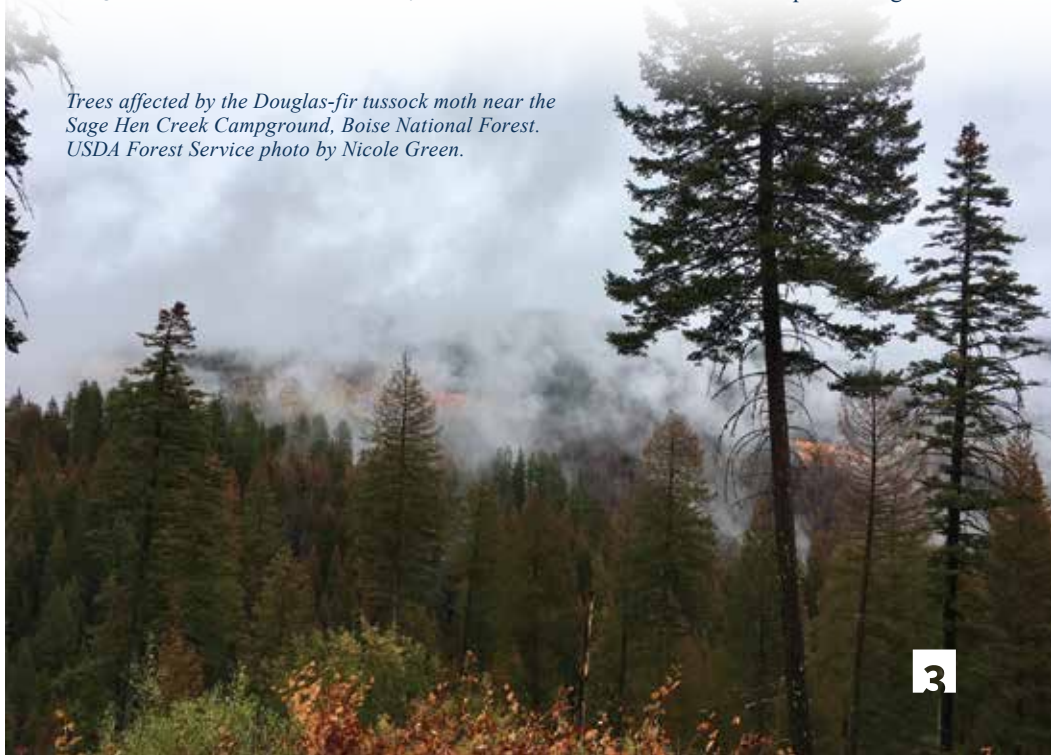
“Transmission may vary depending on the host tree species, and that will change with latitude and climate, including everything from microclimate to more ecoregional effects. The density of trees as well as tree diversity will also modulate the intensity of an outbreak,” said Polivka.

Polivka and his team incorporated the accumulated experimental data and data from older outbreaks into an epidemiological

Trees affected by the Douglas-fir tussock moth near the Sage Hen Creek Campground, Boise National Forest. USDA Forest Service photo by Nicole Green.

¹ This publication reports research involving pesticides. It does not contain recommendations for their use, nor does it imply that the uses discussed here have been registered. All uses of pesticides must be registered by appropriate state or federal agencies, or both, before they can be recommended.

CAUTION: pesticides can be injurious to humans, domestic animals, desirable plants, and fish or other wildlife—if they are not handled or applied properly. Use all pesticides selectively and carefully. Follow recommended practices for the disposal of surplus herbicide and herbicide containers.





A Douglas-fir tussock moth caterpillar killed by a natural viral infection in Tonasket, Washington. USDA Forest Service photo by Connie Mehmel.

model that predicts the time course of the viral infection in Douglas-fir tussock moth populations. The model uses two key inputs: moth population size and viral infection rate.

The first time they tested the model as a predictive management tool was during the outbreak in the Boise National Forest, home of Sage Hen Creek Campground. The team studied the outbreak in 2017, monitoring the insects through the course of that summer. While there, they met Forest Service entomologist, Nicole Green, who was working on the outbreak as a biological technician.

“There were pockets of really high mortality for that outbreak. Some trees were 100-percent defoliated,” said Green. “It can be especially jarring looking at defoliated hillsides from afar because you’re seeing the tops of the trees where the damage is worst, and it can look like a mountainside of dead trees, even though there might be some needles left and some trees could recover.”

The team ran the new model, hoping to predict when the outbreak would collapse. Like any model, its accuracy was limited by the completeness of the data that was used, and it turned out to need a little tweaking. “In our 2018 prediction on the Boise National Forest, we overestimated how quickly the outbreak would collapse, and there was a lot of resultant defoliation,” Polivka said.

They went back and updated the model using data from the Boise National Forest outbreak. “Between 2018 and 2019, we were able to refine the model to make more robust and accurate predictions,” he said. This time it paid off.

In 2019, there was an extensive Douglas-fir tussock moth outbreak in the Okanogan-

Wenatchee National Forest, and land managers there consulted Polivka. “Using our model, we were able to assist. We made predictions that were a lot more robust that indicated certain areas that didn’t need to be sprayed. In the end, those areas were not sprayed, and the moth populations crashed like we predicted,” he said.

To Spray or Not to Spray

Green now works out of the Boise field office for the Forest Service Intermountain Region Forest Health Protection program. Forest Health Protection staff, which included Mehmel before she retired, partner with land managers to provide technical assistance on disturbance agents, such as insects, diseases, and invasive plants.

“Our job is to keep current on what’s going on and to provide the facts to land managers about what we would expect to happen,” Green explained. “In that sense, Carlos’s work—helping us to predict when a tussock moth outbreak will crash naturally—has been really valuable.”

Douglas-fir tussock moths are always around in low numbers, usually not causing visible defoliation. Historically, outbreaks happen at fairly predictable intervals and locations. Really extensive outbreaks are rare, but when they happen there are many factors to consider when deciding whether to try to control them. These include the severity of the outbreak, the availability and effectiveness of control measures, and the long-term effects of controlling an outbreak versus allowing it to run its course.

“This is a native insect,” said Green. “You don’t necessarily want to spray just because it’s there.

Aerial view of Douglas-fir tussock moth damage in the Boise National Forest. USDA Forest Service photo by Laura Lowrey.



A Douglas-fir tussock moth caterpillar crawls along a branch in the Flathead National Forest. USDA Forest Service photo by Erika Williams.

LAND MANAGEMENT IMPLICATIONS

- Epizootics (epidemics in animals) caused by the naturally occurring form of the virus that affects Douglas-fir tussock moths can preempt the need for costly and labor-intensive pest management measure such as spraying insecticides.
- Understanding how the virus spreads through a population of Douglas-fir tussock moths can improve predictions about the course of the infection and its potential to cause an outbreak to collapse, reducing or preventing defoliation.
- A new model can identify cases where significant defoliation might occur and can predict the natural duration of the Douglas-fir tussock moth outbreak, which can help land managers decide whether to intervene.
- Environmental factors seem to play a role in determining how the virus spreads through a tussock moth outbreak. More research is needed to pin these factors down, but host tree species diversity and tree density are possible influences on outbreak intensity.



It has a role to play in forests. If the outbreak is minor, it could even help to create diverse habitats in the forest. The decision to intervene is usually more of a factor when the outbreak affects recreation, like in a campground, or when there is something else that you want to protect like rare species habitat.”

As the signs in Sage Hen Creek Campground warned, it’s not just the aesthetics of an area that are affected; human health can be harmed by having the caterpillars around. In addition, there are secondary problems that can come with a Douglas-fir tussock moth infestation.

“The decline in forest health left by tussock moth defoliation leaves the forest susceptible to infestation by bark beetles or to wildfire. The double jeopardy it can cause to the health of a given forest is a concern,” said Polivka.

For all these reasons, gaining a better understanding of this forest pest and how to deal with it is critically important to forest managers. “That’s the purpose of the model—it helps to get at the big question, which is whether to intervene and use the pesticide spray version of the virus or if the natural viral infection is going to take care of the outbreak and prevent significant defoliation,” said Polivka.

Polivka and his collaborators are waiting for the next outbreak so that they can do more field research and find out if the model needs further refinement. “It’s a challenging insect to work with,” he said. “The outbreaks are so cyclical, and we are currently having trouble finding any within their range.”

When he does get word of the next big outbreak, the work can continue, and more insights can be gained about this native insect and the virus that keeps it in check. “For now, we’re in a dry spell,” Polivka said.

For Futher Reading

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Scientist Profile



CARLOS POLIVKA is a research fishery biologist with the Pacific Northwest Research Station where he has worked since 2003. He studied ecology and evolution at the University of California, Los Angeles and went on to earn M.S. and Ph.D. degrees from the University of Oklahoma and University of Chicago, respectively. His research background is in behavioral ecology and ecological theory. In addition to the ecology of fishes, he has been studying the effects of insect pests on forest health since 2010.

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