USDA Forest Service
U.S. DEPARTMENT OF AGRICULTURE

Pacific Northwest Research Station | Issue 246 | February 2022

Science FINDINGS

INSIDE

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

The Scent of Stress: Understanding Links Between Fire-Injured Pine and Red Turpentine Beetles Can Aid Postfire Management

Researcher Dan Mikowski uses a laser range finder to determine specific distance between traps for red turpentine beetles at a wildfire site in central Oregon. USDA Forest Service photo by Rick Kelsey.

IN SUMMARY

*The red turpentine beetle (*Dendroctonus valens*) is native to North America and attacks stressed, dying, or recently dead pine trees, especially fire-injured ponderosa pine. State and federal agencies use baited traps to detect, monitor, and manage populations of native and nonnative insect species. Trapping efforts are labor intensive, and the lures themselves can be relatively expensive, so it's important to use effective lures.*

Researchers Rick Kelsey and Doug Westlind, with the USDA Forest Service Pacific Northwest Research Station, have finetuned a more effective lure recipe to trap red turpentine beetles in Pacific Northwest forests. More effective lures will improve monitoring efforts and may also be used for early detection of invasive red turpentine beetles from China carrying exotic pathogens.

The researchers also found the accuracy of an existing model that predicts delayed mortality for large ponderosa pine after fire exposure substantially improved when information about the presence or absence of red turpentine beetles was included. This improved accuracy can help land managers better identify large, dying pines after wildfire and inform science-based management plans that address pre- and postfire management efforts for both prescribed burns and wildfire.

"Nature will bear the closest inspection. She invites us to lay our eye level with her smallest leaf, and take the insect view of its plain."

—Henry David Thoreau

Spring in the Pacific Northwest signals the beginning of insect trapping season. Amidst spring flowers and budding trees, you may notice an occasional fluorescent green and orange triangle-shaped trap strapped to a tree trunk or a multiple-funnel trap hanging from a metal stand. The traps are often in city parks, on state and federal lands, or in areas that see an influx of goods, such as ports or transportation corridors.

Insects are notorious stowaways. Hidden on equipment or pallets, they travel across continents and oceans on goods that are transported around the world. This can have devastating economic and ecological consequences. In 2016, a study published in *Nature Connections* estimated that invasive insects annually

Pitch tubes visible on the trunk and frass at the base of the tree indicate the presence of red turpentine beetle. USDA Forest Service photo by Doug Westlind.

*A red turpentine beetle (*Dendroctonus valens*). The beetles are attracted to ethanol released from stressed pines in combination with monoterpenes. Photo courtesy of Whitney Cranshaw, Colorado State University, Bugwood.org.*

PNW Science Findings

Providing scientific information to people who make and influence decisions about managing land.

PNW Science Findings is published monthly by:

Pacific Northwest Research Station
USDA Forest Service
1220 SW 3rd Ave., Suite 1400
Portland, OR 97204

Send new subscription and change of address information to:

SM.FS.pnw_pnwpubs@usda.gov

Rhonda Mazza, editor; rhonda.mazza@usda.gov

Jason Blake, layout; jason.p.blake@usda.gov

To find Science Findings online, visit https://www.fs.usda.gov/pnw/ and click on **Publications**.

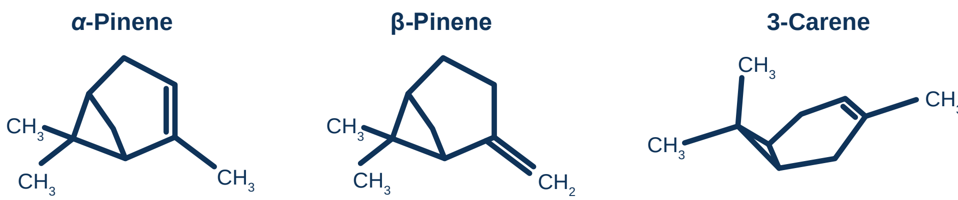
To become a digital subscriber visit: https://www.fs.usda.gov/pnw/publications/subscriptions.shtml

USDA United States Department of Agriculture

Forest Service

Key Findings

- Fire-injured ponderosa pine release vapors of ethanol mixed with resin monoterpenes, including (–)-β-pinene, (+)-3-carene and (+)-α-pinene, among others. Red turpentine beetles at study sites in Oregon and Washington were most attracted to lures with β-pinene plus ethanol, followed by 3-carene plus ethanol, and lastly α-pinene plus ethanol.
- Traps caught more red turpentine beetles as the lures released increasing amounts of β-pinene, ethanol, or both compounds. Releasing β-pinene plus ethanol with high-release frontalin, a dual function sex and aggregation pheromone for red turpentine beetle, did not increase the number of beetles captured.
- Slight modifications to 3-carene and α-pinene structures did not substantially change their attraction compared to β-pinene when all three chemicals were paired with ethanol.
- Factoring in the presence of red turpentine beetle attack within 1 year after fire, along with crown scorch and bole scorch proportions, improved the accuracy of a model that predicts delayed mortality for large-diameter (more than 21 inches) ponderosa pine. This is attributed to the beetles detecting ethanol in heat-stressed tissues, which signaled an additional level of injury beneath the bark not measured by bole and crown scorch.



Monoterpenes are organic compounds that produce the fragrant smells associated with pine trees. Above are structures of 3 monoterpenes compared for primary attraction of red turpentine beetles when released with ethanol. Adapted from Kelsey and Westlind (2020).

cause the equivalent of nearly $78 billion in worth of damage worldwide. The gypsy moth (*Lymantria dispar*), a native of both Europe and Japan, has defoliated trees on millions of acres in the United States.

Many countries have agencies tasked with inspecting goods before they enter or leave the country. "We want to be a good citizen in ensuring that we're not exporting an insect that's going to be damaging in other countries," explains Christina Buhl, forest entomologist for Oregon Department of Forestry.

Early alerts about the presence of nonnative insects are critical for management. That's why in the United States, the USDA Animal and Plant Health Inspection Service, in conjunction with state agencies, set traps each spring to monitor native insect populations and detect introductions of nonnative insects. But a good trap depends on good bait.

"We want to make sure that if we're doing trapping, it's a really effective trap that's being put out," Buhl says. "It's not just the quality of the lure; it's the time spent placing the lure that's labor and cost prohibitive."

Creating an effective lure requires an understanding of chemical ecology—the study of chemical interactions between organisms such as insects and plants. Buhl, whose Ph.D. is in chemical ecology, describes the field as "a dark corner of science" that doesn't receive much attention because it's difficult to understand these interactions.

One of her colleagues who has spent much of his career in this dark corner of science is Rick Kelsey, an emeritus research forester with the USDA Forest Service Pacific Northwest (PNW) Research Station. He has studied ethanol synthesis and accumulation in stressed trees. Along with his colleague Doug Westlind, a forestry technician also with the research station, the team spent the past decade identifying the role of ethanol and resin monoterpenes in attracting the Pacific Northwest native red turpentine beetle (*Dendroctonus valens*) to colonize fire-injured ponderosa pine (*Pinus ponderosa*) trees.

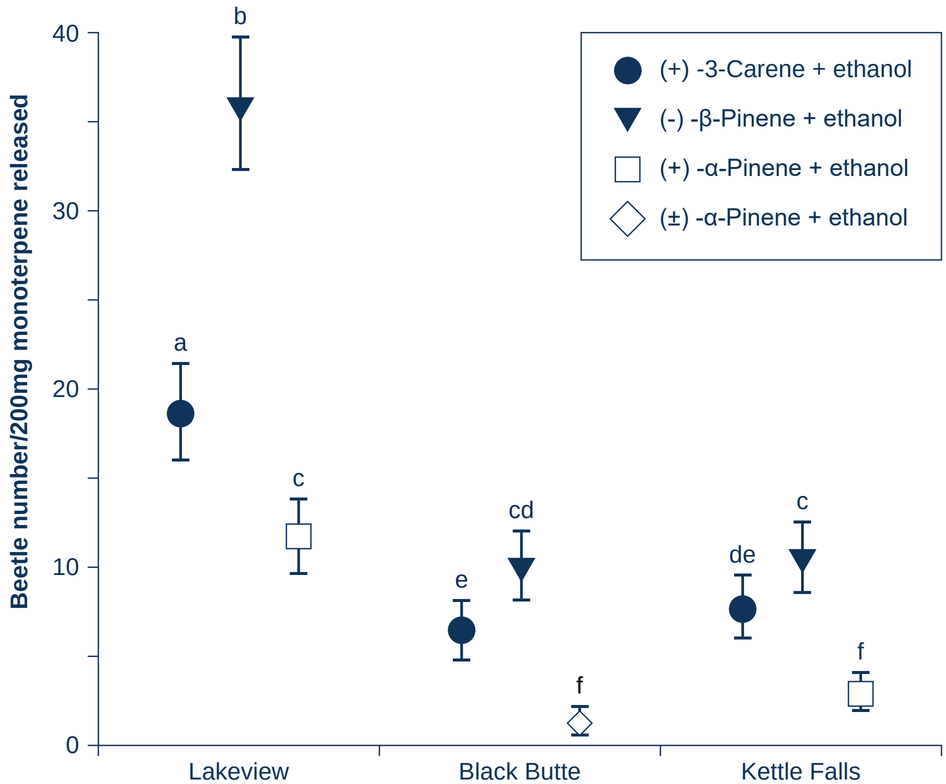
Even if you haven't heard of monoterpenes, you've likely smelled them while walking through a stand of pine trees or working with pine wood, which naturally releases monoterpene vapors. β-Pinene, 3-carene, and α-pinene are the more abundant monoterpenes in ponderosa pine resin; they produce that recognizable piney smell. When stressed by disease or fire injury, pines also release ethanol. Alone, ethanol is a weak attractant, but when combined with the monoterpenes, the smell signals to bark beetles that the tree is weakened and vulnerable to colonization.

"We are continuing to understand the physiology of stress ethanol production and expanding into how this influences the beetles so we can better understand the connection between tree stress and the beetles," says Kelsey.

Unlike the mountain pine beetle that has killed thousands of acres of lodgepole pine in the Colorado Rockies, red turpentine beetles aren't typically a direct cause of tree mortality. Instead, they further weaken trees and make them more susceptible to other stressors. An exotic pathogen from China is one of the potential stress agents.

In the early 1980s, red turpentine beetles were accidently exported to China, which has several native pine species such as Chinese red pine (*Pinus tabuliformis*). Once introduced to the new environment, the beetles and the microbial community they transport, including fungal pathogens, spread and directly contributed to the mortality of millions of Chinese red pine. Over time, the community of microbial species transported by red turpentine beetles in China has shifted, and they now carry many fungi that are not in North American forests.

"There is concern that the red turpentine beetles could bring new and more virulent fungal pathogens from Chinese pine into the United States, although we don't know for certain how they would affect our pine. Plus, how the beetles from China respond to β-pinene plus ethanol needs testing," explains Westlind. "There's also a concern that the red turpentine beetle could make its way to South America, Australia, or New Zealand where they grow a substantial amount of pine."



β-Pinene plus ethanol caught the most beetles across three Pacific Northwest sites when ponderosa pine monoterpenes plus ethanol were tested against each other. Adapted from Kelsey and Westlind (2020).

A Lure that Attracts Nearly Twice the Beetles

To improve the efficiency of current lures used for trapping red turpentine beetles, Kelsey and Westlind have focused on identifying the attraction strength of each resin monoterpene when released in combination with ethanol. Earlier research suggested 3-carene was a better attractant than either β-pinene or α-pinene and that 3-carene combined with ethanol proved to attract the most beetles. However, when other researchers combined all three monoterpenes in 1:1:1 proportions and released this mixture with ethanol, it didn't greatly increase the capture rate of beetles when used as a lure. "This was different from what we were seeing with one monoterpene plus ethanol," Kelsey says.

In 2016, Kelsey and Westlind compared the attraction strength of the three ponderosa pine monoterpenes plus ethanol against each other. At field sites in Washington near Kettle Falls and in Oregon near Black Butte and Lakeview, they tested traps baited with randomly assigned lures containing β-pinene plus ethanol, 3-carene plus ethanol, α-pinene plus ethanol, and traps with no lures as a control. At the end of the trapping period that spanned late April to mid-June, the number of beetles caught by each type of monoterpene were averaged. β-Pinene plus ethanol attracted 1.4 to 1.9 times more beetles than 3-carene plus ethanol; α-pinene plus ethanol proved the least attractive to the beetles.

"The response to β-pinene was completely unexpected," says Westlind. "We thought by adding ethanol we would just increase the catch for each monoterpene without any change in their order. Instead, we found that by adding ethanol, β-pinene became the best lure."

Kelsey and Westlind dug deeper to identify what parts of the molecular structure influenced the beetle attraction. This involved hydrogenating the 3-carene and α-pinene, essentially breaking their double bonds by inserting hydrogen atoms and turning the molecules into *cis*-carane and *cis*-pinane, respectively.

"Everything you do to the molecule's structure will change its properties," explains Kelsey. "For example, the molecule

Doug Westlind collecting red turpentine beetles at a lure test site in northern California. USDA Forest Service photo by Rick Kelsey.

might still have a similar odor, but its evaporation rate might change. The question was how does that impact the beetle's response."

In May 2018, at a study site outside of Sisters, Oregon, where prescribed burns had been conducted the previous two springs, traps containing lures of *cis*-carane plus ethanol, *cis*-pinane plus ethanol, β-pinene plus ethanol, and a control of ethanol were placed across the landscape. After the beetles were counted and the results analyzed, β-pinene plus ethanol proved to be the best attractant, followed by *cis*-carane plus ethanol, *cis*-pinane plus ethanol, and finally, ethanol. "We didn't expect hydrogenation to enhance the attraction," Kelsey says. "I thought by taking out the double bonds, they wouldn't be attractive at all, but they were."

With β-pinene plus ethanol identified as having the greatest attractant strength, Kelsey and Westlind wanted to test whether increasing its dosage affected the number of beetles captured. "The chemicals used in the lures may or may not be expensive, but the cost of traps, their field placement and maintenance is" says Westlind. "If you can max out the dosage then you'll trap more beetles, so you could space your traps out farther, or place fewer traps."

LAND MANAGEMENT IMPLICATIONS

- β-pinene plus ethanol is an effective lure for red turpentine beetles in Pacific Northwest pine forests, and possibly elsewhere.
- Invasive red turpentine beetles exported from the United States to China now carry novel fungal pathogens that, if introduced to the United States or the Southern Hemisphere, could spread rapidly among fire-injured or other stressed pine trees. The strong β-pinene plus ethanol lure could be a useful first defense to detect the arrival of these red turpentine beetles from China.
- A postfire, tree-mortality model that more accurately identifies which large-diameter (more than 21 inches) ponderosa pine are likely to die within 3 years can help inform decisions about postfire management.

In 2019, the research team selected a study site near Camp Sherman, Oregon, where a prescribed burn was conducted the previous spring and plenty of fire-injured trees remained on the site to attract the beetles. The lures were designed to release β-pinene plus ethanol, each at three different dosages (100, 200, or 400 milligrams per day) to provide nine lure combinations. After 41 days, the beetles were collected and counted.

When looking at how the increasing dosage affected the capture rate, "no matter how high the dose within the range we tried, the beetles never stopped responding; we just caught more and more beetles with higher doses," says Westlind.

Monica Gaylord, a forest entomologist with the USDA Forest Health Protection office, expects this lure research will inform her trapping efforts of red turpentine beetle populations in Arizona. "It's always good to know you have a lure that's been tested so you know that you are actually capturing the beetles and not missing them," she says. "We don't have a huge

Predicting Delayed Tree Mortality After Fire

Fire may not kill a tree immediately, but trees injured by fire are at higher risk of attack by various bark beetles and any fungal pathogens they may carry.

Knowing which fire-injured trees are likely to slowly die in 2 or 3 years is useful information for postfire management. Researchers have developed tools to help identify which trees will likely recover after a fire and which will not.

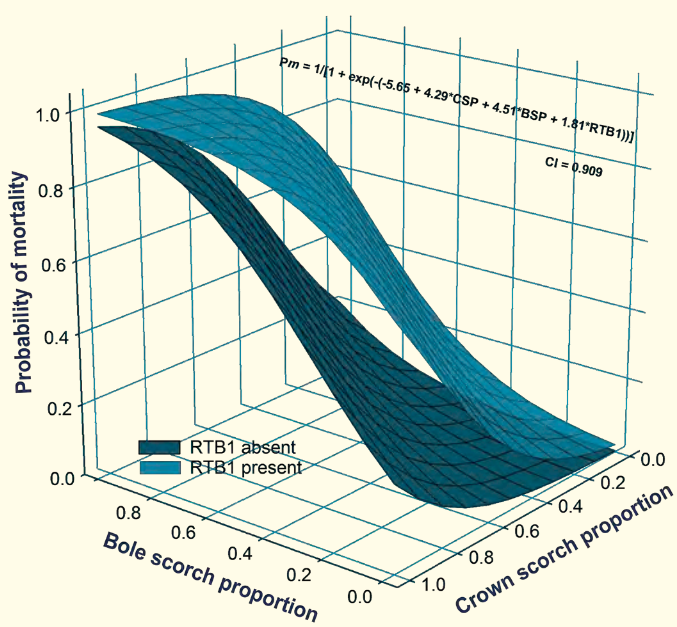
As a forest technician, Doug Westlind has worked with many Forest Service researchers throughout the Pacific Northwest. One such study in the early 2000s had him collecting fire-injured tree data that were later used to create a model to predict delayed mortality for ponderosa pine. This "Malheur" model is still widely used by postfire managers. It requires just two variables to predict delayed mortality: the proportions of scorch to the tree bole (trunk) and the crown.

Years later, Westlind's red turpentine beetle research with research forester Rick Kelsey reminded him that postfire bark beetle attack data were also collected, but never used to build the mortality model.

"I wanted to find out whether or not the beetles were contributing directly to mortality or whether they could be used to predict postfire mortality," he says. Westlind and Kelsey were also interested in predicting the mortality of high-value larger trees, to evaluate any need to protect them during a prescribed fire, and more accurately identify dying trees for hazard removal or salvage after a wildfire.

When they ran the model to include the additional variable of red turpentine beetle or western pine beetle (*Dendroctonus brevicomis)* attack in 1 or 3 years postfire, the accuracy of the predicted mortality improved. And when running the model on ponderosa pines that were 21 inches or larger in diameter, there were further improvements in the accuracy.

"The red turpentine beetle is responding to ethanol generated by heat-stressed stem tissues, that in large trees is not captured by the bole and crown scorch proportion values. This additional indicator of stress enhances the model's ability to more accurately predict delayed mortality," explains Westlind.



Ponderosa pine with diameters larger than 21 inches have a higher probability of dying 3 years after a fire if they are attacked by red turpentine beetle in the first year postfire, as shown here by the Malheur model 3-D prediction planes at different levels of bole scorch and crown scorch proportions. Adapted from Westlind and Kelsey (2019).

Red turpentine beetles are one of the first bark beetles to attack fire-injured ponderosa pine in Pacific Northwest forests. Although they don't directly kill the pines, heavily attacked trees may be more susceptible to other stressors such as disease or drought. USDA Forest Service photo by Doug Westlind.

budget for traps; we can reuse them, but the price of lures can really vary, from $7 to $50. It just depends on the chemical being used."

In Oregon, a local company produces the lures and sells traps that Buhl and her team use to conduct trapping. "We're lucky to have this local resource, and I would hope they would tap into this research of Rick's to use in new lures," she says.

Future Attraction

Now Kelsey and Westlind are both retired and wrapping up their remaining red turpentine beetle research. Their current study delves even deeper into the chemical ecology of resin monoterpenes and red turpentine beetles by testing if there are regional differences in the attraction strength of the respective monoterpenes. For this study, they have research sites in Oregon, Arizona, and northern California. "There's a possibility that the environment in which we're trapping could influence how the beetle will respond and which lure is more attractive," says Kelsey.

Gaylord worked with Kelsey and Westlind to identify the Arizona field site and says she is looking forward to seeing the results: This research will, "give us insight on what the other beetles, which are causing more mortality, might be attracted to because there always seems to be a little bit of regional difference."

Whether another researcher will continue the red turpentine beetle research remains to be seen, but Kelsey and Westlind are hopeful. "What we find out about the red turpentine beetle will provide potential insight into the chemical ecology of other beetles as well," says Westlind. "For a lot of people, this minutia might seem insignificant, but how beetles communicate with their host trees and with other beetles is pretty fascinating stuff." It is also valuable information for forest managers wanting to keep a finger on the pulse of forest health.

> *"Life is a dimension of tree in the eyes of an insect."*
>
> —Sohrab Sepehri, poet

For Further Reading

Kelsey, R.G.; Westlind, D.J. 2017. Ethanol and primary attraction of red turpentine beetle in fire stressed ponderosa pine. Forest Ecology and Management. 396: 44–54. https://www.fs.usda.gov/treesearch/pubs/59236.

Kelsey, R.G.; Westlind, D.J. 2020. Red turpentine beetle primary attraction to (–)-β-pinene+ethanol in US Pacific Northwest ponderosa pine forests. PLoS ONE. 15: e0236276. https://www.fs.usda.gov/treesearch/pubs/61431.

Kelsey, R.G.; Westlind, D.J. 2021. Key structural features in *cis*-carane, (+)-3-carene, *cis*-pinane, (+)-α-pinene, and (–)-β-pinene influencing red turpentine beetle primary attraction when released with ethanol. Agricultural and Forest Entomology. 23: 243–249.

Kelsey, R.G.; Westlind, D.J. 2022. Red turpentine beetle primary attraction increases linearly with (–)-β-pinene+ethanol dose regardless of component ratios, and no change in response with addition of high-release frontalin. Agricultural and Forest Entomology. 24: 63–71. https://onlinelibrary.wiley.com/doi/pdf/10.1111/afe.12469.

Westlind, D.J.; Kelsey, R.G. 2019. Predicting post-fire attack of red turpentine or western pine beetle on ponderosa pine and its impact on mortality probability in Pacific Northwest forests. Forest Ecology and Management. 434: 181–192. https://www.fs.usda.gov/treesearch/pubs/57833.

Writer's Profile

Andrea Watts is a freelance science writer who specializes in covering natural resources topics. Her portfolio is available at https://www.wattsinthewoods. She can be reached via andwatts@live.com.

Science
FINDINGS

Pacific Northwest Research Station
USDA Forest Service
1220 SW 3rd Avenue, Suite 1400
Portland, OR 97204

Official Business
Penalty for Private Use, $300

Scientist Profiles

RICK KELSEY is a recently retired research forester with the Pacific Northwest Research Station. As an emeritus scientist, his research continues to focus on understanding the complex interactions between trees and the biotic (insects, pathogens) and abiotic (fire, drought, etc.) agents that cause them stress. His other research is directed toward discovering compounds in tree tissues with biological activity and understanding their ecological importance. Kelsey received his Ph.D. in forestry from the University of Montana.

Kelsey can be reached at:

USDA Forest Service
Pacific Northwest Research Station
3200 SW Jefferson Way
Corvallis, Oregon 97331

Phone: (541) 745-8275
E-mail: rick.kelsey@usda.gov

DOUG WESTLIND began working as a forestry technician with the Pacific Northwest Research Station in 1991. His early work with the station focused on laminated root rot in Douglas-fir, but since 1997 he has worked on the interactions of fire, insects, and diseases, including bark beetles and black stain root disease in ponderosa pine. He combines extensive field experience with a background in experimental design and statistics. He has a degree in geology from Oregon State University.

Westlind can be reached at:

USDA Forest Service
Pacific Northwest Research Station
3200 SW Jefferson Way
Corvallis, Oregon 97331

Phone: (541) 750-7376
E-mail: doug.westlind@usda.gov

Collaborators

William Brendecke; USDA Forest Service Pacific Southwest Region

Kenneth Neider, Sam Pearcy, and Faith Brown; USDA Forest Service Pacific Northwest Region

Daro Palmer; Washington Department of Fish and Wildlife, Sherman Creek Wildlife Area