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Science and Technology Research at the Canadian Forest Service • Pacific Forestry Centre

Incidence and occurrence of laminated root disease in interior forests

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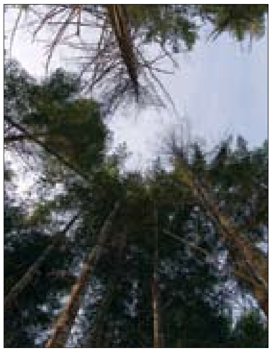
Data to improve inventories and tree-growth estimates

On the cover



Laminated root disease, caused by *Phellinus sulphurascens*, strangles nutrient transport in the roots of Douglas-fir.

Of two conifer-root diseases prevalent in British Columbia forests, laminated root rot, caused by the fungus *Phellinus sulphurascens*, is a major disturbance agent in coastal Douglas-fir stands; in drier, interior Douglas-fir forests, Armillaria root rot, caused by *Armillaria ostoyae*, is more common.

But *Phellinus* root disease scientists recently expanded their research territory to include Douglas-fir–leading forests in the province's southern interior.

"We know *Phellinus* occurs there," says Natural Resources Canada Forest Research Pathologist Rona Sturrock (rona.sturrock@nrcan.gc.ca). "We know it co-occurs with *Armillaria*, but no one had ever gone out and conducted a directed, large-area survey for *Phellinus* in the interior.

The goal of the new research, Sturrock says, is to determine where and how the fungus occurs in several timber supply areas in the region, how it co-occurs with *Armillaria* and how it's distribution relates to that of Armillaria root disease.

"Ultimately, we're trying to determine the impacts of *Phellinus* on these forests, and how analysts might adjust growth and yield predictions to include those impacts."

Phellinus sulphurascens is present in more than 80 percent of Douglas-fir stands on Vancouver Island, and has been found to reduce volume growth in infected coastal stands by as much as 40 to 70 percent.

But information on the fungus's incidence and occurrence in interior forests is incomplete. As well, *P. sulphurascens*' long-term impacts on stand productivity in the southern–interior remain unknown. As a result, says British Columbia Ministry of Forests and Range Forest Pathologist Michelle Cleary, its presence in mature, harvestable timber is inadequately acknowledged in growth and yield estimates and forest inventories.

"Current timber supply models don't include effects of *Phellinus* disease in the interior, because we don't have any information to accurately say what the expected losses are in these types of stands," Cleary says. "That's critical: we need to account for those losses in our timber supply modelling."

Phellinus affects timber volume in infected stands in two ways: by killing trees, and by causing trees with non-lethal infections on their root systems to allocate resources towards defense at the expense of growth.

Results from the study's three years of surveys, conducted across five provincial timber supply areas, show that *P. sulphurascens* occurs in locations ranging from the northern Shuswap south to the U.S. border, and from Merritt to east of the Arrow Lakes. More than 100 stands were surveyed: the fungus was found in one-third of them. In contrast, *Armillaria* was found in about two-thirds of the stands.

Almost three percent of all trees assessed in infected stands were found to have diagnostic sign of *P. sulphurascens* infection: ectotrophic mycelia growing around the root collar.

The stands surveyed included trees occurring both within and outside provincial growth and yield permanent sample plots, from which growth

continued page 3...

Fungus acquires a new identity

For decades *Phellinus weirii* sensu lato had been classified as two forms: one that causes root rot and mortality of Douglas-fir and other conifers (the 'Douglas-fir form'); the other, 'cedar form', occurring almost exclusively on western redcedar and yellow-cedar in western North America. Based on studies using molecular techniques, researchers now recognize the two forms are closely related species: *P. sulphurascens* is the Douglas-fir–predominant species, and *P. weirii, the* cedar. In 2005, Canadian Forest Service Research Pathologist Rona Sturrock and colleagues from the Pacific Forestry Centre and the University of British Columbia established a technique to quickly differentiate the species, which have similar fruiting bodies and culture morphologies.

A similar name change is proposed for *Armillaria ostoyae*, to *A. solidipes*. This new name is being considered by researchers and forest managers.

Sources

"Host–pathogen interactions in Douglas-fir seedlings infected by *Phellinus sulphurascens*" (Phytopathology), "Differentiating the two closely related species, *Phellinus weirii* and *P. sulphurascens*" (Forest Pathology), and other related articles are available through the Canadian Forest Service online bookstore.

Chemical analysis breaks down litter decomposition

A multi-year study of litter decomposition has illuminated key chemical changes that occur as forest biomass breaks down. In determining chemical changes in 11 litters sampled from warmer and colder sites as part of the Canadian Intersite Decomposition Experiment (CIDET), Natural Resources Canada researchers and colleagues have increased understanding of decomposition processes and how they contribute to forest carbon.

"Litter decay is critical to understanding how lignin and water-soluble chemicals work with carbon release and storage during decomposition," says Canadian Forest Service Emerita Research Scientist Caroline Preston (caroline.preston@nrcan.gc.ca), the study's chemist.

Found in plant cell walls, lignin binds with cellulose, another plant fibre, to make cell walls sturdy and strong. The more lignin a plant has, the woodier it becomes: lignin provides the shape and form of stalks, twigs, and tree trunks. Plants need it to conduct water and sequester carbon. After a plant dies, its lignin takes longer to break down than the rest of the biomass, and the carbon therein is released at a slower rate into the environment.

Using nuclear magnetic resonance (NMR) spectroscopy, Preston and colleagues investigated whether increased lignin could account for increased acid-unhydrolyzable residue in decomposing litters from sites with different mean annual temperatures. Acid-unhydrolyzable residue is the material remaining after extraction of plant matter using hot water, boiling sulphuric acid and other solvents. The scientists also tried to determine whether changes in organic composition would follow similar trajectories with carbon biomass loss.

The scientists found that foliar litter decomposition reaches relative equilibrium at six years, due in part to lower concentrations of tannins, phenolics, and other water-soluble structures, while tougher, larger plant compounds such as waxes and lignin are left behind. Litter-decomposition rates were affected by site soil chemistry with high accumulations of some elements such as iron and aluminum, which bind and stabilize organic matter.

"However, in most litter species characterized, the changes in organic composition could be correlated with carbon biomass loss due to climate—primarily temperature," says Canadian Forest Service Research Scientist and CIDET study leader Tony Trofymow (tony.trofymow@nrcan.gc.ca).

Work is underway to compile the research results from the same sample distribution spanning 12 years.

—D.C.

Sources

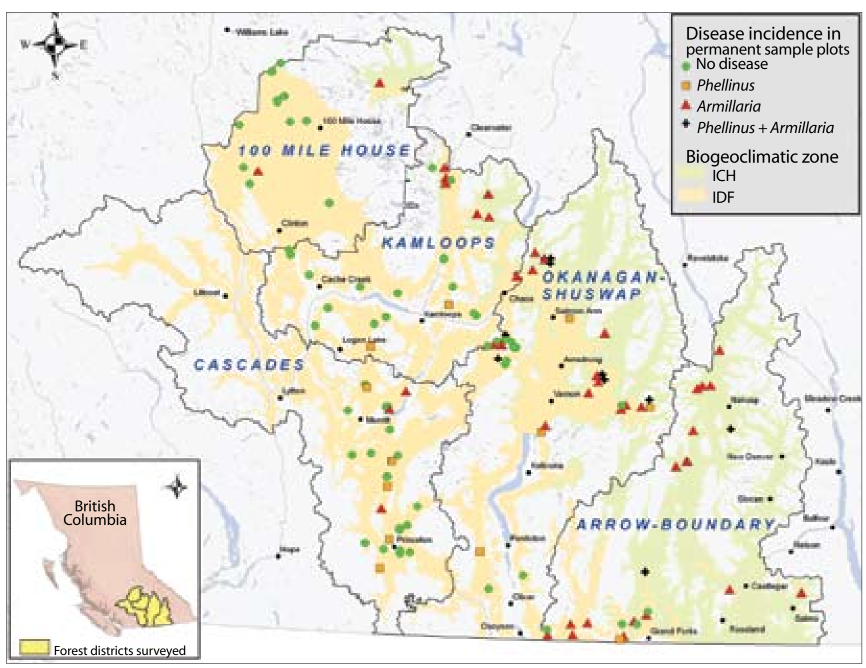
"Chemical changes during 6 years of decomposition of 11 litters in some Canada forest sites" (Parts 1 & 2) was published in the September issue of *Ecosystems*, and is available from the Canadian Forest Service online bookstore.

Root disease survey*... from page 2*

data have been measured and documented over decades. The researchers will use the archived growth data to determine the fungus's impact on tree growth and volume. This information will enable them to determine how best to represent the disease's impacts in growth and yield models, timber supply analyses, and forest inventories.

It will also enable forest managers to make better-informed decisions about root-disease management including species selection when replanting and silvicultural treatments when regenerating infected sites.

—M.K.



Incidence of *Phellinus sulphurasens* and *Armillaria ostoyae*, detected in five provincial timber supply areas during the three-year Canadian Forest Service–British Columbia Ministry of Forests and Range study

Lasers add new dimension to forests' annual check-up

Sources

Preliminary findings towards the use of lidar and digital aerial imagery as sampling tools to characterize volume killed by mountain pine beetle (Mountain Pine Beetle Program working paper 2008-15) is available from the Canadian Forest Service online bookstore.

Forest Dimensions Inc., of Saanichton, British Columbia, collected and provided lidar data for this project and interpreted the digital imagery.

With large areas attacked by the mountain pine beetle in British Columbia, keeping track of how forests across the province are changing is difficult. Now, a new technique by remote-sensing researchers from Natural Resources Canada and the University of British Columbia (UBC) offers forest managers a means of assessing forest health by estimating the volume of pine killed by the mountain pine beetle and other pests.

The researchers looked at how well lidar and digital aerial photography data can estimate the volume of standing dead pine. Lidar, short for light detecting and ranging, employs a laser mounted in an aircraft. By sending tens of thousands of pulses per second, lasers can map terrain heights and vegetation structure with sub-metre accuracy.

"We took an existing set of tools and applied them to a problem that British Columbia's obviously struggling with," says UBC Faculty of Forestry spatial analyst Chris Bater. "We're trying to improve the precision of volume estimates in a way that's cost-effective." The large area surveyed annually in the province requires cost-effective techniques, such as aerial overview surveys. Sample-based surveys aim to provide detailed and cost-effective survey opportunities, especially to assess timber volume losses.

"By sampling with lidar, you can cover a large territory more efficiently," says Bater. "It's taking things that are already done operationally in many parts of the world and combining them towards something useful we couldn't do before."

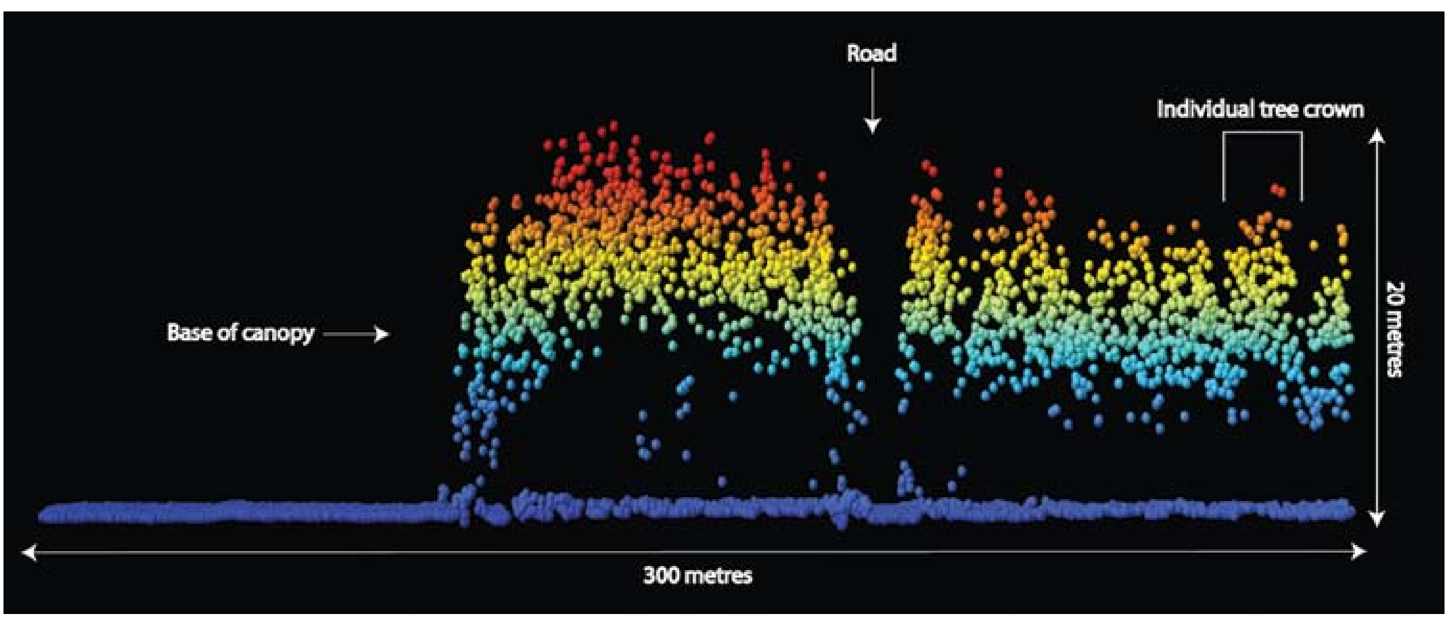
In the lidar project, funded by the Federal Mountain Pine Beetle Program, Bater and colleagues characterized tree height and infestation status by combining forest inventory data on vegetation communities, species composition, and crown closure with independent data they developed from the lidar survey and orthophotography—aerial photography corrected for terrain distortion. Using tree height and species type, they calculated volume for a 15,000-hectare pilot area. Results from lidar were then checked with volume estimates from the forest inventory. With an average difference for most plots of 20 cubic metres per hectare, they matched fairly evenly.

"It's encouraging to see how close the estimates were," says Mike Wulder (mike.wulder@nrcan.gc.ca), the research team leader. The team also learned that this pilot area would take approximately 50 quarter-hectare lidar-photo sample plots to estimate the mean volume of beetle-killed pine within a 10 percent error margin. Achieving a five percent error margin requires nearly 200 photo-plots, and two percent nearly 1250.

The study demonstrates that combining existing forest inventory information with lidar and digital orthophotography offers an effective way to estimate volume over large areas of disturbed forest, says Wulder. The sampling approach adds an efficient and statistically reliable option for forest managers to audit existing information or to update the status of forests affected by the mountain pine beetle—and conveniently, lidar data is already compatible with existing forest inventories and models. Approaches presented in this study are ready for commercial application.

—K.Z.

Transect of a stand of trees, as detected by lidar.
Photo credit: Christopher Bater, Forest Resources Management, UBC



Beetle-wood pulping woes resolved by researchers

When pulp mills first processed beetle-killed pine, trouble started cropping up immediately. The wood was dry, the chips blue, the pulp soapy. Changes to pine wrought by the beetle and its associated blue-stain fungi challenged pulp mills, but industry researchers funded by the federal Mountain Pine Beetle Program and Forestry Innovation Investment have found solutions that may even save mills money.

Kraft and thermomechanical pulp mills have each had their own troubles. Kraft pulping dissolves lignin from wood, leaving the fibres intact for durable paper destined for books and photocopiers. Conveniently, the process also extracts the blue-stain fungi, ridding fibres of the faded grey shades. The parched chips from dead pines require more water than normal logs, but there's little difference in paper quality.

But Kraft mills faced their own slippery problem. Treating the wood produces soap—a mix of fatty acids and resins usually skimmed, converted to tall oil, and burned in their lime kilns to reduce fossil fuel use in chemical recovery.

"When the beetle first struck, mills were swamped with soap because the pine trees reacted by trying to pitch out the invading beetle," says Vic Uloth, chemical recovery specialist at FPInnovations in Prince George. Then the soap disappeared. Soon after, the concentrator that evaporates the black liquor (the mash of chemicals and pulp left after cooking the wood) for burning began gumming up, and the recovery boilers began producing too much steam.

Uloth and colleagues analyzed the black liquor. The soap was still there; it was just sinking in the liquor. Two factors caused this to happen: blue-stain fungi thrive on fatty acids in the pine, which strips the acids from the wood, and an attacked tree releases up to three times more resinous pitch than usual, which boosts the resins in the timber. Together, these factors lower the fatty-acid–to–resin ratio in the resultant soap below that required for the soap to float. Uloth found that adding canola plant waste to the mix increased the fatty acids sufficiently to make the soap float.Saskatchewan farms, it just so happens, generate tons of plant waste from their canola crops.

Uloth and colleagues recently tried adding canola waste to the kraft process in trial runs at the Cariboo Pulp & Paper Mill in Quesnel. Results were promising, and they hope to integrate the process into industry, which could save each affected mill up to $2 million a year.

Research funded by the federal Mountain Pine Beetle Program into how to compensate for problems inherent in beetle-killed wood may help pulp mills across British Columbia save millions of dollars each year. Photo: kds-photo © 2007 iStock

It's a different story for thermo-mechanical pulp mills, where wood chips are physically ground into pulp. The mechanical process doesn't rid wood of the fungus, and the lingering pigments dull paper by five to eight notches on the industry's 100-point brightness scale.

"Brightness is a big issue," says Barbara Dalpke, a FPInnovations, Vancouver, fibre-supply researcher. Thermo-mechanical pulp is used to make newsprint and glossy catalogues, she points out, so "even one percent is a big deal."

Post-refiner hydrosulfite bleaching, optimal for healthy wood, wasn't brightening the blue-stained pine, and switching to peroxide reduces the yield. A team led by FPInnovations pulp-bleaching researcher Thomas Hu tried adjusting the pulp bleaching sequence and alkalinity. They found that by introducing hydrosulfite earlier, at the refiner stage, it mixes better into the pulp and brightens sheets nearer to regular levels. Adding peroxide after the refiner stage helped, too. Again, the pilot test went well, and they hope to scale it to a full mill.

—K.Z.

Sources

Mountain Pine Beetle Program working papers reporting on using mountain pine beetle-killed wood for pulp and paper are available from the Canadian Forest Service online bookstore.

Biofuels from beetle-killed wood emerging in

Sources

Bioenergy options for woody feedstock: are trees killed by mountain pine beetle in British Columbia a viable bioenergy resource? (BC-X-405), *Bioconversion of beetle killed lodgepole pine to bioethanol* (Mountain Pine Beetle working paper 2009-24), and "Biomass energy production opportunities from large scale disturbances in Western Canada" are available via the Canadian Forest Service online bookstore.

More information on Natural Resources Canada's Pulp and Paper Green Transformation Program can be viewed on the internet at cfs.nrcan.gc.ca/subsite/pulp-paper-green-transformation/home

As British Columbia's interior forest landscapes have been mottled red and grey from mountain pine beetle infestation, the world's energy interest has gone green. The international push for sustainable energy from reputable suppliers has led researchers at Natural Resources Canada and the University of British Columbia to assess the potential use of beetle-killed pine as biofuels.

No matter the form, all biofuels store energy less compactly than fossil fuels—for example, to heat a house to the same temperature, more carbon dioxide (CO_2) is released by burning wood than by burning oil. But biofuels are preferable because they release carbon that was removed from the atmosphere within the lifetime of the tree, which lasts anywhere from 50 to 400 years. Fossil fuels, in contrast, release carbon that has been stored underground for hundreds of millions of years, adding to atmospheric greenhouse gases and climate change.

The mountain pine beetle has killed about 580 million cubic metres of wood. Researchers are asking whether it is better for the global climate to let the wood rot in the forest, releasing the carbon slowly, or to salvage it and use it to offset fossil carbon use.

Canadian Forest Service carbon accounting team leader Werner Kurz and colleagues are developing means to assess where and when salvage logging would benefit the carbon cycle. While carbon is only one of many criteria to consider in managing forests, the effects of salvage logging on the carbon cycle in terms of local and global carbon budgets must be considered.

"Even with higher emissions in the short term, if we let the forests regrow, we end up with greater carbon sinks in the long term," says Kurz (werner.kurz@nrcan.gc.ca). "We can even reduce the risk that wildfire will emit the carbon without us capturing the energy to offset fossil fuels."

Researchers Brad Stennes, Kurt Niquidet, and Jack Saddler have used federal Mountain Pine Beetle Program funding to examine options for beetle-killed wood in British Columbia's alternative energy portfolio. Of the options for handling the energy stored in trees, three have stood out for beetle-killed pine. We can access it directly by burning the wood, convert it to bioethanol and add it to gasoline, or press it into biofuel pellets to ship to buyers around the world.

Light in colour and heft, biofuel pellets look like pencil-thin corks with the ends roughly snapped. Pellet mills make them by pressing the shavings and sawdust left over from milling logs. Most of the million tonnes British Columbia presses each year are shipped to Europe, where subsidies for renewable energy and penalties for burning fossil fuels make wood pellets appealing.

In the mid-2000s, strong lumber markets and the beetle-driven rise in available timber boosted production of lumber and, with it, fuel pellets. With no end of supply in sight, beetle-killed pine pellets were poised to take their place as a cheap and green alternative to increasingly costly fossil fuels.

"There was a lot of optimism around bioenergy from beetle-killed wood," says Canadian Forest Service Economist Brad Stennes (brad.stennes@nrcan.gc.ca). Then the 2008 global economic crash intercepted that trajectory. Then the softwood market crunch slowed British Columbia lumber processing, which shrunk the supply of mill residuals and increased pellet cost.

Exporting pellets to Europe makes economic sense to British Columbia when pellet mills can use residuals. With lumber production still low, the mill residuals remain in short supply. The alternative—chipping and transporting roadside residuals from harvesting sites for bioenergy use—can be economic if located near the bioenergy site, but is constrained by costs as distance increases. The most expensive option, direct harvest for energy, is not cost-effective unless energy prices are much higher than they are currently.

Mills make fuel pellets by pressing the shavings and sawdust left over from milling logs. Most of the million tonnes of pellets British Columbia makes each year are shipped to Europe.

British Columbia's alternative energy portfolio

Bioenergy is available in a simpler form than pellets: unprocessed biomass. Burning biomass to create heat for steam is both an easy and efficient way to access its energy. Projects to offset fossil-fuel use with biomass are cropping up throughout British Columbia, helped in part by the provincial government's aim for the province to return to self-sufficiency in its power needs and by Natural Resources Canada's Pulp and Paper Green Transformation Program.

A popular method of producing energy from biomass is cogeneration, which creates electricity by harnessing heat from biomass burned on-site. Mills are especially suited to cogeneration: they already gather and process forest biomass, and they possess the industrial capacity to burn and harness what would otherwise be treated as waste. Celgar, Mercer International's mill near Castlegar, currently sells up to seven megawatts back to the provincial power grid as a by-product of pulping, and with new planned investments in energy capacity, will be able to supply up to 30 megawatts of electricity over their internal needs.

Energy production that involves burning biomass directly is feasible only for fixed production points like wood stoves and cogeneration plants. Renewable sources like solar, wind, and tidal power similarly rely on immobile infrastructure. Internal combustion engines are another story.

"A major CO_2 offender is transport, but very limited options exist for replacing gasoline and diesel with a renewable energy source," says University of British Columbia forest biotechnology researcher Jack Saddler. "That's why we're looking at turning softwood residues into ethanol, which can be blended and substituted for gasoline."

Saddler's research has shown it is technically possible, and could one day be economically feasible, to convert beetle-killed pine to ethanol. By treating the wood chips with steam, Saddler found the enzymes broke down the carbohydrates more efficiently, boosting the sugar and subsequent ethanol yield.

It is pine's structural strength that weakens its potential as a biofuel. Nature designed feedstocks such as sugar from sugar cane and starch from wheat or corn to be broken down and easily used, but lignocellulosic materials such as wheat straw, corn stover, and wood are meant to last a long time. Lignin in softwoods further complicates the breakdown process, as anyone familiar with the long life and decay resistance of cedar and Douglas-fir knows.

Research, in part funded by the federal Mountain PIne Beetle Program, indicates it is possible to convert some of British Columbia's vast supply of beetle-killed wood into ethanol fuel.

Photo: Jack Saddler, University of British Columbia

Although converting softwood residues to sugars and then to ethanol has its challenges, lifecycle analysis—the total energy bill of a product from cradle to grave—shows that it may be greener than many corn-to-ethanol processes. What's more, unlike the seasonal harvest constraints on corn and wheat, we can harvest trees year-round; and British Columbia has the infrastructure and expertise to manage forests sustainably. Further, as Saddler says, because we can't eat trees, "the food-versus-fuel dilemma is a less contentious part of the biomass-to-ethanol debate."

Globally, more than 50 companies—including several in British Columbia—are developing commercial means to produce ethanol from softwood. As demand for more sustainable biofuels grows, more people are realizing the benefits of turning beetle-killed pine residues into biofuels.

—K.Z.

Outbreaks thin and accelerate volume growth in young

Understanding the complex interactions between insects and their hosts enables foresters to better manage natural ecosystem processes to meet objectives.

The most recent results from a multi-year Natural Resources Canada study examining impacts of sweeping defoliation caused by a western blackheaded budworm (*Acleris gloverana*) outbreak on stands of regenerating western hemlock on Haida Gwaii, off British Columbia's central coast, provide some such insights on pest–host interrelationships in temperate coastal forests.

In 2004, Canadian Forest Service Research Entomologist Vince Nealis (vince.nealis@nrcan.gc.ca) revisited study plots established on the islands after the last outbreak ended there in 2001, and measured impact: how many trees had died as a result of outbreak defoliation, how many had recovered, and consequences on growth rates.

He found overall mortality of juvenile hemlock due to the infestation to be low—only about seven percent—but aggregated. "In some stands, most trees are dead, but these are surrounded by green, recovering stands."

Dead tops (topkill) on surviving trees—a major impact of blackheaded budworm infestation—were counted in 1999. At that time, topkill affected

Breaking the code for predicting outbreak timing

Western blackheaded budworm (*Acleris gloverana*) is the Avenger of budworm species. Unlike other budworm species' outbreaks, *A. gloverana* strikes suddenly and disappears fast during outbreak, leaving stands of red conifers in its wake as the intense infestations percolate across a landscape of young, regenerating trees.

The blackheaded budworm oubreaks also differ in their almost clock-work regularity—they occur every 12 to 15 years in coastal British Columbia. However, the severity of these outbreaks can vary over the insect's extensive range.

"If you want to undertake management intervention or prevention, it would be helpful to get a heads-up a year or two before the trees turn red," says Canadian Forest Service Research Entomologist Vince Nealis (vince.nealis@nrcan.gc.ca).

Researchers from Natural Resources Canada's Pacific and Atlantic forestry centres recently cracked the code for predicting if and exactly when blackheaded budworm will outbreak in an area. Nealis worked with eastern colleagues to extend an Atlantic project testing pheromone lures on eastern blackheaded budworm (*A. variana*), infesting balsam fir in Cape Breton, Nova Scotia, to endemic western blackheaded budworm populations in British Columbia. Glacier National Park, in the province's interior, and Haida Gwaii, off the central coast, served as western test sites for lures made from *A. variana* and *A. gloverana* pheromones.

Both lures performed well in attracting *A. gloverana* moths to traps. More significantly, Nealis says, "in the process of comparing the two lures, we also were detecting the rise of the next coastal outbreak."

After four years of steadily increasing catch numbers, pheromone trap catches in Haida Gwaii surpassed outbreak-threshold levels in 2008; sure enough, in 2009, foresters mapped defoliation on the islands.

Nealis and colleagues also correlated catches with egg counts from sampled trees. Trapped budworm-moth numbers consistently corresponded to increasing budworm-egg numbers, confirming trap-catch frequencies directly relate to budworm population levels.

With this new tool to track population trends, forest managers gain one- to two-year advance notice of outbreaks. By adjusting and planning operations to take outbreaks into account, managers could turn blackheaded budworm's ability to hit young stands fast and hard to advantage.

—*M.K.*

western hemlock stands in coastal forests

Blackheaded budworm outbreaks naturally thin juvenile stands of western hemlock in west coast forests.

20 percent of young trees and was most severe in the tallest trees in the young stands that had been pre-commercially thinned in the early 1990s—that is, in stands where forest managers had invested the most money before the infestation in order to increase height growth. Topkill is a problem for any tree, but because western hemlock lacks strong apical dominance, topkill in hemlock becomes a major timber-quality problem: it turns young hemlocks into bushes as the trees grow out rather than up.

When Nealis revisited these stands, he found slow recovery of dominant leaders.

"These were trees that in some cases were as young as 17 years old when they lost their leaders to budworm," he says, "and at 22 years, they still didn't have growing tops; they're not growing *up*."

But their radial increment growth—the amount of wood added to stem girth—told a different recovery story. Core samples showed radial growth had slowed significantly during the two years after defoliation—regardless of amount of defoliation. Then, at Year 3, the trees rebounded. Increment growth rate was greater four and five years after defoliation than it had been before the outbreak.

All trees, regardless of their extent of defoliation, rebounded. But rebound was greatest in the most damaged stands—the stands that had been spaced prior to the outbreak.

From a forest management perspective, these new results indicate that stands spaced soon before an outbreak will sustain the most dead trees and lost tops—damage that hemlocks take a long time to recover from. If stands aren't thinned, fewer trees will die and trees will increase radial increment growth after the outbreak thins stands naturally.

However, thinning may be necessary in naturally regenerating western hemlock stands, which grow in thickly and stagnate quickly.

"There may be a middle ground," Nealis says. "Thinning young stands after budworm outbreaks, thinning when trees are older, or thinning less intensively may mitigate the most severe damage. We would need to investigate further to determine what works best."

Such practices might also enable forest managers to more efficiently and cost-effectively use processes that naturally occur in regenerating hemlock forests to increase growth and growth rates. —*M.K.*

Trapping blackheaded budworm moths with new pheromone lures enabled researchers to predict outbreak onset.

Sources

Visit the Canadian Forest Service online bookstore for "Defoliation of juvenile western hemlock by western blackheaded budworm in Pacific coastal forests" published in a 2004 issue of Forest Ecology and Management. See also *Information Forestry*, December 2005. "Pheromones and Populations of Western Blackheaded Budworm, *Acleris gloverana* Walsingham (Lepidoptera: Tortricidae)" and "Depletion and Recovery of Pacific Coastal Forests Following Disturbances by Forestry and Insect Defoliation" are in press.

Techniques aid identification of resistant white pine

Sources

Visit the Canadian Forest Service online bookstore for Natural Resources Canada research on blister rust resistance in western white pine.

New information about invasive pathogen *Cronartium ribicola* and resistance in western white pine may help forest managers re-establish the economically and ecologically valuable tree species in western North American forests.

National Sciences and Engineering Research Council post-doctoral candidate David Noshad (dnoshad@nrcan.gc.ca) recently developed an *in vitro* screening process that permits researchers to identify partial resistance to white pine blister rust, the devastating disease caused by *C. ribicola*, in western white pine. Noshad's research at Pacific Forestry Centre complements ongoing work on blister rust resistance in western white pine by Natural Resources Canada colleagues, particularly retired Research Scientist Richard Hunt.

"The genetic families of white pine that I looked at had been identified by tree breeders as 'difficult to infect,'" Noshad says. "We confirmed that four or five are indeed partially resistant to the rust."

Following up his results with electron-microscopic examination of the resistant plant tissues, Noshad detected some of the structural defense mechanisms that confer resistance. "Mostly, the stomata are occluded with some kind of waxy compound," Noshad says.

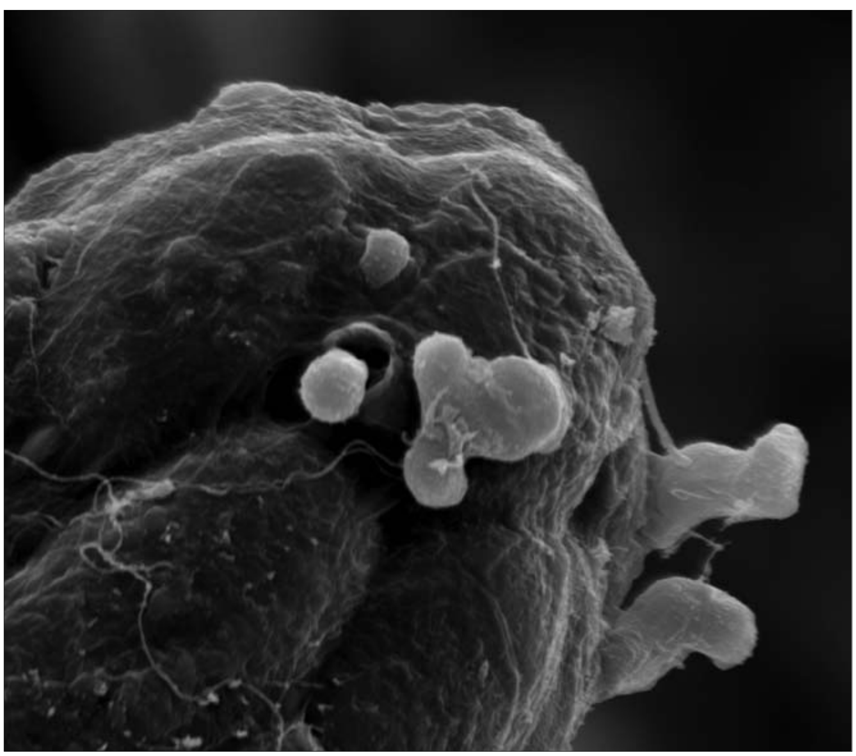
He also tracked pathogen development through *C. ribicola*'s entire life cycle, which comprises five life stages. He examined it weekly with both light and electron microscopes for one year, and manipulated its environment to determine effects of temperature, humidity, and other factors. *Cronartium ribicola* requires two host species to complete its five-stage life cycle. The host in British Columbia during the rust's aecial (early) life stage is western white pine; currants from the *Ribes* family host the pathogen during a later life stage. "This work suggests that *Ribes* may be the main host," Noshad says. "The pathogen wants to survive on *Ribes*, but *Ribes* plants go dormant in the fall—they lose their leaves, so the rust transfers to pine to survive the winter. It's a very flexible pathogen."

Since it was introduced to North America on seedlings shipped to Vancouver from Europe in the early 1900s, *C. ribicola* has spread across the continent and nearly wiped out once-common western white pine forests. The rust kills its pine hosts by forming cankers on the bark of the trees and cutting off flow of nutrients between roots and needles. *Ribes* hosts tend to suffer only leaf spots and some leaf loss.

Of all the white pines, western white pine is particularly susceptible to *C. ribicola*. Being both drought tolerant and cold hardy, it grows well across many biogeoclimatic zones and elevations. It has a deep rooting system that prevents soil erosion, it provides habitat for wildlife, and it has uniform wood characteristics that increase its value for timber. It is also naturally resistant to certain kinds of root disease that affect other conifer species common in British Columbia. For these reasons, forest researchers are keen to isolate and propagate rust-resistant strains of western white pine to grow in British Columbia and elsewhere.

Since Noshad presented the results of this research at conferences and via a live web–video seminar at the Pacific Forestry Centre last year, researchers from across Canada and the U.S. have contacted him about his work. *—D.C./M.K.*

In tracking the life cycle of white pine blister rust-pathogen *Cronartium ribicola* week-by-week, Noshad determined effects of temperature and humidity on the rust's development. Shown here, nodules (telia) containing *C. ribicola* teliospores.



New from the bookstore

...continued from page 12

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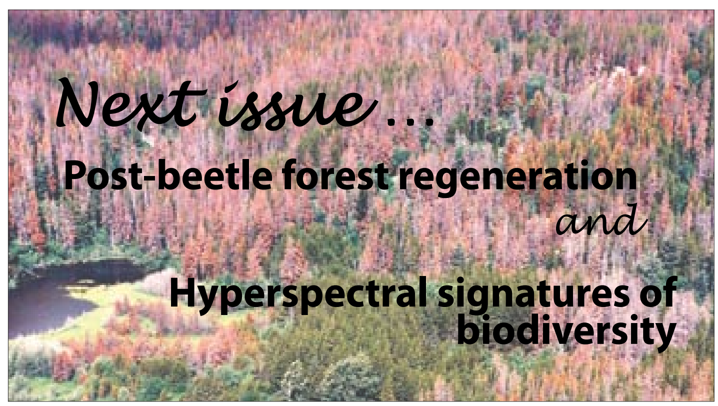
continued page 11...



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