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Pacific Forestry Centre
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Dwarf mistletoe

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Natural Resources Canada / Ressources naturelles Canada
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Canada

Managing Dwarf Mistletoe - A Biological and Genetic Control Approach

"Research into developing a biological control strategy for dwarf mistletoe looks promising..."

Dwarf mistletoe may sound like a cute festive ornament, but in a forest it can mean disaster.

Not to be confused with Christmas mistletoe (*Viscum album*), dwarf mistletoe (*Arceuthobium* spp.) is a parasitic plant that infects conifers, causing suppressed growth, decreased wood quality and reduced seed crop production. Found in western Canada and the U.S. as well as parts of Mexico and Asia, dwarf mistletoe causes more damage to commercially important conifer timber stands than any other pathogen, with annual volume losses estimated to be over 3.7 million m3 in B.C. alone. The Canadian Forest Service is developing a biological control strategy to manage the parasitic plant.

"Although research studies into biological control of dwarf mistletoes took place in the late 1960s and early 1970s, it did not continue because logging practices at that time reduced the impact of dwarf mistletoe infection," says Dr. Simon Shamoun, research scientist in the Pest Management Methods and Effects of Forestry Practices Networks. "But the current emphasis on partial cutting means that it is theoretically possible that every tree planted or naturally regenerated will be literally showered with mistletoe seeds (inoculum) from infected border trees, resulting in plantation failure. Biological control strategies would be particularly appropriate in respect to current forestry practices where direct silvicultural measures are not possible."

Adds Dr. Paul Addison, manager of the Effects of Forestry Practices Network, "Dwarf mistletoe can limit the use of partial cutting (non-clearcut) systems in many places in Canada. An effective biological control strategy for this species will be one more step toward sustainable forest management."

So far, Shamoun's research into developing a biological control strategy for dwarf mistletoe looks promising for two of B.C.'s major conifers, western hemlock and lodgepole pine. Working at the Pacific Forestry Centre, he has identified two hyperparasitic fungi that are potential biocontrol agents. One is *Colletotrichum gleosporioides*, a species that attacks the shoots and berries on western hemlock and lodgepole pine dwarf mistletoes. The other, *Nectria neomacrospora*, destroys the endophytic system (the internal swelled areas on an infected tree branch) of western hemlock dwarf mistletoe, preventing the resprouting of mistletoe shoots.

"Our plan is to develop a multiple infection formulation where both the shoots of dwarf mistletoe and its endophytic system are attacked by fungi that are not only indigenous to B.C. but are specific to certain organs in the parasite," explains Shamoun. "Such a biocontrol strategy does not upset the ecosystem by eradicating the parasitic plant completely, but effectively manages dwarf mistletoe by reducing the amount of inoculum."

Shamoun plans to treat infected trees bordering new openings in partial cut stands, or single residual trees within openings, rather than treating entire stands. "It has been observed (in openings) that as the crown of trees expand, the mistletoe plants in the interior of the crown eventually die out, and if the rate of growth of the trees sufficiently exceeds the spread characteristics of the mistletoe, the tree can escape infection. An effective biocontrol agent therefore does not have to eradicate mistletoe from entire stands."

In keeping with the concept of managing dwarf mistletoe without disturbing the complexities of the ecosystem, Shamoun also plans to investigate genetic resistance strategies that are both environmentally acceptable and economically feasible.

This research is being conducted in cooperation with: Forest Renewal B.C.; the B.C. Science Council; the B.C. Ministry of Forests (Vancouver and Kamloops regions); industrial partners MacMillian Bloedel, Riverside Forests Products, Dr. H. Kope (Contact Biologicals Inc.), and Dr. W. Hintz (MycoLogic Inc. - University of Victoria); graduate students S. Deeks (c/o Dr. Z. K. Punja, Simon Fraser University), T. Ramsfield (c/o Dr. B. Vander Kamp University of British Columbia) and C. Jerome (c/o Dr. B. Ford, University of Manitoba); and C. Oleskevich, Dr. A. Thomson and Dr. R. Hunt of the Canadian Forest Service. Currently collaboration is underway with U.S. Forest Service in Alaska, Washington and Oregon.

Dr. Shamoun can be reached at
sshamoun@pfc.cfs.nrcan.gc.ca

Catching Tree Thieves using DNA Analysis

"DNA matching in trees has never before been applied to forensic purposes in Canada."

Their getaway vehicle may be a logging truck rather than a white Ford Bronco, but tree rustlers might soon be subject to forensic techniques similar to those used to apprehend other criminals. DNA analysis may become a vital investigation method for apprehending tree thieves and ultimately curbing the crime.

The Canadian Forest Service in partnership with the B.C. Ministry of Forests has been testing the feasibility of tree genotyping (using DNA to distinguish between individual trees) to determine if a specific log has been harvested without authority.

"The results from the feasibility study have been very encouraging," explains Dr. Eleanor White, research scientist with the Canadian Forest Service, Forest Biodiversity Network. "We were able to extract DNA from needles as well as from the inner bark of yellow cedar. We cloned the DNA and screened the genomic clones for microsatellites (highly variable DNA regions used as DNA markers) to see if enough of them could be identified for individual genotyping. Not only were we able to extract the DNA in large amounts and maintain good quality, but we discovered that the genome (all the genetic material in the chromosomes) of yellow cedar contains the genetic structure that would be necessary to do DNA matching."

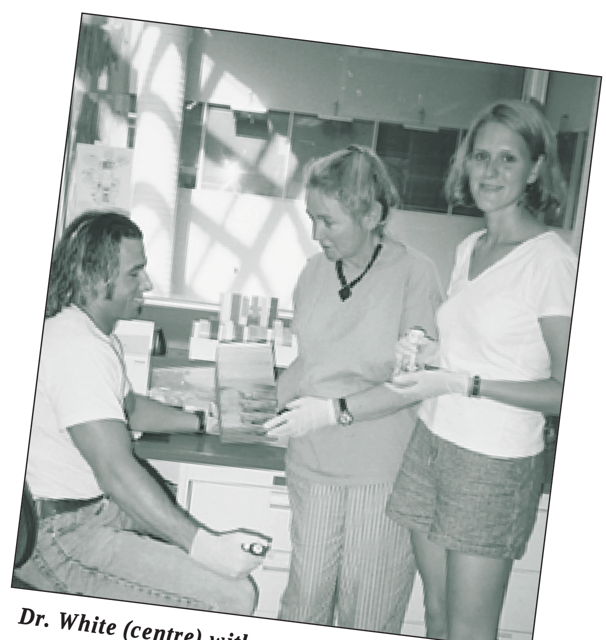
Tree thefts occur on Crown land, private land, and on ecological reserves throughout Canada's forests. In B.C., between 10 and 20 million dollars annually is lost to tree rustlers. Convictions in the past have been secured through matching the shape and annular rings of a "biscuit" piece cut from the butt of the stolen tree with its stump. But thieves now remove a meter from the butt of the stolen log to make the "biscuit" technique ineffective. Without that technique, "catching them in the act" is virtually the only evidence that can stand up in court against an accused individual or company. Through DNA analysis, however, a tree thief could be convicted even if there were no witnesses to the crime.

"The goal of this project is to provide 'baseline DNA data' to make the matching of DNA in individual trees much easier and less expensive," says Jerry Hunter of the Compliance and Enforcement Branch in the Ministry of Forests. "Not only will DNA help catch thieves, it will also deter them."

Due to the complexity of this initiative, the first phase was limited to DNA matching in yellow cedar only. "But since the research was so successful with yellow cedar," adds White, working at the Pacific Forestry Centre, "we applied it to red cedar, some of which was 257 years old. That was a bit more challenging as at that age the heartwood is full of contaminants which kill the enzymes used to analyze DNA. But we found that extracting the DNA from a block of an old tree was possible, which means that this forensic technique may be applied to forest products like cedar shakes well after the tree has been stolen and the wood processed."

Although similar DNA analysis techniques have been used to analyze forest genetic diversity, DNA matching in trees has never before been applied to forensic purposes in Canada. But should the research prove to be successful in apprehending thieves and deterring them from stealing, it is possible that the process will be applied to other tree species across the country.

Dr. White can be reached at ewhite@pfc.cfs.nrcan.gc.ca



Dr. White (centre) with assistants in the DNA lab

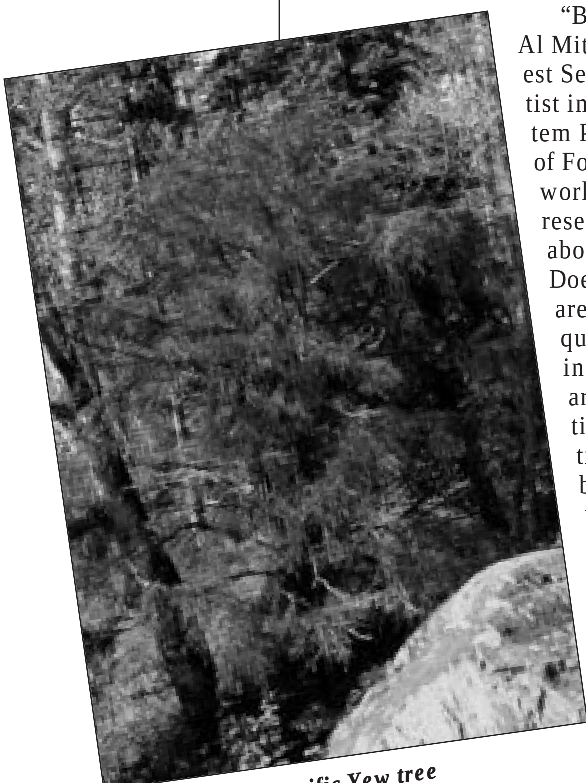
Getting to Know Yew

"The Pacific yew story has been a voyage of inquiry."

The most exciting phrase to hear in science, the one that heralds the most discoveries, is not 'Eureka!' (I found it!) but 'That's funny'... Isaac Asimov

When it comes to research on Pacific yew, "That's funny" is a common phrase. Since the discovery of Taxol, an anti-cancer drug extracted from the bark of Pacific yew, researchers at the Pacific Forestry Centre have been studying the distribution, growth and resiliency of the species to determine its tolerance to environmental stresses. The results have been very surprising.

"Before 1991," says Dr. Al Mitchell, Canadian Forest Service research scientist in the Forest Ecosystem Processes and Effects of Forestry Practices Networks, "you could ask researchers questions about Pacific yew — Does it grow in open areas? Can it grow quickly? Does it survive in water deficient areas? Would vegetative propagation of old trees in natural stands be possible? — and the answers would have been no. But research now indicates that the answer to all of these questions is actually yes."


Pacific Yew tree

Pacific yew is a long-lived tree usually found in the understory of old-growth stands. This led to the assumption that the tree is slow-growing and intolerant of full sunlight. However, studies on acclimation to sun and shade now indicate that Pacific yew has many mechanisms to mitigate stresses associated with growing in exposed areas.

Although Pacific yew grows slowly in the deep shade of natural stands, intensive nursery culture of rooted cuttings of Pacific yew can result in substantial growth (40 cm yearly). This may mean that yew grows slowly because of the low light environment and not necessarily because it is genetically programmed to grow slowly.

"It was also believed that Pacific yew could grow only in riparian zones (near streams)," explains Mitchell. "But through monitoring soil water deficits and photosynthesis, we found that Pacific yew can tolerate severe water stress. It appears that although trees growing in different areas may look remarkably different, they seem to be able to acclimate to a wide range of environmental conditions."

With respect to the likelihood of successful vegetative propagation (rooting cuttings), Mitchell explains that because Pacific yew trees in natural stands tend to be very old (100 to 300 years) it was assumed that they could not be propagated (it is almost impossible to propagate pine trees over the age of 60). But Pacific yew can be successfully propagated, even if the tree is well over 100 (although older trees were harder to propagate).

One of the most surprising discoveries in Pacific yew research has been the detection of the yew big bud mite. "During our investigations of Pacific yew stress tolerance, we made a serendipitous discovery," said Mitchell. "There is a mite that infests the buds of Pacific yew (Forest Pest Leaflet 79, May 1997) and we have deduced that it may have been introduced to B.C. from Europe. This mite could affect the success of programs to conserve Pacific yew through cultivation in nurseries."

The Pacific yew story has been a voyage of inquiry and a demonstration of how the search for conservation and cultivation options for the sustainable development of Taxol has led CFS researchers to discoveries that will help to predict and prepare for the consequences of disturbances to Pacific yew and to forest ecosystems.

Adds Dr. Paul Addison, Manager of the Effects of Forestry Practices Network, "The basic understanding of this species is fundamental to the development of strategies for its management. In this case, Dr. Mitchell has again demonstrated the need for research in forestry."

Dr. Mitchell can be reached at amitchell@pfc.nrcan.gc.ca

Detecting Forest Pests

"We often don't know about these pests until some time after they're reached our shores."

For some, the word "exotic" triggers thoughts of tropical islands. But for Canadian Forest Service (CFS) scientists Dr. Lee Humble and Dr. Eric Allen, "exotic" coupled with the word "species" may mean serious damage to native plants and trees, as well as to native insect species in Canada.

Pests or non-indigenous species from other countries have been "hitching" rides on cargo or dunnage on ships since the beginning of trade on this planet. Although few species outlast the journey, survival rates are rising as vessels coming from other continents now take less time to arrive at our ports. Greater numbers of containers being shipped across borders, more trade from temperate countries, and changes in the overall global movement of people all raise the potential for exotic species such as insects, fungi, nematodes, bacteria and plants to reach our shores. In collaboration with the Canadian Food Inspection Agency, CFS researchers in the Forest Biodiversity and Forest Health Networks attempt to determine what native and non-native species are present within Canada's borders.

Chinese longhorn beetle

"We often don't know about these pests until some time after they've reached our shores," says Dr. Allen, head of the Forest Health unit at the Pacific Forestry Centre. To determine the pathways through which exotic pests enter the country, Dr. Allen focusses on quantifying high-risk commodities such as wood-based wire rope spools that have been found to contain some non-native insects. In cooperation with other scientists in the Forest Health Network, he is developing detection methodologies and creating risk scenarios to determine the likelihood of certain non-indigenous species establishing in Canada. Taking into consideration the life history of a particular species, Dr. Allen looks at the climate of the country that the species is native to and matches it to where the climate may be similar in Canada.

"Three years ago we started looking at some urban parks and national wildlife areas in B.C.'s lower mainland to see if certain non-indigenous species that were a threat to forestry were established," says Dr. Humble, an entomologist who heads two insect trapping projects in the area. Two exotic species that the research team were trying to locate, the European spruce bark beetle and the European pine shoot beetle, were never found. However, Dr. Humble and his staff did discover four well established exotic European or Asian ambrosia beetles.

From these forested areas on the lower mainland, 1500 trap collections were brought back to the insectary at the Pacific Forestry Centre for inspection this past summer. At this facility, containing more than 7500 different species of insects, staff examine and identify non-indigenous species in an attempt to detect newly introduced insects at an early stage. In this case, they found some six distinct species of exotic insects in one collection. Based on these studies, researchers were able to determine that more than 20 percent of the total bark beetle fauna at these sites was non-native.

"There is no way of knowing whether an introduced species is going to be harmful," says Dr. Humble. "They have not evolved with the plant species they're attacking on this continent. There tend to be no evolutionary checks or balances, so the plant may actually be more susceptible to the pest." Dutch elm disease, chestnut blight and white pine blister rust are all examples of exotic tree diseases that have affected native plant diversity in Canada.

"The threats posed by introduced species to biodiversity are immense, insidious and ever-increasing," says Gerrit van Raalte, manager of the Forest Biodiversity Network. "That is why the work of Drs. Humble and Allen is extremely important."

At the Pacific Forestry Centre, staff are developing new tools that will greatly assist in tracking down non-indigenous species. With this information, scientists will eventually be able to assess the rate of introduction of these species, determining whether these rates are increasing or decreasing. "We have a unique set of circumstances here," says Dr. Humble. "In both the Forest Health and Forest Biodiversity Networks we're striving to develop methods to detect introduced pests."

Dr. Humble can be reached at lhumble@pfc.nrcan.gc.ca Dr. Allen can be reached at eallen@pfc.nrcan.gc.ca

Is There Life

"Nothing has been looked at in this particular scale or detail probably within coastal North America."

The term old-growth often inspires thoughts of the temperate rainforests of British Columbia; western redcedar and Douglas-fir tower amidst a vast carpet of ferns and moss-covered logs. Yet, beneath the lush canopy of ancient forests is a complex system for moderating local climate change, storing carbon and providing a fundamental habitat for mammals, birds, fish and insects.

In the last 100 years these forests have undergone enormous changes through harvesting and other disturbances. More recently, old-growth forests have been the focus of attention for many who fear that Canada (home to 25% of the world's coastal temperate rainforests) is in danger of losing one of its most significant natural assets.

Dr. Tony Trofymow, research scientist in soil ecology, and other Canadian Forest Service (CFS) scientists such as Dr. Caroline Preston and Dr. Doug Goodman, have devoted their energies to examining changes in forest ecosystems on southern Vancouver Island following the conversion of old-growth forests to managed forests. As part of the Forest Ecosystem Processes Network at the Pacific Forestry Centre, they aim to determine whether old-growth conditions recover in older second-growth forests.

Using a chronosequence research model, scientists study changes in the nature and fluxes of carbon and nutrients with forest development (comprising the four stages of regeneration, immature, mature and old-growth), the diversity of soil fauna and flora, small vertebrates and vascular and non-vascular plant varieties. By examining long-term changes in the forest ecosystem, CFS scientists assist foresters in developing forest practices that improve the care of managed forest lands in B.C. and hence preserve biodiversity and sustainability.

What are Chronosequences?

Imagine being able to travel ahead in time about 150 years to see how second-growth forests compare to today's old-growth forests. Will they have the same characteristic plant and animal species, upholding a similarly complex level of ecological interaction? "Because of the nature of forests and how long-lived they are it's quite difficult to answer these sorts of questions," says Trofymow. "There are two sorts of studies you can do; you can cut down a forest and then watch for 100 years and see what kinds of things come back," but "that takes several generations of foresters." An easier way is to set up a chronosequence which enables researchers to examine forests at several stages of growth during a relatively short period. He describes this approach as "substituting space for time". Used to conduct timber inventories and predict tree growth in the forest industry, CFS scientists apply the chronosequence model to arrive at a more complete picture of future forests. "Nothing has been looked at in this particular scale or detail probably within coastal North America," explains Trofymow.

Initiated by Forest Ecosystem Dynamics Program in 1991, researchers began to look for sites to study changes resulting from converting forests in the Coastal Western Hemlock (CWH) zone of southern Vancouver Island. In 1992, five western hemlock dominated sites and five Douglas-fir sites were chosen and chronosequence plots established. These sites gave scientists a chance to observe two climatic extremes: the drier forest types of the zone on the leeward side of the Island (Douglas-fir) and the wetter types on the windward side of the Island (western hemlock). Each of the ten sites had stands inside an area of five square kilometers or less, comprised of four ages and similar within environmental conditions such as elevation and slope.

What factors does the chronosequence model take into account?

The chronosequence model has three component study topics including: ecosystem description, ecosystem processes, and biological diversity. Ecosystem description looks at site and soil descriptions, structural characteristics of the forest environment, and indicator plant species.

As a soil ecologist, Dr. Trofymow is interested in ecosystem processes studies which examine microbial activities, soil respiration, rates of decomposition, and how they vary in different forest stands and different stand ages. One of his main questions concerns the amounts of carbon tied up in detrital materials

After Old-Growth?

such as coarse woody debris, the forest floor, and other organic matter, and the loss rates and influx rates into these detrital pools. "One of the things we wanted to get a better handle on was how those sorts of pools changed during secondary stand succession," he says. An essential part of the ecosystem processes studies, scientist Caroline Preston looks at how mineral soil organic matter, litter fall, forest floor, and dissolved organic carbon are transformed from original plant carbon into various compounds, and are then lost as carbon dioxide in the atmosphere. Dr. Preston also explores the role of tannins (from various tree barks) within forest ecosystems.

The ecosystem processes studies are linked to the Canadian Intersite Decomposition Experiment (CIDET), a climate change study that Dr. Trofymow has led since 1992. The experiment looks at how rapidly needles, leaves, grasses, and wood decompose and release carbon into the atmosphere. Finding out how organic matter decomposes helps determine how these releases influence levels of carbon dioxide, a greenhouse gas connected to global climate change.

As part of the biodiversity studies, researchers look at soil fauna such as collembola, plant life such as canopy lichens, and vertebrates such as salamanders to determine possible discrepancies in different forest stands. Due to an interest in the conservation of biodiversity, CFS forest soil ecologist Doug Goodman studies types and distribution of ectomycorrhizas, a symbiosis of tree roots and fungi found mostly in the forest floor. Dr. Goodman's study concerns whether old-growth is required habitat for some species of ectomycorrhizal fungi.

How does this research approach benefit forestry?

The chronosequence approach provides information that can be used by provincial agencies and forest companies for improving the management of forest lands in B.C. And because the study looks at varied aspects of a forest, the chances of coming up with satisfying responses are great. "The chronosequence studies undertaken by Tony Trofymow and his collaborators clearly demonstrate the benefits of multi-disciplinary research needed to

Dr. Trofymow checking data logger in old-growth chronosequence plot

support the forest industry's migration to ecosystem based management," says Bill Meades, manager for the Forest Ecosystem Processes Network.

CFS scientists and other researchers will be reporting on their results of the first five years of the chronosequence experiment at a workshop to be held at Ocean Pointe Resort in Victoria from February 17 to 19, 1998. This meeting will give biologists, foresters and researchers the opportunity to share findings from recent studies in coastal B.C. on the effects of converting old-growth forests to managed forests. The three day workshop called "Structure, Processes and Diversity in Successional Forests of Coastal British Columbia" will also introduce general audiences to the idea of using chronosequences as an effective tool to conduct forest studies. Says Trofymow, "I think it's going to be able to give us a good understanding that will lead into a lot of insights, and hopefully better forestry practices in the future."

Dr. Trofymow can be reached at ttrofymow@pfc.forestry.ca. Information on the workshop is available via the World Wide Web at http://www.pfc.cfs.nrcan.gc.ca

Studying the World Underfoot

"What we have is a mutualistic symbiosis of a root of a plant and a fungus."

"To see a world in a grain of sand, and a heaven in a wild flower." These words by English poet William Blake bring to mind the abundance of flora and fauna thriving in the soil. Shaded by nature's canopy, the role of these lesser known organisms is essential for the overall function of forest ecosystems. One such living entity is a fungus and plant root that combine to form ectomycorrhizae. Formed by almost all trees in temperate forests, these tiny structures help trees acquire water and nutrients.

"What we have is a mutualistic symbiosis of a root of a plant and a fungus," says Doug Goodman, a biologist with the Canadian Forest Service (CFS) in the Ecosystem Processes Network. Mutually beneficial for each partner, these ectomycorrhizal roots produce plant hormones that cause the morphology of the root to be altered depending on the species of fungus and its host species. On the southeastern coast of Vancouver Island, Dr. Goodman and others studied dominant and co-dominant species of ectomycorrhizal fungi and a large number of less common species in mature and old-growth stands of Douglas fir.

His study showed that mature stands (about 80 years old) had acquired an ECM flora very similar to that of old-growth stands, at two sites where the old growth was adjacent to mature stands.

Ectomycorrizae – a mutualistic symbiosis of a fungus and plant root

"I found only marginal evidence that any of the 70 types of ectomycorrhizal fungi we observed were more abundant in one age class than the other, and no evidence that any fungus was specific to one age class," he says. Dr. Goodman demonstrated that the original diversity of ectomycorrhizal fungi should be able to recover by the time a second stand matures, given appropriate management of mature or old-growth stands that are close to a maturing stand.

Questions remain however about the dispersal of ectomycorrhizae and the effects of clearcutting on these dispersal patterns. "We don't know at what age ectomycorrhizae re-enter maturing stands, and that knowledge could be necessary for their conservation," explains Dr. Goodman. "We also don't know what happens where a large area of forest has been clearcut and old-growth patches haven't been left behind. It may be important in the landscape to maintain patches of old growth to provide an area from which these fungi can disperse into maturing stands."

Through his work at the Pacific Forestry Centre, Dr. Goodman collaborates with Dr. Tony Trofymow in assessing the effects on biological diversity of converting old-growth forests to second-growth forests. Dr. Goodman is also currently editing and contributing to a publication for forest ecologists with Dr. Trofymow and other researchers titled *A Manual of Concise Descriptions of North American Ectomycorrhizae*. "This manual is useful to ecologists studying the effects of various forest management regimes on ectomycorrhizal communities. In order to study a community you have to be able to identify its members," says Dr. Goodman.

By studying ectomycorrhizal fungi in mature and old-growth forests in B.C., Dr. Goodman and his collaborators provide a greater understanding of their functional diversity and the effects of different forest management regimes on these symbiotic fungi.

Dr. Goodman can be reached at
dgoodman@pfc.cfs.nrcan.gc.ca

Root Rot Research Reveals Results

"It is one of the most damaging root diseases affecting Douglas fir."

It may sound like a new design for your veneered coffee table, but laminated root rot is not something you want associated with your home.

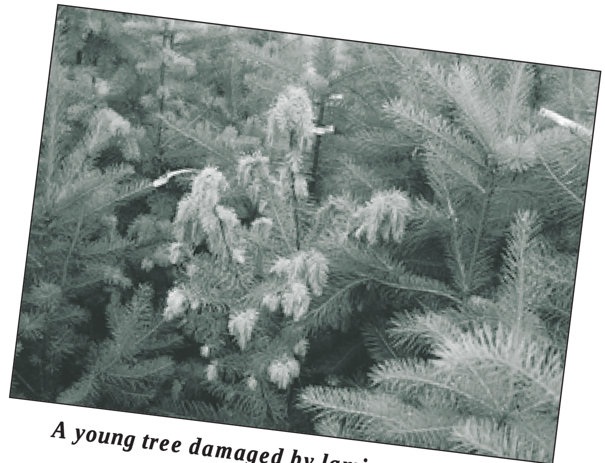
Caused by the fungus *Phellinus weirii*, laminated root rot (LRR) causes wood to decay and separate along annual rings as laminations (hence the term, "laminated root rot"). It is one of the most damaging root diseases affecting Douglas-fir in northwestern North America, reducing timber volume and growth by millions of cubic meters annually.

"There are a number of fungi that cause root diseases in B.C. but *P. weirii* is the major root pathogen on the coast," explains Rona Sturrock, researcher in the Canadian Forest Service Effects of Forestry Practices Network. "While LRR has been a natural component of coastal ecosystems for thousands of years, its incidence in our forests, particularly in management stands, has been increased by several factors such as the restocking of infected sites with only Douglas-fir, and in the loss of a native, LRR-tolerant conifer, white pine to white pine blister rust."

Like many root diseases, LRR spreads via root contact and can survive in stumps and roots for decades, acting as inoculum for subsequent rotations. There are several management strategies for LRR, most of which are best conducted at the time of stand regeneration when inoculum can be reduced through stump removal or other means, or when tree species which are immune (or have a low susceptibility to the fungus) can be planted.

Sturrock and other researchers at the Pacific Forestry Centre are trying to determine if there are any Douglas-fir families that are more tolerant to LRR than others. It is the first screening study of its kind involving *P. weirii*.

"A few years ago we developed a technique for inoculating seedlings," explains Sturrock. "That research, and funds provided recently by Forest Renewal B.C., have enabled us to conduct our current study with material provided by the B.C. Ministry of Forests under their Douglas-fir Tree Improvement Program. We are hoping to provide B.C. Ministry of Forests with information on disease tolerance so they can build it into their breeding program."



A young tree damaged by laminated root rot

"The Douglas-fir Tree Improvement Program is a breeding program for coastal Douglas-fir," adds Mr. Jack Woods, research scientist with the Ministry of Forests. "We are hoping to find and promote tolerant Douglas-fir families. We provided the Canadian Forest Service with 97 families of Douglas-fir of which we know the genetic history. We hope to apply the research to our breeding program."

For each of the 97 Douglas-fir families, 36 seedlings were inoculated, adding up to approximately 3500 inoculated trees. The seedlings that have survived are now five years old.

"To discover if there are any family-related trends, we are studying seedlings that were not killed or infected by *P. weirii*," said Sturrock. "We have found that every family had seedlings that had been killed or infected by the fungus, so it appears that, at least so far, none of the families are resistant to LRR. But it appears that some have a stronger tolerance to *P. weirii* than others. Of course, these are only preliminary results; our study is still ongoing."

If this research provides evidence of Douglas-fir tolerance to the fungus, the next step in the project would be to screen candidate families against a variety of *P. weirii* isolates to confirm tolerance and determine how broad that tolerance is. The ultimate goal of the research is to enable the production of tolerant trees for diseased sites where Douglas-fir is the preferred species.

Rona Sturrock can be reached at
rsturrock@pfc.cfs.nrcan.gc.ca

Light on Canopies

"We have found a way to use airbourne lasers for reliable estimates of tree height."

Tree height estimates are critical to forest inventories. They show how well a stand is growing and make possible a good estimate of the amount of wood it contains. But aerial photo interpretation is not very accurate for tree heights, and measurements taken from ground level are expensive and difficult to obtain.

"We've found a way to use airborne lasers for reliable estimates of tree height," says Canadian Forest Service scientist Dr. Steen Magnussen, working in the Landscape Management Network. "We were able to interpret the foliage signals with the help of exact tree measurements on the ground."

Laser data from terrain mapping have offered foresters a tantalizing possibility. In the last decade, airborne laser scanning has become the technology of choice for terrain mapping, because of its speed and accuracy and its ability to penetrate forest canopies and give a clear ground signal. A single laser pulse typically produces both a clear ground reflection and, somewhat above it, a less distinct reflection from contact with foliage. These vegetation signals are discarded by terrain mappers. Foresters want to know about the canopies creating these reflections. But the patterns of reflection have resisted interpretation.

A partial aerial view of the Shawnigan Lake trial as "seen" by the laser scanner

The difficulty is that the laser pulse can hit anywhere on the canopy. Whereas the ground reflections show a clear connected surface, the leaf reflections, when plotted, occur in a "cloud" at various levels throughout the canopy.

Magnussen's group decided to take a close look at these canopy reflections under controlled conditions. They used the 36 plots in the Shawnigan Lake fertilizer and thinning trial, which has collected precise data on canopy structure to test the results of various growing techniques. By flying a laser scan of these plots, they were able to compare the canopy laser reflections with exact measurements of the canopy structure.

Magnussen found that, on average, the vegetation hits reflected the canopy of the stand. The average height of the leaf reflections above the ground was about equal to the height of the mean of the leaf area, so there was as much leaf area above as below the reflection mean. Furthermore, the vertical profile of laser hits corresponded closely or reasonably to the vertical profile of the canopy in 25 of the 36 plots.

"Of course, inventory agencies care more about tree height than leaf area," says Magnussen. "So we had to find a way of estimating tree height from the cloud of canopy hits. The big variable is tree density. With tightly packed trees, the maximum tree heights will closely match the highest laser hits, but with widely spaced trees, there may be few or no treetop hits. So we've worked out a simple procedure in which the forester just adds information on stems per hectare in the stand and applies it to the profile of laser reflections to estimate an average maximum tree height."

Dr. Murray Strome, manager of the Landscape Management Network, explains, "Accurate forest inventories are essential for planning and monitoring forest management at all levels. These range from the local level for harvest planning, silviculture, wildlife management and erosion/pollution control to the landscape on the provincial level for establishing broad policies such as "Annual Allowable Cute", and at the national level for monitoring the Criteria and Indicators of sustainable forest management."

Magnussen's group plans to launch further tests. But in view of the need and the ready availability of information from terrain mapping, he sees immediate use for the method. Moreover, as terrain mapping projects reach completion, scanning companies may be able to add tree height estimation as a new and valued service.

Dr. Magnussen can be reached at smagnussen@pfc.cfs.nrcan.gc.ca

Staff Comings and Goings

Sen Wang

Sen Wang joins the Pacific Forestry Centre as a forest economist. Specializing in forest economics and policy, Sen will focus his research on Canada's competitiveness in the international forest products market in comparison with forest-dominant jurisdictions in the Pacific Rim and elsewhere. He holds a master of science degree from the University of British Columbia (UBC), and is currently a candidate for a doctoral degree at UBC in forest resources management.

Florence Scott has recently retired after 32 years with the federal government. Florence worked at the Pacific Forestry Centre as Human Resources Manager for over 17 years, coordinating and implementing the human resource program. She also advised senior management and staff on the interpretation and application of policies, regulations, collective agreements, directives and the resolution of human resource dilemmas.

David Broad

Welcome to **David Broad** who takes over for Florence Scott as Manager of Human Resources. David joins us from Fisheries and Oceans, Pat Bay where he was Human Resources Manager.

Guy Gondor leaves the Pacific Forestry Centre after 10 years. As Chief, Informatics, Guy was responsible for the operation and management of the computing centre.

Recent Publications

A method for estimating canopy openness, effective leaf area index, and photosynthetically active photon flux density using hemispherical photography and computerized image analysis techniques
Frazer, G.W.; Trofymow, J.A.; Lertzman, K.P.

Information Report BC-X-373. Pacific Forestry Centre, Victoria, B.C. (1997)

Les ressources canadiennes en biomasse forestière: estimations à partir de l'inventaire des forêts du Canada.
Penner, M.; Power, K.; Muhairwe, C.; Tellier, R.; Wang, Y.

Rapport d'information BC-X-370F. Centre de foresterie du Pacifique, Victoria, Colombie-Britannique. (1997)

The Bridge. September 1997.
Maides, R. (Editor)

First Nations Forestry Program. Natural Resources Canada, Canadian Forest Service/Indian and Northern Affairs Canada. Pacific Forestry Centre, Victoria BC. (1997).

Ferns. Forest ecosystem research network of sites.
Anon.

(Brochure) Natural Resources Canada, Canadian Forest Service, Pacific Forestry Centre, Victoria BC. (1997).

A field estimation procedure for downed coarse woody debris.
Taylor, S.W.

Technology Transfer Note No. 2. Canadian Forest Service, Pacific Forestry Centre. (1997).

Une methode d'evaluation sur le terrain des debris ligneux grossiers.
Taylor, S.W.

Note de Transfert Technologique. Numéro 2. Service canadien des forêts, Centre de foresterie du Pacifique. (1997).

A review of tree wounding.
Nevill, R.J.

Technology Transfer Note No. 3. Canadian Forest Service, Pacific Forestry Centre. (1997).

Aperçu des blessures des arbres.
Nevill, R.J.

Note de Transfert Technologique. Numéro 3. Applications de la recherche forestière. Service canadien des forêts, Centre de foresterie du Pacifique. (1997)

Predicting forest floor moisture contents from duff moisture code values.
Lawson, B.D.; Dalrymple, G.N.; Hawkes, B.C.

Technology Transfer Note No. 6. Canadian Forest Service, Pacific Forestry Centre. (1997).

Decay associated with logging injuries in Western Larch, *Larix occidentalis*, and in Lodgepole Pine, *Pinus contorta*.
Allen, E.; White, T.

Technology Transfer Note No. 7. Canadian Forest Service, Pacific Forestry Centre. (1997).

A more complete list of recent publications is available via the World Wide Web at: http://www.pfc.cfs.nrcan.gc.ca

Upcoming Events

Professional Foresters for 50 Years - Learning From the Past to Shape the Future
March 4 - 6, 1998
Victoria, B.C.

The Association of B.C. Professional Foresters is celebrating a major milestone in 1998 with their fiftieth Annual General Meeting. The meeting will focus on the celebration with a review of activities and accomplishments over the last fifty years, combined with a look to the future and what the next fifty years might present to the profession of forestry. The program is designed to be of interest to both foresters and non-foresters and everyone is welcomed to attend.

Contact:
Chris Lee,
Canadian Forest Service,
Pacific Forestry Centre
506 West Burnside Road,
Victoria, B.C. V8Z 1M5
Telephone: (250)363-0792
Fax: (250)363-0775
E-mail: clee@pfc.cfs.nrcan.gc.ca

Automated Interpretation of High Spatial Resolution Digital Imagery for Forestry
February 10 - 12, 1998
Victoria, B.C.

The Canadian Forest Service Landscape Management Network is holding a forum of papers and discussion sessions on computer-assisted methods of forest interpretation and parameter extraction from high resolution digital imagery. Participants will be scientists, technology developers, forestry practitioners, and forest managers. Concentration will be on forestry requirements, current capabilities and future activities.

Contact:
Don Leckie,
Canadian Forest Service,
Pacific Forestry Centre
506 West Burnside Road,
Victoria, B.C. V8Z 1M5
Telephone: (250)363-0624
Fax: (250)363-0775
E-mail: dleckie@pfc.cfs.nrcan.gc.ca or check http://www.pfc.cfs.nrcan.gc.ca

Structure, Processes and Diversity in Successional Forests of Coastal British Columbia
February 17 - 19, 1998
Victoria, B.C.

The main purpose of this workshop is to share findings from recent studies in forest types of coastal B.C. on the effects of converting old-growth forests to managed forests, how various ecosystem attributes change during stand succession and the extent to which they are restored as forests mature. Topics include: changes in stand structure and composition; site carbon and nutrient balance; and species diversity.

Contact:
Rod Maides,
Canadian Forest Service,
Pacific Forestry Centre
506 West Burnside Road,
Victoria, B.C. V8Z 1M5
Telephone: (250)363-0737
Fax: (250)363-6006
E-mail: rmaides@pfc.cfs.nrcan.gc or check http://www.pfc.cfs.nrcan.gc.ca

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Editor: Joanne Stone
Layout: Jennifer Adsett
Writers:
Lissa Cowan
Joanne Stone

For further information:
Phone: (250) 363-0606
Fax: (250) 363-6006
Email: jstone@pfc.cfs.nrcan.gc.ca

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