PROCEEDINGS OF THE FORTY-EIGHTH ANNUAL WIFDWC

WAIKOLOA, HAWAII

AUGUST 14 – 18, 2000

PROCEEDINGS OF THE FORTY-EIGHTH WESTERN INTERNATIONAL FOREST DISEASE WORK CONFERENCE

OUTRIGGER WAIKOLOA BEACH HOTEL
WAIKOLOA, HAWAII

AUGUST 14 – 18, 2000

Compiled by:

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Western International Forest Disease Work Conference
48th Meeting – August 14 – 18, 2000
Waikoloa, Hawaii

Program

Monday - August 14

9:00 - 5:00 Western Nursery Pathology Workshop

4:00 - 9:00 Registration/Social mixer (no-host bar)

Tuesday – August 15

7:00 - 8:00 Registration (cont.)

7:00 - 8:00 Disease Control Committee Breakfast

8:00 - 8:15 Welcome & Announcements

8:15 - 8:45 Keynote Address: Ecology of Exotic Invasions; Dr. David Perry, Professor of Forest Ecology (retired), Oregon State University, Corvallis.

8:45 - 10:00 Regional Reports

10:00- 10:30 BREAK

10:30-Noon White Pine Blister Rust in the West and sage advice for the future. Panel chaired by MaryLou Fairweather, USDA Forest Service, Region 3.

- Impact assessment and restoration strategies for five-needle pines in southwest Oregon. Ellen Goheen, USDA Forest Service, Region 6.
- Biogeography of White Pine Blister Rust spread and intensification in the far western U.S., with emphasis on the conditions in central California. Detlev Vogler, University of California, Berkeley.
- 30 years after pruning and thinning – Did it work? John Schwandt, USDA Forest Service, Region 1.
- The status of White Pine Blister Rust in Intermountain Region white pines. Jim Hoffman, USDA Forest Service, Region 4.
- Environmental acclimation and adaptation: Historical and/or Ongoing? Geral McDonald, USDA Forest Service, Intermountain Research Station.

Noon - 1:30 **Hazard Tree Committee luncheon**

1:30 - 3:00 Wood decays and sapstain fungi on imports/exports.
Panel chaired by Barbara Illman, USDA Forest Service, Forest Products Laboratory and University of Wisconsin.

- Exotic fungi and insects on wood product imports. Barbara Illman.
- Insects, fungi, wood and humans. Thomas Hofacker, USDA Forest Service, Washington Office.
- An exotic staining fungus that is killing trees in the Seychelles Islands. Joan Webber, Forestry Commission, Alice Holt Lodge, Surrey, UK.
- Research funding opportunities, Panel Members.

3:00- 3:30 **BREAK**

3:30 - 5:15 Dwarf mistletoes of North & Central America.
Panel chaired by Bob Mathiasen, Northern Arizona University.

- Current status on the biology and spread of European mistletoe, *Viscum album*, in California. Robert F. Scharpf , USDA Forest Service, Southwest Research Station.
- Mistletoe phylogenetics: Current relationships gained from analysis of DNA sequences. D. L. Nickrent, Southern Illinois University.
- Spatial patterns of hemlock dwarf mistletoe infections in an old-growth Douglas-fir/western hemlock forest. David Shaw, University of Washington.
- True mistletoes on pines in Central America. Catherine Parks, USDA Forest Service, Pacific Northwest Research Station.
- Adult sex ratio of juniper mistletoe, *Phoradendron juniperinum*, on one-seeded juniper. C. M. Daugherty, Northern Arizona University.
- Status of dwarf mistletoes in Central America. Robert Mathiasen, Northern Arizona University.

5:15 **Group Photograph**

7:00 - 9:00 Poster Session

Session chaired by Rona Sturrock, Canadian Forest Service, Pacific Forestry Centre.

- Impacts of partial cutting in sub-boreal spruce forests on stand structure and spread of tomentosus root disease. Ted Newbery, Kathy Lewis and Michael Walters, University of Northern British Columbia.

- Aerial digital sketchmapping. Forrest Oliveria and Charlie Schrader-Patton, USDA Forest Service, Region 8.

- White pine blister rust infection and mortality in sugar pine: results through age 15. R. Sniezko, A. Bower, E. M. Goheen and J. Langhoff, USDA Forest Service, Dorena Genetic Research Center and Region 6.

- Breeding for durable resistance to *Phytophthora lateralis* in *Chamaecyparus lawsoniana*: an early assessment. R. Sniezko, E. Hansen and D. Goheen, USDA Forest Service, Dorena Genetic Research Center.

- The Five Rivers study: Opportunities to study forest diseases in a replicated, landscape-scale ecosystem experiment. Bernard Bormann, Walt Thies and Paul Thomas, USDA Forest Service, Pacific Northwest Research Station.

- Cloning and characterization of a defense responsive PR-10 gene in sugar pine. Abdul K.M. Ekramoddoullah, Xueshu Yu, Doug W. Taylor, and Nina Piggott. Canadian Forest Service, Pacific Forestry Centre, Victoria, BC.

- White pine blister rust in the Central Rocky Mountains: time to consider the impacts. Eric L. Smith, David W. Johnson and William R. Jacobi.

- Black stain root disease of pinyon pine: landscape scale analysis. Sam Harrison and Bill Jacobi, Colorado State University.

- The anatomy of black stain root disease centers in pinyon pine. Holly Kearns and Bill Jacobi, Colorado State University.

- Aerial surveys for Swiss needle cast in western Oregon. Alan Kanaskie, Mike McWilliams, Dave Overhulser, Jack Prukup and Keith Sprengel, Oregon Department of Forestry.

- Windthrow risk project. R. Richert, W. Littke and J. Browning, Cedar River Middle School, Washington State.

- Assessing loss potential in forests from exotic species introduced in solid wood packing. R. Sequeira, D. Legeido and J. Pasek, USDA-APHIS, Raleigh, NC.

- Pest risk assessment for importation of solid wood packing materials into the United States. J. Pasek, USDA-APHIS, Raleigh, NC.

- Armillaria root disease: Species and genet diversity across a mixed-conifer landscape in the Blue Mountains of eastern Oregon. Brennan Fergusen, Tina Driesbach, Catherine Parks, Greg Filip and Craig Schmitt.

Wednesday – August 16

7:00 - 8:30 Dwarf Mistletoe Committee breakfast

8:30 - 10:00 Application of Biological Control to Vegetation Management in Forestry. Panel chaired by Simon Shamoun, Canadian Forest Service, Pacific Forestry Centre.

- Riding the biological control wave from the mongoose to *Uromyces pisi* f.sp. europae. Eloise Killgore, Hawaii State Department of Agriculture, Plant Pest Control Branch.

- Recent developments in the biological control of Kahili Ginger with *Ralstonia solanacearum* in Hawaii. Robert Anderson, Pacific Cooperative Studies Unit, Department of Botany, University of Hawaii at Manoa.

10:00- 10:30 BREAK

10:30 – 11:30 Application of Biological Control…(cont.)

- Effort toward biocontrol of invasive *Rubus* spp. in Hawaiian forests. Donald Gardner, USDI, U. S. Geological Survey, Hawaii.

- Development of biological control strategy for management of forest weeds in Canada. Simon Shamoun, Natural Resources Canada, Canadian Forest Service, Pacific Forestry Centre.

11:30 - 1:00 Rust Committee luncheon

1:00 - 2:00 Exotics: National Policy.
Discussion lead by David Thomas, USDA Forest Service, Washington Office and Borys Tkacz, USDA Forest Service, Washington Office.

- Executive Order 13112. Invasive Species: What does it mean? How did it come about?
- The National Council on Invasive Species: the Current Status.
- The Invasive Species Advisory Committee and Working Groups.
- The National Management Plan: How will the Forest Service be affected?

2:00- 2:20 Overview of sudden oak death in coastal California. Susan Frankel, USDA Forest Service, Region5.

2:20- 2:40 Screening for resistance to white pine blister rust in western white pine and sugar pine. Richard Sniezko and Andrew Bower, USDA Forest Service, Dorena Genetic Research Center.

2:40- 3:00 *Arceuthobium americanum* in central Oregon *Pinus contorta* stands: effects on crown architecture, host tree population dynamics, canopy structrure and understory composition. Robert Godfree, Portland State University.

3:00- 3:30 BREAK

3:30 - 5:00 Business Meeting

5:30 - 9:00 Social Hour/Lu'au

<u>Thursday – August 17</u>

7:30 - 7:30 Field Trip

<u>Friday - August 18</u>

7:00 - 8:30 Root Disease Committee breakfast

8:30 – 8:50 Infection processes of *Phellinus weirii*. Rona Sturrock, Canadian Forest Service, Pacific ForestryCentre.

8:50- 9:10 A survey of Northern spotted owl nests in Douglas-fir dwarf mistletoe brooms in the Siskiyou zone of southwest Oregon. Katy Marshall, USDA Forest Service, Region 6.

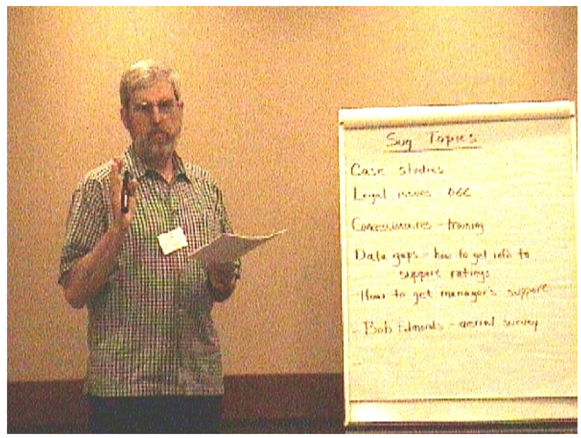
9:30- 10:00 BREAK

10:00 - Noon Exotic root diseases.
Panel chaired by Ellen Goheen, USDA Forest Service, Region 6.

- Rapidly evolving root disease pathogens. Clive Brasier, British Forestry Commission.

- When exotics go native. Everett Hansen, Oregon State University.

- Conservation strategies for threatened hosts. Don Goheen, USDA Forest Service, Region 6.



WIFDWC 2K – FIELD TRIP

August 17, 2000

0730 **Leave Outrigger Waikoloa Beach Hotel**

0900 **Onomea Valley**.

Lowell Thomas, University of Hawaii, Operation Miconia.

Miconia control by pathogen release

Tour: Hawaii Tropical Botanical Garden

1130 **Hawaii Volcanoes National Park**

Kipuka Puaulu Picnic Area, Lunch

Don Gardner, Plant Pathologist, BRD/USGS. *Ohia* decline, *Koa* dieback, control of alien species by pathogen releases.

Insect Quarantine Lab, Volcanoes NP Research Center, **Wendell Sato,** USDA Forest Service

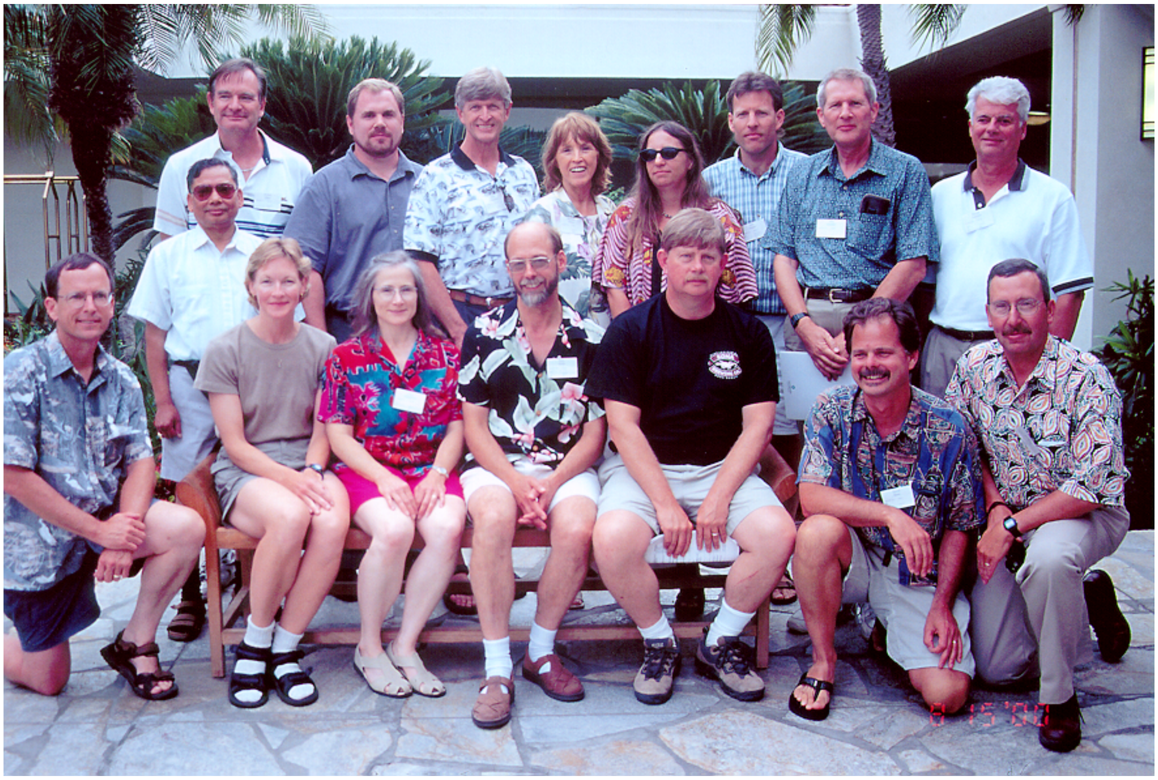
1330 Tour: **Crater Rim Drive**

1700 Sunset at **Pu'uhonua o Honaunau, National Historic Park**

1900 **Return to Outrigger Waikoloa Beach Hotel**

GROUP 1: Bottom Row (L to R): Bill Jacobi, Det Vogler, John Schwandt, Blakey Lockman, Jane Taylor, Catherine Parks, Judy Adams, Carolyn Daugherty, Bill Woodruff, Dan Nickrent; **Top Row:** Fred Brooks, Geral McDonald, John Pronos, Mike McWilliams, Paul Hennon, Paul Mistretta, Pete Angwin, Alan Kanaskie, Jerry Beatty, Bob Mathiasen, Greg Filip, Everett Hansen, Sally Campbell, Liana Carroll, Clive Brasier, Susan Frankel.

GROUP 2: Bottom Row (L to R): Rich Hunt, Mary Lou Fairweather, Ellen Goheen, Eloise Killgore, Katy Marshall; **Top Row:** Borys Tkacz, Will Littke, Dave Latelle, Carrie Burns, Yun Wu, Kathy Lewis, Simon Shamoun, Rob Anderson, John Browning.



GROUP 3: Bottom Row (L to R): **Rich Sneizko, Rona Sturrock, Diane Hildebrand, Eric Smith, Don Goheen, Dave Shaw, Jim Hoffman;** Top Row: **Abdul Ekramoddoulah, Bob James, Rona Sturrock, Brennan Ferguson, Mike Schomaker, Barbara Illman, Marianne Elliott, Dan Omdal, Don Gardner, Dave Johnson.**








CHAIRPERSON'S OPENING REMARKS

Bill Jacobi
Dept. of Bioagricultural Sciences and Pest Management, Colorado State University

Good morning, I am Bill Jacobi from Colorado State University. I would like to welcome you to the 48th annual Western International Forest Disease Work Conference.

I appreciate the opportunity to serve as chairperson of this year's WIFDWC. I have found this organization to be a great benefit over the years for my students and myself in our research and educational programs.

If you are attending for the first time please feel free to speak up and ask questions. This is supposed to be a formal- informal group. We are all here to learn and discuss tree health issues.

Before I proceed any further we would like to have a minute of silence for those members who died this year. Larry Weir who worked with the state of Oregon Dept. of Forestry, Mike Larsen, Mycologist, Rocky Mountain Research Station, Moscow, ID, and Dave French of the University of Minnesota.

Wow! We are actually meeting in Hawaii. WIFDWC members have talked about meeting in the great state of Hawaii for years -actually ever since it was formed in 1953. We have met in just about all the neat places in the west from Juneau, Victoria, Monterey, Durango, Santa Fe, Taos, Coeur d'Alene, etc. but never Hawaii. Yea we finally made it!

We need to recognize the efforts of **Jerry Beatty** on local arrangement for setting up the entire local arrangements including the field trip. I am sure we all appreciate the fact that Jerry had to come over here this spring and check out the luau and field trip sites.

Pete Angwin as secretary has had to deal with getting information out to members and interested folks from Nepal and elsewhere.

Sue Hagle had done a fantastic job as program chair. She could not be with us but she has organized some super panels and talks. We need to thank all the speakers and panel chairs also for getting the final product together.

Judy Adams has made our web page a reality and kept it working like a charm. **John Schwandt** has been his usual helpful self, keeping the money straight as our treasurer.

Without the mighty efforts of these people we would not have a meeting. Let's thank them now since sometimes we forget at the end of the meeting when we are all heading for the planes home.

As Chair, I am supposed to say a few pithy things and then get the meeting going.

So these are my few pithy words:

These are momentous times: We are definitely in the electronic age. All our meeting information was available over the web, registration could occur over the web

These are momentous times because of the world economy. We are importing more goods into North America than ever before. We have a tidal wave of packing materials and wood products hitting our shores and transportation centers like we have ever seen. Insects and pathogens are found daily.

Thus is fitting that this meeting should be in a local where imported organisms have made important impacts on the ecosystems of the Hawaiian Islands. We hope to learn from those tackling these issues here in Hawaii and see how this information can help us in the rest of North America.

These are momentous times because the increase in the transport of insects and pathogens across border comes at a time of reductions in govt. spending on tree health issues. There are fewer students being educated, there are fewer forest research dollars, there are fewer of us, fewer management options if we want to reduce or modify the impact of some organisms.

However, these are really exciting times; not discouraging times since we find we are challenged to help in all areas of forestry including recreation sites, ecosystem management, resource extraction, nature centers, urban forests to name a few.

So how can we handle these momentous times?

1. We all need to find the most productive use of our time- do what we can do well and find someone to cooperate with on the topics we do not handle well.

2. We need to challenge others to help us manage trees for a healthy future.

3. We need to cooperate on projects

4. We need to give information freely at meetings like this.

5. We need to make sure we take the time to explain the importance of tree pathology to publics, politicians, and others.

6. We need to support the efforts to educate new students who can add to our ranks with new energy and ideas

7. We need to reach out to other sciences to help us understand our issues and reach out and support other sciences so our science is included in their work.

8. Most importantly, we need to keep our lives in balance since the most important things in our life are not our science and trees, but our health and the well being of our families and friends.

So lets officially open the meeting and I wish for all of you to have a great productive meeting.

KEYNOTE ADDRESS

An Ecocultural Story of Hawai'i

Dave Perry
Professor of Forest Ecology (retired)
Oregon State University

E Komo mai 'oukou 'ia Hawai'i ka nani! Welcome to beautiful Hawai'i. Ha, the breath, wai, the freshwater, 'i of the supreme creator.

I want to talk-story with you about this most beautiful, magical, and tragic place. It's a story of awesome creativity, profound loss, and enduring values.

86 miles below our feet the Earth's mantle opens like a vulva and pours molten rock through the overlying crust and onto the ocean floor. One of about of 100 such hotspots scattered around the globe, the one below our feet is the largest, hottest, and one of only a handful not associated with a plate boundary. The temperature--1650 degrees C---suggests an origin deep in the lower mantle, perhaps at the edge of the core itself. Isotopic composition suggests at least some of the material originates from the core, and some can be traced to old ocean floor subducted into the mantle eons ago to be eventually recycled.

The progeny of this deep birthing lie scattered as islands and volcanic seamounts along a 6000 kilometer arc reaching NW almost to the Aleutian islands, marking the movement of the Pacific Plate as it slides at 8.5 cm/yr across the stationary hotspot. 129 volcanoes lie along this arc, the oldest dated at 80 million years. Those northwesterly of Midway island, about 1/2 way along the arc, have weathered below the ocean surface.

The 15 volcanoes composing the islands of Hawaii began emerging 5 million years ago with Ni'ihau and Kaua'i, followed 1.5 to 2.5 million years later by O'ahu, then what is called Maui Nui (Big Maui), consisting of the islands Molkai'i, Lanai'i, Kaho'olawe, and Maui. The island of Hawaii--the Big Island--began emerging from the waves 430,000 years ago and now comprises 5 volcanos--from oldest to youngest Kohala, Mauna Kea, Hualalai, Mauna Loa, and Kilauea. A sixth--Lo'ihi is building off our SE coast with the peak currently about 1 km below sea level. When talking about this island it's impossible to be accurate without invoking superlatives. Measured from their bases on the seafloor, Mauna Kea is the tallest mountain on the planet and Mauna Loa is the second tallest and most massive. Kilauea is the most active volcano on the planet. Sitting on the summit of Mauna Kea are the most powerful optical telescopes on the surface of the earth, the Keck twins. Mauna Kea is also a sacred mountain to Hawaiians, and there is considerable tension about the presence of the observatories.

The Hawaiians were astute observers and knew very well the islands differed in age and the order of age. In one of the mo'olelo--the stories of old, Pele, Earth Mother Goddess, resides first on Ni'ihau, but is chased from there by her sister Namakaokaha'i, Goddess of the sea. Pele resides for a time on Kaua'i, but once again is dislodged by Namakaokaha'i and flees to Oahu. This scene repeats until Pele eventually takes up residence in Halema'uma'u crater on Kilauea, which is where she now makes her home.

Two thousand miles from North America and even further from Asia and Australia, the islands were slow to be colonized by land species. It's estimated that a new species was blown in, drifted in, or was carried in by sea birds on average once only once every several thousand years. Once here, however, new species, genera, and families spun off at an extraordinary rate. According to evolutionary biologist Kenneth Kaneshiro, "no where else do you find so many examples of explosive adaptive radiation". Peter Vitousek calls Hawaii the greatest place on Earth to study evolution. To give a few examples:

- **An estimated 10,000 species of arthropods stem from 400 to 500 colonizing species: 800 species of Drosophilid flies are thought to have originated from a single ancestor.**

- **1000 endemic species of land snails from 15 colonists.**

- **1000 species of flowering plants and 150 ferns from an estimated 250 colonists.**

- **140 species of birds evolved from an estimated 20 colonists: 45 species of the endemic honeycreepers are believed to have evolved from a single colonizing species. There were 3 species of raptors, including an eagle, one of which--the Io, or Hawaiian hawk, is left; 4 species of owls, one of which is left; and 3 species of crows (or ravens), one of which is left and barely hanging on (with 8 known individuals in the wild). There is fossil evidence for at least 22 species of flightless goose-like ducks, stilts, and ibisis, all but one extinct by the time Cook arrived.**

With endemism in most taxa running above 90%, by far the majority of native flora and fauna are found nowhere else on Earth.

Polynesians are believed to have arrived in Hawaii about 1500 years ago, with a second wave of migration about 500 years later. According to Jared Diamond's "express train theory", which is supported by linguistic analyses, the people who were to become the Polynesians began expanding out of SE Asia, southern China, Indonesia, or Taiwan about 6000 years ago. By 3200 yrs ago they had reached the islands of central Polynesia and developed the large, double-hulled sailing canoes and other technology that allowed long voyages across open ocean. From central Polynesia they radiated south to New Zealand, east to Easter island, and north to Hawaii. There is compelling evidence they reached the Americas on trading voyages.

Polynesians brought a number of domesticated plants and animals: pigs, dogs, chickens, bananas, coconut palms, sweet potatoes, yams, breadfruit, bamboo, sugar cane, and--most importantly--their elder brother the taro plant, mainstay of diet and of central importance in the culture. The native Hawaiian historian David Malo gives the following account of the origin of taro:

> ***The first-born son of Wakea (*****the primordial ancestor)** ***was of premature birth and was given the name Haloa-naka. The little thing died, however, and its body was buried in the ground at one end of the house. After a while from the child's body shot up a taro plant (the stem of which was named) Haloa. After that another child was born to them, whom they called Haloa, from the stalk of the taro plant. He is the progenitor of all the peoples on Earth.***

They also brought some hitchhikers: the Polynesian rat and the gecko to name two.

Highly skilled farmers, the Hawaiians cleared much of the lowlands and patches of forest in the uplands for cultivation. Even the leeward, dry parts of the islands were intensively cultivated. They instituted an ecological system of land division--called ahupua'a--based on watersheds where there were streams, and laid out to reach from mountain to sea where there were not. Each ahupua'a contained fishing, planting, timber, and upland forests for birdcatching. The Hawaiians built fishponds and developed sophisticated, extensive irrigation systems. They developed numerous cultivars of the major food plants: for example there were at least 50 varieties of banana and an estimated 300 varieties of taro. In other words, Hawaiians understood very well basic ecological principles of maintaining healthy crops: local adaptation and landscape diversity.

It isn't surprising that hunting and especially conversion of lowland forests to agriculture by Polynesians impacted the native biota. Since the early 1970's fossil evidence has been uncovered for 38 bird species that had gone extinct or were locally extirpated before the arrival of Europeans. Patrick Kirch estimated that 1/3 to 1/2 of the nonmarine mollusk and bird faunas went extinct after the arrival of Polynesians.

But this was only prelude to what was to come.

In January of 1778, Captain James Cook with two ships, the Resolution and the Discovery, was making way north in search of a sea route between the Pacific and Atlantic, Cook's first voyage north of the Equator in the Pacfic. On Jan. 18 they came upon a group of islands that turned out to be Oahu, Kauia, and Ni'ihau. This was a surprise, as no one in the islands of the South Pacific, where Cook had sailed extensively, had told him of islands to the north. (I find it an interesting coincidence that, at a time when Kamehameha was invoking the war god Kukailimoku--literally Ku snatcher of land--for help in uniting the islands, who should show up but the most accomplished land snatchers on the planet). Cook sailed north on his futile search for the northwest passage, returning to Hawaii two years later. The Hawaiians first believed Cook was one of their major Deities, Lono, a fair skinned God of whom it was foretold would one day return to his children in Hawai'i.

However, on his second visit, in a tragic escalation of misunderstanding (Mark Twain called it justifiable homicide), Cook was killed at Kealekekua Bay south of Kailua-Kona.

In the years to follow the litany of invasion and loss accelerated considerably.

In 1794 Captain George Vancouver, who had been a midshipmen with Cook in his voyages to Hawai'i, now in command of the Discovery, left cattle and sheep with Kamehameha. Not long after goats, horses, and European pigs arrived, the latter larger and more likely to go wild than the Polynesian variety. The Ali'i--the chiefs--became so fond of the new hoofed animals they put a kapu--a strict prohibition--on killing them. In result their populations grew quickly and they began having a major impact on native vegetation, consequently on native arthropods, mollusks, and birds. By the late 1800's loss of forest cover had reached a point that people were becoming alarmed, including the powerful sugar planters, who depended on intact watersheds for a reliable water supply. Tree planting and open season, including bounties, on ungulates followed, with mixed success (wild pigs are abundant, and there is a whole subculture based on pig-hunting). In 1979 a federal court order forced the removal of feral sheep from Mauna Kea in order to protect endangered habitat.

By 1800 Honolulu was becoming a major port-of-call, and problems with introduced diseases followed. In 1804 the first killer epidemic struck the human population--probably cholera or Typhoid fever-- with great loss of life among Hawaiians on Oahu. It was not the last. With the appearance of mosquitoes and foreign birds (more than 130 species introduced since 1850) came avian pox and avian malaria, to which native birds have no resistance. Today no viable populations of native birds are found below the upper elevational range of mosquitoes.

Among the other pests to arrive were black rats, ants, social bees, yellowjackets, and a long list of alien plants, many of which are a benign presence, some of which wreak havoc. By conservative estimate, more than 4000 foreign plant species have been introduced to Hawai'i, about a quarter of which have become naturalized (Smith 1989). Of these, approximately 90 weedy species are causing significant problems. There are synergistic effects between the presence of alien animals (esp. ungulates) and weed problems, and the areas most resistant to weed invasion are those least disturbed by feral animals. Aggressive social insects, especially ants and yellowjackets, have had significant impacts on the once rich native invertebrate fauna, and continue to do so. Virtually the whole native lowland insect fauna is now extinct (Howarth and Medeiros 1989), and impacts are spreading upward in elevation. The loss of native insect fauna initiates cascading effects, as these animals are important as pollinators, food for native birds, and probably a host of other ecosystem services. Biological control was started very early in Hawai'i , however in too many cases the control agents became problems themselves. Many parasitic wasps introduced for biological control now prey on native insects, and the rosy snail, introduced to control the giant African snail (at which it was ineffective), is implicated in the extinction of many species of the native land snails (Howarth and Medeiros 1989).

Today, of 1304 species of native plants (>90% endemic), 106 are extinct and 282 are listed under the ESA. Thirty three of the original 93 known bird species are extinct and 31 of the survivors are listed under the ESA. I think it's fair to say we have no good idea about how many native invertebrates are extinct or endangered.

"Hawaii is a metaphor for our island Earth, adrift in the sea of space." Wrote Kim Sikoryak (1989). Some aspects of the vulnerability of Hawaiian flora and fauna to invasions arise from the uniqueness of this place: a chain of isolated islands, rich in endemics, filled with species with (not surprisely) no evolved defenses to stresses such as grazing animals and foreign diseases. But much of what has been experienced in Hawai'i is a wakeup call for elsewhere--a canary in a coalmine. The lessons are simple and clear. Although many introduced species may cause minor problems or none at all, the few that do become major problems. They do not respect boundaries, so setting aside reserve areas is useless. Once established, they may be difficult--or more likely impossible--to control. They thrive on disturbance, invading most successfully ecosystems already stressed by other factors, which as others have pointed out raises significant concerns about the vulnerability of systems stressed by climate change. The experience in Hawai'i leaves no doubt that the most, and perhaps only, successful way to deal with invasive exotics is to keep them out in the first place. Anything else is playing Russian roulette with more chambers loaded than not.

References

Howarth, F.G. and A.C. Medeiros. 1989. Non-natïve invertebrates. In: Conservation Biology in Hawai'i. C.P. Stone and D.B. Stone (eds.), Univ. Hawai'i Press. P 82-87.

Smith, C.W. 1989. Non-native plants. In: Conservation Biology in Hawai'i. C.P. Stone and D.B. Stone (eds.), Univ. Hawai'i Press. P 60-69.

PANEL: WHITE PINE BLISTER RUST IN THE WEST AND SAGE ADVICE FOR THE FUTURE

Mary Lou Fairweather - Moderator

Impact Assessments and Restoration Strategies For Five-Needle Pines in Southwest Oregon

Ellen Michaels Goheen
USDA Forest Service
Southwest Oregon Forest Insect and Disease Service Center
Central Point, Oregon

Southwest Oregon is home to one of the most diverse forest ecosystems in North America. Eleven conifers and numerous evergreen and deciduous hardwood species grow in these forests. Among these are three species of five-needle pines: western white pine (*Pinus monticola*), sugar pine (*P. lambertiana*), and whitebark pine (*P. albicaulis*). The ecological and historic importance of five-needle pines in southwest Oregon is considered high among the "ecologically aware" yet limited information is available on their status. It is acknowledged that the introduction of white pine blister rust (caused by *Cronartium ribicola*) and decades of fire exclusion that resulted in overstocking and subsequent mortality due to mountain pine beetle (*Dendroctonus ponderosae*) have taken their toll; however, slow losses in number and stature of single species are easy to ignore in such diverse stands. Many who prescribe silvicultural activities in today's stands are unaware of the magnitude of the role these species had historically; they replant five-needle pines according to the current stand component or dismiss them from consideration as a viable planting option altogether because of their presumed early mortality. This ignorance has become even more apparent as emphasis has shifted towards management of late successional species and forests with decreased interest in the roles that early to mid seral species may play. In this region, plant pathologists are the champions for five needle pines and the leaders in acquiring the data to document their ecological and historical significance.

Impact Assessments

Included in our data acquisition are ground surveys to assess the status of five needle pines. A recent assessment of approximately 1000 acres in the Prospect Corridor, part of the scenic highway corridor on the Rogue River National Forest that leads to Crater Lake National Park and an area where groves of large sugar pines have attracted travelers since the late 19th century, documents high levels of recent mortality of pines, high stand densities, and low levels of pine regeneration. While Douglas-fir is the dominant tree in the Corridor; pines, including ponderosa, western white, and sugar pine are present on approximately1/2 the plots. Pines contribute only a small percentage of the live trees per acre (4 to 7 percent). They are not well represented in the small size classes. However, pines contribute significantly to total live tree basal area, supplying 17 to 44 percent of the basal area in stands in the Corridor. Large pines are well represented throughout. Average stand-level basal areas for the corridor range from 230 to 250 square feet per acre. Individual plot basal areas range from 0-600, averaging 250 square feet per acre. Basal areas on plots with pines exceed the threshold for mountain pine beetle risk (approximately 180 square feet of basal area per are on these sites) on 77 percent of the plots. Mortality, particularly in larger size classes, was high for the five-year period estimated. Seven and one half percent of all pines greater than 20 inches diameter had died during this time; 10.5 percent of all the sugar pine greater than 60 inches diameter had died. Normal background mortality for large pines is should be closer to .5 to 2.5 percent for a five-year period.

We conducted surveys looking at large sugar pine health on the Umpqa National Forest as well. We randomly selected 200, 20 to 70 inch diameter trees as a part of a sugar pine clearing demonstration. Basal area around selected trees averaged 240 sq feet per acre, again exceeding the threshold for risk of mountain pine beetle mortality. Fifty-four percent showed declining growth rates. 40 trees had at least one recently-killed sugar pine within 200 feet. Twenty-five percent had visible white pine blister rust.

We also examined Forest-level inventory data on the Umpqua National Forest and compared the 1957 and 1968 inventories with our most recent inventory conducted in the mid 1990s. These plots were established on systematic grids and we consider them to be relatively comparable. The overall percent of plots with five-needle pines dropped from 60 percent in 1957 to 40 percent in the mid 1990s. The percent of plots with larger (greater than 5 inches diameter) western white pine was halved over the 40-year period, while the percent of plots with larger sugar pine declined only slightly. Because the 1957 inventory only reported on trees greater than 5 inches diameter, we compared the 1968 inventory with recent data for information on smaller western white and sugar pine. Plots with small sugar pine dropped from 27 to 19 percent and plots with small western white pine decreased from 20 percent to 15 percent over the approximately 25-year period.

We looked at data from plots established by the Ecology group in Southwest Oregon to describe the various characteristics of the Plant Associations. These plots were established in "relatively undisturbed" older stands throughout the Rogue River, Umpqua, and Siskiyou National Forests. Pine cover was looked at in a comparison of plot data that spanned approximately 10 years from the 1980s into the 1990s. Pine cover dropped approximately 5 percent on those plots over that time period.

We are currently involved in a project to sample a subset of these Ecology plots across SW Oregon to document the insect and disease influences in the area. Preliminary data from a random selection of plots indicates that 26 percent of the 292 plots that we have visited have five-needle pines. Forty-five percent of the plots with five-needle pines have trees with white pine blister rust and 39 percent have pines killed by mountain pine beetle or pine engraver beetle (*Ips* spp.).

Some of our most recent work on five-needle pine health has taken us to the stands along the Pacific Crest Trail on the Umpqua National Forest where we focused our attention on whitebark pine. We established 21 transects along a 30-mile stretch of the trail. Forty-six percent of the whitebark pine trees are alive and infected by *C. ribicola*, 44 percent are alive and healthy, 10 percent are dead. White pine blister affects trees in all but the largest size classes (trees greater than 20 inches diameter). Seventy-seven percent of all the whitebark pines greater than 4.5 feet tall and less than 3 in. diameter are affected. Ninety-two percent of the white pine blister rust infected whitebark pine have cankers on or within 6 inches of the bole. White pine blister rust is the most frequently encountered mortality agent of whitebark pine in this area and accounts for 2/3 of the mortality. Mountain pine beetle alone killed 13 percent of the trees. White pine blister rust and mountain pine beetle occur together on 18 percent of the dead trees. Thirty-four percent of all live white pine blister rust infected whitebark pine are topkilled; in approximately 50 percent of these trees at least 30 percent of the top is dead.

Future assessments on the status of five-needle pines in Southwest Oregon will include additional surveys aimed specifically at whitebark pine, large scale hazard analysis for white pine blister rust, and historical trend data for mountain pine beetle mortality.

Restoration Strategies

Restoration strategies for five-needle pines currently underway in Southwest Oregon fall into four categories; 1) reducing overall stand densities to reduce risk of mountain pine beetle mortality, 2) individual tree or "legacy tree" management to reduce risk of mountain pine beetle mortality, 3) reestablishing five-needle pines in areas where their numbers have dwindled, and 4) managing white pine blister rust through a variety of silvicultural activities such as use of white pine blister rust-resistant stock, pruning. and white pine blister rust hazard analyses. The remainder of the discussion focuses on legacy tree management and reestablishing five needle pines.

Several demonstrations and studies have been established to showcase activities associated with maintaining large sugar pines in mixed stands. These involve selecting an individual tree and clearing competing vegetation in a zone around that tree. This prescription is often referred to as "doughnut thinning". In some cases all the woody vegetation is removed in a circle extending to 25 feet past the tree's crown dripline. In others the clearing zone is reduced to 10 feet past the dripline. Variations on this concept include leaving all the larger or cohort trees in the clearing zone. Regardless of the magnitude, the focus of the density management is the tree rather than the stand. Most treatments are only recently established. Extensive monitoring is planned or underway.

Reestablishing five-needle pines where their numbers are reduced from historic levels is also underway. This has been made more feasible by the increased availability of rust-resistant stock for Southwest Oregon. In most circumstances emphasis is placed on using already-created openings, such as root disease centers, as opportunities for planting rust-resistant western white pine and sugar pine. Silviculturists are also more frequently prescribing small openings or group selection harvest and recommending the planting of five-needle pines where appropriate. In stands on the Umpqua National Forest and the

Roseburg District of the Bureau of Land Management, demonstration areas exist where already-established sapling-size Douglas-fir trees have been cut and replaced by rust-resistant sugar pines. This reflects current acknowledgement of the importance of sugar pine on these sites.

There are still many challenges to restoring five-needle pines in Southwest Oregon. Documenting their ecological roles, historical significance, and current status must continue and that information made accessible to a wider public. Mythology associated with the effects of white pine blister rust must be countered; not all sites are high hazard, not all infections are lethal. Performance of rust-resistant stock must be monitored and results made available. Serious dialogue on when and how to restore these species in "no management" zones such as Wilderness Areas and Research Natural Areas must occur. "Southwest Oregon Pathologists for Pines" must evolve into "People for Pines".

Pruning and Thinning Effects After 30 Years In Northern Idaho White Pine Stands

John W. Schwandt and Michael A. Marsden

Introduction:

In 1969, a total of 48 one-quarter acre plots were established on five 15-year old western white pine stands in northern Idaho. Four treatments were replicated at lower-, mid-, and upper-slope positions, and included: thinning and pruning white pine (T&P WP), thinning and pruning all species (T&P All), thinning only, and no treatment (Control).

The study was designed to evaluate effects of pruning and/or thinning on levels of blister rust infection and mortality. Pruning was expected to eliminate many infections plus reduce target area for new infections (Weber 1964, Stillinger 1947). Thinning was expected to reduce the microclimate for blister rust infection and increase tree growth so that fewer infections would be lethal (Stillinger 1947).

1991 Observations

Plots were remeasured in 1991 and showed that white pine survival increased from about 40% on the control and thin only plots to nearly 70% on the pruned and thinned plots. We also found that 65-75% of the uninfected white pine were on the thinned and pruned plots (Schwandt et al. 1994). Although the trees were only 35-40 years old, white pine volumes had increased dramatically on the thinned and pruned plots compared to the thinned only and control plots.

The size and density other species had greatly increased especially in the thinned only and control plots, but no attempt was made to account for volume increases on trees that had not been tagged originally.

1999 Observations

In 1999(30 years after treatment), all plots were remeasured using the 1991 procedures (Schwandt et al.) except that all trees greater than 6 inches in diameter were tallied as well as all of the originally tagged trees. Average diameters for all trees increased from 7.4 on the controls to 8.5 inches on the thinned treatments and from 8.3 to over 9 inches on trees with merchantable volumes.

After 30 years, only 50% (1,223 of 2,417) of the originally tagged white pine were still alive and just over half (667 of 1,223) of these appeared to be uninfected by blister rust (clean). However, the levels of infection and mortality varied widely between the 4 sites. Infection levels were nearly 93% at Johnson Draw, 73.8% at Priest Lake, 65.9% at Two Cut Draw and 58.1% at Potter Creek (Figure 1). The percent of uninfected white pine varied from 7% at Johnson Draw to nearly 42% at Potter Creek. White pine mortality at the Johnson Draw site was nearly 80% compared to about 50% at the Priest Lake site and 37% and 36% at the Two Cut Draw and Potter Creek sites respectively (Figure 1.).

During the 22 years prior to 1991, 45.4% of the 2,413 original white pine died which is equivalent to more than 2% per year. A total of 94 white pine died since 1991, which is an eight-year loss of about 7% of the 1,316, live white pine. This is less than one percent per year which indicates that mortality rates have declined dramatically. The number of uninfected white pine dropped from 703 in 1991 to 667, so new infections increased by about 5% over the same time period.

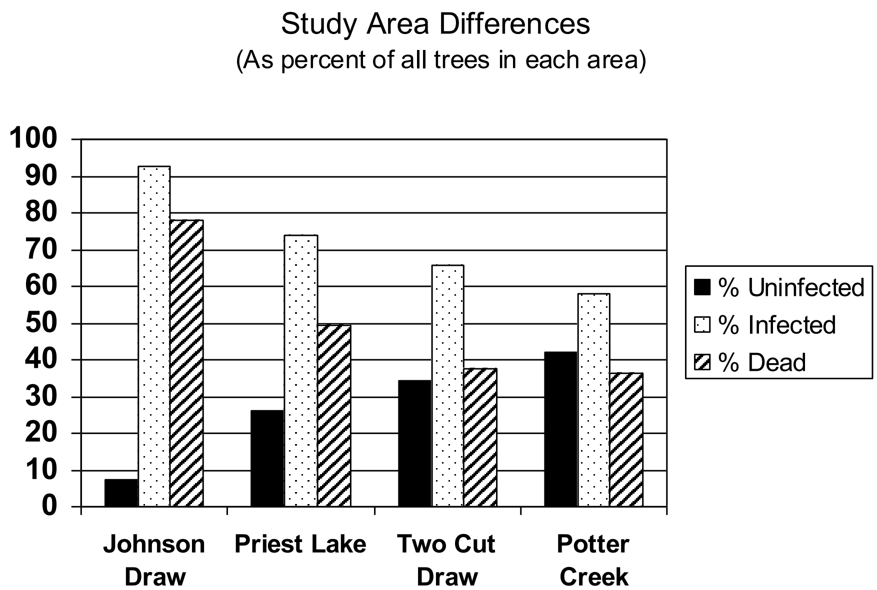


Figure 1. Percent uninfected, infected (including dead), and dead at each study area.

Treatment Effects on White pine survival and mortality:
The pruning and thinning treatments significantly effected the distribution of the surviving and clean trees. White pine survival averaged 63% in the thinned and pruned plots versus 36% in the thinned only plots and about 40% in the control plots (Figure 2).

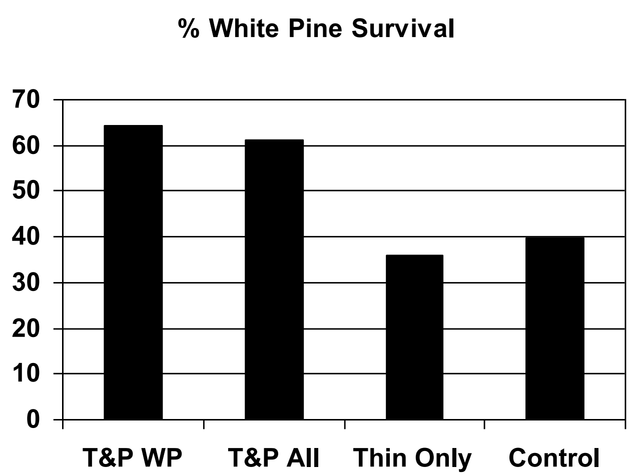


Figure 2. Treatment effects on percent white pine survival; all areas combined.

Percent white pine survival (uninfected plus clean trees) on the two pruned and thinned treatments was nearly double that of the thinned only or control plots in all but Potter Creek (Figure 3).

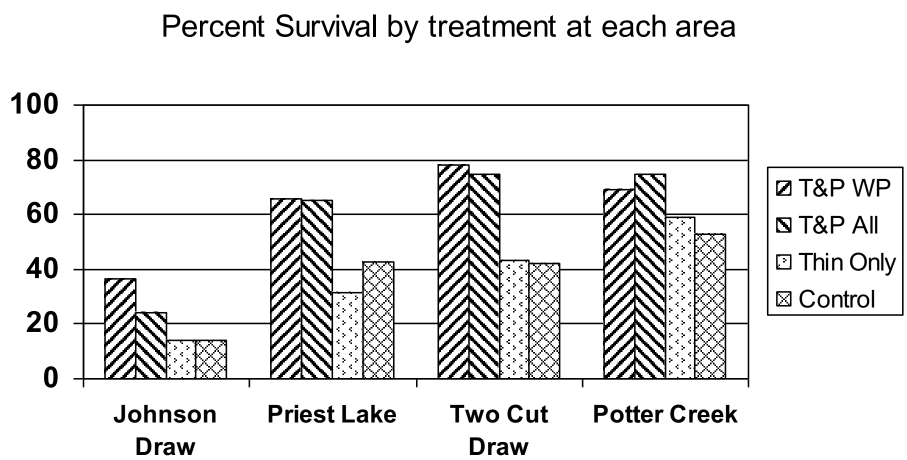


Figure 3. Treatment effects on percent white pine survival in each study area.

Treatment Effects on Uninfected White Pine:
The distribution of white pine that had no visible blister rust infections ("clean") was also significantly effected by treatment. The average number of clean trees on the pruned and thinned treatments increased by 25-150% over the control plots and by 72-400% over the thin only plots. The percent of clean trees on thinned plots was much less than the control plots on all areas except Potter Creek where it was about the same.

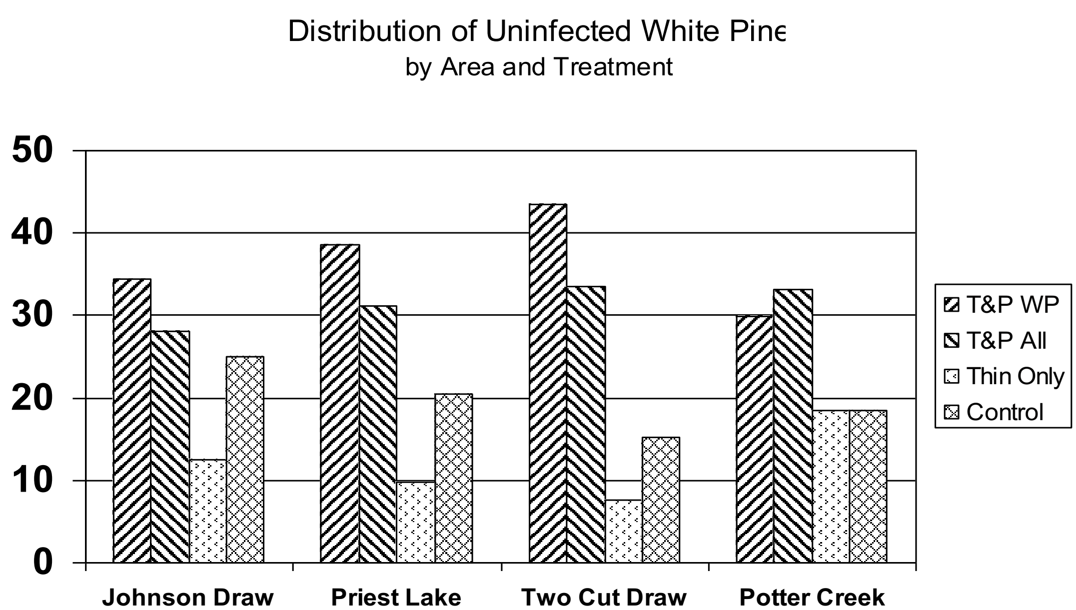


Figure 4. Distribution of 100 Percent of Uninfected White Pine per area by treatment.

Treatment Effects on Trees per Acre (TPA)

Although the percentage differences between treatments are impressive, it is important to look at the actual number of clean trees per acre represented by the percentages. For example, the number of clean white pine per acre at the Johnson Creek site only increased from 5.3 TPA on the thin only treatment to 10.7 TPA on the control and an average of 13 TPA on the two thin and prune treatments (Figure 5).

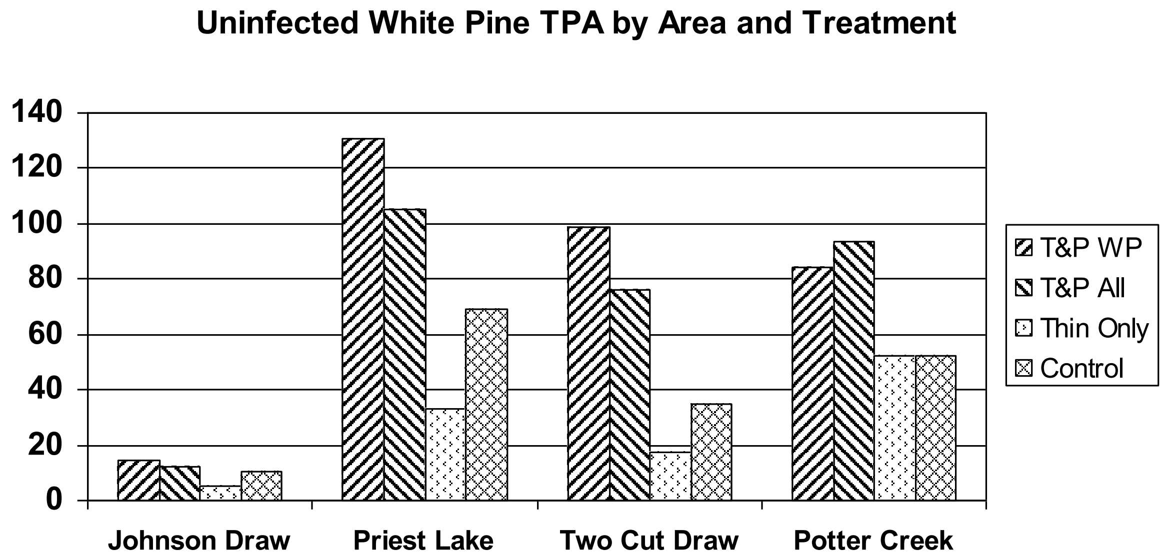


Figure 5. TPA of uninfected white pine by area and treatment.

In spite of the pruning and thinning to favor white pine, there are large numbers of other species on most plots. Stocking densities were originally 2,000 to 13,000 trees per acre (TPA) and were thinned to a 10x10 spacing; approximately 400 TPA.

Although no cutting was done in the control, an effort was made to identify the best crop trees on the same spacing. These tagged trees were the only trees measured in the past and some are still small and suppressed. However, many of the untagged trees are now vigorous co-dominants larger than 6" in diameter, so they were tagged and measured in 1999. As a result, an additional 541 trees were added to the database in 1999. Except for the Priest Lake area, nearly 75% of the new trees were on the control plots. Seventeen percent of the added trees were white pine (87% in the control treatment), while the other 83% were primarily grand fir (55%), western redcedar (11%) and DF (7.2%). The additional trees increased the TPA by about 60% in the control plots of all areas but Johnson Draw where it resulted in a doubling of TPA.

As expected, the thinning treatment reduced the average number of live trees per acre below that of the controls for all species including white pine (Figure 6). However, the TPA of surviving white pine is significantly greater on the pruned and thinned plots than the controls or thinned only plots. White pine survival on pruned and thinned plots varied from a low of about 45 TPA at Johnson Draw to over 200 TPA at Priest Lake while white pine survival on the thin only treatments varied from 21 TPA to 105 TPA and 41 TPA to 175 TPA on the control plots.

Over the past 30 years there has been a gradual species conversion from white pine to other species, especially on the control and thin only plots. The Priest Lake area is the only area where white pine remains the major species, and it is barely 50% in the thin only and control plots compared to about 70% in the two pruned and thinned treatments. In Johnson Draw the white pine TPA in the thinned and pruned treatments are double the TPA in the thinned or control plots, but are only 20% of the total live trees. In Two Cut Draw and Potter Creek the live TPA are about 40-50% of the total trees in the pruned and thinned plots and only 20-35% in the thin only and control plots.

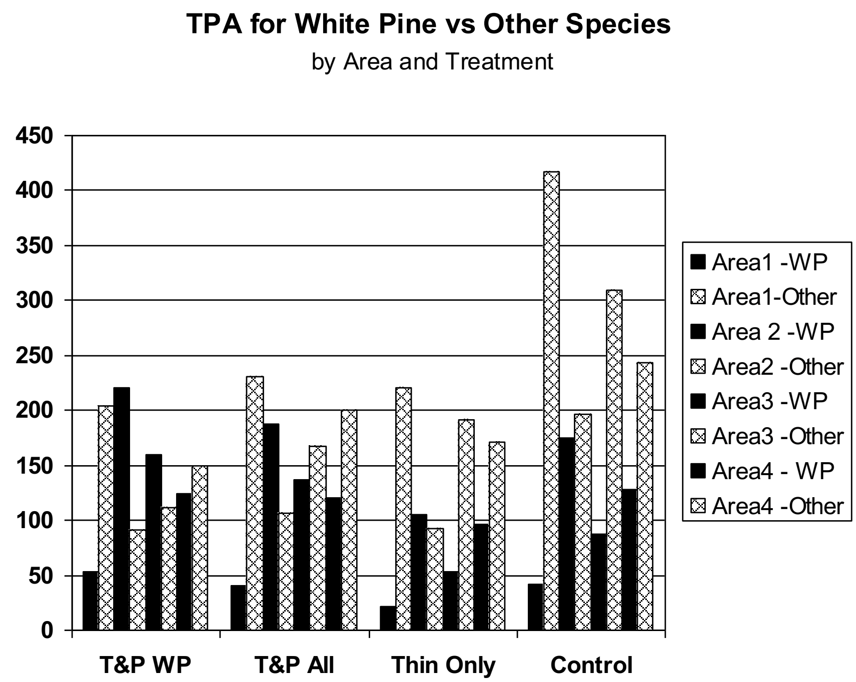


Figure 6. Treatment effects on TPA for white pine vs other species in each area (Area 1 = Johnson Draw; Area 2 = Priest Lake; Area 3 = Two Cut Draw; Area 4 = Potter Creek).

Treatment Effects on Volume:
Effects on white pine volume were similar to that recorded in 1991 for the tagged trees; white pine volumes on pruned and thinned plots were more than twice that of the controls and 63% greater than the thin only plots. However, when all trees greater than 6 inches were added, the volumes on the control plots were much greater than in 1991. Total merchantable board foot volumes for all species on the control plots were actually equal to or greater than those on the treated plots (Figure 7). However, plots that were pruned as well as thinned still had a valuable white pine component, while plots that were thinned only or left as controls had transitioned to non-white pine stands.

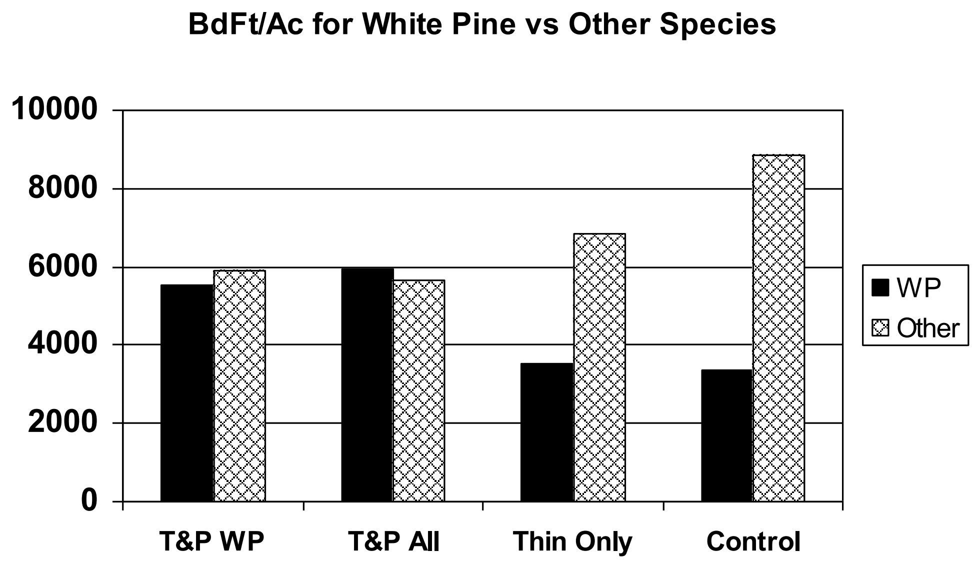


Figure 7. Treatment effects on merchantable BdFt/Ac of white pine vs. other species.

Unfortunately, this species conversion is what has occurred in much of the native stands where white pine was historically a major stand component. White pine were largely removed by blister rust (depending on the site hazard), and usually replaced by less valuable climax species. However, even if the volume of other species approaches that of the white pine, the dollar value will be substantially less due to the historic difference in desirability of white pine lumber over most other species. Even though the volumes of the other species on the thin and prune plots in figure 7 were about the same as the white pine volumes, the values for the white pine volume make the thin and prune treatments much greater than the values for the other species.

The pattern of species conversion in figure 7 held true for these treatments in all areas except the pruned and thinned plots at Priest Lake where white pine remained the dominant species in the stand.

Conclusions and Management Implications:

The importance of pruning must be weighed in light of both the incidence of blister rust and the stocking level of white pine. Although pruning had a very positive affect on white pine survival, it is not a panacea to white pine blister rust problems. Even though pruning may double the number of white pine that survive, this number may be too small to be worth the effort in areas with very high levels of blister rust or low stocking levels. Pruning doubled the number of trees surviving at Johnson Draw, but an increase from 21 TPA to 45 TPA may not be enough white pine to justify the pruning.

In areas with low levels of blister rust (and adequate stocking levels), the benefits of pruning also may not be large enough to justify the pruning. Even though Potter Creek had 58% infection, it was the only stand where pruning treatments didn't double the amount of survival or numbers of clean trees compared to thinning alone or the controls. The percent of surviving white pine in the Potter Creek control plots (22%) was only slightly better than the thinning (21%) and slightly less than the 28% in both thinning and pruning treatments. This represents an increase of only about 10 TPA (from 144 to 155), which is probably not enough to justify the pruning treatment. Two Cut Draw had about the same level of mortality as Potter Creek, but had higher infection levels and much greater treatment effects.

There were many trees with cankers 20-40 feet up in the bole which indicates the trees are still susceptible to rust infection, but these cankers will not be able to rapidly kill trees, and may only cause top kill if much of the crown below the canker is still green. However, the fact that the majority of the uninfected trees are in the pruned plots, indicates that pruning provides additional protection, and even if these trees become infected in the future, it may only result in top kill or very slow mortality.

If the management objective is to restore or maintain white pine, it is crucial to prune to improve survival if there is much rust infection in the white pine. If stands are thinned, the white pine component becomes even more at risk to rust infection because many plots that were thinned only actually had poorer survival than the control plots.

Treatment effects are long-lived, and may actually increase over time since the greatest proportion of uninfected trees is on the pruned plots. Therefore stands where white pine is an important component should be evaluated to determine levels of rust and potential benefits of pruning. This study did not have a prune only treatment, so actual benefits from just pruning can only be estimated, but should be substantial. This study also did not look at genetically improved white pine stock. Much of the white pine planted in the past 10 years has genetically improved levels of resistance, so additional studies will have to be initiated to determine the effectiveness of pruning in this type of stock.

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The Status of White Pine Blister Rust in Intermountain West White Pines

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White-pine species are of limited frequency in the forests of the Intermountain West (Utah, Nevada, Southern Idaho, and Western Wyoming). Limber pine (*Pinus flexilis*) is the most widely distributed species, occurring a wide variety of generally arid sites throughout the region. Whitebark pine (*P. albicaulis)* is limited to alpine areas mostly in western Wyoming, Idaho, and a few ranges in Nevada. Western white pine (*P. monticola)* and sugar pine (*P. lambertiana*) are only found in the Intermountain West in the mountain ranges of western Nevada near Lake Tahoe. Bristlecone pines (*P. aristata and P. longaeva)* are restricted to only a few alpine locations in Nevada and Utah. Despite their relatively limited numbers and distribution, the white pine forests and trees are important in the Intermountain West because they help prevent erosion, retain the snowpack, provide aesthetics, and most importantly provide food and habitat for countless insect, animal, and/or plant species.

Within 30-years after introduction into Vancouver, British Columbia, a tree disease, white pine blister rust, caused by the fungus (*Cronartium ribicola*) found its way to the subalpine white pine areas in Idaho. A semi-formal survey in 1967 indicated the disease was present in low levels of incidence and intensity throughout southern Idaho and western Wyoming.

During 1995-1997 we conducted a formalized white pine blister rust survey of Intermountain West white pines. Overall incidence (number of infected sample stands) of the disease in all surveyed stands was 59% based on a sampling of 127 stands. Disease intensity (% of live sample trees with an infection) averaged 36%. Compared to the 1967 survey in eastern Idaho and western Wyoming, the disease appears to have increased substantially: the 1967 incidence in sampled stands was 11.5% compared to 1997 incidence of 67.2%; and average disease intensity went from 38.3% to 52.4%.

Southward spread of the disease from Idaho and Wyoming appears to have slowed or even stopped. However, the disease was found for the first time in the white pine forests of western Nevada indicating continued disease expansion eastward from infected stands in the central Sierra Mountains. The disease was not found in eastern Nevada or anywhere in Utah.

Blister rust: Where do we stand?

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Introduction

The objective of this paper is to evaluate some emerging issues concerning white pine blister rust (WPBR) in North American five needle pines. Rust history at two locations will be used to focus these issues and to examine some new tools and technology that can help with future management of the disease. The fungus that causes WPBR, *Cronartium ribicola*, simultaneously appeared at 16 known locations within the inland range of western white pine (WWP, *Pinus monticola*) in 1923 (Mielke, 1943). All introductions were verified by backdating WWP infections. Pee Wee Gulch, not among the listed original introduction sites, was later also backdated to 1923 (R. T. Bingham field notes). This site, located about 11 km west of Clarkia, ID on the East Fork of Emerald Creek, will focus the discussion for WWP. WPBR in and near Yellowstone National Park will focus the discussion on whitebark (*P. albicaulis*) and limber (*P. flexilis*) pines. WPBR first appeared in the central Rocky Mountains at Sunshine Creek just north of the north boundary of Yellowstone National Park when an infected *Ribes* plant was found in 1937.

Northern Idaho Western White Pine: Pee Wee Gulch

1923 to 1951

The Pee Wee Gulch stand is special because 10 phenotypically resistant WWP were found in 1951 (Bingham, 1983). Because of these selections, considerable data are available about the stand and its development. Judging from a 1933 aerial photo of the site, the natural stand originated after a 1910 – 1915 clear-cut. The notes show that the land belonged to Potlatch Corporation in 1951. The stand is currently part of the Idaho Panhandle National Forests (NF). About 14 ha (Figure 1) of the stand that contained the resistant phenotypes were surveyed in 2000 to reconstruct stand history from 1923 to the present. In 1950, the stand was about 36 years old and had been exposed to blister rust for 27 years. Resistant tree selection notes (data on file) indicated that *Ribes lacustre* and *R. hudsonianum* were in heavy concentration in the stream-bottom until eradication in 1936. Eradication records for the St. Joe NF show that 2.5 ha of stream-bottom should have supported 2760 *R. lacustre* and 564 *R. hudsonianum* bushes (Hartman, et al., 1940). The 11.5 ha of upland should have supported about 600 *R. lacustre* bushes. Bingham's selection notes indicate that WWP reproduction was dense (ca 5000 WWP/ha). Even though most of the *Ribes* were removed in 1936, the site still showed heavy infection in 1943, 1944, 1947, and 1948. At the time of selection in 1951, the stand supported an average of 200 WPBR cankers per tree. Based on this canker frequency, the probability of escape in this stand was 1 x 10^{-12} (McDonald and Hoff, 1982). Thus, the resistant selections have high probability of possessing resistance genes. Unfortunately, only one of the 10 trees, selection #5, produced seed during the period selections from other areas were progeny-tested (Bingham, 1983). Consequently, only selection #5 was tested and it did pass resistance to its offspring (data on file). Later selection #50 was tested and it too passed resistance to its progeny (data on file). The northwestern (figure 2A) and southeastern (figure 2C) upland slopes of the Pee Wee Gulch stand were dominated by WWP in 1951. Selection #5 is in the center of each photograph. Selections #5, #38, #49, #56 were cankerless in 1951, while trees #50, #51, #52, #53, #55, and #57 supported 1 or 2 verified but dead or poorly growing cankers (data on file).

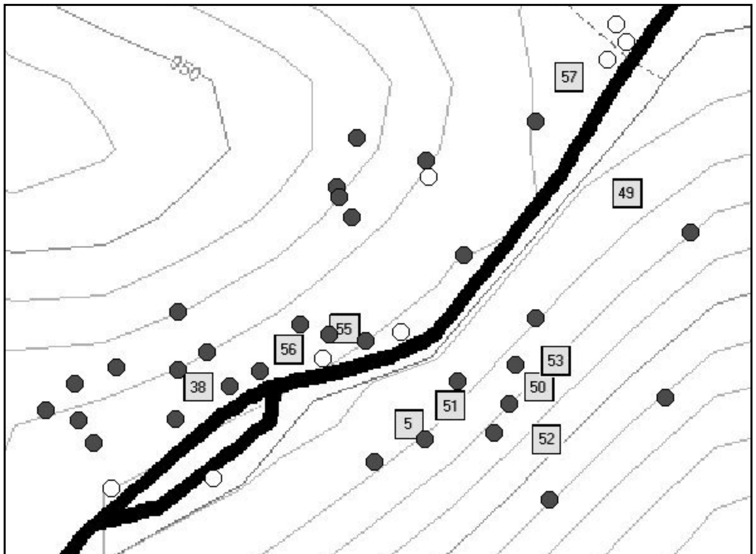


Figure 1. Map of western white pines at Pee Wee Gulch in 2000. Numbered boxes show original (1951) resistant selections, closed dots show surviving trees of original cohort, and open dots show regeneration selected for genetic tests (see text).

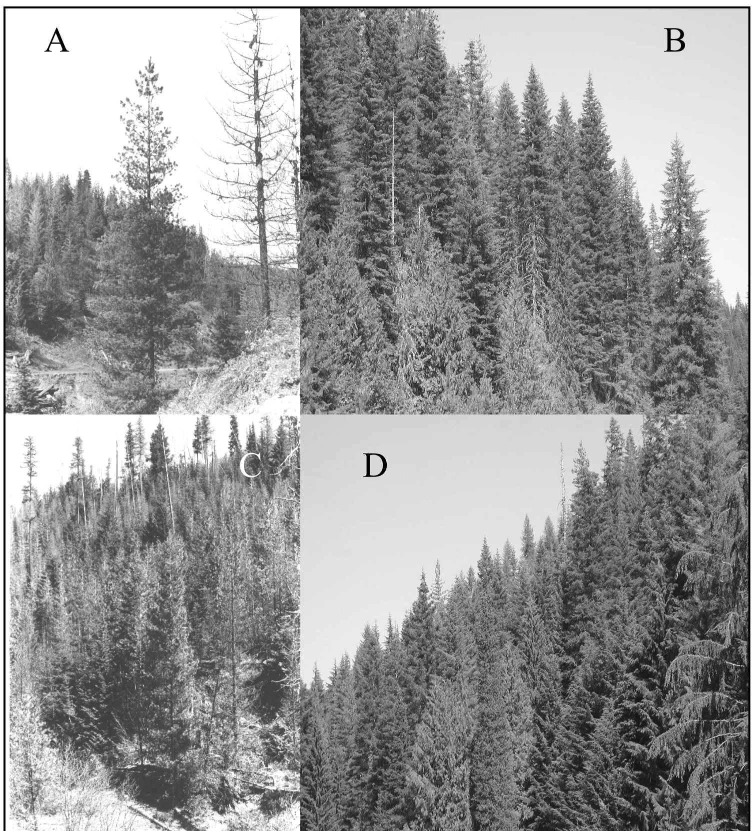


Figure 2. Four photographs of upland Pee Wee Gulch stands on southeast and northwest facing slopes of the east fork of Emerald Creek near Clarkia, ID. (A) June 1951 view of resistant tree # 5 looking northwest (USFS Photo). (B) July 2000 view of the same slope as in A taken from a point slightly south and west from A (USFS Photo). (C) June 1951 view of resistant tree # 5 (in foreground) looking northeast at the northwest slope (USFS Photo). (D) July 2000 view of the same slope as in C taken from a point slightly south from C (USFS Photo).

1951 to 2000

The issue at hand is the fate of these trees and their surviving cohorts after 50 additional years of exposure to WPBR. In the summer of 2000, these 10 trees along with their surviving cohorts and some regeneration were relocated and mapped (Figure 1). The stand is dominated today by Douglas-fir (*Pseudotsuga menziesii*) and grand fir (*Abies grandis*) (Figures 2C and 2D). However, several WWP still survive, including all of the original selections. The original tags were still attached and visible on nine trees. The tag for tree #56 was missing but tree location was appropriate. Today, tree #5 supports 2 flagged branches about 10 m up (presumably caused by poorly growing cankers); tree #51 had a dead top that was caused by a canker; and tree #53 had a broken top caused by a poorly growing canker. The remaining resistant phenotypes appeared to be healthy. Another 31 trees were examined which were judged to belong to the original cohort. Twenty-tree of these trees were judged rust-free. Of the remaining eight trees, six had dead or fading tops and two had flags high in their crowns. The upland (11.5ha) that supported 50 to 75 thousand WWP in 1923 supports 41 survivors today. Current stocking is 2.6 healthy, 0.3 full crowned and cankered, and 0.7 top-killed WWP/ha at the Pee Wee Gulch site.

Where do we stand?

The long-term *in situ* performance of the Pee Wee Gulch resistance selections may provide a glimpse of the long-term performance of materials from the early breeding program. Two experimental plantations were installed in the early 1970s to field test progeny produced by this breeding (Bingham et al., 1973). One plantation, Merry Creek on the Idaho Panhandle NF, was the subject of an intensive analysis of infection rates (McDonald and Dekker-Robertson, 1998) due to its unexpected high infection rate. Meanwhile, a sister plantation, installed at Gletty Creek on the Colville NF, exhibits a relatively low infection rate. Both sites received the same kinds of stock except for susceptible controls. Controls at both sites came from local squirrel caches. At Merry Creek, proportion of infected controls, F1, and F2 were .94 in 6 years, .96 in 26 years, and .89 in 26 years respectively. Proportion of rust-caused mortality at Merry Creek was respectively 1 in 12 years, .84 in 26 years, and .54 in 26 years. The matching values at Gletty Creek in 26 years were .94, .46, and .20 for proportion infected and .70, .31, and .13 for proportion rust-killed (data on file). Several questions can be asked. Are resistant phenotypes 5 times more frequent than originally indicated? Second, is the northern ID resistant phenotype characterized by a single horizontal resistance trait? Third, do the resistant selections, similar performing cohorts, and original before-rust populations differ genetically? Fourth, do the current F2 populations and the Pee Wee survivors differ and, if so, how? How many stands like Pee Wee (high selection for resistance) exist in the northern Rocky Mountains and does stand replacement fire pose a significant risk to naturally selected resistance genes? Should we search out such stands and provide them the opportunity to regenerate?

Central Rocky Mountain Whitebark and Limber pine

Whitebark pine

Records show WPBR moved into the vicinity of Yellowstone National Park from an isolated 1934 pine infection located in the upper Lochsa River in northern ID (Joy and Chapman, 1937), a distance of about 300 km in one year (calculated by GIM). Pine infection first appeared near the north boundary of Yellowstone Park in 1947 (Brown and Graham, 1967). This infection, first reported in 1949, occurred in Sunlight Creek just 3 km north of the Park boundary (Gynn and Chapman, 1949). During a visit to Sunlight

Creek in July of 2000, observed rust infection was severe (Figure 3A and 3B). *R. hudsonianum* was common in the upper reaches of Trail Creek (a tributary of Sunlight Creek) and clumps of *R. lacustre* were frequent along the creek as well as on the adjoining uplands. In the 50 years since introduction, nearly pure stands of whitebark pine show high levels of mortality and the occurrence of some rust-free individuals (figure 2-A). Such pines may pass elevated levels of resistance to their progeny (Hoff et al., 2000). Just north of the Park boundary, a nearly pure stand of old-growth whitebark pine supported a very high infection rate (figure 3B). Mortality was not yet high but increased mortality seems inevitable. At the north Park boundary, near the high point of Tom Miner Basin, a pure stand of whitebark showed extensive damage, nearly 100 percent infection but little mortality. On a historic note, aeciospores were collected in this vicinity from cankers found on whitebark pine on July 18, 1969 (Krebill, 1969). An extensive stand of old-growth whitebark pine on Mount Washburn inside the Park was also visited on the July 2000 trip. A very low rust incidence makes this stand notable. About 2 *Ribes* plants/ha were observed in a cursory examination of the Mount Washburn stand.

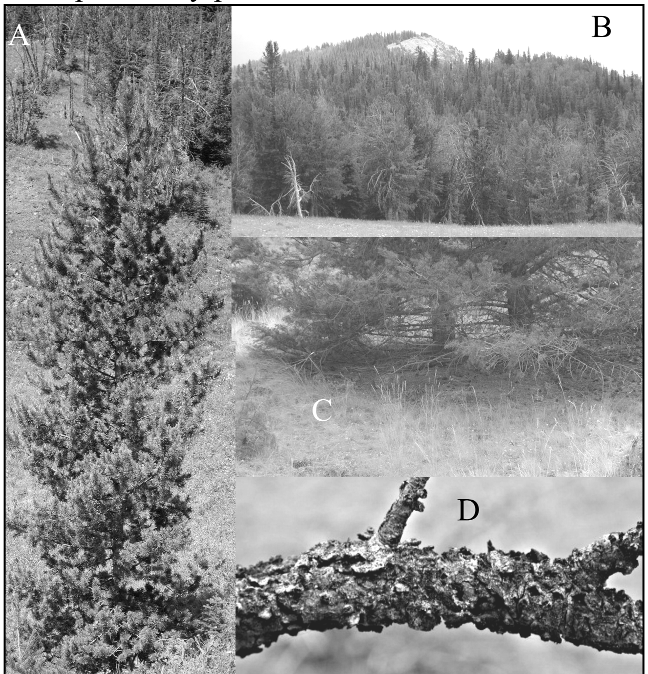


Figure 3. Blister rust on whitebark pine and limber pine in the vicinity of Tom Miner Basin on the north boundary of Yellowstone National Park. (A) Phenopically resistant (canker-free) whitebark pine – notice heavy blister rust damage to whitebark pine in background. (B) Nearly pure stand of old-growth whitebark pine showing high levels of blister rust infection. (C) Limber pine growing on dry site near the Yellowstone River near Corwin Springs, MT. (D) Old blister rust canker on limber pine shown in C (all are USFS photos taken July, 2000)

Limber pine

Blister rust was first reported in Yellowstone National Park at Carnelian Creek (Gynn and Chapman, 1951a) and Mount Washburn (Gynn and Chapman, 1951b) on cankers backdated to 1945. Infection on whitebark or limber pine growing in the Slide Lake Creek drainage (approximately 5 km northwest of Mammoth Hot Springs) was dated to 1948 (Gynn and Chapman, 1950). On July 28, 2000, infection was observed on both *Ribes* and limber pine at Kingman Pass (5 km south of Mammoth Hot Springs) in the Park. WPBR aeciospores were collected from limber pine near this site on May 28, 1969 (Krebill, 1969). An unusual timing of spore stages was observed in that both pycnia and aeciospores were at optimal development simultaneously. A recent report also mentions that aeciospores commonly release in August and September on the Shoshone NF (Harris, 1999). Another unusual aspect of blister rust in limber pine is its occurrence on very dry sites. Old blister rust cankers were observed at a site along the western shore of the Yellowstone River near Corwin Springs, MT (Figure 3D). Other infection centers at very dry sites are known. The recently reported observation of WPBR in Colorado (Johnson and Jacobi, 2000) is on a very dry site (W. Jacobi, personal communication). A newly reported center at Indian Pass (Harris 1999) just north of Cody, WY is also located on a very dry site (D. Despain, personal communication). Could presence of WPBR on these dry sites signify genetic adaptation or perhaps even a hybrid between *C. ribicola* and *C. occidentale*, the causal agent of pinyon rust?

The historic blister rust survey reports include some interesting notes about the distribution of pinyon rust. *C. ribicola* and *C. occidentale* are so morphologically similar on the *Ribes* host that a special staining test was the only method of reliable identification (Acree and Goss, 1937; Ford and Rawlings, 1956). In the 1950s, Gynn and Chapman (1952, 1957, 1959) provide information on the distribution of *C. occidentale* on *Ribes*. Pinyon rust was found in the southeastern corner of Idaho and the adjoining western central WY. It was found near Laramie, WY as well as on the Roosevelt, White River and Arapaho NF in CO. The rust was found on the Bridger NF near Yellowstone National Park and as far north as Glendive, MT. All locations, except for Glendive, are well within the range of limber pine (Little, 1971). WPBR appeared in southeastern ID in 1942 and apparently reached southeastern WY (Laramie) by 1949 (Brown 1978), after reaching Yellowstone Park in 1937.

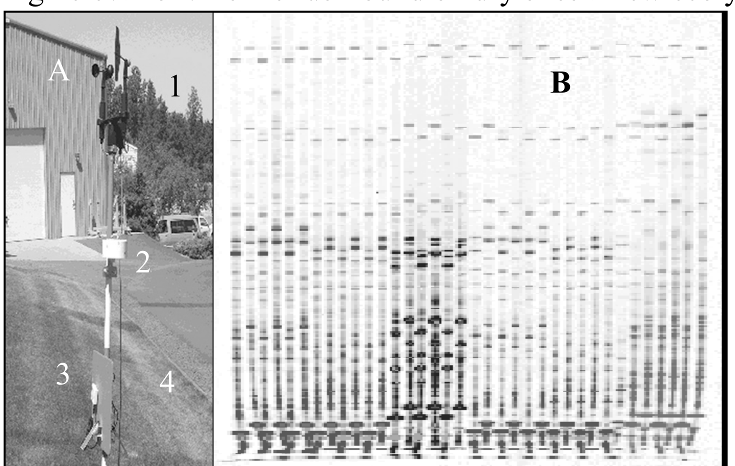
Infections began appearing on limber pine growing on a very dry site a few miles east of Yellowstone Park as early as 1941 (Brown, 1970). The infection trend has continued to build on dry limber sites. Sites and levels are 10 percent at Cathedral Spires on the Black Hills NF (Lundquist and Geils, 1992), 52 percent at Indian Pass northwest of Cody, WY (Harris, 1999), 50 percent at Cherokee Park Road in north central CO (Johnson and Jacobi, 2000) and 78 percent at Jensen Pass in southeastern ID (Smith and Hoffman, 1998). The Jensen Pass location is about 200 km northeast of the Raft River Range, which currently supports abundant rust on single leaf pinyon (*P. monophylla*) at 2000 m elevation (Van Arsdel and Krebill, 1995). No WPBR infection was found on limber pine at Mt. Harrison, ID located about 80 km northwest of the Raft River Range (Smith and Hoffman, 1998). Pinyon rust infected up to 90 percent of single leaf pinyon pine stems in the Pine Nut Mountains near Minden, NV (Van Arsdel and Krebill, 1995). WWP also grows in these mountains, but a 1997 survey did not reveal any WPBR (Smith and Hoffman, 1998). However, a late-season aeciospore producing form of WPBR was found in 1997 on whitebark pine at Mt. Rose, NV about 50 km northwest of the Pine Nut Mountains (Smith et al., 2000). WPBR was first found in this region about 75 km west in northern El Dorado County, CA in 1938 (Smith, 1996).

This short historical sketch demonstrates that ecological opportunity exits for the rusts to hybridize. How could it happen? No mechanisms are known by which hybridization could occur on the *Ribes* hosts and recent phylogenetic studies do not demonstrate that the rusts are closely related (Vogler and Bruns, 1998). Aeciospores of both rusts are known to travel long distances as indicated previously. In addition, there is some evidence that aeciospores of cereal rust can fertilize another thallus (McDonald, 1978). The rusts have almost identical susceptibility profiles across *Ribes* species (Hahn, 1928). Both hosts of both rusts occur in mixed or neighboring stands at a few locations. Therefore, direct hybridization via pycniospores might be feasible. Hybridization must be added to the list of hypothesized explanations for the action of blister rust in dry limber pine and other anomalies in its life cycle. Other hypotheses such as "wave years" (McDonald and Hoff, 2000) and some form of ecotypic variation (McDonald, 1996) must also be considered.

New findings about the genetic architecture of WPBR should be added to this story. Using molecular techniques (Hamelin et al., 2000) compared blister rust collections obtained from WWP from western Canada, southwestern white pine (*P. strobiformis*) from New Mexico, and eastern white pine (*P. strobus*) from eastern Canada. Evidence was presented that showed WPBR on the North American continent consists of isolated eastern and western populations. No samples from the northern Rocky Mountains of the USA were included.

Where do we stand?

The behavior of WPBR described above raises some important questions. First, extensive stands of whitebark pine near Yellowstone Park should see high rates of mortality in the near future. How will these stands be replaced? What are the factors giving rise to the large amount of variation in rust occurrence and damage? Are trees showing low or no canker incidence in areas of high rust activity phenotypically resistant or escapes (McDonald and Hoff, 2000)? Are epidemiological principals the same at both low and high elevation? Is the rust found on dry sites a new ecotype? Is it a hybrid with *C. occidentale*? Can the behavior of rust on dry sites be explained by wave year theory? If a hybrid or ecotypes have occurred, how will their existence factor into continental genetic architecture of the white pine blister rust?



Sample Info	ACGC/CCCG102	ACGC/CCCG103	ACGC/CCCG104	ACGC/CCCG105	ACGC/CCCG106	ACGC/CCCG107
S9 (AC/CC)(ACGC/CCAT)	230.29	233.33	234.41	242.72	244.54	
S28 (AC/CC)(ACGC/CCAT)	230.26		1 234.26			248.62
GH26 (AC/CC)(ACGC/CCAT)	230.2	233.44	234.3			248.83
GH45 (AC/CC)(ACGC/CCAT)		233.04	234.22			

C

Sample Info	ACGC/CCCG108	ACGC/CCCG109	ACGC/CCCG110	ACGC/CCCG111	ACGC/CCCG112	ACGC/CCCG113
S9 (AC/CC)(ACGC/CCAT)	250.82	251.84	252.65	253.57	254.38	256.52
S28 (AC/CC)(ACGC/CCAT)	250.61	251.73	2 252.55	253.46	254.28	256.31
GH26 (AC/CC)(ACGC/CCAT)	250.81	251.83		253.66	254.37	256.5
GH45 (AC/CC)(ACGC/CCAT)	250.61	251.63	252.44	253.36		256.2

Figure 4.Illustration of two new technologies. (A) Weather stations based on inexpensive and accurate data loggers 1: wind speed and direction, 2: 10 bit temperature and relative humidity, 3; leaf wetness duration and light in sun, 4: leaf wetness duration and light in shade. (B) Amplified fragment length polymorphisms from western white pine on gel from a 48 channel automated sequencer (image courtesy of M-S. Kim). (C) DNA fragment length data extracted from gel in C showing absence (box 1) and presence (box 2) of polymorphisms (Courtesy of M-S. Kim).

To the Future

Molecular Biology - Host

The Pee Wee Gulch stand of WWP raises many questions about the nature and management of resistance genes. Many of these issues can be addressed with molecular biology. A powerful technique known as amplified fragment length polymorphisms (AFLP) is being applied to WWP (M-S. Kim personal communication) and initial results are promising (Figures 4B and 4C). This technique could also help sort out the resistance architecture of whitebark and limber pines. Sequencing and tagging of mitochondrial and choroloplast DNA shows promise in the study of whitebark pine genecology (B. Richardson personal communication). Finally, pathogeneses-related proteins have been observed in the white pine blister rust pathosystem (Yu et al., 2000). A host-encoded protein was reported that is related to frost hardiness and is elevated upon WPBR infection in susceptible plants but not in resistant (slow-rusting) plants (Yu et al., 2000). Concentration of this protein is subject to immunoassay and may provide a way to rapidly screen for resistant genotypes where the probability of escape is high.

Molecular Biology – Rust

Molecular techniques have been successfully used to investigate the formation of natural hybrids of the tree rusts *Melampsora medusae* and *M. occidentalis* (Newcombe et al., 2000). Brasier (2000) recently listed several other cases of natural hybrids among species of the plant pathogenic genera of *Heterobasidion*, *Phytophthora*, and *Ophiostoma*. The AFLP technique mentioned above also can be a powerful tool for the investigation of the genetic architecture of blister rust. Key considerations leading to hybrid creation are ecological concurrence and mating biology (Brasier, 2000). As noted above, *C. ribicola* and *C. occidentale* have had ample opportunity to hybridize. An important question is whether mechanisms for gene flow exist between the species. Given the potential importance of such hybrids to most aspects of the blister rust problem, a search for evidence of hybridization should be afforded the highest priority. The AFLP technique mentioned above also can be a powerful tool for the investigation of the genetic architecture of WPBR, including the question of hybridization or adaptation.

Epidemiology, Modeling, and Integrated Management

Successful application of integrated management of blister rust anywhere in North America will require more understanding of all epidemiological aspects of blister rust (Hoff et al., 2000). The role of wind is poorly understood and other weather data needed to drive models at the fine spatial and temporal scales necessary to capture the essence of blister rust behavior are not available. Much more information is needed about the biology of rust/*Ribes* interaction (McDonald, 2000). Epidemiological considerations are fundamental to predicting and managing blister rust behavior as it claims increasing numbers of stands of five-needle pines in the Great Basin, Colorado, and elsewhere.

Computer models can be of great benefit by organizing and formalizing the hundreds of interactions occurring among the various elements of a complex system such as a blister rust epidemic. Some modeling work has been completed (McDonald et al., 1981; McDonald, 1996; Rice, 1992). Current models need verification and reliable fine-grain climate data on which to run. Much work is still needed. I suggest that all interested organizations pool their resources and help create a standardized North American blister rust simulator. Fine-grain climate data are needed to better understand the interaction of *C. ribicola* with its environment as well as to supply data to a model. Recent advances in data logging technology afford an opportunity to supply accurate geo-referenced data. Reliable, accurate, and relatively inexpensive data loggers and environmental sensors are readily available. For example, a station capable of logging wind speed, wind direction, relative humidity, temperature, leaf wetness, light, and temperature in sun and shade (Figure 4A) can be implemented for about $1000. We should install about 100 of these stations and begin collecting geo-referenced site-specific data for use in model development, model verification, and bridging to long-term hourly climate data that is readily available from about 8000 stations west wide. Upcoming satellites designed to supply climate data to agricultural models may prove to be useful as well.

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PANEL: WOOD DECAY AND STAIN FUNGI ON WOOD IMPORTS/EXPORTS

Barbara Illman - Moderator

Introduction

Barbara Illman
USDA Forest Service
Forest Products Lab.
University of Wisconsin

Exotic species, also known as non-natives, introduced, nonindigenous species or invasives are changing the natural areas in the United States. These exotics may have expanded beyond their native range or been introduced from other countries around the world. Many scientists think that the spread of exotic species is one of the most serious, yet least appreciated threats to biodiversity. Exotics inflict a heavy toll on American agriculture, reducing the quality and raising the cost of food, feed, and fiber. This panel presents a review of problems encountered with exotic species on wood product imports, a list of insect and fungal infestations found in the United States in the last 12 months, and a case history of a newly reported disease.

Exotic Fungi and Insects on Wood Product Imports

Barbara Illman
USDA Forest Service
Forest Products Lab.
University of Wisconsin

Forest health risks are emerging from exotic species of insects and fungi on wood product imports into North America. The products are unprocessed wood that includes packing materials, chips, logs, timber, and lumber. Wood packing materials account for 50% of the wood imported into the United States alone. These include dunnage, packing crates, packing blocks, spools and pallets.

With increasing international trade, all countries are being challenged to contain indigenous species within their borders. Several countries seek mitigation treatment of wood products to kill *Bursaphelenchus xylophilus*, *Heterobostrychus aequalis* and *Rhagiium* spp. The United States, Britain and Canada have concerns about the importation of the spruce bark beetle, *Ipes typographus*, and symbiont stain fungus, *Ophiostoma polonica*. When the Asian long-horned beetle infested Brooklyn, New York, more than 2000 trees had to be destroyed, costing the federal and state government more than $5 million. A similar infestation now plagues Chicago. The USDA has prohibited the importation of untreated wood packing material from China and has proposed extending this ban to other countries. The International Plant Protection Convention (IPPC) is considering a proposal for a treatment standard that would be required on the exportation of wood packing materials worldwide.

Mitigation methods for debarked packing material that are being investigated include fumigants, kiln heating, and microwave or gamma irradiation. Our laboratory is conducting research on kiln heat parameters needed to kill the Asian long-horned beetle (ALB) on lumber. Wooden pallets from China have previously carried the Asian long-horned beetle into the United States. A surrogate species, *Monochamus carolenesis*, has been selected for the studies, as it is indigenous to the Midwest, has similar size and life cycle as ALB. Timber colonized by pheromone-attracted *Monochamus* on the Nicolet National Forest will be milled into lumber, kiln treated and assayed at the Forest Products Laboratory (FPL). Our ultimate goal is to establish efficacious, practical and verifiable kiln heat treatment schedules for eliminating insects and fungi associated with wood packing materials.

Detection methods are needed for identification and location of invasive species. The methods would be used for quarantine pest detection on imports to determine compliance of treatment requirements and efficacy of the mitigation methods. Some diagnostic methods that are being considered include ultrasound, DNA fingerprinting, tomography, pheromone lures, and electronic sniffers. Our laboratory is testing the use of new nondestructive ultrasonic equipment patented at FPL and licensed by Perceptron. We expect to determine if the ultrasonic assay system can be used for detecting and locating ALB in timber and lumber.

Insects, Fungi, Wood and Humans

Tom Hofacker
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Washington Office

Within approximately the past 12 months, infestations of five new exotic insects and diseases have been found in North America.

- *Tetropium fuscum*
- *Calidium rufpenne*
- *Tomicus minor*
- *Phytophthora*
- *Hesperophanes campestris*

The brown spruce longhorned beetle (*Tetropium fuscum*) was discovered in Nova Scotia; the smaller Japanese cedar longhorned beetle (*Calidium rufpenne*) was found in Connecticut and Massachusetts; the smaller European pine shoot beetle (*Tomicus minor*) was captured in a pheromone trap in Ontario; the plum pox virus (a Potyvirus) was found in Pennsylvania and Ontario; a previously unknown species of *Phytophthora* was found to be the causal agent of sudden oak death in California. In addition *Hesperophanes campestris*, a longhorned beetle from China, has been repeatedly captured in traps placed outside of warehouses in New Jersey. With international trade and the import of wood into the United States continuing to accelerate, all forests are at risk to exotic invasions. This risk seems high enough that the threat of invasive species should be considered in future forest-planning efforts.

A New Wilt Disease of Takamaka Trees in the Seychelles

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The broadleaved, evergreen tree *Calophyllum inophyllum* is widely distributed within the Indian Ocean area, commonly occurring as a littoral species. One variety, known as takamaka (*C. inophyllum* var. *takamaka*) is found on the coast of East Africa and in the Seychelles. In 1994, a previously unreported wilt disease was found to be affecting takamaka in the Seychelles, causing extensive tree mortality in amenity and recreational areas. First records of the disease were limited to Mahe, the principal island of the Seychelles group, and the causal agent was identified as the fungus *Verticillium calophylli* [M. Ivory & W. Andre (1995): African Journal of Mycology and Biotechnology **3**, 169-170]. Much earlier records from the 1940's, also indicated that the same fungus had been isolated from diseased trees of other *Calophyllum* spp. in El Salvador and Mauritius.

As a result of these findings, a number of questioned needed to be addressed:

- Could diseased trees be cured using fungicide injection?
- Was the fungus transmitted by bark beetles (*Cryphallus trypanus*) found breeding in dead and dying takamaka trees?
- Was the disease a recent introduction and, if so, where had it come from?

Two fungicides were tested: thiabendazole and propiconazol. Using low pressure fungicide injection it proved possible to treat lightly diseased trees with a formulation of thiabendazole, but much less effective with the propiconazol formulation. The thiabendazole also persisted in treated trees for more than year. However, it proved to have much less activity against the takamaka pathogen than propiconazol, leaving the question remaining of whether the disease could be fully arrested using fungicide injection.

Work assessing the potential for insect transmission of the disease yielded more unequivocal results. Individuals of *C. trypanus*, especially those which emerged from the thicker, bark on the trunk and major branches of diseased trees, carried spores of the fungus. The number ranged from just a few spores to more than a hundred on an individual beetle, and vector beetles probably introduced the pathogen into the xylem of healthy trees when they tunneled into the pith of leaf-scars [D. Wainhouse *et al*. (1998): Forest Ecology and Management **108**, 193-199]. While isolating the takamaka pathogen from the insect vectors, it also became apparent that the fungus was a species of *Leptographium* and not, as previously supposed, a species of *Verticillium* [J. Webber, K. Jacobs & M. Wingfield (2000): Mycological Research **103**, 1588-1592]. The association of *L. calophylli* with a bark beetle vector was consistent with the biology of *Leptographium*, although most species within this genus occur on conifer hosts.

Comparison of more than 50 isolates of *L. calophylli* using RAPD, also showed there was genetic variation between individuals [J. Webber (1999): Forest Research Annual Report 1998-99, pp.21-25, Stationery Office, UK]. This suggested that the outbreak of the disease on the islands had either resulted from multiple introductions or had been present for some time and natural variation had arisen. However, the pathogen was essentially the same as the form of *L. calophylli* isolated from Mauritius in the late 1930's. In contrast, the RAPD profile of the fungus from El Salvador was consistently different, suggesting that despite morphological similarities, the El Salvadorian and Seychellese forms of the fungus are essentially different species.

Currently, the disease remains a problem and has spread to a number of the islands in the Seychelles, possibly as a result of unrestricted movement of takamaka wood from island to island. This case history illustrates the problem of trying to contain and control a newly reported disease, which may have been present, but unrecorded, for some time and which is spread by an insect vector. Confusion over the taxonomic identity of the disease agent can add to the problem.

PANEL: DWARF MISTLETOES OF NORTH AND CENTRAL AMERICA

Bob Mathiasen - Moderator

Viscum album in California – An update

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Preface: This report is a brief summary of field studies and a dissertation written by Karsten Dufft as partial fulfillment for a masters degree in biology under the direction of Dr. Hans Weber, Professor of Biology, Phillips University, Marburg, Germany. (See footnote 1.) I assisted Mr. Dufft in the design and field work on this study.

The European mistletoe, *Viscum album* has continued to spread in Sonoma County in the areas around Sebastopal and Santa Rosa since it was introduced nearly a century ago; Scharpf and Hawksworth, 1976. To date, the parasite has not spread out of the county or out of this general area of infestation. The most recent survey in 1996 indicated that the area infested by *V. album* was about $220Km^2$ (138 square miles), in comparison to $114Km^2$ (71 square miles) infested in 1991, Hawksworth, Scharpf and Marosy 1991. The survey indicates that the spread consists mainly from an enlarging periphery of the original infestation.

In 1991, *V. album* was found on 23 different species of deciduous trees, the most common being maple, apple, black locust, red alder and Freemont cottonwood (Hawksworth, Scharpf and Marosy 1991). In 1996, these five species were still the most commonly infected, but willow (*Salix*) was also frequently infested. (Table 1).

Nine previously uninfested tree species were recorded as having one or more infection in 1996 (Table 2). All of these species were growing as planted trees or ornamentals within the area of infestation. As shown in Table 3, nearly all the susceptable hosts and mistletoes were found in "gardens", ripirian zones, or in street plantings and abandoned orchards.

Except for the damage done to ornamental plantings, the only threat to native trees appears to be to red alder (*Alnus rubra*). This species appears to be highly susceptible and suffers substantial damage from *V. album*. Continued spread of this pathogen, especially in the native alder stands along the coast, could result in unforseen and unwanted management problems. The fact that the parasite has not spread out of the initial area of infestation for nearly 100 years suggests that long distance spread of *V. album* is very unlikely. However, continued localized spread, especially through native alder and maple stands is highly probable. Periodic monitoring of the parasite in these stands would be a wise management practice.

[1]"Unterschungen zur Verbreitung der Laubholzmistel *Viscum album* L. spp. *album* (Viscaceae) in Sonoma County, California."
Diplomarbeit am Fachbereich Biologie der Philipps-Universität Marburg.
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Mistletoe phylogenetics: Current relationships gained from analysis of DNA sequences

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Introduction

The purpose of this paper to briefly summarize some of the advancements made in our understanding of evolutionary relationships of mistletoes. It is no exaggeration to say that the past decade has witnessed a virtual revolution in phylogenetic investigation, owing mainly to the application of molecular methodologies and advancements in data analysis techniques. These powerful approaches have provided a source of data, independent of morphology, that have been used to address questions in green plant evolution, including parasitic plants like mistletoes.

How Many Mistletoes?

The term mistletoe is not strictly a taxonomic term but refers to shrubby branch parasites that occur in four families of the sandalwood order (Santalales). Of the total 90 genera and 1306 species of mistletoes (Table 1), Loranthaceae has the majority of genera (83%) and species (69%). Another 26% of the total mistletoe species are found in Viscaceae, mainly because of the speciose genera *Phoradendron* and *Viscum*.

How Many Times Did Mistletoes Evolve?

As indicated in Table 1, molecular data have been instrumental in shaping our understanding of phylogenetic relationships in Santalales. At present, complete nuclear small-subunit (18S) rDNA and chloroplast *rbcL* sequences have been obtained from representatives of all mistletoe groups. Analyses of these genes separately and in combination give the same general topology for the order (Fig. 1). Olacaceae are basalmost and, although paraphyletic, this assemblage is sister to the remaining members of Santalales. This position is in agreement with traditional concepts and fits with the observation that Olacaceae is the only family in the order with parasitic and nonparasitic members. The two-gene tree (Fig. 1, no. 1) also shows that *Schoepfia* is not closely related to other Olacaceae but is sister to *Misodendrum*, a mistletoe that parasitizing southern hemisphere beech trees (*Nothofagus*) in Chile and Argentina. Indeed, if this phylogeny is correct, *Misodendrum* may represent the oldest genus that evolved the mistletoe habit.

The topology of the tree shown in Fig. 1 indicates that aerial parasites evolved independently in Misodendraceae and Loranthaceae. The ancestral node for both clades each gave rise to root and stem parasite lineages: *Schoepfia* (root par.) and *Misodendrum* (stem par.) vs. *Gaiadendron* (root par.) and *Moquiniella/Tupeia* (stem pars.). It is generally recognized that the three root parasitic genera in Loranthaceae (*Atkinsonia,* *Gaiadendron*, and *Nuytsia*) are primitive, however, sequences for both 18S rDNA and *rbcL* from all three genera are not available to test this hypothesis. If these genera were not basal in the family, then their root parasitic habit would have to be interpreted as a reversal from an aerially parasitic ancestor. Such directionality for this character has neverbeen documented (nor suggested) and is highly unlikely (i.e., under Dollo parsimony, the character state polarity "root parasite to stem parasite" is irreversible). Once aerial parasitism had evolved in Loranthaceae, it appears that this habit was selectively advantageous given the explosive adaptive radiation of genera and species that subsequently ensued in the southern hemisphere. Therefore, the molecular results obtained to date strongly suggest an independent evolution of the mistletoe habit in Misodendraceae and Loranthaceae (Fig. 1, no. 2).

Within the sandalwood order, the next occurrences of the mistletoe habit are in Santalaceae. The number of times this evolutionary event happened cannot be stated precisely at present because molecular data are incomplete for all relevant genera. One possible case of independent evolution of aerial parasitism involves the three neotropical genera traditionally classified in Eremolepidaceae (Fig. 1, no. 3). Both 18S rDNA and *rbcL* sequences for all three genera have been obtained and upon analysis they emerge within a clade composed of *Exocarpos* and *Omphacomeria* (tribe Anthoboleae of Santalaceae). The three genera are not monophyletic, hence there is no support from the molecules for maintaining a separate family Eremolepidaceae. Indeed the entire "family" Santalaceae represents a series of grades which will require further work to arrive at an evolutionarily sound circumscription. Another possibly unique evolution of the mistletoe habit occurred within tribe Amphorogyneae and involves four genera: *Dendromyza* (including *Cladomyza*), *Dendrotrophe*, *Dufrenoya* (including *Hylomyza*), and *Phacellaria* (Fig. 1, no. 4). Recent work by Jill Macklin (unpublished, pers. com.) using nuclear ITS rDNA sequences indicates these aerial parasites are monophyletic (evolved once from a common ancestor) and that the basalmost genus is *Dendrotrophe*. Interestingly, the genus *Phacellaria* is an obligate parasite on other mistletoes (usually Loranthaceae). At present, sequences for *rbcL* are lacking for the two genera shown in Fig. 1 (*Dendrotrophe* and *Dufrenoya*), hence their position on this tree was determined from the 18S rDNA sequence alone. Efforts are being made to include a full complement of sequences for these and other Amphorogyneae because resolving their position in Santalaceae may help shed light upon the evolutionary origin of Viscaceae.

Emerging from the series of Santalaceae grades is a strongly-supported clade that represents the family Viscaceae (Fig. 1, no. 5). This group of seven genera is clearly monophyletic and support (using bootstrap resampling techniques) is high (100%) using 18S rDNA, *rbcL* or combinations of the two molecules. As previously demonstrated empirically (Nickrent and Starr 1994), rates of molecular evolution in Viscaceae are higher than other families in the order. Surprisingly, despite these high rates, relationships within the family are remain unresolved. *Phoradendron* is clearly sister to *Dendrophthora* and *Korthasella* sister to *Ginalloa*, however these are the only well-supported clades within the family. It is likely that more sequences from genes with fast evolutionary rates are required to tease apart the intergeneric relationships in Viscaceae.

Infrageneric Relationships in Viscaceae

At present, all mistletoe infrageneric molecular phylogenetic studies have been in Viscaceae. Molecular phylogenetic analyses have been published on three of the seven genera: *Arceuthobium* (Nickrent et al. 1994), *Korthalsella* (Molvray et al. 1999), and *Phoradendron* (Ashworth 2000). The following gives a brief summary of the results from these studies as well as preliminary information about *Viscum*.

Arceuthobium. Interspecific relationships in dwarf mistletoes have been addressed using a variety of biochemical methodologies beginning with flavonoids (Crawford and Hawksworth 1979) and continuing with isozymes (Nickrent 1986) and DNA sequencing (Nickrent et al. 1994). The taxonomic and systematic results from the latter two studies were summarized in Nickrent (1996). The original ITS study of *Arceuthobium* included sequences from 22 taxa, however, since that time sequences from an additional six New World taxa have been obtained. Given that these sequences are from Central American taxa, their relationships are discussed in Mathiasen et al. (2000) and will not be repeated here. In general, the topology of the dwarf mistletoe ITS tree is fully congruent with the one published in 1994, but greater resolution has been obtained by adding other taxa. If section *Pusilla* were reduced to a *Series*, the New World dwarf mistletoes would comprise five Sections: *Arceuthobium*, *Americana*, *Penda*, *Campylopoda*, and *Vaginata*. The latter section would then be divided into fives Series: *Globosa*, *Minuta*, *Pusilla*, *Rubra*, and *Vaginata*. Nearly complete taxon sampling has been achieved for New World *Arceuthobium*, hence it is likely that the tree topology will remain stable. Sequences from seven members of Section *Campylopoda* are known and all are very similar or identical to those of the four taxa represented on the tree. Therefore, it is unlikely that additional sequences from this Section will alter the results. Only two Mexican taxa remain to be added to achieve complete sampling for the New World taxa: *A. oaxacanum* (Series *Rubra*) and *A. yecorense* (Series *Stricta*). Continuing phylogenetic work with *Arceuthobium* involves obtaining sequences of the remaining Old World taxa (*A. juniperi-procerae, A. azoricum, A. chinense, A. minutissimum, A. pini, A. sichuanense*, and *A. tibetense*). Attempts are being made to extract genomic DNA from herbarium specimens with some success.

Korthalsella. The study by Molvray et al. (1999) used nuclear ITS rDNA and chloroplast *trnL-F* spacer sequences from 25 populations of *Korthasella* collected from across its range. Parsimony analyses of each data set separately and in combination were highly congruent. A species from Queensland Australia (*K. papuana*) was sister to the remaining taxa and these taxa were further resolved as two subclades with either differentiated or undifferentiated inflorescence branches. These results indicate that a classification based upon morphology (Danser 1937) is not supported by genetic data. Moreover, plants on different hosts that are genetically closely related can have markedly different morphologies (internode shapes). This prompted the authors to propose host influence on the morphology of the parasite, an issue visited by workers looking at other viscaceous genera such as *Arceuthobium* (Gill 1935) and *Viscum* (Meyer von Freyhold 1987).

Phoradendron. The genus *Phoradendron*, comprising at least 100 species of New World mistletoes, is closely related to *Dendrophthora*. Indeed, a single morphological character defines the two genera: one anther locule for *Dendrophthora* and two for *Phoradendron*. The monophyly of these genera has been questioned based upon molecular evidence (Nickrent and Duff 1996). More recently, a detailed molecular phylogenetic analysis of these two genera was conducted using nuclear ITS and 26S rDNA sequences (Ashworth 2000). One taxon, *D. guatemalensis*, was tentatively included in this genus despite the absence of male flowers. More recently (Kuijt, pers. com.), bilocular anthers have been observed in this taxon, hence it will be transferred to *Phoradendron* (*P. navicularis* (Standley) Kuijt). Thus, five *Dendrophthora* and 35 *Phoradendron* taxa were analyzed with parsimony using santalaceous genera as outgroups. Three major clades were identified: clade A, a morphologically heterogeneous one containing all five *Dendrophthora* species plus *P. crassifolium, P. piperoides*, and *P. sulfuratum*; clade B, containing seven *Phoradendron* species typically with biseriate inflorescences and one pair of basal cataphylls; and clade C containing the remaining 25 *Phoradendron* taxa (with the exception of *P. californicum*) that have biseriate or triseriate inflorescences and that generally lack basal cataphylls. As with *Arceuthobium* and *Korthalsella*, this study has demonstrated how morphological characters can be unreliable indicators of phylogenetic relationships. Although all five *Dendrophthora* species were resolved in clade A, this clade also contained three *Phoradendron* species, supporting the previous suggestion that neither genus is monophyletic.

Viscum. The utility of ITS sequences for resolving phylogenetic relationships in *Arceuthobium*, *Korthalsella* and *Phoradendron* prompted an investigation of its utility in the more speciose Old World genus *Viscum* (Nickrent, unpublished). ITS sequences for five species of *Viscum* were generated: *V. album* , *V. cruciatum* (both Europe), *V. capense*, *V. continuum* (both South Africa), and *V. triflorum* (Kenya). Substitutional and insertion/deletion mutations were quite high, even in relatively conserved regions such as the 5.8S rDNA (1% of the sites polymorphic). Indels in ITS-1 and -2 prevented unambiguous alignment of the South African and European species. For this reason, variable domains of 26S rDNA were examined (portions of D2, D7 and D8 resulting in ca. 1 kb of sequence). In contrast to ITS, the 26S rDNA alignment was easily accomplished with essentially no ambiguous regions. Using the same species as above, ca. 100 potentially phylogenetically informative sites were obtained. A collaboration with V. Ashworth is currently underway to further explore 26S rDNA sequencing in *Viscum*.

Dwarf Mistletoe Coevolution with Their Hosts?

The incredible proliferation of molecular phylogenetic studies may prompt one to ask "how can these results be used?" One interesting topic that can be explored when working with parasitic organisms is whether the evolutionary histories of the two sets of organisms are related in any way. For example, it has been observed among animals that host speciation and divergence is accompanied by speciation of its parasites. This process has been called the Fahrenholtz Rule (Nobel and Nobel 1976) and was defined by Price (1980) as: “common ancestors of present-day parasites were themselves parasites of the common ancestors of present day hosts.”

Does the Fahrenholtz Rule apply to parasitic angiosperms? A requirement for answering this question is the presence of relatively detailed phylogenies for and sufficient numbers of both the host and the parasite species. Moreover, there must exist some degree of host specificity because parasites exhibiting very broad host ranges are eliminated *a priori*. Dwarf mistletoes (*Arceuthobium*) are good candidates for determining whether host tracking is taking place because numerous host and parasite combinations can be seen in nature. Several molecular phylogenies of the genus *Pinus* have been published (Krupkin et al. 1996, Liston et al. 1999, Wang et al. 1999), however, none of these approached complete sampling of the 100 or so species in the genus. Sampling in the Wang et al. (1999) paper was aimed at Eurasian pines whereas Liston et al. (1999) utilized all recognized subsections of the genus. When only species common to both studies are considered, the trees are congruent with respect to major clades, thus genes from the chloroplast and nucleus appear to be tracking the same phylogenetic signal.

Because of its broad subsectional sampling, the nuclear ribosomal ITS tree of Liston et al. (1999) was compared to the ITS phylogeny of *Arceuthobium* (Nickrent 1996, Nickrent et al. 1994) to test the Fahrenholtz Rule. As shown in Fig. 2, there is little congruence between the host and parasite trees. For example, dwarf mistletoe species within Section *Camylopoda* parasitize hosts representing all the major clades on the tree (in subgenera *Strobus* and *Pinus*). Species in *Arceuthobium* Series *Vaginata, Rubra* and *Globosa* and Section *Americana* are primarily parasites of *Pinus* subgenus *Pinus*. Despite this, the relationships among these series and sections do not correspond to the host phylogeny. Thus, it appears that speciation in *Arceuthobium* has not been “synchronized” with speciation in the pine hosts. It has been hypothesized that *Arceuthobium* migrated from the Old World to the New World and there encountered a great diversity of hosts that were available for colonization (Hawksworth and Wiens 1972). The high proportion of Pinaceae parasitized by dwarf mistletoes today suggests that such an adaptive radiation took place possibly after many host species had already become well-defined. The absence of any pattern of host tracking further suggests cycles of colonization and speciation that operated under different evolutionary constraints and that host fidelity was not maintained. By comparison, dwarf mistletoes have more rapid life cycles and faster evolutionary rates than conifers (Nickrent et al. 1998, Nickrent and Starr 1994), therefore they possessed high genetic potential for rapid adaptive radiation.

Conclusions

Molecular phylogenetic methods have proven invaluable in resolving a number of evolutionary questions about mistletoes. For example, there is now little doubt that the families Loranthaceae and Viscaceae are not closely related but represent independent “evolutionary experiments” with the mistletoe habit. These results fully support the concept of separate families first proposed from morphological, cytological, and biogeographical data (Barlow 1964). Although answering some questions, additional data inevitably reveal new questions that require further investigation. Examples of questions that remain to be resolved include 1) the relationship between *Misodendrum*, *Schoepfia* and Loranthaceae, 2) whether the three root parasitic Loranthaceae are monophyletic and basal within the family, 3) the number of santalaceous lineages that evolved the mistletoe habit, 4) which santalaceous lineage is most closely related to Viscaceae, and 5) the phylogenetic relationships among genera of Viscaceae. Molecular methods offer exciting opportunities to directly test questions such as these.

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Table 1. Numbers of Mistletoes

Family	No. Genera	No. Species	Example Genera
Loranthaceae	75	ca. 900	*Agelanthus, Amyema, Phthirusa, Psittacanthus, Scurrula, Struthanthus*
Misodendraceae	1	ca. 8	*Misodendrum*
‘Santalaceae’*	4 (of 38)	37 (of 490)	*Dendromyza, Dendrotrophe, Dufrenoya, Phacellaria*
‘Eremolepidaceae’*	3	11	*Antidaphne, Eubrachion, Lepidoceras*
Viscaceae	7	ca. 350	*Arceuthobium, Dendrophthora, Ginalloa, Korthalsella, Notothixos, Phoradendron, Viscum*
Totals	90	1306	

* Santalaceae are paraphyletic and include Eremolepidaceae

Figure 1.

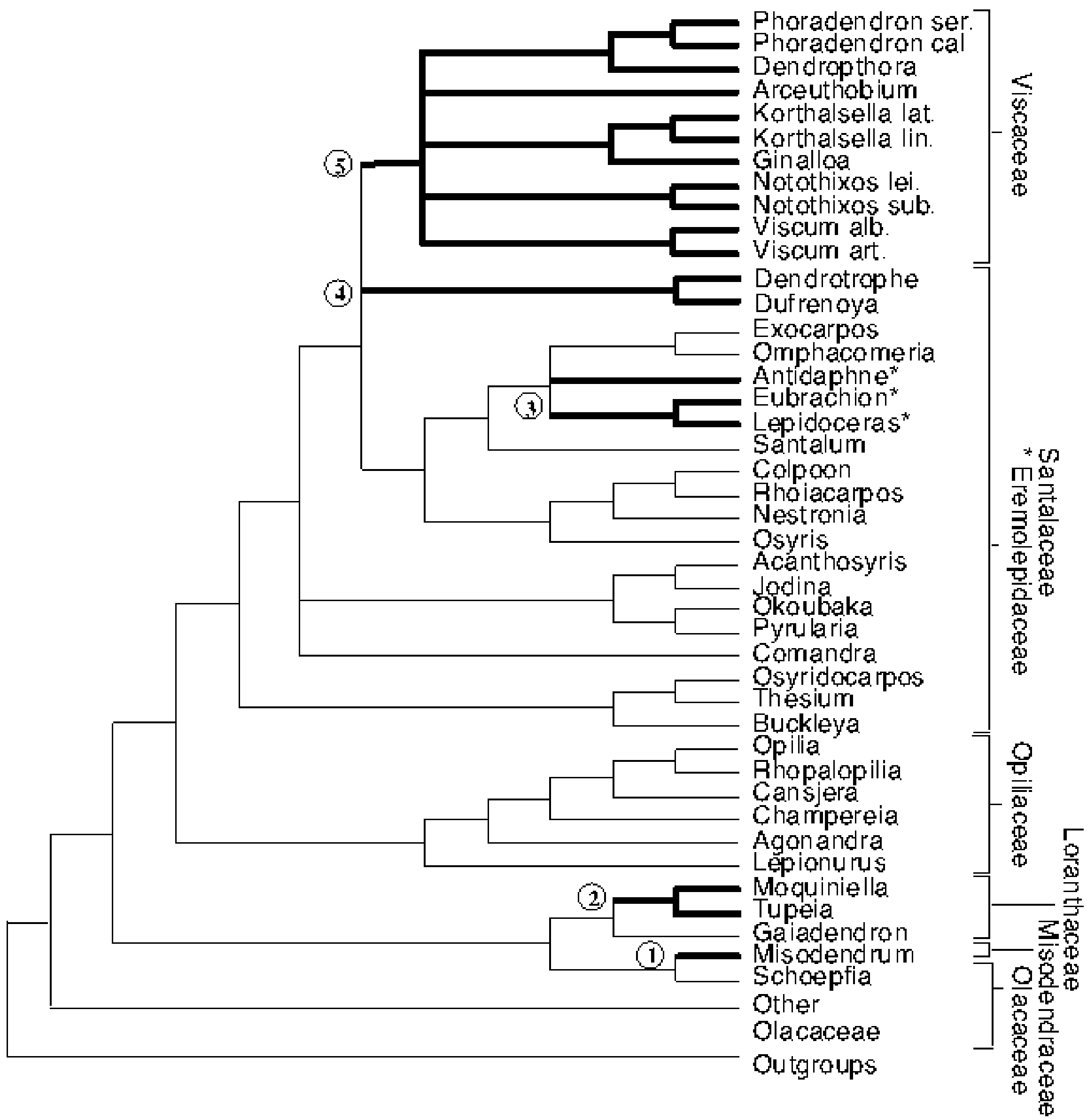

Figure 1. Consensus tree resulting from an heuristic search of a data matrix composed of nuclear 18S rDNA and chloroplast *rbcL* sequences for Santalales. Details of relationships with Olacaceae and outgroups are not shown. Branches with thick lines indicate mistletoe taxa. The circled numbers refer to five potential independent evolutionary occurrences of the mistletoe habit. Sequences of *rbcL* from Amphorogyneae (*Dendrotrophe* and *Dufrenoya*) were not available, hence the position of this clade was determined solely from the 18S rDNA sequences.

Figure 2

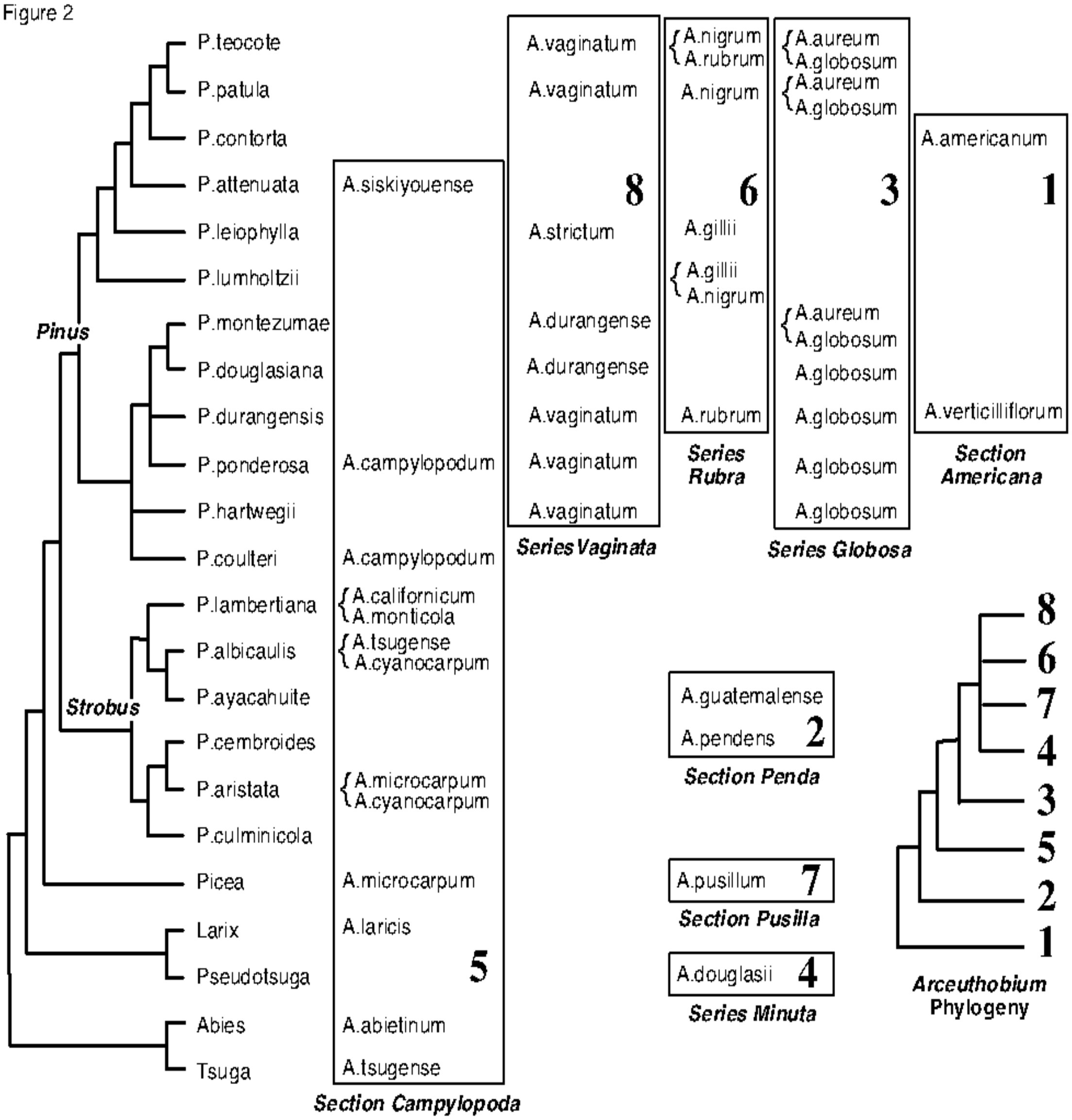

Figure 2. Comparison of ITS phylogeny of *Arceuthobium* with a phylogeny of the Pinaceae hosts. The host phylogeny is the strict consensus tree reported in an ITS study of *Pinus* by Liston et al. (1999). This tree was grafted to the intergeneric topology obtained following a multigene study of Pinaceae by Wang et al. (2000). Dwarf mistletoe - host combinations (principal hosts only) are aligned in horizontal rows. Vertical boxes enclose *Arceuthobium* species groups (Sections and Series) as determined by the ITS analyses. The inset tree gives the overall topology of the *Arceuthobium* ITS tree. This figures clearly shows that *Arceuthobium* phylogenetic relationships cannot be predicted from the host phylogeny.

Spatial patterns of hemlock dwarf mistletoe occurrence in the T.T. Munger Research Natural Area, an old-growth forest preserve

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We are investigating the spatial patterns of western hemlock dwarf mistletoe in the old-growth (500 yr) Douglas-fir/western hemlock forest of the T.T. Munger Research Natural Area (RNA) to determine how dwarf mistletoe develops and spreads in Douglas-fir forests where hemlock is not particularly abundant in the early stages of succession. In addition, we are interested in the implications of mistletoe infections for the long term management of the RNA. The 478 ha RNA is located in the southern Cascade mountains of Washington State, Gifford Pinchot National Forest, on the Wind River Experimental Forest. Soils of the RNA are well drained loams and sandy loams derived from volcanic tephra, while the entire RNA slopes east and southeast as it is on the lower slopes of a shield volcano, Trout Creek Hill (792 m elevation). Elevation varies from 335 to 610 m. The vegetation types vary from drier salal and Oregon grape Western Hemlock Plant Associations to the drier Pacific Silver Fir Plant Association types at higher elevations. Pacific silver fir predominates at lower elevations than is typical of other sites. Rainfall averages 2,528 mm, snowfall averages 233 cm. The forest appears to have originated after a fire, or series of fires 500 years ago. Douglas-fir dominated the stand in the first 200 years, but in the last 300 years western hemlock, western redcedar, Pacific yew, and Pacific silver fir have become abundant. Douglas-fir recently lost dominance in terms of basal area and wood volume, while western hemlock also dominates in density and foliage amount. DeBell and Franklin (1987) and Franklin and DeBell (1988) predict that Douglas-fir should become extinct in the next 700 years. Western hemlock will eventually dominate the forest, with Pacific silver fir, western redcedar, Pacific yew, and grand fir playing a potentially important future role.

Western hemlock dwarf mistletoe is extensive throughout the old-growth stands of Douglas-fir and western hemlock on the Trout Creek Hill Division of the Wind River Experimental Forest and the RNA. The site provides an opportunity to study dwarf mistletoe in old-growth forests where western hemlock is not the primary successional species. Most research to-date on western hemlock dwarf mistletoe has been done in coastal forests of Alaska, British Columbia, Washington and Oregon. Stand replacement fire (~500 year return interval) is the primary large landscape disturbance in the Wind River Region of the central Cascades Range, rather than the wind disturbed systems of the coast. Perhaps in the past, this RNA would have burned in the next century, but with fire management and a fragmented landscape, the potential for fire is minimized. Therefore, western hemlock and mistletoe may continue the current successional regime for centuries.

We took advantage of two large, permanent, plot systems in the RNA to investigate the spatial patterns of dwarf mistletoe. The first is a 12 ha plot in the lower SE portion of the RNA, which includes the Wind River Canopy Crane. All trees > 5 cm dbh are mapped, average tree density is 437 trees/ha with a basal area of 71.9 m^2/ha. Western hemlock is the most abundant tree (241 trees/ha) in all but the larger size classes, with 44 % of the basal area. Douglas-fir has only 7 % of the stems, yet has 40 % of the basal area. The second 42 ha plot system was a series of mortality strips that form a stepwise east-west strips through the RNA. There are 103, 1 square acre plots, in the strips that were established in 1948 for the purpose of understanding long term growth and mortality in old-growth forests (King 1961, DeBell and Franklin 1987, Franklin and DeBell 1988). All trees > 45.7 cm (18 inches) were tagged, but not mapped, in the mortality strips, although 50 growth and yield subplots occur in the center of every other mortality plot with small diameter trees included.

We went through each plot system and estimated the Dwarf Mistletoe Rating (Hawksworth 1977) for all western hemlock, Pacific silver fir, grand fir, and noble fir. A total of 2,888 western hemlock, 571 Pacific silver fir, 49 grand fir, and 7 noble fir , > 5 cm dbh were surveyed on the 12 ha plot. Infected were 724 western hemlock (25 %), 12 Pacific silver fir (2 %), 0 grand fir, and 2 noble fir (28%). A total of 1,822 western hemlock, 170 Pacific silver fir, 26 grand fir, and 10 noble fir > 45.7 cm were surveyed on the mortality strips. Infected were 1,075 western hemlock (59 %), 45 Pacific silver fir (26 %), 1 grand fir (3 %), and 2 noble fir (20 %).

The average DMR of western hemlock only was calculated for each acre square of the mortality strips and illustrated on a map. Of the 103 existing plots in the mortality strips, 99 had western hemlock on them, with 82 having at least one infected western hemlock tree (82.8 %) and 74 have an average rating > or = to 0.5 (74.7 %). An amazing 25 plots average DMR 6! A large infection center, perhaps approaching 100 ha is present in the northern region of the RNA. The pattern in the lower RNA is more complex, with the least mistletoe in the tallest and most productive forests of the eastern, and lower, RNA where western redcedar is also most abundant.

The 12 ha plot is 33% infected on an area basis. The spatial pattern indicates discrete infection centers separated by un-infected areas, as is the classic pattern in expanding infection centers. There is plenty of hemlock between the infection centers to facilitate spread. The DMR 1 infected trees tend to be at the margins of the infection centers and indicates that the infection centers are actively spreading.

Also, there is a small infection center in the lower SW portion of the 12 ha plot, which is at least 35 m from the nearest infected tree. This infection center must have begun by passive bird dispersal of seed. In the RNA, Red Crossbills, Gray Jay, and Steller's Jays are common in the upper canopy of this forest, and frequent western hemlock trees.

Based on these spatial patterns we conclude:

1. Hemlock dwarf mistletoe is actively spreading from distinct infection centers into the remaining uninfected areas of the RNA. The entire RNA will eventually become infected.

2. The increasing population of western hemlock and decreasing Douglas-fir implies that dwarf mistletoe will have no major barriers to spread, only western redcedar is capable of providing a significant non-host barrier to spread.
3. The disturbance of 500 years ago must have left some large areas unburned and these areas were refugia for hemlock and dwarf mistletoe. The extent of hemlock dwarf mistletoe in the northern RNA is so widespread this may have been the source for the entire RNA populations that exist today.
4. Bird dispersal of mistletoe may have aided the rapid spread into the remaining RNA as western hemlock trees became more abundant over the last 300 years.
5. Potential long term successional scenarios:
    - 5a. This forest may degenerate into a classic massively infected, old-growth, pure hemlock forest, where gap-phase regeneration is occurring in heavily infected disease centers. Dwarf mistletoe will continue to infect all regeneration, and the cycle will continue until a catastrophic disturbance (fire) destroys the stand and eradicates dwarf mistletoe from the site.
    - 5b. Shade tolerant non hosts and occasional hosts such as Pacific silver fir, grand fir, and western redcedar will increase in importance as western hemlock sustains increasing mortality from dwarf mistletoe. The forest will eventually become a complex multi-species stand, with western hemlock forming areas of intense infections and light infections, yet the hemlock generally remaining infected throughout the RNA.
    - 5c. The decline of Douglas-fir and the crown die-back and top-die-back of western hemlock will contribute to such a heavy fuel load that fire is un-stoppable and eventually the RNA will burn. However, because of the mistletoe induced gappy-ness of the forest, the fire may burn especially un-even, leaving large areas of refugia for mistletoe.
6. The long term management of the RNA will take advantage of the successional development of the dwarf mistletoe populations as a model of how mistletoe develops in old-growth forest. There are no negative implications for the RNA, rather, there is opportunity to follow development of an important parasite on an extensive set of long term growth and mortality plots.

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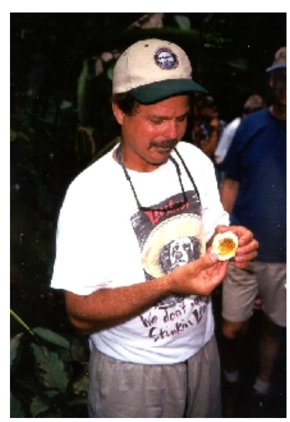

True Mistletoes on Pine in Central America and Chiapas, Mexico

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Introduction

General Biology of True Mistletoes

The evolutionary advantage of parasitism of higher flowering plants by other higher flowering plants is not completely understood. Most parasitic plants are believed to have originated in the tropics, where the soils are typically mineral-poor. By parasitizing already successful plants, such parasites were able to exploit an adequate supply of minerals, nutrients, and water. True mistletoes are hemiparasitic flowering plants, which belong to one of three plant families: Loranthaceae, Viscaceae or Eremolepideaceae within the order Santalales (Kuijt 1969, Calder 1983). In southern Mexico and Central America, both the Loranthaceae and Viscaceae are represented, but only a few species within these families are parasites of pines there.

Life History of True Mistletoes on Pines

True mistletoe infections first appear as slight swellings at infection sites (Kuijt 1969). Swellings become visible 1 to 2 years after infection occurs. Aerial shoots arise from the endophytic system, a network of root-like, absorbing strands imbedded in host tissues. The endophytic system extracts minerals and water from the host tree and lives as long as adjacent host tissues are alive. While the mistletoe is dependent upon its host for water and minerals, the leaves of true mistletoes produce most, if not all, of the carbohydrates required by the mistletoe for survival and reproduction (Kuijt 1969). Large shrubby plants are visible on infected trees several years after initial infection has occurred. True mistletoes do not usually induce the formation of witches' brooms on infected hosts as do the dwarf mistletoes.

Effect on Pines

Pines severely infected by true mistletoes are stressed, suffer reduced growth rates, and are sometimes killed (Vazquez et al. 1982, 1985, Vazquez 1993, 1994, Beatty et al. 1999, Pineda and Melgar 1999). Mortality is generally believed to be a result of the trees being so weakened that secondary diseases or insects attack them, resulting in their death. Bark beetles in the genera *Dendroctonus, Scolytus* and *Ips* are common insects reported to attack trees weakened by true mistletoes (Vazquez et al.1982, 1985, Vazquez and Chavez 1989, Vazquez 1993). However, in general, true mistletoes are not considered to be as damaging as the dwarf mistletoes from the perspective of causing reduced growth or mortality of their hosts.

Species Descriptions

The true mistletoes parasitizing pines in the southernmost state of Mexico, Chiapas, and in Central America are predominantly species in the genus *Psittacanthus*. *Psittacanthus* flowers are either terminal or occur in axillary racemes of paired triads or lateral umbels of diads. The flowers are large for mistletoes; they are bisexual, subtended by a bract or bracteole, and are usually brightly colored red and/or yellow. Fruits are large pseudoberries and vary in color, but are frequently blue or black when ripe (Burger and Kuijt 1983, Kuijt unpublished). Birds disseminate the seeds, but little is known about which avian species are responsible for dissemination in the pine forests of Central America and Chiapas.

The other true mistletoes reported on pines in Central America and southern Mexico are members of the genus *Struthanthus*. Species of *Struthanthus* are often unisexual and have glabrous stems that are erect, pendent, climbing, or clambering by means of twisted petioles, twining terminal shoots, or attaching epicortical roots (Burger and Kuijt 1983). Their leaves are opposite or subopposite. Their inflorescences occur in the axils of leaves and consist of triads associated with bracts. The central flower of the triad is usually sessile and the laterals often have short pedicels. Their flowers are generally small (less than 10 mm). Male flowers have six petals that become reflexed at anthesis. Their fruit is a berry.

Historically, the true mistletoe thought to be the most common parasite of pines in Central America is *Psittacanthus schiedeanus* (Schlecht. & Cham.) Blume (Standley and Steyermark 1946, Vazquez et al. 1982, 1985). Most specimens of true mistletoes collected from pines that we examined in herbaria in Central America were identified as *P. schiedeanus*.

In 1987 Kuijt described two new species of *Psittacanthus* that parasitize pines in Central America. *Psittacanthus pinicola* Kuijt was initially described based on specimens from the lowlands of Belize, and *P. angustifolius* Kuijt was described from western Nicaragua. However, only the pine host of *P. pinicola* in Belize was designated to the specific level as *Pinus caribaea* var. *hondurensis* (Senecl.) Barr. et Golf. by Kuijt (1987). Kuijt did not designate the pine host of *P. angustifolius* from Nicaragua, perhaps because he described this mistletoe based on herbarium specimens only. However, because the type locality for *P. angustifolius* is in western Nicaragua near the border with Honduras, we assume the host was *Pinus oocarpa* Schiede (Mathiasen et al. 2000a).

Based on our field surveys of the pine forests in Central America and Chiapas, Mexico, and our examination of herbarium specimens in Honduras and Guatemala, we now believe the most common true mistletoe on pines in these forests is *Psittacanthus angustifolius*, and not *P. schiedeanus*. We have not observed *P. schiedeanus* on pines during our surveys and all of the specimens of *P. schiedeanus* we have examined in herbaria, thus far, represented collections of *Psittacanthus angustifolius*. We can only speculate on why *P. schiedeanus* was consistently identified as the common species of *Psittacanthus* parasitizing pines in Central America, but it is probably related to the description of this mistletoe by Standley and Steyermark (1946) in their flora of Guatemala. In it, they comment that *P. schiedeanus* commonly infects species of *Pinus*. Therefore, despite the major morphological differences between *P. schiedeanus* and *P. angustifolius* (see below) investigators continued to classify the common mistletoe on pines in Central America as *P. schiedeanus*. However, we are now certain that this is incorrect and we are not convinced at this point that *P. schiedeanus* (sensu stricto) occurs on pines in Central America. However, we will need to examine additional herbarium specimens in other Central American countries and probably Mexico, before we can be more certain that *P. schiedeanus* is not a parasite of pines in Central America.

Psittacanthus angustifolius is quite distinct from *P. schiedeanus* and they can be easily distinguished based on the following characteristics:

P. angustifolius - The stems of this species are sharply quadrangular. Its leaves are paired and are narrowly falcate (to 17 X 2.5 cm) with attenuate apices and petioles about 5 mm in length. Many leaves are asymmetrical. This species has terminal flowers consisting of 4-6 triads with bright orange flowers. Its petals are consistently 7-8 cm long and each petal has a conspicuous, fleshy ligule-like median crest that extends inward. Another distinctive character of this mistletoe is that the lower peduncles of the flowers have a foliaceous bract about 2 cm long. The flower pedicels are about 1.5 cm long and have a very conspicuous terminal cupule. The stamens are dimorphic with filaments that are approximately 5 cm long. The fruit is black to dark purple when mature (Kuijt 1987).

P. schiedeanus - This species also has sharply quadrangular stems, but they are conspicuously four-winged: each corner of the stem has a flattened extension of stem tissue. Many of the paired leaves of this mistletoe are also asymmetrical, but they are ovate (not falcate) ranging in size up to 20 X 8 cm. Its petioles are stout and about 1 cm in length. Leaves and stems are a conspicuous bluish-green color (often described as being similar to the color of Eucalyptus leaves). The flowers of this species are terminal, but they are leafless, which results in a forked habit consisting of a condensed axis 1-2 cm long bearing 8-10 triads. Another very distinctive characteristic of this mistletoe is that a primary bract is fused to the entire length of the triad peduncles. The flower buds have orange tips, but the rest of the petal is bright yellow. Petals are from 8-9 cm long, strongly recurved when open, and bright yellow. The stamens are dimorphic with filaments about 4 cm long. The style is 7-8 cm long and bright yellow with a conspicuous red tip. Fruits are black when mature (Burger and Kuijt 1983).

Summary of the True Mistletoes We Have Observed Affecting Pines in Central America and Chiapas, Mexico

Over the last few years, during several trips to Belize, Guatemala, Honduras, El Salvador, and Chiapas, Mexico, we have observed true mistletoes parasitizing pines in these countries as follows:

Psittacanthus angustifolius Kuijt

This true mistletoe appears to be the most common true mistletoe on pines based on our surveys (Fig 1). We observed it in several Departments in Honduras (Beatty et al. 1999, Mathiasen et al. 2000a). In addition, specimens of this species have been collected from several other locations in Honduras and deposited at the Standley Herbarium. Therefore, we determined that this mistletoe is widely distributed throughout the high elevation pine forests of Honduras (Beatty et al. 1999, Mathiasen et al. 2000a). We have also found it in central Guatemala south and north of La Cumbre along Guatemala Routes 14 and 17 (Departments Baja Verapaz and Alta Verapaz). It also occurs in central Chiapas, Mexico near Jitotol and east of San Cristobal de las Casas (Mathiasen et al. 2000b). It has also been reported near Atenango, Chiapas (Kuijt unpublished). Although we have observed this mistletoe in northern El Salvador, we were unable to collect specimens because we were in Monte Cristo National Park. It also occurs in western Nicaragua, but the extent of its distribution there has not been determined (Kuijt 1987).

So far we have observed *P. angustifolius* parasitizing *Pinus oocarpa*, *P. maximinoi* H. E. Moore, and *P. tecunumanii* (Schw.) Eguiluz et Perry, but it is most common on *P. oocarpa* (Beatty et al. 1999, Mathiasen et al. 2000a, 2000b).

Psittacanthus pinicola Kuijt

Psittacanthus pinicola occurs in widely scattered populations in the low-elevation *Pinus caribaea* var. *hondurensis* forests of Belize. We have also observed it in the Mountain Pine Ridge region of western Belize on this host. In Honduras we collected it near Concordia (Olancho Department) on *Pinus oocarpa*. There are other collections of this mistletoe from Olancho and Gracias a Dios Departments, Honduras and from a few locations in Nicaragua (Kuijt, unpublished). In addition, we have seen specimens of *P. pinicola* in the Standley Herbarium collected from El Salvador and Nicaragua, so this mistletoe is probably more widespread in low-elevation pine forests in Central America than previously believed (Fig 2).

Struthanthus deppeanus (Cham. & Schlecht.) Blume

This mistletoe appears to be uncommon on pines in Central America. We observed *Struthanthus deppeanus* on *Pinus oocarpa* approximately 25 km southwest of Tegucigalpa, Honduras, on the road to Lepaterique (Department Francisco Morazan). However, we have also seen collections in the Standley Herbarium from Cusuco National Park

(Department Cortes) and from Celaque National Park (Department Lempira) in Honduras. Therefore, this mistletoe is probably more widespread in the pine forests of Honduras than the one local we have observed would indicate.

We have also observed *S. deppeanus* at two locations in Guatemala: approximately 15 km west of Uspantan on Highway 7-W (Department Quiche) on *Pinus oaxacana* Mirov, and approximately 20 km south of Rabinal on the El Chol road (Department Baja Verapaz) on *Casaurina* spp. We think this mistletoe is probably rare in Guatemala, but we have no way of ascertaining how common it was before the extensive harvesting of pine forests in this country occurred (Perry 1991).

Struthanthus deppeanus appears to be more common in Chiapas, Mexico, than in Central America. It is common south of San Cristobal de las Casas along Mexico Route 190 and near Jitotol along Mexico Route 195. So far, we have observed it parasitizing *Pinus psuedostrobus* Lindl. and *P. tecunumanii* in Chiapas. Therefore, to date, we have observed it on a species of Casaurina and four pines: *Pinus oocarpa*, *P. oaxacana*, *P. psuedostrobus*, and *P. tecunumanii*.

We are continuing our studies of the distribution, host range, phenology, impact, and ecology of the true mistletoes parasitizing pines in Central America and southern Mexico in cooperation with Dr. Jorge Macias, Grupo de Ecologia Quimica, ECOSUR, Tapachula, Chiapas, Mexico, and Dr. Jose Melgar, Escuela Nacional de Ciencias Forestales, Siguatepeque, Honduras. We hope to make additional contacts in Nicaragua and Guatemala.

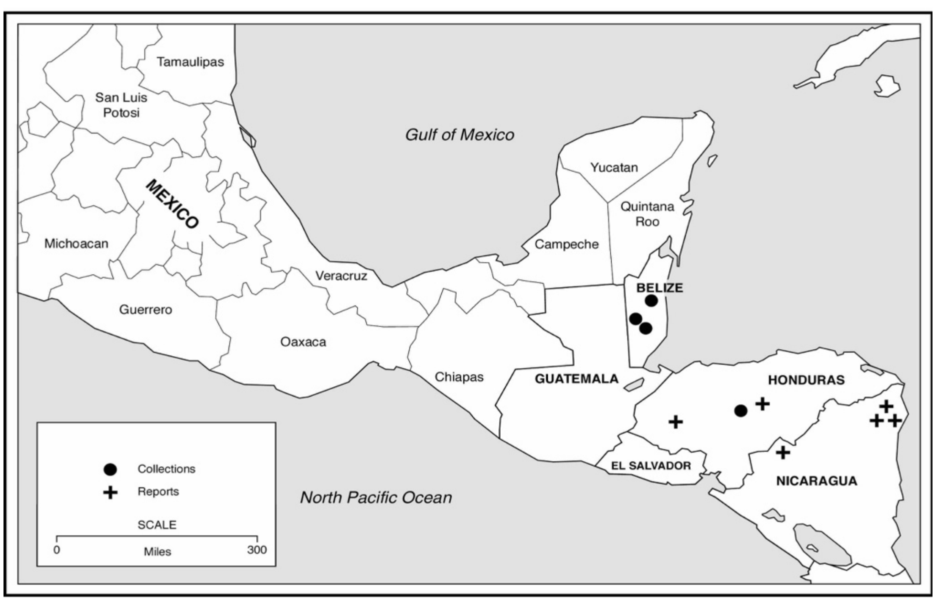

Figure 1. Distribution of *Psittacanthus pinicola* in Central America

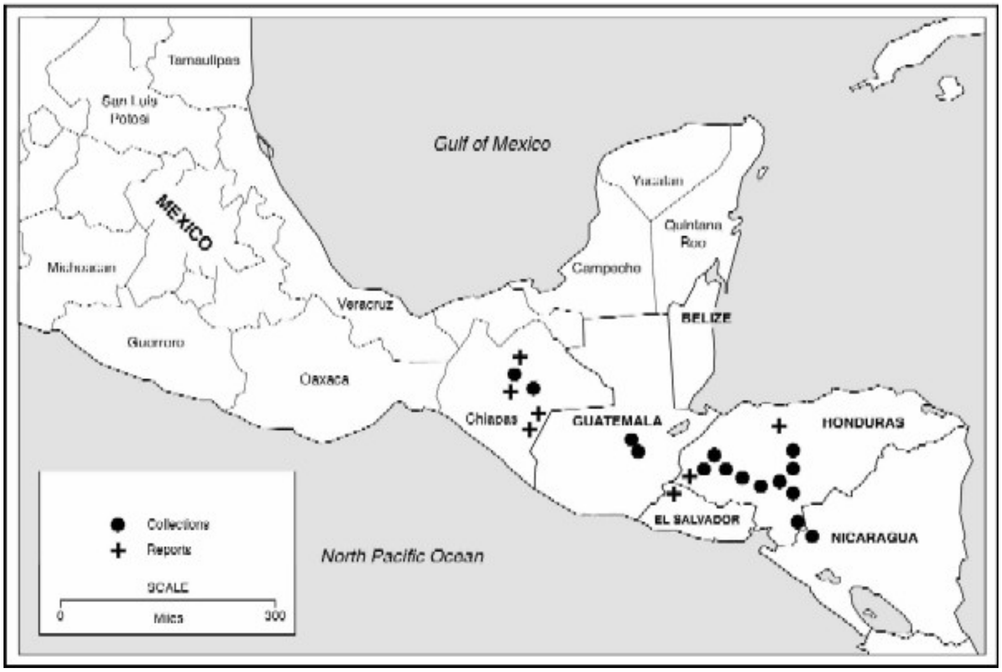

Figure 2. Distribution of *Psittacanthus angustifolius* in Central America and Mexico

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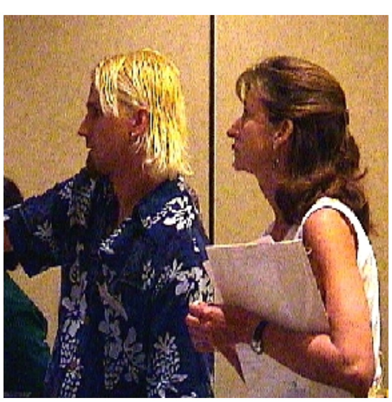
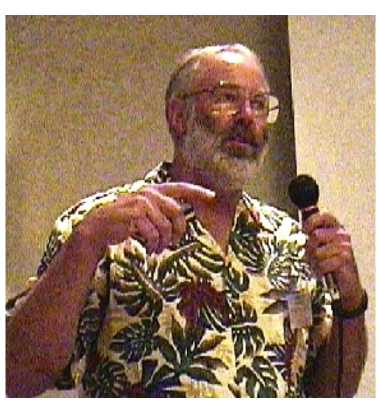
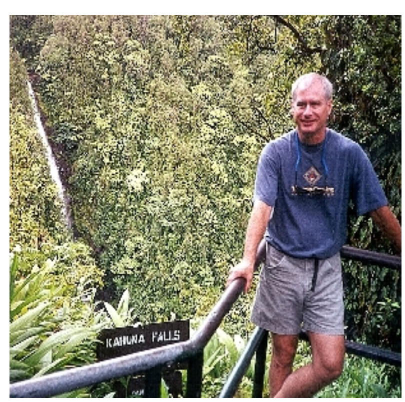

Adult Sex Ratio Of Juniper Mistletoe In One-Seed Juniper In Northern Arizona

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Introduction

Juniper mistletoe (*Phoradendron juniperinum* Engelm.) is a dioecious parasitic flowering plant that commonly occurs on several different junipers (*Juniperus* spp.) in the western United States (Wiens 1964, Hawksworth and Scharpf 1981). The sex ratio of several dioecious mistletoes has been reported to be female-biased (Showler 1974, Barlow and Wiens 1976, Wiens and Barlow 1979, Nixon and Todzia 1985, Wiens et al. 1996). However, juniper mistletoe has been reported to have a male-biased sex ratio (Dawson et al. 1990a), as have many other dioecious plants (Willson 1981).

Wiens et al. (1996) reported a female-biased sex ratio for hemlock dwarf mistletoe (*Arceuthobium tsugense* (Rosendahl) G. N. Jones) when it occurred on its principal host western hemlock (*Tsuga heterophylla* (Raf.) Sarg.). However, when this mistletoe occurred on other hosts, its sex ratio was essentially 1:1. Because Dawson et al. (1990a) only examined the sex ratio of juniper mistletoe on one host (Utah juniper), we undertook this study to determine if juniper mistletoe also has a male-biased sex ratio when parasitizing a different host, one-seed juniper (*Juniperus monosperma* (Engelm.) Sarg.). In addition, we investigated the distribution of male, female and non-reproductive mistletoe plants within host trees, as did Dawson et al. (1990a).

Materials and Methods

Our study site was located in the Coconino National Forest east of Flagstaff, Arizona, in Sections 16 and 21 of Township 22 North, Range 9 East at elevations between 1920 and 2010 m. The study area was in the pinyon-juniper type group (Barrett 1980). Soil in the area consisted of lava, ash, and volcanic cinders with low moisture and nutrient availability.

Ten one-seed junipers were selected for sampling based on the following criteria: 1) greater than 4 m in height with rounded, uniform live crowns; 2) severe mistletoe infection in the live crown; 3) easily accessible from all sides; and 4) not shaded by other trees on any side of the tree's crown.

The study was conducted from August 20 to October 2, 1999, while male mistletoe plants were at or just past anthesis so their gender could be easily determined. In late September and early October, when many males were past their peak anthesis, male plants could be distinguished from most adult female plants because female plants usually had maturing fruits. Those adult females that did not have maturing fruits still had mature female flowers which occurred on single segments and in pairs on the distal ends of shoots (Wiens 1964). After peak anthesis adult male plants usually had old flowers still attached.

Whenever a plant could not be positively identified as male or female, it was classified as non-reproductive. Non-reproductive plants usually represented young plants that had not yet produced flowers (Dawson et al. 1990a), or adult plants that had no flowers or fruits on them. Adult plants without flowers or fruits could not be accurately sexed by their color, size, or habit. Although we searched each tree carefully for mistletoe plants, we undoubtedly did not sample every small, non-reproductive plant on each tree. Many non-reproductive plants were less than ten cm in height, occurred on small branches, and since they frequently were nearly the same color as juniper foliage, they were difficult to detect. In addition, dead mistletoe plants were not included in the sample because their sex could not be accurately determined. Non-reproductive plants were not recorded on Tree 1. After sampling Tree 1 and discovering that many plants were non-reproductive, we sampled non-reproductive plants on all subsequent trees.

For each tree, we recorded its sex (one-seed juniper is dioecious), diameter to the nearest 0.25 cm around all the stems at the base of each tree (one-seed juniper usually has multiple stems, Figure 1), total height to the nearest 0.1 m, height to the bottom of the live crown to the nearest 0.1 m, and mistletoe rating. The mistletoe rating used was a modification of the 6-class dwarf mistletoe rating system (Hawksworth 1977). The system we used divided the live crown of each tree into three equal thirds and each third was rated as: 0 - no mistletoe plants occurred in the third; 1 - less than half of the branches traversing the third had one or more mistletoe plants; or 2 - more than half of the branches traversing a crown third had one or more mistletoe plants. Ratings for each third were then summed to give a total rating from 0 to 6 for each tree. This is a slight modification of the 6-class system because the habit of one-seeded juniper consists of multiple trunks emanating from the same general location on the ground and therefore, the same branch or trunk could occur in each third of the live crown. Thus, a branch could have a mistletoe infection in each of the thirds and contribute to the overall rating three times. In the 6-class dwarf mistletoe system each branch is only considered for a single third depending on its origin on the main trunk of the tree being rated. This works well for coniferous trees with a single trunk with radiating branches, but is not adequate for rating one-seed junipers that have multiple main trunks.

Individual mistletoe plants were cut from trees using hand pruners, pruning poles, or pruning saws. Before each plant was removed from a branch, its height to the nearest 0.1 m was determined using a 7.8 m long leveling rod graduated in 0.1 m intervals. In some instances, large central trunk branches with multiple mistletoe infections were cut at a measured height and placed on the ground. Before these branches were cut, marks were placed on each branch at 0.5-m intervals. The leveling rod was then placed along the branch on the ground, aligned with the correct heights, and used to determine heights of mistletoe plants as they were removed from the branch. After each mistletoe plant was removed from a tree branch it was carefully examined for male flowers, female flowers or maturing fruits. A 10X-hand lens was used whenever necessary to determine male flowers from females (Wiens 1964). The sex (male, female or non-reproductive) and height of each mistletoe plant were recorded and transferred to an electronic database (Microsoft Excel).

A chi-square analysis was used to determine if the ratio of male to female mistletoe plants exhibited a sex bias. As previously noted, Dawson et al. (1990a) reported a male-biased sex ratio for juniper mistletoe on Utah juniper and so we hypothesized that this mistletoe would also have a male-biased sex ratio on one-seed juniper. Dawson et al. (1990a) analyzed their data using a log likelihood ratio chi-square statistic (g values) while we used the chi-square statistic (p values). Since g is approximately distributed as chi-square, both methods commonly result in the same conclusions (Zar 1984), particularly when large samples are used. We used a p value of ≤ 0.05 to determine the existence of statistically significant differences.

Table 1. Sex, base diameter, height, height to live crown, and mistletoe ratings for ten one-seed juniper sampled near Flagstaff, AZ.

Tree	Sex[1]	Base Diameter (cm)	Height (m)	Height Live Crown (m)	Mistletoe Rating[2] Bottom Third	Middle Third	Top Third	Total
1	M	51.8	7.1	0.4	1	1	2	4
2	F	68.1	5.5	0.3	1	2	2	5
3	F	53.3	4.5	0.3	2	2	2	6
4	F	62.5	4.6	0.3	1	2	2	5
5	M	93.7	5.7	0.1	1	2	2	5
6	M	61.5	4.8	0.3	1	2	2	5
7	M	80.0	4.9	0.4	1	2	2	5
8	M	66.5	4.6	0.3	1	2	2	5
9	F	69.6	4.7	0.1	1	1	2	4
10	F	64.8	4.1	0.1	1	1	2	4
Mean		67.2	5.1	0.3	1.1	1.7	2	4.8

[1] M - Male; F - Female. [2] See text for explanation of the mistletoe rating used.

Results

Sex, base diameters, heights, and mistletoe ratings of the ten one-seed junipers sampled are presented in Table 1. Five of these trees were males and five were females. Diameters at the base of these trees ranged from 51.8 to 93.7 cm (mean 67.2 cm) and heights varied from 4.1 to 7.1 m (mean 5.1 m). Mistletoe ratings ranged from 4 to 6 (mean 4.8). Most of the trees (7) had severe levels of infection in the upper two thirds of their live crowns. All of the trees, except Tree 3, had lower levels of infection (mistletoe ratings of 1) in the lower third of their live crowns.

We sampled 5414 adult plants (an average of 541 plants/tree) that could be accurately sexed on the ten trees and another 3154 non-reproductive plants (an average of 350 plants/tree) on nine of the ten trees. Of the 5414 plants we sexed, 2661 (49%) were males and 2753 (51%) were females. The difference in the number of male and female plants in our sample was not significantly different from the number expected for a 1:1 sex ratio; therefore, the sex ratio of juniper mistletoe on the ten trees was essentially 1:1 (Table 2).

Six trees did not have a statistically significant difference in sex ratio from 1:1 (Table 2). Two trees had a male-biased sex ratio (Trees 1 and 9) and two trees had a female-biased sex ratio (Trees 4 and 7). Although two of the trees with female-biased sex ratios represented trees with large sample sizes (937 and 657 plants, respectively), more trees (6 versus 4 trees) had more male plants than female plants. Therefore, the overall sex ratio of the juniper mistletoe population on the ten trees did not have a statistically significant sex bias towards either sex. We did not observe any pattern in male or female sex bias based on the sex, base diameter, or height of the host trees (Tables 1 and 2).

Table 2. Number of adult juniper mistletoe plants and sex ratios on ten one-seed junipers sampled near Flagstaff, AZ. * Sex ratios that exhibit a significant sex bias. Chi-square statistics ($p \leq 0.05$).

Tree	Adult Plants	Sex Ratio (% Females)	p
1	223	39*	0.001
2	1011	52	0.157
3	670	51	0.699
4	657	56*	0.003
5	452	49	0.510
6	541	48	0.414
7	937	57*	0.001
8	484	48	0.413
9	274	41*	0.004
10	165	44	0.312
Total	5414	51	0.211

The distribution of adult plants by one-meter height classes for individual trees is presented in Table 3. The pattern of infection was the same in all trees sampled. Generally, there were fewer adult plants in the top meter of each tree. Most of the adult plants were usually within the middle of the trees (Table 3). The lower two meters of each tree had the fewest numbers of adult plants. In contrast, the majority of non-reproductive plants were usually found below two meters in height in a tree (Table 4. The shift in distribution of non-reproductive plants, as compared to adult plants, to lower parts of the live crowns is evident when Tables 3 and 4 are compared. Most of the non-reproductive plants we observed in the lower crown (< one meter in height) were small plants < 10 cm tall. Table

4 also presents the distribution of mistletoe plants (male, female, and non-reproductive plants combined) by one-meter height classes. Most of the plants (59%) were in the middle to upper parts of the live crown of the host trees (2.1 – 4.0 m). Twenty-three percent of the plants were in the lower crown (< two meters in height), but most of these plants (89%) were non-reproductive.

Table 3. Number of adult mistletoe plants (male and female combined) by one-meter height classes for ten one-seed junipers sampled near Flagstaff, AZ.

Height Class (m)	Number of Adult Plants Tree Number 1	2	3	4	5	6	7	8	9	10	Total
0.1 – 1.0	0	0	2	0	7	0	5	1	1	0	16
1.1 – 2.0	0	27	28	15	18	58	41	18	13	11	229
2.1 – 3.0	21	301	184	165	155	154	218	190	86	80	1554
3.1 – 4.0	40	340	397	341	144	246	462	186	135	74	2365
4.1 – 5.0	43	291	59	136	104	83	211	89	39	-	1055
5.1 – 6.0	56	52	-[1]	-	24	-	-	-	-	-	132
6.1 – 7.0	63	-	-	-	-	-	-	-	-	-	63
Total	223	1011	670	657	452	541	937	484	274	165	5414

[1] No plants sampled because tree height was less than the height class (Table 1).

Table 4. Number of non-reproductive mistletoe plants by one-meter height classes for nine one-seed junipers sampled near Flagstaff, AZ.

Height Class (m)	Number of Non-reproductive Plants Tree Number 2	3	4	5	6	7	8	9	10	Total	All Plants Total[2]	% of All Plants
0.1 – 1.0	9	142	11	8	72	174	5	11	4	436	452	5
1.1 – 2.0	143	358	104	41	184	386	29	38	20	1303	1532	18
2.1 – 3.0	60	87	81	22	82	174	41	42	21	610	2164	25
3.1 – 4.0	32	114	57	16	82	118	41	82	17	559	2924	34
4.1 – 5.0	33	23	18	18	23	65	9	38	-	227	1282	15
5.1 – 6.0	9	-[1]	-	10	-	-	-	-	-	19	151	2
6.1 – 7.0	-	-	-	-	-	-	-	-	-	-	63[2]	1
Total	286	724	271	115	443	917	125	211	62	3154	8568	100

[1] No plants sampled because tree height was less than the height class (Table 1).
[2] Male, female, and non-reproductive plants combined. Includes Tree 1 data from Table 3.

Discussion

Although Dawson et al. (1990a) reported a statistically significant male-biased adult sex ratio for juniper mistletoe in southern Utah, we found that the adult sex ratio for the juniper mistletoe population we sampled on one-seeded junipers in northern Arizona was essentially 1:1. Our results demonstrate the variation in sex ratio that can occur among individual trees. This tree-to-tree variation has been demonstrated in other studies of mistletoe sex ratio (Nixon and Todzia 1985, Mathiasen and Shaw 1998). Because of this tree-to-tree variation, a large sample of mistletoe plants should be sampled for dioecious mistletoe sex ratio studies and data should be analyzed using the results for the entire sample population and not on an individual tree basis. If a large number of adult mistletoe plants (e.g., > 2000) are sampled and a statistically significant deviation from the expected 1:1 sex ratio is found, then specific genetic, physiological, and/or environmental mechanisms for the sex ratio bias may be in operation. However, Dawson et al. (1990a) only sampled a total of 466 adult plants on thirty Utah junipers in their study of juniper mistletoe sex ratio. This represents an average of approximately 15 plants/tree. We sampled over 5400 adult plants, an average of over 500 adult plants per tree, and found that although the sex ratio of juniper mistletoe varies among individual trees, the overall sex ratio of this mistletoe population did not differ significantly from a 1:1 ratio.

Seeds of *Phoradendron* are primarily disseminated among trees by birds (Sutton 1951, Kuijt 1969, Scharpf and Hawksworth 1974, Hawksworth and Scharpf 1981, Calder 1983). Although birds (e.g., Western bluebirds, Townsend's solitaires, and American robins) have been observed eating juniper mistletoe seeds and are undoubtedly involved in seed dissemination among host trees (Gehring and Whitham 1992), no investigations of within-tree dissemination have been completed for this mistletoe. It has usually been assumed that within-tree intensification occurs because birds are attracted to mistletoe-infected trees, spend long periods of time feeding on mistletoe fruits, and hence, defecate mistletoe seeds on the same tree (Hawksworth and Scharpf 1981). This pattern has been reported for the desert mistletoe (*Phoradendron californicum* Nutt.) (Cowles 1936). Cowles (1936) also reported that large accumulations of mistletoe seeds occur directly beneath perches on host trees frequently used by the birds responsible for seed dissemination of this mistletoe.

Although we did not observe accumulations of mistletoe seeds in the host trees we sampled, we did observe many individual mistletoe seeds scattered on juniper branches we had pruned from trees. Some of these seeds had bird feces on them, but many had no indication of bird dissemination. Many of these seeds occurred on small host branches less than five mm in diameter. Because many of these seeds were on small branches at the edge of the crown, not directly below a probable perch for a vector, it is unlikely they were bird-disseminated. If these seeds were bird-disseminated, then it would have to be a case of "fly-over:" birds leaving trees defecated seeds and these seeds landed on the tree and adhered to the small branches. Therefore, the actual role played by avian vectors in the within-tree dispersal of juniper mistletoe needs further research.

Another possibility is that many of the seeds we observed on small branches represent self-dispersal by gravity and/or rain and wind. Female mistletoe plants produce hundreds of fruits. Some of the mature fruits not eaten by birds could fall through the crown of the host tree or seeds may fall from over-mature fruits. Since the fruits and seeds of the juniper mistletoe are sticky (particularly the seeds), self-dispersed fruits and seeds are certainly capable of adhering to branches and foliage as they fall through the crown. Self-dispersal by gravity is not thought to be a principal means of seed dispersal for true mistletoes (Calder 1983, Liddy 1983). But a few investigators have postulated this means of dissemination for some mistletoes (Blakely 1922, McLuckie 1922) and the species of *Korthalsella* in New Zealand are primarily self-dispersed by gravity and rain (Stevenson 1934). We hypothesize that the initial location of infection in junipers greatly influences where subsequent infections will occur within individual trees because we propose that self-dispersal of this mistletoe is more common than previously believed. Therefore, which side and at what height avian vectors of this mistletoe tend to perch for feeding, observation, or hiding on host trees will directly influence the distribution of subsequent within-tree infection. Although we believe self-dispersal is a principal means of within-tree dissemination for juniper mistletoe, further research is needed to test this hypothesis.

Birds initiate many new infections in the upper crown of host trees, because they tend to perch near the tops of trees (Cowles 1936, Hawksworth and Scharpf 1981, Gehring and Whitham 1992). Infections then spread to the middle and lower crown by self-dispersal mechanisms and some subsequent bird dissemination from the same tree and other infected trees may occur. The large number of small, young, non-reproductive plants in the lower crown of the host trees we sampled supports our hypothesis of a "top-down" spread of juniper mistletoe infections by self-dispersal. Dawson et al. (1990b) also hypothesized that there is a great amount of self-dispersal within host trees by juniper mistletoe, but they called this process "intra-tree-dispersal."

Most of the mistletoe plants were found in the middle to upper crowns of the host trees and these were primarily adult plants. In contrast, most of the non-reproductive plants were found in the lower crown. This pattern is probably the result of the host tree's crown structure and within-tree self-dispersal of the mistletoe. The crown structure of one-seeded juniper usually has its greatest branch and foliage biomass at 2-4 m above the ground (Born and Chojnacky 1985). This greater biomass provides more surface area on which mistletoe seeds can adhere and germinate. Therefore, more infections, and hence more plants, should occur in this region of greater crown biomass as our results and those of Dawson et al. (1990a, 1990b) demonstrate.

We plan to sample additional severely infected one-seeded junipers at other locations to determine if other juniper mistletoe populations have a 1:1 adult sex ratio on this host. We also plan to expand this research to include a determination of the sex ratio for juniper mistletoe populations on Utah juniper in northern Arizona. However, we now hypothesize that if a large number of juniper mistletoe plants is sampled from severely infected Utah junipers, the overall sex ratio will be essentially 1:1 as it was for the population of juniper mistletoe we sampled on one-seeded juniper in this study.

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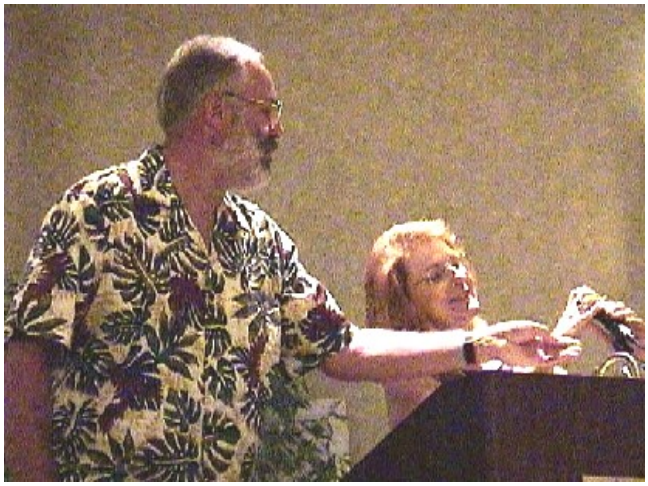

Status of Dwarf Mistletoes in Central America

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Introduction

Although the dwarf mistletoes (*Arceuthobium* spp., Viscaceae) are widespread and common parasites of Pinaceae in the United States and Mexico, only five species are known from Central America: *Arceuthobium aureum* ssp. *aureum*, *A. globosum* ssp. *grandicaule*, *A. guatemalense*, *A. hawksworthii* and *A. hondurense*. Some of these taxa are considered to be among the rarest dwarf mistletoes in the Western Hemisphere. Another species, *A. nigrum*, has been reported from western Guatemala and Chiapas. As discussed below, we now have morphological and molecular evidence that show a close relationship between the Chiapan population with *A. hondurense* from Honduras.

Little is known regarding the distribution, host range, ecology, and phenology of the Central American *Arceuthobium* taxa (Hawksworth and Wiens 1996). In an effort to fill this gap, field work was conducted in Belize, Guatemala, Honduras, western El Salvador, and Chiapas, Mexico. As a result of this work, we have extended the distribution of some Central American dwarf mistletoe taxa and found that others may now be even less common than reported by Hawksworth and Wiens (1970, 1972, 1977, 1984, 1996). We have also learned more about the host range of these mistletoes and a little more about their phenology. The following summarizes our findings.

Golden Dwarf Mistletoe (*Arceuthobium aureum* Hawksw & Wiens ssp. *aureum* Hawksw. & Wiens)

This dwarf mistletoe occurs in central Guatemala. It seems to be most common in the pine forests west and south of Coban. Hawksworth and Wiens (1977, 1996) reported that golden dwarf mistletoe primarily parastizes *Pinus montezumae* Lamb. and *P.*

pseudostrobus Lindl. and rarely occurs on *P. oaxacana* Mirov. Although we looked for these dwarf mistletoe - host combinations in Guatemala, we did not discover it. The only host we found golden dwarf mistletoe parasitizing was *Pinus maximinoi* H. E. Moore (Mathiasen et al. 1999b). This mistletoe has not been previously reported to induce witches' brooms on its hosts (Hawksworth and Wiens 1977, 1996), however, our work indicates that it commonly causes witches' brooms on *P. maximinoi* (Mathiasen et. al. 1999b). Although Hawksworth and Wiens (1996) (see pages 46 and 56) suggested that *P. oocarpa* Schiede might be a principal host of the golden dwarf mistletoe, we have yet to document this combination. We have observed large trees of *Pinus oocarpa* growing next to severely infected *P. maximinoi* near La Cumbre, and none of the *P. oocarpa* were infected (Mathiasen et al. 1999b). In addition, our observations in pine stands infected with the golden dwarf mistletoe near Chilasco indicate this mistletoe does not infect *P. tecunumanii* (Schw.) Equiliz et Perry, a species closely related to *P. oocarpa* (Perry 1991, Farjon and Styles 1997).

A dwarf mistletoe recently collected from near the summit of Montana de Celaque in western Honduras by Dr. Jose Melgar could be golden dwarf mistletoe based on his morphological measurements and photographs. Because Dr. Melgar collected the mistletoe from *Pinus ayacahuite* Ehren., his discovery would not only be the first report of golden dwarf mistletoe from Honduras, but also the first report of this mistletoe on Mexican white pine. We plan to visit Montana de Celaque in November, 2000 and cooperate with Dr. Melgar to confirm the identity of the dwarf mistletoe.

Golden dwarf mistletoe was first reported to have continuous flowering from February through May (Hawksworth and Wiens 1977). Hawksworth and Wiens (1996) later modified this range to be continuous flowering and seed dispersal throughout the year, or at least during the dry season (November - May). Observations made in early May 1999 found no flowering individuals, whereas flowering plants were seen in March 2000. While we have not observed seed dispersal in this species in March or May, female plants did have fruits at various stages of development in both months. These additional observations show that more information is needed on the phenology, distribution, and host range of this dwarf mistletoe species.

Large-stemmed Dwarf Mistletoe (*Arceuthobium globosum* Hawksw. & Wiens ssp. *grandicaule* Hawksw. & Wiens)

In Central America this dwarf mistletoe only occurs in western Guatemala. Although it is common in the highlands of central Mexico and has been reported as far south as Oaxaca, it has not been discovered in Chiapas. Therefore, the Mexican and Guatemalan populations of this dwarf mistletoe species are separated by ca. 500 km. The Guatemalan populations of the large-stemmed dwarf mistletoe have plants that are predominantly brownish-green, flower from early March into June, and are even larger than the plants found in central Mexico. The Mexican populations have green plants and flower from January to May. Therefore, we plan to conduct additional morphological studies of both populations in the future. Perhaps these widely separated populations are sufficiently distinct to warrant taxonomic recognition. It is questionable whether analysis of ITS rDNA sequences will provide sufficient numbers of changes (nucleotide substitutions) to differentiate these populations because both subspecies of *A. globosum* and *A. aureum* are genetically very similar.

To date we have only found the large-stemmed dwarf mistletoe parasitizing *Pinus rudis* Endl. and *P. pseudostrobus* in Guatemala. It is most common on *P. rudis* in the Sierra de los Cuchumatanes north of Huehuetenango, but it has also been reported from other high elevation locations including the slopes of the highest volcano in Central America, Volcan Tajumulco at an elevation of just over 3660 m (12,000 feet).

The plants of this dwarf mistletoe are the largest of any *Arceuthobium*. We found male plants measuring over 80 cm in height and female plants over 65 cm. They often occur in large clusters of plants that are greater than a meter in diameter. It commonly occurs on the main stems of infected trees.

Guatemalan Dwarf Mistletoe (*Arceuthobium guatemalense* Hawksw. & Wiens)

The Guatemalan dwarf mistletoe is only known to parasitize Mexican white pine (*Pinus ayacahuite*) and is one of the rarest species of *Arceuthobium*. It commonly forms large witches' brooms and systemic infections. The species was originally described by Hawksworth and Wiens (1970) from an area in the Sierra de los Cuchumatanes about 10 km south of San Juan Ixcoy, Guatemala. Our observations in this area indicate that the white pines have been extensively harvested, and the few white pines remaining are not infected with this mistletoe. Our attempts to locate this dwarf mistletoe at several other locations where it had been collected previously (Hawkworth and Wiens 1996) were also unsuccessful owing to timber harvesting. Although Hawksworth and Wiens (1996) commented that this dwarf mistletoe is quite common around Santa Eulalia, this is no longer the case. We found only two small mistletoe populations near Santa Eulalia where, as above, most of the white pines had been harvested. White pine is a valuable tree in Guatemala and has a number of commercial uses including hand-made furniture.

We have only found one new location for this dwarf mistletoe in Guatemala: 12 km north of Ixchiguan in Department San Marcos. Therefore, it appears that this dwarf mistletoe is being extierpated from the pine forests of Guatemala. Because the Guatemalan dwarf mistletoe is only known outside of Guatemala from a few locations in Chiapas and Oaxaca, Mexico, it is certainly one of the rarest dwarf mistletoes in the Western Hemisphere. We were unable to collect this mistletoe in Chiapas because the previous collection sites are now part of a military base south of San Cristobal de las Casas. We plan to visit the Oaxacan sites in December 2000.

The flowering period of the Guatemalan dwarf mistletoe has been reported to be in August and early September (Hawksworth and Wiens 1972, 1996). However, we found it near peak flowering in May in the Sierra de los Cuchumatanes near Todos Santos, Guatemala. It had just started flowering in May at the population north of Ixchiguan. Therefore, this species may have two distinct flowering periods (spring and late summer) or populations may flower at different times throughout the year. More information on the flowering and seed dispersal periods for this dwarf mistletoe is needed.

Hawksworth's Dwarf Mistletoe (*Arceuthobium hawksworthii* Wiens & C. G. Shaw III)

Specimens of Hawksworth's dwarf mistletoe have been collected from Belize since 1959, but this taxon was not described until 1994 (Wiens and Shaw 1994). It was previously considered to represent a disjunct population of *Arceuthobium globosum* Hawksw. & Wiens (Hawksworth and Wiens 1972) and later was classified as the golden dwarf mistletoe (Hawksworth and Wiens 1977). However, a detailed analysis of the Belize populations by Wiens and Shaw (1994) indicated these populations are distinct from the golden dwarf mistletoe populations found in central Guatemala.

Hawksworth's dwarf mistletoe is one of the rarest dwarf mistletoes because so far it is known only from a small area in the Mountain Pine Ridge region of western Belize. However, Wiens and Shaw (1994) speculated that this dwarf mistletoe might occur in eastern Guatemala in a disjunct population of its principal host, *Pinus caribaea* var. *hondurensis* (Senecl.) Barr. & Golf., that occurs in the vicinity of Poptun (Perry 1991).

Several excursions to Belize were made to observe flowering, seed dispersal, host range and distribution of Hawksworth's dwarf mistletoe. One trip to eastern Guatemala was made in an attempt to locate this species near Poptun. A summary of our findings, taken from Mathiasen et. al. (1999a), is presented below.

Distribution

Hawksworth's dwarf mistletoe is common in the Mountain Pine Ridge east of Augustine, particularly along the Baldy Beacon, Hidden Valley Falls, Brunton Trail, Orchid Hill and Granite Cairn Roads. We observed populations of Hawksworth's dwarf mistletoe at an elevation of 520 m at several locations, but the mistletoe is most common above 600 m. The reasons for the lower elevation limitation are unclear, because its pine hosts are continuously distributed throughout the Mountain Pine Ridge at elevations below 500 m. In addition, as was reported by Wiens and Shaw (1994), we did not observe Hawksworth's dwarf mistletoe in the lower elevation *Pinus caribaea* var. *hondurensis* forests closer to the coast of Belize.

Our surveys now provide adequate information to estimate the distribution of this rare dwarf mistletoe in the Mountain Pine Ridge. Apparently it only occurs in an area of approximately 250 sq. km (Figure 1). Because the highlands of the Mountain Pine Ridge are geologically distinct and have evidently been isolated from other highland regions of Central America for several thousand years (Bateson 1972, Bateson and Hall 1977, Means 1997), Hawksworth's dwarf mistletoe has been separated from other dwarf mistletoe populations long enough to have evolved into a distinct taxon, endemic to the Mountain Pine Ridge. Molecular phylogenetic analyses of nuclear ribosomal ITS sequences

(Nickrent 1996) support the treatment of Hawksworth's dwarf mistletoe as a separate species.

In March 1998 we surveyed the pine populations near Poptun, Guatemala. These pine populations are typical *Pinus caribaea* var. *hondurensis* as reported by Perry (1991). We estimate the overall forest area dominated by pine near Poptun to be restricted to about 300 square km, so the majority of the pine forest (elevation 500 to 700 m) in this area was surveyed. Hawksworth's dwarf mistletoe was not observed in these forests, and we believe it does not occur there. Therefore, it is doubtful that Hawksworth's dwarf mistletoe occurs in Guatemala.

Host Range

We examined host material collected from several pines at different elevations in the Mountain Pine Ridge in an attempt to clarify the identity of the hosts parasitized by Hawksworth's dwarf mistletoe (Wiens and Shaw 1994). For dwarf mistletoe-infected pines, specimens with needles and mature female cones were collected and forwarded to J. P. Perry, Jr. for confirmation of our tentative field identifications. Additionally, a sample was taken from a putative hybrid (*Pinus caribaea* var *hondurensis* X *Pinus oocarpa* var. *ochoterenai*). In all cases our identification of the host agreed with those of Mr. Perry, except that he felt the putative hybrid was best classified as *P. oocarpa* var. *ochoterenai*. Our field observations from the Mountain Pine Ridge confirm that *P. caribaea* var *hondurensis* is the principal host of Hawksworth's dwarf mistletoe in this area. In many areas this pine is severely infected and tree mortality is common in severely infested pine stands.

We were unable to find locations with sufficient numbers of *Pinus oocarpa* var. *ochoterenai* growing near severely infected *P. caribaea* var. *hondurensis* to gather quantitative data on the comparative susceptibility of these hosts to Hawksworth's dwarf mistletoe. However, based on our observations at several locations where *P. caribaea* var. *hondurensis* and *P. oocarpa* var. *ochoterenai* were both parasitized by this dwarf mistletoe, we believe the latter pine is less susceptible. In some areas where many *P. caribaea* var. *hondurensis* were severely infected and where many dead pines of this species had evidence of past mistletoe infection (witches' brooms), infection of large (> 10 m in height) *P. oocarpa* var. *ochoterenai* was much less severe and less frequent. In addition, we observed infection of small *P. caribaea* var. *hondurensis* (less than 2 m in height) under larger individuals of this species but small *P. oocarpa* var. *ochoterenai* growing in the same areas were not infected. Therefore, we have tentatively classified *P. oocarpa* var. *ochoterenai* as a secondary host using the host susceptibility classification system of Hawksworth and Wiens (1972, 1996).

The taxonomic status of the *Pinus oocarpa* populations in the Mountain Pine Ridge is still in question and some investigators consider these populations to be more representative of *P. tecunumanii* (Farjon and Styles 1997). Others consider these populations to represent *P.*

oocarpa var. *ochoterenai* (Hunt 1962, Perry 1991). We have chosen to follow the classification of Perry (1991) for these pine populations.

Plant Measurements

Measurements from fresh specimens of male and female plants of Hawksworth's dwarf mistletoe were made, thus augmenting the small amount of data available for this species. Plant height (nearest 0.1 cm), width of shoot bases (nearest 0.1 mm), third internode length (nearest 1.0 mm), and third internode width (nearest 0.1 mm) were measured on the dominant shoots from 150 infections of each sex (300 total plants). Means, standard deviations, maximums, and minimums for these four morphological characters are presented below:

	Female				Male			
	Mean	S. Dev.	Max.	Min.	Mean	S. Dev.	Max.	Min.
Height (cm)	15.6	3.4	27.8	9.6	15.7	3.8	32.8	7.8
Base (mm)	3.8	0.8	6.9	2.1	3.5	0.9	7.8	2.3
Third Internode Length (mm)	12.2	2.3	19.0	7.0	11.8	2.6	21.0	6.0
Width (mm)	2.7	0.5	4.5	1.9	2.5	0.5	4.4	1.7

The largest plants found were males (approximately 33 cm), heights which slightly exceeded the maximum value (30 cm) reported by Wiens and Shaw (1994); otherwise, these sizes and ranges are consistent with those reported by Wiens and Shaw. It is interesting to note that based on our measurements of 300 Hawksworth's dwarf mistletoe plants [the largest set of plant measurements completed for a single dwarf mistletoe species of which we are aware (see Hawksworth and Wiens 1996)], male and female plants do not differ significantly in these four morphological characters. So while this species definitely displays a distinctive sexual dimorphism (Wiens and Shaw 1994), male and female size is approximately the same.

Phenology

Male plants of Hawksworth's dwarf mistletoe were still flowering on March 5, 1998 at elevations over 800 m in the Mountain Pine Ridge area. As was reported by Wiens and Shaw (1994), male flowers had perianths that were predominantly 3-merous and rarely 4-merous, but we did not observe male flowers with the vivid red color inside the perianth lobes described by Wiens and Shaw. The male flowers we observed were the same color on the inside as on the outside - a shade of yellowish-brown that is slightly darker than the staminate spike shoot color. Female flowers were in an early stage of fruit development on many plants and no mature fruits were observed on this date (early March). Wiens and Shaw (1994) speculated that Hawksworth's dwarf mistletoe disperses its seed in June. However, our observations in early June 1998 indicated that fruits were immature.

Additional observations from August 18-20, 1998 revealed only a few fruits nearing maturity. At this time, no seeds were being dispersed and attempts to manually expel seeds were unsuccessful. Incipient seed dispersal was observed in early October 1999. Anthesis was not occurring in June 1998, August 1998, or October 1999. Wiens and Shaw (1994) speculated that Hawksworth's dwarf mistletoe has multiple flowering and seed dispersal periods. However, this taxon appears to have only one period of anthesis annually (mid January through early March) and one annual seed dispersal period that we estimate is from mid October through November. Therefore, fruit maturation only requires 7 - 8 months. We plan to visit Belize again in early November 2000 to document seed dispersal of Hawksworth's dwarf mistletoe.

Sex Ratio

Dwarf mistletoes are dioecious and most species have a 1:1 sex ratio (Hawksworth and Wiens 1996), but some species are reported to have a female-biased sex ratio (Hawksworth and Wiens 1996, Wiens et al. 1996). In May and August 1998 we systematically examined separate infections of Hawksworth's dwarf mistletoe and determined their sex based on flower morphology of mature plants. Twenty *Pinus caribaea* var. *hondurensis* were felled and the sex of mature mistletoe plants determined. Of 1066 infections examined, 522 were male and 544 were female, thus the sex ratio is essentially 1:1 like most species of *Arceuthobium*.

Honduran Dwarf Mistletoe (*Arceuthobium hondurense* Hawksw. & Wiens)

Honduran dwarf mistletoe was described in 1970 from southeast of Tegucigalpa, Honduras on *Pinus oocarpa* (Hawksworth and Wiens 1970). Hawksworth and Wiens (1972, 1996) speculated that this dwarf mistletoe could be so rare in Honduras that it might be in danger of extinction if the extensive harvesting of pine forests continued. Since then, three additional populations of this rare dwarf mistletoe have been discovered (Beatty et al. 1998, Mathiasen et al. 1999b). The four known locations in Honduras are:

1. Cusuco National Park, Cortes - approximately 20 km northwest of San Pedro Sula.
2. Piedra Grande Area, Francisco Morazan - approximately 20 km southeast of Tegucigalpa.
3. Lepaterique Area, Francisco Morazan - approximately 5 km east of Lepaterique.
4. Celaque National Park, Lempira - on main trail to mountain summit from visitor's center.

However, so little is still known about its host range and distribution in Central America that it can still be considered one of the rarest dwarf mistletoes described from the Western Hemisphere. It may also occur in El Salvador in the vicinity of Montecristo (Santa Ana Province) near the borders of Honduras and Guatemala, but this tentative report (Hawksworth and Wiens 1996) needs to be confirmed. Our brief attempt to locate this dwarf mistletoe in the Montecristo area in 1999 failed. However, we agree with Hawksworth and Wiens that should dwarf mistletoe be discovered in the Montecristo area, it most likely would be Honduran dwarf mistletoe because the most common host there is *P. oocarpa*.

Based on our observations of Honduran dwarf mistletoe in Honduras and of black dwarf mistletoe (*Arceuthobium nigrum* Hawksw. & Wiens) in Mexico, we concluded that the black dwarf mistletoe populations in Chiapas, Mexico, should be classified as Honduran dwarf mistletoe. Our identification was based on morphological characters (plant color and size, male flower perianth lobe color, female flower stigma length) and host range of the dwarf mistletoe in Chiapas and Honduras (parasitism of *P. tecunumanii*). To determine whether these populations were best assigned to *A. nigrum* or *A. hondurense*, plant samples were obtained from Chiapas, Mexico and Honduras. Sequences of nuclear ITS rDNA clearly indicate that the Chiapan plants are very closely related to *A. hondurense* from Honduras, not *A. nigrum* (from Oaxaca, Mexico). These results thus confirm our suspicions based upon morphological characters. Moreover, the geographic range and number of populations of Honduran dwarf mistletoe have been modified dramatically. This also indicates that the report of black dwarf mistletoe in Guatemala (Hawksworth and Wiens 1977) was probably based on an observation of Honduran dwarf mistletoe. Therefore, it now appears that the Honduran dwarf mistletoe is not in danger of extinction as suggested by Hawksworth and Wiens (1996, p. 222).

Host Range

Thus far, Honduran dwarf mistletoe has only been reported to parasitize *Pinus oocarpa* and *P. tecunumanii* (Mathiasen et. al. 1999a, Mathiasen et. al. 2000). Hawksworth and Wiens (1996) recorded the host of Honduran dwarf mistletoe in northwestern Honduras as *P. maximinoi*, but this host classification was tentative and based on information provided to one of us (J. S. Beatty) by Honduran Forestry personnel. Our examination of the pines being parasitized in northwestern Honduras indicates that the host is *P. oocarpa* var. *ochoterenai* (or *P. tecunumanii* depending on which pine expert you follow) and not *P. maximinoi* as reported by Hawksworth and Wiens. Therefore, we conclude that Honduran dwarf mistletoe only parasitizes *P. oocarpa* and *P. tecunumanii* in Honduras (Mathiasen et. al. 1999a, Mathiasen et. al. 2000). Because so little is currently known about the distribution and host range of Honduran dwarf mistletoe, it is likely that once its distribution is better documented in Central America, it may be found parasitizing other species of *Pinus*.

Plant Measurements

Measurements were made from fresh specimens of male and female plants of Honduran dwarf mistletoe collected in March and August, 1998. Measured characters were the same as for Hawksworth's dwarf mistletoe (above), but only 25 infections of each sex were measured for this species. Means, standard deviations, maximums, and minimums for these four morphological characters are presented below:

	Female				Male			
	Mean	S. Dev.	Max.	Min.	Mean	S. Dev.	Max.	Min.
Height (cm)	13.6	3.0	19.4	9.1	20.2	4.5	32.2	11.5
Base (mm)	4.0	0.6	5.8	2.8	4.4	0.7	6.3	3.6
Third Internode Length (mm)	10.7	2.5	16.0	7.0	14.0	2.3	18.0	8.0
Width (mm)	3.3	0.3	3.9	2.7	3.4	0.5	4.8	2.8

The sizes and ranges of these characters for female plants are nearly identical to those reported for this taxon (both sexes combined) by Hawksworth and Wiens (1972, 1996), but the sizes and ranges for male plants are larger. For instance, the largest plant (s) reported by Hawksworth and Wiens (either sex) was only 21 cm compared to the 32-cm male plant we measured from southeast of Tegucigalpa. However, measurements of the Chiapan populations of Honduran dwarf mistletoe indicate that male plants can exceed 50 cm in height. In addition, our observations of this mistletoe from several locations indicate the color of both male and female plants varies from the olive-brown, grayish green colors reported by Hawksworth and Wiens (1972, 1996) to dark brown (nearly black) and reddish brown.

Phenology

Male plants of Honduran dwarf mistletoe had begun flowering and some fruits on female plants were beginning to disperse seed in late August 1998. Therefore, flowering and seed dispersal of Honduran dwarf mistletoe starts slightly earlier than September, which was reported by Hawksworth and Wiens (1972, 1996) as the period of both flowering and seed dispersal. However, we have also found male plants of Honduran dwarf mistletoe flowering in March and November, so this mistletoe may have two or more flowering periods. It is also possible that different populations flower at different times throughout the year. The inside of male flower perianths of Honduran dwarf mistletoe is bright red as previously reported (Hawksworth and Wiens 1972, 1996), but perianth lobes become the same color as male shoots when dried. Just as for Hawksworth's dwarf mistletoe, male and female plants of Honduran dwarf mistletoe also demonstrate a high degree of sexual dimorphism. Male plants are more open and spreading and female plants are more compact and densely branched.

Sex Ratio

In August 1998 we systematically examined infections on five *Pinus oocarpa* trees and determined the sex of 64 mature mistletoes. On small trees (less than 6 m in height) binoculars were used to score mistletoe sex from the ground. Only one larger tree (10 m in height) with several infections was destructively sampled. The sex ratio of this small sample of mature plants was essentially 1:1 (31 females and 33 males), but a larger sample is needed to confirm this preliminary finding.

Black Dwarf Mistletoe (*Arceuthobium nigrum* Hawksw. & Wiens)

Hawksworth and Wiens (1977) speculated that black dwarf mistletoe occurs in western Guatemala (Department San Marcos) based on a report by Dr. Ed Clark. Unfortunately, Dr. Clark did not collect specimens of the "black" dwarf mistletoe he observed. Although the distribution map in Hawksworth and Wiens (1996) indicates this mistletoe does occur in western Guatemala, their discussion of its distribution (page 229) mentions that it is only a possibility that this species occurs in Guatemala. Our attempts to find black dwarf mistletoe near San Marcos, Guatemala, have not been successful. The pine forests around San Marcos have also been extensively harvested and it will be difficult to find this dwarf mistletoe if it does still occur in that area. As our discussions above indicate, we now know the population of this mistletoe in Chiapas is actually Honduran dwarf mistletoe. Therefore, we believe the "black" dwarf mistletoe seen in Guatemala was probably a population of Honduran dwarf mistletoe. Therefore, the most southern populations of black dwarf mistletoe known are in central Oaxaca, Mexico (Hawksworth and Wiens 1996).

Phylogenetic Relationships and Classification of Central American *Arceuthobium*

The previously published molecular phylogeny of *Arceuthobium* based on ITS rDNA sequences included 22 taxa (Nickrent et al. 1994). The affinities of *A. hawksworthii* and *A. aureum* ssp. *aureum* were mentioned in Nickrent (1996, p. 171), although these taxa were not included on the phylogram published in that chapter. In addition to these two taxa, ITS sequences have since been obtained from *A. hondurense*, *A. globosum* ssp. *grandicaule*, and *A. aureum* ssp. *petersonii* (Figure 2). Many of the previously reported relationships (clades) remain, but the addition of the new taxa provided greater resolution. For example, both subspecies of *A. globosum* and *A. aureum* are very closely related and occur on a well-supported clade. As mentioned above, the taxon originally named as *A. nigrum* from Chiapas has an ITS sequence nearly identical to the accession of *A. hondurense* from Honduras. These sequences are most closely related to *A. hawksworthii*. A relationship between *Arceuthobium bicarinatum* Urban, a species that occurs on the island of Hispaniola, and *A. hondurense* had been proposed based upon morphological evidence (Hawksworth and Wiens 1996). ITS data do not support this proposed relationship but indicate that *A. hondurense* is a component of Series *Stricta* along with A. *durangense, A. strictum*, and *A. vaginatum*. Moreover, ITS analyses indicate that *A. bicarinatum* is a component of Series *Pusilla* and is most closely related to *A. pusillum* of eastern North America, a surprising result given their divergent morphologies. Given these genetic data, the classification proposed in Nickrent (1996) must be ammended. It is proposed that *A. hondurense* be moved from Section *Pusilla* into Series *Stricta*. Because Section *Pusilla* emerges as a clade among other Series of Section *Vaginata*, a classification that is more compatible with the molecular data would rename this Section as a Series.

Plant Collections

Specimens of the above dwarf mistletoes collected from our trips to Central America and southern Mexico have been deposited at the Deaver Herbarium, Northern Arizona University, Flagstaff, AZ; the US National Herbarium, Washington, D.C.; the Forestry Herbarium, Ministry of Agriculture, Belmopan, Belize; the Herbario Paul C. Standley, Escuela Agricola Panamericana, Zamorano, Honduras; and the Herbario, Escuela Nacional de Ciencias Forestales, Siguatepeque, Honduras.

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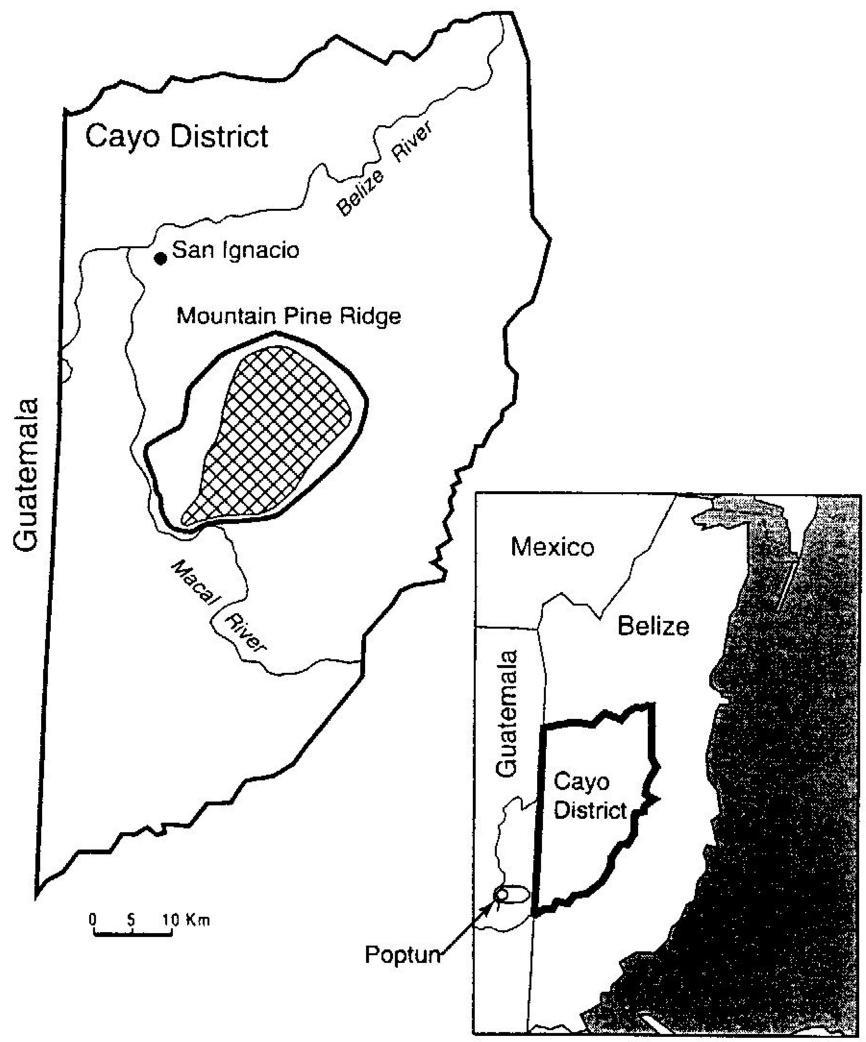
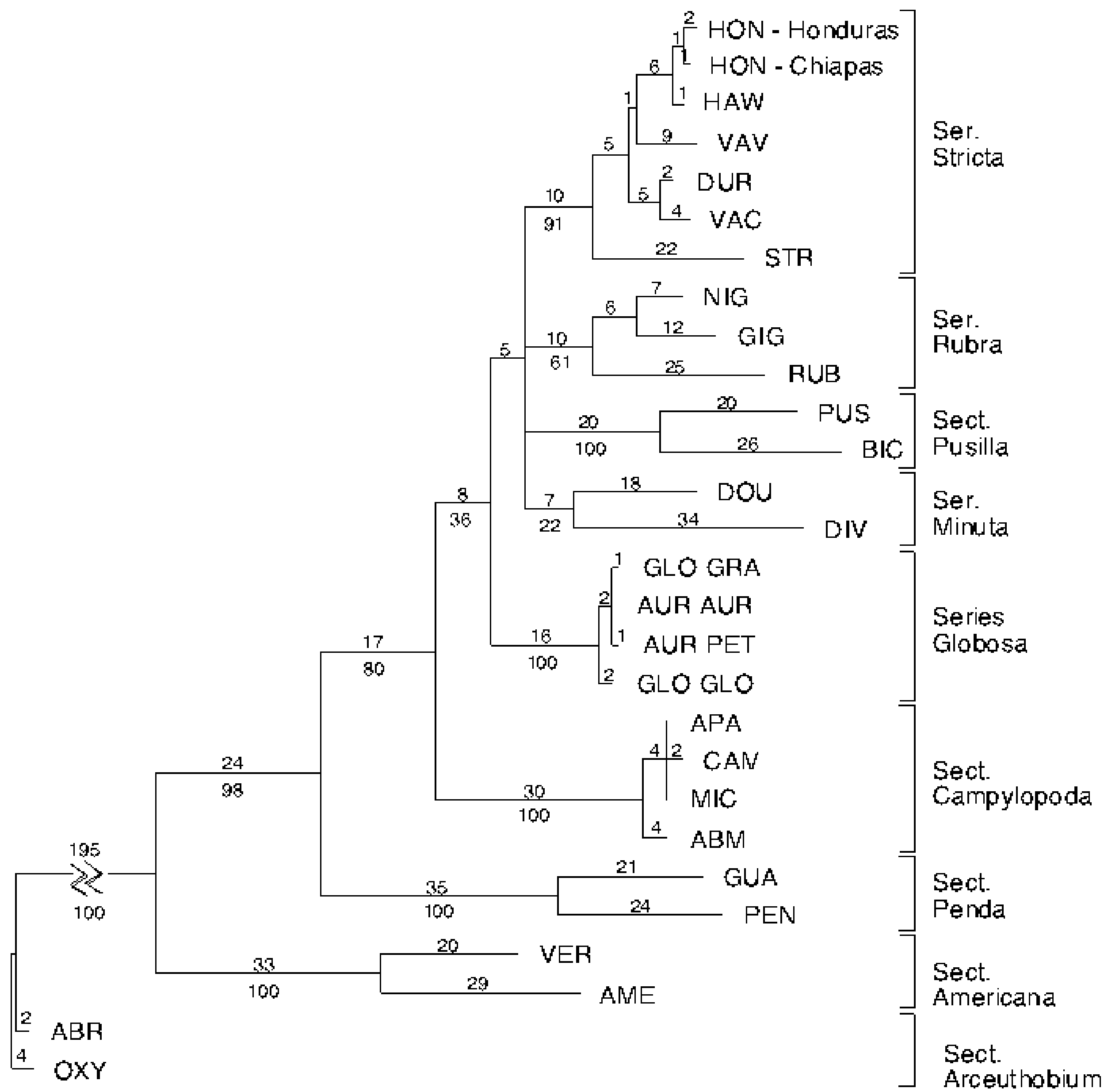


Figure 1. Location of the Mountain Pine Ridge Region (MPR) in Belize and the approximate distribution of *Arceuthobium hawksworthii* within the MPR. The thick line in blow-up represents the MPR and the cross-hatched area represents the distribution of *A. hawksworthii* (approximately 250 sq. km). Approximate area of pine forests surveyed in Guatemala is indicated by dark line around Poptun.

ABM = A. abietinum (Engelm.) Hawksw. & Wiens f. sp. magnificae Hawksw. & Wiens
ABR = A. abietis-religiosae Heil.
AME = A. americanum Nutt. ex Engelm.
APA = A. apachecum Hawksw. & Wiens
AUR-AUR = A. aureum Hawksw. & Wiens ssp. aureum
AUR-PET = A. aureum ssp. petersonii Hawksw. & Wiens
BIC = A. bicarinatum Urban
CAM = A. campylopodum Engelm.
DIV = A. divaricatum Engelm.
DOU = A. douglasii Engelm.
DUR = A. durangense (Hawksw. & Wiens) comb. nov.]
GIL = A. gillii Hawksw. & Wiens ssp. gillii
GLO-GLO = A. globosum Hawksw. & Wiens ssp. globosum
GLO-GRA = A. globosum ssp. grandicaule Hawksw. & Wiens
GUA = A. guatemalense Hawksw. & Wiens
HON = A. hondurense Hawksw. & Wiens
MIC = A. microcarpum (Engelm.) Hawksw. & Wiens
NIG = A. nigrum (Hawksw. & Wiens) comb. nov.]
OXY = A. oxycedri (DC) M. Bieb.
PEN = A. pendens Hawksw. & Wiens
PUS = A. pusillum Peck
RUB = A. rubrum Hawksw. & Wiens
STR = A. strictum Hawksw. & Wiens
VAV = A. vaginatum (Willd.) Presl. ssp. vaginatum
VAC = A. vaginatum ssp. cryptopodum (Engelm.) Hawksw. & Wiens
VER = A. verticilliflorum Engelm.

Figure 2. Strict consensus phylogram (of 10 equally parsimonious trees of length 733) derived from an analysis of nuclear ribosomal ITS sequences. Numbers above the branches represent number of nucleotide substitutions, numbers below the branches are bootstrap percentage values (100 replications). Nodes without bootstrap values were present in less than 50% of the replications (i.e. not strongly supported). If Section Pusilla were reduced to a series, then Section Vaginata would be monophyletic, albeit with only 36% bootstrap support. Species abbreviations are as follows:

Figure 2 (cont.).



PANEL: APPLICATION OF BIOLOGICAL CONTROL TO VEGETATION MANAGEMENT IN FORESTRY

Simon Shamoun - Moderator

Riding the Biological Control Wave: From the Mongoose to *Uromyces pisi* f.sp. *europaei*

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Abstract: The history of biological control in Hawaii is legendary. From the rudimentary attempt to control armyworms in 1865 to sophisticated quarantine facilities for weed control in 2000, biological control practitioners have played a major role in combating invasive species that have become established in the vulnerable ecosystems of the Islands, which are often referred to collectively as the endangered species capitol of the world. The history is not without its failures, but they have served as honing tools for researchers and regulators alike in developing new approaches and more efficient means of processing and releasing biological control agents. The use of pathogens and the diseases they cause to control invasive weed species in Hawaii are a recent trend, but their successes have been dramatic ensuring their important role in the preservation of the native Hawaiian ecosystem.

Key words: biological control, mongoose, invasive weeds, pathogens

In records compiled by the Hawaii Department of Agriculture (HDOA) for the years 1890 to May 2000, the number of biological control organisms purposely introduced into Hawaii to control pests, including insects, plants, and animals, totaled 765 predatory and parasitic insects, birds, fishes, snails, bats, amphibians, and fungi (24). But the practice of biological control actually began in 1865 when William Hillebrand, a physician and naturalist, imported the mynah bird (*Acridotheres tristis tristis* L.) from India to control armyworms that were infesting pasture grasses (5). The mynah, however, was an omnivorous feeder and in addition to the armyworms, it also fed on other insects, a variety of fruits, berries, and even garbage. But the population of mynah birds never reached a sufficient level to impact the fauna or flora whether native or introduced to Hawaii (4).

In 1883, sugarcane growers imported the mongoose (*Herpestes auropunctatus auropunctatus* Hodgson) from Jamaica to control the rat population that was feeding on and destroying the canes (15). Jamaican sugarcane growers had imported the mongoose from India for the same purpose (9). Many years later, however, naturalists in Hawaii and Jamaica have decried the introduction of this omnivorous animal as a biological control project gone awry (4,8,15). At first, the mongooses were an instant success, but as the rat population diminished, the mongooses looked to other food sources. Their habitats extended to grasslands, desert scrub, lowland forests, the seacoast, cultivated areas and even the suburbs. In addition to rats, they attacked birds, small reptiles, fishes, insects, crabs, arachnids, and learned to eat eggs (2). They decimated ground nesting, native bird populations including the Hawaiian goose or nene (*Nesochen sandvicensis*) (25,31), the dark-rumped petrel (*Petrodroma phaeopygia*) and Newell's shearwater (*Puffinus puffinus newelli*) (1,15,21), and caused much grief to the poultry industry.

Prior to 1890, biological control was practiced by private citizens without any oversight or controls. In order to regulate the influx of pests and agricultural commodities into the Islands, King David Kalakaua of the Kingdom of Hawaii, enacted the "Laws of the Hawaiian Islands" to prevent the introduction of unwanted insect pests and to control those already present in the Islands (10). In 1893, the Kingdom was replaced by the government of the Republic of Hawaii, which appointed Albert Koebele as entomologist to solve insect pest problems using biological control means. He was successful in controlling scale insects, aphids, and armyworms. In 1902, he was sent to Mexico to search for insects and diseases of lantana (*Lantana camara* L.), the first attempt to control a weed pest in Hawaii (7). He released 23 insect species but only eight became established. Host specificity testing was not practiced, and only those insects that Koebele believed to be specific to lantana were shipped to Hawaii. To this day, all of Koebele's insect introductions have remained beneficial.

During the period 1904 through 1942, other research agencies, such as the Hawaii Sugar Planters' Association, the USDA ARS Fruit Fly Laboratory, and the Pineapple Research Institute, released natural enemies to control pest problems (10). These agencies were not subject to official reviews. In order to control the introduction of all types of organisms into the Islands, the Board of Agriculture adopted a strict review policy 1944 (22). The stricter guidelines prompted the HDOA to construct an insect quarantine facility in Honolulu in which research and host range studies of all potential biocontrol insects could be completed. But it would be another 40 years before the HDOA would construct a containment facility for the purpose of studying plant pathogens as weed biocontrol agents

In 1974, Eduardo E.Trujillo, University of Hawaii at Manoa, released the white smut pathogen *Entyloma ageratinae* (Trujillo) Barreto *et al* (3) to control Hamakua pamakani or mist flower (*Ageratina riparia* K & R), on the islands of Oahu, Maui, and Hawaii (28). The pathogen was discovered on diseased plants in Jamaica and host range tests were conducted at the Foreign Disease and Weed Science Research Unit (FDWSRU) at Fort Detrick, Maryland. Within three months of the release, severe epidemics occurred at those sites where optimal disease conditions prevailed, i.e., temperatures between 10 - 20°C and humidity levels >98% (26). Sites at which the temperature and humidity were not optimal showed a 50% reduction in weed populations. The dramatic display by *E.ageratinae*, convinced many environmentalists of the potential of pathogens as biocontrol agents.

Trujillo continued in weed control research and released another pathogen in 1986. He had traveled to Central America and found a leaf spot disease on Koster's curse (*Clidemia hirta* (L.) D. Don), another invasive, noxious, forest weed Pathogenicity tests and host range studies at FDWSRU showed that *Colletotrichum gloeosporioides* f.sp. *clidemiae* Trujillo *et al*. was specific to Koster's curse (27). Although not as dramatic as the *Entyloma* fungus, *C.g. clidemiae* is very destructive under very humid to wet conditions (Conant, pers.comm.).

Because of Trujillo's successes, the HDOA began construction of a plant pathogen containment facility at their headquarters in Honolulu, where foreign or non-indigenous pathogens would be studied and researched for their biological control potentials. The construction project lasted six years and was certified by State and Federal Agencies in 1991. Its containment features allow research on a range of pathogens, including high risk, aerosolizable rust fungi.

The first project undertaken in the quarantine facility was the host range testing of the systemic rust pathogen*, Gymnoconium nitens* (Schw.) Kern & Thur, which is commonly found on blackberry (*Rubus argutus* Link) in the Southeastern United States (12). In Hawaii, *R. argutus* is a noxious weed that forms thickets in disturbed mesic to wet forests and open grassland areas on all islands. Don Gardner, USGS Biological Resources Division, brought the rust to the quarantine facility in Honolulu in 1992, where it was inoculated onto two native or endemic *Rubus* species, *R. macraei* Gray and *R. hawaiensis* Gray, and two introduced species, *R. spectabilis* Pursh and *R.ellipticus* Sm. *G. nitens* infected both of the native *Rubus* species and the project was terminated. The two introduced species were not susceptible.

The first release of a biocontrol pathogen from the quarantine facility was a result of a cooperative project between Trujillo and the HDOA. Banana poka (*Passiflora tripartita* (Juss.) Poir var. *tripartita* Holm-Nie. Jörg. & Laws. (=*Passiflora mollissima* Neal)) was introduced to Hawaii as an ornamental, but it's strangling liana or vines have invaded native forests on the islands of Hawaii, Maui, and Kauai where it has inhibited growth and reproduction of native forest flora (16). Trujillo's search for biocontrol agents on *P. tripartita* in Colombia and Ecuador (Andean regions) resulted in the release of two insects and a fungal pathogen. Biological control activity of the two insects has been minimal. The pathogen *Septoria passiflorae* Syd. was isolated from leaf spots on Hawaiian banana poka planted as a trap crop in Colombia (29). Infected leaves were sent to the quarantine facility in Honolulu for isolation, pathogenicity tests, and host range testing. Since there are no native plants within the family Passifloraceae in Hawaii, testing consisted of six introduced *Passiflora* spp. *S. passiflorae* infected only one other weedy species, *P. foetida* L., and permission to field release *S. passiflorae* was received in 1996. The disease is currently well established on the islands of Kauai, Maui and Hawaii, causing leaf spots followed by premature defoliation of the vines (30).

Ivy gourd (*Coccinia grandis* (L) Voigt) is a noxious, cucurbit vine commonly found in the coastal lowlands of Oahu and Hawaii (17). In 1992, an exploration was undertaken by HDOA exploratory entomologist Robert Burkhart to collect biocontrol agents for this weed in Kenya where ivy gourd is a native species. Besides three insects that have been released over the past four years, he discovered a rust disease that was very devastating to ivy gourd. He shipped samples of the disease to Honolulu, but none of the rust spores were viable upon arrival. Since his exploration ended, there was no further attempt to recover the rust.

The second release of a biological control pathogen from the quarantine facility occurred on October 17, 1997, with the inoculation of the fungus *Septoria hodgesii* Gardner (=*S. myricae*) onto fayatrees (*Myrica faya* Aiton) at Volcanoes National Park on the island of Hawaii (13). It is believed that fayatree was brought to Hawaii by Portuguese laborers from the islands of Madeira and the Azores (18). It now occupies 35,000 ha on the main islands (32). *S. hodgesii* was isolated from diseased waxmyrtle (*M. ceriferae*) and shipped to the containment facility in Hawaii. The fungus causes leaf spots, followed by premature leaf drop. Although the fungus was released at several sites at Volcano, the incidence of leaf spots remain at a very low level. It is believed that the prolonged drought that has continued for the past decade coupled with the sulfurous emissions from the nearby eruption at Kilauea Iki have negatively impacted the biological control activity of this fungus.

Several horticultural specimens of miconia, *Miconia calvescens* DC., were planted in the Onomea area, north of Hilo on the island of Hawaii in the 1950s. Because it was an attractive plant with large velvety dark green leaves and purple-colored undersides, the plant was propagated and sold at nurseries (23). By 1980, the invasive and pestiferous nature of the species began to manifest itself, but it wasn't until 1990, that warnings from eyewitnesses who had traveled to Tahiti prompted environmentalists to mount an emergency action plan to eradicate *M. calvescens* (6,11). *M. calvescens* became the most threatening of all non-indigenous plant species to become established in Hawaii. The Hawaiian miconia invasion was not hopeless as the situation was in Tahiti where 70% of the native forest had been transformed into solid stands of *M. calvescens* (20), but the threat was real. The action plan called for the implementation of two control modes: the conventional means (herbicides), and the search for biological control agents.

Exploration for natural enemies of *M. calvescens* by the HDOA began in 1991 in its native range of the Neotropics (Central and South America). In 1996, a *Colletotrichum gloeosporioides* was isolated from a leaf spot by Robert W. Barreto of the University of Viçosa at Viçosa, Brazil. Host range tests included six other genera in the Family Melastomataceae and 17 species in the Order Myrtales present in Hawaii. The fungus was host specific to *M. calvescens* (14), and in 1997, the pathogen *C.g. miconiae* Killgore *et al* was released in the Onomea area. It was not until 1999 that biological control activity was observed. And in March 2000, the government of French Polynesia approved the release of the *C.g. miconiae* on the island of Tahiti where it is now established (Meyer, pers. comm.).

Gorse, *Ulex europaeus* L., was brought to Hawaii by sheep ranchers during the 1920s, as a browse and hedgerow for their sheep on the southern slopes of the volcano Mauna Kea on the island of Hawaii. When the sheep were replaced with cattle, however, the gorse was left unchecked and it now covers over 14,000 hectares of pasture and forest lands on the southern and eastern slopes of the Mauna Kea (19). Although many insects have been released to control gorse, only recently has a pathogen been released. In 1992, a rust disease on gorse was shipped from England to the containment facility in Honolulu. Host range testing of 36 members of the Fabaceae lasted for 4 years. The rust *Uromyces pisi* f. sp. *europaei* (MacDonald) Wilson & Henderson was pathogenic to gorse and lupines (*Lupinus* sp.). Since there are no native lupines in Hawaii, the permit to release the rust was granted in 1999, a process that required 3 years of review. In January 2000, the rust was released at Mauna Kea.

Summary

For over a century, the use of biological control agents has played a major role in managing pest problems in Hawaii, from sugarcane rats to the invasive, imported gorse. The science was borne as a countermeasure to serious pest introductions when control methods did not exist, failed, or was not feasible. And throughout this history, the science has evolved with lessons learned from costly mistakes.

For the past 26-years, the use of pathogens in controlling invasive weed species in Hawaii has been impressive at times. Since 1974 there have been six pathogen releases; two of which have yet to become established, but four pathogens have impacted their target hosts with significant levels of control. Unlike other control agents, these pathogens have also retained their host specificity levels. With these records, the use of pathogens as control agents for weeds will continue to contribute to the legacy of biological control in Hawaii for many years to come.

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Recent Developments in the Biological Control of Kahili Ginger with *Ralstonia solanacearum* in Hawaii

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ABSTRACT

Kahili ginger (*Hedychium gardnerianum*) is an invasive weed in the tropical forests of Hawaii and elsewhere. The wilt-causing bacterium *Ralstonia* (=*Pseudomonas*) *solanacearum* has previously been investigated as potential biological control agent for kahili ginger. This bacterium was shown to have significant potential in controlling this weed if effective delivery methods could be developed. To address this need, research into the development and field-testing of new application techniques for the control of kahili ginger with *R. solanacearum* were studied in *Metrosideros polymorpha* forests on the island of Hawai'i. Two objectives were investigated in this study: 1) pilot testing of *R. solanacearum*-encapsulated alginate beads for *Hedychium* control, and 2) to determine the optimal application protocols for use by resource managers engaging in kahili ginger biocontrol. Treatments consisted of inoculating mechanically wounded ginger mounds with bacterial encapsulated alginate beads to determine the efficacy of this application method in the field. All mounds treated with this method became infected 6-8 weeks after inoculation. Both rhizome and stem infections were observed. Infections spread within mounds and into the soil as rotting rhizome tissues decayed away. Because of its ease of application, bacterial encapsulated alginate beads provide an alternative method for inoculating this weed in remote areas that are not easily accessible.

Introduction

Hedychium gardnerianum is an aggressive, shade-tolerant alien weed that threatens the long-term stability of invaded native plant communities in Hawaiian ecosystems (Loope and Medeiros, 1994; Smith, 1985). Commonly known as kahili or wild ginger, and native to eastern India (Naik and Panigrahi, 1961), this species has been introduced throughout the tropics and is now invasive in many forest ecosystems (Harris *et al.*, 1996; Cronk and Fuller, 1995; Macdonald *et al.*, 1991). A very aggressive shade-tolerant plant, kahili ginger is able to form dense thickets on undisturbed sites in the understory of open and closed-canopy ohia-lehua (*Metrosideros polymorpha*) rain forests as well as in open areas. It has the ability to form monotypic stands 2 - 2.5 m high under dense canopies of intact rain forests where it displaces native understory vegetation and threatens the survival of some endangered species (Loope and Medeiros, 1994). Kahili ginger reproduces both vegetatively, via its massive rhizome system, and sexually, through the dispersal of seeds, although the first is more common.

The genus *Hedychium* is primarily a Himalayan genus with approximately 50 species; 25 of which grow in the region bordered in the north from Nepal to Burma and to the south by the Indian Ocean. The rest of the genus occurs in Malaysia and Indonesia (Harris *et. al.,* 1996). Kahili ginger is a cold tolerant species of this genus that can be found at elevations up to 2,500 m in its native habitat (Neal, 1965). Unlike the ecosystems in which it invades, kahili ginger is never found as a component of the forest understory in its endemic range (Harris *et. al.,* 1996). Brought to Hawai'i by the horticultural industry, it has escaped cultivation and is now naturalized in the state. This plant was first collected in 1954 at Hawai'i Volcanoes National Park, and populations are now found on all islands between sea level and 1700 m. In addition, kahili ginger has invaded more than 500 ha within the boundaries of Hawai'i Volcanoes and Haleakala National Parks (Smith, 1985).

Previously our lab conducted host-range and field assessment studies of the ginger strain of the bacterium *Ralstonia* (=*Pseudomonas*) *solanacearum* as a possible biological control agent of kahili ginger (Anderson and Gardner, 1999). This bacterium was shown to have significant potential as a biological control agent against *H. gardnerianum* if more effective methods of delivery could be found. Initial results of tests with a spray suspension of bacteria and water (1 x 10^6 CFU/ml) have provided control, but the spray is not practical in remote areas due to the large amount inoculum required (Anderson and Gardner, *in press*). Recent research with alginate beads and powder formulations, have shown that these carriers are an effective delivery method for *Ralstonia* and other rhizobacteria (Mooney *et al.*, 1996). To address this problem and to develop more effective delivery methods for this biological control agent, further testing is needed to determine the efficacy of various application techniques on kahili ginger. Therefore, the objectives of this study were twofold: 1) pilot testing of *R. solanacearum*-encapsulated alginate beads for *Hedychium* control, and 2) to determine the optimal application protocols for use by resource managers engaging in kahili ginger biocontrol.

Methods

Inoculum preparation

An inoculum consisting of a suspension of bacteria and water must be prepared prior to the production of alginate beads. To facilitate the use of this technology by resource managers, the methods of inoculum preparation are designed so that they can be performed outside the laboratory. The inoculum for this study was made by using rhizome tissue of kahili ginger that was previously infected by R. solanacearum (see Anderson and Gardner, 1999). Rotting rhizomes from previously infected ginger mounds were harvested in the field. Once collected, the rotting rhizomes were rinsed with tap water to remove soil, then mashed with a hammer or sliced by a machete into approximately 3 cm^3 pieces. The rhizome pieces were rinsed again, and then mixed with tap water at a rate of 10% (w:v) in 10 L plastic liquid containers. After incubating the suspension for 14 days at prevalent ambient temperatures, a nearly pure R. solanacearum inoculum is produced, with a final concentration of ≈ 1 x 10^9 cfu (colony forming unit)/ml. When the inoculum is plated on TZC agar, numerous creamy-white bacterial colonies typical of R. solanacearum are produced (Kelman, 1954).

Bead preparation
Using the inoculum prepared as above, the bacteria are then encapsulated into alginate beads following a modification of the methods outlined by Bashan (1986). Before processing, a 1% (w:v) sodium alginate solution is prepared with the bacteria suspension. Once mixed, processing the alginate beads is very simple with the use of a peristaltic pump and plastic water bath containers. The inoculum is pumped dropwise into 0.1 M $CaCl_2$ solution, where the beads are formed instantly upon contact with the salt solution. Once the beads are formed, they are held in the $CaCl_2$ solution for 2 hours to harden.

As the bacteria are entrapped in the process of bead formation, most of the initial population is lost. To alleviate this problem and to allow remaining bacteria to multiply inside the beads, the beads were incubated for an additional 48 hours in a fresh inoculum suspension. This process allows the few entrapped bacterial cells to multiply inside the beads to form a massive bacterial population similar to and sometimes more than the beginning population levels. When plated out on TZC agar, numerous bacterial colonies emerge from the beads as the alginate degrades away. The beads averaged 1-3 mm diameter and produced ≈ 1 x 10^9 cfu/10 beads when dissolved in a 0.25 M KPO^{-4} buffer solution.

Field experiments

A study location heavily infested with kahili ginger was selected in open-canopied ohia-lehua forests near the research center in Hawai'i Volcanoes National Park on the island of Hawai'i. Elevation at the study sites was 1200 m, with a mean annual rainfall of 3,300 mm and temperature of 17° C (Santos *et al.*, 1986). Belt transects were established and 15 rhizome mounds falling on this transect were used to evaluate the alginate beads as effective inoculant carriers. The average size of each mound was 1.5 m^2 (rhizome clump diameter). Prior to treatments, all stems were removed and rhizomes are mechanically wounded with a brush cutter. Alginate beads were then spread uniformly over mounds until cut surfaces were covered. Cut stems were then placed back on top of mounds to prevent desiccation of beads and enhance the microclimate for *R. solanacearum* infection. Control mounds were treated similarly, but with alginate beads made from sterile distilled water. Plots were monitored monthly for *R. solanacearum* infection.

Results

No infections were observed in mounds treated with sterile water beads. In the bacterial encapsulated bead treatments, both rhizome and stem infections were observed in all mounds within 6-8 weeks. Following treatment, the number of stems produced on rhizome mounds varied among mounds. Some mounds had no regrowth, while others resprouted similarly to the non-treated controls. Many surviving shoots were much reduced in height and failed to mature or flower. Although resprouts were common on treated mounds, many of them became infected with the bacterium as they became mature. The new shoots usually arise from beneath the mound; however, most of the wounded areas exhibited signs of bacterial infection. Symptoms of shoot infection included interveinal chlorosis, water soaking, and epinasty. Besides epinasty and chlorosis, new shoots also emerged completely infected and necrotic. Rhizome symptoms included water soaking, aggregation of bacterial slime, and decay of infected tissues. Once infected, the diseased rhizomes decay away within 9-12 months and the bacteria are released into the soil. Seedlings germinating near infected mounds were also affected by the bacterium, causing death and stunting. In addition, seedlings of the most dominant tree in the Hawaiian forest, *M. polymorpha* were observed growing in the center of decayed kahili ginger rhizomes.

Discussion

Because of the ability of kahili ginger to invade large tracts of forested areas, application of suitable biological control agents must be practical for success. Of great importance in establishing a biological control program for kahili ginger is the ability to prepare large amounts inoculum in the field. Results from a previous study confirmed that a useful bioherbicide spray can be made using *R. solanacearum*-infected kahili ginger rhizomes and water (Anderson and Gardner, *in press*). By using infected rhizomes from the field as inoculum sources, resource managers can easily make the required amount of inoculum necessary for management of this alien weed. Although we previously achieved satisfactory control with the bacterial spray suspension, this method of application is not practical in remote areas with rough terrain that are not easily accessed. Not surprisingly, this is where most of the infestations of kahili ginger occur.

The bacterial encapsulated alginate beads are the most promising application technique in the biological control of kahili ginger because of their ease in handling in the field and slow consistent release of the bacterium. The encapsulation protects the bacteria from environmental stress, which has been the limiting factor in previous field inoculations of kahili ginger. The beads are easily produced in the lab, and can be packaged and stored in this manner for several months without loss of viability (Bashan, 1986).

Although *R. solanacearum* shows great promise as a potential bioherbicide, kahili ginger is very tough species, and large plants are often able to resist total infection from just a single inoculation. Therefore, follow-up applications are recommended to enhance the spread of the bacterial infection during the first few post-inoculation years. After this time, inoculum levels of the bacterium in the soil should be sufficient to provide adequate control without further management action. The bacterial spray is an effective method for inoculation and is useful in easily accessed forest areas. Bacterial encapsulated alginate beads provide an alternate method of inoculation in remote areas. Covering mounds with treated host debris enhances infection activity by increasing moisture levels near the inoculation sites and is recommended for both methods. A combination of both methods is desirable in easily accessed locations.

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Efforts Toward Biocontrol of Invasive *Rubus* Species in Hawaiian Forests

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From the standpoint of land managers of natural areas, the distinction between native and nonnative species is of primary consideration in determining the desirability or undesirability of plants and animals in Hawaii. Perturbations caused by invasive species are by far the most significant problems faced by mangers of natural areas in Hawaii. Whereas island systems are stable within themselves, they are particularly vulnerable to disruptions caused by introduced species, which among the plants include representatives of all growth forms: vines, lianas, trees, shrubs, grasses and herbaceous species. This is due in part to the abundance of "empty niches" in native systems. Two major examples of this are the lack of native land-dwelling mammals and the absence of gymnosperms in Hawaii's native flora. Because of Hawaii's extreme isolation from continental areas, a notably high degree of endemism is found among the native flora and fauna (Wagner et al., 1990).

Whereas control through mechanical removal and/or chemical herbicides is pursued in Hawaii, biocontrol is looked to as perhaps the only viable alternative to the control of particularly aggressive or widely distributed introduced species. The "classical," as opposed to the "mycoherbicide" approach to biocontrol, is considered more applicable in natural areas, notwithstanding the fact that it does involve the introduction of alien control agents to the native system. In this approach, natural enemies, insects and disease organisms, are sought in the native habitats of the target species. These are tested for host specificity and virulence in their native country, and/or in quarantine in Hawaii, and released under permit if they are shown to be suitable control agents. Hawaii Volcanoes National Park is thought to be the only national park to operate a foreign insect containment facility in support of a biocontrol program directed at conservation, as distinct from agricultural, or horticultural objectives.

As a plant pathologist, I have collaborated with a UDSA Forest Service exploratory entomologist and a plant pathologist, and with a Hawaii Department of Agriculture plant pathologist in a number of biocontrol studies. Other than species of *Rubus* as described below, targets of our biocontrol programs to date have included the shrub *Myrica faya,* introduced to Hawaii from the Azores and Madeira; the passion vine *Passiflora mollissima* from Venezuela, Colombia, and Ecuador; and several members of the family Melastomataceae from tropical America. Invasive grasses in Hawaii have heretofore not been targeted for biological control because of the historical prominence of the sugar cane industry. With the decline of sugar, however, this policy may chance in the future.

The genus *Rubus* includes briars, brambles, blackberries and raspberries. Seven introduced *Rubus* spp. are presently known in Hawaii (Gerrish et al., 1992). At least two of these have proven to be aggressive and capable of disrupting native habitats. Because the islands have no commercial raspberry or blackberry industry, or even significant production of these fruits by homeowners, no opposition to the importation of insect or disease agents for biocontrol is encountered from this standpoint. However, Hawaii does have two endemic species of *Rubus,* one of which is considered a "species of concern." Thus, any biocontrol introductions must be sufficiently host-specific that they will not attack either of these species.

Gymnoconia nitens on *Rubus argutus*

Rubus argutus, formerly known as *R. penetrans* in Hawaii, is known locally by the common name prickly Florida blackberry. Three insect species previously had been introduced for the control of this plant, but have not been entirely effective. A systemic rust fungus, *Gymnoconia nitens*, is known on *R. argutus* in the southeastern U. S. and was selected for testing as a potential biocontrol agent in Hawaii because of its apparent virulence in its native habitat and because it appeared to be limited to this host. Rooted stem cuttings from the Hawaiian population of the blackberry were cultivated in a greenhouse at North Carolina State University, Raleigh, and inoculated with the rust from local, naturally infected populations of *R. argutus*. Positive results led to further testing in the newly completed foreign plant pathogen containment facility of the Hawaii Department of Agriculture in Honolulu.

In an effort to err on the side of caution, test plants were exposed to far higher levels of rust inoculum under quarantine than they would be expected to encounter under natural field conditions. Nevertheless, plants of various *Rubus* spp. in Hawaii responded differently to these high inoculum levels. *Rubus rosifolius, R. ellipticus,* and *R. glaucus* showed no reaction to inoculation, nor did *R. spectabilis* from the Pacific Northwest, which was also tested in quarantine. However, the two native Hawaiian species, *R. hawaiensis* and *R. macraei*, along with *R. argutus,* did show early reaction to inoculation, including a low level of sporulation on *R. macraei.* The indicated sensitivity of the native species to *G. nitens,* albeit under artificial inoculations conditions, made release from quarantine into the field in Hawaii impractical at this time (Gardner et al., 1997).

Phragmidium violaceum on *Rubus argutus*

In view of the reported success of the rust fungus *Phragmidium violaceum* in the control of two introduced species of *Rubus, R. ulmifolius* and *R. constrictus* in Argentina and Chile (Oehrens and González, 1977), and for *R. fruticosus* in Australia (Bruzzese and Hasan, 1986), we made an effort to determine the possible effectiveness of this rust against *R. argutus.* Collaborators in the study included the National Park Service plant pathologist, a USDA Forest Service biocontrol entomologist, and a plant pathologist and an entomologist of INIA, the Chilean agricultural research service. Rooted cuttings of the Hawaiian populations of *R. argutus, R. hawaiensis,* and *R. macraei* were brought to the INIA research facility at Temuco, Chile, where various approaches were used to experimentally inoculate them with locally obtained *P. violaceum.* Whereas similarly inoculated control plants of *R. constrictus* became readily infected, no response to the rust was noted among any of the plants from Hawaii (Norambuena et al., 1992).

Efforts for *Rubus ellipticus*

Rubus ellipticus var. *obcordata*, locally known as yellow Himalayan raspberry, presently is largely restricted to in mid to upper elevation sites on the island of Hawaii. Despite its current limited distribution, it has proven to be aggressively invasive and to pose a serious, widespread threat to native habitats. As the name implies, the species is native to the region of the Himalayas, and also occurs in provinces of southern China, where current biocontrol work is concentrated. As plant pathologist of the Biological Resources Division of the US Geological Survey, I am collaborating with plant pathologists of the Plant Protection Institute, Peoples' Republic of China, in searching for natural enemies of *R. ellipticus* in that country. Only preliminary efforts have been undertaken thus far, including locating sparse populations in the central and southern provinces of Sichuan and Yunnan. Whereas in some sites substantial damage to plants has been found caused by leaf-feeding, tip boring and leaf binding insects, it is likely that some of the insects are general feeders and thus will not prove suitable as biocontrol agents in Hawaii. A nonsystemic rust fungus, tentatively identified as *Hamaspora rubi-sieboldii*, was found at one site, but infection did not appear to cause significant impact on the plant. Insects and pathogens found are to be preliminarily screened for host specificity by the Chinese collaborators on plants from Hawaii established at the Plant Protection Institute in Beijing to determine which species should be sent to quarantine in Hawaii for further study.

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Development of Biological Control Strategy for Management of Forest Weeds in Canada

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Abstract

Biological control strategy for management of competing forest vegetation "forest weeds" is poised to become an established component of forest management. The potential use of plant pathogens, mainly fungi, are presently considered the most promising biological control agents. Development of alternatives to chemical pesticides has become important in forest management plans due to economic constraints, non-target effects, and increasing public concerns about the environment. Biological control strategies which utilizes microbial organisms or their secondary metabolites to control major reforestation weeds have shown promise. In the conifer regeneration sites, biological control agents need to be sufficiently virulent to mitigate the aggressiveness of forest weeds for their competition with young conifer seedlings for light, nutrients, and physical space. In British Columbia (BC), Canada, a special research program on development of biological control agents for management of forest weeds and diseases was established at the Canadian Forest Service-Pacific Forestry Centre (CFS-PFC) in 1986. Among the target weeds considered were: hardwood weed species such as *(Acer macrophyllum*), (*Alnus rubra*), and (*Populus* spp.). In the boreal forests a grass species *Calamagrostis canadensis*, and in the coastal and interior BC , salal (*Gaultheria shallon*) and *Rubus* spp., respectively. Most recently, a new research project was initiated on microbial biological control of dwarf mistletoes (*Arceuthobium* spp.). Plant pathogens, mainly fungi, from these weeds and disease were isolated, identified and tested for their potential use as biological control agents. To date, scientists at the CFS- PFC, Victoria, and Northern Forestry Centre at Edmonton, Alberta, have successfully obtained five U.S. patents on different biological control pathosystems. These includes biological control of *C. canadensis* with *Colletotrichum* and *Fusarium* species and a low temperature basidiomycete (snow mold), biocontrol of *A. rubra* with *Nectria ditissima*, biological control of hardwood weed species with *C. purpureum,* and biological control of invasive weedy *Rubus* spp. with *Fusarium avenaceum*. The collaborative research agreement between CFS- PFC and MycoLogic Inc.- University of Victoria is directed to obtaining registration and commercialization of the formulated product of *C. purpureum* under the proposed name "Chontrol™" for biocontrol of hardwood weed species in conifer regeneration sites and utility rights-of-way. This success model may set a precedence for the development of future biological control agents for major reforestation weeds and forest diseases.

Keywords: *Chondrostereum purpureum*, *Fusarium avenaceum*, *Arceuthobium* spp., *Valdensinia heterodoxa* , *Colletotrichum gloeosporioides*, *Nectria neomacrospora*, competing forest vegetation, *Gaultheria shallon, Rubus*

Introduction

The demand for increased forest production and sustainability have increased the intensity of forest management and the importance of vegetation competing with young conifers (Shamoun, 1999). Control of competing vegetation can take many forms, including removal by mechanical or manual brushing and chemical herbicides (Wall *et al.* 1992). These methods have distinct disadvantages such as environmental concern, non-target effects, and cost-effectiveness. This has necessitated a more intensive search for alternative management strategies for invasive forest weeds that are cost effective, efficacious, environmentally safe and sustainable (Jobidon 1991, Watson and Wall 1995).

The idea of using plant pathogens for management of weeds is not new. However, the concept of the development of a bioherbicide/mycoherbicide technology as a specialized field of study is very young. The use of a biological control strategy in natural ecosystems entails the enhancement of naturally occurring plant pathogens, thus quickening the decline of competing vegetation through the manipulation of these pathogens. The expected result should be an increase in early conifer growth rate and a shorter rotation age of commercially valuable crop trees (Wall and Hasan 1996).

As in other ecosystems, three major biological control strategies are being used with respect to management of competing forest vegetation: classical, inundative (bioherbicde or mycoherbicide), and augmentative (silvicultural manipulation). The classical biocontrol strategy has been used to control exotic forest weeds. The inundative strategy using indigenous plant pathogens is one of the more promising approaches for management of native forest weeds. The augmentative strategy of forest stands has been promoted by sound research based on knowledge of the biology of plant pathogens, autecology of the target weeds and the ecology of forest ecosystems (Wall 1984, Wall *et al*. 1992). Markin and Gardner (1993) and Wall and Hasan (1996) and have reviewed in detail numerous examples of forest weed biocontrol initiatives worldwide.

A focused program on development of biological control agents for forest weeds was established at the Canadian Forestry Service-Pacific Forestry Centre (CFS-PFC) in 1986 (Dorworth 1990). Among the target weeds considered were *Acer macrophyllum* Pursh, *Alnus rubra* Bong., *Calamagrostis canadensis* (Michx.) Beauv., *Epilobium angustifolium* L., *Gaultheria shallon* Pursh, *Populus tremuloides* Michx., and *Rubus* spp., including wild red raspberry [*Rubus strigosus* Michx. = *R. idaeus* var. *strigosus* (Michx.) Focke], thimbleberry (*R. parviflorus* Nutt.), and salmonberry (*R. spectabilis* Pursh). Plant pathogens from these weeds have been isolated, identified and tested for their potential use as biological control agents (Dorworth 1990, Wall and Shamoun 1990, Oleskevich *et al.* 1998). To date, researchers at CFS-PFC and Northern Forestry Centre- Edmonton, have successfully secured five U.S. patents on different biological control pathosystems, including biological control of *C. canadensis* with *Colletotrichum* sp. and *Fusarium* sp., and by using snow mold (Winder 1995, Mallet 1999), control of *A. rubra* with *Nectria ditissima* Tul. (Dorworth 1994), biological control of weed trees with *C. purpureum* (Wall *et al.* 1996) and biological control of weedy *Rubus* spp. with *Fusarium avenaceum* (Shamoun and Oleskevich 1999).

The use of *Chondrostereum purpureum* has been tested on hardwood weed species and efforts are directed towards commercialization of the formulated product of *C. purpureum* under the trade name "Chontrol™", according to an agreement between CFS-PFC and MycoLogic Inc., University of Victoria, British Columbia (BC), Canada (Shamoun and Hintz 1998a).

The feasibility of using *Fusarium avenaceum*, for control of weedy *Rubus* spp., *Valdensinia heterodoxa* Peyronel for salal (*Gaultheria shallon*), and snow mold for marsh reed grass (*C. canadensis*) have shown promise as inundative biological control agents. Further research is underway for their development as mycoherbicides (Shamoun and Oleskevich 1999, Shamoun *et al.* 2000, Mallett *et al.* 2000). Research efforts are underway to elucidate the interaction of various endophytic fungi with *Alnus* spp. and *Rubus* spp., and to assess their potential use as mycoherbicides (Sieber *et al.* 1991, Shamoun and Sieber 1993, Shamoun and Sieber 2000).

At CFS- PFC, a new research project on biological control of dwarf mistletoes was initiated. To date, several fungal parasites associated with dwarf mistletoes (*Arceuthobium* spp.) have shown promise as potential biological control agents, including *Colletotrichum gloeosporioides* rapidly destroys shoots and berries within a mistletoe infection. Also, *Nectria neomacrospora* substantially reduces mistletoe shoot and seed production (Shamoun and DeWald 2000). A new management tool for control of dwarf mistletoe is necessary as the change in forestry practice in British Columbia has led to a reduction in the size of the blocks that are harvested and a move to partial harvesting systems. These operations increase the ratio of trees remaining around the edge of cut areas to seedlings developing in the cut areas, thus enhancing mistletoe spread and damage. It is not necessary to treat the entire stand, as control can be achieved with a mix of pathogens sprayed on affected border and within stand trees in a young conifer plantations (Shamoun 1998).

The objective of this article is to illustrate two case studies: 1) *C. purpureum* as a potential biological control for *A. rubra* in conifer regeneration and utility rights-of-way sites, and 2) *F. avenaceum* as a potential control agent for invasive *Rubus* spp. in conifer regeneration and riparian sites.

Case study I: Biological control of hardwood weeds with *C. purpureum* :

Traditionally, periodic manual brushing of competing hardwood weed species or spraying with chemical herbicides in conifer regeneration sites and within rights-of-way (ROW) has been used. These approaches have serious disadvantages, including high labour requirements, resprouting from cut stumps, and concerns over soil and water contamination. Recently, biological control of invasive hardwood trees using the fungus *C. purpureum* to suppress regrowth has been suggested (Scheepens and Hoogerbrugge 1989, Wall 1994, Shamoun *et al.* 1996, Dumas *et al.* 1997). This strategy could considerably increase intervals between repeat cutting operations in conifer regeneration sites and ROW, particularly if sufficient effectiveness is attained and automation of simultaneous brushing and stump treatment operations was developed. A biological control strategy using *C. purpureum* would have a low likelihood of soil or water contamination and minimal risk to non-target plant species (de Jong *et al.* 1996, Ramsfield *et al.* 1996, Shamoun and Wall 1996)

A research program was established to develop and register *C. purpureum* as the first mycoherbicide for use in Canadian forests as an essential component of an integrated forest vegetation management in conifer reforestation sites and utility ROW (Shamoun and Hintz 1998a).

Case study II: Biological control of invasive weedy *Rubus* spp. with *Fusarium avenaceum*:

Biological control strategies that utilize microbial control organisms or their secondary metabolites are receiving greater consideration for use within conifer regeneration sites. A research project focusing on the biological control of *Rubus* spp. using indigenous fungi has been established. Three *Rubus* spp., wild raspberry, thimbleberry and salmonberry are being targeted due to their capacity to rapidly invade reforestation sites, effectively reducing the growth and survival of many conifer species in Canada and the northern United States (Oleskevich *et al.* 1996). The study has thus far assessed fungi associated with *Rubus* stem and leaf diseases and selected a candidate pathogen, *F. avenaceum*. The biological control strategy utilizes inundative levels of fungal inoculum applied as a foliar spray to incite leaf damage and to temporarily suppress *Rubus* growth. Inoculum production methods, amendment of inocula with adjuvants, and co-application with low doses of glyphosate have been investigated to increase fungal pathogenicity (Abbas *et al.* 1995, Oleskevich *et al.* 1998).

Materials and Methods

Case study I: Biological control of hardwood weeds with *C. purpureum*:

The site for this field experiment was established under a utility ROW near Duncan, BC (48°49'N, 123°50'W) encompassing healthy red alder (*A. rubra*) of 5-10 cm diameter, in September 1994. Within a randomized block design containing 30 plots, six treatments were compared: two fungal formulations (*C. purpureum* isolates PFC 2139, PFC 2140), a control formulation treatment, two chemical treatments (12% Vision® spray and a carbopaste formulation of Vision®), and manual cutting (slash). Alder trees were cut with a brushing chain saw and the appropriate treatment was applied manually to the cut wood surface. *Chondrostereum purpureum* was grown on nutrient base, formulated, and dried in the laboratory, and subsequently resuspended and applied as a paste to cut stumps (Wall et al. 1996). During the following two growing seasons, data collected included occurrence of resprouting from stumps, the number of living sprouts per stump, and stump mortality based on the presence and absence of living sprouts. The presence of fruiting bodies of *C. purpureum* and other basidiomycetes on treated stumps was assessed 18 month post-treatment.

Case study II: Biological control of invasive weedy *Rubus* spp. with *Fusarium avenaceum*:

Fusarium avenaceum was collected and purified from diseased foliage and stems of wild raspberry from central (49° to 54° latitude) and coastal British Columbia, between May to September, 1990-1994. *F. avenaceum* caused foliar damage in pathogenicity tests on detached *Rubus* leaves. Inundative applications of conidial inoculum were made to *Rubus* plants in shadehouse trials. Plants were rated for up to 3 wk after inoculation and compared to control plants, and experiments were repeated. In efforts to enhance pathogenicity, amendments to *F. avenaceum* inoculum included nutrients (sucrose, neopeptone, malt, sodium alginate), humectants (starch, psyllium hydrophilic muciloid), dispersants (Tween 80, wetting agents), stickers/surfactants (Silwet L-77®- Loveland Industries, Greeley, CO, USA), and formulation into an invert emulsion. The strategy of combining *F. avenaceum* with low doses of glyphosate (RoundUp® - Monsanto Canada, Sardis, BC, Canada) to increase host susceptibility was assayed, after determining the effect of the herbicide on fungal growth and germination. The presence of phytotoxins produced by *F. avenaceum* grown in a rice medium was also investigated (Oleskevich *et al.* 1998).

Results and Discussion

Case study I: Biological control of hardwood weeds with *C. purpureum*:

Re-sprouting of cut alder stumps occurred throughout the six treatments by spring 1995, reaching a maximum height of 50 cm among resprouts within the slash treatment. Re-sprout mortality occurred on many stumps by mid-summer, resulting in 65-100% mortality (Table 1). Alder stumps treated with *C. purpureum* and with herbicides showed significantly less living sprouts than other treatments, with a mean of less than 1 living resprout per stump. Analysis of first year data by planned contrasts revealed that *C. purpureum* and herbicide treatments resulted in similar levels of stump mortality and resprouting of alder, and were statistically different from the formulation control and slash treatments. Both fungal treatments gave similar results. At 2 yr post-treatment (1996), > 95% stump mortality was recorded on stumps treated with fungal and herbicide treatments, with PFC 2139 and Vision® reaching 100% mortality. In comparison with 1995, all treatment plots had less resprouting and higher stump mortality. Analysis of 1996 data the trend showed a trend similar to 1995, that the overall *C. purpureum* treatments were not significantly different from herbicides but were different from the formulation controls and slash treatment.

Table 1. Mortality and number of living sprouts on cut stumps of red alder treated with *Chondrostereum purpureum* or chemical herbicides.

Treatment	1995		1996	
	Mortality (%)	Living sprouts (no. per stump)	Mortality (%)	Living sprouts (no. per stump)
Slash control	65.00b	4.45a	86.00ab	1.18a
Formulation control	70.00b	3.49a	72.00 b	0.37b
PFC 2140	83.00ab	0.95ab	96.00a	0.02b
PFC 2139	92.00a	0.45b	100.00a	0.00b
Vision® (spray)	97.00a	0.35b	99.00a	0.01b
Vision® (Carbopaste)	100.00a	0.01b	100.00a	0.00b

Treatments with the same letter are not significantly different ($P \leq 0.05$; Duncan's multiple range test).

Fruiting bodies of *C. purpureum* were observed about 18 mo after *C. purpureum* inoculation of red alder stumps. The peak of *C. purpureum* fruiting bodies was found in spring 1996, on 66% and 84% of the stumps treated with PFC 2139 and PFC 2140 respectively, on about 19% of stumps treated with herbicides, and on 43% of stumps which had received the formulation control and slash treatment (Table 2). Fruiting bodies of *Trametes* (*Coriolus)* *versicolor* (L.:Fr.) Pil. and *Schizophyllum commune* Fr. and other basidiomycetes were observed on many stumps in all treatment plots.

Table 2. Occurrence (percentage) of fruiting bodies of basidiomycetes on red alder stumps.

Treatment	*Chondrostereum purpureum*	*Schizophyllum commune*	*Coriolus versicolor*	Others
Slash control	42	19	28	37
Formulation control	43	17	13	21
PFC 2140	84	15	9	11
PFC 2139	66	13	18	19
Vision® (spray)	15	3	6	11
Vision® (Carbopaste)	23	13	4	8

Results of these tests, and similar large scale field trials conducted in the conifer reforestation sites of BC interior (Harper *et al.* 1998), Ontario (Dumas *et al.* 1997) and in the Netherlands (de Jong *et al.* 1990), indicate that *C. purpureum* is quite effective as a biological control agent of stump sprouting of alder, aspen and American black cherry, respectively.

Case study II: Biological control of invasive weedy *Rubus* spp. with *Fusarium avenaceum:*

A formulation of *F. avenaceum* was developed by growing the fungus on rice grain (Abbas *et al.* 1995), and subsequent inoculum combined with an organosilicone surfactant at a concentration 0.4% Silwet L-77®, enhanced greater foliar damage than other formulations (data not shown). Extensive foliar necrosis occurred with this formulation within 24-48 h on wild *R. strigosus* and *R. parviflorus* , resulting in large areas of necrotic leaf tissue, leaf curl and death. *Rubus strigosus* was the most susceptible to the formulated spray, followed by *R. parviflorus* and *R. spectabilis*, respectively. Analysis of variance showed significant differences between *F. avenaceum* and Silwet L-77® treatment and all other treatments for *R. strigosus* ($F=61.39$, $P<0.001$), *R. parviflorus* ($F=38.43$, $P<0.001$) and *R. spectabilis* plants ($F=12.39$, $P<0.001$) (Table 3). All treated *Rubus* spp. flushed new leaves by 3 weeks, and the new foliage and stems were free of damage symptoms. A preliminary host- range study showed no effects on major conifer species when sprayed with *F. avenaceum* and Silwet L-77®. . The incorporation of low- doses of glyphosate was not further pursued, as the combined action of *F. avenaceum* with glyphosate did not exceed that of glyphosate alone (data not shown). Phytotoxin extraction and analysis of *F. avenaceum*- infested rice filtrates revealed a single toxin, moniliformin at levels of 3,300 p.p.m. (Oleskevich *et al.* 1998). The enhancement of foliar necrosis by the combined action of *F. avenaceum* and Silwet L-77® may have been achieved by stomatal egress and through the maximum uptake of *Rubus* plants of the phytotoxin, moniliformin (Stevens 1993, Shamoun and Oleskevich 1999). Similar results were demonstrated on *Ascochyta pteridis* Bers. for biocontrol of bracken [*Pteridium aquilinium* (L.) Kuhn.] (Womack and Burge 1983), and most recently, by using *F. avenaceum* for biocontrol of *C. canadensis* (Winder 1999). The biorational strategy for management of weedy *Rubus* spp. and other agricultural weeds is a promising approach (Abbas *et al.* 1991, Jobidon 1991). Ongoing research is underway to screen other phytotoxins associated with *F. avenaceum* isolates collected from *Rubus* spp. by using biochemical and tissue culture techniques (Hollmann *et al.* 1999). Based on the research results by Oleskevich *et al.* (1998) and Shamoun and Oleskevich (1999), ongoing research activities are being focused on using biorational applications of the formulated *F. avenaceum* on invasive weedy *Rubus* spp. in conifer and riparian regeneration sites.

Table 3. Foliar necrosis of *Rubus* plants resulting from inundative applications of *Fusarium avenaceum* inoculum, originating from infested rice cultures, and combined with an organosilicone surfactant (Silwet L-77®), means + SEM.

Treatment	Foliar injury*		
	Rubus strigosus	*Rubus parviflorus*	*Rubus spectabilis*
control-water	0.44 ± 0.18d	0.20 ± 0.13c	0.20 ± 0.13b
surfactant (Silwet L-77®)	1.89 ± 0.26b	2.17 ± 0.31b	0.67 ± 0.21b
F. avenaceum	1.33 ± 0.17c	1.38 ± 0.38b	0.75 ± 0.25b
F. avenaceum + surfactant	3.89 ± 0.11a	3.31 ± 0.18a	2.00 ± 0.26a

*Foliar injury rating index with <2 = slight injury, 2-3.5 = moderate injury, and >3.5 = severe injury. Within a column, values followed by the same letter are not significantly different ($P = 0.05$; Student-Newman-Keuls test).

Conclusions and General Prospects

Biological control strategy for management of competing vegetation is poised to become an essential component of forest management practices. Plant pathogenic fungi are presently considered the most promising biological control agents. Research and development on this subject was a result of public pressure and demand for alternative management strategies that are cost-effective, environmentally safe and sustainable (Wagner 1993).

Recent advances in formulation technology, phytopathology, molecular biology and silviculture have accelerated the commercialization and production of three biological control products for management of invasive and competing forest vegetation in South Africa, The Netherlands and Canada, respectively (STUMPOUT® , BioChon™ and CHONTROL™) (Morris *et al.* 1998, Ravensberg 1998, Shamoun and Hintz, 1998a, 1998b).

Development of bioherbicide/mycoherbicide is more promising strategy for management of indigenous forest weeds. The augmentative biological control has special relevance for forestry and therefore could be termed as "silvicultural manipulation" strategy which can be promoted by sound research programs based on ecology of forest ecosystems, biology of plant pathogens and autecology of target weeds. Biological control agents will likely provide alternatives to some chemical herbicides and other unpractical vegetation management tools.

The enhancement of the effectiveness and safe use of biological control agents can be achieved by integrating them with manual brushing practices, such as application of Control™ or STUMPOUT® on cut stump of hardwood weeds, or combining foliar pathogens such as *Fusarium avenaceum* with adjuvants/surfactants or low-doses of registered herbicides for foliar applications onto target weeds.

The main concern to both regulatory authorities and to the public in general, in using fungal pathogens for control of forest weeds, is their potential threat to non-target plants. This is especially relevant to classical biological control strategy, where exotic pathogens are introduced into new ecosystems. In contrast, risk analysis of indigenous fungal pathogens used as mycoherbicides (e.g. *C. purpureum*) is extremely low, according to the investigations by de Jong et al. (1990). Recently, results based on advanced epidemiological modeling systems and molecular analyses and monitoring (e.g. PCR-DNA technology: RAPD, RFLPs, rDNA and mtDNA) studies, have revealed the safe use of native fungal pathogens (de Jong *et al.*1996, Becker *et al.* 1999, Gosselin *et al.* 1999, Ramsfield *et al.* 1996 Ramsfield *et al.* 1999). In contrast, most of the plant pathogens that have caused serious losses to forest tree species in the new world were introduced accidentally in forest products and nursery stocks, such as Dutch elm disease, chestnut blight, and white pine blister rust disease (Manion, 1981), and not through using native plant pathogens via planned biological control programs (Cook *et al.* 1996).

The potential use of biotechnological techniques to enhance the efficacy of biological control agents is very promising strategy for development of bioherbicides (Watson and Wall 1995). From a practical, sociological, economical and ecological viewpoint, bioherbicide technology should be viewed as an essential component of an integrated forest vegetation management that will be employed in combination with manual brushing, mechanical removal, adjuvants/surfactants, plant growth regulators, and reduced doses of chemical herbicides. Current research on forest weed biocontrol should yield several improvements in forest management, including new commercial products and more widely acceptable approaches to forest management.

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PANEL: EXOTICS- NATIONAL POLICY
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The Development of the Executive Order 13112 on Invasive Species and National Implications to the Forest Service

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Introduction-The Problem

Many non-indigenous species have beneficial effects, including many of our food crop and livestock, pets, horticultural plants, and biological control agents brought in from other countries to effectively control other harmful organisms. On the other hand, many exotic species causesignificant adverse effects, both biologically and economically. It is estimated that invasive species have a $137 billion impact in the United States (Figure 1) (Pimentel et al. 2000). For example; exotic and non-indigenous weeds cause an estimated $7.4 billion in agricultural losses annually. Noxious and exotic weeds pose a significant threat throughout the United States, and if the situation continues, significant losses in biological diversity and agricultural production will occur. On National Forest System lands, the current inventory of noxious weeds is 3.6 million acres. It is estimated that noxious and exotic weeds are expanding at 4,600 acres per day in the western United States**.** During FY 1999, funding was available to treat approximately 110,000 acres. Some accidentally introduced insects and pathogens have caused extensive damage to the forests and urban trees of the United States (e.g. Chestnut blight fungus - *Cryphonectria parasitica* , Dutch elm disease fungus - *Ophiostoma ulmi* , white pine blister rust fungus – *Cronartium ribicola*, European gypsy moth – *Lymantria dispar*, balsam woolly agelgid – *Adelges picea*, Hemlock woolly adelgid – *Adelges tsugae*, and Asian longhorned beetle – *Anoplophora glabripennis*). Economic losses to non-indigenous forest pests are estimated to be $4.2 billion per year (Pimentel et al. 2000) from reduced timber yields or prices and increased control and management costs. Ecological impacts of non-indigenous forest pests include: tree species conversions, wildlife habitat destruction, degradation of riparian communities, increased fuel loading, increased damage from native pests, and loss in biodiversity. The risks of accidental introductions of non-indigenous species continue to grow with increased world trade and travel.

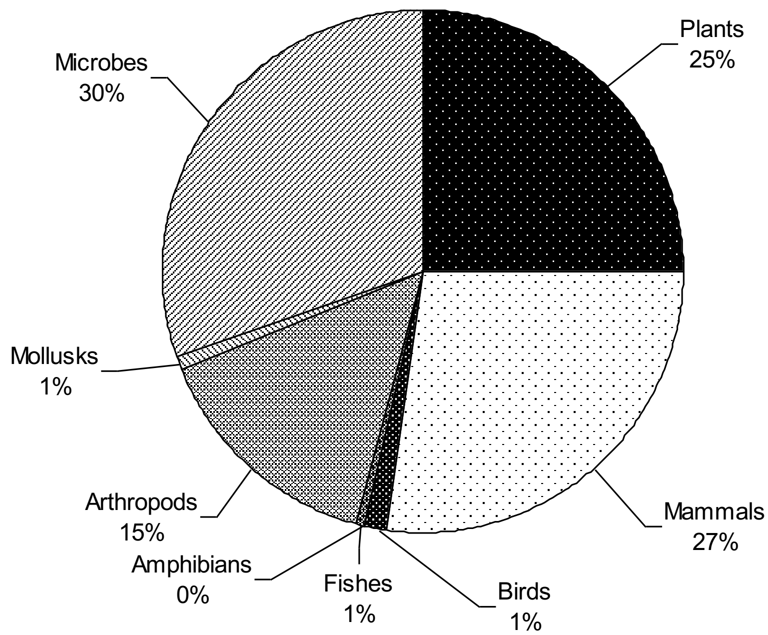

Figure 1. Estimated Annual Costs Associated with some Non-Indigenous Species Introductions Into the U.S. Total annual cost is $137 Billion (Pimental et al 2000).

In September 1993, the Office of Technology Assessment (OTA) published the report "Harmful Non-Indigenous Species in the United States." (OTA 1993). This report had been requested by Congress in 1991 due to the alarming increase in infestations of noxious and non-indigenous species. The report included assessments of the impacts of non-indigenous plants, terrestrial vertebrates, insects, fish, aquatic invertebrates and plant pathogens as well as analyses of technological and policy issues and options. As a result of the OTA report, both the Deputy Secretary of Interior and Deputy Secretary of Agriculture became actively involved in addressing the invasive species issue in the United States. In May 1994, a Memorandum of Understanding was signed by 16 Agencies from within 5 Cabinet level Departments establishing the Federal Interagency Committee for the Management of Noxious and Exotic Weeds (FICMNEW). The membership, by Department, is as follows: Bureau of Land Management, USDI; Forest Service, USDA; National Park Service, USDI; Fish and Wildlife Service, USDI; Bureau of Reclamation, USDI; Animal and Health Inspection Service, USDA; Agriculture Research Service, USDA; Natural Resource Conservation Service, USDA; Agricultural Marketing Service, USDA; Agricultural Stabilization and Conservation Service, USDA; Environmental Security, DoD;Federal Highway Administration, DoT; Environment and Health, DoE; and Cooperative State Research, Education and Extension Service, USDA. Another MOU was signed at a later date to bring the Environmental Protection Agency within FICMNEW.

The purpose of FICMNEW

1. FICMNEW will work cooperatively to accomplish an ecological and integrated approach to the management of noxious and exotic weeds on Federal lands and provide technical assistance on private lands.

2. Federal Agencies propose to work together within the scope of their perspective authorities toward a common goal of achieving sustainable, healthy ecosystems that meet the needs of society.

3. Additionally, all Federal Agencies desire to achieve the advance of knowledge and skills, good land stewardship practices and public awareness of noxious weed issues.

FICMNEW currently has two co-chairpersons represented by a representative from the Fish and Wildlife and the National Park Service. Annually, the Interagency Committee briefs the appropriate Secretary of the five participating Departments and Congress.

Due to the increased interest in noxious and exotic weeds, both the Departments of Interior and Agriculture orchestrated two weed summits in the United States to discuss the significance of noxious weeds in the east and west. The first was held in Denver, Colorado and Deputy Secretary Garamendi for the Department of Interior and Governor Romer gave keynote addresses. Approximately 140 individuals from various agencies, both state and federal organizations and environmental groups participated. The second summit was held in Ft. Lauderdale, Florida. Deputy Secretary Rominger from the Department of Agriculture and Lt. Governor Buddy presented the keynote addresses. The outcome of the two summits was a clear need for a national strategic plan to guide all agencies and organizations, regardless of boundaries, on how to best to address this national problem.

A third summit was held in Albuquerque, New Mexico with an objective of obtaining input from all interested organizations and Agencies and to develop the outline for a National Strategy for Invasive Plants. FICMNEW then took all the comments and started drafting the National Strategy. The "Pulling Together National Strategy for Invasive Plant Management" was released with over 101 signatory partners agreeing to a single national strategy for the United States.

During the same timeframe as the three weed summits, Deputy Secretary Rominger requested that each Agency within USDA (i.e. Agricultural Marketing Service, Agricultural Research Service, Animal and Plant Health Inspection Service, Cooperative State Research, Education and Extension Service, Forest Service and Natural Resource

Conservation Service) develop an Agency Strategy on dealing with noxious weeds within each Agency's authorities. The Forest Service assembled an interdisciplinary team from staffs from the National Forest System, Research and State and Private Forestry. The Forest Service Noxious Weed Strategy was finalized in February, 1996. All seven Agency strategies were then consolidated within the USDA Noxious Weed Strategy, which was approved in April, 1996.

The purpose of the Forest Service Noxious Weed Strategy is to: 1) Increase the understanding and awareness of noxious weeds and the role they play in wildland ecosystems; 2) Develop a consistent approach to noxious weed issues within the Forest Service; and 3) Institutionalize consideration of noxious weed issues as a high priority in all Forest Service Activities, such that it is "a way of doing business."

The FS Noxious Weed Strategy is focused in five areas. They are: Prevention and Education; Control; Inventory, Mapping and Monitoring; Research; and Administration and Planning. A detailed action plan is being developed and implementation priorities are being identified once funding becomes available. Extensive Congressional outreach is occurring to increase the awareness of the problem and the solutions necessary to solve the noxious weed issue within the Forest Service.

To develop alternative funding sources, the Forest Service, in partnership with other Agencies and the National Fish and Wildlife Foundation, created the "Pulling Together Partnership", which is a matching grant proposal program to fund projects involving local partnerships with other Agencies and operators. In the first year of the program, 1996, $500,000 of Federal money was matched by $1 million in matching funds from other partners. Additional funds have been allocated by other Federal Agencies, and additional funds are being sought to increase the Federal share for future projects.

Within the Forest Service, the Range Management Staff with National Forest Systems has the leadership role in the noxious weed program. In Fiscal Year 2000, Range Management allocated $8 million to the Region's for noxious weed control programs, as compared to $5 million in FY 1999. Forest Health Protection (FHP) within State and Private Forestry and Forest Insect and Vegetation Management and Protection Research (VMPR) work closely in partnership with Range. In FY 1997 through FY 2000, FHP and VMPR collaboratively funded $400,000 for Special Technology Development Programs to fund research in exotic pests. Part of the funds were used for the development of biological control agents for noxious weeds. The cooperative effort is anticipated to continue in the future. In FY 1999, VMPR funded $1.2 million for weed research, and FHP funded $300,000 for the exotic weed program in Hawaii and $255,000 to develop human health and safety risk assessments and background statements for herbicide programs which are utilized in the noxious weed control program. FHP also allocates funds to the Region's to provide technical assistance in the noxious weed program and herbicide program, in addition to FHP's core focus areas.

Funding has been provided by FHP to Hawaii by authority of the Hawaii Tropical Forest Recovery Act of 1992 to control exotic plants, but currently does not have the authority to use funds for weed control elsewhere in the continental US. The exotic plant situation in Hawaii is unique, in that native vegetation is changing at an alarming rate. Prior to settlement, Hawaii had about 1,094 native plants. In the following years, Hawaii has been invaded by numerous non-native plants, and the invasion continues as evidenced by the recent introduction of Miconia. About 869 new non-native invasive species or subspecies are now established in Hawaii. At the same time, at least 107 native plants have been forced to extinction. These non-native invasive, aggressive weed species can drastically alter native ecosystems, resulting in changes in biodiversity, forest productivity, watersheds and opportunities of ecotourism.

Hawaii has taken a very aggressive approach in attempting to deal with exotic species. Operation Miconia is a prime example in an eradication attempt while the problem is relatively small. *Miconia calvescens* is native to South America and was introduced in Tahiti in the early 1900's. It now has occupied 70 percent of Tahiti's native forests. Miconia was detected in Hawaii about 25 years ago, and still remains relatively small in acreage. To effectively deal with the situation, the Coordinating Group on Alien Pest Species (CGAPS) was formed. This is a partnership of Hawaii Department of Land and Natural Resources, Hawaii Department of Transportation, Hawaii Farm Bureau, Hawaii Visitors Bureau, National Park Service, The Nature Conservancy of Hawaii, U.S. Customs Service, U.S. Department of Agriculture, U.S. Fish and Wildlife Service, U.S. Navy, U.S. Postal Inspection Service, and the U.S. Postal Service. CGAPS is a multi-agency partnership to coordinate more effective protection for Hawaii's economy, environment, health, and way of life from alien pests. In 1996, the Governor of Hawaii and the Deputy Secretary of Agriculture announced Operation Miconia and released the "Silent Invasion" which effectively identifies the non-native invasive species problem in Hawaii and the necessary steps to control the problem. "Silent Invasion" very effectively increased public awareness as to the magnitude of the problem in Hawaii. The efforts of CGAPS is an excellent examples of the effectiveness in dealing with problems through partnerships.

In 1997, 527 concerned scientists and individuals sent Vice President Al Gore a letter expressing their concern on non-native invasive species in the United States and the lack of a coordinated effort on behalf of the Federal Government to effectively deal with this issue. In June, 1997, Vice President Al Gore requested the Secretaries of Agriculture, Interior and Commerce to work closely with the Council on Environmental Quality and the Office of Science, Technology and Policy to craft a new cross-departmental strategy on non-native invasive species. As a result of the Vice Presidents request, the Ad Hoc Task Force for Alien Invasive Species was established with representation from each appropriate Agency within the three Departments. The Vice President requested that the Task Force develop an Administration strategy on non-native invasive species that would include creative partnerships for leveraging dollars for dealing with this important issue.

The Task Force prepared a “draft” Administration strategy that identified the short and long-term actions that the Administration can take to deal with non-native invasive species.

At the request of the Administration, the "draft" Strategy was put aside so that outside partners could be brought into the development of a National Management. The Administration requested several actions to occur. One action was to issue a Presidential Executive Order, which took over a year to develop. The President signed Executive Order 13112, titled "Invasive Species," on February 3, 1999. Invasive species are defined in the EO as those organisms that are both non-native (alien) to the ecosystem under consideration and whose introduction causes or is likely to cause economic or environmental harm or harm to human health. The EO established a National Council on Invasive Species that is co-chaired by the Sec. of Interior, Sec. of Agriculture, and Sec. of Commerce and includes Secretaries of State, Treasury, Defense, Transportation, and the Administrator of the Environmental Protection Agency. The National Council is directed by the EO to insure that federal activities concerning invasive species are coordinated, complimentary, cost-efficient, effective, and rely on existing organizations. The EO also directed the National Council to prepare and issue a National Invasive Species Management Plan within 18 months.

The National Council on Invasive Species has recently selected Executive Director, Ms. Lori Williams. As required by the EO, an Advisory Committee was established with a total membership of 42 individuals from across the United States representing various stakeholder groups. To assist in the development of a National Management Plan, six Working Groups were established, with each Group co-chaired by a Federal and non-Federal member. The National Council has issued a Draft Invasive Species Management Plan for public comment in October, 2000.

In November, 1998 the Ecosystem Sustainability Corporate Team (ESCT) of the Forest Service established the Invasive Species Issue Team, one of five Issue Teams. The Charter of the Team is to develop a short-term and long-term Action Plan as to how the Agency can effectively deal with the invasive species issue. The Team has also drafted an assessment of the invasive species issue within the Forest Service.

The Forest Health Protection (FHP) Staff recently completed a new Action Strategy for invasive insects and pathogens to enable the Agency to implement the EO. This Action Strategy sets forth a Program Goal for FHP to reduce the adverse social, economic, and ecological effects of non-native invasive species of forest insects and pathogens on forests and trees. Specific Objectives and Actions are presented for exclusion and prevention of introductions of invasive insects and pathogens, early detection of new introductions, management or control of established populations, inventory and monitoring, restoration or recovery of damaged ecosystems, and communication.

The Forest Health Protection Staff is currently preparing an Action Strategy for Invasive Plants, which may expand the FHP role in the invasive plant program in the United States.

A Memorandum of Understanding is currently being reviewed for the establishment of an Interagency Committee on Invasive Insects, Diseases and Animals. The intent is to establish an Interagency Committee amongst thirteen Federal Agencies to coordinate insects, diseases and animal activities similar to how FICMNEW coordinates invasive plant activities.

Conclusions

Since the release of the 1993 Office of Technology Assessment Report "Harmful Non-Indigenous Species in the United States", a considerable number of activities have occurred to more adequately address the non-native invasive species issues have been summarized in this discussion. The momentum that has developed as a result of the OTA report needs to maintained and increased if we are to adequately control the invasive species problem in the United States.

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PANEL: EXOTIC ROOT DISEASES

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Traditional, morphologically-based species concepts in fungi have tended to go hand-in-hand with a perception that fungal species are 'genetically-watertight' units between which almost no gene-flow occurs. Indeed, prior to 1990, examples of interspecific hybridisation in fungi were rare (only about six examples). However, observations on the reproductive (breeding barriers) between the internationally migrant Dutch elm disease pathogens (*Ophiostoma ulmi* and *O. novo-ulmi*), led the author to suspect that episodes of intense ecological disturbance ('episodic selection') involving pathogens, such as introduction events, were resulting in hybridisation between fungi. Since hybridisation could lead to altered pathogenicity, it could be of particular significance for the health of forests and natural ecosystems.

A theoretical model for hybridisation between introduced and resident plant pathogens was produced (Brasier, C*an J Bot* **73,** S1231-1240, 1995; see Fig. 1). This assumes that fungi which are related but evolved in different geographic areas are less likely to have evolved strong barriers to hybridisation (gene flow). The potential for hybridisation between an immigrant and a resident, however, will depend upon many other factors. These include the frequency of niche contact; the nature of any genetic barriers to hybridisation; the degree to which their genomes can recombine; and the ability of any resulting hybrids to compete with the 'parent' species. Possible outcomes range

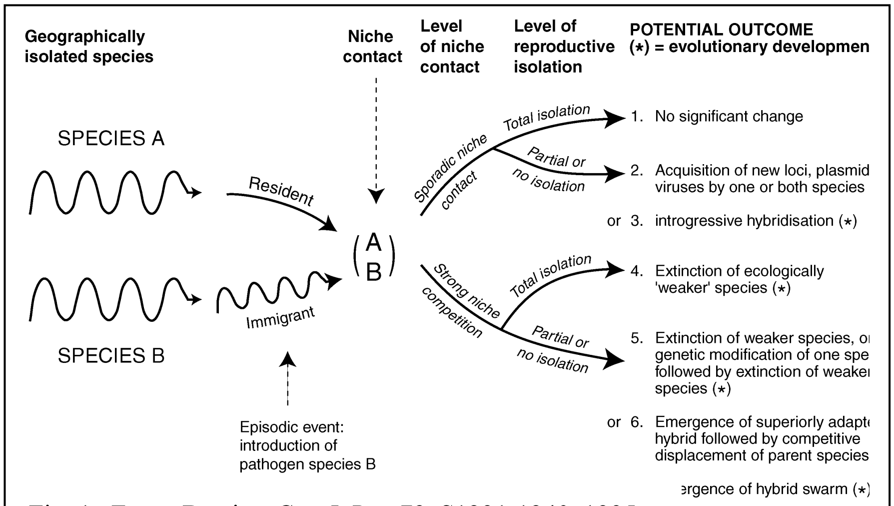


Fig. 1. From Brasier, *Can J. Bot.* **73,** S1231-1240, 1995.

from the acquisition of a single gene by one parent to a full species hybrid incorporating the genomes of both parents.

Since 1994, at least eight examples of interspecific hybridisation have come to light. Significantly, no less than seven of these involve forest pathogens (Brasier, *Nature* **405**, 134–135, 2000). The author has been involved in researching two of these: the Dutch elm disease pathogens, and a new *Phytophthora* on alder in Europe.

Regarding the Dutch elm disease example, this involves *Ophiostoma ulmi* (responsible for the first pandemic) and *O. novo-ulmi* (responsible for the second pandemic). (These DED pathogens can be root transmitted as part of their life-cycle). As *O. novo-ulmi* has migrated around the world, it has rapidly replaced *O. ulmi* (c.10% per annum reduction in frequency of *O. ulmi* at any one site). This replacement process probably occurs mainly in the bark around the beetle breeding galleries, where the two species come into close physical contact.

O. ulmi and *O. novo-ulmi* are strongly but not totally reproductively isolated from each other. There is now evidence (i) that rare and transient (unfit) hybrids occur between the two species when they intermix (Brasier *et al., Mycol. Res***. 102***,* 45-57, 1998). (ii), That this allows *O. novo-ulmi,* which initially spreads at epidemic fronts as a genetic clone, to acquire new vegetative compatibility (vc) and mating type genes from *O. ulmi* (M. Paoletti. pers. com). (iii), That *O. novo-ulmi* probably discards any 'unwanted' *O. ulmi* genes it acquires during the process. (see Abdelali *et al*., *MPMI* **12**, 6-15, 1999). As a result, *O. novo-ulmi* becomes rapidly genetically diversified in terms of vc types and mating type at epidemic fronts. This increase in vc diversity probably allows it to resist the spread of deleterious viruses, which might otherwise bring about its demise (see Chapters 4 & 12 in *The Elms*, Kluwer, Boston, 2000).

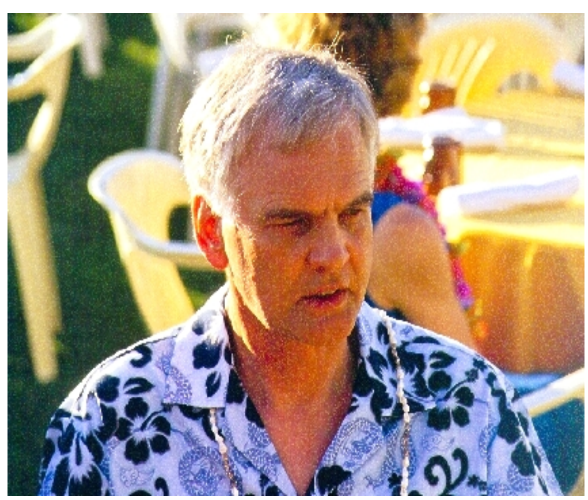
The alder *Phytophthora* is responsible for a new collar, root and stem necrosis of riparian and shelterbelt *Alnus glutinosa* and other *Alnus* spp. across Europe. Previously, *Phytophthora* had not been recorded as a pathogen of alder. Initial studies on the alder pathogen indicated it was morphologically related to *P. cambivora,* a common pathogen of hardwood trees. However it had a different breeding system, different temperature-growth relationships and a high frequency of zygotic abortion, features which suggested it might be a species hybrid. Subsequent studies have shown that it is a swarm of heteroploid (near diploid to near tetraploid) hybrids between *P. cambivora*, and a *Phytophthora* close to *P. fragariae* (Brasier *et al*., *PNAS*, **96**, 5878–5883, 1999). Neither of these species is an aggressive pathogen of alders. The hybrid may, therefore, have acquired the ability to exploit a new host, a possibility previously demonstrated with laboratory generated

Phytophthora species hybrids. It also appears, from studies on ITS sequences and AFLPs of genomic DNA, that the alder *Phytophthora* hybrids are recently evolved and still evolving. How their evolution may proceed is uncertain.

Two other recent examples of interspecific hybrids involve the *Melampsora* tree rusts. One concerns emergence of natural hybrids between *M. medusae* and *M. oxidentalis* on commercial poplar clones (*P. deltoides* × *P. trichocarpa*) bred and planted for resistance to *M. oxidentalis* in the Pacific North West (Newcombe *et al*., *Mycological Research*, **104**, 261–274; 2000). These new rust hybrids can attack *P. deltoides*, the new commercial popular clones and the local *P. trichocarpa*. Another intriguing new hybrid story, yet to be described in detail, involves emergence of hybrids between the S and P species of *Heterobasidion* on conifers in northern California (M. Garbelotto, personal communication, and Garbelotto *et al*., *Phytopathology,* **86**, 543–551, 1996).

The recent flurry of examples may be a glimpse of an accelerating but inadequately monitored environmental process. Interspecific gene-flow between forest pathogens may be increasing as a result of (i) human mediated ecological disturbance effects that promote hybridisation (such as the increasing international movement of plants and their associated pathogens); (ii) similar disturbance effects that allow the survival and expression of resulting hybrids (such as enhanced host stress or access to novel hosts). (Brasier, *Bioscience*; in press, 2001). Certain fungal groups such as *Phytophthora* species, rusts and insect-associated ascomycetes might be more likely to give rise to hybrids. However, the observation of hybrids between *Heterobasidion* spp. suggests that any fungal pathogen groups could be involved.

Through hybridisation, even a small genetic modification to a pathogen, such as the acquisition of a single gene conferring a new host specificity, could have a profound effect on its behaviour. This is well illustrated by the recent demonstration that, when the *O.novo-ulmi* cerato-ulmin gene is transferred into the common hardwood bark saprotroph and bark beetle associate, *O. quercus*, the latter becomes a potential vascular wilt pathogen (Del Sorbo *et al. MPMI*, **13***, 43-53,* 2000). Introduced pathogens, therefore, can have a potential ecological impact far beyond the initial disease levels that they cause.



When Exotic Pathogens Go Native

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At a recent blister rust/*Ribes* meeting in Oregon (Hummer and Sniezko 2000), I heard *Cronartium ribicola* referred to as a “naturalized” pathogen. I objected instinctively, I suppose because my pathological upbringing taught me to treat blister rust as the enemy and because this phraseology seemed a political threat to disease control dollars. The speakers probably had no such nefarious objectives in mind, but were simply trying to express the fact that the fungus has been in North America for 100 years now, and isn’t going to go away. It did start me thinking, however, about the differences between introduced and indigenous pathogens, and what standard I would accept to move blister rust, or *P. cinnamomi*, for that matter, from one category to the other.

On reflection, the question seems more complicated, and interesting, than my first reaction suggested. So—does the word ‘naturalized’ have a constructive place in the plant pathologist’s lexicon? I want to explore the issue through three objectives:

1. What does happen to non-indigenous pathogens with time?
2. What do we mean by ‘naturalized’?
3. Is ‘naturalized’ a useful concept for non-indigenous pathogens?

Model Invasions

The issue was crystallized by Professor Hal Mooney from Stanford University, in a recent seminar titled “Fight Them on the Beaches, or Let the New Order Begin!” Is the fight over-are other distinctions mute- once the invader gains the beachhead? What happens between the beachhead and the new evolutionary and ecological order that Mooney described? A “Technical Report” published by the Ecological Society of America in their series on “Issues in Ecology” (Mack et al. 2000) provides a useful overview and outline of the ecological process of invasion. The examples are primarily plants and animals, but the intent is to provide a chronology and definitions that will cover pathogens as well. They present the invasion of the prickly pear, *Opuntia*, into South Africa as a general example (Figure 1).

Three distinct stages are evident in the process of establishment of a non-indigenous organism in a foreign environment: the lag phase of population growth; the exponential growth phase; and a plateau phase. Immigrants, foreign organisms in transit or newly arrived, are extremely vulnerable, and most die. During the lag phase populations of the few successful species increase slowly. This phase may extend for years or even indefinitely. Those organisms that find a conducive environment and reach a critical population size may enter an exponential phase of rapid population growth and range extension. They are termed ‘invasive species’ if in the process they displace native species.

In the ecological model, the plateau phase follows when they reach the limits of growth as determined by environment or host.

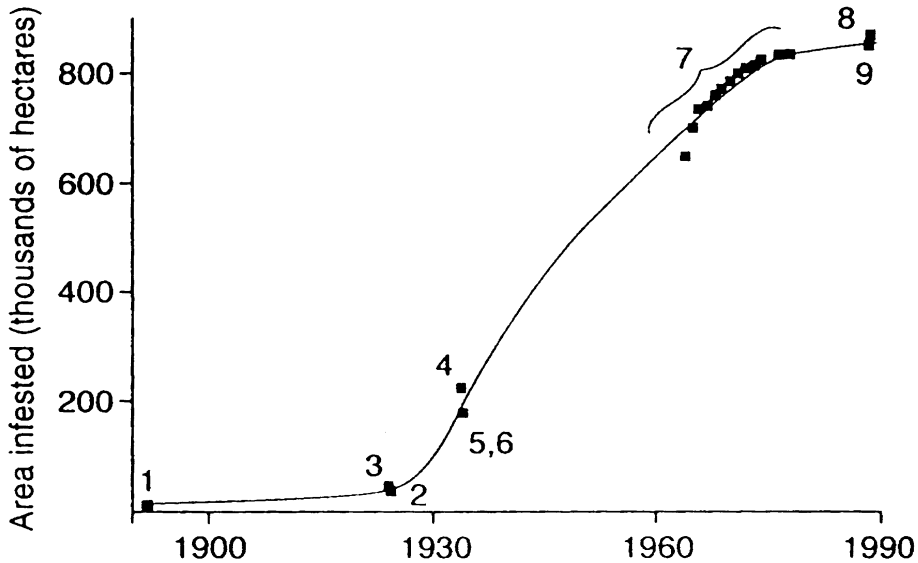

Figure 1. Increase of *Opuntia* after introduction to South Africa. (After Mack et al. 2000)

The plateau phase is not the end of change for invasive pathogens, however. The structure of both host and pathogen populations and the surrounding forest community continues to shift after range and host limits have been reached. This is the process of establishing the new ecological and evolutionary order. We know little about it for any invasive organisms, but a few forest pathogens provide the best-studied examples. Invading pathogens that affect tree evolutionary fitness are not yet in equilibrium with host populations and forest community structure. Susceptible tree genotypes are progressively removed from the population, triggering a continuing shift in plant community structure as resistant or tolerant species gain the competitive advantage. We can hypothesize three kinds of changes:

A. Pathogen evolutionary shift from episodic genetic selection to routine or stabilizing selection (Brasier 1986);
B. Frequency dependent host selection producing more diverse host populations, following the Red Queen hypothesis (Clay and Kover 1996).
C. Forest community shift to a new dynamic equilibrium.

Population genetic structures of epidemic pathogens tend to be simple or even clonal, in response both to introduction of only one or a few individuals, and to the selective advantages enjoyed by highly pathogenic individuals in an epidemic situation. The first steps in changing population structure may be rapid in short-cycling sexual pathogens such as *Ophiostoma novo-ulmi*, with distinct pathogenic and saprotrophic phases. Pathogenic fitness emphasizes growth rate and is favored by asexual reproduction, often producing a clonal population structure (Brasier 1986). After the epidemic front passes, different selection pressures come to play, favoring sexual reproduction and increasing population diversity. The change is driven in part by mycoviruses spreading in the epidemic clonal population, and results ultimately in a "mature" population structure.

We can hypothesize that a similar process will occur in pathogens with different life histories, but at different rates. *Armillaria mellea* was introduced into Cape Town, South Africa perhaps 300 years ago. It is still there, seemingly genetically unchanged, as a single vegetative clone, slowly spreading from its original point of introduction (Coetzee and others, unpublished).
The Red Queen hypothesis from theoretical population genetics (Clay and Kover 1996) focuses on pathogens and parasites as the theoretical force maintaining sexual reproduction in host populations. Through frequency dependent selection, pathogen virulence genotypes shift to match predominant host resistance genotypes, in an endless arms race. The host can only hope to stay ahead by diversifying its population through sexual reproduction. Thus a "mature" host population structure includes multiple alleles for resistance.

An invading pathogen will ultimately create a new dynamic equilibrium with its host and the associated plant community. In some cases the host population in time may recover as resistance genes are selected and spread through the population, and the host may resume its former place in the forest community. In other situations, however, the new equilibrium will be very different than that seen before the introduction. It seems unlikely that chestnut will ever recover its place as the dominant tree in the deciduous forest ecosystems of the eastern United States.

Definitions

Now we will address the word "naturalized". Where in Figure 1 does *Opuntia* (or any invasive organism) become "naturalized"? The authors of the ESA paper consider those immigrants that don't die in the lag phase to be naturalized. Generally, introduced plant and animal species that are established, able to reproduce and maintain their populations beyond the limits of cultivation, are deemed naturalized by plant and animal taxonomists. For example, the Oregon State University, Oregon Atlas project, cataloguing the plant species of the state, states simply that "naturalized species are established in nature, reproducing naturally beyond cultivation"

This is the sense of the word that I reacted against in the blister rust meeting. Judging from the discussion at this WIFDWC, there seemed to be a consensus that this use of the term is dangerous for forest pathology. It implies "here to stay" before the epidemic has properly begun, and at a stage where populations usually haven't even been detected yet.

There is another, legal, definition of "naturalized." Consider the chronology and requirements for immigrants to gain citizenship. Only legal immigrants are eligible, and then only after 5 years in "resident alien" status, with demonstrable "good moral character." Study and a test to demonstrate knowledge of the laws and Constitution of the country are required, followed by an Oath of Allegiance. Then immigrants become naturalized citizens. Only in the next generation are the final limits removed, and then ethnic distinctions often remain for additional generations.

In this sense, to "naturalize" means "To confer the rights and privileges of a native citizen on," "To become established as if native." This is a higher standard, more appropriate, it seems to me, for pathology. The original question remains, however: Is it useful to distinguish "naturalized" pathogens from natives and new arrivals? I think so. If we define our terms carefully.

I suggest that we not even consider application of the term until after the epidemic has past and the population is in its post epidemic phase. Range and host limits must have been reached, and, I think, a new community structure established and stabilized. A mature population structure in host and pathogen should have developed, but this may be impossible or impractical to measure, so I suggest reequilibrated community structure as a surrogate for pathogen and host genetic shifts.

It seems useful to distinguish non-indigenous pathogens that have achieved such ecological and genetic integration from new immigrants and epidemic phase invasive pathogens, and from indigenous pathogens that they have come to resemble, for a number of reasons:

- "Those who ignore history are doomed to repeat it;"
- Historical origins are key to understanding the current evolutionary biology of an organism;
- These pathogens are biologically interesting, as experiments in evolution;
- They are likely to respond less predictably to changing environments than indigenous pathogens;
- We can't hope to restore "historical conditions" unless we distinguish old invaders from endemic pathogens;
- Disease management strategies should change as the genetic structures of host and pathogen populations change. It may even be possible to accelerate the shift to a mature population structure in some pathogens, to the benefit of the suffering forest.

Some Examples

Phytophthora cinnamomi can be considered naturalized in the Southeastern United States. It was first introduced more than 200 years ago, and has evidently reached the climatic limits of its range. All hosts in the occupied territories have at least been exposed to it by now. We don't know about its population structure, but certainly changed forest communities are well established in its aftermath in the SE. Chestnut and chinquipins are gone from the southern end of their historic range, never to return under their own power (Crandall et al. 1945). Littleleaf disease continues to exert itself, but in predictable locations, and hastens forest succession to species and soil conditions less favorable to the pathogen (Campbell and Copeland 1954). *P. cinnamomi* will no doubt rear up again, perhaps in surprising places as climate change and new silviculture offer it new opportunities. The status of *P. cinnamomi* in Hawaii is unclear, but it was certainly introduced long ago and is widely distributed on all of the islands (Kliejunas et al. 1977).

It is one of the causal agents in Ohia decline, but this is an old and evidently recurring disease, with complex ecological interactions. I think *P. cinnamomi* is “naturalized” by the strict criteria, but the National Park and others are short-sighted to ignore it as indigenous or unimportant in ecosystem dynamics.

P. lateralis is certainly not naturalized in the range of Port-Orford-cedar, despite its widespread distribution and presence for at least 50 years. In some local areas the epidemic is flattening as the last susceptible trees are killed, but it has not reached the host range limits and it continues to intensify in many watersheds. The population structure of the pathogen is still very simple (Hansen et al. 2000), and forest communities are only beginning to adjust to the loss of cedar.

Cryphonectria parasitica, cause of chestnut blight, meets the strict criteria for a “naturalized” pathogen in the eastern U.S. It seems unlikely that we will ever witness a population genetic change in the chestnut; it has been reduced to an essentially asexual species. But its niche in the forest community has been taken by oak species and a new, seemingly stabilizing, forest community is present. The pathogen population structure is now complex, with sexual and asexual reproduction and many vegetative compatibility groups.

Finally, let us return to the question of white pine blister rust in North America. It cannot be considered naturalized, because it is still expanding its range to the south, now threatening Mexican 5-needled pines. In the Pacific Northwest, plant community structures are still changing rapidly in response to loss of the white pines. Secondary epidemics of root rot and bark beetles have been loosed as pines are replaced by rust resistant but root rot susceptible *Abies* species and Douglas-fir. Still, there are signs that a new equilibrium will eventually be established. In areas where disease pressure has been greatest, natural selection has favored resistant or tolerant individuals, and these survivors are now reproducing, creating a natural F2 population with a higher proportion of resistant individuals. The rust population is also changing. In a few areas where chance or human intervention left concentrations of pines with simple genetic resistance to blister rust, new pathogenic races of the pathogen have been selected.

Summary

We might usefully recognize three categories of pathogens in our discussions of invasive species:

1. Native, indigenous, or endemic pathogens that have evolved with the ecosystem;
2. Non-indigenous, invading or invasive pathogens, in the lag or exponential phase of their epidemic, to be fought tooth and nail;
3. Non-indigenous “naturalized” pathogens, post-epidemic phase, and well into establishment of the new ecological and evolutionary order.

This limited use of “naturalized” can be useful to us, so long as we are careful to define our meaning, and remember that sister disciplines have adopted a much less restrictive definition. In the WIFDWC discussion, Det Vogler suggested that we might fruitfully consider "naturalization" as a process, and not an end state. The process begins in the immigrant population as individuals adapted to the new environment are selected and others die. It continues through the epidemic and long into the post-epidemic period as host and pathogen populations continue to change and adapt to the new reality.

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Development of a Risk Reduction Strategy
For A Virulent, Exotic Root Disease Pathogen

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What happens when a virulent, exotic root pathogen becomes established on lands managed by Federal agencies in the United States? With *Phytophthora lateralis*, cause of Port-Orford-cedar root disease in southwestern Oregon and northwestern California, we are finding out what the response will be. After a long process of denial, procrastination, outside intervention, and initially tentative and very localized attempts at management, the USDA Forest Service and USDI Bureau of Land Management are finally developing a comprehensive range-wide root disease risk reduction strategy for Port-Orford-cedar.

Port-Orford-cedar (Chamaecyparis lawsoniana) is a beautiful and unique tree species that is native to a very limited area extending from Coos Bay, Oregon south to the mouth of the Mad River in California and from the Pacific coast inland roughly 50 miles. A small, discrete population also occurs in the Scott Mountains of California. Port-Orford-cedar is the largest member of its genus, is very shade tolerant, and, despite its small natural range, has a very wide ecological amplitude. Port-Orford-cedar lumber is among the most valuable of all conifer woods, and the tree can command prices of $2,000.00 to $12,000.00 per thousand board feet on the export market. Port-Orford-cedar also has great value in its native forests for the ecological roles it plays. It grows well on the many ultramafic soils that occur in Southwest Oregon and northwestern California and is often the only tree species that can attain large size on sites with such soils. It also contributes to increased calcium content in serpentine soils when it grows on them, favoring occurrence of a number of rare plant associates. It is a particularly significant riparian species throughout its range, providing essential stream shade and stabilizing stream banks with its extremely fibrous root system. Furthermore, when it dies and falls into a stream, Port-Orford-cedar contributes to superior fish habitat through the long-lasting effects its decay-resistant wood has on stream structure.

Port-Orford-cedar root disease was first reported affecting ornamental cedars near Seattle, Washington in 1923. It subsequently was observed killing Port-Orford-cedar landscape trees progressively further south in the Willamette Valley through the 1940s and first was confirmed in the native range of Port-Orford-cedar at Coos Bay in 1952. Since its introduction, *P. lateralis* has spread widely onto favorable sites in all but the most southerly part of its host's native range. The origin of the causal pathogen is unknown.

P. lateralis is extremely virulent to Port-Orford-cedar. Its host range is very narrow, and, besides Port-Orford-cedar, it only affects Pacific yew (*Taxis brevifolia*) when the latter species is growing in close association with infected cedars. P. lateralis is greatly favored by cool, moist conditions and spreads actively downhill via zoospores in water when such conditions prevail. It also forms resistant structures that allow it to survive for long periods when conditions are sub optimal. It can be spread passively over long distances when resistant spores are carried in soil or mud. Humans are the main vectors of *P. lateralis,* and spread into new areas occurs most commonly when resistant spores are transported in mud clinging to vehicles during times when favorable cool wet conditions occur.

The objective of the Root Disease Risk Reduction Strategy for Port-Orford-cedar now being developed by the Forest Service and Bureau of Land Management is to maintain the ecological and economic viability of the species within its native range. Components of the strategy include the following:

1) Locating and Protecting Appropriate Uninfested Areas that contain Port-Orford-cedar- The Agencies have mapped locations of Port-Orford-cedar and root disease across their entire ownerships. Yet-uninfested areas are risk rated based on proximity of root disease and occurrence of major risk factors (roads, streams, topography favorable for overland spread, location of various management allocations, etc.). Appropriate areas deemed to be at low risk (entire uninfested drainages or the uninfested upper parts of drainages where risk of establishment can be minimized through excluding vehicles) will be afforded maximum protection by permanently closing any existing roads and/or not building any new roads into them in the future.

2) **Minimizing Spread and Intensification of *P. lateralis* in Areas Where Root Disease Already Occurs-** The Agencies are implementing combinations of treatments including temporary road closures, roadside sanitation treatments, road design and maintenance improvements, timing of projects when conditions are unfavorable for the pathogen, vehicle washing, and silvicultural treatments to reduce P. lateralis inoculum, minimize spread of the pathogen, and protect cedars on even limited micro sites where they are not affected by the pathogen. Most of these techniques have been used to some extent on a project-by-project basis in the past. Now, however, planning is being done at a drainage-by-drainage level across entire landscapes and use of promising approaches is being expanded greatly.

3) **Implementing a Genetic Conservation Plan for Port-Orford-cedar-** Agency geneticists are in the final stages of refining seed zone maps for Port-Orford-cedar. Seed zones are based on studies of genetic diversity within Port-Orford-cedar populations and their locations will be an important factor in deciding which uninfested cedar stands will be protected by road exclusion. Also, a major effort to identify resistance to *P. lateralis* in Port-Orford-cedar is underway. About 10,000 phenotypically resistant cedars from across the range of the species have been screened for resistance using the branch lesion test developed by Oregon State University. Over a thousand "winner" trees that performed well in the tests have been identified, recollected from, rooted, and are now being maintained in a conservation orchard and at the Dorena Genetic Resources Center. Clones from these trees are undergoing additional testing, are being evaluated for different

resistance mechanisms, and are being used in the first part of an effort to enhance resistance through breeding.

4) **Developing a Research and Monitoring Plan**- The Agencies have developed a prioritized list of what they consider to be the most important research and monitoring needs associated with Port-Orford-cedar root disease and are working hard to take advantage of any funding opportunities. Needs are great, *P. lateralis* is difficult to monitor and is often refractive to experimental investigation, and research funds are not overly plentiful. Fortunately, Oregon State University scientists have had great interest in *P. lateralis* and the disease it causes for some time and have often pursued important work on the pathogen with only minimal support. They deserve much credit for past efforts and are being counted on to continue in the future with better financing. Forest Health Protection groups have become increasingly active in effectiveness monitoring for management techniques.

5) **Promoting Education About Port-Orford-cedar Root Disease-** Humans are responsible for most spread of *P. lateralis*, yet a surprising number of forest workers as well as recreationists have little or no idea of the significance of the pathogen and may inadvertently aid its spread due to lack of knowledge and understanding regarding the issue. Federal Agencies are heavily involved in efforts to disseminate information on the biology and ecology of *P. lateralis* with emphasis on how the pathogen spreads and how spread can be prevented. Presentations at training sessions, workshops, and symposia as well as newspaper articles, television interviews, pamphlets, journal articles, displays at public functions, classroom teaching materials, and strategically placed information signs are being used. The risk reduction strategy will include recommendations on how to further education efforts in a more organized, effective manner than has been the case heretofore.

6) **Enhancing Cooperation Between Forest Managers Who Own Lands with Port-Orford-cedars**- Cooperation between the main Federal agencies that manage Port-Orford-cedars has improved substantially in recent years. A real effort is being made to do this, and now both the Forest Service and Bureau of Land Management have hired Port-Orford-cedar coordinators, are active in the Port-Orford-cedar Technical Committee, recommend very similar techniques for managing *P. lateralis*, and are committed sponsors of the current program to develop a risk reduction strategy. However, between a quarter and a third of the lands that support Port-Orford-cedars are not owned by the Federal Agencies. Most of these properties belong to industrial timber companies or private woodland owners. Gaining the cooperation of these kinds of landowners for integrated Port-Orford-cedar management efforts has proven to be a tremendous challenge. Their cooperation is essential for the success of many individual management projects and is certainly necessary for a truly range-wide risk reduction strategy. The promising direction of the current Agency Port-Orford-cedar resistance breeding projects combined with the fears that many private land owners have about Swiss needle cast on coastal Douglas-fir appears to be an ice-breaker for enhancing cooperation between the Forest Service, BLM, and private forest managers. The Agencies are actively seeking ways to take advantage of this

opportunity. Screening cedars for resistance on private properties and ultimately providing resistant Port-Orford-cedar seed to all interested landowners is being pursued as a way to do this.

Clearly, the current effort by the Forest Service, Bureau of Land Management, and other interested and concerned parties to develop a root disease risk reduction strategy for Port-Orford-cedar is a good and necessary endeavor. Some particular points for WIFDWIC members to consider about the effort in light of possible involvement with future forest tree disease introductions include:

1) It has taken a long time to get to the point we have reached with the Port-Orford-cedar strategy and though parts of it are being implemented, it really isn't completed yet. The effort so far has involved a tremendous amount of time and work and has also been very expensive and rather controversial. With *P. lateralis*, we have been fortunate, in a way, to be working with a water- and soil borne pathogen so spread routes have been somewhat predictable and spread rates, relatively speaking, have been slow. If we were working with an equally virulent exotic pathogen that was air-borne, we wouldn't have had the luxury of taking as much time as we have taken to develop plans and management techniques.

2) It takes a Federal manager who is far-sighted and courageous to support development of a disease reduction strategy of the magnitude necessary to truly deal with a virulent exotic root disease. This type of person is in short supply. Managers need a lot of encouragement from knowledgeable specialists and need constant reinforcement regarding the dangers of ignoring introduced diseases or putting off efforts to manage them.

3) Forest pathologists will have a major part in developing risk reduction strategies for any introduced root pathogens. In doing so, they will have to cooperate with other involved specialists including foresters, ecologists, silviculturists, geneticists, sociologists, and line officers. We need to be able to communicate well with these people.

4) With any introduced disease, there will almost certainly be great need for significant research and monitoring programs. Funding will always be tight for such efforts, especially for research. In the absence of good research results, forest pathologists will be expected to provide "best guess" estimates that will be used in planning. This is very troubling.

5) Unfortunately, there is a high likelihood that more forest pathologists will have opportunities to be involved in risk reduction strategies for introduced tree diseases. The current climate of free trade and minimal inspection of trade goods, including wood and wood products, practically guarantees in my view that more introductions of virulent pathogens will occur. The magnitude of impacts that new introductions may cause can be judged by considering the impacts caused by introductions of the past. The Port-Orford-cedar situation is a testimonial to the fact that such impacts can be great indeed.

SPECIAL PAPERS
Overview of Sudden Oak Death in Coastal California

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Thousands of tanoaks (*Lithocarpus densiflorus*), coast live oaks (*Quercus agrifolia*) and black oaks (*Quercus kelloggii*) are dying along the central coast of California, devastating urban and wildland forests from Big Sur (Monterey County) north to Sonoma County. A previously unknown *Phytophthora* species is associated with the mortality. It appears to be an exotic or invasive pest: in many affected areas it looks like a fire raced through and killed the susceptible species. Oaks, a symbol of California's natural beauty and of the longevity of nature, are dying and thousands of people in the Bay Area are irate and clambering for a cure.

Dubbed Sudden Oak Death, since it causes afflicted trees' crowns to turn from green to brown in a few weeks, it was first reported in 1995 in Marin County on tanoak in residential areas and in adjacent wildlands on Mt Tamalpais. All infested locations are near the coast, in areas influenced by fog; the furthest extent inland is 35 miles in Napa County. Symptoms of Sudden Oak Death have been detected farther north in Mendocino and Humboldt Counties but repeat attempts at isolation have not yielded the new *Phytophthora* (David Rizzo, personal communication, December 2000).

Dead trees are found in patches and do not seem to follow any site factor, (i.e. river bottoms, ridgetops). The dead trees are commonly found in mixed-species forests: redwood with understory tanoak; or tanoak, coast live oak, California bay laurel, madrone, redwood and Douglas-fir, so forests usually have some immune tree species remaining. However, in areas dominated by susceptible tree species mortality rates are as high as 75%.

The cause of the rampant oak mortality was not known for five years, complicated by secondary insect and *Hypoxylon* colonization and by a confusing distribution pattern. In June 2000, David Rizzo, Professor of Plant Pathology at UC-Davis isolated an unknown species of *Phytophthora* from necrotic bark patches on all three impacted species. The previously undescribed *Phytophthora* is genetically similar to *Phytophthora lateralis*, the cause of Port-Orford root disease in Southwestern Oregon and Northwestern CA but differs by several base pairs. In culture the fungus is morphologically different from *Phytophthora lateralis,* producing numerous deciduous sporangia and prolific chlamydospores. Oospores have not been observed. (David Rizzo, personal communication, December 2000).

The key symptom of Sudden Oak Death is black or reddish ooze dripping from the trunk. Similar "bleeding" can be caused by other species of *Phytophthora,* by bacteria or mechanical injury so laboratory isolation is needed for diagnosis and many reports are false. Despite this limitation, it is the best indicator to look for to identify trees affected by the new *Phytophthora*. The ooze is the host response to infection; if you chop away the outer bark, behind the ooze is a necrotic patch of inner bark. The dead and discolored area can extend a centimeter into the wood. Typically, removal of adjacent outer bark reveals many discrete areas of necrotic bark scattered up and down the bole, each surrounded by black zone lines, stopping at the ground line. Necrotic areas have not been found in the roots.

In small tanoak, less than approximately 4 inches DBH, the first symptom is a wilt of the branch tips, followed by branch dieback. The branches reflush, but the new growth dies leading eventually to tree death. After death, the tanoaks resprout at the base but the sprouts die.

Several organisms are commonly found on trees infected with the new *Phytophthora,* including the fungus *Hypoxylon thouarsianum,* Western oak bark beetles and Ambrosia beetles. These organisms may hasten tree death or deterioration but their roles are not clearly understood.

There is no treatment or management practice to prevent or cure trees infected with the new *Phytophthora*. Questions abound since the causal agent is previously unknown and there isn't a body of scientific literature to draw from. How does the pathogen spread - in water, air or soil? How long does it remain viable on firewood cut from infested trees? Does it infect other species? What is the establishment potential throughout California, North America, and Europe?

To address Sudden Oak Death statewide the California Department of Forestry and Fire Protection and the California Forest Pest Council created the California Oak Mortality Task Force, an independent, multi-organization group. The task force brings together public agencies, non-profit organizations and private interests to implement a comprehensive, unified program to address Sudden Oak Death through research, management, education and public policy. More information on Sudden Oak Death can be found at the task force website: www.suddenoakdeath.org.

The impacts of Sudden Oak Death include changing forest structure and composition in ways that will alter ecosystem structure and function, primary productivity, biodiversity, wildlife habitat, water regimes, susceptibility to exotic invasion, and hill slope stability. The dead trees are causing an immediate hazard to the communities sprawling under and among them. Marin County has declared itself a disaster area. The media coverage and political interest is intense prompting many to ask whether this is the next chestnut blight. More research and monitoring are needed to predict the ultimate impact of this forest pathogen.

Some Recent Highlights From A White Pine Blister Rust Resistance Program For Western White Pine And Sugar Pine

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Introduction: In Oregon and Washington (USDA Forest Service, Region 6), there has been a white pine blister rust resistance program for over 40 years. Artificial inoculation at Dorena Tree Improvement Center, and subsequent evaluation of resistance mechanisms of both sugar pine (*Pinus lambertiana*) and western white pine (*Pinus monticola*) seedlings with white pine blister rust (*Cronartium ribicola*) has been a major component of this program. Only recently has there been a strong emphasis on out planting some of the resistant seedlots to evaluate their performance under field conditions. This presentation presents preliminary results from recent inoculations and field plantings of western white pine and sugar pine.

Artificial Inoculations: Western white pine (WWP) and sugar pine (SP) seedling families sown in 1994 and 1996 provided an opportunity to assess several things, including performance of checklots from: (a) the Idado WWP resistance program (USDA Forest Service, Region 1), (b) the California SP program (USDA Forest Service, Region 5), as well as previously identified 'slow rusting' and major gene resistance (MGR) families from the Dorena program and seed orchard bulk lots. Two 'strains' of rust were used in inoculations, with some replications being inoculated with 'wild' type (presumably no 'Champion Mine' strain present), and some replications being inoculated with 'Champion Mine' strain (which 'overcomes' the major gene resistance in WWP);

Results through the third inspection (two years after inoculation) indicate that the high resistant Dorena WWP 'MGR' families have relatively low cankering with 'wild' type strain of the rust (in fact, as expected, the highest incidence of canker-free of all tested seedlots), but showed a very high frequency of cankering when inoculated with 'Champion Mine' strain. Sugar pine families with major gene resistance (for the hypersensitive reaction in the needles) appear to be unaffected by the 'Champion Mine' strain.

Other results to date show that:

(1) the two homozygous dominant 'MGR' sugar pine seedlots both unexpectedly showed low levels of stem infection with both strains of rust
(2) 'slow rusting' resistance seem to be more common in WWP than in SP
(3) the five Idaho control cross seedlots had a incidence of cankering and 'slow rusting' similar to some of the Region 6 open-pollinated 'slow rusting' seedlots
(4) the 'slow rusting' families appeared to not be adversely affected by the 'Champion Mine' strain
(5) in at least some geographic areas there was a positive family correlation between needle lesion frequency and percent cankering

(6) on a family mean basis, some of the better 'slow rusting' families were also relatively highly rated for canker-free.

Three years of assessments are remaining on the 1996 sowing, and there some of the 'slow rusting' families have started to show increased mortality (but delayed over the 'non-resistant' families).

Field Testing: Seedlings from 12 sugar pine and 13 western white pine families were planted at Happy Camp, California in 1996, for field validation of families artificially screened for white pine blister rust. Container stock (1-0) from a mixture of resistant and non-resistant families was planted in 12 blocks in a randomized complete block design. An initial assessment was done in early summer 1999, in which height, number and type of cankers (normal, bark reaction, partial bark reaction or blight) was recorded. These results indicated moderate levels of blister rust infection, with sugar pine having a significantly higher percentage of trees infected (both active and inactive cankers) and significantly more stem infections per infected tree than western white pine (based on all trees, including healthy). Height differed significantly between species, and among families within a species, but the number of cankers per tree was not significantly different between families at this age. An unexpected result from this assessment is the very high percentage of infections that are bark reactions (completely inactivated infections), despite the fact that only some of the families of both species were selected for this mechanism. The reason for this high level of bark reaction is unknown at this time. A subsequent assessment took place in July 2000 to track the progression of blister rust infection in the individual families, and contrast differences in infection, and subsequent mortality between the two species. In addition, it will show whether the observed bark reactions have remained inactive, and the current status of infection scored in 1999 as partial bark reaction.

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The Impact Of *Arceuthobium americanum* On The Population Dynamics, Canopy Structure And Understory Composition Of Central Oregon *Pinus contorta* Stands

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Introduction

The effects of many species of *Arceuthobium* on the growth and mortality of host trees are well known. Being hemiparasites, *Arceuthobium* spp. derive the majority of their required nutrients from their hosts, and sufficiently infected trees often suffer reduced height and diameter growth and increased mortality rates (Baranyay and Smith 1972, Hawksworth and Wiens 1996, Mathiasen 1996). Since the volume and merchantability of timber grown in stands infected by dwarf mistletoe can be severely reduced, forest management initiatives in North America have for decades been aimed at dwarf mistletoe control or eradication (Childs and Shea 1967). However, few studies have investigated the implications of *Arceuthobium* infection on the structure and dynamics of forest communities.

Since many dwarf mistletoe species infect trees which are dominant or co-dominant elements of at least some stages in the seral development or climax condition of many forest types, the potential array of factors influenced by *Arceuthobium*-induced death and growth reduction of infected trees is large. Some evidence suggests that the increased mortality of dominant tree species characteristic of heavily infected stands may alter the successional status of the stand itself (Tinnin et al. 1982), and it has been shown that the presence of *Arceuthobium americanum* changes the age structure of climax stands of *Pinus contorta* var. *murrayana* (henceforth *Pinus contorta*) by freeing resources for use by younger tree cohorts (Wanner 1986, Wanner and Tinnin 1989). Given the strong effect of *Arceuthobium americanum* on the growth, mortality and crown structure of *Pinus contorta* (for review see Hawksworth and Wiens 1996), I hypothesized that the structure, composition and developmental characteristics of forest communities dominated by *Pinus contorta* would be strongly influenced by the level of infection of *Arceuthobium americanum*. I further hypothesized that the effects of dwarf mistletoe on canopy structure would be mediated through changes in both the population dynamics of *Pinus contorta* and in the crown architecture of individual trees.

Materials and Methods

Data Collection

In 1998 and 1999 I collected data in a study site located near Crescent Lake in the central Oregon Cascades. The site is typical of the central Oregon pumice zone, with climax *P. contorta* forest communities on low-lying flats and basins grading to mixed *Pinus* *ponderosa*/*Pinus contorta* communities on slopes and ridges. I located thirty-six square 0.49 hectare plots within the study site and collected data for an extensive array of tree, canopy, understory and abiotic variables within each plot (for complete study methodology see Godfree 2000). I specifically focused on the live crown ratio (LCR) and height of individual trees, the size class structure of *P. contorta*, the vertical foliage distribution of foliage through the forest canopy, and the richness, diversity (Shannon and Wiener 1949) and total cover of the understory plant community. The canopy-level structural variables I considered included the degree of foliage stratification, the mean canopy foliage height and the number of canopy strata which contained foliage. I quantified the level of infection and witches' broom formation in each plot using Hawksworth's (1977) Dwarf Mistletoe Rating (DMR) system and a modified form of Tinnin's (1998) Broom Volume Rating system.

Model Construction and Statistical Analysis

i. Population Dynamics

I investigated the relationships between infection level and the crown architecture and size class structure of *P. contorta* using multiple regression techniques, and assessed the role of dwarf mistletoe relative to other abiotic and biotic variables by interpreting standardized partial regression coefficients and associated statistical tests.

The main abiotic variables included in the analyses were slope angle, slope aspect, soil type, and topographic position; the latter two variables are of known importance in central Oregon pumice communities (see Franklin and Dyrness 1988). Plot-level infection level and the abundance of different size classes of *P. ponderosa* and *P. contorta* were the principle biotic variables considered.

ii. Canopy Structure

I investigated the role of dwarf mistletoe on canopy structure by using structural equation modeling (SEM). SEM is a multivariate statistical technique in which hypothesized models describing the relationships between large numbers of variables are tested for fit against observed variance-covariance matrix data sets (see Kline 1998). I hypothesized that the impact of *A. americanum* on the degree of canopy stratification, the number of canopy strata, and the mean foliage height of the forest canopy would be mediated through two main variables: stand-level tree diameter variability and the mean plot-level LCR of live *P. contorta*. Both factors were found to be influenced by the level of dwarf mistletoe infection in previous analyses (see below). I also hypothesized that the presence of large *P. contorta* and *P. ponderosa* would influence canopy structure by reducing the density of the dominant *P. contorta* size class (DBH > 14.5 - 30 cm).

iii. Understory Composition

I used SEM to investigate the relationships between a range of biotic and abiotic variables and the richness, diversity and abundance of the forest understory. I considered the stand-level size-class distributions of alive and dead standing trees to be excellent biotic indicators of stand condition and developmental stage, but since using all *P. contorta* and *P. ponderosa* size-class variables in the structural models was not possible (due to sample size), I used factor analysis to decompose the 19 size-class variables into three orthogonal linear composite variables which explained 56% of the total variance in the size-class data set. The first factor related to the density of all size classes of *P. ponderosa*, the second distinguished between stands consisting mainly of mature *P. contorta* and those dominated by a greater range of size classes, and the third related to the abundance of sapling and seedling-sized *P. contorta*. In the initial structural models, I hypothesized that mean plot-level DMR as well as an array of abiotic variables including slope angle, slope aspect, topographic position and soil type would directly influence the three size-class factors, and that these changes would in turn alter the richness, diversity and total cover of the understory. I specifically hypothesized that infected stands would contain fewer dominant *P. contorta*, and that these stands would therefore have a greater understory cover and species richness. Such a scenario would be explained by Connell's (1978) Compensatory Mortality Hypothesis (CMH), which argues that any loss in competitive ability of the community dominant will ultimately result in a higher degree of community diversity as resources are freed for use by subordinate species. I also hypothesized that abiotic variables would directly influence all understory variables.

Results

Population Dynamics

I found that dwarf mistletoe had a significant impact on the dynamics of the entire *P. contorta* population at the spatial scale considered. Stands that contained *A. americanum* tended to exhibit a reverse-J size-class distribution, with extremely abundant small trees, saplings and seedlings but with fewer dominant trees. This contrasted with uninfected stands, which had unimodal size class distributions centered on dominant *P. contorta*. The density of dominant *P. contorta* was negatively correlated with plot-level DMR ($r = -0.25$, $p < .05$), but, more importantly, the relationship strengthened once variability from other sources was accounted for in the corresponding multiple regression models. However, other factors also influenced the density of dominant *P. contorta*. These included the density of emergent *P. contorta*, the density of emergent *P. ponderosa*, and slope angle. Saplings and seedlings were positively correlated ($p < .05$) with plot-level DMR at the plot scale, but at smaller scales the importance of log abundance in the understory and the density of dominant trees appeared to increase in importance. However, even at this scale plot-level DMR had a unique and strongly positive influence on seedling and sapling density.

Canopy Structure

The effects of *A. americanum* on canopy structure were complex, and analysis of the unique relationships between infection and each of the structural indices proved difficult because many other variables also contributed strongly to canopy structure. However, SEM proved a useful tool with which to assess these relationships, and I identified several main mechanisms underlying these complex relationships. In pure stands containing only *P. contorta*, I found that *A. americanum* reduced the overall degree of stratification of the canopy, the number of layers of the canopy, and the mean canopy foliage height. The loss of stratification was the result of the lack of tall, dominant-sized trees in infected stands, since the lack of tall trees reduced the height of the canopy. In contrast, *A. americanum* altered mean canopy height by at least two mechanisms: 1) by reducing the number of upper canopy strata, and 2) by increasing the LCR of individual trees. I found that the presence of infection in the lower crown significantly reduced the height above the forest floor of the lowest *P. contorta* foliage, while infection in the upper crown reduced tree height significantly. At the stand level, the mean LCR of trees increased linearly with mean plot-level DMR, and these mechanisms resulted in heavily infected stands containing shorter trees with crown bottoms close to ground level.

In mixed stands containing *P. ponderosa*, I found that the role of *A. americanum* differed from that in pure stands. Since large *P. ponderosa* in the study area greatly exceeded *P. contorta* in height, the presence of these trees compensated for the loss of upper canopy associated with infection by *A. americanum*. The models suggested that in such stands, infection actually increases the degree of foliage stratification because the loss of dominant trees results in reduced rates of self-pruning in remaining trees (since the level of interspecific competition is lower). This in turn increases the LCR of these trees. The longer crowns characteristic of *P. contorta* growing in infected stands add more foliage to the lower canopy, reducing the mean canopy height but increasing the number of canopy strata and, hence, the degree of canopy stratification.

I also found that other variables influence canopy structure in the same manner as *A. americanum*. For example, the presence of emergent trees increased the LCR and decreased the height to the lower crown of resident trees by reducing the density of smaller, dominant *P. contorta*.

Understory Composition

The structural models tested indicate that in the area studied little or no correlation exists between the level of infection by *A. americanum* and the richness or diversity of the understory community. However, the total understory cover was higher in infected stands, and the path between these variables was significantly mediated by stand condition. The results suggest that the loss of dominant *P. contorta* typical of stands infected by *A. americanum* acts to increase in the total cover of the understory community.

Discussion

The results of this study indicate that *A. americanum* can, under certain conditions, have a strong influence on central Oregon *P. contorta* communities. The presence of dwarf mistletoe appears to shift the *P. contorta* population structure towards smaller, younger size classes; infected stands tend to have abundant regeneration and comparatively few dominant trees. In the study site examined here, an extensive stand-replacing fire event occurred around 120 years ago (for more extensive discussion, see Godfree 2000 and Wanner 1986), and many of the mature trees now present became established in the two to three decades following this fire. This regeneration cohort appears to now be represented principally by the dominant *P. contorta* size class. The presence of *A. americanum* in these post-fire regeneration cohorts has subsequently altered the normal pattern of stand development by causing increased mortality among these trees, and, as a result, infected stands now have a diverse, reverse-J size-class structure characterized by continuous regeneration. Apparently, the presence of dwarf mistletoe reduces the ability of mature trees to compete amongst themselves, and as a result the dense stands characterized by a unimodal size distribution do not develop. I concur with Wanner and Tinnin's (1989) contention that freed resources made available as a result of the growth reduction and death of mature *P. contorta* in infected stands results in the abundant regeneration typical of these stands.

The different size-class structure of infected versus uninfected stands has important consequences for canopy structure because the shape of individual tree crowns varies according to stand density and size-class distribution. As mentioned, in uninfected stands interspecific competition between members of the dominant tree cohort is apparently reduced (since fewer mature trees are present), and the open canopies typical of these stands are conducive to the development of trees with long, low-lying crowns. This in turn increases the amount of foliage near the ground level, resulting in a lowered canopy. Furthermore, the loss of taller, dominant trees appears to reduce the number of upper-canopy strata, which also alters canopy structure. At the individual tree level, on the other hand, infected trees also tend to have low-lying branches and witches' brooms which outlive uninfected branches (Hawksworth and Wiens 1996), and the structural models described indicate that this may also lower mean canopy height and increase the total number of canopy strata. Collectively, these results indicate that *A. americanum* has the capacity to influence canopy structure not only by altering the size-class structure of the *P. contorta* population, but also directly by changing the crown shape of individual trees.

The data also suggest that the reverse-J tree size distributions typical of infected stands affects the understory in a different way than unimodal size distributions. The total cover of understory species was higher in infected stands, which I suggest is due to the opening of the forest canopy and the subsequent freeing of light, water and nutrient resources. I observed dense, uninfected stands to contain little understory cover, which indicates that the high level of competition existing within such stands combined with increased foliage higher in the forest canopy tends to result in poor understory growing conditions. However, not all understory plants respond equally to the more favorable growing conditions typical of infected stands: the majority of the increased cover in infected stands was associated with more abundant and vigorous *Purshia tridentata* (bitterbrush). In fact, I found that the richness of the understory assemblage was not significantly influenced by stand population structure, and, hence, not by infection. That infected stands do not have a higher understory diversity appears to refute my original hypothesis that Connell's (1978) CMH would explain the patterns of understory change associated with stand-level infection. In this system, it appears that although the overall competitive ability of trees in infected *P. contorta* stands is lowered by infection (due to poor health or mortality of mature trees, increased light in the understory, etc.), relatively few species are able to utilize the associated freed resources, and few (if any) new species niches are produced. I suggest that this is the result of the very harsh growing conditions typical of *P. contorta* communities across the pumice zone of central Oregon. The area is typified by poor, droughty soils, and by severe frost pocket effects (Franklin and Dyrness 1988; also see Godfree 2000 for experimental evidence of frost pockets across the study site), and these effects probably limit the number of species that exist in any particular location much more strongly than variation in stand structure. The clear importance of topographic position in the structural models used to predict understory species richness supports these conclusions.

One very important finding of this study is that many of the effects of *A. americanum* on the populations dynamics and canopy structure of *P. contorta* stands are not unique. For instance, any factor which reduces the density of the dominant *P. contorta* size class (such as larger *P. ponderosa* and *P. contorta*) will affect the overall stand structure in much the same way as *A. americanum*, because many of the important stand-level effects of *A. americanum* appear to be associated with increased mortality and growth reduction of infected dominant trees. Furthermore, many of the effects of infection on tree crown shape do not appear unique to the parasite: stand density influences tree LCR, soil conditions, disease and crowding influence tree height, and so on (see Godfree 2000 for complete discussion of the effects of infection on crown architecture). One exception to this is witches' broom formation, which structurally appears to be a unique feature of infected stands (although simulation brooms and rust-induced brooms may be similar). Many of the effects of *A. americanum* on stand structure and understory composition also vary in both nature and significance according to a host of biotic and abiotic factors including tree assemblage, topographic position and soil type.

Despite these findings, however, *A. americanum* clearly has a strong influence on the structure of monospecific and mixed *P. contorta* forests in the area studied. Though many individual variables are not uniquely influenced by *A. americanum*, stands that contain high levels of infection appear to collectively differ from uninfected stands. For example, infected stands often contain abundant regeneration, large amounts of woody debris and needle cover on the forest floor, a high density of large standing snags, trees with large live crown ratios and witches' brooms, enhanced understory cover, and, under some circumstances, a high density of mature trees. Such conditions are unlikely to be found in any single uninfected stand. Furthermore, due to the patchy nature of infection, a great variety and diversity of conditions may all occur within a small geographic area. I therefore suggest that *A. americanum* is an important factor in producing structural diversity in *P. contorta* forests, and that the most diverse systems will contain stands representing a range of infection levels.

Finally, the stand-level effects of *A. americanum* were limited by the degree of dominance of *P. contorta* in the stand. In pure or relatively pure stands, the influence of the parasite can be large, and this ultimately can be attributed to the relatively severe pathogenic effects of *A. americanum* on individual *P. contorta*. Since in this forest system many of the stand-level structural changes induced by infection appear to be mediated through changes in the population structure of the host, it appears reasonable to suggest that other dwarf mistletoes could also have a similar effect in different forest communities. I suggest that the role of a dwarf mistletoe species may be important when three main conditions are met: 1) the dwarf mistletoe is a severe pathogen of the host, 2) the host is the dominant tree species in the stand and 3) the population density or regeneration capacity of the host is not maintained at an unusually low level by other abiotic or biotic factors (inluding succession). Several other species of *Arceuthobium* (e.g., *A. douglasii* and *A. vaginatum*) appear to fill these criteria, and more research is needed to determine the importance of these as agents of chronic disturbance in conifer-dominated forest communities.

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Infection Of Roots Of Coastal Douglas-fir By *Phellinus weirii*

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Introduction

Phellinus weirii (Murr.) Gilbn. is a native basidiomycete that causes significant root disease of several conifer species in western North America. Coastal Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) is the most economically important host of the fungus (Thies and Sturrock 1995).

Infection by *P. weirii* starts when healthy roots of susceptible tree species contact infected stumps or roots (i.e., residual inoculum) left from a previous stand. The fungus has an ectotrophic growth habit (Garrett 1956) that sees it grow along the bark surface of inoculum source roots onto the bark surface of susceptible host roots. *Phellinus weirii* eventually penetrates bark and cambial tissues of colonized roots to grow endotrophically and decay wood tissues.

Details on the infection process of *P. weirii* are sparse. It is believed that the rapid ectotrophic spread of *P. weirii* enables it to 'find' and utilize existing infection courts such as bark abrasions, wounds, and small diameter feeder roots although it appears able to penetrate intact, injured bark (Wallis and Reynolds 1962).

Recently, Sturrock et al. (2000) found evidence of genetically-based resistance of coastal Douglas-fir to *P. weirii*. It has been suggested that trees showing tolerance to the fungus are those able to compensate for killed roots by producing callus tissue and adventitious roots, or those able to confine the fungus to a butt decay through the production of mechanical or chemical defenses.

To confirm these or determine other possible resistance mechanisms, we need a better understanding of the host-pathogen interaction between Douglas-fir and *P. weirii*, including the infection process of the fungus. The purpose of this study was to document the stages of *P. weirii* infection and response of host roots over a one year period following inoculation of coastal Douglas-fir roots with the fungus.

Materials and Methods

Healthy, 27-year-old coastal Douglas-fir trees were identified at the north end of Cowichan Lake, situated within the Coastal Western Hemlock biogeoclimatic zone (Green and Klinka 1994). The trees were originally planted as 2-year-old bareroot stock at a 2.5 m spacing. Following partial excavation, the roots of sixty trees were inoculated with *P. weirii* isolate PFC-Pw581 in March 1999 using a technique developed by Sturrock and Reynolds (1998). Briefly, a *P. weirii* inoculum unit, comprised of a *P. weirii*-colonized block of red alder into which was inserted a Douglas-fir branch segment (needles removed), was placed in direct contact with individual roots. Two primary lateral roots per tree were inoculated with one unit per root at a distance at least 30 cm from the bole. Minimum root diameter for inoculated roots was 1.0 cm. The excavated soil was then replaced over the units and exposed roots.

Following placement of inoculum units (aka inoculation), portions of inoculated roots of five randomly chosen trees were excavated once a month for 12 months (mid-April 1999 to mid-March 2000) using trowels and pulaskis. Before root pieces were removed from the soil the maximum linear extent of ectotrophic mycelium both proximal and distal to the inoculation point (i.e., the point where the inoculum unit contacted root bark) was noted visually and the inoculation point was marked with a pushpin. This section of root with ectotrophic mycelium plus an additional 5 to 10 cm at both ends were cut from trees with loppers, a swede saw, or a chainsaw for large diameter roots. After root pieces were removed from the soil the maximum linear extent of ectomycelium was also marked with pushpins. Root pieces were then labelled by tree number, wrapped in newspaper and returned to the Pacific Forestry Centre for storage at 4ºC.

Prior to assessment in the laboratory, each root piece was lightly rinsed with water to remove excess soil and other debris and then patted dry with paper towels. The total linear extent of ectotrophic mycelium (= ectomycelium) as marked in the field with pushpins was then confirmed and pins adjusted, if necessary, by inspection of the root surface with a dissecting microscope for the presence of diagnostic setal hyphae. Values for total linear extent of ectomycelium were recorded for each piece of excavated root and used later to calculate both the surface area of each piece available to be colonized by the fungus and the surface area actually colonized.

Next, each piece of excavated root was cut cross sectionally into 5 cm segments with a bandsaw, beginning at the inoculation point and ending at the maximum proximal extent of ectomycelium and at the maximum distal extent of ectomycelium. The proximal and distal end of each 5 cm segment was marked and segments were numbered. For example, 5 cm segments distal to the inoculation point were labelled consecutively as D1, D2, etc.; 5 cm segments proximal to the inoculation point were labelled as P1, P2, etc. Ends were painted with a solution of 5% ascorbic acid to delay oxidation and each end was examined for evidence of discolored bark and wood tissues. Segments with this evidence were photographed and subsequently sampled for histological work-up (see below). Mean diameter at the proximal and distal end of each segment was measured with digital calipers. Bark was then peeled away from each segment with a scalpel and the exposed xylem surface was assessed for evidence of *P. weirii* infection including stain and setal hyphae and production of resin or callus tissue, or both, by the host. For each root piece, the area of this zone of infection was measured and recorded and used later to calculate the total surface area of exposed xylem with evidence of *P. weirii* infection. These zones of infection were classified as lesions. Lesions are defined here as localized areas of diseased or disordered tissue (Federation of British Plant Pathologists 1973). Numbers and locations of lesions were also recorded.

The ends of each segment were then assessed visually for evidence of stain caused by *P. weirii* infection. Segments with stain or those suspected to be infected by *P. weirii* were incubated for two to five days in a plastic container with moist paper towelling. Infection by the fungus was confirmed by the presence of typical reddish-brown, wiry setal hyphae in incubated wood. The volume of wood in each segment infected by *P. weirii* was measured and recorded and then totalled for each piece of excavated root.

Histology

Segments with suspected evidence of *P. weirii* infection, including stain and disrupted tissues, were sampled for histological investigation. A 1 cm^3 piece of affected tissue was removed from a segment with a coping saw and razor blades and placed in FAA (formalin, acetic acid and ethanol) for 48 hrs and then transferred to 70% ethanol. Samples then went through an alcohol dehydration series, followed by paraffin embedding. Embedded samples (blocks) were then mounted on microtome stubs. Next, the block faces were opened and placed into a 50:50 mixture of Mollifex and ethylene glycol for 24 - 48 hrs to facilitate softening of tissues. Finally, samples were sectioned, mounted, and stained with 10% picroaniline blue and 1% safranin red. Sections were viewed with a compound microscope using bright field and phase contrast illumination.

Results

Three of the 120 *P. weirii* inoculum units used to try to initiate infection of selected roots in this study failed (i.e., had no evidence of viable *P. weirii* when excavated). For roots successfully inoculated with viable units, colonization of root surfaces by *P. weirii* was first evident in April 1999, one month after the units were placed. For the 10 root portions sampled in April, mean total linear extension of ectomycelium was 4 cm (Table 1). For these same 10 root pieces, the mean percentage of available bark surface area actually colonized by the fungus was about 11%. There was no evidence of *P. weirii* infection on the xylem surface of roots sampled in April, although staining patterns in histological slides indicated some changes to host tissues but without any host defense response, consistent with host dormancy in April.

For root portions sampled in June, mean total linear extension of the fungus was 16 cm (Table 1) and mean percentage of available bark surface area actually colonized by the fungus was about 30%. Again, there was no evidence of *P. weirii* infection on the surface of exposed xylem of roots sampled this month.

By July 1999, four months after placement of inoculum units, there was evidence of *P. weirii* infection on both the surface and in deeper xylem tissues of six of the ten root pieces sampled. Mean percentage of surface area of xylem with *P. weirii*-caused stain and callus tissue or resin was about 5% (Figure 1). The number of lesions occurring on each of the six root pieces ranged from one to four. All lesions occurred within the D1 – D3 and P1 – P3 segments, i.e., 5 - 15 cm proximal and distal to the inoculation point (Table 2). The mean percent volume of sampled root with endotrophic growth of the fungus was about 10%.

Mean percentage of root piece bark surface area actually colonized by ectomycelium was about 80%. Mean total linear extension of the fungus was 16 cm, the same as for June.

Table 1. Mean linear growth (cm) of ectotrophic mycelium of *Phellinus weirii* on roots of coastal Douglas-fir inoculated with the fungus; n = number of roots with viable inoculum units.

Sample Month	Mean linear growth in cm	Sample Month	Mean linear growth in cm
April 1999	4 (n=10)	October	35 (n=10)
May	11 (n=10)	November	35 (n=10)
June	16 (n=9)	December	37 (n=10)
July	16 (n=10)	January 2000	38 (n=9)
August	26 (n=10)	February	32 (n=10)
September	35 (n=10)	March	33 (n=9)

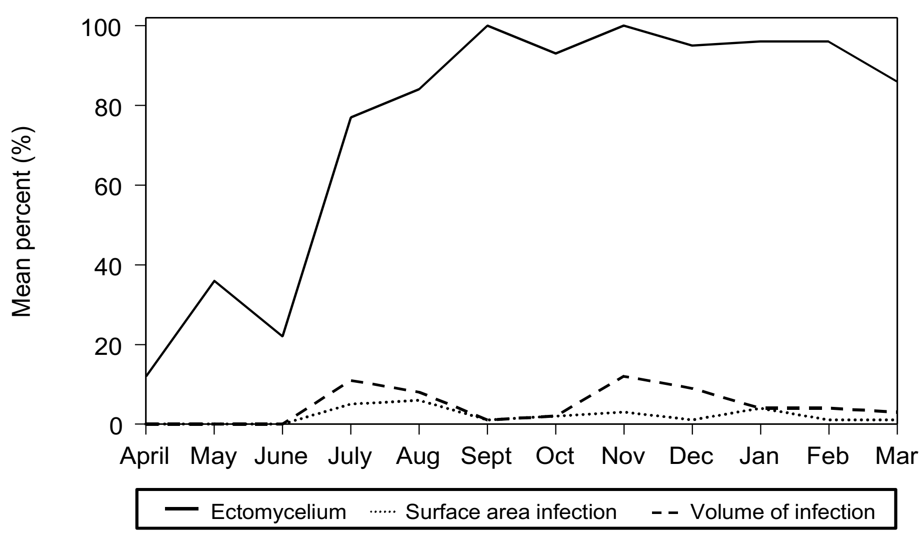

Figure 1. Graph showing three aspects of *P. weirii* infection of coastal Douglas-fir roots inoculated with the fungus. For each monthly sample of roots, mean percentage of: 1) bark surface area colonized by ectotrophic mycelium (ectomycelium), 2) surface area of xylem with evidence of *P. weirii* infection (e.g., stain, setal hyphae, callus tissue, resin), and 3) volume of root piece xylem with stain and/or more advanced decay.

After the July 1999 sampling and up to and including the February 2000 sampling, the mean monthly percentage of available root piece bark surface area actually colonized by ectomycelium fluctuated between 90 and 100%. Mean total linear extension of the fungus was 26 cm in August 1999 and 32 cm in February 2000. In general, evidence of *P. weirii* infection continued to be found on both surface and in deeper xylem tissues during this seven month period, with mean percentage levels of affected tissues never going above 5% for the xylem surface area and 10% for volume of infected xylem (Figure 1). The mean number of lesions found on infected roots each month fluctuated (Table 3). For example, there was a mean of two lesions per infected root from the August sample (Table 4), three lesions per infected root from November roots (Table 5) and a mean of one lesion per infected root from roots collected in December 1999 (Table 6). In most cases, one or more lesions occurred close to the inoculation point, i.e., within the D1 or P1 segments or both. By the end of sampling in March 2000, lesions had been recorded at a maximum distance of 15 cm distal to the inoculation point on several infected roots and 25 cm proximal to the inoculation point on one root sampled in January 2000.

For the final roots sampled in March 2000, mean total linear extension of the fungus was 33 cm and mean percentage of root piece bark surface area with ectomycelium was about 85%, down slightly from the July 1999 – February 2000 sample period. Levels of *P. weirii* infection evident both on the surface of exposed xylem and in deeper xylem tissues were also somewhat lower than in preceding months.

Table 2. Location of lesions caused by *P. weirii* on roots of coastal Douglas-fir inoculated with the fungus: roots sampled in July 1999. Root segments are 5 cm long. Segments distal (D) and proximal (P) to the inoculation point (indicated by arrow at bottom of table) are labelled D1, D2, etc. and P1, P2, etc., respectively.

Root No.	**ROOT SEGMENT**								**Total # lesions**
	D4	**D3**	**D2**	**D1**	**P1**	**P2**	**P3**	**P4**	
1				X					1
2				X		X			2
3					X	X			2
4					X		X		2
5			X	X	X	X	X		4
6						X			1

↑Location where inoculum unit was placed.

Table 3. Mean number of lesions per root on roots of coastal Douglas-fir inoculated with *P. weirii;* n = number of roots with lesions.

Sample Month	**Mean # lesions/root**	**Sample Month**	**Mean # lesions/root**
April 1999	nil	October	1 (n=6)
May	nil	November	3 (n=8)
June	nil	December	1 (n=7)
July	2 (n=6)	January 2000	2 (n=8)
August	2 (n=5)	February	2 (n=8)
September	1 (n=5)	March	2 (n=2)

Table 4. Location of lesions caused by *P. weirii* on roots of coastal Douglas-fir inoculated with the fungus: roots sampled in August 1999. Root segments are 5 cm long. Segments distal (D) and proximal (P) to the inoculation point (indicated by arrow at bottom of table) are labelled D1, D2, etc. and P1, P2, etc., respectively.

Root No.	**ROOT SEGMENT**								**Total # lesions**
	D4	**D3**	**D2**	**D1**	**P1**	**P2**	**P3**	**P4**	
1				X	X		X	X	2
2		X	X	X	X	X			3
3				X	X				1
4			X	X	X	X	X	X	3
5					X	X	X		1

↑Location where inoculum unit was placed.

Table 5. Location of lesions caused by *P. weirii* on roots of coastal Douglas-fir inoculated with the fungus: roots sampled in November 1999. Root segments are 5 cm long. Segments distal (D) and proximal (P) to the inoculation point (indicated by arrow at bottom of table) are labelled D1, D2, etc. and P1, P2, etc., respectively.

Root No.	**ROOT SEGMENT**								**Total # lesions**
	D4	**D3**	**D2**	**D1**	**P1**	**P2**	**P3**	**P4**	
1				X	X		X		4
2				X	X	X			1
3					X	X			2
4				X	X	X			3
5		X	X	X	X	X			2
6					X	X	X	X	4
7			X	X					2
8				X	X	X			2

↑Location where inoculum unit was placed.

Table 6. Location of lesions caused by *P. weirii* on roots of coastal Douglas-fir inoculated with the fungus: roots sampled in December 1999. Root segments are 5 cm long. Segments distal (D) and proximal (P) to the inoculation point (indicated by arrow at bottom of table) are labelled D1, D2, etc. and P1, P2, etc., respectively.

Root No.	**ROOT SEGMENT**								**Total # lesions**
	D4	**D3**	**D2**	**D1**	**P1**	**P2**	**P3**	**P4**	
1			X	X					1
2							X	X	1
3					X	X	X		1
4						X	X		1
5						X			1
6					X				1
7						X			1

↑Location where inoculum unit was placed.

Histology

A summary of results from histological sections is provided in Table 7. The first host response noted was early necrophylactic periderm (NP) formation in some sections prepared from tissues collected/sampled two months after inoculation, in May 1999. By July 1999, NP formation was typical in infected roots although it was usually overcome or circumvented with subsequent kill of phloem, vascular cambium and xylem tissues in sections of affected roots. This pattern of infection and host response carried on through September 1999 sampling after which host dormancy precluded any significant host response. The fungus remained active throughout the entire sampling period (Figure 2).

Table 7. Summary of results for histological slides prepared from roots of coastal Douglas-fir inoculated with *P. weirii*.

Sample Month (s)	Comments
April 1999	• No evidence of *P. weirii* penetration. • Host dormant.
May 1999	• Some evidence of *P. weirii* colonization of outer phellem. • Host response = early stages of necrophylactic periderm (NP) formation.
June 1999	• Evidence of increased frequency of affected bark tissue indicating ongoing infection by *P. weirii*.
July 1999	• More advanced symptoms than June, with frequent killing of phloem and vascular cambium and penetration of xylem in sectors of affected roots. • Host response = weak attempts at NP formation that were overcome or circumvented by fungus growing into xylem.
August – September 1999	• Patterns of tissue change indicate ongoing attempts by roots to wall-off affected tissue and replace lost tissue by callusing.
October 1999 – March 2000	• Host dormant. • *P. weirii* alive in affected xylem.

Discussion

Following artificial inoculation of roots of coastal Douglas-fir with *P. weirii* in March 1999, the fungus began colonization of host root bark within one month. Ectotrophic growth continued over a twelve month study period, with an exponential increase occurring during the period between June and September 1999 sampling. For root pieces sampled in June, mean total linear extension of the fungus was 16 cm; mean percentage of available bark surface area actually colonized by *P. weirii* was 30%. For root pieces collected in September 1999, mean total linear extent of ectomycelium and mean percentage of available bark surface area actually colonized by *P. weirii* were 35 cm and 100%, respectively. For root pieces sampled in the subsequent 6 months (Oct. 1999 –

March 2000), maximum mean total linear extension of the fungus was 38 cm and mean percentage of available bark surface area colonized by *P. weirii* was around 95%.

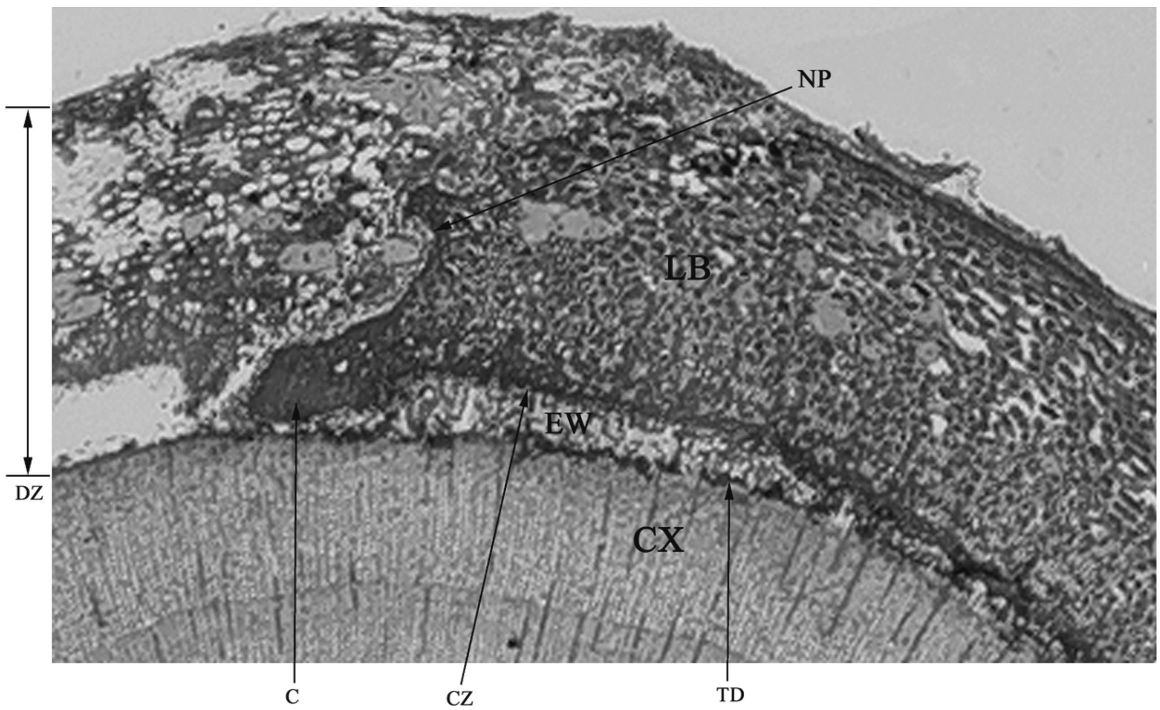

Figure 2. A cross section of a Douglas-fir root inoculated with *P. weirii* in March 1999 and sampled in February 2000. There was localized rapid invasion and death of a region of the bark (DZ) including the vascular cambium prior to the resumption of vascular cambium activity. With the breaking of dormancy, a necrophylactic periderm (NP) formed separating dead and living bark tissue. Callusing (C) was also initiated and with renewed vascular cambial activity, traumatic resin ducts (TD) and early wood (EW) was formed. The fungus heavily colonized the pre-existing xylem (CX; 1998 and earlier). Cambial activity ceased in mid-season and the early wood formed was often filled with ergastic substances. The cambial zone (CZ) was dead at the time of sampling although the external bark tissue remained alive.

Phellinus weirii exemplifies the ectotrophic growth habit, the term used by Garrett (1956) to describe root-inhabiting fungi that exhibit a continuous external mycelial spread over the root systems of their host plants. Wallis and Reynolds (1962) cited ectotrophic mycelium advancing as far as 40 cm in one year along roots of Douglas-fir that they inoculated with the fungus. What is the advantage of this growth strategy? Garrett (1956) suggests that it allows the fungus to become established and subsequently invade host roots at a number of consecutive points; a strategy more likely to overwhelm or evade host resistance than an attack concentrated at one location on a root. Sampling of infected root pieces in this study utilized a novel approach, that of peeling bark and cambial tissues to allow assessment of host reaction and presence of *P. weirii* on the exposed xylem surface.

This sampling revealed the occurrence of lesions on many infected root pieces, particularly on those sampled from July 1999 onward. Lesions have more commonly been associated with *Armillaria*-infected roots than with roots infected by *P. weirii*. In this study, lesions were found close to the inoculation point and at one to several more locations on the majority of infected roots. These results suggest that *P. weirii* initiates and utilizes several points of entry along a susceptible host root; the tactical advantage of the fungus over the host that Garrett (1956) alluded to. Interestingly, not all lesions occurred consecutively along infected roots. For example, on one of the five root pieces with lesions collected in August 1999 there was a lesion in each of the D1 and P1 segments, no lesion in the P2 segment, and one in each of the P3 and P4 segments.

Others (Buckland et al. 1954, Wallis and Reynolds 1962, 1965, Wallis 1976) have suggested that the rapid ectotrophic spread of *P. weirii* enables it to 'find' and utilize existing infection courts such as bark abrasions, wounds, and small diameter feeder roots. The results of this study also support this suggestion. On roots with inadvertent excavation wounds or those with areas of thinned bark, such as where roots crossed but did not graft, there was frequently necrotic bark and stained wood tissues; evidence that *P. weirii* used these 'weak' spots to invade.

Despite the formation of callus tissue on 55 of the 117 Douglas-fir roots successfully inoculated with *P. weirii* in this study, the fungus did infect and begin decay in these roots. Over the year of sampling, the mean percentage of wood volume with incipient decay (stain) or more advanced decay for all sampled root pieces ranged from 0 – 10%, with maximum decay occurring in root pieces collected in July and November 1999. Over the same 12 months, for all root pieces the percentage of xylem surface area with evidence of *P. weirii* infection never went above 5%. These results suggest that lesions on the roots in this study restricted *P. weirii* spread in the cambium but not the xylem of infected roots. This finding may explain why the majority of trees infected by *P. weirii*, especially those older then 10 – 15 years, appear to die gradually; only a minority of trees infected by the fungus are killed quickly by it advancing in the cambial zone (Sinclair et al. 1987).

Histological sections also revealed that *P. weirii* penetrated bark, cambial, and xylem tissues and, despite the formation of necrophylactic periderms, killed vascular cambia. Also, the initiation of callus tissue was frequently observed but often it was overcome by the fungus. Sections from roots sampled in May 1999, just two months after inoculation, showed some evidence of *P. weirii* colonization of outer bark tissue and early stages of NP formation. Sections from roots sampled in June showed increased frequency of affected bark tissue. By July 1999, the fungus had penetrated deeper xylem tissues in several roots, almost as though 'forced' to because of host response/lesion formation at the xylem surface. This pattern of frequent but 'limited' infection was seen in roots sampled for the remainder of the 12 month study period.

One problem encountered during assessment of histological sections was our inability to easily distinguish between tissue disruption caused by *P. weirii* infection and that caused inadvertently when roots were excavated initially for inoculation or finally, for destructive sampling. It is possible that *P. weirii* colonization of some roots was facilitated by such wounding. This made it difficult to categorize stages of the *P. weirii* infection process and accompanying responses by host roots. This problem is recognized as a shortcoming of using artificial inoculation to study and describe the infection process of a fungus but one which is outweighed by the benefits of such a technique.

Finally, the inoculum potential of the inoculum units used in this study was clearly enough to initiate infection of small and large-diameter roots, although it is not known if this infection would be sustained and continued over a period longer than 12 months. A second study like this one has been initiated, but roots will be sampled for a total of 18 months. To facilitate interpretation of observed infection stages and host responses, especially for histological sections, even greater care will be taken to reduce root wounding and bruising during excavation for this second study.

Acknowledgement

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A Survey Of Northern Spotted Owl Nests On The Applegate Ranger District And Ashland Resource Area Of Southwest Oregon

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Introduction

This survey was done to provide forest managers on the Applegate Ranger District, Rogue River National Forest and the Siskiyou Mountains portion of the Ashland Resource Area, Medford District, Bureau of Land Management with information about northern spotted owl nests in Douglas-fir dwarf mistletoe brooms.

In parts of southwest Oregon the northern spotted owl (*Strix occidentalis* var *caurina*) commonly nests in Douglas-fir dwarf mistletoe brooms. On the Applegate Ranger District of the Rogue River National Forest approximately 90 percent of the known spotted owl nests are in Douglas-fir dwarf mistletoe brooms. Local forest managers needed a better understanding of the owls' use of brooms to plan management of surrounding forests to ensure suitable nesting habitat and maintain vigorous stands at the same time.

In 1997 the Rogue River National Forest provided funds for a survey of spotted owl nest sites. The objectives of the survey were to collect information about Douglas-fir dwarf mistletoe infection around the nests, the dwarf mistletoe brooms and platforms in the brooms, and characteristics of the nests, the nest trees and the surrounding stands.

Methods

We randomly selected 35 nest sites from a list of known spotted owl nests in Douglas-fir dwarf mistletoe brooms on the Applegate Ranger District of the Rogue River National Forest and on adjacent land in the Ashland Resource Area of the Medford District, Bureau of Land Management. At each site we defined the nest stand as the 20 acres of suitable habitat immediately surrounding the nest. We delineated the boundaries of these stands using aerial photographs.

Data was collected at several levels in each nest stand. At each of the 35 nest trees, we collected data on the nest tree, the nest broom and any other brooms in the nest tree. We then selected 11 of the nest stands for more intensive data collection. We located ten variable radius plots in a grid in each stand, including one plot around the nest tree. At each plot we tallied "in" trees by species and measured the diameter of all live Douglas-fir trees and the level of Douglas-fir dwarf mistletoe infection. We also collected information about site and stand conditions at each plot. We used Tinnin's modification of Hawksworth's six-class dwarf mistletoe rating system to quantify the Douglas-fir dwarf mistletoe infection (Tinnin 1998).

Results

Douglas-fir Dwarf Mistletoe Infection Levels

Broom Volume Ratings (BVR) of the nest trees ranged from one to six. The average BVR of the nest trees was 2.94. This indicates that on average just about half the nest trees' crowns were occupied by brooms. Sixty-eight percent of the other Douglas-fir trees in the nest plots were also infected. Broom Volume Index (BVI, the average BVR of <u>infected</u> Douglas-fir) of these trees was 2.68, indicating that on average one third to one half the crowns of the other Douglas-fir trees in the nest plots were occupied by brooms.

On average, the nest plots had more infection and more intense infection compared to the non-nest plots (Table 1). This was partly because 48 percent of the non-nest plots had no infection. However, nest plots had higher BVR and BVI values even when the comparison included only the non-nest plots that had infected trees. BVI of Douglas-fir trees in the non-nest plots was 1.80, indicating that on average less than one third of the crowns of infected Douglas-fir in the non-nest plots were occupied by brooms.

Table 1.	Average BVR	BVI	Percent Douglas-fir trees infected
Nest plots	1.95	2.71	72
All non-nest plots	0.27	1.73	15
Non-nest plots with infected Douglas-fir	0.48	1.80	64

Stands

In ten of the eleven stands at least 40 percent of the plots had some level of Douglas-fir dwarf mistletoe infection. There was great variation among the stands in the percentage of Douglas-fir trees infected. However, the overall average was 28 percent. In nine of the eleven stands the average BVI was less than three, indicating that in most of the stands the majority of infected trees had less than half their crowns occupied by brooms.

Brooms

We characterized the brooms using a system developed by Tinnin and Knutson (1985). They classified Douglas-fir dwarf mistletoe brooms into three types based on their structure and point of origin on the hots tree. Type 1 brooms originate out on branches. They are limited in size by their weight. Type 2 brooms originate within a few feet of the bole. The supporting limb is greatly thinkened and often turns upwards. Type 3 brooms originate on the bole, creating a dense profusion of branches. Both Type 2 and 3 brooms can become very large. We found that the majority of nests were in Type 3 brooms, which were otherwise quite rare in the nest trees (Figure 1). Type 2 brooms had the next highest rate of use and occurrence. Type 1 brooms contained the fewest nests even though they were by far the most common type of broom.

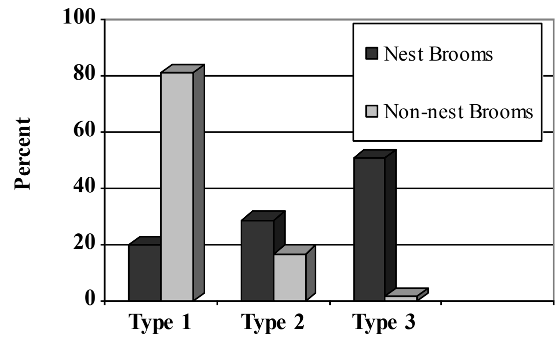

Figure 1.

Fifty-seven percent of the nest brooms were in the lower third of the nest trees' crowns. Forty percent were in the middle third. Only three percent were in the upper third. Similarly, 56 percent of non-nest brooms were in the lower third, 34 percent were in the middle third and ten percent were in the upper third of the nest trees' crowns.

Table 2.	Platform volume (ft^3)	
	Type 2	Type 3
Nest brooms	10.6	31.9
Non-nest brooms	1.7	11.6

Platforms in Type 2 and 3 brooms with nests were larger than platforms of the same type in non-nest brooms (Table 2). Type 3 brooms were the largest. Type 1 brooms weren't measured because it was difficult to see them clearly very far up in the crowns.

Site Characteristics

Thirty-one percent of the nest plots were on the lower third of the slope, 37 percent were on the middle third and 26 percent were on the upper third. Twenty, 54 and 22 percent of the non-nest plots respectively, were on the lower, middle and upper third of the slope. Six percent of nest plots and two percent of non-nest plots were in draws. None of the nest plots and only two percent of non-nest plots were on ridge tops. Most of the plots, both nest and non-nest, were on north or east aspects. Most had three or four canopy layers. Average basal area per acre was 239 ft^2 in nest plots and 260 ft^2 in non-nest plots. Hardwoods were plentiful, especially Pacific madrone. Nest plots had an average of 0.6 snags per acre; non-nest plots averaged 0.3 per acre.

Discussion

In general, the nest trees and Douglas-fir trees immediately around them in the nest plots were relatively heavily infected. The remaining non-nest plots were a mixture of uninfected and lightly infected trees. The majority of stands had one or two heavily infected plots. The nest plot was often, but not always the most heavily infected plot. On average, 40 percent of the plots had some level of infection. The majority of owl nests were in Type 2 and 3 brooms that were low in the tree crowns and had large platforms compared to the platforms in other brooms. The owls nested most often in trees on the middle and lower third of the slopes.

We used these results to make recommendations for managing infected stands for current and replacement spotted owl nest habitat in the survey area:

> Manage for several clumps of infected Douglas-fir covering one third to one half of a 20 acre nest stand. Ideally, current nest habitat might include one heavily infected clump having at least one Type 2 or Type 3 broom, and several lightly infected clumps.
>
> Select infected clumps for replacement habitat that have infections confined to the lower third of the tree crowns as much as possible and manage them to maintain it in the lower third as long as possible. This will create the least impact on tree vigor.
>
> Many nest trees and Douglas-fir trees in their immediate vicinity have half or more of their crowns occupied by brooms. Previous studies have shown that tree growth declines and mortality increases significantly once this level of infection is reached (Pierce 1960, Mathiasen et al. 1990, Filip et al. 1991). Douglas-fir trees with heavy infections are also vulnerable to crown fires (Hawksworth and Wiens 1996). Therefore, we recommended managing for replacement nest trees. One way to create replacement nest trees might be to open the canopy around selected large diameter, vigorous trees with low BVRs and a Type 2 or Type 3 broom. This would allow the brooms to increase in size without significant impacts on the early growth of the tree.
>
> Favor infected areas that are on the lower to middle third of the slope to minimize the rate of dwarf mistletoe spread from tree to tree through the stand.

This survey was a snapshot of the current status of spotted owl use of Douglas-fir dwarf mistletoe for nesting in one geographic area. Many questions remain, including how owls and their prey use Douglas-fir dwarf mistletoe brooms in the rest of their home range, how infected stands developed into suitable habitat, what will happen to these stands in the future and what the effects of silvicultural manipulation might be, both on the owls and the dwarf mistletoe.

Acknowledgements

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POSTERS

Rona Sturrock - Moderator

Hyperparasitic fungi of lodgepole pine dwarf mistletoe

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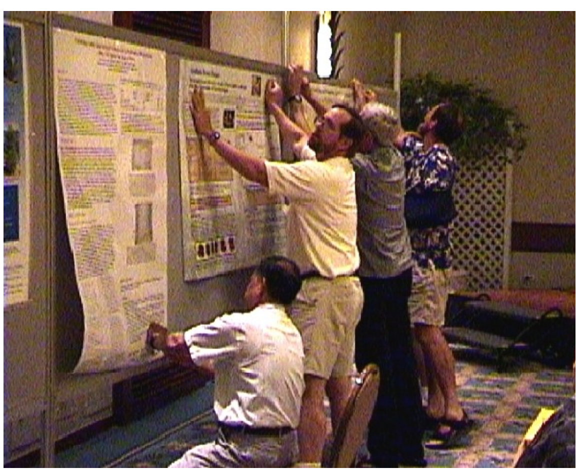
(presented at the 1999 WIFDWC, Breckenridge, CO)

Lodgepole pine dwarf mistletoe (*Arceuthobium americanum*) is a serious pest of lodgepole pine trees in British Columbia forests. The Forest Practices Code of 1996 legislated clear-cut size reduction, increased riparian reserves and a trend to partial cutting systems, which may promote dwarf mistletoe intensification. Biological control of lodgepole pine dwarf mistletoe is again being studied as an alternative to silvicultural manipulation. Diseased *A. americanum* was collected from the interior region of British Columbia during the summer of 1998. *Colletotrichum gloeosporioides* and *Caliciopsis arceuthobii*, which have been reported to parasitize dwarf mistletoe, were found in British Columbia. *C. gloeosporioides* was found to infect the shoots and fruit of *A. americanum* throughout the host geographic range, while *C. arceuthobii* was found to infect the female flowers within more limited geographic range. *Cylindrocarpon gillii* has been reported on *A. americanum*, but was not found in the survey of 1998. Current research is focused on the host-parasite interaction between *C. gloeosporioides* and *A. americanum*.



Impacts of Partial Cutting In Sub-Boreal Spruce Forests On Stand Structure And Spread Of Tomentosus Root Disease

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Inonotus tomentosus is an important agent of gap formation in mature sub-boreal forests of British Columbia. It also causes reductions in timber volume, which may be exacerbated by partial cut systems. To quantify mortality rates and stand dynamics that result from tomentosus root disease infection, and from partial cutting, four stand types were sampled: old growth (unharvested) regimens with and without tomentosus, and partial cut regimens (1952-54) with and without tomentosus. Disturbance chronologies indicate that tomentosus contributes to low-intensity disturbance, but does not significantly increase spruce mortality. Partial cutting did not significantly affect spread rates of the disease, but spruce volumes in infected partial cut stands were lower than uninfected stands. Old-growth forests are undergoing a compositional shift to fir-dominated forests, whereas partial cut stands are maintaining a higher relative density of spruce. In particular, partial cut stands without tomentosus have an increased transition probability for spruce.




Aerial Digital Sketchmapping

Forrest L. Oliveria and Charlie Schrader-Patton

Sketchmapping has been used as a method of recording infestation, defoliation, and mortality caused by insects or diseases, fire damage, and numerous other applications that can be detected and surveyed from an aircraft. Aerial detection of defoliation, dying, and or dead trees is the primary method of infestation detection. Early and accurate detection of SPB infestations is vital for implementing timely suppression measures and reducing adverse impacts. The major shortcomings of traditional aerial sketchmapping have been; (1) keeping the observers from getting lost over the landscape being sketchmapped (2) sketched features can be inaccurate, since the sketchmapper must juggle numerous maps in the cockpit and (3) the large amount of time and expense needed to interpret and digitize the points and polygons and features.

The digital aerial sketchmapping system discussed here uses a combination of currently available technologies. An existing off the shelf software package, GeoLink PowerMap® by Micheal Baker GeoReseach, Inc., of Billings, MT, has been customized to address the special needs of this application. The software is installed on a laptop or PC104 portable computer that is connected to a global positioning system and a touch sensitive monitor.

The system keeps the surveyor positioned on a moving map background with an airplane icon. The displays can be created using any geo-referenced image (tiff, jpeg, DRG, etc). The map display automatically updates as the plane flies over different territory. The aerial surveyor has the capability of entering point or polygon (including nested polygons) data and attributes about each feature by touching the touch sensitive monitor. After the mission the sketched features are translated into the appropriate format and copied onto a floppy diskette for transfer to a GIS. The resulting geo-reference maps are used with GPS units to navigate to the sketchmapped feature. The ground checkers can then verify causation, mark boundaries, assign treatment priorities, calculate current and expected losses, and assign treatment method.

Although the digital sketchmapping system is still being improved to address the special needs of the users, the project has made significant advances toward a system that is a tremendous leap forward for aerial sketchmappers. This system allows the sketchmapper to spend more time with their eyes looking at the landscape rather that at a notebook or stack of maps or photographs.

White Pine Blister Rust Infection And Mortality In Sugar Pine: Results Through Age 15

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Introduction

White pine blister rust (WPBR) caused by the fungus *Cronartium ribicola* was introduced to western North America in 1910 (Mielke, 1943). Since that time, it has spread throughout much of the range of sugar pine (*Pinus lambertiana*), causing widespread mortality. A very low frequency of natural resistance has made the management of sugar pine difficult. Screening and breeding for WPBR resistance by the USDA Forest Service and USDI Bureau of Land Management began nearly 45 years ago. This cooperative program has yielded seed from families with varying levels and types of resistance, most notably a single dominant gene conferring immunity to most strains of WPBR. This major gene resistance (MGR) (Kinloch, et al., 1970) produces a hypersensitive reaction that prevents the disease from becoming established in the host tissue. The discovery of a strain of WPBR that is capable of overcoming MGR (Kinloch and Comstock, 1981) illustrates the danger of relying solely on a single gene mechanism for resistance. The availability of sugar pine stock with various single- and multi-gene WPBR resistance mechanisms, combined with the appropriate site choice and silvicultural treatments, may make sugar pine a viable choice for reforestation in areas where it was once an integral part of the ecosystem.

Materials And Methods

- Six sites.
- 53 families from open-pollinated, phenotypically resistant wild trees screened for WPBR resistance in the early 1970's; 6 with major gene resistance (MGR), 25 non-MGR families common across all 6 sites.
- 2 sets, 4 blocks/set, 10 seedlings/block.
- Randomized complete block design, 10 tree row-plots[1] at 8' x 8' spacing.
- Measured at 5, 10, and 15 years.
- Height, presence & location of infection, cause & severity of damage recorded.
- In 1996-97 at age 15, # of cankers/tree, and height of highest canker recorded.

[1]Poker planted in random non-contiguous single-tree plots.

Results

- Blister rust infection varied significantly by site at all ages, with the widest spread in site means being at age 10 (15.9 to 95.0%).
- Infection percentage on all sites increased dramatically between age 10 and 15.
- Over all six sites 68.9% of all non-MGR trees were clean at age 5. This dropped to 48.3% by age 10 and to only 8.9% at age 15.
- Infection levels at age 15 for 6 families known to have MGR lie within the expected range of 50% on 5 of the 6 sites.
- Mean infection percentage at age 15 was 47.8 for MGR and 91.6% for non-MGR families with a range of 77.7 to 99.1%.
- Mean number of cankers per tree on all living, infected, non-MGR trees varied widely by site from 2.3 to 11.9, although due to high mortality on some sites, these means are based on widely differing numbers of trees/site.
- Mean height of the highest canker ranges from 59.8 to 144.5cm with 88% of all cankers below 2.0 meters.
- Mortality percentage at age 15 ranged from 41.2 to 91.2 %
- Mean mortality percentage at age 15 was 38.7 for MGR and 63.0% for non-MGR families respectively.
- Some trees have survived because lateral branches took over after the leader was killed by a canker, resulting however, in severe forking.

Discussion And Conclusions

- It is encouraging that except for the Hayes and Rocky plantations (which had "high" hazard ratings), mortality % is much lower than infection % and to date, there is no evidence of the presence of a virulent strain of rust on these sites.
- At young ages, repeated pruning of lower branches could be effective in reducing the probability of an infection on a branch becoming lethal. Pruning may be essential for providing adequate sugar pine stocking on higher hazard sites.
- On sites of comparable rust hazard rating, without pruning approximately 50% of the trees in MGR families would be expected to remain uninfected, while only 25% or less of the trees in the non-MGR families would be expected to remain uninfected.
- A recent visit to 4 of the 6 sites showed little new infection or recent mortality. The potential impacts of future infections higher in the crown will be smaller, and resistance mechanisms such as bark reaction and tolerance are operating.
- The viability of planting sugar pine in southwest Oregon will depend on several factors, including rust hazard, effectiveness of silvicultural treatments, type and durability of resistance, and the development of virulence in the rust population.

Acknowledgements

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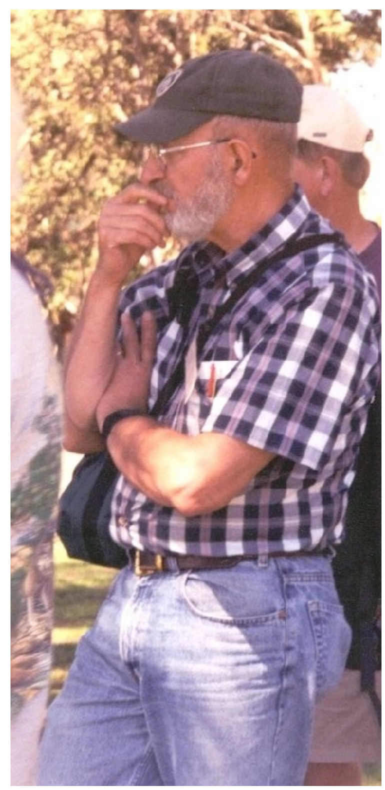

Breeding For Durable Resistance To *Phytophthora lateralis* In *Chamaecyparis lawsoniana*: Early Assessment

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Introduction

Port-Orford-cedar (*Chamaecyparis lawsoniana*) is an important component of the forest ecosystem in southwest Oregon and northwest California. It is also a valuable species for wood and bough production in these areas, and horticulturally (often referred to as Lawson cypress) it has been planted worldwide. With the advent of the introduced root rot disease caused by *Phytophthora lateralis*, the horticultural use of Port-Orford-cedar has been almost eliminated in the Pacific Northwest U.S., and its use in reforestation or restoration plantings has been minimal. This poster examines the progress in breeding for resistance and some questions to resolve in the future.

Phytophthora lateralis continues to spread within the range of Port-Orford-cedar, adversely affecting the ecosystems in which it occurs. Management activities to slow or stop the progression of the disease have been initiated, and a program to breed resistant populations of Port-Orford-cedar has begun. The USDA Forest Service and USDI Bureau of Land Management in conjunction with Oregon State University, have been actively examining the potential to develop durable genetic resistance to *P. lateralis*. Most of the tree selections to-date have been on USDA Forest Service and USDI Bureau of Land Management lands, but many non-federal landowners have also participated.

Phytophthora lateralis

P. lateralis is the pathogen responsible for the most serious disease of Port-Orford-cedar. The disease begins in the fine roots, and grows up the roots and into the tree, evident by an advancing margin of red-brown necrotic phloem near the root collar, before foliage begins to dry (Hansen et al. 2000). The origin of P. lateralis is unknown, but it appears to be an introduced pathogen. Several studies of P. lateralis indicate that it has very little genetic variability (McWilliams 2000), much lower variation than other Phytophthora species studied.

Breeding for Resistance

Based on earlier work indicating genetic variability in resistance to P. lateralis (Hansen et al. 1989, Sniezko et al. 1996), an operational screening program was initiated in 1997. Since then, over 9000 Port-Orford-cedar trees from throughout the native range of the species have been evaluated for resistance using a branch dip inoculation method. Rooted cuttings from the top candidates (~10% of all selections) are being used to confirm resistance of the top selections as well as to establish a breeding orchard.

This species lends itself well to a program of resistance breeding. Flower production can be stimulated on very young trees (Elliott and Sniezko 2000) and vegetative propagation by rooted cuttings is relatively simple. Control pollinations on earlier selections began in 1996 and the full-sib progenies are now undergoing resistance testing. Operational seed production from resistant parents can be accomplished within a few years in potted orchards.

Relatively few field trials have been established, but the results are encouraging (Sniezko et al. 2000). These plantings have demonstrated that rooted cuttings or open-pollinated seedlings from parents rated high for resistance have much higher survival than those of parents rated low for resistance with the stem dip or root dip screening tests. Most of the mortality in the field tests (the oldest test is now 11 years old) appears to occur in the first two years. Rooted cuttings from the most resistant parents have shown 50-80% survival in the field, while cuttings from nonresistant parents have generally shown 0-5% survival; open-pollinated seedlings from the most resistant parents have shown 25-50% survival versus 0-35% for other parents.

Preliminary results from trials initiated in 2000, show at least one parent that has very high resistance even when crossed with an array of other genotypes indicating a possible homozygous dominant for major gene resistance (unpublished data). Further testing in the next few years will likely show many more high resistant genotypes. Investigations into the mechanisms of resistance have just started.

Resistant Port-Orford-cedar can be used in restoration and reforestation plantings as well as in the horticultural industry. Wind-pollinated and controlled cross seed from the breeding orchard has been collected in limited quantities from a small number of resistant parents and can be made available. The number of resistant parent trees producing seed is expected to increase dramatically in the next few years as new information from validation tests using rooted cuttings becomes available. This will help ensure a broad genetic base for forest plantings. Studies of geographic variation in Port-Orford-cedar (Kitzmiller and Sniezko 2000) will be used to delineate breeding zones for the species.

Some questions to resolve for the future:

a) What resistance mechanisms are present in the Port-Orford-cedar and how are they inherited?
b) Is there any evidence of 'virulent' strains of Phytophthora lateralis?
c) Where did Phytophthora lateralis originate, and is it genetically more variable than known strains?
d) Why are some resistant genotypes susceptible only in the first year or so after planting?

e) Will resistant trees survive long-term under field conditions of high hazard?
f) What resistance mechanisms are present in other Chamaecyparis species?

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The Five Rivers Study: Opportunities To Study Forest Diseases In A Replicated, Landscape-Scale Ecosystem Experiment

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The Five Rivers Watershed

The Siuslaw National Forest is seeking to implement the Northwest Forest Plan on 32,000 acres in the Five Rivers watershed, 20 miles east of Waldport, Oregon. The watershed is 87% federal land; 50% has been intensively managed for timber production and is now in 5- to 50-year-old plantations, accessible by an extensive road network that is expensive to maintain. The Forest is using a landscape approach to meet Plan objectives: managing existing plantations to speed development of late-successional habitat; improving aquatic conservation by increasing large wood in streams, decreasing stream temperatures, and growing large conifers in riparian areas; producing timber on matrix-allocation lands; and applying adaptive management. Roads will be managed to maintain access, reduce maintenance costs (currently on 570 miles) and erosion, and to restore woody debris movement. The adaptive management objective, specified in the EIS, will be met by establishing a 16,000-acre management experiment that applies three pathways to four replicate, 1,300-acre roadsheds—areas encompassing branches of the road system. Roadsheds, rather than watersheds, are used because of the need to treat numerous plantations in a large area, and thus to access them by roads.

Design of the Five Rivers Management Experiment

Roadsheds were chosen for the study from a pool of potential areas after a similarity analysis. Pathways were assigned at random to each of four blocks with roadshed groups found most similar. The Siuslaw NF will monitor a wide range of stand, road, riparian, and stream conditions with fixed-plot stand, road, and stream exams. Funding and cooperators for supplemental research are being sought to study management-disturbance and biodiversity-heterogeneity interactions, understory species and road-management effects, and effectiveness of the planning model.

Management Pathways

The three pathways were all designed to meet Plan objectives but in very different ways. The **passive pathway** assumes existing plantations will develop old-growth characteristics through density-driven self-thinning and disturbances such as windthrow, diseases, and insect outbreaks. Roads will be closed by removing culverts and by adding waterbars and vehicle diversions. No woody debris will be added to associated streams. The **continuous pathway** reflects continuous access and traditional silviculture, by keeping the roads open, by distributing light thinning in time and space to increase growth of residual trees in plantations, and by adding wood to streams as needed. The **pulsed pathway**, in a short period, applies heavy thinning in plantations (to 40 residual trees/acre) and adds many logs to the streams, then closes the roads (like the passive pathway), but then reopens them 30 years later for another pulse.

Diseases as Disturbance Agents

Diseases are an important part of the forest ecosystem, likely to interact with management and other disturbances (e.g., insects, wind, snow, fire) to influence how well each pathway meets the Plan objectives in different parts of the landscape. Expected disease interactions can be compared with actual interactions to learn more about how diseases can be managed to better meet Plan objectives. For example, diseases affecting intermediate and suppressed trees may help to reduce tree density in plantations left unthinned, thus speeding development of old-growth habitat. Diseases that attack widely spaced residual trees may slow and reduce the extent of old-growth habitat development. Diseases are likely to interact differently with thinning, windthrow, insects, and woody debris treatments across the varied landforms, aspects, and soil conditions. A better understanding of these interactions can help shape future landscape management strategies. Diseases important in the Five Rivers watershed include:

Swiss Needle Cast. Caused by a fungus (thought to be native) that reduces growth in Douglas-fir trees and that may affect stand development. The current outbreak in the Oregon Coast Range appears to be spreading into the Five Rivers watershed.

Laminated Root Rot. The single most important disease in Five Rivers. The fungus attacks Douglas-fir roots especially, causing trees to topple easily. Effects on stand development (such as canopy gaps) and species composition are easily found.

Armillaria. A fungus that attacks stressed trees, especially in young plantations.

Annosus. A fungus that attacks damaged trees.

Western Hemlock Dwarf Mistletoe. Mistletoe is not common in Five Rivers because there are few hemlocks. As hemlocks are planted, this disease may become more important.

Opportunities to study the interactions of management pathways, disturbances, and diseases can be explored by contacting Bernard Bormann (541 750-7323; bbormann@fs.fed.us), Walt Thies (541 750-7408; wthies@fs.fed.us), or Paul Thomas (541) 563-3211; pgthomas@fs.fed)

Cloning and characterization of a defense responsive PR-10 gene in sugar pine

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Abstract

Pin m III, a protein isolated from western white pine (*Pinus monticola*), was previously correlated with increased frost hardiness. Its gene expression was inducible by winter temperatures and the white pine blister rust pathogen, *Cronartium ribicola* (Yu et al. 2000). *Pin l* I protein, a homologue of *Pin m* III from sugar pine (*Pinus lambertiana*), also increased during the winter months and was also up-regulated in foliage infected by white pine blister rust. To further characterize *Pin l* I, an expression cDNA library from poly(A)$^+$mRNA extracted from a pooled collection of resistant sugar pine needles 2 days to 6 weeks after inoculation with blister rust was screened with a digoxigenin labeled *Pin m* III probe. From this cDNA library, a 3'end partial cDNA was cloned and sequenced. Additionally, the RT-PCR fragment for the full length coding region was cloned and characterized. Sequence analysis indicated an open reading frame of 486 bases encoding a protein of 161 amino acids with a molecular mass of 18 kD and a predicted isoelectric point of 5.53. The deduced amino acid sequence showed highest homology (~95%) to *Pin m* III and was also similar to the intracellular pathogenesis-related (PR) protein from asparagus (~37% homology) and the major pollen allergen from white birch (~28% homology). These are members of the ribonuclease-like PR-10 family. Dot blot and Western blot analyses of needles collected from mid September to mid November showed that the *Pin l* I gene was expressed during cold acclimation, with the highest expression in the fall and winter months preceding the peak of protein accumulation. Southern analysis indicated a multiple gene family, which was confirmed by genomic PCR cloning of two of the gene family members.

White Pine Blister Rust in the Central Rocky Mountains: Time to Consider the Impacts

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White pine blister rust (WPBR) has long been an important element of North American forest management. Limber and whitebark pine infestations in Wyoming and Idaho continue to intensify and spread (Harris 1999, Smith and Hoffman 2000), recently moving into northern Colorado (Johnson and Jacobi 2000). However, little consideration has been given to the potential ecological and resource impacts of WPBR in the central Rocky Mountains and Intermountain West. Without basic impact information, efficient research priorities and management alternatives cannot be developed. Addressing these issues requires immediate, close cooperation between research and field staffs from several disciplines.

Currently, white pine blister rust infestations surround an uninfested core area of the central Rocky Mountains on all sides, and they continue to spread and intensify. No biological or geographic barriers exist to impede WPBR's continued spread into the Colorado Front Range. The isolated infestation in southwestern white pine in New Mexico's Sacramento Mountains (Conklin 1994) has spread north to new sites, and there is little reason to think its northward movement will not continue. Colorado imports of WPBR-infected pine horticultural nursery stock could create new infestation centers in mountain towns. There have been several confirmed instances of infested pine nursery stock being shipped into Colorado. There is concern that new WPBR genotypes may eventually spread into the area through Midwest and Great Plains urban and shelterbelt plantings of host pines, which could create more virulent strains of the organism (Hamelin and others 2000).

Historically, WPBR has impacted what were once some of the most valuable timber species in North America: eastern and western white pine and sugar pine. The susceptible pines of the Central Rocky Mountains, limber and bristlecone, (and whitebark on the northern edge of the region), have little value as a timber species. However, because of the habitats in which they grow and other characteristics of these species, widespread mortality can be expected to have significant resource impacts. Concerns stem from the role of these trees:

- As wildlife food sources and habitat;
- In high elevation watershed snow pack dynamics;
- As scenic and recreational area resources in heavily visited sites;
- As potential genetic resources for restoration and biotechnology;

- In other ecological processes, especially in harsh sites where limber and bristlecone pine are among the few well-adapted conifers.

Past and future human and non-human disturbances to these forest stands, as well as to the associated resources, may amplify WPBR effects on hosts trees, effected ecosystems, and impacted resources.

There is a host of questions concerning the ultimate range of WPBR in the central Rockies. The introduction of WPBR into less studied ecosystems poses some basic questions needing answers before the magnitude of potential ecological and resource impacts can be projected. For example:

Where are the susceptible pines? Their location outside of timber management areas, in remote areas, and as minor stand components, create difficulties in answering this basic question.

Which of these white pine habitats will be well suited to WPBR establishment? Given the lack of establishment of WPBR in bristlecone pine elsewhere in the West, some dry limber pine sites may not experience significant WPBR establishment. However, information is sparse about the microclimates in some of the high elevation, remote white pine habitats.

How will the distribution and types of local ribes species affect the spread of WPBR? Differences in ribes species' effectiveness as alternate hosts may be important, especially in more extreme sites.

Similar needs exist for WPBR and southwestern white pine (Geils 1993).

Recent survey findings for limber pine from the northern Rocky Mountains, and for multiple species in the Intermountain West, indicate high levels of infection may be possible through much of the currently uninfested range of white pines (Kendall and others 1996, Smith and Hoffman 2000).

Central Rocky Mountain limber and bristlecone pines, along with whitebark pine in northwestern Wyoming, generally exist as minor components in mixed species stands, or in harsh, dry sites ranging from grasslands to timberline. In contrast to the highly commercially-valued, once common, eastern and western white pine and sugar pine, they are relatively scarce, slow growing, and located in less accessible areas outside of timber production zones. The historic lack of a need to understand these species for timber management purposes limited their study until fairly recently. Thus, ecological information about these species and the sites they occupy is still meager, although several studies are in progress. Less information yet exists about the potential to manage trees on these sites. Efforts to better understand limber pine ecology will be vital in predicting the future of limber pine-WPBR interactions and the resource impacts that may result.

Intensive study of whitebark pine, prompted partially by the impact of WPBR-caused mortality on this important grizzly bear food source, has provided an improved basis for its restoration and management (for example: Schmidt and McDonald 1990, Kendall and Coen 1994, Tomback and others, in press). Individuals from several agencies and disciplines have cooperated to study whitebark pine and to address the impact of WPBR in northern Rocky Mountain ecosystems. These efforts serve as a model for how pathologists, ecologists, wildlife biologists and others might collaborate to better address white pine - WPBR impacts elsewhere.

To address the need for better information on WPBR impacts in limber pine, we have formed an informal working group to share information and coordinate studies. Participants include field and research pathologists, ecologists, foresters, and others from Colorado and Wyoming, and from multiple agencies and universities. Significant new and ongoing activities in the region include:

- Remeasurement of WPBR permanent (PTIPS) plots in Wyoming and South Dakota;
- A review of Colorado and Wyoming limber pine occurrence and stand and plot data sources for limber pine;
- Discussions with regulatory officials concerning options for addressing interstate importation of potentially infested nursery stock;
- Continuing support and testing of a WPBR impact simulation model linked to the Forest Service's Forest Vegetation Simulator (FVS);
- Limber pine physiology and ecological studies at sites in National Forests, Rocky Mountain National Park, Niwot Ridge and Shortgrass Steppe LTERs, and elsewhere;
- Coordination and information sharing sessions between participating pathologists, foresters, tree physiologists, ecologists, and others.

Proposed and potential working group activities include:

- Joint proposals for USDA and NSF competitive grants;
- Analysis for a landscape level hazard rating model;
- Organization of a cross disciplinary conference;
- Assessment of remote sensing options for finding and inventorying white pine populations;
- Expanded cross-disciplinary coordination with peers from outside the region.

The central Rocky Mountains will continue to be impacted by the spread and intensification of WPBR in its white pines. Resource managers, and the researchers and staff specialists who provide them information, have the benefit of nearly 100 years of WPBR research and experience from across the rest of the United States. Little time may remain to gather information on a wide range of ecosystems containing limber pine before they are permanently altered by this disease. Now is the time to consider the potential impacts. Impacts will vary by ecosystem, resource management goals, other disturbances, and management actions. Using this information to select and prioritize protection and mitigation measures while there are still options is certainly preferable to waiting until the only alternatives are limited restoration activities.

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Aerial surveys for Swiss Needle Cast in Western Oregon

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Introduction

In the last decade Swiss needle cast, caused by the native fungus *Phaeocryptopus gaeumanni*, has severely damaged Douglas-fir in the coast range of western Oregon. Trees damaged by Swiss needle cast have sparse transparent crowns and discolored foliage The primary impact of the pathogen on Douglas-fir (which is the only susceptible tree species) is premature loss of foliage which results in significant reduction in tree growth. Recent reduction in volume growth from Swiss needle cast in western Oregon likely exceeds 100 million board feet per year.

Aerial Survey Procedures

Since 1996, annual aerial surveys from a twin-engine plane have been employed to monitor the amount and distribution of damage. Flights were made in April and May at 1,500 to 2,000 feet above the terrain, following north-south lines separated by two miles. The surveys covered about 2.9 million acres of forest each year. Observers looked for areas of Douglas-fir forest with obvious yellow to yellow-brown foliage, a symptom of Swiss needle cast.   Patches of forest with these symptoms (the patches are referred to as polygons) were drawn onto 1:100,000 scale topographic maps. Sketch maps were digitized and the data analyzed using Arcview software.

Aerial Survey Results

After four years of surveys, we have little doubt that Swiss needle cast symptoms continue to intensify, especially in the northern half of the Coast range. In 1999, 295,000 acres of Douglas-fir forest had obvious symptoms of Swiss needle cast, which is an increase of 122,000 acres compared to the 1998 survey in the same area. Much of this increase represented new areas with damage, rather than enlargement of previously mapped areas. Obvious Swiss needle cast symptoms were detected as far as 30 miles inland from the coast, which is an increase over previous surveys. However, most areas with symptoms that can be detected from the air are within about 18 miles of the coast, and often within the sitka spruce vegetation zone. The widespread planting of Douglas-fir within this vegetation zone, which is characterized as having a climate favorable to Swiss needle cast, may be a contributing factor to the recent disease increase.

Two flights were made over the west slopes of the Cascade Range (more than 70 miles inland from the coast), and no obvious Swiss needle cast damage was observed. However, observations on the ground indicate that the disease is present and damaging in few locations.

Did We Map The Same Areas Each Year?

Often areas mapped with symptoms in one year were not detected the following year. When comparing the 1998 and 1999 surveys, about 55,000 acres were mapped in both years. In other words, about 31 percent of the acres mapped in 1998 also were mapped in 1999. When we superimposed the 1998 and 1999 maps, we found that 1,016 polygons overlapped and likely were attempts to map the same area of damaged forest. This represents about 50 percent of the polygons mapped in the 1998 survey. This may be due to timing of the survey (early or late), conditions at the time of the observation flight (clouds can affect color perception), changes in the forest from harvesting, or errors in sketch-mapping the precise location of the polygon.

Factors Affecting Survey Results

Survey results vary from one year to the next because symptoms change rapidly in response to weather conditions before and during the flight period (mid-April through May). Surveys flown later (close to the time of bud-burst) usually detect more areas with symptoms than those conducted earlier. In 1997, an unusual period of warm sunny weather at the end of May enhanced symptom expression, so we re-surveyed a portion of the northern Coast range. The late survey (end of May) detected twice as many acres of forest with symptoms than the earlier survey (late April) of the same area. Clear weather is required for flying, but the showery weather typical of April and May prevents precise scheduling of the survey for same time each year.

Factors other than the presence of the pathogen strongly affect disease and symptom development, and these factors remain poorly understood. The shape and distribution of survey polygons and the observer's comments suggest that symptoms are most obvious on southerly aspects and on exposed ridge tops, indicating a strong environmental interaction. Observations on ground plots also confirms this. Extreme weather events such as windstorms and unusually low temperatures appear to affect foliage loss and discoloration.

Ground Verification

We visited 100 disease monitoring plots located in the northern half of the survey area and compared disease severity ratings of plots that occurred within aerial survey polygons to those that were not in polygons. Swiss needle cast was present and damaging on all plots. Disease severity was slightly greater (significant at the .01 level, students t-test) in plots that occurred within aerial survey polygons than in those outside of polygons.

Many more acres of Douglas-fir forest are affected by Swiss needle cast than indicated on the aerial survey maps. Our maps represent only those areas where disease symptoms have developed enough to be visible from the air. Monitoring plots and other ground checks have shown that even though damage in an area may be severe in terms of needle loss, it might not be mapped by the surveyors, who depend on discoloration as the main indicator of damage.

Appropriate Use Of The Aerial Survey Information

The survey information is most useful for mapping general areas in which Swiss needle cast is causing significant damage to Douglas-fir forests. It depicts a zone in which Douglas-fir management should take into consideration the effects of the disease. By overlaying the distribution of polygons with vegetation and topographic maps, the survey also provides some insight into factors that affect distribution and severity of the disease. The acreage estimates are useful for documenting trends over time, but they are not an accurate measure of the true amount of forest with Swiss needle cast damage.

Swiss needle cast aerial survey information is available at:
http://www.odf.state.or.us/fa/fh/maps.htm

Windthrow Risk Project

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Background: A teacher-intern program (Teacher on Summer Assignment or TOSA) is conducted yearly by the forest products industry. This program matches teacher skills with forest research projects. The 2000 TOSA project consisted of searching existing weather databases to build a wind-force model for western Washington State.

Wind-throw risk assessment is conducted as part of an integrated asset protection program by timberland management units. Wind damage includes: loss of forest products & revenue, loss of stand structure in regulated stream buffer zones, loss of set-aside wildlife habitat, and loss of recreational & aesthetic quality. Failure to mitigate these losses contributes to not fulfilling site and regional forest management objectives. This process is hampered by the lack of localized or regional models of wind-force.

The study objectives included: (1) develop a landscape perspective of wind-force in the western Washington, (2) quantify wind-force patterns over the last 10-years using force-vector information from weather data centers, (3) field validate wind-throw patterns, and (4) provide recommendations towards development of a regional GIS wind-throw model. Moreover, as part of the TOSA project develop a middle school lesson incorporating wind-throw project into the students' curriculum.

Methods: Wind data stations were identified using the resources of the NOAA Climatological Database and National Weather Service Websites. Localized weather data was collected from airports facilities reports. Wind data was used to create: frequency tables and graphs of endemic & catastrophic wind events, wind frequency graphs, yearly wind gust scatter plots, top wind gust tables, and wind orientation tables for selected data stations.

Conclusions**:** Computer searches of existing weather data were used to develop wind flow patterns in the study region. Data is presented on the frequency, magnitude, and direction of wind events associated with wind-throw in western Washington forestry zones. Field evaluations of wind-throw in the Willapa Hills Management Zone confirm that wind direction and magnitude are the dominant hazard predictors. The contributions of stand structure, soil type, and presence of root-rot (Heterobasidion annosum) and topography were also investigated. The information will be added to a current GIS based wind-hazard-rating system that is used to mitigate wind losses.

Assessing Loss Potential In Forests From Exotic Species Introduced In Solid Wood Packing

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ABSTRACT

Some 360 exotic insect species and an unknown number of plant pathogens are already established in forests in the United States. Exotic species have many deleterious effects, including competitively displacing or directly destroying native species. The effect of newly introduced pest species is a function of the characteristics of the pest organism, the characteristics of the host(s), the nature of the pest–host interaction, and the interactions of the pest–host complex with the biological and physical environment. The potential economic losses from new introductions of exotic forest pests transported with solid wood packing materials was assessed during our study using formal risk assessment procedures. We used hypothetical scenarios to exemplify the magnitudes of damage expected from exotic invasive forest pests. These are not meant to represent the totality of impact expected from all exotic species, nor do they represent the only possible examples. In our approach, each potential pest was described in terms of its damage potential, time needed to build up a damaging population within a discrete area, rate of spread, hosts attacked and host susceptibility conditions, expected geographic range, and other details relevant to damage forecast. The distribution and density of hosts susceptible to each of eight representative pests was obtained for each county in the continental United States, plus Hawaii. Host growth minus natural mortality and harvest was assumed constant. Likely points of introduction and initial establishment were selected as initial infestation foci. From these initial foci, each pest was analyzed separately in terms of its yearly spread for a thirty-year forecast. Hosts would increasingly came under attack as the pest expanded its range. The buildup period required to reach damaging levels was simulated with a logistic function (a parameterized Weibull). Losses were expressed in terms of timber volume and value. Assumptions for model parameters were developed from information obtained from published literature and from heuristics obtained from experts. In summary, data to establish the impact of a pest population, which make up the supporting information for damage estimates, included: a) U.S. distribution of the forest resources at risk; b) density of the tree resources at risk; c) expanding "fronts" of the pest infestation over time (single vs. multiple entries, slow- vs. fast-spreading species); d) degree of pest_induced mortality and damage expected; and e) average expected forest growth rate. Damage estimates were obtained yearly by multiplying 'green' timber values by estimated yearly damage.

Pest Risk Assessment For Importation Of Solid Wood Packing Materials Into The United States

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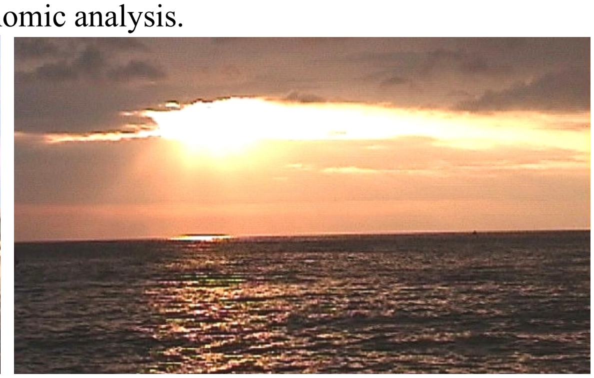
Many exotic forest pests can be readily transported into the United States on untreated wooden pallets, crating, bracing, and other solid wood packing materials. Recent introductions of forest pests associated with importation of solid wood packing materials indicate that current United States regulations likely are inadequate to exclude such pests. Most (97%) of quarantine-significant tree pests found by port inspectors are associated with solid wood packing materials. About 9% of maritime shipments contain bark, providing protection for numerous pests, despite bark-free import requirements. A pest risk assessment was drafted for the solid wood packing material pathway to provide scientific support for development of more effective regulations applicable to all import countries. The document includes a description of pathway characteristics, an assessment of potential for pest entry and establishment, and analyses of potential economic and environmental effects of introduction. Nineteen potential pests of concern, including insects and fungi, representing an array of geographical origins, host types, and pest habits were selected for detailed analysis of pest risk potential. Pest risk potentials were described in relation to current regulations and practices and without regard to potential mitigation measures or proposed regulations (i.e., baseline assessment). For each potential pest, seven risk elements were evaluated by experts to obtain an overall qualitative ranking (high, moderate, or low risk). Probability of pest establishment was described by elements for: pest with host or commodity at origin potential, entry potential, colonization potential, and spread potential. Elements describing consequences of establishment included: economic damage potential, environmental damage potential, and social and political considerations. To improve rating consistency, objectivity, and transparency, criteria were developed to define each element. In addition to the qualitative rankings, quantitative projections of economic impact were developed for several potential pest species based upon hypothetical scenarios of introduction and spread. Additional steps planned in the development of new import requirements include a public comment period for the draft pest risk assessment (from October 17, 2000 to February 15, 2001), development of proposed mitigation alternatives, a risk reduction analysis, an environmental impact statement, and an economic analysis.



Armillaria Root Disease:
Species and Genet Diversity Across a Mixed-Conifer Landscape in the Blue Mountains of Eastern Oregon

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Presented at Western International Forest Disease Work Conference, Waikoloa, HI, August 2000

INTRODUCTION

Figure 1. Armillaria rhizomorphs

Armillaria ostoyae (Romagn.) Herink causes root disease in coniferous forests of western North America. Infections centers are initiated by basidiospores and expand by root-to-root contact between host trees and by rhizomorph (Figure 1) growth through soil. Inoculum survives as infected roots and stumps for more than three decades (Roth et al. 1980). *Armillaria ostoyae* can infect a wide range of coniferous hosts, although seral species such as ponderosa pine and western larch are considered more resistant than Douglas-fir and grand fir. Understanding population structure is essential to disease management efforts. Somatic incompatibility (SI) plate pairings is a tool used by many researchers to delineate *Armillaria* genets (Table 1).

Over the last 20 years, a series of root disease surveys on adjacent watersheds on the Malheur National Forest in the Blue Mountains of northeast Oregon identified discrete, small to large Armillaria root disease infection centers. We suspected this area contained large genets of *A. ostoyae*.

OBJECTIVES

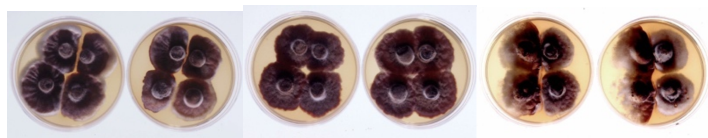
- **Determine the species of *Armillaria* causing conifer mortality.**
- **Delineate genet boundaries and locations.**

METHODS

We collected 112 *Armillaria* isolates from dead and dying conifers on our study area in eastern Oregon, most from Douglas-fir or grand fir. Isolates were maintained and pairings performed on enhanced malt extract agar. Tester isolates of *A. ostoyae* and North American Biological Species X (NABS X) were obtained for species verification. Pairings for both species and genet determinations were performed in a method similar to Wu et al. (1996). Plates were examined after approximately 24 days and scored for one of three reactions between opposing isolates: fusion (= same genet); gap formation (= different genet, same species); black line formation (= different species) (Figure 2).

Table 1. Summary of studies utilizing SI pairings to delineate Armillaria genets.

Author	Species	Forest type	Location	Genet diam. (m)	Size and frequency
Adams 1974	*mellea*	ponderosa pine	eastern OR	800-1450	few very large
Shaw & Roth 1976	*mellea*	ponderosa pine	central WA	800	few very large, at least 460 years old
Korhonen 1978	*mellea*	mixed conifer/hardwood	Finland	120-150	N/A
	bulbosa	“	“	“	N/A
	ostoyae	“	“	“	N/A
Ullrich & Anderson 1978	*mellea*	hardwood	VT	up to 50	several small, single medium
Anderson et al. 1979	*mellea*	ponderosa pine	central WA	400-450	several large
Kile 1983	*luteobubalina*	eucalypt	southern Australia	up to 580	many small, single large
McDonald & Martin 1988	*Armillaria* spp.	conifer	ID, OR, WA, MT	N/A	many small
Smith et al. 1992	*bulbosa*	hardwood	MI	up to 635	one medium, one large, at least 1500 years old
Worrall 1994	*calvescens*	hardwood and conifer	NY	11.7	many small, few medium
	gemina	“	“	17.1	“
	gallica	“	“	18.5	“
	ostoyae	“	“	10.6	“
Rizzo et al. 1995	*ostoyae*	red/jack pine	northern MN	up to 140	many small, fragmented large
Legrand et al.	*ostoyae*	beech, beech-pine, pine	central France	up to 210	many small, few medium
1996	*cepistipes*	beech, beech-pine	“	up to 130	“
	gallica	beech, beech-pine	“	up to 290	“



A **B** **C**

Figure 2. Examples of reactions between diploid isolates. Zones of reaction run vertically between colonies on each plate. A. fusion, B. gap formation, C. black line formation**.**

RESULTS

- Two species of *Armillaria* were found: *A. ostoyae* (108 isolates) and NABS X (4 isolates).
- We identified 5 genets of *A. ostoyae* and 1 of NABS X (Figure 3, Table 2).
- The largest *A. ostoyae* genet is estimated to be at least 2400 years old, and if continuous covers 878ha. This is the largest and oldest known documented fungal genet.

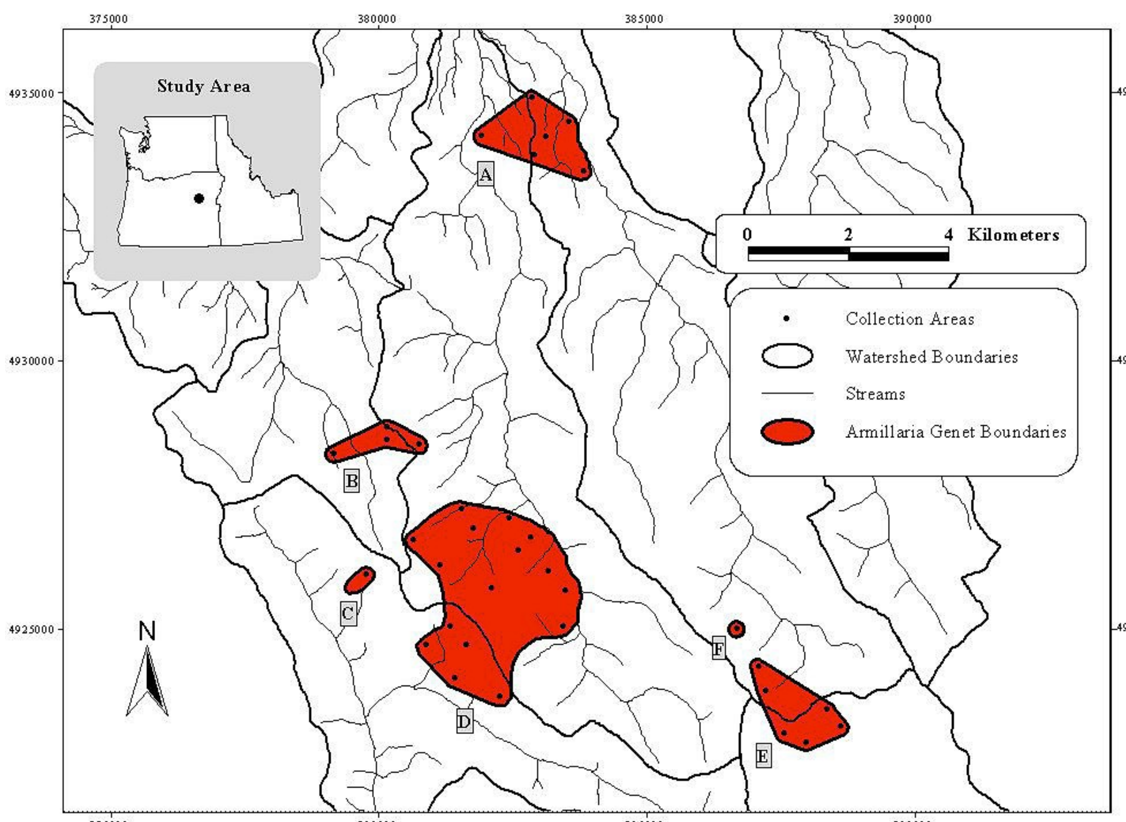


Figure 3. Genets of *A. ostoyae* (A-E) and NABS-X (F) as determined by somatic incompatibility pairings. Points within genets are locations of sampled stands, each representing 1-6 individual isolates.

Table 2. Characteristics of genets shown in Figure 3.

Genet	Species	# Isolates	Max. width (km)	Area (ha)	Age (yr)
A	*A. ostoyae*	26	2.3	228	1300
B	*A. ostoyae*	6	1.8	83	800
C	*A. ostoyae*	2	NA	18	NA
D	*A. ostoyae*	61	4.1	878	2400
E	*A. ostoyae*	13	2.1	182	1200
F	NABS-X	4	NA	NA	NA

IMPLICATIONS

- Low genet diversity suggests that basidiospores rarely initiate detectable disease centers in this forest type.
- To promote desired future conditions, disease management strategies may need to include asymptomatic areas within genet boundaries.
- Current paradigms maintain that stands created under the scenario of low-intensity, frequent fires allow for conditions that promote a more "resistant" forest structure and composition. Yet, massive *A. ostoyae* genets have formed on this landscape over many forest generations under the influence of low intensity, frequent fires.

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COMMITTEE REPORTS

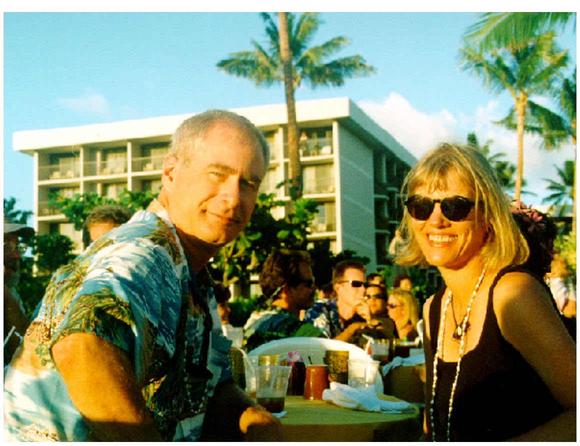
19th Annual Western Nursery Pathology Workshop

Submitted by Diane M. Hildebrand

The 19th annual Nursery Pathology Workshop was held in conjunction with the Western International Forest Disease Work Conference on Monday, August 14, 2000 from 10 am to 4 pm. Approximately a dozen participants included state, federal, and industrial forest pathologists involved in forest tree nurseries, and other interested individuals.

Participants shared their news, projects, and concerns. Discussions of particular interest included Sudden Oak Death in California by Susan Frankel, and the "Nursery Management Reliable Process" program by Willis Littke. In this Weyerhaeuser program, monitoring of soil pathogens is integral to the decision of when to fumigate.

New participants were added to the Nursery Pathology Mailing List, which was sent electronically to each participant who provided an e-mail address.



Disease Control Committee Report

Submitted by R.L. James

The Disease Control Committee met on Tuesday, August 15. Although only a few people were in attendance, discussions were lively and informative. Most discussions centered around forest nursery pathogens, including *Botrytis cinerea* and *Fusarium* spp. Discussions included ways of controlling these important pathogens using chemical and non-chemical treatments. Examples include treating conifer seeds with benomyl and other fungicides to control seed-borne *Fusarium* diseases and using pre-plant solarization treatments instead of chemical fumigation to reduce levels of soil-borne pathogens. Although alternatives to methyl bromide have not been developed for all bareroot forest nurseries, some potential alternatives showing promise include bare fallowing (with periodic soil cultivation) for at least one year prior to sowing and alternative chemical fumigants using chloropicrin, Telone®, and dazomet. Other tested alternatives such as organic soil amendments, different green manure crops, and solarization have usually not been as effective. Efforts during the next few years will continue to fine tune alternative treatments to the needs of individual nurseries.

Concern was voiced by Terry Shaw (from long distance) about some of the "quack" treatments that are currently being implemented to control some important tree diseases. His examples include using unproven remedies to treat declining oaks in Marin County, California (caused by *Phytophthora* sp.) and conifers infected with Armillaria root disease. In the case of *Armillaria*, he questions the efficacy of using fertilizers to reduce exisiting and potential damage in forest stands and cites the lack of documented data in peer-reviewed publications. Also, in the case of oak decline, apparently some companies are recommending treatments to homeowners without even knowing anything about disease etiology. It is important that disease control methods be rigorously evaluated under different forest, nursery, and environmental conditions before being recommended by professional plant pathologists.

Hazard Tree Committee Report

Submitted by John Pronos

Twenty-seven members of the Hazard Tree Committee met for lunch on Tuesday, August 15, 2000. The meeting was devoted to two topics: 1) Putting western hazard tree information on the Web, and 2) developing an agenda for the next Hazard Tree Workshop planned for May, 2001 in Coeur d'Alene.

Information on the Web

The Forest Health Protection staff in St. Paul maintains a web site devoted to hazard trees. The site is maintained by Joe O'Brien and contains a lot of good information, but the focus is almost entirely on hardwoods. Joe has agreed to add western material to his site. If individuals have publications, meeting announcements or digital images they would like to see included on the St. Paul site they can contact Joe directly or work through John Pronos.

2001 Hazard Tree Workshop

John Schwandt and Jane Taylor will host the next workshop in Coeur d'Alene. It will likely be a 2 or 2 ½ day session with at least 1 day spent on indoor presentations. One possible location for the meeting is the North Idaho College campus. The group agreed that it would be fine to have the meeting there and have participants stay at local motels. It was widely agreed that the field trip should include dissections of defective hazardous trees.

Several excellent topics were suggested for the indoor presentations and included:

- Case studies: follow specific tree accidents from failure to legal resolution that provide information to help us improve our efforts.
- Legal issues: try to get local Forest Service or other federal or state attorneys to present their views on hazard trees.
- Concessionaires – big issue with most western Forest Service regions. We hold them responsible to deal with hazard trees, but they are, for the most part, un-qualified to do this work. Can we influence how their permits are written and require their personnel to receive training?
- Data gaps – what information do we need and how do we get it? A good example is how to gather data to support rating systems.
- How do we motivate managers to be more supportive of hazard tree programs?
- Mountain meteorology – can we learn more about the weather patterns that can influence some tree failures?

Dwarf Mistletoe Committee Report

Submitted by Robert Mathiasen, Jerry Beatty, and Katy Marshall

I. TAXONOMY, HOSTS, AND DISTRIBUTION

1. Our work on the taxonomic status of the shore pine dwarf mistletoe is continuing. More specimens of male plants of western hemlock dwarf mistletoe were collected from several populations throughout Oregon and Washington in early August and additional morphological measurements completed. We have started analysis of the shore pine dwarf mistletoe data and hope to draft a manuscript this winter. (R. Mathiasen, Northern Arizona University, Flagstaff, AZ; E. Wass, Canadian Forest Service, PFC, Victoria, B.C.; R. S. Smith, Grand Forks, B.C.)

2. Further observations of the phenology of Hawksworth□s dwarf mistletoe *(A. hawksworthii*) will be made in early November 2000 in Belize. (R. Mathiasen, Northern Arizona University, Flagstaff, AZ;)

3. Another population of the Honduran dwarf mistletoe (*A. hondurense*) was discovered on *Pinus tecunumanii* in October 1999 in Celaque National Park near Gracias, Department Lempira, Honduras. This is only the fourth location reported for this dwarf mistletoe from Honduras, but specimens deposited at the Standley Herbarium at Zamorano, Honduras indicate it also occurs in other areas of Celaque National Park. (R. Mathiasen, Northern Arizona University, Flagstaff, AZ; J. Melgar, ESNACIFOR, Siguatepeque, Honduras; C. Parks, PNWRS, LaGrande, OR; and J. Beatty, WTCFID, FI&D, Region 6, Sandy, OR)

4. Our field observations and molecular analysis have confirmed that the black dwarf mistletoe *(A. nigrum*) populations in Chiapas, Mexico are actually Honduran dwarf mistletoe (*A. hondurense*). This extends the distribution of this dwarf mistletoe from Honduras into southern Mexico and indicates that it probably occurs in Guatemala. (R. Mathiasen and S. Sesnie, Northern Arizona University, Flagstaff, AZ; D. Nickrent, Southern Illinois University, Carbondale, IL; C. Parks, PNW Research Station, LaGrande, OR; and J. Beatty, WTCFID, FI&D, Region 6, Sandy, OR)

5. Male plants of *Arceuthobium globosum* ssp. *grandicaule* measuring over 81 cm in height were discovered on *Pinus rudis* in the Sierra de los Cuchumatanes near Chemal in western Guatemala in March 2000. Female plants measuring over 66 cm in height have been discovered in the same populations. These represent the largest dwarf mistletoe plants discovered thus far in the Universe. Frank Hawksworth□s previous maximum plant height for this dwarf mistletoe was 70 cm. More trophy size dwarf mistletoe hunting in Guatemala is scheduled for August 2001. (R. Mathiasen and S. Sesnie, Northern Arizona University, Flagstaff, AZ; C. Parks, PNW Research Station, LaGrande, OR; and J. Beatty, WTCFID, FI&D, Region 6, Sandy, OR)

6. A review of the hosts and geographic distribution of *Arceuthobium oxycedri* was completed and submitted to the Journal of Plant Pathology. Following several updates in host nomenclature, 15 taxa of *Juniperus*, 2 *Chamaecyparis*, 5 *Cupressus*, and 1 *Thuja* are reported as hosts. Juniper dwarf mistletoe is reported from 28 countries across northern Africa, western Europe, the Balkans, Russia and other former Soviet Republics, the Near East, the Indian subcontinent, and western China. Previous reports from Bhutan and Hungry are corrected; and reports for Portugal, Armenia, and Afghanistan are questioned. Although not supported by valid reports, the mistletoe is suspected to occur in Nepal and Bhutan. (B. Geils, RMRS, Flagstaff, AZ; W. Ciesla, Fort Collins, CO; R. Adams, Gruver, TX)

II. PHYSIOLOGY AND ANATOMY

1. A series of experiments under environmentally controlled conditions (greenhouse and growth chamber) are being established to investigate the effects of reduced light and moisture on host physiology and mistletoe latency. The subject mistletoes are southwestern dwarf mistletoe, Douglas-fir dwarf mistletoe, lodgepole pine dwarf mistletoe, and hemlock dwarf mistletoe. Results of the study are hoped to provide a better understanding of host and pathogen responses following partial cutting and parameter estimates for a mistletoe simulation model. (B. Geils, RMRS, Flagstaff, AZ; T. Kolb, Northern Arizona University, Flagstaff, AZ)

III. LIFE CYCLES

1. We continued our study of the sex ratio of Chihuahua pine dwarf mistletoe (*A. gillii*) in southern Arizona. We sampled additional *A. gillii* populations in the Santa Catalina, Huachuca, Santa Rita, and Chiricahua Mountains in 2000. So far the sex ratio of all the populations we have sampled is essentially 1:1. (R. Mathiasen and C. Daugherty, Northern Arizona University, Flagstaff, AZ; and D. Russell, Bureau of Land Management, Grants Pass, OR)

IV. HOST-PARASITE RELATIONS

No submissions.

V. EFFECTS ON HOSTS

No submissions.

VI. ECOLOGY

1. A preliminary study was completed on trophic interactions in dwarf mistletoe infested ponderosa pine communities of the Colorado Front Range. The objective of this work conducted by Kalian Mooney, University of Colorado, was to evaluate the importance of trophic cascades and other interactions among predators and herbivores of southwestern

dwarf mistletoe. The important bird predators were chickadees and nuthatches; ants and spiders were identified as the important arthropod predators; and the lepidopteron *Dasypyga alternosquammella* as the principle herbivore. Based on differences between trees with or without bird enclosure, birds appeared to reduce the numbers of all insects (ants only marginally) and reduce the number of cursorial spiders (but not web spiders). Together birds and arthropod predators significantly reduced the population of herbivores. Although 36% to 39% of shoots had been fed upon, there was no significant difference in the amount of remaining mistletoe between predator-free and predator-exposed branches. Life history data and parasitoids were collected for *D. alternosquammella*. An increase in the probability of herbivory was related to greater host branch diameter and greater mistletoe shoot size. An expanded study is being established to further explore 1) the interactions among birds, ants, and spiders as competitors and predators, 2) the indirect effects of predators and direct effects of herbivores on mistletoe fitness, and 3) the influence of host branch morphology (including brooming) on the abundance of predators, herbivores, and herbivory. (B. Geils, RMRS, Flagstaff, AZ; Kailan Mooney and Yan Linhart, University of Colorado, Boulder, CO)

2. We are conducting a study to compare bird diversity in dwarf mistletoe infested and uninfested ponderosa pine stands in northern Arizona. The objective of this research is to determine the relationship between avian relative abundance and species diversity, and infestation by Southwestern dwarf mistletoe (*A. vaginatum* subsp. *cryptopodum*) in ponderosa pine forests of northern Arizona. We hypothesize that birds occur in greater abundance and with wider species diversity in stands that are infested with dwarf mistletoe compared to similar uninfested stands. The fixed radius point-count method is being used to determine an index of relative avian abundance and species diversity within stands of varying mistletoe infestation severity. Twenty 80 acre study sites have been selected in pure pine forests west of the San Francisco Peaks in the Coconino National Forest. Five study sites in each of the following classes were selected: 1) severely infested (mean DMR > 2.0); 2) moderately infested (mean DMR 1.1-2.0); 3) lightly infested (mean DMR 0.1-1.0); and 4) uninfested (mean DMR 0). Eight point-count stations have been established within each stand. Birds were sampled at each point count station 6 times in 1999, and 6 times in 2000. Detailed stand characterization is being completed in 40 1/10-acre plots within each stand. Each tree encountered is being rated for dwarf mistletoe infection using Hawksworth's dwarf mistletoe rating, Tinnin's broom volume rating, % volume broomed, and an absolute broom volume rating. In addition, ground cover, shrub/sapling cover, canopy structure, and coarse woody debris data are being collected to identify potential covariates. It is our goal to quantify how several avian species respond to different levels of dwarf mistletoe infestation and to recommend what levels of mistletoe infestation might be most beneficial to birds. (T. Parker, R. Mathiasen, and C. Chambers, Northern Arizona University, Flagstaff, AZ)

3. We are investigating bird and mammal use of Douglas-fir dwarf mistletoe-induced witches' brooms in the Southwest. This research will aid managers in determining which broom and tree characteristics are important for wildlife habitat. There are two phases of the study. The first phase is a comparison of wildlife use in broomed and unbroomed

trees. Three stands were selected on the San Francisco Peaks on the Coconino National Forest in Northern Arizona. We laid out 4x4 grids (each point 80.5m apart) in each stand and systematically selected pairs of broomed and unbroomed trees (based on diameter at breast height) at each point to climb. We climbed trees in these stands in the fall of 1998 and 1999. Thus far, we have found significantly more use in the broomed trees versus the unbroomed trees. Due to what appears to be preferential use of broomed trees by birds and mammals in these areas, a second phase was added to the study in order to increase the scope of inference. During the summer of 1999, 5 transects on 4 national forests in Arizona and New Mexico were randomly selected. Fifteen broomed trees (5 trees in 3 diameter classes) on each transect were systematically selected and climbed to examine for wildlife use. We have finished collecting all field data and we are now analyzing it. (S. Hedwall, C. Chambers, R. Mathiasen, Northern Arizona University, Flagstaff, AZ; B. Geils, RMRS, Flagstaff, AZ; M. Fairweather, FHP, R3, Flagstaff, AZ; and C. Parks, PNWRS, LaGrande, OR)

4. We have started a study to examine wildlife use of witches' brooms in ponderosa pine in northern Arizona. The first field season (2000) involved locating study sites and selecting sample trees. This is a continuation of work on wildlife use of witches' brooms in Douglas-fir. (G. Garnett, R. Mathiasen, and C. Chambers, Northern Arizona University, Flagstaff, AZ)

5. I am continuing to study the growth of infected Douglas-fir trees in a thinned stand in the Okanogan forest. The trees ranged from 2.5 to 15 cm dbh at the time the study was initiated. The study is in its thirteenth season. I plan to initiate a study of the pattern of development of brooms in Douglas-fir and ponderosa pine. This will be the first season for that work. Sharon Stanton is studying the effects of brooming, as distinct from DMR, on the growth of ponderosa pine. That work should be completed by the end of this year. Some papers we have published or are working on include: 1. Tinnin and Forbes. 1999. Red squirrel nests in witches' brooms in Douglas-fir trees. Northwestern Naturalist 80:17-21; 2. Tinnin, Parks, and Knutson. 1999. Effects of Douglas-fir dwarf mistletoe on trees in thinned stands in the Pacific Northwest. Forest Science 45:359-365; 3. Parks et al. 1999. Wildlife use of dwarf mistletoe brooms in Douglas-fir in Northeast Oregon. Western Journal of Applied Forestry 14:100-105; 4. Tinnin. 2001. Effect of dwarf mistletoe on bole taper and volume in young Douglas-fir. Western Journal of Applied Forestry (in press); 5. Godfree. 2000. Lodgepole pine dwarf mistletoe in central lodgepole pine stands: effects on crown architecture, host tree population dynamics, canopy structure and understory composition. Doctoral Dissertation. (Near completion). (B. Tinnin, Portland State University, Portland, OR)

VII. GENETICS

1. The Central Zone Genetic Resource Program in Region 5, USDA Forest Service initiated a test dwarf mistletoe inoculation on one block of our resistance test plantation. The primary intent of the inoculation was to evaluate seed retention on the seedlings that were covered with bird netting, covered with bridal veil, or uncovered, and to evaluated

germination from two different inoculation times. Some seedlings were inoculated in December while others were inoculated in March. Seed retention results were 65% for uncovered seedlings, 68% for seedlings covered with bird netting, and 75% for seedlings covered with bridal veil. The lower percentage for uncovered seedlings was attributed to the small size of several of the seedlings, either in a tendency to loose the seed more easily or in the difficulty to relocate the seed. This trend was seen on small seedlings that were covered as well. Of the retained seed, 14% from the March inoculation and 13% from the December inoculation appear to have germinated. The overall germination rate for total seed placed was 9%. These results are tentative at this time. A more thorough evaluation is planned. (D. Ringnes, USDA Forest Service, Camino, CA)
2. Selected lodgepole pine trees from the Colorado State Forest Service seed production area (near Michigan Reservoir) were identified in 1971 as apparently having above-average growth, form, and mistletoe resistance. Half-sib seedlings from 11 putatively-resistant trees were compared to seedlings from 5 putatively-susceptible trees (from an infested, natural stand at Pingree Park) in an inoculation trial conducted on the Fraser Experimental Forest. The trial consisted of 5 seedlings per source, out planted in 1984, and inoculated in 1988 and 1990. By 1999, mistletoe shoots had appeared on at least one seedling from each putatively-resistant source; only one putatively-susceptible source included no visibly infected seedlings. New infections appeared each year since 1992; 33% of all surviving seedlings were infected. The long incubation period for lodgepole pine dwarf mistletoe observed in this field study is consistent with expectations and is attributed to the short growing season at Fraser. (B. Geils, RMRS, Flagstaff, AZ; G. Fechner and J. Sprackling, RMRS, Fort Collins, CO)

VIII. MANAGEMENT

1. Our dwarf mistletoe suppression program is on the skids these days. We do not have any suppression projects because of cuts in suppression funding and because dwarf mistletoe projects get lower priority than our bark beetle projects. Permanent plot-wise, we have a good system of plots in place, and I expect we will begin to harvest some useful data from these plots in about 2-5 years. The Targhee National Forest plots are being used by Brian Geils in his efforts to update the Dwarf Mistletoe model linked to the Forest Vegetation Simulator (formerly Prognosis). Otherwise we don't have anything to report. (J. Hoffman, FHP, Region 4 Boise, ID; J. Guyon, FHP, Region 4, Ogden, UT)

2. We continue to fund Dwarf Mistletoe Suppression projects but the emphasis has changed over the last 10 years. Although we still have projects that are tied directly to treating a specified number of acres on a few sites, we are also partially funding projects at a much broader scale, such as ecosystem management projects that have dwarf mistletoe management concerns. These projects encompass analysis and treatment of sites within an area of 10,000 or more acres. (M. Fairweather, FHP, Region 3, Flagstaff, AZ)

3. A project involving the use of prescribed burning to control dwarf mistletoe in a non-commercial forest was completed on the San Carlos Reservation. Preliminary results

indicate some mortality and lower broom die-back. Victoria Wesley, Forest Health specialist for the tribe is the project leader and we will be working together to provide the results from this project. (M. Fairweather, FHP, Region 3, Flagstaff, AZ)

4. Project title: Management of Dwarf Mistletoes by Biological and Genetic Control Methods.

Research Objectives: the overall objectives of the project is to survey and collect fungal hyperparasites and to investigate their potential use as biological control agents for dwarf mistletoes. Currently the focus of this research program is on biological control of western hemlock and lodgepole pine dwarf mistletoes. Most recently, research efforts are underway to explore the use of genetic control method for management of western hemlock dwarf mistletoe.

Research progress:

In vitro germination and development of western hemlock dwarf mistletoe (*Arceuthobium tsugense* subsp. *tsugense*) – A novel procedure for *in vitro* culture of western hemlock dwarf mistletoe was developed for the first time. A factorial experiment evaluated the effects of media (Harvey's medium (HM) and modified White's medium (WM), temperature (15° C and 25° C), presence or absence of light, and plant growth regulators (the auxin 2,4-D) and the cytokinin (BAP) at varying concentrations (0.001 mg/l to 1.00 mg/l). Seeds explants germinated in less than one week in culture and produced radicles. Optimal conditions for radicle elongation were WM at 20° C in the presence of light and without plant growth regulators. Some of the radicles split at the tip to yield callus while others swelled to become spherical holdfasts. Holdfasts were also produced at the tips of radicles, and callus arose from split holdfasts. Factors that positively influenced holdfast production were Harvey's medium, light, and 2-4-D at 1 mg/l. Callus development from split radicles and split holdfasts was optimal on WM with 0.5 mg/l 2,4-D and 1 mg/l BAP at 20° C in the dark. The tissue culture procedure will be useful for studying genetic resistance and the physiological and biochemical mechanisms of the host-parasite interactions, as well as, to screen naturally occurring hyperparasites fungi for their potential use as biological control agents against dwarf mistletoes.

Histopathological investigation of the infection of germinated seeds and callus of western hemlock dwarf mistletoe by *Nectria neomacrospora* (Anamorph: *Cylindrocarpon cylindroides*) and Colleto*trichum gloeosporioides* in dual culture- the selection of these two hyperparasitic candidate fungi was based on their performance as promising biological control agents under field conditions. The potential use of these two fungi was evaluated for their pathogenicity on germinated seeds and callus grown *in vitro*. Mistletoe seeds were germinated on Harvey's tissue culture medium in one half of a petri plate while the other half contained water agar on which the fungal growth was initiated from mycelial plug. Callus tissue was initiated on Harvey's medium or White's modified medium, challenged with fungi on Harvey's medium (*Cylindrocarpon cylindroides*) or modified White's medium (*Colletotrichum gloeosporioides*), as fungal growth rates were found to be moderate on these media. Mistletoe tissue were prepared for light microscopy at various days post-contact with fungi. In seeds, both endosperm and radicle were colonized, and cushion development, cell wall degradation, and intercellular and intacellular colonization was evident. Cells infected with *Cylindrocarpon cylindroides* were disorganized and appeared plasmolysed. The in vitro screening method developed in this investigation was useful to elucidate host-pathogen interactions and was sensitive enough to show that *Cylindrocarpon cylindroides* was more aggressive at colonization than *Colletotrichum gloeosporioides.*

Field trials continue monitoring of the field trials which were initiated in 1997 on the potential use of *Cylindrocarpon cylindroides* and *Colletotrichum gloeosporioides* as potential biological control of western hemlock dwarf mistletoe.

Exploring the use of genetic resistance strategy for management of western hemlock dwarf mistletoe- early results suggests levels of resistance to western hemlock dwarf mistletoe within western hemlock clones in conifer plantations in British Columbia. An understanding of the mechanisms involved and factors influencing resistance to western hemlock dwarf mistletoe will support the selection and breeding the host plants which are more resistant to infection. Research objectives include: 1) utilization of *in vitro* (tissue culture) system already developed at Dr. Shamoun's lab as a rapid screening method for resistance in western hemlock populations to western hemlock dwarf mistletoe; 2) elucidation and characterization of inheritance of resistance in hemlock populations to western hemlock dwarf mistletoe. To date, we have planted 300 young seedlings of western hemlock representing 50 provenance under greenhouse conditions. These young seedlings will be infected with seeds of western hemlock dwarf mistletoe in October, 2000. The experiment will be monitored in the next 1-3 years for selection different resistance traits to western hemlock dwarf mistletoe. This research venture is a collaborative research effort with Charlie Cartwright- Hemlock breeder, BC Ministry of Forests.

Biological control of lodgepole pine dwarf mistletoe- this project is part of a Ph.D. work conducted by Tod Ramsfield who is working under the direction of Drs. Bart van der Kamp and Simon F. Shamoun. To date, we have achieved : 1) continue collection of the potential candidate hyperparasite *Colletotrichum gloeosporioides* from lodgepole pine dwarf mistletoe. A total of 91 pure cultures were preserved at the fungal culture collection of Dr. Shamoun's lab.; 2) inoculated 36 lodgepole pine seedlings with *A. americanum* seeds under outside conditions at the Pacific Forestry Centre. Also inoculated 31 lodgepole pine seedlings with *A. americanum* under shadehouse conditions; 3) established a partial shoot removal trail in Lytton, BC where treatments were no shoots removed, ¼, ½, ¾, and all shoots removed and shoots cut in half to determine how *A. americanum* responds to stress; 4) during the summer, 2000, a field trial was established to assess the efficacy of the formulated *C. gloeosporioides* on *A. americanum* at Lytton, BC; 5) sample tree canopy to observe the distribution of *C. gloeosporioides* at different canopy levels of lodgepole pine trees; 6) projected work will explore the role of *Colletotrichum* in the endophytic system, using culture technique, microscopy and DNA markers.

Publications:

1) Deeks, S., Shamoun, S.F. and Punja, Z. 1999. Tissue culture of parasitic flowering plants: methods and applications in agriculture and forestry. In Vitro Cell. Dev. Biiol.- Plant 35: 369-381.
2) Kope, H. and Shamoun, S.F. 2000. Mycoflora associates of western hemlock dwarf mistletoe plants and host swellings collected from southern Vancouver Island, British Columbia. Canadian Plant Disease Survey 80: 144-147.
3) Deeks, S., Shamoun, S.F. and Punja, Z. 2000. *In Vitro* germination and development of western hemlock (*Arceuthobium tsugense* subsp. *tsugense*). Plant Cell, Tissue and Organ Culture (In press).
4) Deeks, S., Shamoun, S.F. and Punja, Z. 2000. A histopathological study of infection of germinated seeds and callus of western hemlock dwarf mistletoe by *Cylindrocarpon cylindroides* and *Colletotrichum gloeosporioides* in dual culture. Canadian Journal of Plant Pathology (In press).
5) Completion of M.Sc. thesis by S.J. Deeks at Simon Fraser University- Tissue culture of western hemlock dwarf mistletoe and its application to studies on biological control. This work was conducted at the Pacific Forestry Centre under the supervision of Drs. Simon F. Shamoun and Zamir K. Punja (SFU).

Poster presentations at the joint meeting of the Canadian Phytopathological Society and the Pacific Division of the American Phytopathological Society- June 18-21, 2000, Victoria, BC, Canada:

1) Deeks, S., Shamoun, S.F. and Punja, Z. 2000. The application of in vitro culture of western hemlock dwarf mistletoe to studies on biological control.
2) Ramsfield, T., Shamoun, S.F. and van der Kamp, B. 2000. Factors related to seed production by lodgepole pine dwarf mistletoe.

A proposal has been accepted by I.U.F.R.O. to establish a new working group on “Parasitic Flowering Plants in Forests”. Dr. Simon Francis Shamoun has been selected as a Coordinator for this group. If any one is interested to join this working group, please, contact Dr. Shamoun at the following e-mail address: SShamoun@PFC.Forestry.CA ; Phone: (250) 363-0766; Fax: (250) 363-0775. (S. Shamoun, Pacific Forestry Centre, Victoria, B.C.).

IX. SURVEYS

1. We are currently working up data and preparing a manuscript on spatial patterns of hemlock dwarf mistletoe in the old-growth forest of the T.T. Munger Research Natural Area (RNA), Gifford Pinchot National Forest. We DMR'd all western hemlock and true fir trees > 5 cm on a 12 ha mapped plot (3,516 trees) surrounding the canopy crane. We are now running spatial statistics (Ripley's K) on the data to determine negative and positive association between infected and uninfected trees, DMR 1 and DMR 6 trees, and trees with their highest rating in the upper third versus all infected hemlock. We also hope to develop

some novel ways to determine whether non-hosts are playing a role in the shape of the infection centers. Figure 1 shows our 12ha map of the infection centers. In this portion of the RNA, there are clearly delineated infection centers, with two small, isolated infection centers in the lower left-hand side. The nearest infected tree to these centers in over 30 meters away, and therefore, we hypothesize that bird-transported seed began the center!

Other projects at the WRCCRF include a senior thesis project by Morgan Dutton from University of Washington entitled: An analysis of western hemlock response to hemlock dwarf mistletoe. This work was done with Tom Hinckley at UW, and involved an investigation of foliage morphology, nitrogen status, isotopic C, chlorophyll content, and effect on height growth. The major affect of mistletoe seems to be on nitrogen content of infected branches, as height, and other foliage characteristics were not significantly different between infected and uninfected branches. Percent nitrogen levels in uninfected foliage samples averaged 1.06%, significantly higher than infected foliage which averaged 0.80%. Morgan sampled foliage from 3 locations on each branch, apex (A), middle (B), and base (C) of branches. Infected branches were A: 0.68%, B: 0.69%, C: 1.03%. Uninfected branches were A: 1.08%, B: 1.06%, C: 1.05%. She feels that the branch autonomy theory, i.e. branches are fairly isolated from the main tree, explains the lack of effect on whole tree characteristics. The very wet location (100 inches precipitation) may prevent a huge drought effect on the trees, and this also limits the effect of mistletoe on whole tree characteristics.

We also DMR'd all hemlock and true firs > 45.7 cm dbh on 104, one-acre plots which form stepped strips in the T.T. Munger RNA (2,089 trees). We then took average DMR for each 1 acre plot. Before we can proceed with any more analysis, we have to go out and GPS the plots, so that is our summer project this year. Future work on this data set will include analysis of the relation of DMR and growth increment for western hemlock. (D. Shaw, E. Freeman, J. Chen, and D. Braun, Wind River Canopy Crane Research Facility, Carson, WA).

X. MODELING

1. In 2000, we began our first 10-year remeasurement of plots established under the Pest Trend Impact Plot System. Data analysis will be forthcoming. Many more plots will be remeasured in the next couple of years. (M. Fairweather, FHP, Region 3, Flagstaff, AZ)

2. Recently several industrial companies proposed to limit sizes of clearcuts in coastal forests of British Columbia, and to emphasize silviculture systems that retain many live trees in harvested areas. These new practices raised concerns that the resulting forest conditions will encourage spread of hemlock dwarf mistletoe (*Arceuthobium tsugense*) and increase future impacts of the parasite on trees, stands and forests. New strategies are needed to suppress parasitic effects of dwarf mistletoe where forests are managed for timber production, or to sustain forest conditions associated with infestations that are desired for wildlife habitat and other amenities. A detailed model of dwarf mistletoe spread developed by the US Forest Service is being tested for BC conditions. It was attached both

to a version ("Pacific Northwest" variant) of the US tree growth model "Forest Vegetation Simulator" (FVS) which models growth effects in complex (multi-age, -species) stands, and to the ministry Tree and Stand Simulator (TASS) for detailed, spatial growth projections of relatively simple stands. Further model development and evaluation of projections are planned for actual forest conditions and/or data. A working group of government and industry co-operators and interested specialists (including scientists, managers and other interested persons) provides input and advice. Please contact J. Muir for further information and opportunities to participate. (J. Muir, BC Ministry of Forests, Victoria, B.C.)

3. Work continues on development, documentation, and evaluation of the spatial-statistical model for spread and intensification of dwarf mistletoe. Characteristics of the pattern of tree distribution (stem clumpiness) and spatial autocorrelation of DMR (infection patchiness) were examined using data from the Grand Canyon dwarf mistletoe control study. Parameter values for stem clumpiness and infection patchiness were computed for a 10-acre, stem-mapped plot (and portions of that plot); changes in these parameters over time were also determined. Model behavior in terms of long-term changes in DMR, DMI, and percent infected were compared against observed data using levels of stem clumpiness and infection patchiness consistent with those determined for the plot. Additional mapped data are being analyzed to explore change in these parameters as stands develop, variation by host and stand type, and sensitivity to measurement errors. The spatial-statistical model has been fit and tested against two versions of the Forest Vegetation Simulator (FVS) to test it with data for ponderosa pine in the Southwest and for western hemlock in British Columbia. FVS is a stand-average, distant-independent model. Future work is planned to fit this mistletoe spread and intensification model to the TASS program for simulating the growth of individual, mapped trees. (B. Geils, RMRS, Flagstaff, AZ; D. Robinson, ESSA, Vancouver, BC; J. Smith, Northern Arizona University, Flagstaff, AZ; J. Muir, BC Min. of Forests, Victoria, BC)

4. Work continues on improvement and validation of the Dwarf Mistletoe Impact Model (DMIM), widely available to users of FVS. An enhancement of a former release of the DMIM demonstrated more realistic predictions of mistletoe spread from overstory to understory trees. Data from numerous long-term studies in the western US regions provided an opportunity to update the empirical spread and intensification functions in the DMIM for additional host species and to compare results from simulations to actual observations. These studies include data for ponderosa pine in the Pacific Northwest, Rocky Mountain, and Southwestern Regions, fir in the Pacific Southwest Region, western larch in the Northern Region, and lodgepole pine in the Intermountain and Rocky Mountain Regions. Although some studies were established more recently, many span several decades and represent a variety of stand types and management histories. The project is a collaboration of Forest Health Protection staff from each western region, Forest Health Technology Enterprise Team, and the Rocky Mountain Research Station; the project is expected to be complete in 2001 with revision of the model. (B. Geils, RMRS, Flagstaff, AZ and 14 others)

5. Efforts are underway to adapt survey procedures to use GPS technology, and to update the DMLOSS and JPINE simulation programs to use the GPS survey data and information in the provincial database managed with ArcView. (F. Baker, Utah State University, Logan, UT)

6. A paper discussing 40 years of dwarf mistletoe spread and intensification in a regenerating black spruce stand is in the final drafts for the Northern Journal of Applied Forestry. For the first 30 years *A. pusillum* killed some trees, but the number of infected trees remained constant. In the last 10 years, however, the number of infected trees has increased greatly, and mortality centers free of host trees are becoming defined. Very little of the stand will survive a normal 90 year rotation. (F. Baker, Utah State University, Logan, UT)

XI. MISCELLANEOUS

1.   A database catalog for the Forest Pathology Herbarium-Fort Collins, mistletoe collection has been developed. With completion of the monograph by Hawksworth and Wiens, the mistletoe collection they assembled is to be transferred to the University of California (western North American species) and to the Smithsonian Institution (other species). Preliminary to that transfer, however, it is necessary to have a complete and current catalogue of specimens and process for identifying sheets by collector, host, collection site and for tracking annotation history and disposition. In the near future, the Forest Pathology Herbarium-Berkeley, mistletoe collection may be added, and the catalog published. (B. Geils and R. Galliano-Popp, RMRS, Flagstaff, AZ)

Rust Committee Report

Submitted by Rich Hunt

Rich Hunt chaired the meeting and started off the round table reporting on rusty events. He reported: 1) the Corvallis ribes conference proceedings are now published in HorTechnology 10(3) – 18 papers & 1 abstract. 2) The BC people held a white bark pine meeting at Apex mountain on July 13. 3) He continues to work on and be frustrated by "Spots only" resistance in white pine. Dave Johnson reported that blister rust is now in northern CO. Rich Sniezko invited all to attend the IUFRO white pine working group meeting the last week of next July in Grants Pass or Medford. There is a possibility that the IUFRO rust meeting for 2002 will be in China, failing that it could be in western North America. Abul Ekramoddoulla summarized his protein work with white pine and *Cronartium ribicola,* including MGR resistance in Pw & Ps and his plans to use the promoter of the cold gene to trigger antibody defence in Pw. Boris Tkacz mentioned that there would be a white pine project review in September. Geral McDonald covered many white pine topics with which he is associated including: 1) A management model. 2) An epidemiology model (for this he is keen to have co-operators gathering environmental data – contact him for details). 3) The concept of "environmental races". 4) Resistance in Pwb. 5) *Cronartium ribicola* penetration process of pines. 6) The use pedigreed Pw and others with RFLP markers in order to generate a genetic map of Pw. 7) The ecological effects Pw removal. Eric Smith is modelling growth & yield. He plans on having a Pf and blister rust meeting in CO in a couple of years. Ellen Goheen is to co-ordinate a multi-regional proposal (including BC) where different Pw stock types (eg. pre-pruned outplants; browse cylinders, other ideas?) will be planted out to determine if there are differential wpbr effects. (Contact Ellen if you are interested in participating). She will be surveying Pwb in Crater Lake shortly. Jim Hoffman reported that most of the trees surveyed in 1996 in the Boise NF are now dead from BB. John Schwandt reported: 1) He is looking at Pwb stands. 2) That F2 resistant stands may range in rust infection from 10 to 80% and a student is to attempting correlations to weather parameters. 3) The olde pruning study is still out there and still yielding data that supports that pruning works. However, spacing opens the stand, perhaps permitting more ribes to grow, thus weakening or nullifying the goodness of pruning. 4) He is stillworking on the wpbr model with Ft. Collins. 5) He would like people to contact him if they can corroborate or deny that many cankers occurred in 1995 or 1996. Rich Hunt is to receive credit for any inaccurate reporting of the meeting.

Root Disease Committee Report

Submitted by Ellen Michaels Goheen

The WIFDWC Root Disease Committee meeting was called to order at 7:50 am. Twenty members were in attendance.

Announcements were made regarding two upcoming International root disease meetings:

> The IUFRO Working Party 7.02.01 Root and Butt Rots will be meeting September 16-22, 2001 in Quebec City. Information regarding this meeting can be obtained at http://iufro-rbr2001.cfl.cfs.nrcan.gc.ca
>
> The IUFRO Working Party 7.02.09 Phytophthora Diseases of Forest Trees will be held in Western Australia, September 29-October 5, 2001. Information regarding this meeting can be obtained at http://wwwscience.murdoch.edu.au/conf/phytophthora/index.html

Walt Thies sent his regrets for not attending this year's WIFDWC. He anxiously awaits starting field work on the black stain plots in eastern Oregon and invites all interested parties to come out and help examine the many excavated root systems that will result from this project.

The Committee discussed sponsoring a panel at next year's meeting. In 1999 we talked about having a panel that focused on root diseases and fertilization at an upcoming meeting. Will Littke and others suggested that the panel include the role of nutrient balance in disease development and information on nutrient status of trees. Because much of the nutrient/root disease questions have come out of Idaho and a great deal of fertilizer work has been done in Canada, the group decided to hold off on this particular topic until the 2002 meeting in British Columbia where greater participation from Canada and Idaho folks could be expected. It was agreed that having the root disease committee sponsor a panel at the 2001 meeting was still a good one and that a topic would present itself once we discovered if there was a particular theme to the meeting. Ellen will follow up with Interim Program Chairperson Alan Kanaskie and with the 2001 Program Chairperson once announced.

The remainder of the session was spent in a round robin of reports and discussions.

Rich Hunt and Rona Sturrock reported on root disease work being done by the Canadian Forest Service. Rich continues work on tomentosus root rot, including monitoring the disease on 30m square plots. Rona is working on infection processes of *Phellinus weirii* using protein and molecular techniques and on identifying trees resistant to *P. weirii*. She noted that there would be a tech transfer note coming out on stumping research soon. Duncan Morrison continues his work on various aspects of Armillaria root disease, Mike

Cruikshank is studying Armillaria impacts on tree growth, and Don Norris has been doing a lot of work on pop-up logging and root disease management.

Carrie Burns, Washington DNR, reported that the video, “The Rotten Truth”, produced by Dan Omdal is available for $24.00 US from Washington State University Continuing Educational Services.

Willis Littke continues work on relationships between commercial thinning activities and associated root disease impacts as well as root disease management by species manipulation. He related that Weyerhaeuser Corp.is very interested in how root disease pockets are used by wildlife species and are managing some root disease pockets for wildlife habitat.

John Pronos introduced the topic of SPORAX® and its use in true fir stands. He related that the USFS in California has a policy to treat all recently cut stumps in developed recreation sites with SPORAX® and asked the group how others were dealing with treating true firs in general forest management situations. A lively discussion followed with a variety of opinions expressed and a number of experiences told. No consensus was reached on how and when true fir stands are or should be treated.

Greg Filip brought the group up to date on a number of root disease-related projects he is working on. Annosus root disease has become a concern in a few noble fir Christmas tree plantations in Oregon. The disease is spread from relatively small stumps; fruiting bodies are occurring on these small stumps, and mortality caused by annosus root disease has been substantial. Greg continues to monitor Armillaria root disease in ponderosa pine, true fir, Douglas-fir, and western hemlock thinning plots that were installed 20 to 30 years ago. Greg also has plots looking at silvicultural treatments in heavily root disease infested areas. He mentioned that 25 years worth of root disease study at Glenwood, WA has been summarized in a WJAF article and that Dan Omdal continues to monitor the stumping sites at Glenwood.

Alan Kanaskie reported that 20-year results from a root disease study that Larry Weir installed in 1980 will be published in 2001. He also told us that Oregon Department of Forestry now has 50,000 acres of 100% coverage root disease surveys mapped and in their database.

Johns Schwandt would like to exchange ideas with anyone who has experience artificially inoculating with *Armillaria ostoyae*. Please get in touch with John.

Richard Sniezko noted that work on Port-Orford-cedar resistance to *Phytophthora lateralis* is making good progress. Posters on the topic were presented at this meeting. Those with questions should get in touch with Richard or with Don Goheen.

Borys Tkacz went on record saying he "does give a damn about root disease" and is especially interested in more discussions about the impacts of root disease in altered ecosystems.

Geral McDonald reported on recent publications he has in Mycologia (characterizing the Armillaria reference strains), Experimental Mycology (mating behavior of Armillaria) and Wildland Fire (landscape-level discussions of the relationships between Armilaria, white pine blister rust, and fire exclusion). Geral continues to work on landscape-level root disease patterns using satellite imagery and molecular techniques to distinguish Armillaria species.

Blakey Lockman briefly discussed ongoing root disease related projects in Montana and northern Idaho. These include root disease implications of the silvicultural treatments associated with Douglas-fir beetle management, monitoring of tomentosus root rot in western larch, and investigating decline of ponderosa pine.

Yun Wu asked the group for more information regarding the history and use of *Phlebia gigantea* as a biological control for annosus root disease.

The group engaged in a small discussion about root disease management in campgrounds. A decision was made to discuss a joint publication on this topic with members of the Hazard Tree Committee. Ellen will follow up with Hazard Tree Committee Chairperson John Pronos.

The meeting adjourned at 9:20 am.

The following items were submitted after the meeting:

Pete Angwin reported that 1) permanent plots to assess the impacts of black stain rot disease on Douglas-fir are being remeasured in 30 second growth stands on the Happy Camp Ranger District of the Klamath National Forest. Plot establishment and initial measurements were done in 1996 following an extensive survey of 1,152 stands in 1993. 2) A new POC root disease infection area was identified at Aikens Creek, four miles from an infestation at Fish Lake (Orleans Ranger District, Six Rivers NF) and 1-2 miles from the Klamath River. The infestation at Fish Lake was the first instance of spread to the Klamath River drainage. Evidence of POC bough cutting was found in the area. 3) An outplanting trial of 392 POC seedlings was established in a root disease-infested area at the town of Hiouchi. The test was made to validate POC resistance selections made on the basis of testing at Oregon State University. Although 35 seedlings died 16 weeks after planting, no mortality appeared to be due to POC root disease. And 4) POC branch samples were collected from 14 "survivor" trees from mortality areas along the Sacramento River (the southeastern edge of the range of POC) and from a new infection site in the town of Dunsmuir. The samples were taken to Oregon State University for testing.

Judy Adams would like members to know that preliminary discussions have taken place at FHTET concerning future enhancements to the root disease model. The focus would be on simplification for broader audience appeal. Some of the changes that have been recommended would include:

- Runs automatically (like mistletoe model)
- Convert it into a less technical model (pathologist hand-holding becomes unnecessary)
- Geographical or variant differences are imbedded within the model

Improving the root disease model should be listed as an important project at the Planning Session this fall. An initial scoping meeting may be convened after the holiday season. She also wrote that this fall FHTET would coordinate a Model Program Planning Session to develop a 5-10 year strategic plan for development, maintenance, and support activities. Prioritization of efforts will be an important element of this meeting. There will also be a period of time set aside to review alternative methods for accomplishing work that may be more effective or efficient.

Thanks to all who participated in discussions at the meeting and provided additional information.

REGIONAL REPORTS

Rocky Mountain Regional Report

Submitted by Dave Johnson

1. New and Continuing Projects

Root and Soil Diseases or Relationships (including Mycorrhizae)

Epidemiology of Armillaria root disease in campgrounds (J. Worrall, T. Harrington, P. Gauss).

Ski area vegetation management: biology and impacts of the Armillaria root disease/western balsam bark beetle complex (T. Eager, J. Negron).

Stem Diseases: Malformations, Witches'-Brooms, Dwarf Mistletoes, Etc.

Silvicultural control of dwarf mistletoe in young lodgepole pine stands (B. Geils, D. Johnson).

Miscellaneous Studies

GIS-based landscape-scale prediction system for pinyon pine decline (W. Jacobi, S. Harrison, T. Eager, R. Mask).

Stand characterization and manipulation associated with western balsam bark beetle and decline of subalpine fir in the central Rocky Mountains (T. Eager).

Vegetation management planning in developed recreation sites (D. Johnson, J. Worrall).

DISEASE CONTROL COMMITTEE REPORT - 2000
ROCKY MOUNTAIN REGION

The Bessey Nursery, located in Halsey, Nebraska, is participating in the nationwide project for developing alternatives to methyl bromide. Basamid (Dazomet), solarization and fallowing with tilling will be compared to methyl bromide as alternative treatments. Soil samples were tested at Oregon State University for pathogenic nematodes and soil-borne fungi. Eastern redcedar was sown in the treated beds and will be evaluated for emergence and growth vigor for the next two years along with soil samples to compare the best yield results of the various treatments.

ROOT DISEASE COMMITTEE REPORT - 2000
ROCKY MOUNTAIN REGION

PROJECT TITLE: Pest Trend Impact Plots In The West- Rocky Mountain Region

INVESTIGATORS: Tom Eager, Jeri Lyn Harris, Jim Worrall and Bernard Benton, Forest Health Management, Rocky Mountain Region.

COOPERATORS: Judy Adams, Forest Health Technology Enterprise Team; Jim Friedley, BIA Southern Ute Agency; Don Brake, BLM Gunnison Resource Area Office; Elizabeth Stiller, Randy Rick, Jim Allen and Steve Pische, Black Hills NF; Sam Schroeder, White River NF; Gary Roper, Mike Morrison and Mike Westfahl, Routt NF; Paul Langowski and Steve Johnson, Roosevelt NF; Jon Morrissey, Grand Mesa, Uncompahgre and Gunnison National Forests; Phil Kemp and Bob Vermillion, San Juan NF.

YEARS: Begun- 1991; End- indeterminate

PROJECT DESCRIPTION: From 1991, a network of permanent plots were installed to track the spread and intensification of root diseases, dwarf mistletoes, stem rusts and western spruce budworm in a variety of cover types throughout the Rocky Mountain Region. The objective of the project is to establish a series of permanent plots to provide data for the validation and calibration of various insect and disease computer simulation models. Work on these plots continues with the remeasurement of Comandra blister rust and white pine blister rust plots planned in 2000.

PROJECT TITLE: GIS-Based Landscape-Scale Root Prediction System For Pinyon Pine Decline.

INVESTIGATORS: William Jacobi and Sam Harrison, Dept. of Plant Pathology and Weed Science, Colorado State University (CSU); Tom Eager, Roy Mask and Michelle Frank, Forest Health Management, Rocky Mountain Region.

COOPERATORS: Eric Smith, Forest Health Technology Enterprise Team; Jose Negron and John Lundquist, Rocky Mountain Forest and Range Experiment Station; Robin Reich and Gene Kelly, CSU; John Guyon, R4 FHP; Terry Rogers, R3 FHP; Phil Kemp, Eric Lindroth and Dan Greene, Dolores Ranger District, San Juan NF; Jim Friedley, BIA Southern Ute Agency; John Waconda, BIA Albuquerque Area Office; Dan Ochocki, Colorado State Forest Service, Durango District.

YEARS: Begun- 1998; End- 2000

PROJECT OBJECTIVE: To produce a GIS-based landscape scale prediction system for incidence of pinyon pine decline in Southwest Colorado. The general principles of this model will be applicable, with local modifications, to pinyon/juniper forests throughout the Intermountain West.

PROJECT DESCRIPTION: Although a variety of causes are responsible for decline of pinyon pine in various areas, in many locales the key agents are black stain root disease (Leptographium wageneri) and pinyon ips (Ips confusus). Using aerial photography and site visits by field personnel, mortality centers in pinyon pine on the San Juan National Forest and Southern Ute Indian Reservation will be located and entered into a GIS database along with soil and site characteristics and locations of disturbed areas. By analyzing the data using spatial statistics, a hazard rating system will be developed for pinyon pine decline in Southwest Colorado.

During the 1998 field season, conventional and digital color infrared aerial photographs were acquired in the study areas on the San Juan NF and Southern Ute Indian Reservation. Ground transects were run over a sample of mortality sites, where insect, disease and site characteristics were recorded.

RECENT PUBLICATIONS (as of October 2000)

Allen, K.K. and J.D. McMillin. 1999. Evaluation of mountain pine beetle activity in Beaver Park on the Spearfish/Nemo Ranger District of the Black Hills National Forest. USDA For. Serv., Renewable Resources, Rocky Mountain Region Biol. Eval. R2-00-01. 17 p.

Harris, J.L. 1999. White pine blister rust disease of limber pine in the Bighorn and Medicine Bow National Forests. USDA For. Serv., Renewable Resources, Rocky Mountain Region Biol. Eval. R2-00-02. 8 p.

Harris, J.L., K.K. Allen, and J. McMillin. 1998. Little Bighorn Analysis Area, Medicine Wheel and Tongue Ranger Districts, Bighorn National Forest. Insect and Disease Survey. USDA For. Serv., Renewable Resources, Rocky Mountain Region Biol. Eval. R2-99-03. 25 p.

Harris, J.L. 1999. Evaluation of white pine blister rust disease on the Shoshone National Forest. USDA For. Serv., Renewable Resources, Rocky Mountain Region Tech. Rep. R2-99-05. 11 p.

Harris, J.L. 1999. Phomopsis Blight at Bessey Nursery. USDA For. Serv., Renewable Resources, Rocky Mountain Region Biol. Eval. R2-99-07. 6 p.

Johnson, D.W. 1999. Evaluation of Porcupine and Snyder Creeks dwarf mistletoe thinning studies, Routt National Forest, Colorado. USDA For. Serv., Renewable Resources, Rocky Mountain Region Tech. Rep. R2- 62. 12 p.

Johnson, D.W. 1999. Disease survey of Buckhorn Creek lodgepole pine stand forty years after establishment, Canyon Lakes Ranger District, Arapaho and Roosevelt National Forests. USDA For. Serv., Renewable Resources, Rocky Mountain Region Tech. Rep. R2- 63. 5 p.

Johnson, D.W. Picea engelmannii Parry ex Engelm., 1863. 1999. *IN*: Schutt, Schuck, Lang, Roloff [eds.]. Enzyklopadie der Holzgewachse (Encyclopedia of Woody Plants). Ecomed Verlag, Landsberg, Germany. 8 p.

Johnson, D.W. and W.R. Jacobi. 2000. First report of white pine blister rust in Colorado. Plant Disease 84(5): 595.

McConnell, T.J., E.W. Johnson, and B. Burns. 2000. A guide to conducting aerial sketchmapping surveys. USDA For. Serv., Forest Health Technology Enterprise Team, Ft. Collins, CO. FHTET 00-01. 88 p.

McMillin, J.D. and K.K. Allen. 1999. Evaluation of mountain pine beetle activity in the Black Hills National Forest. USDA For. Serv., Renewable Resources, Rocky Mountain Region Biol. Eval. R2-00-03. 18 p.

McMillin, J.D., J.L. Harris and K.K. Allen. 2000. Insect and disease survey of the Bighorn National Forest. USDA For. Serv., Renewable Resources, Rocky Mountain Region Biol. Eval. R2-00-04. 27 p.

McMillin, J.D., and K.K. Allen. 2000. Impacts of Douglas-fir beetle on overstory and understory conditions of Douglas-fir stands, Shoshone National Forest, Wyoming. USDA For. Serv., Renewable Resources, Rocky Mountain Region Tech. Rep. R2-64. 17 p.

Negron, J.F., W.C. Schaupp, Jr., K.E. Gibson, J. Anhold, D. Hansen, R. Thier, and P. Mocettini. 1999. Estimating extent of mortality associated with the Douglas-fir beetle in the Central and Northern Rockies. Western Journal of Applied Forestry 14(3): 121-127.

Negron, J.F., W.C. Schaupp and E. Johnson. 2000. Development and validation of a fixed-precision sequential sampling plan for estimating brood adult density of *Dendroctonus pseudotsugae* (Coleoptera:Scolytidae). The Canadian Entomologist 132: 119-133.

Schaupp, W.C., Jr. 1999. Evaluation of the mountain pine beetle at the site of the Jamestown prescribed fire of May 1999, on the Boulder Ranger District, Roosevelt National Forest, Colorado. USDA For. Serv., Renewable Resources, Rocky Mountain Region Biol. Eval. R2-99-09. 20 p.

Schaupp, W.C., Jr., M. Frank, and S. Johnson. 1999. Evaluation of the spruce beetle in 1998 within the Routt Divide Blowdown of October 1997, on the Hahns Peak and Bears Ears Ranger Districts, Routt National Forest, Colorado. USDA For. Serv., Renewable Resources, Rocky Mountain Region Biol. Eval. R2-99-08. 15 p.

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History Of The Lodgepole Pine Dwarf Mistletoe Vector Study On The Fraser Experimental Forest In Colorado

Thomas H. Nicholls
Research Wildlife Biologist & Forest Pathologist, retired
North Central Research Station, St. Paul, MN.

This is a brief history of the lodgepole pine dwarf mistletoe vector study on the USDA Forest Service's Fraser Experimental Forest (FEF) in Colorado.

The 36-sq mile FEF, in the Arapaho National Forest, is located 6 miles SW of Fraser, in Grand County. It is administered by the Rocky Mountain Research Station (RMRS) headquartered in Ft. Collins, CO. The elevation of the Forest ranges from 8,800 to 12,804 ft.

The USDA Forest Service dedicated the FEF in 1937 as an outdoor laboratory to research sub-alpine forests representative of much of the central and southern Rocky Mountains. In 1978, the Forest was designated a World Biosphere Reserve by the United Nations, one of many worldwide dedicated to the study and conservation of the diversity and integrity of plant and animal communities within natural ecosystems. Experimental Forests and Biosphere Reserves, by their nature, are strategic for carrying out long-term ecological and environmental studies, such as the study reported here.

The study was initiated in 1982 by Forest Service Research Plant Pathologists Thomas H. Nicholls, of the North Central Research Station (NCRS), St. Paul, MN, and the late Frank Hawksworth of the RMRS, Ft. Collins, CO, along with the assistance of Laura Merrill who was working with Frank at the time. The objective of their study was to identify animal vectors of lodgepole pine dwarf mistletoe (Arceuthobium americanum) and to determine their potential importance in the establishment of new infection centers that could not be explained by normal spread of mistletoe seeds shot up to 50 feet from ripe mistletoe fruits.

Lodgepole pine dwarf mistletoe causes major economic timber production losses through tree deformity and mortality. The study identified several bird and mammal vectors of lodgepole pine dwarf mistletoe seed. Using bird banding and radio telemetry techniques, Tom and Frank documented how mistletoe seeds were carried beyond the normal seed dispersal range of infected trees. Birds and mammals, foraging in infected lodgepole pine, become inadvertent targets of explosive, sticky mistletoe seeds that often stick to their feathers or fur. As these animals move about the forest and clean their bodies, mistletoe seeds are sometimes deposited on healthy lodgepole pine where seeds germinate and cause new infections.

Study results explained how new infection centers could become established in the forest, sometimes far-removed from main infection centers. The most practical management plan for controlling infection centers initiated by animal-disseminated seed is to find them through timely, systematic surveys when they are small enough to remove infected trees.

This management action can effectively prevent or slow the spread of mistletoe from small, isolated pockets of infection to adjacent healthy, susceptible trees.

An alternative control method using a growth regulator was tested on the FEF in cooperation with Forest Pathologists David Johnson, USDA Forest Service, Forest Pest Management, Lakewood, CO, and Kathy Robbins of NCRS. The objective of this work was to determine whether small pockets of infected trees could be saved and adjacent trees protected by treating infected trees with an Ethephon growth regulator which releases ethylene, a natural gas found in nature that causes, among other things, tree leaves to abcise at the end of the growing season.

Ethephon was effective in causing mistletoe shoots to drop off trees, thereby, significantly reducing seed dispersal for 3 to 4 years after treatment of infected trees using ground sprayers. However, the parasite in the host tissue was not killed and new mistletoe shoots began to develop on some infections with female shoots fruiting 4 to 5 years after treatment. It was found that frequent Ethephon treatments would be required to effectively manage this disease making it economically unfeasible under forest conditions. However, Ethephon treatments using ground sprayers can be used to slow the development of dwarf mistletoe in high value trees located in campgrounds, small parks, golf courses, and around buildings, so it was registered for this use. Aerial application of Ethephon was not effective in controlling lodgepole pine dwarf mistletoe.

The results of the FEF Ethephon work stimulated many other studies of the growth regulator for use on other mistletoe species.

Tom, later looking though the eyes of a wildlife biologist rather than those of a forest pathologist, switching disciplines in 1986, found that control of dwarf mistletoe infection pockets may not be the best management action to take in all situations, especially in terms of ecosystem health.

While dwarf mistletoes are often a major cause of tree deformity and mortality in affected coniferous stands throughout the northern hemisphere, where they cause significant losses in timber production, the resulting dead and declining trees often have a positive affect on many wildlife species. Mistletoes create canopy openings providing conditions suitable for plant species not ordinarily found in dense, healthy stands which in turn attract a variety of animal species. Mistletoe shoots are eaten by some mammal and bird species. Insect prey is abundant in affected trees attracting a wide variety of insect eating birds such as woodpeckers and warblers. In addition, there are several species of raptors and songbirds that nest in witches' brooms of various dwarf mistletoe species. Thus, based upon the Fraser study and other related studies, mistletoes have been found to play a positive role in creating more compositional (both plant and animal), structural, and functional diversity in the forest. Whether this is good or bad depends upon the management objectives for any given stand or forest.

Early study results found that the gray jay was one of the most important vectors of lodgepole pine dwarf mistletoe on the FEF. As a result, later work began to focus on gray jay movements, longevity, site fidelity, and communication to better understand this species. During the course of these later studies, it became clear that the gray jay, a year-round resident of the Forest, is an integral part of the ecosystem, maybe even a keystone species, and a remarkable, highly intelligent, long-lived bird with amazing survival tactics and communication skills.

In fact, the ecology of the gray jay was so interesting to Tom that he has continued research on the bird as a Forest Service Volunteer since his retirement in 1994 as has his wife, Mary Lou, also a Forest Service Volunteer. Tom, and NCRS Wildlife Technician, Leanne Egeland, have studied gray jays on the FEF for 19 consecutive years and is believed to be the longest continuing study of gray jays in the United States. During that time, they have studied, banded, and released over 446 individual gray jays using over 40 mist-net trapping locations located about 1/2 mile apart centered on the FEF Headquarters Compound. Many of the adult jays have been retrapped many times over the years in the same locations where they were originally banded, often with dwarf mistletoe seeds adhering to their feathers.

Many of the banded gray jays have achieved long-lived status of between 8 and 15 years of age. The FEF has the distinction of having the oldest recorded living gray jay in the wild. It was recently recaptured on 8 Sept 2000, 15 years after it was originally banded in 1985, a U.S. record for gray jay longevity according to the USGS Bird Banding Laboratory.

The record bird was originally banded at the FEF Headquarters as a hatch-year bird on 16 Aug 1985. It dispersed about 2 miles away and was retrapped and released on its new territory on 8 Sept 1998,10 Sept 1999, and 8 Sept 2000. The bird's weight has remained normal and steady over the years ranging between 69 and 73 grams. A new Fish & Wildlife Service band was put on the bird a couple of years ago because the original band, although readable, had worn thin and was about to fall off the bird. The old band was still on the bird in 2000. As with any record bird, the "reading of the band number" was witnessed this time by Sandra Ryan and Mark Dixon, employees of RMRS and by Mary Lou Nicholls. After a few photos, the bird was released back to the wild.

Study results on the FEF indicate a relatively long life span and high site fidelity for resident adult gray jays that live in permanent all-purpose territories in the sub-alpine forests where they live under extreme winter weather conditions at high elevations. The bird survives these harsh conditions because it has a rather unique way of preserving food. Gray jays possess two large mandibular salivary glands, one on each side near the base of the bill. The jay shapes its food into an oval pellet, or bolus, with its tongue and permeates it with saliva. The sticky saliva is used to glue food pellets to vegetation during the non-winter months where they dry to form a hard protective covering around the food. What is even more remarkable, gray jays can remember where they store most of their food enabling them to survive the long winters on the FEF.

Next year, 2001, will be the 20th anniversary of the study at which time future plans will be discussed. Also, 20 years of gray jay data will start to be summarized and analyzed in preparation of a paper dedicated to the late Frank Hawksworth who inspired the study in the first place, made it possible, and who made all of the hard work enjoyable as well.

The following papers, listed in chronological order, have been published based on information gathered, in all or part, during the FEF study.

Nicholls, T.H.; Hawksworth, F.G. 1983. Animal vectors of lodgepole pine dwarf mistletoe. Abstract A561. Phytopathol. 73(5):836.

Nicholls, T.H.; Hawksworth, F.G.; Merrill, L.M. 1984. Animal vectors of dwarf mistletoe, with special reference to Arceuthobium americanum on lodgepole pine. In: Hawksworth, F. G.; Scharpf, R.F., eds. Biology of dwarf mistletoes: Proceedings of the symposium; 1984 August 8; Fort Collins, CO. General Technical Report RM-111. Fort Collins, CO: USDA Forest Service, Rocky Mountain Forest and Range Experiment Station: 102-110.

Nicholls, T.H.; Hawksworth, F.G.; Merrill, L.M. 1984. A preliminary look at animal vectors of lodgepole pine dwarf mistletoe. In: Dubreuil, Suzanne H., comp. Proceedings of the 31st Western International Forest Disease Work Conference; 1983 August 22-26; Coeur d'Alene, ID. Missoula, MT: USDA Forest Service, Northern Region: 54-56.

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Nicholls, T.H.; Egeland, L.; Hawksworth, F.G.; Johnson, D.W.; Robbins, M.K. 1987. Control of dwarf mistletoes with a plant growth regulator. In: Troendle, C.A.; Kaufmann, M.R.; Hamre, R.H.; Winokur, R. P., eds. Management of subalpine forests: building on 50 years of research: Proceedings of a technical conference; 1987 July 6-9; Silver Creek, CO. General Technical Report RM-149. Fort Collins, CO: USDA Forest Service, Rocky Mountain Forest and Range Experiment Station:154-156.

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Hawksworth, F.G.; Johnson, D.W. 1989. Biology and Management of Dwarf Mistletoe in Lodgepole Pine in the Rocky Mountains. General Technical Report RM-169. Fort Collins, CO: USDA Forest Service, Rocky Mountain Forest and Range Experiment Station. 38 p.

Nicholls, T.H. 1989. Ethephon tests for control of lodgepole pine dwarf mistletoe in Colorado. In: van der Kamp, Bart J., comp. Proceedings of the 36th Western International Forest Disease Work Conference; 1988 September 19-23; Park City, UT. Vancouver, Canada: Dept. of Forest Science, University of British Columbia. 34-37.

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WIFDWC BUSINESS MEETING

Submitted by Pete Angwin

WIFDWC Chairman Bill Jacobi called the meeting to order at 3:48, Wednesday, August 16, 2000. Thirty-five members were present.

Thanks were extended to members of the 2000 WIFDWC Committee: Jerry Beatty (local arrangements), Sue Hagle (program chair), John Schwandt (treasurer), Pete Angwin (secretary) and Judy Adams (web site coordinator). Sixty-three participants registered for the meeting.

The minutes of the 1999 WIFDWC/WFIWC meeting held in Breckenridge, Colorado, were approved as written.

John Schwandt, WIFDWC Treasurer, gave a brief Treasurer's report. The balance in the WIFDWC account was about $3,500. However, approximately $1,300 of this will be used to cover the WIFDWC portion of the budget shortfall from the 1999 WIFDWC/WFIWC meeting. This shortfall resulted when expenses exceeded the amount of registration fees that were collected. A complete Treasurer's report will be included in the next Proceedings. Approximately $1,600 was spent to bring 3 speakers (Clive Brasier, Joan Webber and Dan Nickrent) to the meeting. John recommended that in the future, requests for travel assistance for special speakers be made early, so that registration fees that are collected will be sufficient to offset meeting expenses.

Future Meetings

The WIFDWC Railroad Committee announced the nominees for officers for the 2001 meeting: Chairman: Dave Johnson, Interim Program Chair: Al Kanaskie and Secretary: Katy Marshall. The selections were approved by a unanimous vote. John Schwandt will continue in his position as Treasurer and Judy Adams will continue to administer the WIFDWC web site.

The 2001 WIFDWC will be held in Monterey, California. Susan Frankel is local arrangements chair. Susan showed slides of Monterey. Locations and potential dates for the meeting were discussed. The general consensus was to meet at a moderately-priced motel and to avoid conflicting with the APS meeting in late August *(Secretary's Note: the 2001 WIFDWC Meeting has since been set for September 10-14, at the Carmel Mission Inn in Carmel, CA).*

The 2002 WIFDWC will be held in Powell River, British Columbia. The meeting has historical significance as the 50th WIFDWC. Rona Sturrock gave a status report on the planning efforts. Stephan Zeglan is taking the lead in local arrangements. There will be opportunities to visit field sites with Armillaria root disease, laminated root rot, white pine blister rust, etc. Dates for the meeting will be determined next year.

A lively discussion was held regarding the location of the 2003 WIFDWC. Mary Lou Fairweather nominated Flagstaff, Arizona for the meeting and Ellen Goheen nominated Ashland, Oregon. Ashland was selected by a vote of 19 to 16. Ellen Goheen will serve as local arrangements coordinator.

Old Business

WIFDWC Outstanding Achievement Award: Current members of the WIFDWC Outstanding Achievement Award committee are Jim Byler, Will Littke and Bart van der Kamp. A proposal was made to have committee members serve 3-year terms, with a new member joining and an old member leaving the committee each year. A new member would be elected at the business meeting each year. Jim Byler would leave the committee in 2000, Will would leave in 2001 and Bart would leave in 2002. The motion was moved, seconded and passed. Rona Sturrock was nominated as the new member of the committee, with a term to end in 2003. The motion was moved, seconded and passed.

Will Littke led a discussion on the criteria and process for choosing the WIFDWC Outstanding Achievement Award recipient. The committee recommended that since the award is primarily for the purposes of recognition, the recipient should be a current or active member of WIFDWC who is still active in Forest Pathology. Their sense was to not divide this into separate "research"/"non-research" awards, but to leave it open for the committee to decide who would receive the award. This year, two award recipients, Lew Roth and Duncan Morrison, made up for the lack of an award last year. In the future, one award will be given per year. Nominations should be forwarded to a committee member.

WIFWDC Website: In 1999, the decision was made to put the WIFDWC Committee Reports, as well as a synopsis of the meeting on the WIFDWC website. A committee made up of Fred Baker, John Muir and Judy Adams was formed to explore issues pertaining to publishing the proceedings on the web. Fred Baker volunteered to investigate the logistics and costs associated with publishing our past proceedings on CD-ROM. Judy reported that the committee had not yet met, so no recommendations were made. It was decided that Bill Jacobi or Dave Johnson would contact Fred and the issue would be tabled until next year.

Joint Meetings With WFIWC: A discussion was held regarding the issue of continuing to hold joint meetings with the entomologists every five years. At the WFIWC meeting in Portland last March, a vote was taken and they decided to invite us to their meeting in 2004. Frustration was expressed regarding the difficulty of designing a fully integrated program. Various suggestions were made, including increasing our program contributions, holding sessions both together and apart, holding the first day of the meeting separately, starting program planning two years in advance of the meeting, having a unified meeting theme, and having two program chairs. Several motions were moved, seconded and carried:

1. That we meet with WFIWC in 2004.
2. That we have dual program chairs, one pathologist and one entomologist.
3. That we nominate a committee in 2001 to start working on the joint meeting and we recommend that the entomologists do the same.

Honorary Life Members: In 1999, the criteria for awarding Honorary Life Membership status and what to charge HLMs for meeting registration and Proceedings were discussed. As a result, two bylaw change proposals were prepared in writing by John Laut, who was unable to attend the meeting. The proposals were as follows:

Proposed Amendments to the BYLAWS of the Western International Forest Disease Work Conference, as published in the Proceedings of the 46th (1998) Conference, pp159-162;

1. The paragraph in Article 2 "Membership" pertaining to Honorary Members (last paragraph on p. 159) be amended to read:

Honorary Life Membership will be automatically awarded to those members of WIFDWC (as defined above) who have attended at least 5 previous meetings of WIFDWC, and have retired from active forest pathology endeavors. Newly retired members who meet this criterion should notify the current WIFDWC Chairperson of their status. Other MEMBERS who have retired but do not meet the attendance criterion, or other outstanding contributors to the field of Forest Pathology, may request, or be proposed for, Honorary Life membership, to be voted on by secret ballot, by members present at an annual business meeting.

A list of Honorary Life Members will be published in the Proceedings of each meeting.

A 50% or more reduction in registration fees for Honorary Life Members, to include a copy of the Proceedings, should be considered by the executive committee, as per Article 7, amended in 1999.

2. Article 9 (p. 162) "PROCEEDINGS" shall be amended to read:

Distribution of Proceedings will be made to all registrants, including Honorary Life Members. The Secretary will query all Honorary Life Members to determine if they wish to receive a copy of the current Proceedings at cost (printing and postage).

Notes (John Laut)
An historical review (Laut, 1997 Proceedings, p. 106) shows the preferred term to be "Honorary Life Membership" (also see Hawksworth, Laut and Frankel, WIFDWC, A brief History and Index to Proceedings, 1-40, (p.9), distributed with the 1992 proceedings). The

original designation of "honorary member" was made in 1964 (p. 113) and in 1967 (p. 108) the designation was clarified by carried motion to show that it "begins with termination of principle employment and that such designation be irrevocable" (emphasis mine). Thus the recommended addition of the word "Life" in this amendment.

The recommendation for reduction of registration fees was placed in Article 7 "Meetings" by vote of the members at the 1999 meeting. The wording of this amendment follows that amendment.

Existing bylaws, Article 9, provides that Honorary members will receive a "free" copy of the Proceedings following a query from the Secretary. However, I believe that Honorary Life Members, who do not attend a particular meeting should at least pay the cost of the Proceedings if they want a copy.

The two bylaw changes were discussed and brought to separate votes. The changes to Article 2 passed, but the statement, **"to be voted on by secret ballot"** was omitted. The change to Article 9 failed. As a result, HLMs who wish to receive a copy of meeting Proceedings will continue to do so at no cost.

New Business

Name Change For Disease Control Committee: The group next discussed a proposal to change the name of the Disease Control Committee to the Invasive Disease Control Committee. Concern was raised that adding the term "Invasive" would limit the current broad scope of the committee. Following the suggestion that a new, appropriately inclusive term for the name of the committee be developed, further discussion was tabled until next year.

Change To Non-Profit Organization Status: Discussion followed on the advantages and disadvantages of WIFDWC becoming a "501-3C Non-Profit Organization". A major advantage would be gaining tax-exempt status. Disadvantages include the numerous governmental hoops that would have to be passed in order to gain that status, including the requirement that we develop a WIFDWC Constitution to replace our current bylaws. John Schwandt agreed to further investigate the requirements, advantages and disadvantages of our becoming a 501C Non-Profit Organization.

The meeting was adjourned at 5:06pm.

TREASURER'S REPORT, 48th WIFDWC

Submitted by John Schwandt

The following is a summary of transactions for the WIFDWC account since 11/1/99. The joint meeting with the entomologists in Breckenridge, Colorado failed to collect enough in registration fees to cover all costs so we split the deficit with the entomologists and covered our net loss with the surplus from previous meetings.

TRANSACTION			**BALANCE**
Balance reported in last report (as of 11/1/99) including: $3,577,12			
Surplus (balance) from prior meetings		2,165.95	2,165,95
Balance of income from Joint meeting		1,228.96	
Interest on account 11/1/98-11/1/99		182.21	2,348.16
Additional expenses for 1999 joint WIFDWC - WFIWC meeting Breckenridge, Colorado	*Amount*	*99 Mtg Balance*	
Balance as of last report (11/1/99)		1,228.96	
Printing/Binding of Proceedings	-3,500	-2,271.04	
Reimbursement (50%) from entomologists	1,135.52	-1,135.52	
Misc. expenses (commemorative postcards)	-193.69	-1,329.21	
WIFDWC Shortfall for 1999 meeting		-1,329.21	1,018.95
WIFDWC 2000 MEETING – Waikoloa, HAWAII		*2000 Mtg Balance*	
Total registration (after refunds of $575)	12,888,00	12,888.00	
Meeting setup expenses	-735.00	12,153.00	
Hotel meeting rooms, breaks, meals. AV, etc.	-8,683.03	3,469.97	
Field trip transportation	-1,065.00	2,404.97	
Field trip food and entrance fees	-1,545.00	859.97	
Misc. expenditures (awards, etc)	-213.77	646.20	1665.15
Printing/mailing costs for Proceedings	?	?	
Outside speaker expenses	-1650.00		15.15
Misc Transactions through 12/31/2000			
Sales of Proceedings	34.00		49.15
Bank service charges	-29.97		19.18
Dividends 11/2/99-12/31/2000	131.64		150.82
Balance as of 12/31/2000			**$150.82**

I am also holding $2,217.13 in hazard tree conference funds. ($200 was spent since last year in preparation for the next conference in 2001).

WIFDWC OUTSTANDING ACHIEVEMENT AWARDS - 2000

Submitted by Will Littke

Purpose: At Breckenridge, CO, WIFDWC authorized the recognition of members who have demonstrated a significant contribution to forest pathology. The nomination process consists of letters of recommendations from the general membership. A three-person committee reviews these nominations and decides on the award.

In 2000, the awards committee consisted of James Byler, Bart Van der Kamp and Will Littke. In light of the inaugural award year in 2000, the committee decided to recognize the significant contribution of our members from Canada and the United States by awarding two joint awards.

The 2000 Outstanding Achievement Awards were presented in Hawaii to Duncan Morrision and Lew Roth. Rich Hunt accepted for Duncan and Everett Hansen for Lew Roth. Abstracts of their nomination letters are provided below.

Everett Hansen and Rich Hunt accepting the 2000 WIFDWC
Outstanding Achievement Awards for Lew Roth and Duncan Morrison

Nominations: Both Duncan and Lew have a long distinguished history of working with/for the WIFDWC organization. I have summarized a few of the comments from the members nominating these individuals.

Duncan Morrison:

“Dr. Duncan Morrison is a Research Scientist in Forest Pathology with the Canadian Forest Service at the Pacific Forestry Centre. He is an expert on biology and management of root diseases including Armillaria root disease, laminated root rot, Annosum root disease, and black stain root disease, and on the management of tree hazards. He is an adjunct professor on the Faculty of Forestry at the University of British Columbia. He is a member of the Canadian Phytopathological Society, and the Canadian Institute of Forestry. He is a member of the IUFRO Working Party S2.06.01 on Root and Butt Rots; he served as that working party's Organizing Chairman and Chairman in 1988 and 1993, respectively. Duncan has been an active member of WIFDWC since the early 1970s, presenting information, organizing panels, field trips, and local arrangements, and serving as the WIFDWC Chairman in 1992. He currently is WIFDWC's Historian". (Ellen Michaels Goheen)

Lew Roth:

"After school, Lew taught Forest Pathology for years at Oregon State University. In addition to his pioneering work on Phytophthora lateralis, Armillaria, and dwarf mistletoes, he was responsible for training many Plant Pathologists, among them Everett Hansen, Earl Nelson, Larry Englander, and others. His inspiration and leadership to his students and colleagues was equaled only by his skills at observation. Always one to tell it as he sees it, he has a firm understanding of both fungal ecology and forest management. He has influenced a generation of forest pathologists and land managers, and to this day continues to challenge the assumptions and knowledge of those fortunate enough to be around him" (Mike McWilliams)

MEMORIAL STATEMENTS

David W. French

November 10, 1921 - January 11, 2000

By
F.A. Baker

Dave was born in Mason City, Iowa and was raised in upstate New York. He received his BS degree in Forestry from the University of Minnesota in 1943, and then served three years in the Army. He earned MS and Ph.D. degrees from the Department of Plant Pathology, University of Minnesota, the latter in 1952. Dave was promoted to full professor in 1963. He served the department as associate director and superintendent of the Lake Itasca Forestry and Biological Station, and as assistant department head and department head.

In the classroom and in the field, Dave was an outstanding teacher. His lectures brought diseases to life. Students soon learned to appreciate his dry sense of humor. His writing style was clear, concise, and easy to read. His textbook Forest and Shade Tree Pathology is still reprinted today, and probably outsells all other forest pathology texts combined. Dave's class so intrigued students that many went on to graduate school in plant pathology.

Dave guided many graduate students to successful careers in forest pathology. He developed students by getting them started, keeping in touch with them, providing the equipment, travel and encouragement they needed, and then staying out of their way to let them reach their full potential. He treated his students as equals; he often said it was important to treat students right, as they could come back to be your boss, as Al Wood did!

Under Dave's guidance, the University of Minnesota contributed in many areas of forest pathology. Work on aspen cankers has probably led to understanding the infection process of Hypoxylon canker and the role of branch stubs. Dave recognized the importance of jack pine stem rusts in Minnesota's forests, and a long succession of students have helped to understand the biology of the rust fungi and to develop rust resistant seedlings. He recognized that dwarf mistletoe was the major factor affecting black spruce, and his recommendations calling for eradication of this parasite have been proven almost 40 years later. The forest products industry frequently called upon Dave for help. Throughout these research efforts, Dave always tried to foresters solve problems on the ground. He also brought other disciplines to bear in solving problems. For example, he was among the first to use remote sensing to locate dwarf mistletoes and oak wilt. He was also involved in the practical application of prescribed burning to manage diseases. Dave once used the oak wilt fungus and prescribed burning to keep oaks from colonizing grassland islands important for nesting habitat for geese.

Dave's greatest influence on Minnesota, however, was in the areas of Dutch elm disease and oak wilt. Dave not only researched these diseases, he knew them. He grew trees for therapy, but the trees were always available for an experiment. He made sure that any class that wanted had fresh disease samples from his nursery. Elms, oaks, and even white pines succumbed to experimental inoculations or to diseases that Dave encouraged, just to have around. The lucky survivors were given away as Christmas trees or as shade trees. Dave thoroughly enjoyed trying new trees and learning which species could survive in Minnesota, and the diseases that would keep others out. He showed that Dutch elm disease and oak wilt could be managed; even today Minnesota's Dutch elm disease control programs are still in place, because many elms still survive. How many other DED researchers succeeded in helping their communities keep their elms? Dave was successful because he worked well with people, from tree trimmers to administrators to legislators. He gave them information they could use; he talked with people, and returned their calls, even when he had several inch thick piles of phone messages. People came to listen to him. The first time I saw Dave speak was at a Horticulture Industries conference. The room filled before his talk, he held them spellbound, and then answered questions for an extra ten minutes. And then the room emptied. A tough act for the rest of us to follow.

Dave was about people; he understood that people implemented management. He could find the right people and convince them to act. In doing so, he helped establish one of the strongest state shade tree and urban forestry programs in the nation. Some call him the father of urban forestry in Minnesota. While he would probably deflect credit, his fingerprints are present at every major step along the way. In recognition of his accomplishments, the Department of Plant Pathology at the University of Minnesota is accepting donations to establish an endowed chair in urban tree health.

Dave contributed to his profession, his university and his state. He encouraged many people along the way. He mentored many of us as we became his friends and colleagues. We are diminished.

Mike Larson

By
A.E. Harvey

As you know, we lost Mike last spring to a heart attack, just after he retired. His plans were to enjoy life a little, without the everyday stress imposed by the “up tempo” life of full time research. He also intended to finish off his work with *Phellinus* (etc.) on a more casual pace. Unfortunately, it was not to be. He will be missed! His personal library on and knowledge of the taxonomy of fungi were legendary. His contributions to mycology, and forestry, were both significant and extensive. His instinctive ability to unravel the intricacies of the genus *Phellinus* (and others) has been world class and his basic understanding of the place and functions of fungi in forest ecosystems admirable, especially with regard to the small details the rest of us were inclined to forget. His publication record was extensive, upwards of 140, with most in well respected journals or proceedings. We miss “Uncle Mike” and his droll humor, in both his professional and personal life, and wish him Godspeed!

Larry Weir

December 13, 1923 – April 3, 2000

By
A. Kanaskie

Lawrence Carlton Weir was born on December 13, 1923 in Olds, Alberta. He died in Salem Oregon on April 3, 2000, at the age of 76.

Larry spent much of his life in Alberta and British Columbia. He served in the Canadian Army form 1943 to 1947. His exposure to the great outdoors began in 1951 as a back-country park warden in Banff national park. It was here that he learned the wisdom of the hills, cross-country skiing and horsemanship (at least partly). It was during an argument with a horse, in which the horse won, that Larry decided there had a be a better way to earn a living.
His experience in forest pathology began in 1953, when he became an insect and disease ranger for the Canadian Forestry Service in Calgary, Alberta, under C. McGuffin. In 1955 Larry became a forest pathology technician under V.J. Nordin in Calgary. During these years his duties included detecting, identifying, and monitoring insects and diseases and their impacts on forests throughout Alberta.

Having obtained sufficient field experience, Larry decided to turn professional. He received a B.S. degree in Forestry in 1959 form the University of British Columbia. He continued his studies at Iowa State University, earning an M.S, degree in Plant pathology in 1961. According to Larry, there were two reasons for choosing pathology over entomology: first, diseases don't bite back, and secondly, they're still there the next time you want to check on them.

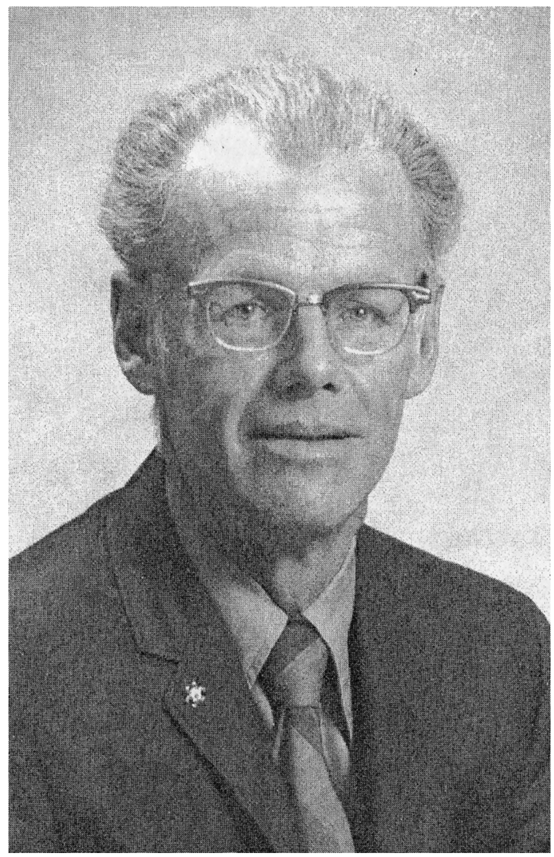
While finishing his degree at Iowa State, Larry took a position with the Canadian Forestry Service in Victoria, B.C. as a research officer in forest pathology. He worked on a variety of diseases, but had a particular interest in root diseases. He held this job for 11 years, from 1960 through 1970.

Larry arrived in Salem, Oregon in 1970, and became the first forest pathologist for the Oregon Department of Forestry. He continued his work on root diseases, and established several long-term applied research projects relating to spread and control of root diseases, several of which continue to this day. His correspondence and writings reflect a keen and thorough observer with a strong interest in the history of forest pathology. He retired from the department of Forestry in August of 1984, after 14 years of service.

Larry was quite a colorful character on and off the job. One of his favorite sayings was "if you can't get to a diseased area bone dry and in your bedroom slippers, it's inaccessible". Well known for his musical talents, particularly piano and singing, he often entertained his colleagues at meetings. In Salem, he founded and directed the Salem Community Chorus, which he directed for 18 years. His community spirit and sharp sense of humor complimented his technical contributions to forest pathology in the Pacific Northwest.

Larry is survived by his wife Kathleen, whom he married in 1952, a daughter, Michelle of Salem, a son, Aubry of Vancouver, B.C., and three grandchildren.

Larry and wife Kathleen in 1952, soon after news that they were expecting a baby girl



Larry in 1999

WIFDWC PAST MEETING LOCATIONS AND EXECUTIVE COMMITTEES

YR	LOCATION	CHAIRMAN	SECY/TR	PROGRAM CHAIR	LOCAL ARRNGMTS
53	Victoria, BC	R. Foster			
54	Berkeley, CA	W. Wagener	P. Lightle		
55	Spokane, WA	V. Nordin	C. Leaphart	G. Thomas	
56	El Paso, TX	L. Gill	R. Davidson	V. Nordin	
57	Salem, OR	G. Thomas	T. Childs	R. Gilberston	
58	Vancouver, BC	J. Kimmey	H. Offord	A. Parker	
59	Pullman, WA	H. Offord	R. Foster	C. Shaw	
60	Centralia, WA	A. Parker	F. Hawksworth	J. Parmeter	K. Shea
61	Banff, AB	F. Hawksworth	J. Parmeter	A. Molnar	G. Thomas
62	Victoria, BC	J. Parmeter	C. Shaw	K. Shea	R. McMinn
63	Jackson, WY	C. Shaw	J. Bier	R. Scharpf	L. Farmer
64	Berkeley, CA	K. Shea	R. Scharpf	C. Leaphart	H. Offard
65	Kelowna, BC	J. Bier	H. Whitney	R. Bega	A. Molnar
66	Bend, OR	C. Leaphart	D. Graham	G. Pentland	D. Graham
67	Santa Fe, NM	A. Molnar	E. Wicker	L. Weit	P. Lightle
68	Couer D'Alene ID	S. Andrews	R. McMinn	J. Stewart	C. Leaphart
69	Olympia, WA	G. Wallis	R. Gilbertson	F. Hawksworth	K. Russell
70	Harrison Hot Springs, BC	R. Scharpf	H. Toko	A. Harvey	J. Roff
71	Medford, OR	J. Baranyay	D. Graham	R. Smith	H. Bynum
72	Victoria, BC	P. Lightle	A. McCain	L. Weir	D. Morrison
73	Estes Park, CO	E. Wicker	R. Loomis	R. Gilbertson	J. Laut
74	Monterey, CA	R. Bega	D. Hocking	J. Parmeter	
75	Missoula, MT	H. Whitney	J. Byler	E. Wicker	O. Dooling
76	Coos Bay, OR	L. Roth	K. Russell	L. Weir	J. Hadfield
77	Victoria, BC	D. Graham	J. Laut	E, Nelson	W. Bloomberg
78	Tuscon, AZ	R. Smith	D. Drummond	L. Weir	R. Gilbertson
79	Salem, OR	T. Laurent	T. Hinds	B. van der Kamp	L. Weir
80	Pingree Park, CO	R. Gilbertson	O. Dooling	J. Laut	M. Schomaker
81	Vernon, BC	L. Weir	C.G. Shaw III	J. Schwandt	D. Morrison/R. Hunt
82	Fallen Leaf Lake, CA	W. Bloomberg	W. Jacobi	E. Hansen	F. Cobb/J. Parmeter
83	Coeur D'Alene, ID	J. Laut	S. Dubreuil	D. Johnson	J. Schwandt/J. Byler
84	Taos, NM	T. Hinds	R. Hunt	J. Byler	J. Beatty/E. Wood
85	Olympia, WA	F. Cobb	W. Thies	R. Edmonds	K. Russell
86	Juneau, AK	K. Russell	S. Cooley	J. Laut	C. G. Shaw III
87	Nanaimo, BC	J. Muir	G. DeNitto	J. Beatty	J. Kumi
88	Park City, UT	J. Byler	B. van der Kamp	J. Pronos	F. Baker
89	Bend, OR	D. Goheen	R. James	E. Hansen	A. Kanaskie
90	Redding, CA	R. Hunt	J. Hoffman	M. Marosy	G. DeNitto
91	Vernon, BC	A. McCain	J. Muir	R. Hunt	H. Merler
92	Durango, CO	D. Morrison	S. Frankel	C. G. Shaw III	P. Angwin
93	Boise, ID	W. Littke	J. Allison	F. Baker	J. Hoffman
94	Albuquerque, NM	C. G. Shaw III	G. Filip	M. Schultz	T. Rogers
95	Whitefish, MT	S. Frankel	R. Mathiasen	R. Mathiasen	J. Taylor/J Schwandt
96	Hood River, OR	J. Kliejunas	J. Beatty	S. Campbell	J. Beatty/K.Russell
97	Prince George, BC	W. Thies	R. Sturrock	K. Lewis	R. Reich/K. Lewis
98	Reno, NV	B. Edmonds	L. Trummer	G. Filip	J. Hoffman/J. Guyon
99	Breckenridge CO	F. Baker	E. Michaels Goheen	J. Taylor	D. Johnson
00	Waikoloa, HI	W. Jacobi	P. Angwin	S. Hagle	J. Beatty

WIFDWC HONORARY LIFE MEMBERS

Living and Deceased (D)

"Honorary Members are WIFDWC members who have retired from continuous employment in the field of forest pathology"

Paul Aho 84	Norm Alexander 94	Ed Andrews 77
Stuart "Stuie"Andrews (D) 73	Jesse Bedwell (D) 66	Robert Bega (D) 85
Warren Benedict (D) 66	John Bier (D) 67	Dick Bingham 75
Bill Bloomberg (D) 90	Roy Bloomstrom (D) 92	Thomas "Buck" Buchanan (D) 72
Don Buckland (D) 56	Hubert "Hart" Bynum (D) 72	Elmer Canfield 83
Toby Childs D 68	Fields Cobb 93	Ross Davidson (D) 68
Oscar Dooling (D) 86	Charles Driver 92	Norm Engelhart (D) 59
David Etheridge 75	Lowell Farmer 65	Mike Finnis 84
Ray Foster 75	Dave French (D) 95	Alvin Funk 89
Lake Gill D 66	Linnea Gillman 80	James Ginns 96
Clarence "Clancy" Gordon (D) 81	Don Graham 80	John Gynn (D) 66
John Hansbrough (D) 68	Hans Hansen (D) 60	John Hart 99
Homer Hartman (D) 66	Bob Harvey 92	George Harvey (D) 76
Frank Hawksworth (D) 91	Dwight Hester (D) 83	Tommy Hinds 85
Ray Hoff 95	John Hopkins 87	Benton Howard (D) 71
John Hunt D 59	Paul Keener (D) 67	James Kimmey (D) 66
Tom Laurent 85	John Laut 93	Don Leaphart (D) 75
Paul Lightle 73	Otis Maloy 91	Neil Martin 89
Art McCain 93	Tom McGrath 97	Neil McGregor (D) 77
Jim Mielke (D) 66	D. Reed Miller (D) 70	Alex Molnar 76
Virgil Moss (D) 66	Earl Nelson 95	Tom Nicholls 95
Vidar Vordin 92	Harold Offord (D) 65	Nagy Oshima (D) 76
Lee Paine 81	Dick Parmeter 91	Roger Peterson 94
Clarence Quick (D) 68	Jerry Riffle 86	Jack Roff 75
Lew Roth 79	Ken Russell 96	Bob Scharpf 91
E. Mike Sharon 95	Charles G. Shaw (D) 84	Pritam Singh 97
Albert Slipp (D) 60	Richard B. Smith 90	Richard S. Smith 95
Willhelm Solheim (D) 65	James L. Stewart	Jack Sutherland 96
Al Tegethoff 80	Phil Thomas (D) 76	Jim Trappe 86
Eugene Van Arsdell	Allan Van Sickle 97	Willis Wagener (D) 65
Gordon Wallis 83	Charles "Doc" Waters (D) 60	Larry Weir 84
Conrad Wessela 66	Stuart Whitney 91	Roy Whitney 90
Ed Wicker 91	Ralph Williams 94	John Woo (D) 86
Ernest Wright (D) 65	Bratislav Zak 76	Wolf Ziller (D) 73

WIFDWC SOCIAL ACHIEVEMENT AWARD WINNERS

YR	LOCATION	WINNER
57	Salem, OR	Stuie Andrews
58	Vancouver, BC	Stuie Andrews
59	Pullman, WA	Don Leaphart
60	Centralia, WA	Keith Shea
61	Banff, AB	Phil Thomas
62	Victoria, BC	Toby Childs
63	Jackson, WY	Alex Molnar
64	Berkeley, CA	Reed Molnar
65	Kelowna, BC	Art Parker
66	Bend, OR	Gardner Shaw
67	Santa Fe, NM	Larry Weir
68	Couer D'Alene ID	Bob Scharpf
69	Olympia, WA	Dick Parmeter
70	Harrison Hot Springs, BC	Jim Kimmey
71	Medford, OR	Ed Wicker
72	Victoria, BC	Vivian Muir
73	Estes Park, CO	Tom Laurent
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75	Missoula, MT	Art McCain
76	Coos Bay, OR	-----
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91	Vernon, BC	Willis Littke
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94	Albuquerque, NM	Mary Lou Fairweather
95	Whitefish, MT	Susan Frankel
96	Hood River, OR	Ken Russell
97	Prince George, BC	AWARD RETIRED

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