PROCEEDINGS OF THE 43rd ANNUAL WESTERN INTERNATIONAL FOREST DISEASE WORK CONFERENCE

Whitefish, Montana
August-September, 1995

Proceedings of the 43rd Annual Western International Forest Disease Work Conference

Whitefish, Montana
August-September, 1995

Compiled by:
Robert L. Mathiasen
Northern Arizona University
School of Forestry
Flagstaff, Arizona

Proceedings of the Forty-Third Western International Forest Disease Work Conference
Whitefish, Montana August / September 1995

Compiled by Robert L. Mathiasen

TABLE OF CONTENTS

PANEL - TAXONOMIC RELATIONSHIPS OF POROID TAXA IN THE HYMENOCHAETACEAE WITH PARTICULAR EMPHASIS ON THE ORGANISM CAUSING LAMINATED ROOT ROT

SPECIAL PAPERS

PANEL - DWARF MISTLETOE TAXONOMY

SPECIAL PAPERS

PANEL - WHITEBARK PINE IN WESTERN FOREST ECOSYSTEMS

PANEL - DISTURBANCE ECOLOGY

POSTERS

COMMITTEE REPORTS

REGIONAL REPORTS AND WIFDWC BUSINESS

CHAIRMAN'S OPENING REMARKS

Susan Frankel
Plant Pathologist
USDA Forest Service
Pacific Southwest Region
San Francisco, CA 94111

Welcome to Whitefish, Montana for the 43rd annual Western International Forest Disease Work Conference (WIFDWC). WIFDWC is a participatory event so I encourage your participation through questions and discussion.

I would like to thank this year's organizing committee:
Robert Mathiasen and Paul Hennon for putting together an interesting program; Jane Taylor for taking care of the myriad details involved with local arrangements; John Schwandt for managing our money and Secretary Robert Mathiasen for sending out the mailings and keeping the conference plans moving along. They all did an excellent job of putting together this year's conference.

We are already planning for next year's meeting to be held in the Hood River Area on the border between Oregon and Washington. Everett Hansen, Peter Angwin and Gregg DeNitto are on the "Railroad Committee" to select officers for next year's meeting. Sally Campbell has been appointed interim program chairman. If you have any suggestions for next year's program please pass them on to her.

WIFDWC Survey Results

The last mailing that the 1995 WIFDWC organizing committee sent you included a questionnaire to see if WIFDWC could be changed to better meet the needs of its members. In the remainder of this presentation, I will present a summary of the questionnaire results.

Background of Respondents

We received 39 completed questionnaires: 33 from professional pathologists, 1 from a retired entomologist, 1 from a student and 4 from retirees. The group was dominated by USDA-Forest Service employees (54%) with 5% working for the Canadian Forest Service. Twenty-two percent work for Universities and 14% work for a state government (several pointed out that their University is a state institution). Five percent were working in the private sector. There was almost an even split between researchers and extension personnel: 50% performed primarily extension duties, 44% primarily research and 6% were split evenly between research and extension. The average respondent attended 5.8 WIFDWC's in the past 10 years with two replies from people that had never attended and three that came to all 10.

Overall Satisfaction

Sixty-six percent reported that WIFDWC met most of their needs. Fourteen percent said WIFDWC met all their needs and only 1 person (that identified himself as a retired entomologist) said WIFDWC met none of his needs.

Suggestions

Program suggestions that were most popular were: 69% wanted more information on new technologies; approximately one third of the respondents wanted to meet with other societies, or expand the geographic base of WIFDWC (such as having a National Forest Pathology meeting, or meet more often with entomologists.

People generally liked the format of WIFDWC. Again one third wanted more discussion and less formal presentations and one third asked for smaller, concurrent sessions. Skipping the field trip was very unpopular with only 6% in favor and many commenting to keep the field trip and expand post and pre-trip field trips.

We also asked whether registration fees should be used to cover costs to bring in guest speakers. Sixty-four percent agreed that WIFDWC funds could be used to bring in guest speakers.

Write-in suggestions included:

-expand the luncheon meetings so there is more time for committees to talk;
-drop the social achievement award and start a professional achievement award;
-Compile a list of E-mail, FAX and phone numbers for publication in the Proceedings.
-Work more closely with the Society of American Foresters.
-Expand coverage of ornamental tree diseases and agroforestry tree diseases and include items of interest to arborists.
-Hold pre-conference workshops on taxonomy, sampling or other topics of interest.
-Hold joint meetings with wildlife biologists or ecologists.

Several commented on the time of year the meeting was scheduled for: several asked for occasional Winter meetings so there wouldn't be a conflict with field work. Others liked the summer because it didn't conflict with teaching assignments.

In the words of one respondent "WIFDWC is beautiful as it is. Don't change too much." I hope you find this to be a "beautiful" week.

PANEL
TAXONOMIC RELATIONSHIPS OF POROID TAXA IN THE HYMENOCHAETACEAE WITH PARTICULAR EMPHASIS ON THE ORGANISM CAUSING LAMINATED ROOT ROT

Walt Thies, Moderator
Pacific Northwest Research Station
USDA Forest Service
Corvallis, OR 97331

Prologue

In 1914 *Poria weirii* Murrill, was described as occurring on western redcedar in northern Idaho (Murrill 1914). Later the host range was extended to most conifer species growing in the Northwestern United States and Canada. It became generally accepted by forest pathologists in the region that two recognizable forms of the fungus existed: a redcedar form and a Douglas-fir form. In 1974, based on characteristics of the fruiting body, both forms of the fungus were included in the new name *Phellinus weirii* (Murr.) Gilb. (Gilbertson 1974), and the disease it caused was commonly known as laminated root rot. Recently a new combination was proposed that would result in the pathogen causing laminated root rot on Douglas-fir being called *Inonotus sulphurascens* (Pliat) Larsen et al. (Larsen and others 1994).

Forest pathologists and land managers in the region currently recognize and commonly use *Phellinus weirii* as the causal agent for laminated root rot (Thies and Sturrock 1995). The primary goal of this panel is to examine the nomenclature for this pathogen and to present some of the molecular evidence that is becoming increasingly important in taxonomic considerations.

Epilogue

Based on the discussion it appears that *Phellinus weirii* will continue to be the name used for the pathogen causing laminated root rot; however, it is apparent that within the next few years a more appropriate name will likely be introduced into common usage.

Citations

Gilbertson, R.L. 1974. Fungi that decay ponderosa pine. Tucson: University of Arizona Press. 197 p.

Larsen, M.J.; Lombard, F.F.; Clark, J.W. 1994. *Phellinus sulphurascens* and the closely related *P. weirii* in North America. Mycologia. 86: 121-130.

Murrill, W.A. 1914. An enemy of the western red cedar. Mycologia. 6: 93-94.

Thies, W.G., and Sturrock, R.N. 1995. Laminated root rot in western North America. Gen. Tech. Rep. PNW-GTR-349. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 32 p. In coop. with: Natural Resources Canada, Canadian Forest Service, Pacific Forestry Centre.

TAXONOMY AND NOMENCLATURE OF POLYPOROID HYMENOCHAETACEAE WITH SPECIAL REFERENCE TO *PHELLINUS WEIRII* AND RELATED SPECIES

Robert L. Gilbertson
Department of Plant Pathology
University of Arizona, Tucson AZ 85721

The Past

The history of nomenclature of polyporoid Hymenochaetaceae goes back to Linnaeus and the starting point of nomenclature in 1753. Many of these fungi were undoubtedly known to naturalists and herbalists long before this time as many have large and conspicuous basidiocarps and cause decay, deterioration and breakage in important tree species. A detailed account of the history of nomenclature of these fungi is not appropriate here and only major aspects pertinent to the Hymenochaetaceae and the two species of interest here will be reviewed. Elias Magnus Fries published his Systema Mycologicum in 1821. This two volume work was designated as the starting point of nomenclature for polypores until the International Botanical Congress of 1981 when the starting point was changed to Linnaeus' Species Plantarum published in 1753. However, the Friesian names were conserved. In the Systema and subsequent publications culminating in the Hymenomycetes Europaei in 1874, Fries developed his generic concepts and essentially recognized 8 genera of polypores. One of these genera, *Polyporus*, was much larger than any of the others, and (with the exception of *Cyclomyces*) contained all of the species now placed in the Family Hymenochaetaceae. His system was modified by elevation of two subgenera in the genus *Polyporus* to generic rank by subsequent workers. These were *Poria* and *Fomes*. The resulting ten genera are essentially the arrangement followed by Saccardo who set out to catalog all described fungi in his Sylloge Fungorum beginning with Vol. I in 1871. This modified Friesian system was followed by conservative taxonomists for well over one hundred years. The fungi which are now recognized as the polyporoid taxa of Hymenochaetaceae were largely placed in three genera. Those with resupinate basidiocarps were in the genus *Poria*. Those with annual pileate basidiocarps were in the genus *Polyporus*. Those with perennial pileate basidiocarps were in the genus *Fomes*. Needless to say these large Friesian-Saccardo genera are heterogeneous aggregates based on artificial characters and do not reflect phylogenetic relationships. Overholts' manual of pileate polypores of the U.S. and Canada (1953) is based on the Friesian-Saccardo genera. Gilbertson (1956) and Lowe (1957, 1966) followed Friesian-Saccardo concepts in publications on *Fomes* (which contained the hymenochaetaceous polypores with perennial, pileate basidiocarps), and *Poria* (which contained the hymenochaetaceous polypores with resupinate basidiocarps). This system provided a readily mastered practical and stable classification that appealed to forest pathologists and other workers to whom taxonomy was often an irritating necessity that should be kept as simple as possible and free of confusing constant changes.

Long before the Friesian-Saccardo system became history in North America progressive mycologists in Europe, North America, and Asia were recognizing segregates from the large genera and attempting to develop classification systems based on smaller genera that reflected natural phylogenetic relationships. The two major genera of polyporoid Hymenochaetaceae were established during this period: *Inonotus* by Karsten in 1880 and *Phellinus* by Quélet in 1886. Species with annual basidiocarps were placed in *Inonotus* and species with perennial basidiocarps were placed in *Phellinus*. Hyphal structure or other microscopic characters did not play a role in the delimitation of the two genera. This concept has essentially been followed by European mycologists including Patouillard (1900), Bourdot and Galzin (1928), Donk (1933), Pilát (1938), Bondartzev and Singer (1941), Bondartzev (1953), Pegler (1964), Domanski (1965), Domanski et al. (1967), and Ryvarden (1978). In the meantime a remarkable figure appeared on the mycological scene in North America at the turn of the century. This was W.A. Murrill of the New York Botanical Garden. He split the North American polypores up into about 57 genera, 13 of which contained the taxa now placed in the Hymenochaetaceae. He retained *Inonotus* and *Phellinus* but in a more restricted sense. Murrill's system is represented in his treatment of polypores in Vol. 7 of North American Flora published in 1907. His concepts were such a radical departure from the entrenched Saccardo-Friesian system that they failed to gain general acceptance before he died in 1957.

Two of the genera that Murrill described in North American Flora in 1907 are *Fomitoporia* and *Fuscoporia*. He later described *Fomitoporia weirii* Murrill in 1914 from specimens sent to him from Idaho and Washington by James Robert Weir for whom the species was named. The type specimens were "collected on a trunk of *Thuya* (sic) *plicata* at Priest River, Idaho, in the Kaniksu National Forest, in 1912, by James R. Weir." Murrill's original description states that the tubes "are indistinctly 2-3 times stratified in older specimens". He correctly describes the basidiospores and setal hyphae which he called "cystidia". He also remarks that "younger stages would be referred to *Fuscoporia*, and the older stages sometimes have rather the appearance of "reviving" from year to year instead of being truly perennial, as is the case in most species of *Fomitoporia*". At the end of the paper, Murrill makes the combination *Poria weirii* Murrill, " for the benefit of those using Saccardo's nomenclature". Apparently Murrill anticipated the recombination of his species by someone more conservative and was not about to let anyone get one up on him. So the name of the fungus in the North American literature for the next 60 years became *Poria weirii* (Murrill) Murrill. In 1953 Aoshima, perhaps influenced by Murrill's comments in the original description, proposed the new combination *Fuscoporia weirii* (Murrill) Aoshima. This name is valid as the basionym was properly cited. The ICBN rule requiring this went into effect Jan. 1, 1953 shortly before Aoshima published his new combination.

The Czech mycologist Albert Pilát described *Phellinus sulphurascens* (Bull. Soc. Mycol. France 51:372) from larch in Siberia in 1935. In 1970 Kotlaba and Pouzar concluded that *P. sulphurascens* was a synonym of *Fomitoporia weirii* and also proposed the new combination *Inonotus weirii* (Murrill) Kotl. & Pouzar, a name not generally accepted by North American workers. Gilbertson (1974) proposed the new combination *Phellinus weirii* (Murrill) Gilb. as he believed the natural relationships of the fungus are with species in the genus *Phellinus*. That name was pretty well accepted for 20 years and has become well established in the literature.

Ever since laminated root rot has been known to be a major problem in stands of second growth Douglas fir in the Pacific Northwest, forest pathologists researching this problem have spoken of what they called "annual *Poria weirii*" and "perennial *Poria weirii*". The former referred to the pathogenic form on Douglas Fir and the latter to the form causing root and butt rot in western red cedar. Larsen and Cobb-Poule (1990) recognized *P. sulfurascens* and *P. weirii* as separate taxa. These taxa corresponded to the annual and perennial forms of *Poria weirii*. In 1994 Larsen and Lombard published the results of a detailed study of the two taxa and reported that they are genetically isolated and have slight but significant morphological differences in basidiocarp and cultural characters. They made a convincing case that two distinct species are represented in this complex. They also maintained that *Inonotus* was the best generic placement for *P. weirii* and *P. sulphurascens* based on hyphal morphology and proposed the new combination *Inonotus sulphurascens* (Pilát) M.J. Larsen & Lombard. Ryvarden and Gilbertson (1994) recognized the two as separate species but believed their relationships were with species of *Phellinus* and maintained them in that genus.

Prior to his description of *P. sulphurascens*, Pilát described a new taxon as *Xanthochrous glomeratus* (Peck) Pilát ssp. *heinrichii* Pilát in 1932 (Bull. Soc. Mycol. France 48:28). He elevated the subspecies to species rank as *Xanthochrous heinrichii* Pilát in 1934 (Bull. Soc. Mycol. France 49:272). In 1941 Bondartzev and Singer proposed the new combination *Inonotus heinrichii* (Pilát) Bondartzev & Singer. In their 1970 paper Kotlaba and Pouzar also considered *Inonotus heinrichii* to be a synonym of *Poria weirii* Murrill. Since they regarded both *P. sulphurascens* and *I. heinrichii* as synonyms of *Poria weirii* they did not consider the question of priority of the two names. Since *X. heinrichii* is a valid and legitimate combination, it has priority over *P. sulphurascens* and is the earliest name available for the "annual *Poria weirii*". There has been no published recombination of *X. heinrichii* into *Phellinus*.

The Present

As of now the following names for these fungi have been validly published.

Fomitoporia weirii Murrill (basionym for this taxon)
Poria weirii (Murrill) Murrill
Fuscoporia weirii (Murrill) Aoshima
Inonotus weirii (Murrill) Kotl. & Pouzar
Phellinus weirii (Murrill) Gilb.

Xanthochrous glomeratus (Peck) Pilát ssp. *heinrichii* Pilát (basionym for this taxon)
Xanthochrous heinrichii (Pilát) Pilát
Inonotus heinrichii (Pilát) Bondartzev & Singer
Phellinus sulphurascens Pilát (taxonomic synonym of *I. heinrichii*)
Inonotus sulphurascens (Pilát) M.J. Larsen & Lombard (taxonomic synonym of *I. heinrichii*)

In this situation there are no "correct" names. *Xanthochrous heinrichii* has priority over *P. sulphurascens* and is a valid and legitimate name as is *I. heinrichii*. All of the combinations based on *Fomitoporia weirii* are also valid and legitimate. Any of the valid and legitimate names listed above that are not taxonomic synonyms may be used according to individual preference. Also anyone who does not believe any of the above combinations are acceptable has the privilege of proposing another combination of either specific name in a different described genus. The only requirements are that the new combination be published in a suitable scientific outlet and that the basionym be cited according to the rule in the ICBN. Anyone who does not believe that either or both of these taxa belongs in an existing validly described genus may describe a new genus and recombine either or both taxa in that genus as long as the procedure conforms to the ICBN. However, neither of these actions would invalidate any of the above names and they would still be available for use.

According to Ryvarden (1991) there are 31 valid and legitimate generic names that are typified by species of polyporoid Hymenochaetaceae. These are mostly segregates from the two major genera *Phellinus* and *Inonotus*. These two genera, as originally defined, apparently have phylogenetic integrity because segregates from the two genera contain few "crossovers". However, both are heterogeneous aggregates of species that represent wide diversity in basidiocarp macro and micromorphology, host and substratum relationships, decay characteristics, cultural morphology, and physiological characters such as enzyme production and temperature relationships. Both genera in the original sense contain infrageneric groups that have been considered natural by mycologists in the past and some have been described as genera by Murrill and others. A phylogenetic classification of the polyporoid Hymenochaetaceae should eventually be developed by an analysis of all of these character states combined with elucidation of DNA sequences. An example of this type of analysis (except for molecular data) is that of Fiasson and Niemelä (1984), who developed a revision of the European polyporoid Hymenochaetales based on 36 species. The generic segregates that develop from such an analysis will include *Inonotus* and *Phellinus* in a restricted sense. *Inonotus* will be typified by *I. cuticularis* and *Phellinus* by *P. igniarius*. These typifications would define genera that would not include *P. weirii* or *I. heinrichii*. Of the existing available generic names, *Fuscoporia* Murrill appears the most logical one for these two species, as Aoshima concluded in 1953. *Phellinidium* Fiasson & Niemelä would have been another strong possibility but that name is invalid because of improper citation of the basionym when the authors raised it to the generic level from a subgenus of *Phellinus*. *Phellinidium* is typified by *Phellinus ferrugineofuscus* (P. Karst.) Bourdot and *Fuscoporia* is typified by *Phellinus ferruginosus* (Schrad.: Fr.) Bourdot & Galzin. Either of these typifications would define a genus that might logically include *Fomitoporia weirii* and *Xanthochrous heinrichii*, in my opinion.

The Future

The ultimate generic placement of these two taxa awaits a thorough phylogenetic analysis. For now we can only say that it appears certain that it will not be in *Phellinus* or *Inonotus* in the restricted sense. Therefore any debate about the proper generic placement of *P. weirii* and *I. heinrichii* now is essentially academic and nonproductive. No advance or improvement of the classification of the polyporoid Hymenochaetaceae can be accomplished by switching species back and forth from *Phellinus* to *Inonotus* or vice versa. The wisest course is to maintain the present stability until a satisfactory revision of the group is accomplished. This is likely to happen in the relatively near future in light of the rapidly developing molecular taxonomic research now in progress.

After careful consideration of the ideas of previous workers and my own experience with these fungi, I have formed my own concepts of phylogenetic groupings of segregates from *Inonotus* and *Phellinus* based largely on comparative basidiocarp morphology. Without making any formal taxonomic proposals I will outline these concepts. The following summary is based on a total of 72 species in North American Polypores (Gilbertson and Ryvarden, 1986, 1987) and European Polypores,(Ryvarden and Gilbertson 1993, 1994).

Segregates from *Inonotus*:

1. Basidiocarps resupinate; subiculum soft and cottony: spores hyaline; setae and setal hyphae none; saprophytic.

I. subiculosus (Peck) Parmasto

No close relatives in *Inonotus*. Parmasto described the genus *Inonotopsis* to accommodate this species.

2. Basidiocarps stipitate to sessile; spores hyaline; hymenial setae straight or hooked; setal hyphae none; causing root and butt rots of living conifers.

I. tomentosus (Fr.) Gilb.
I. circinatus (Fr.) Gilb.
I. leporinus (Fr.) Gilb. & Ryvarden
I. triqueter (Fr.) P. Karst.

The genera *Pelloporus* Quél., *Onnia* P. Karst., and *Mucronoporus* Ellis & Everh. are all typified by species in this group.

3. Basidiocarps sessile; spores hyaline; hymenial setae straight or hooked; setal hyphae none or rare; causing butt rots in living hardwoods or conifers or saprophytic.

I. radiatus (Sowerby: Fr.) P. Karst.
I. dryadeus (Pers.: Fr.) Murrill
I. nodulosus (Fr.) P. Karst.
The genus *Mensularia* Laz. is typified by *I. radiatus*

4. Basidiocarps resupinate; spores pigmented; hymenial setae and setal hyphae present; causing trunk rots of living hardwoods and fruiting under bark on broken trunks and branches.
I. andersonii (Ellis & Everh.) Černy
I. obliquus (Fr.) Pilát
I. ulmicola Corfixen
The genus *Phaeoporus* Schroet. is typified by *I. obliquus.*

5. Basidiocarps sessile; spores pigmented; hymenial setae absent; granular core present in context; causing trunkrots of living hardwoods.
I. dryophilus (Berk.) Murrill
I. rheades (Pers.) P. Karst.
I. tamaricis (Pat.) Maire
I. texanus Murrill
The genus *Inocutis* Fiasson & Niemelä is typified by *I. rheades.*

6. Basidiocarps sessile; spores pigmented; hymenial setae present or absent; branched setal hyphae on pilear surface; causing trunkrots of living hardwoods or saprophytic.
I. cuticularis (Bull.: Fr.) P. Karst.
I. farlowii (Lloyd) Gilb.
I. munzii (Lloyd) Gilb.
The genus *Inonotus* P. Karst. is typified by *I. cuticularis.*

7. Basidiocarps resupinate to effused-reflexed or sessile; spores pigmented; hymenial setae present or absent; setal hyphae present in trama or context; causing trunkrots of living hardwoods.
I. glomeratus (Peck) Murrill
I. hispidus (Bull.: Fr.) P. Karst.
I. nidus-pici Pilát
I. quercustris M. Blackwell & Gilb.
I. patouillardii (Rick) Imazeki
I. rickii (Pat.) D.A. Reid
There appears to be no existing genus name typified by any of these species.

8. Basidiocarps sessile; spores pigmented; hymenial setae hooked; setal hyphae absent; causing trunkrots of living hardwoods or saprophytic.
I. arizonicus Gilb.
I. crocitinctus (Berk. & M.A. Curtis) Ryvarden
There appears to be no existing genus name typified by either of these species.

9. Basidiocarps sessile to effused-reflexed; spores pigmented; setae and setal hyphae absent; saprophytic or causing root and butt rots of living hardwoods or juniper.
I. jamaicensis Murrill
I. juniperinus Murrill
I. ludovicianus Murrill
I. porrectus (Pat.) Murrill
There appears to be no existing genus name typified by any of these species.

Segregates from *Phellinus*:

1. Basidiocarps resupinate; short-lived, annual or reviving; spores hyaline; hymenial setae present or absent; setal hyphae present in trama or subiculum; saprophytic or causing root and butt rots in living conifers.

P. contiguus (Fr.) Pat.
P. ferrugineofuscus (P. Karst.) Bourdot
P. ferruginosus (Schrad.: Fr.) Bourdot & Galzin
P. fragrans M.J. Larsen and Lombard
P. palmicola (Berk. & M.A. Curtis) Ryvarden
P. pouzarii Kotl.
P. rufitinctus (Cooke) Pat.
I. heinrichii (Pilát) Bondartzev & Singer
P. weirii (Murrill) Gilb.
I. hastifer Pouzar

The genus *Fuscoporia* Murrill is typified by *P. ferruginosus*. The invalid genus *Phellinidium* Fiasson & Niemelä is typified by *P. ferrugineofuscus*.

2. Basidiocarps resupinate to sessile; spores hyaline, globose, dextrinoid; hymenial setae present or absent; setal hyphae absent; causing heartrots in living hardwoods and conifers or saprophytic.

P. erectus A. David, Dequatre & Fiasson
P. hartigii (Allesch. & Schnabl) Bondartzev
P. hippophäecola H. Jahn
P. juniperinus Bernicchia & Corelli
P. pseudopunctatus A. David, Dequatre & Fiasson
P. punctatus (Fr.) Pilát
P. robustus (P. Karst.) Bourdot & Galzin
P. rosmarinii Bernicchia
P. sonorae Gilb.
P. texanus (Murrill) A. Ames

The genus *Fomitiporia* Murr. is typified by *P. punctatus*

3. Basidiocarps effused-reflexed to sessile; spores hyaline or pale yellowish with age; hymenial setae present; setal hyphae absent; causing heartrots in living conifers or hardwoods or saprophytic.

P. chrysoloma (Fr.) Donk
P. conchatus (Pers.: Fr.) Quél.
P. occidentalis (Overh.) Gilb.
P. pini (Fr.) A. Ames

The genus *Porodaedalea* Murrill is typified by *P. pini.*

4. Basidiocarps resupinate to sessile; spores hyaline; hymenial setae present; setal hyphae absent; causing trunk rots of living hardwoods or saprophytic.

P. arctostaphyli (Long) Niemelä
P. igniarius (L.: Fr.) Quél.
P. laevigatus (Fr.) Bourdot & Galzin
P. lundellii Niemelä
P. nigricans (Fr.) P. Karst.
P. pomaceus (Pers.) Maire
P. populicola Niemelä
P. prunicola (Murrill) Gilb.

P. rhamni (M. Bondartzeva) H. Jahn
P. spiculosus (W.A. Campb. & R.W. Davidson) Niemelä
P. tremulae (Bondartzev) Bondartzev & Borissov

According to Ryvarden (1991) the genus *Phellinus* Quèl. is typified by *P. igniarius*. According to Fiasson & Niemelä (1984) the genus *Phellinus* is typified by *P. torulosus*. They place this group of species in *Ochroporus* Schroet., which they state is also typified by *P. igniarius*.

5. Basidiocarps resupinate to sessile; spores hyaline; hymenial setae present; saprophytic or causing decay in living conifers or hardwoods.

P. ferreus (Pers.) Bourdot & Galzin
P. ferrugineo-velutinus (Henn.) Ryvarden
P. gilvus (Schwein.) Pat.
P. nigrolimitatus (Romell) Bourdot & Galzin
P. punctatiformis (Murrill) Ryvarden
P. repandus (Overh.) Gilb.
P. torulosus (Pers.) Bourdot & Galzin
P. viticola (Schwein.: Fr.) Donk
P. wahlbergii (Fr.) D.A. Reid

There appears to be no existing genus typified by any of these species unless *P. torulosus* is accepted as the type species of *Phellinus*, as Fiasson and Niemelä have done.

6. Basidiocarps resupinate to sessile; spores pigmented; hymenial setae and setal hyphae absent; saprophytic or causing decay in living hardwoods.

P. allardii (Bres.) Ryvarden
P. fastuosus (Lév.) Ryvarden
P. grenadensis (Murrill) Ryvarden
P. inermis (Ellis & Everh.) G.H. Cunn.
P. merrillii (Murrill) Ryvarden
P. melleoporus (Murrill) Ryvarden
P. umbrinellus (Bres.) Ryvarden

The genus *Fomitoporella* Murr. is typified by *P. umbrinellus*. The genus *Fuscoporella* Murr. is also typified by the same species (as *F. corruscans* Murr., a synonym of *P. umbrinellus).*

7. Basidiocarps sessile; spores pigmented; hymenial setae and setal hyphae absent; causing trunkrots in living hardwoods.

P. badius (Berk. ex Cooke) G.H. Cunn.
P. rimosus (Berk.) Pilát
P. robineae (Murrill) A. Ames

The genus *Fulvifomes* Murr. is typified by *Pyropolyporus robineae* Murr.

8. Basidiocarps resupinate to sessile; spores pigmented; hymenial setae present, setal hyphae absent; causing trunkrots of living trees or saprophytic.

P. dependens (Murrill) Imazeki
P. everhartii (Ellis & Galloway) A. Ames
P. extensus (Lév.) Pat.
P. johnsonianus (Murrill) Ryvarden
P. linteus (Berk. & M.A. Curtis) Teng
P. pilatii Černy
P. vaninii Ljub.

P. weirianus (Bres.) Gilb.
There appears to be no existing genus name typified by any of these species.

Literature Cited

Aoshima, K. 1953. Wood-rotting fungi from Japan. (I). Bull. Govt. For. Exp. Sta. Tokyo 59:57-64.

Bondarzew, A. 1953. Polyporaceae of the European part of the USSR and of the Caucasus. Leningrad. 1106 p.

Bondarzew, A. and R. SINGER. 1941. Zur Systematik der Polyporaceen. Ann. Mycol. 39:43-65.

Bourdot, H. and A. Galzin. 1928. Hyménomycètes de France. Sceaux.

Domanski, S. 1965. Basidiomycetes-Aphyllophorales. Polyporaceae I. Mucronoporaceae I. In: Flora Polska (Gryzyby) 2:1-280.

Domanski, S., H. Orlos, and A. Skirgiello. 1967. Basidiomycetes: Aphyllophorales: Polyporaceae Pileatae, Ganodermataceae, Bondarzewiaceae, Boletopsidaceae, Fistulinaceae. In: Flora Polska (Grzyby) 3:1-398.

Donk, M.A. 1933. Revision der niederländischen homobasidiomycetae aphyllophoraceae ii. Nederl. Mycol. Ver. Meded. 22:1-278.

Fiasson, J. L. and T. Niemela. 1984. The Hymenochaetales: A revision of the European poroid taxa. Karstenia 24:14-28.

Gilbertson, R.L. 1956. The genus *Poria* in the central Rocky Mountains and the Pacific Northwest. Lloydia 19:65-85.

Gilbertson, R.L. 1974. Fungi that decay ponderosa pine. Univ. of Arizona press. 197 p.

Gilbertson, R.L. and L. Ryvarden. 1986. North American polypores. Vol. 1. *Abortiporus-lindtneria*. Fungiflora, oslo. p. 1-433.

Gilbertson, R.L. and L. Ryvarden. 1987. North American polypores. Vol. 2. *Megasporoporia-wrightoporia*. Fungiflora, oslo. p. 434-885.

Kotlaba, F. and Z. Pouzar. 1970. Revision of original material of *Phellinus Sulphurascens* Pil., *Xanthochrous glomeratus* ssp. *heinrichii* Pil., and *Polyporus rheades* Pers. (Hymenochaetaceae). Česka mykol. 24:146-152.

Larsen, M.J. and L.A. Cobb-poule. 1990. Phellinus (hymenochaetaceae). Synopsis fung. 3:1-206.

Larsen, M.J., F.F. Lombard, and J.W. Clark. 1994. *Phellinus sulphurascens* and the closely related *P. weirii* in North America. Mycologia 86:121-130.

Lowe, J.L. 1957. Polyporaceae of North America. The genus *Fomes*. N.Y. State Coll. For. Tech. Publ. 80:1-97.

Lowe, J.L. 1966. Polyporaceae of North America. The genus *Poria*. N.Y. State coll. For. Tech. Publ. 90:1-183.

Murrill. W.A. 1907. Family 5. Polyporaceae. North Am. Flora 9:1-131.

Murrill, W.A. 1914. An enemy of the western red cedar. Mycologia 6:93-95.

Overholts, L.O. 1953. Polyporaceae of the United States, Alaska, and Canada. Univ. of Michigan Press, Ann Arbor. 466 p.

Patouillard, N. 1900. Essai taxonomique sur les familles et les genres des Hyménomycètes. Lons-le-saunier. 184 p.

Pegler, D.N. 1964. A survey of the genus *Inonotus* (Polyporaceae). Trans. Brit. Mycol. Soc.47:175-195.

Pilat, A. 1936-1942. Polyporaceae i-iii. In Kavina, C. and A. Pilat. Atlas des champignons de l'europe, tome 3. Praha.

Ryvarden, L. 1978. The polyporaceae of North Europe. Vol. 2. *Inonotus-Tyromyces*. Fungiflora, Oslo. P. 215-507.

Ryvarden, L. 1991. Genera of polypores. Nomenclature and taxonomy. Synop. Fung. 5:1-363. Fungiflora, Oslo.

Ryvarden, L. and R.L. Gilbertson. 1993. European polypores. Part 1. *Abortiporus-Lindtneria*. Fungiflora, Oslo. p. 1-387.

Ryvarden, L. and R.L. Gilbertson. 1994. European polypores. Part 2. *Meripilus-Tyromyces*. Fungiflora, Oslo. p. 388-743.

COMPARISON OF *PHELLINUS SULPHURASCENS* AND *P. WEIRII* FROM ASIA AND NORTH AMERICA USING PLATE PAIRING AND MOLECULAR TECHNIQUES.

Hansen, E.M., M. G. McWilliams, T. A. Dreisbach, P. A. Angwin, and D. Gernandt
Department of Botany and Plant Pathology
Oregon State University
Corvallis, OR 97331

Summary

Results indicated a bipolar, multiallelic mating system in both Asian type and Douglas-fir type, as previously suggested. Pairings between Asian and North American Douglas-fir isolates appeared to be compatible based both on backpairing and hybrid enzyme patterns.

All three populations were readily differentiated by both isozyme and total protein electrophoresis, and M13 fingerprinting distinguished cedar type isolates from the others. ITS DNA sequences were similar for all populations. Differences between cedar type isolates and both DF and Asian type isolates were greater than differences between the Asian and Douglas-fir types in most measures used. It will require analysis of more isolates to determine whether the observed differences between populations are sufficient to warrant recognition of different taxa. WE RECOMMEND CONTINUED USE OF THE NAME *PHELLINUS WEIRII*, UNTIL ONGOING RESEARCH ON SPECIES AND GENUS LIMITS IS COMPLETED.

The Problem

Three distinct fungus populations in eastern Asia and western North America have been identified as *Phellinus* or *Inonotus weirii*, or *P.* (or *I.*) *sulphurascens* (Table 1). Larsen et al. (1994) proposed that *P. sulphurascens* from Russian Siberia and the Douglas-fir form of *P. weirii* from western North America are synonymous, and that both are different from the cedar form of *P. weirii* from North America, based on comparison of types and interfertility between single spore isolates. We gathered the available isolates, made and repeated pairings and compared isozyme and total protein profiles and DNA polymorphisms.

Objectives

1. Compare the three populations using isozyme and total protein profiles, M13 DNA fingerprints, and DNA sequencing.
2. Test for interfertility between the 3 populations, using backpairing and isozyme analysis.

Methods

Pairing tests

Single basidiospore isolates were crossed in all combinations and "backpaired" against unrelated single spore isolates to test for compatibility. Compatible single spore isolate pairings formed a dikaryotic mycelium, which invariably produced a pigmented line of demarcation when paired with an unrelated haploid (Angwin and Hansen 1993).

Isozymes

Isolates were grown in potato dextrose broth, macerated in cold buffer, and absorbed on filter paper wicks. Enzymes were separated using starch gel electrophoresis.

Compatible pairings are revealed when single spore isolates have different alleles for a dimeric enzyme. Some enzymes require the uniting of two protein subunits to form the functional enzyme. When these two subunits are coded for by different alleles in a dikaryon, a triple banding pattern results consisting of the two homodimer bands (one from each nucleus) and the heterodimer band between them. In an incompatible pairing, even with mixed hyphae, only the two homodimer bands are seen.

Total Proteins

Isolates were grown in glucose-yeast-peptone broth, filtered, and the mycelium was ground in a TRIS buffer. Soluble proteins were loaded onto SDS Polyacrylimide gels, and electrophoresed. Protein bands were stained with Coomassie Blue. Comparison of banding patterns was made by calculating a similarity coefficient, the number of bands in common between two isolates divided by the number of bands resolved in the lane with fewer bands, times 100 (Hamm and Hansen 1983).

TABLE 1. COMPARISON OF POPULATIONS

POPULATION	HOSTS	PATHOGENICITY
DF TYPE (*Phellinus weirii*)	MANY	ROOT ROT
CEDAR TYPE (*Phellinus weirii*)	*THUJA PLICATA*	BUTT ROT
ASIAN TYPE (JAPAN) (*Fuscoporia weirii)*	*ABIES, TSUGA, PICEA*	"ROOT AND BUTT ROT"
(SIBERIA) *(Phellinus sulphurascens)*	*LARIX , ABIES, TSUGA, PICEA*	? SAPROPHYTE?

DNA Fingerprinting

Variation within and between populations was compared using a PCR-amplified minisatellite region of the genome. Isolates were grown in potato dextrose broth. DNA was extracted from small portions of mycelium by microwave miniprep (Goodwin and Lee 1993) and stored at -20C before amplification by PCR. The primer sequence (5'-GAG GGT GGC GGT TCT-3') was based on the core sequence of M13 minisatellite DNA. Electrophoresis on 2% agarose was followed by staining with ethidium bromide (Stenlid et al. 1994).

DNA Sequencing

DNA, extracted as above, was amplified using primers that recognized the Internal Transcribed Spacer regions of ribosomal DNA. Amplified DNA was purified, and sequenced on an automatic DNA sequencer.

Results

POPULATION DIFFERENCES

Total Proteins

Protein electrophoresis clearly distinguished cedar type, DF type, and Japanese isolates of *P. weirii* (Table 2). While the overall banding patterns of cedar and DF type isolates were similar (84% band matching), a strongly staining, slow migrating doublet was consistently present in cedar type isolates, and absent in DF type. The 3 Japanese isolates also could be distinguished from both cedar (77% similarity) and DF (78% similarity) type isolates. The Japanese isolates lacked the diagnostic double band of the cedar isolates. Other Asian isolates were not available for total protein electrophoresis. All 3 groups were readily distinguished from the control isolates of *Inonotus tomentosus*, *Phaeolus schweinitzii*, and *Phytophthora.*

Isozymes

Seven enzyme systems (CAT, GOT, MDH, ADH, SrDH, G6PDH, and 6PGD) gave clear and consistently readable banding patterns. Japanese and Siberian isolates were similar at all loci. DF type and Asian type were similar for 4 enzymes; DF type was similar to cedar type for none of the enzymes tested. CATalase differentiated Oregon from Idaho isolates of DF type (data not shown): Oregon isolates were similar to Asian type; Idaho isolates were similar to cedar type.

TABLE 2. SIMILARITY COEFFICIENTS FOR TOTAL PROTEINS

	DF type	Cedar type	Japanese
DF type	96 +/- 5.9	84 +/- 7.5	78 +/- 13.1
Cedar type		98 +/- 2.7	77 +/- 6.6
Japanese			90 +/- 12.3

M13

The M13 primers gave very different results with cedar type isolates than with DF type isolates or isolates from Asia. DNA banding patterns were remarkably uniform among the cedar isolates, suggesting a very low genetic diversity in this population. Asian and DF isolates, by contrast, showed isolate specific banding patterns, with few common bands within or between populations. M13 was not useful for differentiating these two populations.

ITS DNA Sequencing

ITS 1 sequences did not differ significantly between the Japanese, Siberian, Douglas-fir, and cedar isolates tested. All were more similar to each other than to *Phellinus pini* or *P. cancreformans*.

INTERFERTILITY

Plate pairing of single spore isolates

Asian x Asian. Pairings of single spore isolates from the same basidiocarp (3305), backpaired with an unrelated single spore isolate (from 3228), formed pigmented barrage lines in about 50% of the pairings, indicating a bipolar compatibility system (Table 3). Similar pairings between single spore isolates from the two different Asian type basidiocarps, produced 100% pigmented lines, indicating complete interfertility (Table 4). Pairings between Asian type and DF type single spore isolates were also completely compatible, as tested by backpairing, indicating potential interfertility between these two populations (Table 5). These pairing results confirm the pairing results of Larsen et al (1994).

Cedar type x cedar type. Pairings between single spore isolates from 5 basidiocarps were all compatible, as confirmed by backpairing against unrelated single spore isolates. The cedar type population (all from Idaho) appears to be very homogeneous (Table 6).

DF type x DF type. Single spore isolates were available from 4 DF type basidiocarps, 2 from Oregon and 2 from Idaho. Results of interbasidiocarp pairings were very mixed, indicating a complex pattern of partial interfertility. The 2 sets of isolates from Idaho were incompatible with each other, but mostly compatible with the Oregon sets. One way migration of nuclei was detected in about half of the pairings between one of the Idaho sets (from larch) and the Oregon sets (Table 6).

TABLE 3. MATING COMPATIBILITY OF ASIAN TYPE BASIDIOCARP 3305 SINGLE SPORES.

	3305 SINGLE SPORE ISOLATES				
	A1			A2	
	36	38	39	37	40
36	-	-	-	+	+
38		-	-	+	+
39			-	+	+
37				-	-
40					-

Cedar type x DF type. Results of interbasidiocarp pairings were mixed. Oregon DF isolates were completely incompatible with cedar type isolates. Idaho DF type single spore isolates, however, showed a pattern of partial compatibility with the cedar type isolates. One way dikaryotization of some of the DF type isolates by cedar type isolates was suggested. Most anomalies in these pairings involved one of the DF type isolate sets from larch in Idaho (134848) (Table 6).

TABLE 4. INTERFERTILITY OF ASIAN TYPE BASIDIOCARP 3305 SINGLE SPORE ISOLATES PAIRED WITH BASIDIOCARP 3228 ISOLATES

		3305 SINGLE SPORE ISOLATES				
		36	37	38	39	40
	31	+	+	+	+	+
3228	32	+	+	+	+	+
SINGLE	33	+	+	+	+	+
SPORE	34	+	+	+	+	+
ISOLATES	35	+	+	+	+	+

TABLE 5. INTERFERTILITY OF ASIAN TYPE SINGLE SPORE ISOLATES (3305 & 3228) PAIRED WITH DOUGLAS-FIR TYPE SINGLE SPORE ISOLATES (MP8)

		ASIAN TYPE SINGLE SPORE ISOLATES									
		31	32	33	34	35	36	37	38	39	40
DF	3	+	+	+	+	+	+	+	+	+	+
TYPE	5	+	+	+	+	+	+	+	+	+	+
SINGLE	15	+	+	+	+	+	+	+	+	+	+
SPORE	16	+	+	+	+	+	+	+	+	+	+
ISOL.	19	+	+	+	+	+	+	+	+	+	+

TABLE 6. SUMMARY OF HOMOKARYON X HOMOKARYON PAIRINGS AMONG AND BETWEEN HOST AND GEOGRAPHIC POPULATIONS OF PHELLINUS WEIRII

	Oregon DF	Idaho DF	Idaho Larch	Idaho Cedar
Oregon DF	+/+	+/+	+/-	-/-
Idaho DF		+/+	+/-	-/-
Idaho Larch			+/+	+/-
Idaho Cedar				+/+

Di-Mon Pairing

Forty-six dikaryotic (vegetative) isolates of *P. weirii* from various hosts in North America were paired against two sets of homokaryotic (single spore) testers- one from Oregon DF, and one from cedar type. In all cases, either cedar type testers, or DF type testers were dikaryotized, but never both. Only isolates from cedar were compatible with the cedar testers. Isolates from all other hosts (including one from cedar) were compatible with the DF testers. The cedar isolate compatible with DF testers was from western Oregon.

The cedar tree exhibited butt rot, and was growing in the middle of a laminated root rot infection center in a Douglas-fir stand. The isolate from the cedar stump was vegetatively compatible (from the same clone) as 2 isolates from Douglas-fir stumps in the same infection center.

The 3 Japanese isolates were also paired against the DF and cedar type testers. The Japanese isolates were incompatible with the cedar type testers, and two were incompatible with the DF type testers. The third Japanese isolate (Pa22m), however, appeared to be compatible with the DF testers.

Isozymes

Some enzymes require the uniting of two protein subunits to form the functional enzyme. When these two subunits are coded for by different alleles in a dikaryon, a triple banded pattern results, consisting of two homodimer bands (A1A1 and A2A2) and a single intermediate heterodimer band (A1A2). In mixed cultures of single spore isolates that did not anastomose only the homodimer bands are seen. Therefore, the existence of a heterodimer band demonstrates that the two homokaryotic isolates successfully anastomosed and formed a functional dikaryon.

When Douglas-fir type and Siberian isolates were grown in the same plate for six weeks, formation of MDH heterodimers indicated anastomoses and dikaryotization. This pattern was never observed with Douglas-fir x cedar pairings or Siberian x cedar pairings.

Conclusions

1. SIBERIAN ISOLATES ARE BIPOLAR AND MATING COMPATIBLE WITH DOUGLAS-FIR TYPE ISOLATES, CONFIRMING THE WORK OF LARSEN.

2. AVAILABLE JAPANESE AND SIBERIAN ISOLATES ARE SIMILAR.

3. CEDAR-TYPE ISOLATES ARE READILY DISTINGUISHED FROM BOTH ASIAN AND DF TYPE ISOLATES.

4. ASIAN AND DF TYPE ISOLATES REPRESENT RELATED BUT DISTINCT POPULATIONS, SEPARABLE BY ENZYME AND DNA PROFILES.

5. MORE COLLECTIONS ARE NEEDED FROM EUROPE AND ASIA, TOGETHER WITH DESCRIPTIONS OF THEIR PATHOGENICITY.

6. NAME CHANGES SHOULD BE DELAYED UNTIL PROBLEMS OF NOMENCLATURE ARE RESOLVED, ADDITIONAL DNA SEQUENCES ARE AVAILABLE, AND GENUS LIMITS ARE ESTABLISHED.

Table 7. COMPARISON OF ASIAN (A), DOUGLAS-FIR (D), AND CEDAR (C) TYPES OF *PHELLINUS WEIRII.*

	Asian	Douglas-fir	Cedar
Morphology			
macro	AD	AD	C
micro	AD	AD	C
culture	A	D	C
Pathogenicity	?	D	C
Molecular			
serology	AD	DA	C
proteins	A	D	C
isozymes	A	D	C
M13 DNA	?	?	C
ITS DNA	ADC	ADC	ADC
Mating			
potential	AD	AD	C
gene flow	A	D	C

Literature Cited

Angwin, P. A. 1989. Genetics of sexuality and population genetics of *Phellinus weirii.* Ph.D. Thesis, Department of Botany and Plant Pathology, Oregon State University. 175 p.

Angwin, P. A. and E. M. Hansen. 1993. Pairing tests to determine mating compatibility in *Phellinus weirii.* Mycol. Res. 97:1469-1475.

Banik, M.T. , J. A. Paul, H. H. Burdsall, and M. E. Cook. 1993. Serological differentiation of two forms of *Phellinus weirii.* Mycologia 85:605-611.

Goodwin, D. C. and S. B. Lee. 1993. Microwave miniprep of total genomic DNA from fungi, plants, protists, and animals for PCR. BioFeedback 15:438-444.

Hamm, P. B., and E. M. Hansen. 1983. *Phytophthora pseudotsugae*, a new species causing root rot of Douglas-fir. Can. J. Bot. 61:2626-2631.

Larsen, M. J. , F. F. Lombard, and J. W. Clark. 1994. *Phellinus sulphurascens* and the closely related *P. weirii* in North America. Mycologia 86:121-130.

Stenlid, J., J.-O. Karlsson, and N. Hogberg. 1994. Intraspecific genetic variation in *Heterobasidion annosum* revealed by amplification of minisatellite DNA. Mycol. Res. 98:57-63.

TAXONOMIC COMPONENTS OF NORTH AMERICAN POROID HYMENOCHAETACEAE (HYMENOCHAETALES) WITH SPECIAL REFERENCE TO *INONOTUS SULPHURASCENS* AND *I. WEIRII*

Michael J. Larsen, Principal Mycologist
Intermountain Research Station
USDA Forest Service
Moscow, ID 83843

Species of fungi in the family Hymenochaetaceae (Hymenochaetales) decay heartwood, cause root rots and cankers of live standing trees, and destroy slash and other woody residues. Tree diseases have been generally referred to as negative influences in the forest environment. However, in terms of forest productivity and stabilization over many generations, many of these influences may prove useful to natural forest ecosystems, particularly in north temperate forests where organic matter is produced at a higher rate than it can be recycled through the natural processes of decomposition. Overmature forests are more prone to fiber-destroying diseases, particularly stem and root decays, than young vigorous forests. No other class of forest diseases causes more timber damage than root and heart decays.

Taxonomy

Since its publication, the concept of the family Hymenochaetaceae and included genera has remained rather stable. However, generic and species concepts in some instances, have been and still are vague, obscure, or uncertain. In recent times some investigators have used narrower concepts in attempts to separate taxa from what appear to be complexes. Fiasson (1983) and Fiasson and Niemela (1984) have revised the taxonomy and nomenclature of the European species of *Phellinus*. In addition they proposed two new suborders of Hymenochaetales (Hymenochaetinae and Phaeolinae) inclusive of four families (Hymenochaetaceae Donk, Inonotaceae Fiass. et Niem., Phellinaceae Jul., and Phaeolaceae Jul. em. Fiass. et Niem.). Their arrangement is as follows:

Order Hymenochaetales Oberw.
    Suborder Hymenochaetacae Fiass. et Niem.
        Fam. Hymenochaetaceae Donk (genera *Hymenochaete* Lev., *Asterodon* Pat., *Hydnochaete* Bres.)
        Fam. Inonotaceae Fiass. et Niem. (genera *Inocutis* Fiass. et Niem., *Inonotus* Karst., *Phylloporia* Murr.)
        Fam. Phellinaceae Julich (genera *Phellinus* Quel., *Fomitiporia* Murr., ?*Fulvifomes* Murr., *Fuscoporia* Murr., ?*Inonotopsis* Parm., *Ochroporus* J. Schroet., *Onnia* Karst., *Phellinidium*, Kotl., *Porodaedalea* Murr.)
    Suborder Phaeolinae Fiass. e Niem.
        Fam. Phaeolaceae Julich (genera *Phaelous* Pat., *Coltricia* S.F. Gray)

The Fiasson (1983) and Fiasson and Niemela (1984) contribution represents a major departure from historical taxonomic approaches used with *Phellinus*, for chemotaxonomy, protein electrophoresis, nuclear condition and to a limited extent characteristics derived from cultural studies.

Julich's (1984) proposed scheme is similar, but somewhat more inclusive.

Order Hymenochaetales Oberw.

Fam. Clavariachaetaceae Julich (*Claveriachaetae* Corner)
Fam. Hymenochaetaceae Donk (*Asterodon* Pat, *Hymenochaete* Lev.)
Fam. Coltriciaceae Julich (*Aurificaria* Reid, *Coltricia* S.F. Gray, *Coltriciella* Murr., *Cyclomyces* Fr., *Inonotus* P. Karst., *Phylloporia* Murr.).
Fam. Phellinaceae Julich (*Phellinus* Quel.)
Order Phaeolales Julich
Fam. Hapalopilaceae Julich (*Aurantioporus* Murr., *Hapalopilus* P. Karst.).,
Fam. Phaeolaceae Julich (*Phaeolus* Pat., *Pycnoporellus* Murr.).

While Donk's (1964) concept of the Hymenochaetaceae (Aphyllophorales) was much broader. Thus, Aphyllophorales
Hymenochaetaceae
Vararioideae Donk (*Vararia* P. Karst.)
Asterostromatoideae Donk (*Asterostroma* Massee)
Hymenochaetoideae Donk (*Asterodon* Pat., *Clavariachaete* Corner, *Inonotus* P. Karst., *Phellinus* Quel., etc.)..

Pegler (1973) treated three families in one order, the Aphyllophorales. The one of interest in Pegler's scheme is the Hymenochaetaceae
sub Fam. Varariodeae
sub Fam. Asterostromatoideae
sub Fam Hymenochaetoideae

Aurificaria
Clavariachaete
Coltricia
Coltriciella
Cryptoderma
Cyclomyces
Cycloporus
Hydnochaete
Hymenochaete
Inonotus
Mucronoporus
Phaeolus
Phellinus
Pycnoporellus

Gilbertson and Ryvarden (1987) and Ryvarden and Gilbertson (1994) have similar perspectives with regard to the generic make-up of the Hymenochaetaceae, and as presented is the most homogeneous concept of the family to date. They include:

Hydnochaete
Coltriciella
Aurificaria
Coltricia
Inonotus
Phellinus
Phylloporia
Cyclomyces

The Mitic System And Some Definitions Of Setoid Elements

Corner (1932) introduced a series of terms designed to convey the nature and complexity of the formation of hyphal arrangements in fruiting bodies in both space and time. These terms are:

Monomitic hyphal system (figs. 1-2) - composed only of generative hyphae.

Dimitic hyphal system (fig. 3)- composed of generative and skeletal or binding hyphae.

Trimitic hyphal system (fig. 4)- in which three kinds of hyphae are identifiable, 1) generative thin-walled, branching, and septate hyphae which take a longitudinal course in the growing regions. 2) skeletal hyphae arising as lateral branches but which immediately follow a parallel (usually) course as the generative hyphae, and 3) binding hyphae which arise as lateral growths of generative hyphae produced behind the growing regions.

These terms are used to describe the fruiting bodies as a whole or specific tissue types within fruiting bodies. Lowe (1966) in his treatment of *Poria* provided hyphal system designations for fruiting bodies of 133 species. Today the "mitic" system is applied routinely in the taxonomy of polypore fungi (Ryvardan, 1978; Gilbertson and Ryvardan, 1986).

Closely associated with the "mitic" system and associated assortment of different kinds of hyphae are various categories of setae and setae-like structures that are produced in various parts of polypore fruiting bodies, e.g., hymenium, trama, context, pilear surfaces, and edges of dissepiments. Donk (1964) provided the terms "haplosetae" for embedded hymenial setae and "macrosetae", which are extremely long and embedded in the context. He (Donk, 1964) did not note any setoid structure associated with the trama. Similarly, Talbot (1954) used the terms "setae" and "setoid structures". Lentz's (1954) studies and those of other investigators (cited in Lentz, 1954) point to the origin of setae and setae-like structures as arising from generative and not skeletal hyphae. Lohwag (1929) considered that the length of the setae in *Inonotus cuticularis* extended from the tip backwards to the first true septum, a perspective that I subscribe to .Other terms recently introduced include contextual setae/setal hyphae, and tramal setae/setal hypae.

Two Species In The "Weirii-Complex"

Inonotus weirii (Murr.) Kotl. et. Pouz. was described by Murrill (1914) from specimens occurring on *Thuja plicata* Donn collected by J.R. Weir from Priest River, Idaho. The host range of the fungus was extended to *T. occidentalis* L. (Hubert, 1931), *Pseudotsuga menziesii* (Mirb.) Franco (Mounce et al., 1940), and *Abies* spp., *Picea* spp., *Pinus* spp., and *Tsuga* spp. (Bier and Buckland, 1947).

The perception that two recognizable forms of *I. weirii* exist is not new. Mounce et al. (1940) noted differences but concluded that the fungus on Douglas-fir was the same as *I. weirii* on western redcedar or a form of it. Buckland et al. (1954) designated isolates from Douglas-fir as "annual" and those from cedar as "perennial". Clark (1958) determined that "cedar isolates" and "noncedar isolates" may be separated on the basis of cultural characteristics. However, Nobles (1948) did not distinguish the two forms in axenic culture. Angwin (1989) and Angwin and Hansen (1993) developed a backpairing method to determine compatibility in monokaryon-monokaryon and monokaryon-heterokaryon (di-mon) pairings and demonstrated a high degree of genetic isolation (incompatibility) between the western redcedar and Douglas-fir forms. Protein banding patterns demonstrated the genetic differences between the two groups. However, because some examples of partial compatibility were observed in monokaryon-monokaryon pairings, Angwin and Hansen (1993) concluded that the groups are best referred to as "intersterility groups." Pairings by Angwin (1989) and Angwin and Hansen (1993) also confirmed the previous reports (Gillet, 1975; Kao, 1978; Hansen, 1979) of heterothallism and demonstrated that the two forms possess a unifactorial multiallelic mating system. Larsen and Lombard (1989), Larsen and Cobb-Poul (1990), and Larsen et al. (1994) advocated separate nomenclatural recognition at the species level based on differences between the two forms.

Based on compatible pairings between monokaryons of *Inonotus sulphurascens* from Russia and those from the North American Douglas-fir and cedar forms of *I. weirii*, I conclude that the correct name for the Douglas-fir form is *I. sulphurascens.* The name *I. weirii* is applicable to the cedar form; monokaryotic pairings between *I. weirii* (cedar form) and *I. sulphurascens* (and the Douglas-fir form of *I. weirii*) are not compatible. In addition, the differences in cultural characteristics, morphological differences associated with germinating basidospores, significant differences in dimensions of setal hyphae in test tube culture and in setal hyphae in mycelial felts in decayed wood serve to distinguish the two species (Larsen et al., 1994). Mounce et al. (1940) also investigated dimensional differences of setal hyphae between the two forms. They reported that in basidiomata, setal hyphae diameters were slightly greater for the cedar form (6-13.5 *u*m vs 4-10 *u*m), but in culture, the reverse relationship was observed [3-5 *u* vs 4.5-6(-7) *u*m]. Other notable characteristics that differentiate the two species in North America are summarized in Table I.

Inonotus vs. Phellinus

The taxonomy and nomenclature of *I. weirii* were reviewed by Kotlaba and Pouzar (1970). They concluded that names of several xanthochroic polypore species, notably *I. sulphurascens* described from Siberia, were facultative synonyms of *P. weirii* from North America. They also concluded from their studies that the hyphal system of *I. weirii* was monomitic, as did Lowe (1966). Thus, they advocated the use of the generic name *Inonotus* rather than *Phellinus* and introduced the combination *Inonotus weirii* (Murr.) Kotl. & Pouz. This binomial was later taken up by Domanski (1965,1975). Both Pegler (1964) and Parmasto (1959) used *Inonotus heinrichii* Bond. & Sing., a name that Kotlaba and Pouzar (1970) cited as a facultative synonym of *I. weirii.* Gilbertson (1974,1979) and Gilbertson and Ryvarden (1987) preferred to use *Phellinus*. I also conclude from examination of the nomenclatural types of the names in question, and many additional specimens, that the hyphal system of both species is monomitic. The monomitic hyphal system of *Inonotus* separates it from *Phellinus,* along with more short-lived and softer fruit bodies of the former. Thus, the correct generic placement of both species is in the genus *Inonotus.* This conclusion is also supported by the perspective of Lohwag (1929) and Lentz (1954) that an individual setoid structure is a single cell bounded by the first subtending septum. My analysis of setal hyphae in *sulphurascens* and *weirii* is based on this premise. This kind of analysis is time consuming and tedious and each setoid structure must be traced back to its origins. I have diagrammatically included tramal setae/setal hyphae in figure 1 and excluded the structure in figure 2. With the exclusion of this single cell the hyphal structure is composed of only generative hyphae.

It should be kept in mind that the taxonomic function of any taxonomic rank, particularly genera, is to group species into what are clearly homogeneous units defined by a few selected characters and, ideally, genera should by separated by at least one distinctive character--in this case monomitic vs. dimitic (and trimitic?). The difference may not necessarily show the true relationships between species in each genus, but it does provide a most useful and practical tool, albeit being imperfect, for identification. Again, homogeneity of taxonomic rank is of utmost importance, and if species demonstrating different character sets are mixed, then appropriate transfers should be made to other genera.

Table I. Summary of criteria for separating *I. sulphurascens* and *I. weirii*

I. sulphurascens	*I. weirii*
Usually occurring on conifers other than western redcedar	Usually occurring on western redcedar
In North America pathogenesis involved with root-rot results in death of the hosts and windthrow associated with a "root ball"	Pathogenesis does not result in death of host; stem breakage caused by butt-rot
Basidiomata usually annual	Basidiomata usually perennial
Sporulation of basidiomata in late summer/fall	Sporulation of basidiomata in spring/midsummer
Basidiospores with one germ tube; germ tubes and juvenile mycelia 4.5-6*um* in diam.	Basidiospores eventually with two germ tubes; germ tubes and juvenile mycelia 2-3.5*um* in diam.
No columnar tufts of hyphae in test tube cultures at 6 wk	Columnar tufts of hyphae present in test tube cultures at 6 wk
Dimension of setal hyphae in wood and test tube culture are greater than those in *P. weirii*	Dimensions of setal hyphae in wood and test tube culture are smaller than those in the North American representatives of *P. sulphurascens*
Not compatible with *I. weirii*	Not compatible with *I. sulphurascens*

Literature Cited

Angwin, P.A. 1989. Genetics of sexuality and population genetics of *Phellinus weirii.* Ph.D. Dissertation, Oregon State University, Corvallis. 175 pp.

Angwin, P.A., and E.M. Hansen. Intersterility groups of *Phellinus weirii* (Murr.) Gilbertson in western North America. *Canad. J. Bot.* (In press)

Angwin, P.A., and E.M. Hansen. 1989. Population structure of *Phellinus weirii.* Pp. 371-380. *In: Proc. 7th Int. Conf. Root and Butt Rots.* Ed., D.J. Morrison. IUFRO Working Party 52.06.01.

Angwin, P.A., and E.M. Hansen. 1993. Pairing tests to determine mating compatibility in *Phellinus weirii (Murr.) Gilbertson. Mycol. Res.* (In press)

Bier, J.E., and D. C. Buckland. 1947. Relation of research in forest pathology to the management of second growth trees. 1. *Poria weirii* root-rot, an important disease affecting immature stands of Douglas-fir. *British Columbia Lumberman.* 31: 49-51, 64, 66.

Buckland, D.C., A.C. Molnar, and G.W. Wallis. 1954. Yellow laminated root-rot of Douglas-fir. *Canad. J. Bot.* 32: 69-81.

Clark, J.W. 1958. The occurrence and investigations of physiological strains of *Poria weirii* Murr. Ph.D. Dissertation, Yale University, New Haven, Connecticut. 85 pp. + 14 pl.

Conner, E.J.H. 1932. The fruit body of *Polystictus xanthopus*. Ann. Bot. 46: 71-111.

Cunningham, G.H. 1965. Plolyporaceae of New Zealand. New Zeal. Dept. Sce. Indust. Res. Bull. 164: 1-304.

Domanski, S. 1965. *Fungi. Polyporaceae I (resupinaatae), Mucronoporaceae I (resupinatae).* Grzyby. 234 pp. (Translated from Polish, Foreign Scientific Publications Department of the National Center for scientific, Technical and Economic Information, Warsaw, Poland, 1972).

Domanski, S. 1975. *Mala Flora grzybow. Basidiomycetes, Aphyllophorales.* Vol. 1. Auriscalpiaceae-Lachnocladiaceae. Panstowe Wydawnictwo Nankowe, Warsaw, Poland. 318 pp.

Donk, M.A. 1964 A conspectus of the families of *Aphyllophorales* Persoonia 3: 199-324.

Fiasson, J. -L., and T. Niemela. 1984. The Hymenochaetales: a revision of the European poroid taxa. Karstenia 24: 14-28.

Fiasson, J. -L. 1983 Contribution synthetique a la taxonomic phylitique des Hymenochetacees porees d'Europe, specialement du genre *Phellinus*. *Bull. Mens. Soc. Linn. Lyon* 52 (9): 282-299.

Gilbertson, R.L. 1979. The genus *Phellinus* (Aphyllophorales: Hymenochaetaceae) in western North America. *Mycotaxon* 9: 51-89.

Gilbertson, R.L. 1974. *Fungi that decay ponderosa pine.* University of Arizona Press, Tucson. 197 pp.

Gilbertson, R. L., and L. Rybarden. 1987 North American Polypores, Vol. 2, pp. 435-885. Fungi Flora, Oslo.

Gillet, W.D. 1975. Biology of *Poria weirii*, sexuality and effect on height growth of Douglas-fir. M.Sc. Thesis, University of Washington, Seattle. 46 pp.

Hansen, E.M. 1979. Sexual and vegetative incompatibility reactions in *Phellinus weirii*. *Canad. J. Bot.* 57: 1573-1578.

Hubert, E.E. 1931. *An outline of forest pathology*. John Wiley and Sons, Inc., New York. 534 pp.

Julich, W. 1984. Higher taxa of Basidiomycetes. Bibliotheca Mycol. 85: 1-485.

Kao, Y. 1978. *Phellinus weirii*- morphological variability and incompatibility. M.Sc. Thesis, University of Washington, Seattle. 38 pp.

Larsen, M.J., F.F. Lombard, and J.W. Clark. 1994. *Phellinus sulphurascens* and the closely related *P. weirii* in North America. *Mycologia* 86: 121-130.

Larsen, M.J., and L.A. Cobb-Poulle, 1990. *Phellinus* (Hymenochaetaceae). A survey of the world taxa. *Synop. Fung.* 3: 1-206.

Larsen, M.J., and F.F. Lombard. 1989. Taxonomy and nomenclature of *Phellinus weirii* in North America. Pp. 573-578. *In: Proc. 7th Int. Conf. Root and Butt Rots.* Ed., D. J. Morrison. IUFRO Working Party 52.06.01.

Lentz, Paul L. 1954. Modified hyphae of hymenomycetes. *Bot. Rev.* 20: 135-199.

Lowe, J.L. 1966. The Polyporaceae of North America. The genus *Poria*. Tech. Publ. New York State Univ. Coll. Forest. 90: 1-183.

Mounce, I., J. E. Bier, and M. K. Nobles. 1940. A root-rot of Douglas-fir caused by *Poria weirii*. *Canad. J. Res.* (C) 18: 522-533.

Murrill, W. A. 1914. An enemy of the western red cedar. *Mycologia* 6: 93-94.

Nobles, M. K. 1948. Studies in forest pathology. VI. Identification of cultures of wood-rotting fungi. *Canad. J. Res.* (C) 26: 281-431.

Nobles, M. K. 1965. Identification of cultures of wood-inhabiting Hymenomycetes. *Canad. J. Bot.* 43: 1097-1139.

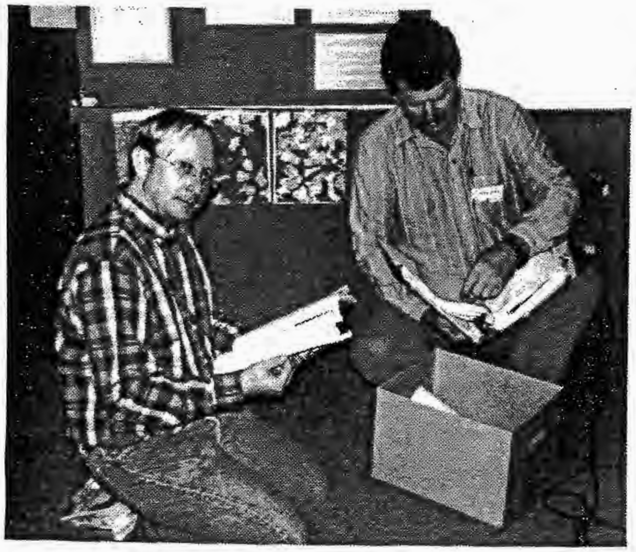
Parmasto, E. 1959. On the distribution of some rare species of Polyporaceae. *Esti Loodus (Talinn)* Biol. Ser., 3: 266-278.

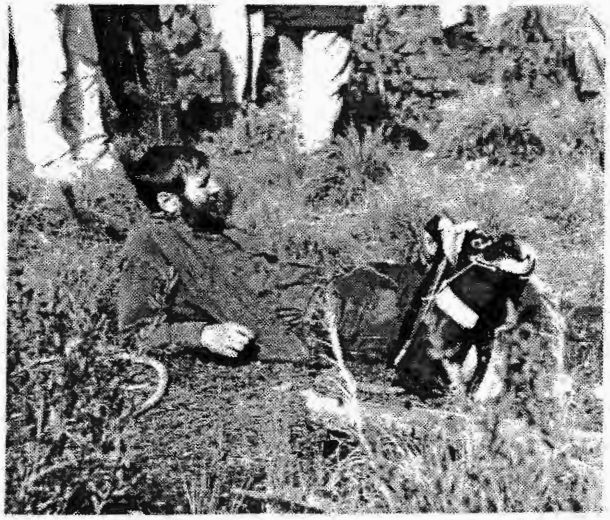
Pegler, D.N. 1973. Aphllophorales IV: poroid families. *In*, The fungi: an advanced Treatise vol. IV B. Eds, G.C. Ainsworth *et. al.* Academic Press, New York. pp. 397-420.

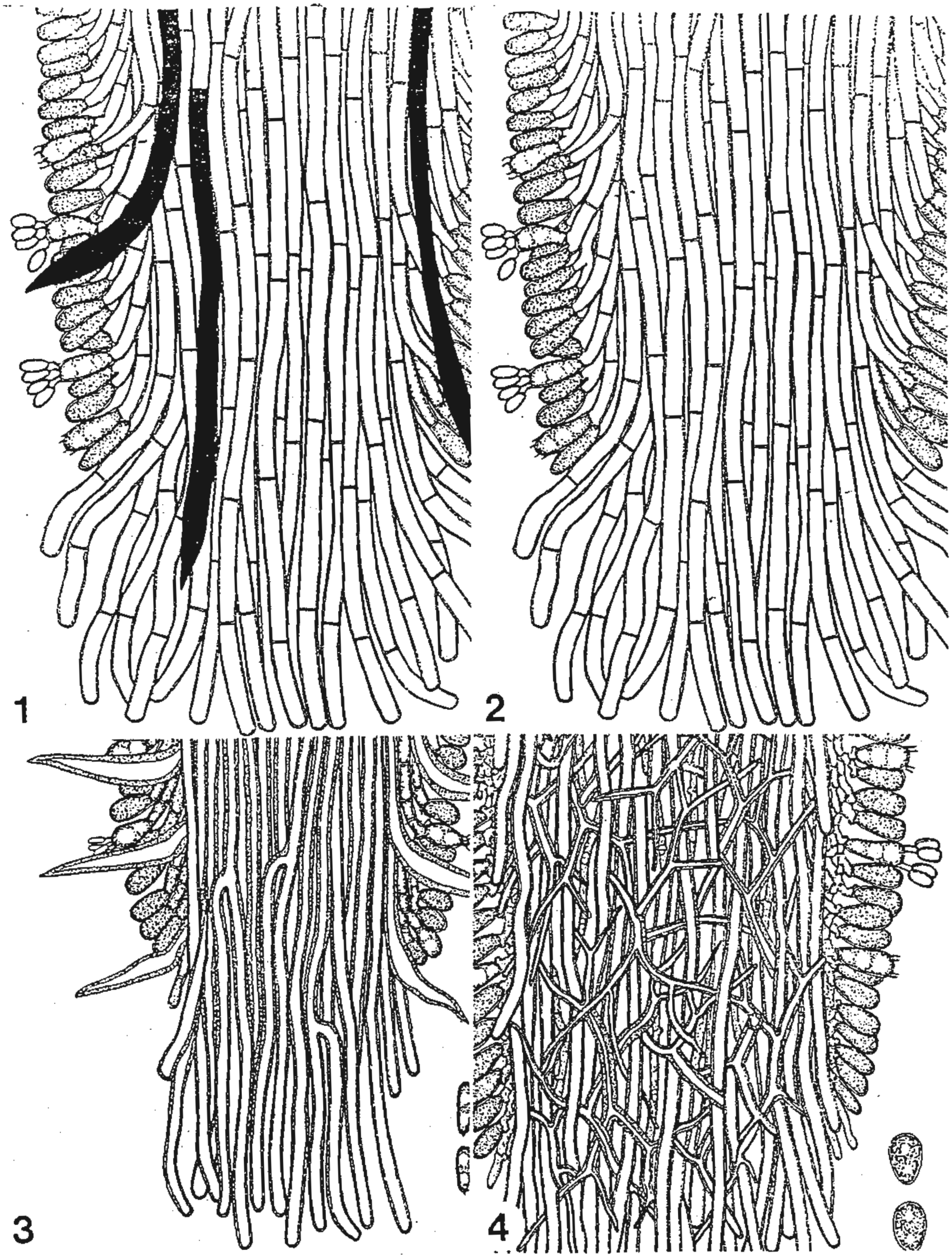
Pegler, D.N. 1964. A survey of the genus *Inonotus*. *Trans. Brit. Mycol. Soc.* 47: 175-195

Ryvarden, L., and R.L. Gilbertson. 1994. European polypores. Part 2: *Synop. Fung.* 7: 394-743.

Talbot, P.H.B. 1954. Micromorphology of the lower Hymenomycetes. *Bothalia.* 6: 249-299.







Figs. 1-4. Longitudinal section of polypore hymenophore in the Hymenochaetaceae depicting monomitic (Figs. 1 and 2 with and without tramal setal hyphae), dimitic (fig. 3), and trimitic (fig. 4) hyphal systems (diagrammatic; after Cunningham, 1965).

SPECIAL PRESENTATION

CURRENT STATUS OF USDA FOREST SERVICE FOREST INSECT AND DISEASE RESEARCH

Paul Dunn
Principal Forest Microbiologist
Forest Insect and Disease Research
USDA Forest Service
P.O. Box 96090
Washington, D.C. 20090

The purpose of the Forest Service is to; first, maintain healthy forest and range; second, sustain and restore forest and range ecosystems; and third, to produce and protect forest and range products. Forest and Insect Disease Research (FIDR) conducts a comprehensive research program in support of those missions in the area of insect pests, fungal diseases, and beneficial roles of microbes and arthropods. The purpose of this paper is to discuss the status of this program.

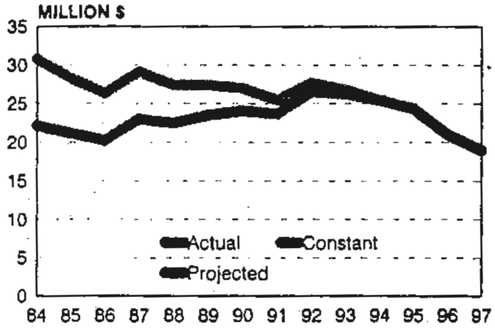


Figure 1. FIDR Budget in 1995 dollars

The FIDR budget has not kept pace with inflation over the past 10 years. In Fiscal Year 1996, the FIDR budget went from this gradual shrinkage to a serious cut. The actual national FIDR budget without adjustment for inflation and in 1995 dollars are displayed (Figure 1). The number of FIDR scientists also reflects this same trend (Figure 2). To compensate for these changes, FIDR has changed its program philosophy to accomplish its mission. We are shifting from large research units with several FIDR scientists focused on a single pest or disease to more interdisciplinary units that integrate FIDR scientists with other ecosystem scientist with a focus on ecosystem management. Within these units, we will continue to maintain pest specialists. Some units will be focused on forest and range products such as wild mushroom harvest, biopulping with fungi, enzymatic bleaching for pulp, and bio remediation of contaminated wood and soil with microbes and arthropods. In the past we have gradually moved off university campuses. In the future, I feel we will want to move back onto campus or regional centers around the universities. With our shrinking pool of FIDR scientists, the ability to work closely with the shrinking pool of university pathologists will be necessary to execute large scale interdisciplinary research programs.

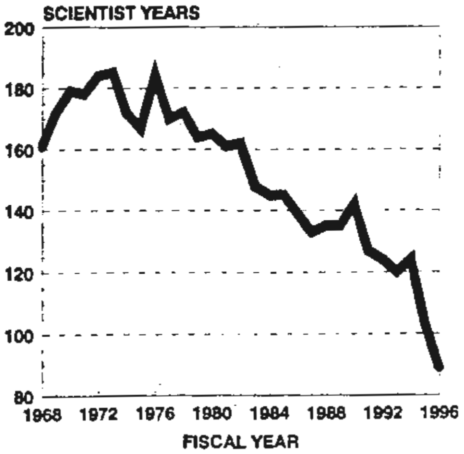


Figure 2. Number of FIDR Scientist

Due to the emphasis of Forest Service Research and FIDR on ecosystem management and due to shrinkage of the FIDR headquarters staff from five staff positions to three, the Forest Service Research Washington, D.C. headquarters is reorganizing. FIDR specialities will be included in the Forest and Range Management and Protection Research Staff (Table 1). This will bring the headquarters staff structure more closely in line with that we are expecting from our new ecosystem management projects.

Table 1. Proposed Staff Structure: Forest and Range Management and Protection Research

Staff Director
- Geneticist
- Quantitative Ecologist
- Fire Biologist
- Fire Physics Specialist
- Forest Operations Scientist
- Pathologist
- Entomologist
- Microbiologist
- Range Ecologist
- Silviculturist
    - Silviculturist/Ecologist

National Emphasis Areas

Exotic pests will be a major emphasis for the future. More than 360 exotic forest insects have been introduced. The number of diseases is much smaller (only about 20), but their impact has been devastating, e.g., chestnut blight, white pine blister rust. There are increasing demands for imported logs and chips. We have helped with assessments for log imports from Siberia, Chile, and New Zealand and know that the potential for additional introductions on logs is high. One common treatment has been methyl bromide. It will be phased out by the year 2001 under provisions of the Clean Air Act. The risk of exotic pests may be even higher with the loss of that treatment. Research needs to work with a variety of partners to assess the risk of introduction and to encourage actions that would prevent introductions. We will need anticipatory studies of exotic diseases with a high potential to be introduced. Research will be needed on monitoring and assessment. Classic biological control alone has proven to be insufficient in Hawaii to provide controls faster than new introductions of insects are being made. We need to develop ecosystem approaches to biological control that will prevent establishment of introduced organisms. We will maintain resistance breeding programs for our important species. This will include our traditional selection techniques but will also include molecular techniques to enhance resistance in the hosts and to reduce virulence in the pathogens.

Biodiversity will be a major emphasis of FIDR programs for the future. Biodiversity is essential to forest health at an ecological, taxonomic and genetic level. Under ecosystem management concepts, all species have value. Since nearly all biodiversity is in the arthropods, fungi, bacteria, and viruses, FIDR will need to develop methods to deal on a practical level with monitoring and assessment of these groups.

Western Disease Emphasis

Forest Service Research, in April 1995, produced a "Proposal for Optimizing Forest Service Forest Pathology Research in the West." This paper has been widely circulated in the western pathology community so I will not repeat its content here. It options continue to serve as guides for the national headquarters staff in allocation of resources in the West.

SPECIAL PAPERS

Mary Lou Fairweather, Moderator

RETROSPECTIVE DWARF MISTLETOE RESEARCH: ASSESSING THE IMPORTANCE, OPPORTUNITIES, AND CHALLENGES.

Lori M. Trummer[1], Paul E. Hennon[2], and Everett M. Hansen[1]
[1]Department of Botany and Plant Pathology
Oregon State University
Corvallis, OR 97331

[2]USDA Forest Service
State and Private Forestry
Juneau, AK 99802

Introduction

Past research on hemlock dwarf mistletoe (*Arceuthobium tsugense* (Rosendhal) G.N. Jones) has clarified parasite taxonomy (Hawksworth et al. 1992, Mathiasen 1994), reported factors influencing spread and intensification (Smith 1966, Richardson and Van der Kamp 1972, Stewart 1976, Shaw 1982, Alfaro et al. 1985, Shaw and Hennon 1991), and modeled parasite behavior (Bloomberg et al. 1980). This research, combined with silvicultural tools, has greatly aided control of the parasite in coastal western hemlock forests. New ecosystem management guidelines, which emphasize retention of structural and biological diversity in managed forests, have altered our thinking of pathogen management and provide an opportunity to maintain a desirable level of hemlock dwarf mistletoe in managed forests. While the presence and intensification of dwarf mistletoe is greatly reduced following clearcutting, the response of the parasite to alternative harvesting methods is unknown. Retrospective dwarf mistletoe studies in old wind-disturbed stands will help to fill this knowledge gap. The challenges and opportunities of such studies are reported.

Predicted Dwarf Mistletoe Response to Clearcut Harvesting Treatments

Hemlock dwarf mistletoe is a relatively easy pathogen to manage since a living host is required, the parasite has a limited dispersal distance, and it spreads most effectively from overstory canopy to the regenerating trees in the understory. Consequently, large clearcuts and subsequent girdling of residual trees after harvest operations have become the most effective methods of pathogen management in southeast Alaska (Shaw 1982, Shaw and Hennon 1991).

The movement of dwarf mistletoe both horizontally and vertically in western hemlock regenerating after a clearcut is fairly predictable. Dwarf mistletoe is spread horizontally by infected residual hemlocks that are left in a stand after harvesting operations. The vertical spread, or upward advance, of the dwarf mistletoe is usually slower than the growth of hemlock regeneration (Shaw and Hennon 1991). Over time, the parasite becomes relegated to the lower one third of the live tree crown. As canopy closure continues, lower branches of the live crown and the dwarf mistletoe infections become shaded and die. Damaging levels of dwarf mistletoe, therefore, are not expected to build through the 100-150 year forest rotation in an even-aged hemlock forest. Parasite introductions from trees left on clearcut edges or introductions from birds or mammals are not expected to be substantial over a forest rotation (Shaw and Hennon 1991).

Predicted Dwarf Mistletoe Response to Alternative Harvesting Treatments

Ecosystem management guidelines, recently adopted by many agencies and corporations, emphasize alternative harvesting methods rather than clearcutting on a site. As a result, overstory hemlock trees, many which contain active dwarf mistletoe infections, would remain after harvest operations. While there is a good understanding of the spread and intensification of dwarf mistletoe following clearcutting and even-aged forest growth, we have a poor understanding of how the parasite will intensify following partial harvest of old-growth stands. Of particular concern to managers is the recognition that dwarf mistletoe spreads most effectively from overstory to understory and that there is increased reproductive success with enhanced light conditions due to stand openings.

Desirable Levels of Dwarf Mistletoe - Why?

Historically, resource managers in Alaska have sought elimination of dwarf mistletoe from areas managed for timber production due to the fear that the parasite would cause unacceptable forest production losses. Severe growth loss, host mortality, and decreased wood quality have been documented in heavily infected trees in the Pacific Northwest (Buckland and Marples 1952, Wellwood 1956, Smith 1969). In Alaska, however, parasite behavior appears less vigorous, possibly due to poor pollination or a longer generation time (Drummond and Hawksworth 1979, Shaw and Loopstra 1991). The reduced vigor of the parasite allows increased opportunity for alternative management strategies in Alaska. Although little is known regarding the ecological importance of hemlock dwarf mistletoe in Alaskan forests, it is assumed to be a contributor to wildlife nesting sites, bird and mammal food, and enhanced biodiversity as reported for other dwarf mistletoe species in the Pacific Northwest (Nicholls et al. 1984, Linhart et al. 1989, Bennetts and Hawksworth 1992). Although high levels of the parasite can result in severe growth loss in the host tree, moderate to low parasite levels can result in minimal growth loss (Smith 1969). Low to moderate parasite levels, therefore, may allow timber production goals to be met concurrently with a general increase in biological diversity and maintenance of critical characteristics and processes of the original forest.

The Retrospective Approach

Studies that quantify the long-term spread and intensification of hemlock dwarf mistletoe following partial harvest of the overstory canopy are lacking. Models of dwarf mistletoe behavior generated from information in western Canada (Bloomberg et al. 1980) are not applicable in Alaska due to a marked difference in parasite behavior between regions and the focus of those studies on spread from small residual trees. In an attempt to fill the knowledge gap, a retrospective study in southeast Alaska was undertaken to document the present condition of hemlocks that had been exposed to dwarf mistletoe since the late 1800's.

The retrospective study utilized eight stands that had been wind-disturbed in a single large storm at the turn of the last century. Partially clearcut stands could not be used since most are small, less than 80 years old, and predominantly regenerated with Sitka spruce rather than western hemlock. The wind-disturbed stands chosen were large, approximately 110 years old, and contained overstory dwarf mistletoe-infected hemlocks that survived the storm.

Plots were located in areas of complete, light, and moderate wind disturbance which was determined by the number of trees that survived the storm. The three intensities of wind disturbance, complete, light, and moderate, was assumed to be a mimic for three intensities of harvesting, clearcut, light partial cut, and moderate partial cut. The assumption that wind disturbed stands can be a mimic for clearcutting is made since the aerial parasite would likely behave in a similar way in either circumstance. The data from the study, therefore, can provide an acceptable approximation of parasite behavior through time following partial harvest of the overstory canopy. Data analysis is in the preliminary stages.

The retrospective approach provided both opportunities and challenges. The opportunity was tempting when considering the alternative: establish partial cuts now and wait a century to obtain results. Analysis of old wind-disturbed stands, in contrast, allowed immediate results. The challenges, however, have been formidable.

First and foremost was problem of knowing how much dwarf mistletoe was in the stand prior to the wind disturbance. To partially overcome this obstacle we assigned one of three numbers to the dead branches of the tree from below the live crown to the base of the tree: zero = no recognizable signs of old infections, 1 = < 50% of the branches had infections, 2 = > 50 % of the branches had infections. This rating was a useful, albeit conservative, estimate of past dwarf mistletoe infection levels.

Second, the determination of which trees were present in the stand prior to the disturbance could only be made through the labor intensive process of increment boring and tree ring analysis. Neither tree heights nor diameters proved to be reliable estimates for the age of a tree. Analysis of tree rings was aided by easily recognizable release patterns from many trees, presumably caused by increased light conditions and nutrient availability immediately following the catastrophic storm.

Third, preliminary data analysis revealed that the amount of dwarf mistletoe infection sources within the plot was a poor predictor of a plot's overall dwarf mistletoe rating (DMR). This was exemplified by a high plot DMR but no infection sources. Further data collection and analysis revealed that the infection sources immediately adjacent to the plot were important contributors to plot DMR. Consequently, a buffer zone of an additional 10 m, the maximum natural dispersal distance of most dwarf mistletoe seeds (Smith 1966), was installed surrounding each plot. We surmise the necessity of the buffer zone was due to the age of stand sampled.

Though challenging, retrospective dwarf mistletoe studies provide a unique opportunity to glimpse the distant future, a future far beyond the span of a single pathologist's career. Careful unraveling of past stand history can allow a wealth of dwarf mistletoe information to be available in a short period of time.

Literature Cited

Alfaro, R., W.J. Bloomberg, R.B. Smith, A.J. Thompson. 1985. Epidemiology of dwarf mistletoe in western hemlock stands in south coastal British Columbia. Can. J. For. Res. 15:909-913.

Bennetts, R.E. and F.G. Hawksworth. 1992. The indirect effects of dwarf mistletoe on bird communities in Colorado ponderosa pine forests. Pp. 14-17. Proceedings of the 39th Western International Forest Disease Work Conference.

Bloomberg, W.J., R.B. Smith, and A. Van Der Wereld. 1980. A model of spread and intensification of dwarf mistletoe infection in young western hemlock stands. Can. J. For. Res. 10:42-51.

Buckland, D.C. and E.G. Marples. 1952. Management of western hemlock infected with dwarf mistletoe. B.C. Lumberman 36:50, 51, 136, 138, 140.

Drummond, D.B. and F.G. Hawksworth. 1979. Dwarf mistletoe in western hemlock in southeast Alaska. USDA Forest Service, Forest Insect and Disease Management, Methods Application Group, Davis CA, Report 79-6. 14 p.

Hawksworth, F.G., D. Wiens, and D.L. Nickrent. 1992. New Western North America taxa of *Arceuthobium* (Viscaceae). Novon 2:204-211.

Linhart, Y.B., M.A. Snyder, S.A. Habeck. 1989. The influence of animals on genetic variability within ponderosa pine stands, illustrated by the species of Abert's squirrel and porcupine. Pp. 141-148. In: Tecle, A et al. (eds). Multiresource Management of ponderosa pine forests. Nov. 14-16, 1989, Flagstaff, AZ. USDA For. Serv., Rocky Mtn. Res. Sta., Fort Collins, CO. Gen. Tech. Rep. RM-185. 282 p.

Mathiasen, R.L. 1994. Natural infection of new hosts by hemlock dwarf mistletoe. USDA For. Serv., Rocky Mtn. Res. Sta., Fort Collins, CO. Research Note RM-RN-530. 6p.

Nicholls, T.H., F.G. Hawksworth, L.M. Merrill. 1984. Animal vectors of dwarf mistletoe, with special reference to *Arceuthobium americanum* on lodgepole pine. Pp. 102-110. In: Hawksworth, F.G. and R.F. Scharpf (eds). Biology of dwarf mistletoes: proceedings of the symposium. USDA For. Serv., Fort Collins, CO. Gen. Tech. Rep RM-111. 131p.

Richardson, K.S. and B.J. Van der Kamp. 1972. The rate of upward advance and intensification of dwarf mistletoe on immature western hemlock. Can. J. For. Res. 2:313-316.

Shaw, C.G. III. 1982. Development of dwarf mistletoe in western hemlock regeneration in southeast Alaska. Can. J. For. Res. 12:482-488.

Shaw, C.G. III and P.E. Hennon. 1991. Spread, intensification, and upward advance of hemlock dwarf mistletoe in thinned, young stands of western hemlock in southeast Alaska. Plant Disease 75:363-367.

Shaw, C.G. III and E.M. Loopstra. 1991. Development of dwarf mistletoe infections on inoculated western hemlock in southeast Alaska. Northwest Science 65:48-52.

Smith, R.B. 1966. Hemlock and larch dwarf mistletoe seed dispersal. For. Chron. 42:395-401.

Smith, R.B. 1969. Assessing dwarf mistletoe on western hemlock. For. Sci. 15:277-285.

Stewart, J.L. 1976. Dwarf mistletoe infection from residual western hemlock on cutover stands. USDA For. Serv., Portland, OR. Research Note PNW-278. 3p.

Wellwood, R.W. 1956. Some effects of dwarf mistletoe on western hemlock. For. Chron. 32:282-296.

INOCULATING PONDEROSA PINE AND DOUGLAS-FIR SEEDLINGS WITH MYCORRHIZAL FUNGI AT THE TIME OF OUTPLANTING

Gregg DeNitto
Plant Pathologist
Forest Pest Management
USDA Forest Service
Redding, CA 96001

Linda Haugen
Plant Pathologist
Forest Health Protection
USDA Forest Service
St. Paul, MN 55108

Abstract

Commercially available spores of *Rhizopogon occidentalis* and *R. parksii* were applied to ponderosa pine and Douglas-fir seedlings, respectively, at the time of outplanting. Pine seedlings were planted on a harsh, twice burned site with limited numbers of hosts present on the site during the previous 10 years. Pine and Douglas-fir seedlings were planted on a recently harvested, higher productivity site. Survival and height and diameter growth were measured at the end of the first and second growing seasons. Roots were assessed for the types of mycorrhizae present at the time of outplanting and at the end of the first growing season. Unit had a significant effect on growth and survival for each of the species-unit situations. Inoculation did not have a significant effect on growth or survival. No differences were observed in the types of mycorrhizae colonizing inoculated and control roots at the end of the first growing season. All of the roots had indications of being colonized by fungi on the site, although the rate of replacement on pine seedlings on the harsher site was slower. Inoculating ponderosa pine or Douglas-fir seedlings with spores of these fungi at the time of outplanting provided no benefit to seedling survival or growth.

Introduction

Mycorrhizae are symbiotic associations between plant roots and certain species of fungi. Mycorrhizal associations are essential to the normal growth of most plants. Some of the benefits attributed to mycorrhizae include increased nutrient and water absorbing capabilities which increases the chances for survival and growth of the plant. Pines are among the species most dependent upon mycorrhizal associations, as demonstrated by the repeated failures of exotic pine plantations when introduced into ecosystems without the appropriate symbionts (Mikola 1970). Early colonization by mycorrhizal fungi is especially important for survival in dry areas (Reid 1979). Seedlings from nurseries may lack well-developed mycorrhizal associations, or be dominated by mycorrhizal fungi that are well adapted to nursery conditions rather than field conditions (Molina and Trappe 1984).

Mycorrhizal fungi cannot grow and reproduce in soil without symbiotic host roots (Marx 1977). The woody root system remaining after the host is removed quickly loses its capability to support ectomycorrhizal fungi (Harvey *et al.* 1980). These two factors may result in decreased opportunities for infection of seedling roots with increasing time between disturbance and reforestation efforts (Amaranthus and Perry 1990). On droughty, poor, or harsh sites, there may be only a brief period favorable for growth and survival of conifer seedlings (Perry *et al.* 1987) following removal of mycorrhizal host plants. On undisturbed sites, the spread of mycorrhizal fungi to new roots is believed to be through fine hyphae, mycelial strands, or rhizomorphs from existing mycorrhizae. On severely disturbed sites these structures may be quickly lost and inoculum may consist mostly of airborne and animal vectored spores and resistant structures remaining in the soil. The presence of these latter forms of spread will depend on the proximity of suitable habitats harboring the needed fungi (Malajczuk *et al.* 1994).

Prior to the 1992 planting season, the Salmon River Ranger District, Klamath National Forest, informed Forest Pest Management, Redding, CA, of a plan to inoculate upwards of 250,000 ponderosa pine seedlings and 150,000 Douglas-fir seedlings with commercially available mycorrhizal inoculum (Forestry Mycorrhizal Applications, Grants Pass, OR). We had a mutual interest in monitoring the effectiveness of this technique, especially on sites with a history of poor conifer establishment. The purpose of our effort was to determine if root dip inoculation increases mycorrhizal infection and provides a survival and/or growth benefit to the seedlings. This was examined for ponderosa pine on harsher, recently non-forested sites and on better, recently forested sites. The effect on Douglas-fir on better, recently forested sites was also examined. Each of these three sites were examined and analyzed independently, although the study designs were similar.

Objectives

1A. To determine whether inoculation of ponderosa pine seedlings with *Rhizopogon occidentalis* prior to planting onto harsh sites results in improved survival or growth.

1B. To verify whether the above inoculation results in colonization of the seedlings by the inoculated fungus.

2A. To determine whether inoculation of ponderosa pine with *Rhizopogon occidentalis* prior to planting onto sites with higher inoculum potential (green sale reforestation) results in increased survival or growth.

2B. To verify whether inoculation of ponderosa pine on green sale sites results in colonization of the seedlings by the inoculated fungus.

3A. To determine whether inoculation of Douglas-fir with *Rhizopogon parksii* prior to planting onto green sale sites results in increased survival or growth.

3B. To verify whether inoculation of Douglas-fir on green sale sites results in colonization of the seedlings by the inoculated fungus.

Methods

The experimental design is a nested randomized complete block. The block effect is composed of the nested effect of plot within unit. Each plot contained one replication of each of two treatments. Each replication is made up of 25 trees of each treatment completely randomized within the plot. All planting was done in the spring of 1992 when conditions were suitable for the site. A unit was a management defined area that had been similarly treated silviculturally.

To address objectives 1A and 1B, units were selected on Picayune Ridge which had been burned by the 1977 Hogg fire, and burned again in 1987. This area typifies harsh, difficult-to-regenerate conditions that result from repeated wildfire. Soils are clay to clay loam. Plantations on the portions of the units where plots were selected have failed repeatedly. Three plots each were established on 3 representative units. The plots are at elevations of 760-920 m (2500-3000 ft). The sites had not been forested for several years, and competing vegetation was present on all plots. Typical vegetation included grasses, deerbrush (*Ceanothus interregimus*), and canyon live oak (*Quercus chrysolepis*). The slope of the plots ranged from nearly level to steep. All plots had a generally south aspect.

Plots consisted of 25 inoculated and 25 non-inoculated 1-0 ponderosa pine seedlings arranged randomly in 6 rows of 8 or 9 seedlings each. Seedlings had been grown at the Placerville nursery. Twenty five additional seedlings from this lot were assessed for mycorrhizal condition at the time of planting. Approximately 30 extra seedlings of each treatment (inoculated and non-inoculated) were planted adjacent to one plot on each of the 3 units to provide material for excavation and examination of root systems during the study. The plots were established in unplanted or failed areas, or between previously planted rows. Treatments were assigned to planting spots prior to planting. A 1 m (3 ft) diameter scalp was made at each planting spot, and each seedling was protected from browse by plastic netting. Spacing between seedlings was approximately 2.5 m (8 ft). One individual planted all of the seedlings on each plot to minimize planting variation.

A suspension of *R. occidentalis* spores was incorporated into the vermiculite and water planting slurry to inoculate the seedlings prior to planting. Spore density of the suspension was determined with a hemocytometer to be 188 million spores per liter. For the planting dip, 2.7 ml of this concentrate was added to 7.5 l (2 gal) of water. Inoculum was prepared fresh at the beginning of each day of planting.

Stem diameter and height were recorded at the time of planting, and each seedling was tagged. Calipers were used to measure the stem diameter (to the nearest mm) of each seedling at soil line. Height was measured to the nearest cm as the distance between ground line on the uphill side and the top of the terminal bud. The same individual did the measurements on each plot.

At the end of the first and second growing seasons survival was determined and seedling heights and diameters of the living trees were remeasured. A sample of the extra seedlings that had been planted were carefully excavated at the end of the first growing season, trying to protect the root systems, and transported in an ice chest for evaluation of their mycorrhizal components and condition.

To meet objectives 2A and 2B, a similar set of plots was established and measured on the Blindhorse sale area. This sale area typifies a higher site quality that had recently been harvested. Soils are a decomposed granite type. The plots are at elevations from 1200-1500 m (4500-5000 ft). The plots were relatively free from competing vegetation, as they were recently harvested and site prepared. The plots are generally on steep slopes with a range of aspects. Only 2 units were selected, with 2 plots per unit. This area was clearcut harvested in 1990 and broadcast burned in 1991, so no scalping was necessary and plastic netting was not used. Ponderosa pine seedlings were tagged and measured as on Picayune Ridge. The 2-0 seedlings had been grown at the J. Herbert Stone nursery in Oregon. Extra seedlings were planted for later excavation at one plot on each unit. Additional seedlings were evaluated for nursery associates. The same spore concentrate was used as on the Picayune Ridge site, with 2.5 ml of the concentrate added to 5.7 l (1.5 gal) of water.

To meet objectives 3A and 3B, Douglas-fir plots were established and measured on the Blindhorse sale area. Three plots per unit on 3 units were established. The units were laid out, planted and measured as above, except inoculum specific to Douglas-fir, *R. parksii*, was used. The seedlings were 2-0 stock from the Stone nursery. A concentrate of approximately 156 million spores of *R. parksii* per ml was used. Eight milliliters of this concentrate was added to 11.4 l (3 gal) of water. Additional seedlings were planted for later excavation at one plot on each of the units.

To analyze the resulting data, each species and site type combination were considered in a separate analysis (i.e. there were three analyses). Three growth variables were calculated and analyzed for each study. They were: percent height increase ([height at end of season - initial height]/initial height X 100); percent diameter squared increase ([diameter squared at end of season - initial diameter squared]/initial diameter squared X 100); and percent volume increase ([volume at end of season - initial volume]/initial volume X 100) where volume is approximated as diameter squared times height. The percent survival was also calculated for each plot. The final value was transformed with an arcsine squareroot function and analyzed. The analysis compared unit, plot, and treatment effect with an analysis of variance using a general linear models procedure, Statistical Analysis Systems version 6.08 (SAS Institute, Cary, NC). This model considered the effect of plot nested within unit.

Results

Seedling Root Observations

At least 25 seedlings of each species and source group were assessed for mycorrhizal associates from the nursery by Dr. Michael Castellano, PNW Experiment Station, and the second author following outplanting. The ponderosa pines from the Placerville nursery planted at Picayune Ridge had primarily ectendomycorrhizal associations and *Thelephora* sp. at the time of planting. The pines planted at the Blindhorse site had fairly high levels of their root systems colonized, primarily by *Thelephora* sp. and some ectendomycorrhizae. Nearly all of the Douglas-firs had *Thelephora* sp., some with a high proportion of their roots colonized at the time of outplanting.

After one growing season in the field, inoculated and non-inoculated seedlings were excavated and examined to determine the types of mycorrhizal associations. The purpose was to determine if the inoculations had resulted in an observable increase in colonization of the roots by the inoculated fungus. The mycorrhizae formed by *R. occidentalis* develop a bright orange mantle. Those of *R. parksii* develop a purple-gray to brown woolly secondary mantle. Fourteen or 15 of each of the treatments from each site and source were evaluated.

The prevalent types of mycorrhizae present on the ponderosa pine from Picayune Ridge were *Thelephora* sp. and ectendomycorrhizae, similar to what was seen in the nursery stock. These seedlings had few root tips recovered because of soil conditions. Other types that were observed on a trace to 1/3 of the roots of one or a few seedlings included several "beige" types, a type typical of *Suillus* or *Rhizopogon*, a gray-white *Rhizopogon* type, a dark gray type, a gray-white *Cortinarius*-like type, and an orange *Rhizopogon* type. The orange *Rhizopogon* type occurred at low frequency on both inoculated and control seedlings. Inoculation did not result in an observed increase in colonization by this type. The nursery fungi were gradually being replaced on both inoculated and control trees by indigenous fungi.

The ponderosa pines from the Blindhorse site had larger root systems than the Picayune Ridge pines, with more root tips, and a greater proportion of the root system colonized by wild types of mycorrhizal fungi. The array of types and levels of colonization were similar between treatments. The only orange *Rhizopogon* type was observed on a non-inoculated seedling.

Douglas-fir seedlings on the Blindhorse site had a wide range of types of fungi colonizing their roots, but two morphological types occurred very frequently. One had a colorless to white mantle and abundant radiating tan to golden hyphae, perhaps a *Hebeloma* sp. The second was a white mycorrhiza with a purple-gray to brown woolly secondary mantle typical of the *Rhizopogon* subgroup which contains *R. parksii*. This purple-gray mycorrhiza could have come from either the inoculation or from natural inoculum. The approximate amount of this associate was determined for each seedling and indicated a wide range of colonization, from a trace to over 50 percent of root tips infected, in both the inoculated and non-inoculated treatment.

Growth and Survival Analysis

Unit had a significant effect on many of the growth variables and survival on most of the sites and seasons (Tables 1, 2, and 3). Overall, unit had an influence on growth for most of the variables, but did not consistently influence seedling survival. Treatment, however, had no effect on survival or growth on any of the three sites with some exceptions (Tables 4, 5, and 6). The volume of ponderosa pine at the end of season 2 on Blindhorse was higher for the control. Survival of Douglas-fir on the Blindhorse site at the end of year 1 and cumulatively at the end of the study were higher for the inoculated seedlings .

Growth conditions for seedlings during the spring and summer of 1992 were relatively good. Although precipitation for the year was below normal, enough rain fell during the growing season, especially significant rainfall in June, to maintain moisture in the higher soil profiles later into the year.

TABLE 1. Effect of unit on percent change in growth and survival variables following inoculation of ponderosa pine with *Rhizopogon occidentalis* at the end of seasons 1 and 2 at Blindhorse.

Variable	Height		Diameter^2		Volume		Survival		Cumulative Survival
Unit\Season	1	2	1	2	1	2	1	2	0-2
44-68	14	24	62	99	85	150	90	99	89
44-72	12	45	113	126	143	236	95	96	91
Significance[a]	NS	*	*	NS	*	*	NS[b]	Nsb	NS[b]

[a] *=significant at the 0.05 level; NS=not significant at the 0.05 level

[b] Level of significance determined for arcsine transformation of percent survival. Values given are means of actual survival.

TABLE 2. Effect of unit on percent change in growth and survival variables following inoculation of ponderosa pine with *Rhizopogon occidentalis* at the end of seasons 1 and 2 at Picayune Ridge.

Variable	Height		Diameter^2		Volume		Survival		Cumulative Survival
Unit\Season	1	2	1	2	1	2	1	2	0-2
29-100	57	50	85	188	195	341	90	85	77
29-33	55	51	63	187	155	343	91	98	90
29-66	39	40	37	141	92	243	71	90	63
Significance[a]	*	NS	*	*	*	*	*[b]	*[b]	*[b]

[a] *=significant at the 0.05 level; NS=not significant at the 0.05 level

[b] Level of significance determined for arcsine transformation of percent survival. Values given are means of actual survival.

TABLE 3. Effect of unit on percent change in growth and survival variables following inoculation of Douglas-fir with *Rhizopogon parksii* at the end of seasons 1 and 2 at Blindhorse.

Variable	Height		Diameter^2		Volume		Survival		Cumulative Survival
Unit/Season	1	2	1	2	1	2	1	2	0-2
44-68	19	30	50	112	80	183	94	99	93
44-72	19	28	80	142	120	215	96	97	93
44-73	20	33	97	182	141	289	99	97	96
Significance[a]	NS	*	*	*	*	*	NS[b]	Nsb	NS[b]

[a] *=significant at the 0.05 level; NS=not significant at the 0.05 level

[b] Level of significance determined for arcsine transformation of percent survival. Values given are means of actual survival.

TABLE 4. Effect of treatment on percent change in growth and survival variables following inoculation of ponderosa pine with *Rhizopogon occidentalis* at the end of seasons 1 and 2 at Blindhorse.

Variable	Height		Diameter^2		Volume		Survival		Cumulative Survival
Treatment\Season	1	2	1	2	1	2	1	2	0-2
Control	13	38	84	122	110	211	91	96	87
Inoculated	13	31	91	102	118	174	94	99	93
Significance[a]	NS	NS	NS	NS	NS	*	NS[b]	Nsb	NS[b]

[a] *=significant at the 0.05 level; NS=not significant at the 0.05 level

[b] Level of significance determined for arcsine transformation of percent survival. Values given are means of actual survival.

TABLE 5. Effect of treatment on percent change in growth and survival variables following inoculation of ponderosa pine with *Rhizopogon occidentalis* at the end of seasons 1 and 2 at Picayune Ridge.

Variable	Height		Diameter^2		Volume		Survival		Cumulative Survival
Treatment\Season	1	2	1	2	1	2	1	2	0-2
Control	50	47	64	176	150	314	84	93	78
Inoculated	51	48	59	168	144	304	84	89	76
Significance[a]	NS	NS	NS	NS	NS	NS	NS[b]	Nsb	NS[b]

[a] *=significant at the 0.05 level; NS=not significant at the 0.05 level

[b] Level of significance determined for arcsine transformation of percent survival. Values given are means of actual survival.

TABLE 6. Effect of treatment on percent change in growth and survival variables following inoculation of Douglas-fir with *Rhizopogon parksii* at the end of seasons 1 and 2 at Blindhorse.

Variable	Height		Diameter^2		Volume		Survival		Cumulative Survival
Treatment\Season	1	2	1	2	1	2	1	2	0-2
Control	19	30	76	140	114	222	94	97	91
Inoculated	19	30	76	151	113	236	99	99	97
Significance[a]	NS	NS	NS	NS	NS	NS	*[b]	Nsb	*[b]

[a] *=significant at the 0.05 level; NS=not significant at the 0.05 level

[b] Level of significance determined for arcsine transformation of percent survival. Values given are means of actual survival.

Discussion

Survival of ponderosa pine and Douglas-fir on the better sites at Blindhorse was high regardless of treatment. First year survival was at levels typical of what occurs operationally on these types of sites. The higher survival of the inoculated Douglas-fir, although statistically significant, operationally would not have provided a benefit. Survival in excess of 90 percent provides more than adequate stocking for the future stand. This significant increase did not continue into the second year when the influence of the inoculated fungus would be expected to be greater because of active colonization of seedling roots and surrounding soil. It is unlikely that mycorrhizae limit first or second year survival on these sites if planting occurs soon after harvesting. Although the sites are disturbed through harvesting and site preparation, they are not left without hosts for a long period of time. In addition to conifer hosts, sprouting hardwoods that are common to these sites are ectomycorrhizal (Largent *et al.* 1980) and may harbor mycorrhizal fungi that can colonize conifer roots. With current management emphasis to reduce the size of harvested areas and the retention of green trees, adequate inoculum should remain available for colonization of tree roots when seedlings are introduced to the site. Inoculating the seedlings at the time of planting will likely not provide any survival or growth benefits under these conditions. Natural components will occupy the root tips rapidly and maintain the biological diversity on the site.

This may not be the case, however, on the same site if the loss of hosts is a result of catastrophic wildfire that severely disturbs the site (Amaranthus and Perry 1990). In this situation, with the loss of sizeable areas of host trees, surface organic matter, and coarse woody debris, the ability of the native mycorrhizal component to remain on site or rapidly recolonize the site when hosts return may be reduced (Parke *et al.* 1984). Introducing potential mycorrhizal fungi to these sites either directly or on colonized seedlings may be possible. However, the specific requirements of each site and situation for the optimal types and mix of mycorrhizal fungi should be known to improve the chances of success and the effectiveness of the inoculation. Trying to achieve this artificially may or may not provide positive results (Perry *et al.* 1987). The greatest benefit may be achieved by assuring the retention of living hosts across the landscape and having them serve as a refugia of soil microorganisms for recolonization of regeneration. These hosts may be conifers or hardwoods that serve as hosts of ectomycorrhizal fungi.

The relatively high survival on the Picayune Ridge site was not typical for this site based on previous experience. It is possible that greater care was taken in the planting of the seedlings than what was previously done. Late spring rains and high moisture availability during the first growing season probably had a major effect on seedling survival in this study.

Mycorrhizae formation is critical for tree survival on sites limited by moisture and temperature (Marx *et al.* 1977; Amaranthus and Perry 1990; Perry *et al.* 1987; Trappe 1977). The Picayune Ridge site may be such a site. It is possible that the limited colonization of the root systems by non-nursery types of mycorrhizal fungi is a result of limited inoculum available on the site. Native fungi seemed to be colonizing the roots at a slower rate there than on the better Blindhorse site. The site had not been occupied by significant quantities of conifer or hardwood mycorrhizal hosts for over 10 years, but rather had a large component of nonectomycorrhizal hosts. The lack of hosts may have resulted in a reduction in the ectomycorrhizal component over time (Amaranthus and Perry 1987).

A different explanation may be the seedling type used on each site. The larger 2-0 seedlings planted on the Blindhorse site had larger root systems. This may have provided these seedlings with a better opportunity to occupy their planting site and obtain moisture for increased root and root tip growth, resulting in more opportunities for infection to occur. Also, the fact that the Blindhorse site was a less harsh, north-facing site may have provided opportunities for greater growth of the roots of these seedlings. The smaller root systems at Picayune Ridge, in conjunction with limited soil moisture availability, may have resulted in fewer root tips and less infection. If this is true, it argues for the need to provide opportunities for rapid colonization of roots by adapted mycorrhizal fungi on harsh sites or to plant seedlings with roots colonized at the time of planting.

The lack of infection by the inoculated fungi on any of the sites could be a result of selecting the improper species for the site, seedling physiology, poor root tip development, or a myriad of other unknown explanations (Trappe 1977). Most successful inoculations have occurred when seedlings were colonized at the time of outplanting or when soil with its mix of infective propagule types was introduced to the seedling at the time of planting (Amaranthus and Perry 1987).

The lack of effect of treatment on seedling survival and growth indicates that under these environmental conditions and using these fungi, spore inoculation at the time of outplanting does not appear to be a useful technique. Whether colonization of seedling roots by appropriate fungi when grown at a nursery prior to introduction to the site would increase survival or growth is unknown. Inoculations with numerous fungi and hosts have been tried with varying success (Molina 1980; Shaw and Molina 1980). Some of the native field mycorrhizal fungi are not well adapted to growing conditions experienced in nurseries and container facilities so species selection and environmental conditions in the nursery are critical to successful colonization (Cordell and Marx 1994; Trappe 1977). Very little information is known about which fungi are best suited for the wide array of conditions that exist in the field. Explorations of what fungi will provide benefit under different field conditions and the techniques needed to grow and colonize seedlings by these fungi need to continue before nurseries can provide inoculated seedlings tailored to specific conditions and needs (Molina 1981). Other techniques, such as soil introduction from sites with hosts, may also be employed when it is recognized that lack of mycorrhizal inoculum is adversely affecting seedling survival.

Literature Cited

Amaranthus, M.P., and Perry, D.A. 1987. Effect of soil transfer on ectomycorrhiza formation and the survival and growth of conifer seedlings on old, nonreforested clear-cuts. Can. J. For. Res. 17:944-950.

Amaranthus, M.P., and Perry, D.A. 1990. Ectomycorrhizae and forest regeneration on disturbed lands in the Klamath Mountains. Eighth North American Conference on Mycorrhizae, 5-8 September 1990, Jackson, WY: 4-5.

Harvey, A.E., Jurgensen, M.F., and Larsen, M.J. 1980. Clearcut harvesting and ectomycorrhizae: survival of activity on residual roots and influence on a bordering forest stand in western Montana. Can. J. For. Res. 10:300-303.

Largent, D.L., Sugihara, N., and Wishner, C. 1980. Occurrence of mycorrhizae on ericaceous and pyrolaceous plants in northern California. Can. J. Bot. 58:2274-2279.

Malajczuk, N. Reddell, P., and Brundrett, M. 1994. Role of ectomycorrhizal fungi in minesite reclamation. In F.L. Pflegler and R.G. Linderman, eds. Mycorrhizae and Plant Health. APS Press, St. Paul, MN:83-100.

Marx, D.H. 1977. The role of mycorrhizae in forest production. TAPPI 60:151-161.

Marx, D.H., Bryan, W.C., and Cordell, C.E. 1977. Survival and growth of pine seedlings with *Pisolithus* ectomycorrhizae after two years on reforestation sites in North Carolina and Florida. For. Sci. 23:363-373.

Mikola, P. 1970. Mycorrhizal inoculation in afforestation. Int. Rev. For. Res. 3:123-196.

Molina, R. 1980. Ectomycorrhizal inoculation of containerized western conifer seedlings. USDA For. Serv. Res. Note PNW-357, Pacific Northwest Forest and Range Experiment Station, Corvallis, OR. 10p.

Molina, R. 1981. Mycorrhizal inoculation and its potential impact on seedling survival and growth in southwest Oregon. In Hobbs, S.D., Helgerson, O.T., eds. Reforestation of skeletal soils: Proceedings of a workshop; 1981 November 17-19; Medford, OR. Corvallis, OR: Forest Research Laboratory, Oregon State University:86-91.

Molina, R., and Trappe, J.M. 1984. Mycorrhizae management in bareroot nurseries. In Forest Nursery Manual: Production of Bareroot Seedlings, Martinus Nijhoff/Dr. W. Junk Publishers, The Hauge. (for Forest Research Laboratory, Oregon State University, Corvallis.): 211-223 .

Parke, J.L., Linderman, R.G., and Trappe, J.M. 1984. Inoculum potential of ectomycorrhizal fungi in forest soils of southwest Oregon and northern California. For. Sci. 30:300-304.

Perry, D.A., Molina, R., and Amaranthus, M.P. 1987. Mycorrhizae, mycorrhizospheres, and reforestation: current knowledge and research needs. Can. J. For. Res. 17:929-940.

Reid, C.P.P. 1979. Mycorrhizae and Water Stress. In A. Riedacker and J. Gagnaire-Michard, eds. Symposium Proceedings: Root Physiology and Symbiosis. 11-15 September 1978; Nancy, France. IUFRO:392-408

SAS Institute. 1989. SAS Companion for the MVS Environment, Version 6, Release 6.08. SAS Institute, Inc. Cary, NC.

Shaw, C.G., III, and Molina, R. 1980. Formation of ectomycorrhizae following inoculation of containerized Sitka spruce seedlings. USDA For. Serv. Res. Note PNW-351, Pacific Northwest Forest and Range Experiment Station, Portland, OR. 8p.

Trappe, J.M. 1977. Selection of fungi for ectomycorrhizal inoculation in nurseries. Annu. Rev. Phytopathology 15:203-222.

Acknowledgements

We would like to acknowledge the assistance played by several people on Salmon River Ranger District, including Dan Blessing, Bill Wais, and Brad Burgess. They were instrumental in implementing this project and providing local support. We would also like to thank other District personnel who helped in planting and measuring seedlings. Our appreciation to Dr. Michael Castellano, PNW Experiment Station, who helped identiify mycorrhizal associates.

LAMINATED ROOT ROT - WITHIN STAND DISTRIBUTION

W. G. Thies
USDA Forest Service
Pacific Northwest Research Station
Corvallis, Oregon 97331

Introduction

Laminated root rot, caused by *Phellinus weirii* (Murr.) Gilb., begins in a stand when uninfected roots of a susceptible tree grow into contact with infected stumps or roots left from the previous stand and are colonized by the pathogen. As the new stand develops the fungus spreads among living trees through root contact (Wallis and Reynolds 1965). The fungus progressively destroys the roots of infected trees. Eventually, a tree dies while standing or loses its structural support and is windthrown. As the fungus spreads and kills more trees, gaps appear in the stand. These gaps, which start as groups of 1-3 trees enlarge and merge to create infection centers which may extend over several hectares. Because the mortality is first noticed as gaps with dead and down trees, the disease is most often thought of as having an aggregated distribution.

The purpose of this paper is to introduce for discussion evidence that laminated root rot is primarily represented by a diffuse rather than an aggregated distribution in infected portions of a stand.

Methods

Our observations have come from studies to test disease management strategies. The study areas (3 to 16 ha) were in mature (45 to 60 years old) coastal Oregon and Washington stands of predominantly Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco). Distribution of the disease on each study area was determined in the same manner:

The study area was subdivided into 30 x 30 m units. Each unit was systematically searched twice: precut, to locate infested standing dead or down trees or stumps that might be moved during harvest; and postcut, to identify infested newly created stumps. Each *P. weirii* infested entity (standing or down tree, or stump) was marked and its location mapped. Infested stumps or down trees were detected based on the presence of stain (incipient decay) or advanced decay typical of that caused by *P. weirii* or ectotrophic mycelium typical of *P. weirii* near the root collar (Thies and Sturrock 1995). The limit of each *P. weirii*-caused gap was mapped as delineated by the last standing live tree at the edge of the opening.

A map was produced of each study area depicting *P. weirii*-caused gaps, infected trees either live or standing dead and down.

Results

Inspection of the 10 study area maps revealed that gaps did not accurately portray disease distribution in the stands. Mortality was generally aggregated around gaps; however, in some cases the mortality was as single trees or a cluster of a few trees. However, when the "hidden infection" represented by live infected trees was considered the area of infected trees (area with inoculum available to infect the next stand) in every case was many times the area defined by gaps or clusters of dead trees.

Discussion

Distribution of laminated root rot within stands differs. Dead and symptomatic diseased Douglas-fir in coastal stands often appear aggregated into fairly discrete gaps. Conventional wisdom suggests that the openings represent the near limit of the disease. Our observations suggest otherwise. In some stands, distribution of the infected trees may be diffuse and difficult to detect; in these cases *P. weirii* may not cause distinct centers but will affect groups of one to several trees throughout the area of infestation. In other stands both distinct gaps and diffuse distribution were present. In the 10 stands discussed here the pattern of *P. weirii* infection was diffuse rather than aggregated, and in no case did openings accurately portray the distribution of the disease. After a stand has been clearcut or thinned the presence of the disease is less obvious and often forgotten until it reappears in the replacement stand.

Our observations were made on a relatively small sample of coastal Douglas-fir stands; however, the presence of the diffuse pattern of infection was consistent and leads to the suggestion that distribution of the disease should be carefully considered. Resource managers need to determine distribution of infected trees before selecting a disease-management strategy. A management strategy that assumes an aggregated inoculum distribution is unlikely to yield the desired results if distribution is diffuse.

Citations

Thies, W. G., and R. N. Sturrock. 1995. Laminated root rot in western North America. Gen. Tech. Rep. PNW-GTR-349. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 32p. In cooperation with: natural Resources Canada, Canadian forest Service, Pacific Forestry Centre.

Wallis, G. W., and G. Reynolds. 1965. The initiation and spread of *Poria weirii* root rot of Douglas-fir. Can. J. Bot. 43:1-9.

NEW METHODS OF CONTROL FOR BLUE STAIN FUNGI

Chad J. Behrendt, Robert A. Blanchette, and Roberta L. Farrell

First and second authors, Department of Plant Pathology,
University of Minnesota, St. Paul, MN 55108
Third author, Clairiant Chemicals Corp., Charlotte, NC
(formally Sandoz Chemicals Biotech Research Corp., Lexington, MA)

Blue stain fungi, such as *Ophiostoma* and *Ceratocystis* species, are pioneer colonizers of freshly cut wood. Colonization by blue stain fungi of freshly cut timber yields a blue to black discoloration of the sapwood. This discoloration causes economic losses due to reduced quality of timber products and reduced brightness of pulps made from stained wood (Chidester et al. 1938; Roff et al. 1980; Blanchette et al. 1992; Seifert 1993). To control blue stain fungi many different procedures have been used in the past including sprinkling of logs with water to inhibit fungal colonization (Tarocinski and Zielinski 1982; Liese and Peek 1984), and the application of various fungicides (Cirelli 1978; Tarocinski and Zielinski 1982). However, current environmental concerns and regulations over the use of pesticides such as pentachlorophenol have initiated the need for alternative methods to control blue stain. Biological control or bioprotection of wood from blue stain fungi using bacteria or other fungal species, such as *Trichoderma*, has been proven to be partially successful in the laboratory (Benko 1988, 1989; Seifert et al. 1988; Kreber and Morrell 1993). However, these organisms have never been proven to be effective in field trials.

Some blue stain fungi have been shown to utilize various components of tree pitch including fatty acids, triglycerides, diterpenoid resin acids, and waxes during colonization of the wood substrate (Blanchette et al. 1992; Farrell et al. 1993; Brush et al. 1994). Beneficial reduction of these various pitch components prior to paper manufacturing has resulted in exploitation of these fungi for biological pitch removal by industry. Colorless strains of the naturally occurring blue stain fungus *Ophiostoma piliferum*, lacking melanin pigments within the hyphae, are widely used as biological processing agents in the pulp and paper industry since they remove detrimental pitch from wood but do not cause discoloration (Farrell et al. 1993; Blanchette et al. 1994). This non-pigmented strain of *Ophiostoma piliferum* is available commercially from Clairiant Chemicals Corporation, Charlotte, NC (formally Sandoz Chemicals Corp.). Results from mills where the non-pigmented strain of *Ophiostoma piliferum* is used to treat wood chips prior to pulping have shown that this strain rapidly colonizes freshly cut non-sterilized wood, inhibits wild type blue stain fungi, and significantly reduces various pitch components in the wood (Blanchette et al. 1992; Farrell et al. 1993). This results in better paper qualities, greater porosity of the wood fibers for adsorbing pulping chemicals, reduced paper breakage and down time, and less flaws in the final paper product (Farrell et al. 1993).

Dispersal of blue stain fungi may occur through rain splash, aerosols, or insect transmission (Dowding 1970, 1973; Land et al. 1985). Spores of blue stain fungi adhere to the body of bark beetles or may be located in specialized carrying structures near the front of the insect called mycangia (Dowding 1984; Harrington 1988, 1993). Dispersal of blue stain fungi into the cambial layer of freshly cut wood following bark beetle attack creates an additional avenue of infection for blue stain fungi that must be considered if complete inhibition and control of blue stain fungi is to be obtained.

This paper examines the ability of a selected non-pigmented strain of *Ophiostoma piliferum* and the fungicide Dursban 4E, to completely inhibit colonization by blue stain fungi in freshly cut wood.

Materials and Methods

Studies in the laboratory were carried out using red pine trees (*Pinus resinosa* Aiton) approximately 15 to 20 years old harvested from the Cloquet Forestry Center, Cloquet, MN. Trees were cut into lengths of approximately 30.5 cm and transported back to the laboratory for inoculation. Inoculation of logs in the laboratory was done one to three days after cutting using fungal mats grown on 2% malt extract broth for 14 days. Cultures were grown at room temperature (20 C), under normal lighting conditions. Fungal cultures used in the laboratory study included the non-pigmented strain of *Ophiostoma piliferum* (abbreviated as NPOP for this paper, commercially available as Cartapip-97™), Clairiant Chemicals Corporation, Charlotte, NC and two naturally occurring blue stain fungi *Ophiostoma piliferum* and *Ophiostoma piceae* (Münch) Syd. & P. Syd., obtained from *Pinus* species in North Central U. S. To obtain the average fungal mat dry weight used for inoculation, five extra mats were dried and weighed with average weights as follows: NPOP 0.105 g ± 0.009, *Ophiostoma piliferum* 0.093 g ± 0.008, and *Ophiostoma piceae* 0.086 g ± 0.013. Treatments included inoculation of logs with NPOP 2 and 4 weeks prior to inoculation with the *Ophiostoma* species, inoculation of logs with each species of *Ophiostoma* 2 weeks prior to inoculation with NPOP, and inoculation of each fungal species alone (control). Logs were inoculated by pressing the fungal mats firmly upon the log end. The logs were then placed in a clear plastic bag. Inoculation of blue stain fungi after prior inoculation with NPOP occurred by placing the fungal mat over the existing NPOP mat on the log end. In other treatments the NPOP mat was applied to log ends previously inoculated with the wild type blue stain fungi. After 14 weeks, 4 logs were aseptically split and analyzed by removing wood chips approximately 3 X 3 X 1 mm from the sapwood and placing them on a select media for *Ophiostoma* species (Sabouraud Dextrose Media with 0.40 g/L cycloheximide, 0.05 g/L chloramphenicol, and 0.05 g/L streptomycin sulfate) (Prince 1989). The percent colonization was determined by dividing the number of chips colonized by the total number of wood chips removed to a depth of 10.2 cm from the log end (average 22 chips/log).

Experiments conducted in the field were carried out at the Cloquet Forestry Center with red pine trees approximately 60 to 70 years old. Trees were felled and cut into approximately 61 cm lengths. Three field studies were carried out; two in 1992 (June and August) and one in 1993 (May). Logs were inoculated with a hand pump sprayer 1 to 2 days after cutting. The entire log including sides and cut ends were sprayed to run off followed by piling of the logs in a pyramidal shape. The number of logs per pile was 13 in 1992 and 10 in 1993. Treatments included NPOP, at a concentration of 5.1 X 10^7 spores/ml, and a water control. The total volume of inoculum and water sprayed was 1,420 ml/log pile in 1992 and 1,150 ml/log pile in 1993. Analysis of logs for the 1992 (June) study was done after 4 weeks, while the 1992 (August) and 1993 (May) studies were done after 8 weeks. The 1992 field trial logs were sampled as in the laboratory study aseptically removing wood chips from the split surface and placing them on selective media for isolating *Ophiostoma* species modified slightly from that used by Harrington (1981) (0.01 g/L cycloheximide and 0.01 g/L streptomycin sulfate). The 1993 field trial logs were sampled as in the laboratory study. The number of chips removed per log, the number of logs sampled per treatment, and the maximum depth into the log from which chips were removed were as follows: 1992 (June) study, 12 chips/log, 2 logs/treatment, and maximum depth of 2.5 cm; 1992 (August) study, 12 chips/log, 3 logs/treatment, and maximum depth of 5.2 cm; and 1993 (May) study, 24 chips/log, 6 logs/treatment, and maximum depth of 5.2 cm.

Additional treatments of NPOP were added in the 1992 (June) study to determine if the time of inoculation after cutting had an effect on the growth of NPOP or the naturally occurring blue stain fungi. Treatments consisted of NPOP, at a concentration of 5.1 X 10^7 spores/ml, inoculated 1 to 2 days after cutting, 2 weeks, and 4 weeks after cutting. Analysis of treatments occurred as stated above in the 1992 (June) study. Bark beetle control was also examined in 1993 and 1994 in the field with the use of Dursban 4E, active ingredient chlorpyrifos (Dow Elanco, Indianapolis, Ind.). Red pine trees cut into approximately 61 cm lengths were piled with ten logs per pile. Treatments included Dursban 4E and a water control. Treatment concentrations for Dursban 4E were 17.8 ml per 850 ml water in 1993, and 16.8 ml Dursban 4E per 800 ml water in 1994. Total volume of water for controls was 850 ml and 800 ml for 1993 and 1994 studies, respectively. Analysis of logs included 6 log halves after 8 weeks and 12 whole logs after 12 weeks in the 1993 study; and 3 whole logs after 8 and 12 weeks in the 1994 study. Logs were examined for bark beetle colonization and the percent of cambium colonized by bark beetle galleries was rated according to the Horsfall-Barrett scale (Campbell and Madden 1990).

Results

Observations of logs from the laboratory study revealed 52% of the wood chips yielding NPOP colonies in logs inoculated with NPOP alone (Table 1). Colonization by *Ophiostoma piliferum* and *O. piceae* in control logs was 78 and 44%, respectively when inoculated with these *Ophiostoma* species (Table 1). Visual observations of log ends showed dense mycelial colonization over the entire log end by *O. piliferum, O. piceae*, or NPOP after 10-12 days prior to challenging. Inoculation of logs with NPOP prior to challenging with the wild type *O. piliferum* or *O. piceae*, resulted in only 0-9% of the wood chips yielding *O. piliferum* or *O. piceae* colonies, while NPOP was isolated from 54-77% of the wood chips (Table 1). When wild type *O. piliferum* and *O. piceae* were used to inoculate logs prior to challenging with NPOP, 0-6% of the wood chips were colonized by NPOP and 56-57% of the wood chips were colonized by *O. piliferum* and *O. piceae* (Table 1). A significant difference was observed in all cases between logs inoculated with NPOP before wild type *Ophiostoma* species and logs inoculated with NPOP after wild type *Ophiostoma* species (Table 1).

Table 1. Mean percent of wood chips yielding the non-pigmented strain of *Ophiostoma piliferum* (NPOP), *Ophiostoma piliferum*, or *Ophiostoma piceae* after 14 weeks. Logs were inoculated with NPOP before and after inoculation with *Ophiostoma piliferum* or *O. piceae*.

Inoculation of logs with	*Ophiostoma piliferum*		*Ophiostoma piceae*	
NPOP	NPOP	*O. piliferum*	NPOP	*O. piceae*
2 wk. after	0c[x]	57a	6b	56a
2 wk. before	62ab	0b	54a	0b
4 wk. before	77a	1b	58a	9b
Control-NPOP	52b	--[y]	52a	--[y]
Control-*Ophiostoma* sp	--[z]	78a	--[z]	44a

[x] Different letters within a column are significantly different according to LSD test, P=0.05.

[y] Control - NPOP logs were not challenged with *O. piliferum* or *O. piceae*.

[z] Control - logs inoculated with *O. piliferum* or *O. piceae* were not challenged with NPOP.

Observations of data from the field studies showed logs inoculated with NPOP after 4 and 8 weeks yielded 95-100% colonization of the wood chips (Table 2). Colonization of the sapwood in non-inoculated logs resulted in 27-63% of wood chips yielding wild type blue stain fungi (Table 2). In logs inoculated with NPOP 1-2 days after cutting, only 0-8% of the wood chips were colonized by wild type blue stain fungi (Table 2). A significant difference was observed in all cases between the control, non-inoculated logs and the logs inoculated with NPOP, except for logs in the 1992 (June) study colonized by wild type blue stain fungi (Table 2).

Table 2. Mean percent of wood chips yielding the non-pigmented strain of *Ophiostoma piliferum* (NPOP) or wild type blue stain fungi (WTBSF) from 1992 and 1993 field studies. Logs were inoculated with NPOP 1 - 2 days after cutting.

	1992 (June)[x]		1992 (August)[y]		1993 (May)[y]	
Treatment	NPOP	WTBSF	NPOP	WTBSF	NPOP	WTBSF
Control	0b[z]	62a	11b	58a	0b	28a
Treated	100a	8a	97a	3b	95a	0b

[x] Logs analyzed after 4 weeks.

[y] Logs analyzed after 8 weeks.

[z] Different letters within a column are significantly different according to the LSD test, P=0.10.

Results from additional NPOP treatments used to determine the effect of time of inoculation revealed that maximum inhibition of wild type blue stain fungi occurred when logs were inoculated 1-2 days after cutting. As the time after inoculation increased from 1-2 days to 4 weeks the amount of NPOP colonizing wood chips decreased, and the percent of wild type blue stain fungi colonizing wood chips increased (Table 3).

Table 3. Mean percent of wood chips yielding the non-pigmented strain of *Ophiostoma piliferum* or wild type blue stain fungi 4 weeks after inoculation of log ends with NPOP.

Time of inoculation after cutting	Non-pigmented strain of *O. piliferum*	Wild type blue stain fungi
1 - 2 days	100	8
2 weeks	92	21
4 weeks	42	50

Logs treated with Dursban 4E completely inhibited bark beetle colonization in the 1994 study and at the 8 week sample time in the 1993 study. At the 12 week sample time in the 1993 study, bark beetles colonized 0-3% of the cambium. The percent of cambium colonized by bark beetles in logs treated with Dursban 4E was 0-3%, and 6-50% in untreated logs (Table 4). There was a lot of variation within treatments, but in general untreated logs were more heavily colonized by beetles than treated logs. An increase in bark beetle colonization was observed as time progressed from 8 to 12 weeks in the 1993 study, but no increase in colonization was observed in the 1994 study.

Table 4. Percent of cambium colonized by bark beetles (according to the Horsfall-Barrett scale) in logs treated with Dursban 4E (active ingredient Chlorpyrifos) in 1993 and 1994 field trials.

	1993		1994	
Treatments	8 week	12 week	8 week	12 week
Control	3.7[z]	5.3	3.3	3.3
Treated	0.0	0.1	0.0	0.0

---

[z] Numbers in table represent values from the Horsfall-Barrett scale: 0= 0%, 1= 0-3%, 2= 3-6%, 3= 6-12%, 4= 12-25%, 5= 25-50%, 6= 50-75%, 7= 75-88%, 8= 88-94%, 9= 94-97%, 10= 97-100%, 11= 100%.

Discussion

Results from both the laboratory and field trials demonstrated that NPOP can successfully inhibit wild type blue stain fungi from colonizing freshly cut wood. The non-pigmented strain of *Ophiostoma piliferum* was able to rapidly colonize freshly cut wood and utilize available nutrients on the log end. Rapid colonization of the wood substrate and tolerance of wood extractives is probably a result of its ability to utilize various resinous pitch components as previously reported (Blanchette et al. 1992; Farrell et al. 1993; Brush et al. 1994). In order to inhibit wild type blue stain fungi NPOP must be able to capture available nutrients present on the log end before wild type blue stain fungi are able to compete for the available resources. The ability of NPOP to rapidly colonize and utilize available resources on freshly cut unsterile wood makes it a competitive biological control agent against the naturally occurring pigmented form of blue stain fungi.

Colonization of logs by NPOP in the laboratory resulted in almost complete inhibition of *Ophiostoma piliferum* and *O. piceae*. Colonization of logs by *O. piliferum* and *O. piceae* in the laboratory also resulted in inhibition of NPOP. The ability of NPOP to inhibit wild type *Ophiostoma* species and wild type blue stain fungi to inhibit NPOP, suggests that rapid resource capture and competition for available resources are the driving mechanism behind this form of biological control.

Inhibition of wild type blue stain fungi also occurred in all three field studies. Inoculation of logs with NPOP resulted in successful colonization of the log by NPOP, and a drastic or complete inhibition of wild type blue stain fungi. Unlike previous studies using *Trichoderma* sp., other Deuteromycetes, or bacteria (Seifert et al. 1988; Benko 1989), NPOP was able to inhibit wild type blue stain fungi from colonizing logs under natural field conditions. The repeated field trials reported here suggests NPOP will be a successful biological control agent in field situations tolerant of varied environmental conditions.

Success of NPOP as a biological control agent is also related to the time of inoculation after cutting. Results showed that logs inoculated with NPOP 1-2 days or 2 weeks after cutting still maintained high percentages of NPOP, but allowed blue stain fungi to increase colonization when NPOP was inoculated 2 weeks after cutting. Therefore inhibition of blue stain fungi can be obtained by inoculation within two weeks of cutting, but maximum protection should occur by inoculating logs as soon as possible after cutting.

Control and inhibition of wild type blue stain fungi from freshly cut log ends appears to be successfully accomplished through inoculation of logs with NPOP. However, colonization of logs by bark beetles may result in the introduction of blue stain fungi into the wood from the sides of the log. Bark beetles carry spores of blue stain fungi (Dowding 1984; Harrington 1988, 1993). Penetration of bark beetles into logs allows for dispersal of the blue stain fungi into the outer layers of the sapwood and extensive mycelia development into the wood (Dowding 1984; Harrington 1988, 1993). Successful control of bark beetles was obtained with application of Dursban 4E to log surfaces. Application of Dursban 4E resulted in minimal bark beetle activity and little blue stain entering into the sides of the logs. It is therefore possible to control blue stain fungi by the combined use of NPOP and Dursban 4E. Although Dursban 4E is effective, the increasing regulations and concerns over pesticide use prompt the search for alternative methods to controlling bark beetles such as semio-chemicals, less toxic insecticides, inhibitory oils, or debarking (Nijholt et al. 1981; Werner et al. 1986; Vite' and Baader 1990; Furniss and Carolin 1992).

The non-pigmented strain of *Ophiostoma piliferum* is an effective biological agent of blue stain in wood. In laboratory as well as 3 field trials it has been shown to be highly successful at preventing blue stain in wood. In situations where bark beetle populations warrant additional control measures, an integrated approach using Dursban 4E and NPOP has proven to be very effective for complete inhibition of blue stain.

Literature Cited

Benko, R. 1988. Bacteria as possible organisms for biological control of blue stain. International Research Group on Wood Preservation Document No. IRG/WP/1339.

Benko, R. 1989. Biological control of blue stain on wood with *Pseudomonas cepacia* 6253: laboratory and field test. International Research Group on Wood Preservation Document No. IRG/WP/1380.

Blanchette, R.A., Farrell, R.L., Burnes, T.A., Wendler, P.A., Zimmerman, W., Brush, T.S., and Snyder, R.A. 1992. Biological control of pitch in pulp and paper production by *Ophiostoma piliferum*. Tappi J. 75(12): 102-106.

Blanchette, R.A., Behrendt, C.J., and Farrell, R.L. 1994. Biological protection of sapstain for the forest products industry. *In* Proceedings of the Tappi Biological Sciences Symposium, Minneapolis, MN. Tappi Press, Atlanta, GA. pp. 77-80.

Brush, T.S., Farrell, R.L., and Ho, C. 1994. Biodegradation of wood extractives from southern yellow pine by *Ophiostoma piliferum*. Tappi J. 77: 155-159.

Campbell, C.L., and Madden, L.V. 1990. Introduction to plant disease epidemiology. John Wiley & Sons, New York. pp. 117-118.

Chidester, G.H., Bray, M.W., and Curran, C.E. 1938. Characteristics of sulphite and kraft pulps from blue stained southern pine. Pap. Trade J. 106(14): 43-46.

Cirelli, D.P. 1978. Patterns of pentachlorophenol usage in the United States of America-an overview. *In* Pentachlorophenol; chemistry, pharmacology, and environmental toxicology. *Edited by* K. Ranga Rao. Plenum Press, New York. pp.13-18.

Dowding, P. 1970. colonization of freshly bared pine sapwood surfaces by staining fungi. Trans. Br. Mycol. Soc. 55: 399 -412.

Dowding, P. 1973. Effects of felling time and insecticide treatment on the inter-relationship of fungi and arthropods in pine logs. Oikos 24: 422-429.

Dowding, P. 1984. The evolution of insect-fungus relationships in the primary invasion of forest timber. *In* Invertebrate -microbial interactions. *Edited by* J.M. Anderson, A.D.M. Rayner, and D.W.H. Walton. Cambridge University Press, Cambridge. pp. 133-155.

Farrell, R.L., Blanchette, R.A., Brush, T.S., Hadar, Y., Iverson, S., Krisa, K., Wendler, P.A., and Zimmerman, W. 1993. Cartapip: a biopulping product for control of pitch and resin acid problems in pulp mills. J. Biotechnol. 30: 115-122.

Furniss, R.L., and Carolin, V.M. 1992. Western forest insects. USDA For. Serv. Misc. Publ. No. 1339. pp. 24-33. Harrington, T.C. 1981. Cycloheximide sensitivity as a taxonomic character in *Ceratocystis*. Mycologia, 72: 1123 -1129.

Harrington, T.C. 1988. *Leptographium* species, their distributions, hosts and insect vectors. *In* Leptographium root diseases on conifers. *Edited by* T.C. Harrington and F.W. Cobb Jr. American Phytopathological Society, St. Paul, MN. pp. 1-39.

Harrington, T.C. 1993. Diseases of conifers caused by species of *Ophiostoma* and *Leptographium*. *In* *Ceratocystis* and *Ophiostoma*: taxonomy, ecology, and pathogenicity. *Edited by* M.J. Wingfield, K.A. Seifert, and J.F. Webber. American Phytopathological Society, St. Paul, MN. pp. 161-172.

Kreber, B., and Morrell, J.J. 1993. Ability of selected bacterial and fungal bioprotectants to limit fungal stain in ponderosa pine sapwood. Wood Fiber Sci. 25: 23-24.

Land, C.J., Banhidi, Z.G., and Albertsson, A.-C. 1985. Surface discoloring and blue staining by cold-tolerant filamentous fungi on outdoor softwood in Sweden. Mater. Org. (Berl.) 20: 133-156.

Liese, W., and Peek, R. 1984. Experiences with wet storage of conifer logs. Dan. Skovforen. Tidsskr. 69: 73-91.

Nijholt, W.W., McMullen, L.H., and Safranyik, L. 1981. Pine oil protects living trees from attack by three bark beetle species, *Dendroctonus* spp. (Coleoptera: Scolytidae). Can. Entomol. 113: 337-340.

Prince, H.N. 1989. Diagnostic medical microbiology. *In* Practical handbook of microbiology. *Edited by* W. O'Leary. CRC Press Inc., Boca Raton, FL. p. 595.

Roff, J.W., Cserjesi, A.J., and Swann, G.W. 1980. Prevention of sapstain and mold in packaged lumber. Forintek Canada Technical Report No. 14R, Vancouver, B.C.

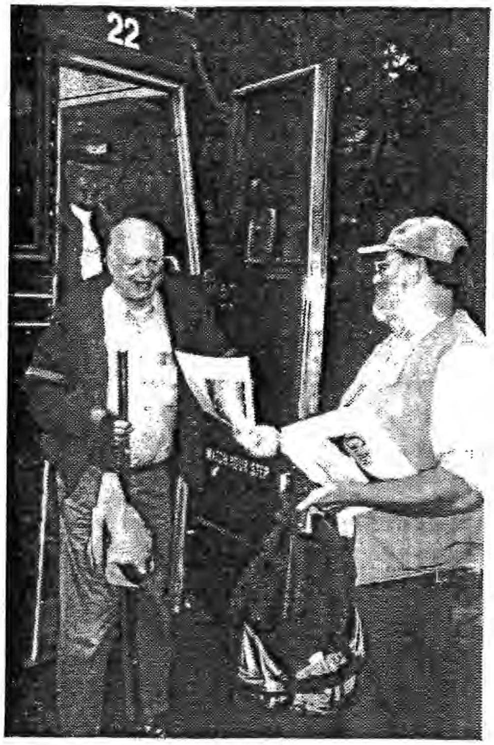
Seifert, K.A. 1993. Sapstain of commercial lumber by species of *Ophiostoma* and *Ceratocystis*. *In* *Ceratocystis* and *Ophiostoma*: taxonomy, ecology, and pathogenicity. *Edited by* M.J. Wingfield, K.A. Seifert, and J.E. Webber. American Phytopathological Society, St. Paul, MN. pp. 141-151.

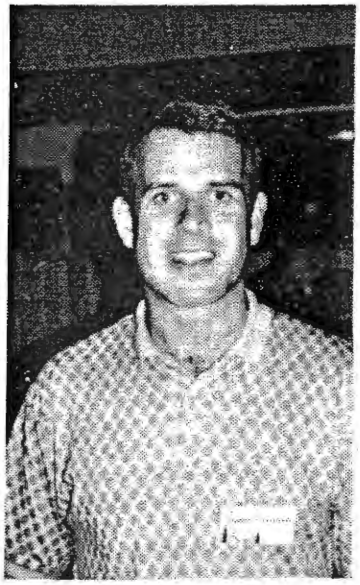
Seifert, K.A., Breuil, C., Rossignol, L., Best, M., and Saddler, J.N. 1988. Screening for microorganisms with the potential for biological control of sapstain on unseasoned lumber. Mater. Org. 23: 81-95.

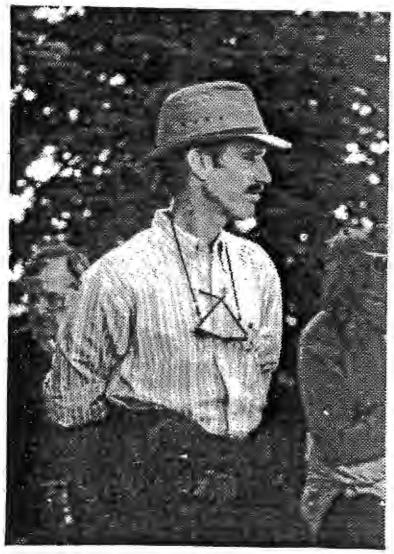
Tarocinski, I.E., and Zielinski, M.H. 1982. Protection of pine sawtimber and sawn timber against blue stain in Poland. International Research Group on Wood Preservation Document No. IRG/WP/3193.

Vite', J.P., and Baader, E. 1990. Present and future use of semiochemicals in pest management of bark beetles. J. Chem. Ecol. 16: 3031-3041.

Werner, R.A., Holsten, E.H., and Hastings, F.L. 1986. Evaluation of pine oil for protecting white spruce from spruce beetle (Coleoptera: Scolytidae) attack. J. Entomol. Soc. B.C. 83: 3-5.







BIOLOGY AND POPULATION GENETICS OF HETEROBASIDION ANNOSUM IN CALIFORNIA FORESTS

Matteo Garbelotto, Alice Ratcliff, Tina Popenuck, Garey Slaughter,
Fields Cobb, William Otrosina, and Thomas Bruns
Department of Environmental Science Policy and Management
University of California
Berkeley, CA 94720

Heterobasidion annosum is a tree root pathogen of worldwide distribution and of significant economic importance in coniferous forests of the boreal hemisphere. Many aspects of the biology of this pathogen have been unraveled in previous research: it is now known that *H. annosum* is a complex species comprising at least three biological species (intersterility groups or ISGs) which display a marked host preference (1, 10). It has also been shown that in pine plantations and natural stands, freshly cut stumps act as major infection courts for airborne inoculum (basidiospores), and that the fungus can then "vegetatively" spread from tree to tree through root grafts and root contacts (9, 14). In infested stands, tree mortality appears in enlarging clusters, called mortality centers. Despite the wealth of previous research, there is insufficient information on the biology and the ecology of this pathogen in natural forest of North America.

The focus of our research at the University of California at Berkeley, has been to further our knowledge of the biology and the ecology of *H. annosum* in California forests. Three main projects are currently ongoing: a) Determine the distribution of *H. annosum* ISGs in California forests, test the hypothesis of ISG host specificity, and investigate the possibility of gene flow between ISGs. b) Determine the genetic structure of *H. annosum* populations in mixed conifer mortality centers. c) Study the dynamics of expansion of *H. annosum* mortality centers in true fir in mixed conifer stands.

I will present the approach used for each project separately, and I will conclude with a short general discussion in which I will try to paste the results together in order to provide a coherent picture of the dynamics of infection, establishment, and spread of this pathogen in mixed conifer forests of California.

1 - Intersterility Groups of *Heterobasidion Annosum* in California a Reappraisal of Host Specificity, Hybridization and Intergroup Gene Flow.

It is well established that different ISGs of *H. annosum* display a marked host preference. In North America the P ISG is found generally on pines, incense cedars, and junipers, while the S ISG is associated mostly with true and Douglas firs, hemlocks, spruces, and sequoias. The pathologies on the respective hosts tend to differ broadly, so that in pine the pathogen is mostly a cambium killer, while in first and spruces it causes extensive decay in the host heartwood and sapwood (12). Greenhouse inoculation experiments and field surveys in California have considerably strengthened the concept of host specialization (11, 18). Interestingly, though, greenhouse inoculation tests also indicated the potential pathogenicity of S isolates on pine trees.

In California both ISGs can be present in the same geographic area and even in the same stand: although hybridization between ISGs has been reported to occur at relatively high frequencies in vitro (2, 17), it has never been observed in the field. Hybridization between ISGs may be an important mechanism for the creation of new genotypes with modified virulence characteristics.

Until recently very extensive field surveys had been hindered by the complex and lengthy procedures needed to differentiate ISGs, all of them requiring the availability of live fungal cultures. The first objective of our study was to develop a new technique to differentiate ISGs, that could be implemented not only on live isolates but also on herbarium specimens and on dry basidiocarps.

The second objective was to determine the distribution and host association of the S and P ISGs of H. annosum in California.

The third objective was to preliminarily investigate on the possibility of gene flow and hybridization between the two ISGs.

A total of 526 samples were analyzed from 60 sites in 8 national forests. Sites were in the California Cascades, Sierra Nevada, and San Bernardino mountain ranges. In each national forest several mortality centers were intensively sampled. This sampling strategy had three main advantages: first, it covered most of the geographic distribution of *H. annosum* from the Oregon border to southern California; second, it allowed for sampling both in the more mesic "West side" sites and in the drier "East side" sites; third, the local intensive sampling allowed for the detection of rare individuals present at low frequencies in each population.

We developed a new molecular technique based on the polymerase chain reaction (PCR) that proved highly reliable to determine the ISG of the isolates, even from dry basidiocarps. The technique, called Taxon Specific Competitive Priming PCR (TSCP-PCR), is based on the concomitant use of PCR primers specific for either the S or the P ISG. When such primers are used together, only the appropriate primer combination will effectively produce an amplification product. Primer combinations for the S and the P ISG produce amplified DNA fragments of different size: size of the fragment obtained is therefore diagnostic of the ISG of the isolate. For a subset of 40 representative samples, results obtained by TSCP-PCR were confirmed by using other previously developed molecular techniques such as isozyme analysis and RFLPs of the PCR amplified ITS (internal transcribed spacer) region (4, 11).

Polymorphisms in the large mitochondrial ribosomal gene were detected by PCR analysis, and could be used to differentiate ISGs and to look at mitochondrial gene flow between ISGs.

Results indicated that all samples from true firs and sequoias belonged to the S ISG. This was true of all isolates, from stumps and trees, even in areas in which P ISG isolates were present and causing mortality in pine trees. On the other hand in one mortality center (M5) in the Modoc National Forest, pines and junipers were infected by P, S, and even hybrid SP isolates. This finding was quite surprising because S isolates had never been recorded before on standing trees. Furthermore this also is the first time that hybrid isolates are found in natural populations of *H. annosum*. The breakdown of isolates from standing trees in the M5 infection center was 35% S, 55% P, and 10% SP hybrid. It was also noted that S isolates were retrieved from trees in all health conditions, from apparently healthy to symptomatic and dead: it is apparent that in M5 the S ISG was actively pathogenic.

The retrieval of hybrid isolates, indicates that hybridization in nature, albeit rare, is possible. All the hybrid isolates belonged to the same genet: the genet had spread to several trees, and therefore was apparently virulent and stable. Isozyme analysis confirmed that the TSCP-determined hybrids were in fact hybrids, and in many enzymatic systems, hybrid isolates were characterized by new hybrid heteromeric bands. The presence of a successful hybrid genet also suggests that gene flow between ISGs may be possible.

The mitochondrial analysis suggested again that gene flow between ISGs may be occurring. In *H. annosum* different types of mitochondrial introns in the PCR amplified ML5-ML6 region are associated with different ISGs (7). Type of intron can therefore be used ad a quasidiagnostic feature of ISGs. The association with different introns was clear-cut in areas where only one ISG is present. In areas where both ISGs were present, 7% of S isolates had the P-specific fragment, suggesting that mitochondrial gene flow may be occurring between ISGs in these areas.

Why are S isolates found on pines and junipers in M5? Three factors should be taken into account: differences in the tree host population (M5 trees are more susceptible), differences in the pathogen population (M5 S isolates are more virulent), or the ecological conditions are conducive to infections by a normally hypovirulent pathogen (e.g. harsher, dry "East side" site). The final outcome is probably due to a combination of all three factors, nevertheless, we would like to suggest that hybridization events may be conducive to gene flow and to the arising of genotypes with new recombinant virulence characters. It is also interesting to observe that our results match results obtained in greenhouse inoculation tests, in which S isolates had a pathogenic effect on pines. We conclude that pine trees may be infected by S isolates, but the conditions that may determine this event warrant further research.

2 - The Genetic Structure of *Heterobasidion annosum* in White Fir Mortality Centers.

The discovery that *H. annosum* is a highly variable complex species, puts forward questions on the general validity of biological models and interpretations developed for a particular population. In other words, modes of infection and spread of the S ISG and the P ISG may differ substantially. Moreover, even within a single ISG, the biology of *H. annosum* in one host may differ from that in another host, or even in the same host, there may be geographic variations.

The model of stump infection and of secondary root-to-root spread was developed in pine plantations (14), and seems to hold true, at least partially, in spruce mortality centers in Scandinavia (16). We wanted to analyze the genetic structure of *H. annosum* in white fir mortality centers, in order to better understand the modes of establishment of this pathogen in a different ecosystem. We were also interested in correlating the genetic structure of the pathogen with previous history of the study sites.

We selected 15 mortality centers in four national forests. All sites were in secondary mixed conifer stands that had been entered for partial logging or salvage operations in a time span ranging from 100 to 10 years previous to our sampling. Size of the centers ranged from 0.1 to 0.5 ha, and included 15 to about 100 trees, depending on the site. All trees in the site were felled, the root systems were excavated and cross sections of the bole (or stump) as well as of the roots (3 to 12 per tree) were collected, and incubated at room temperature in sealed plastic bags for seven to ten days. The imperfect stage of *H. annosum* was then isolated and grown on MEA. Cultures of *H. annosum* were also obtained from context isolations from basidiocarp found in the study sites. Number of isolates obtained in each site ranged from 6 to 80.

Somatic compatibility (sc) tests were used to distinguish genotypes and outline genet distribution in each mortality centers (16). In two study sites random amplified polymorphic DNA (RAPD) markers were generated and used to fingerprint genotypes, and to determine the ISG of the isolates (6). In these two sites, isolates were de-dikaryotized and mating allele distribution and frequency were studied.

Nuclear asset (homokaryotic vs. heterokaryotic) of the isolates was also determined through an array of tests including: a) presence or absence of clamps; b) presence or absence of pigment in culture; c) presence or absence of a typical heterokaryon-heterokaryon somatic interaction; d) ability of presumed homokaryons to heterokaryotized when paired with homokaryotic tester strains.

Overall sc tests and RAPD markers provided us with similar results. All mortality centers were caused by a number of different genotypes. All isolates belonged to the S ISG. Genotype size and distribution indicated that primary infection was predominant, but that secondary spread was present as well. "Vegetative" spread did not appear to be extremely efficient, but it occurred frequently in overstocked or dense stands. The larger genet retrieved had grown on trees 18 m apart. Several trees had been colonized by the same genet in between the two outer hosts. In general, genet distribution was contiguous and not fragmented. This finding suggests that secondary dispersal due to insect vectoring is not efficient or limited to rather short distances.

Stumps did not appear to be the major source of infection: most infections occurred on standing trees. Also multiple infections on the same host by different genotypes were frequently seen. Results also indicated that primary root infection may be possible. Mating allele analysis showed a high number of mating alleles present in a single study area: same alleles were rarely encountered. Only exceptions included different genotypes originated by the same homokaryon in the same tree, or in contiguous trees.

A high number of homokaryons was retrieved in almost all study sites. This finding suggested that heterokaryosis may not be a necessary requirement for pathogenicity in *H. annosum*. Presence of homokaryons could be justified in two ways: first, by the high incidence of successful single basidiospore infections that do not get in contact with other infections; second, by frequent events of dedikaryotization (13). It should also be noted that *H. annosum* heterokaryons are generally composed of proper heterokaryotic mycelium intermingled with the two parental homokaryotic hyphae (8). This situation may allow homokaryons to easily disassociate from each other and from the heterokaryotic mycelium.

3 - Secondary Spread Dynamics of *Heterobasidion annosum* in White Fir Mortality Centers. Impact of Tree Root Architecture and Season on Secondary Growth of Homokaryons and Heterokaryons.

Our results have indicated that "vegetative" spread of *H. annosum* is possible but relatively infrequent, and that most mortality centers are caused by a number of different genets. Results also suggested that homokaryons may play a significant role in infested forest stands. Field observations by us and others (15) also indicate that the expansion of mortality centers is not indefinite, but it invariably comes to an end.

In order to provide some insights on some aspects of the secondary spread dynamics of *H. annosum*, we designed a field inoculation experiment to assess relative virulence of homokaryons, rates of secondary growth of the pathogen in the roots, and impact of root size and season on growth rates of *H. annosum*.

The experiment site was chosen in a seemingly healthy mature mixed conifer stand with abundant presence of white fir. A total of 50 fir trees was selected and four roots were inoculated on each tree. Four (4) homokaryons and 4 heterokaryons were grown for 12 weeks on wood dowels, and individually inoculated on each root, according to a randomized block design (number of blocks = 8). On each tree a sterile wood dowel was inoculated on one of the four roots to serve as a control. Roots were partially excavated, the outer surfaced was sterilized, a bark plug was extracted, and a hole was drilled at distances from the root collar ranging between 0.75 and 1 m. The inoculum dowels were placed in the hole, the bark plug was put back in place, and the whole inoculation was sealed with grafting wax.

Sampling required total excavation of the roots and their excision from the tree at the root collar and at about 1.5 to 2 m from the root collar. Growth had occurred both in the distal direction (from inoculation point away from the tree), and in the proximal direction (from the inoculation point towards the tree). In order to measure fungal growth appropriately, each root was sectioned in 5 cm thick disks. All disks were incubated in separate plastic bags for 7-10 days. Presence of *H. annosum* was recorded for each disk and isolations from each root were made. The cultures obtained were matched with the original inoculated strain through somatic compatibility tests.

Inoculations were done in June 1993: two blocks were sampled in October 1993, and the remaining six blocks were sampled in June 1994. 83% of the total number of roots inoculated were successfully infected and colonized by *H. annosum*. Over 90% of the isolates retrieved matched the original isolates used in the inoculation. In all cases *H. annosum* caused a pathological staining of the root xylem that was absent in the controls.

Growth averaged 30 cm in the distal direction and 45 cm in the proximal direction. No significant differences were found among isolates, or between homokaryons and heterokaryons. Growth after 4 months did not differ significantly from growth after 12 months, indicating that most of the fungal growth had occurred during the vegetative season. A significant difference was found when growth in roots of different size was compared. Roots with a diameter less than 9 cm sustained a significantly decreased growth rate.

Fungal growth in the proximal direction was significantly larger than growth in the distal direction. This result indicates that it may be easier for the pathogen to move towards the host than away from it. Expansion of *H. annosum* in true fir centers then, may proceed in waves, accelerating whenever new roots are infected, and slowing down when the bole of the host is reached.

Conclusion

The information gathered in the last few years indicates that *H. annosum* in true fir mortality centers may behave quite differently that in pine centers. First of all, only S ISG isolates are found on true firs. Greenhouse inoculation tests have also confirmed that there is a strong inhibition of P isolates on true firs (5). On the other hand both S and P ISG isolates can be found in pine mortality centers. P isolates are certainly highly pathogenic in such centers, but S isolates may be pathogenic as well. Furthermore, S isolates in pine centers act as very active wood decayers, being predominant in stumps of all species. Pine mortality centers offer host species that can be colonized by both ISGs: such centers then can be viewed as "hybrid zones" or ecotones, in which both populations are intimately in contact with each other. It is in one of these centers that a virulent and stable hybrid isolate was found, and it is in these areas that possible gene flow between groups may be occurring.

Our genet distribution data strongly indicates that infections are frequent on living true firs. Although the modes of access in standing trees need to be clarified, it is very likely that wounds may act as viable infection courts. The presence of homokaryons also correlates with the hypothesis that wound infections may be frequent. Other wound pathogens, e.g. *Echinodontium tinctorium*, have populations composed of both homokaryons and heterokaryons. Wounds in fact can be much more selective (and smaller in size) than stumps; thus, facilitating single spore infections.

It has been reported that *H. annosum* isolates tend to dedikaryotize, and that heterokaryosis in this organism may be energetically costly (13). Our results provide evidence that heterokaryosis is not required for virulence, and that homokaryons can be fully pathogenic.

Secondary growth in wood can certainly occur. The values obtained in the inoculation experiment matched those that we had calculated for genet expansion in the dissected mortality centers. Nevertheless, some limiting factors were detected, namely size of root, direction of spread, and length of the vegetative season. Efficient tree to tree spread may occur only if roots in contact are quite large. If distance among trees is large, expansion rate may be quite slow due not only to root size, but also to reduced fungal growth in the distal direction. Length of the vegetative season may also have an impact, with fungal growth hindered by short summers in areas at high altitude or low latitude.

In conclusion, our findings give us valuable insights on the modes of action of *H. annosum* in California forests. These insights can be used to assess the validity of ongoing forestry practices, to create new directives aimed at controlling the disease, to enhance the validity of root rot spread models, and to generate further research questions.

References

Capretti, P., Korhonen, K., Mugnai, L., and Romagnoli, C. 1990. An intersterility group of *Heterobasidion annosum* specialized to Abies alba. Eur. J. For. Path. 20:231-240.

Chase, T. E., Otrosina, W. J., and Cobb, F. W., Jr. 1989. Interfertility of S and P groups of *Heterobasidion annosum* in North America. Phytopathology 79:1164.

Chase, T. E., and Ullrich, R. C. 1990. Five genes determining intersterility in *Heterobasidion annosum.* Mycologia 82:73-81.

Chase, T. E., Otrosina, W. J., Spieth, P. T., and Cobb, F. W., Jr. 1991. Use of PCR to distinguish biological species within the *Heterobasidion annosum* complex. Phytopathology 81:1190.

Cobb, F. W., Jr., Chase, T. E., Otrosina, W. J., Ratcliff, A., and Popenuck, T. 1989. Comparative virulence of *Heterobasidion annosum* isolates. Phytopathology 79:1164.

Garbelotto, M., Bruns, T. D., Cobb, F. W., Jr., and Otrosina, W. J. 1993. Differentiation of intersterility groups and geographic provenances among isolates of *Heterobasidion annosum* detected by random amplified polymorphic DNA assays. Can. J. Bot. 71:565-569.

Garbelotto, M., Ratcliff, A., Bruns, T. D., Cobb, F. W., Jr., and Otrosina, W. J. 1995. Intersterility Groups of *Heterobasidion annosum* in California: a Reappraisal of Host Specificity, Hybridization, and Intergroup Gene Flow (Abstract). Phytopathology In Press.

Hansen, E. M., Stenlid, J., and Johansson, M. 1993. Somatic incompatibility and nuclear reassortment in *Heterobasidion annosum.* Mycol. Res. 97:1223-1228.

Hodges, C. S. 1969. Modes of infection and spread of *Fomes annosus*. Ann. Rev. Phytopathology 7:247-266.

Korhonen, K. 1978. Intersterility groups of *Heterobasidion annosum.* Commun. Inst. For. Fenn. 94:1-25.

Otrosina, W. J., Chase, T. E., and Cobb, F. W., Jr., 1992. Allozyme differentiation of intersterility groups of *Heterobasidion annosum* isolated from conifers in the western United States. Phytopathology 82:540-545.

Otrosina, W. J., and Cobb, F. W., Jr. 1989. Biology, ecology and epidemiology of *Heterobasidion annosum*. Pages 26-33 in Proc. Symposium on Research and Management of Annosus Root Disease (Heterobasidion annosum) in western North America.

Ramsdale, M., and Rayner, A. D. M. 1994. Distribution Patterns of Number of Nuclei in Conidia from Heterokaryons of *Heterobasidion annosum* (Fr) Bref and their Interpretation in Terms of Genomic Conflict. New Phytologist V128:123-134.

Rishbeth, J. 1951. Observations on the biology of *Fomes annosus*, with particular reference to East Anglian pine plantations. III. Natural and experimental infection of pines, and some factors affecting severity of the disease. Annals of Botany 15:221-247.

Slaughter, G. W., Parmeter, J. R., Jr., and Kliejunas, J. T. 1991. Survival of sapling and pole-sized conifers near true fir stumps with annosus root disease in northern California. West. J. Appl. For. 6:102-105.

Stenlid, J. 1985. Population structure of *Heterobasidion annosum* as determined by somatic incompatibility, sexual incompatibility, and isoenzyme patterns. Can. J. Bot. 63:2268-2273.

Stenlid, J., and Karlsson, J. 1991. Partial intersterility in *Heterobasidion annosum*. Mycologia 95:1153-1159.

Worrall, J. J., Parmeter, J. R., Jr., and Cobb, F. W., Jr. 1983. Host specialization of *Heterobasidion annosum*. Phytopathology 73:304-307.

PANEL
DWARF MISTLETOE TAXONOMY

Robert L. Mathiasen, Moderator

EXOTIC SPECIES OF *ARCEUTHOBIUM*, INCLUDING *A. HAWKSWORTHII* - A NEW SPECIES FROM BELIZE

Del Wiens
Department of Biology
University of Utah
Salt Lake City, UT 85112

Today I should like to discuss some of the history of the systematics of dwarf mistletoes over the last 30 years during which the extent of biodiversity in this interesting genus was essentially defined. It is unusual that in this day and age you can find a group, especially in the Northern Hemisphere, where so little was known about the extent of systematic diversity. For example, while a number of the North American species had been named before 1960, there had been virtually no studies of the Latin American species and nothing in the way of subgeneric or sectional groups had ever been designated in *Arceuthobium*. As most of you are aware, the object of systematics is, first, to determine the evolutionarily distinct entities, and secondly, to define the relationships between them, preferably in the light of paleogeographic factors. These were always our major objectives as Frank Hawksworth and I proceeded with our study of this fascinating and always surprising group of organisms. Frank, of course, also continued his applied studies, and I pursued various other taxonomic and evolutionary studies. We brought together a good mix of backgrounds and interests. But it was Frank who always kept the focus on dwarf mistletoes.

My collaboration with Frank began in 1960 when I accepted a position at the University of Colorado, Boulder, and Frank had settled in at Fort Collins. I visited him one afternoon because I had seen an article of Frank's on an unusual host (fernbush) of *Phoradendron juniperinum* in the Grand Canyon. This was of interest because I had just completed my thesis on a systematic study of a portion of the large genus *Phoradendron*. The following week Frank came by and asked if I would like to cooperate on a chromosome study of the Rocky Mountain species of dwarf mistletoes (chromosome work was all the rage in those days). I considered this and finally told Frank that if we really wanted to do a chromosome and systematic study of dwarf mistletoes that we should do it properly. Too much of systematics is done in tiny pieces, so I suggested that we study the whole genus so we could get the "big picture." He agreed, and the rest is history. In fact, the "big picture" became something of a private joke between us whenever we discussed objectives.

In 1963 we decided we had to see what was in Mexico. At that time there was only one species known from Mexico and Central America and it was known as *Arceuthobium vaginatum*. During our first day of collecting dwarf mistletoes in Mexico, on the road between Durango and Mazatlan, we discovered five new species and rediscovered another species that had been described by Humboldt's expedition around 1802 but had not been collected since. That March day in 1963 was a red letter event in the history of dwarf mistletoe systematics. I would also like to mention that Roger Peterson, here with us today, was with Frank and me on that trip, and shared this unique experience with us. We have now described 25 taxa from Mexico and Central America (including subspecies).

Early on I had become interested in tropical mistletoes generally. In 1968 I was working on the mistletoes of Sri Lanka (Ceylon). Frank and I decided it would be a good idea to have a look at *Arceuthobium minutissimum* while I was in this part of the world. It is a species from the western Himalayas. So my wife and I went to Kashmir following the Ceylon project and found this species. *A. minutissimum* is a virulent parasite on *Pinus griffithii* in that region, and it forms immense brooms, but the plant itself is extremely small. In fact, Hooker who described the species, considered it to be perhaps the smallest dicotyledon known. This is probably not correct, but it is certainly among the smallest. There is a species of *Viscum* from southern Africa (*V. minimum*) that grows on Euphorbias and the only part of the mistletoe that emerges from the host is a shoot that is about 2 or 3 mm long which produces a berry that is by volume much larger. So there are a number of exceedingly small mistletoes. *Arceuthobium minutissimum* is also interesting because the shoots emerge from the base of the leaf fascicles. There were also some reports from older literature that *A. minutissimum* might be monoecious, but our observations of this species indicated that it was dioecious like all dwarf mistletoes.

During this same time period we visited Nepal where we thought we might find *Arceuthobium chinense*, but did not. To my knowledge it has still not been found there. Nepal is in the central Himalayas and we now know of some other species from that general area, but none from Nepal.

Arceuthobium oxycedri is a another unusual species. One of the most intriguing aspects of this dwarf mistletoe was its extensive distribution. It supposedly occurred from the Azore Islands, throughout both sides of the Mediterranean, through the Middle East to Pakistan, and was also reported from the mountains of East Africa. I was working in Africa in the early 1970's and felt we should study *A. oxycedri* there. I was able to examine populations in the Aberdere Mountains, the Kenya Highlands and around Mt. Kenya itself. These populations were similar to *A. oxycedri*, but also exhibited differences. We also knew there was a report of a dwarf mistletoe from Ethiopia and we expected these would be the same species as in Kenya. I took a trip to Ethiopia and found the dwarf mistletoe there was indeed the same taxon. There was already a name given to the dwarf mistletoe in Ethiopia, *Arceuthobium juniperi-procerae*. This taxon was described by an Italian taxonomist, Chiovenda, in 1911. Chiovenda had the habit of naming just about everything he found. It so happened that in this case he was correct. It is unlikely that we will ever know the original distribution of this dwarf mistletoe in Ethiopia because the country has been so heavily deforested. It would also be useful to look for this dwarf mistletoe across the Red Sea in Yemen, but there has not been an opportunity to do so.

Perhaps the most interesting of all of the dwarf mistletoes occurs on several islands of the Azores. Returning from Africa in 1973 I made it a point to stop and look at this dwarf mistletoe. It parasitizes a very odd juniper, *Juniperus brevifolia*, which is quite distinct from *Juniperus oxycedrus*. The dwarf mistletoe was clearly a new species and is one of the most distinct and unusual in the genus. For example, the habitat is unusual because the Azores dwarf mistletoe is the only *Arceuthobium* that occurs on oceanic islands, the haustorial connection is more reminiscent of *Phoradendron*, e.g. this dwarf mistletoe kills the distal portion of the infected branch. I suspect *Arceuthobium azoricum* will be one of the most primitive and unique species of dwarf mistletoes once Dan Nickrent has had an opportunity to examine it from a molecular perspective. Perhaps it is a relict from the Eocene Period when Europe and North America were in the process of separating.

The most recently discovered species of dwarf mistletoe is *Arceuthobium hawksworthii*. This dwarf mistletoe is from the highlands of Belize and Frank and I had been aware of its existence since the mid 1960's. A forester by the name of Stiles at Oxford University had sent me some specimens of this dwarf mistletoe which I then sent to Frank. We thought it was perhaps a species also occurring in Guatemala which we had named *A. aureum*; however, it had some obvious differences. After Frank's death Terry Shaw and

I thought that it would be nice to have a dwarf mistletoe named after Frank and I suggested this Belizean dwarf mistletoe was the best possibility for a new species. So Terry and I decided to go to Belize and determine its status. It proved to be distinct from *A. aureum* in many features (Table 1). *Arceuthobium hawksworthii* is darker and much larger than *A. aureum*. It causes extensive brooming on its host and appears to have multiple flowering and seed dispersal periods. In addition, *A. hawksworthii* demonstrates striking sexual dimorphism, which *A. aureum* does not. In fact, there are few similarities between *A. hawksworthii* and *A. aureum*. Although both species belong to the *A. vaginatum* group, their distinctness is supported by Dan Nickrent's molecular studies.

Arceuthobium hawksworthii is presently known only from the Mountain Pine Ridge region of Cayo District, Belize. However, there is a highland area in Guatemala not too distant from the Mountain Pine Ridge region where the host, *Pinus caribaea* var. *hondurensis*, also occurs. It would be worth examining the host populations in this area to determine if *Arceuthobium hawksworthii* occurs in Guatemala. It may also parasitize *Pinus oocarpa* at higher elevations in the Pine Mountain Ridge region of Belize. *Arceuthobium hawksworthii* occurs in a beautiful area of tropical America and I think naming this dwarf mistletoe after Frank is an appropriate tribute to Frank in recognition of his outstanding contribution toward understanding the biology of dwarf mistletoes.

Today, one of the remaining problems in dwarf mistletoe systematics, in addition to determining their molecular relationships which Dan Nickrent is pursuing, is the need for examining the species that occur in the eastern Himalayas of China. This would include southeastern Tibet and Hunnan, Yunnan, and Sichuan provinces. There have already been a few new species discovered in these areas and this may represent an area where dwarf mistletoes have undergone significant speciation, but not on the same scale of that in Mexico which is also the center of pine diversity.

In terms of controlling dwarf mistletoes, or any other species for that matter, I believe the only effective ones are biological in nature. If we hope to find any insects or pathogens that might be useful as biological controls of *Arceuthobium* in North America we need to look in the eastern Himalayas where climatic regimes are similar to those of North America. It is not likely that potential biological controls will be found in the tropics of Mexico or Central America, since the tropics will probably not have predators or pathogens of dwarf mistletoes that are also cold hardy. I would also like to stress that in terms of management of dwarf mistletoes, what really is important is a thorough knowledge of the community and ecological dynamics of these parasitic flowering plants.

In closing, I would like to thank WIFDWC for inviting me to speak today. I have enjoyed meeting many of Frank's colleagues in forest pathology, some of whom I have met before, and many others that I have met for the first time. Thank you.

Table 1. Characteristics distinguishing between *Arceuthobium hawksworthii* and *A. aureum subsp. aureum.*

Trait	*A. hawksworthii*	*A. aureum subsp. aureum*
Distribution	Highlands of west central Belize	Highlands of central Guatemala
Hosts	*Pinus caribaea* var. *hondurensis* *P. oocarpa* var. *ochoterenai*(?)	*P. pseudostrobis* *P. montezumae*
Witches' Broom Formation	Extensive	Absent
Growth form	Shoots relatively tall, c. 15-25 cm, few shoots arise from an infection; inflorescences longer and more open (see below)	Shoots relatively short, 7-15 cm, numerous shoots arise from an infection; inflorescences short, densely clustered (see below)
Sexual dimorphism	Extreme	Moderate
Shoot color	Pistillate plants pale green, the inflorescences dark brown-gray; staminate plants becoming pale yellow with age	Both pistillate and staminate plants pale yellow - yellow-brown
Inflorescence	Ca. 1.5-2.5 cm long, bearing 6-9 fertile nodes (plus an apical flower); pistillate inflorescences somewhat darkened; staminate inflorescences same color as shoots	Ca. 1.0-1.3 cm long, bearing 2-4 fertile nodes (plus an apical flower); pistillate a staminate inflorescences both pale yellow
Anthesis	Periodic: Feb. (possibly also June and Oct)	Continuous (at least during dry season)
Staminate flower:		
(1) Color of perianth segments	Vivid dark red on inside, same color as shoots on outside.	Same color as shoots on both surfaces
(2) Mature buds	Elongate, flattened, 3 mm long	Rounded, 1.5 mm long
(3) Diameter	3 mm	2 mm
(4) Perianth lobe width	1.5 mm	1.0 mm
(5) Anther diameter	ca. 0.75 mm	ca. 0.5 mm
(6) Central cushion (nectary)	ca. 1.0 mm	ca. 0.5 mm
Pistillate flower:		
(1) Stigma	Not exceeding length of perianth lobes at any stage of development	Exceeding perianth lobes by ca. 0.3 mm, anthesis, sometimes included on mature fruit
(2) Color	Stigma, perianth lobes, and subtending bracts dark brown-gray	All flower parts and bracts same color as shoots
Fruit:		
(1) Equatorial line	Approximately medial	Approximately one third the distance below apex
(2) Surface	Not glaucous (?)	Glaucous
(3) Shape & size	Narrowly elliptic (4.0 x 1.5 mm)	Broadly elliptic (3.5 x 2.5 mm)
Pedicel length (at dispersal)	2 mm	1 mm
Dispersal period	Periodic: May-June (possibly also Sept and Dec.)	Continuous (during the dry season)

CHANGES IN TAXONOMY, HOSTS, AND DISTRIBUTION OF *ARCEUTHOBIUM*

Brian W. Geils
USDA Forest Service
Rocky Mountain Forest and Range Experiment Station
240 W. Prospect Street, Fort Collins, CO 80526

In 1972, the Agriculture Handbook, Biology and Classification of Dwarf Mistletoes (*Arceuthobium*), by Hawksworth and Wiens provided a taxonomic review of the genus. In this monograph, Hawksworth and Wiens recognized 28 species plus 2 *formae speciales* (for *Arceuthobium abietinum*), 2 sub-species for *A. gillii*, and 3 subspecies for *A. vaginatum*. Subsequent study lead these authors to revise their concept of the genus and publish a new monograph in 1995, Dwarf Mistletoes: Biology, Pathology, and Systematics. This new Agriculture Handbook updated the systematics of *Arceuthobium* using new data on morphology, physiology, phenology, isozyme analysis, and DNA sequences. Forty-two species were recognized; 2 subspecies were acknowledged for each of 4 species (*A. aureum, A. globosum, A. tsugense*, and *A. vaginatum*). Information on life cycle, reproduction, evolution, biogeography, and host relations was updated from the previous monograph and new material presented on ecology, biotic associates, physiology, anatomy, pathology, and control. In this review, I list the new taxa (Table 1), identify their principal hosts and distribution (Table 2), specify additional principal hosts and range extensions of formerly recognized taxa (Table 3), and contrast the classification system of the 1972 monograph (updated to include new species) with the classification system proposed in the 1995 monograph by Nickrent (Table 4).

Seventeen *Arceuthobium* taxa are included by Hawksworth and Wiens (1995) that had not been recognized in the 1972 monograph (Table 1). Three species are new discoveries; 2 species are elevated from subspecies; 9 species and 3 subspecies are segregated from previously described species. The newly discovered species are: *A. pendens* from pinyons of central Mexico, *A. yecorense* on hard pines of northern Mexico, and *A. tibetense* on firs of southwest China (Table 2). The remaining 14 taxa (Table 1) are recognized as species or subspecies based on re-examination of herbarium material, new information on life history, and application of molecular analysis techniques. Large differences between the populations of "*durangense*" and typical *vaginatum* and between "*nigrum*" and typical *gillii* are sufficient to justify specific status for these mistletoes. Equally large differences in other populations are sufficient to recognize the species: *A. aureum, A. azoricum, A. hawksworthii, A. juniperi-procera, A. littorum, A. monticola, A. oaxacanum, A. sichuanense*, and *A. siskiyouense*. Lesser but significant differences are observed in *A. aureum* subsp. *petersonii, A. globosum* subsp. *grandicaule*, and *A. tsugense* subsp. *mertensianae*.

Records of new host associations and distributions are also reported in Hawksworth and Wiens 1995 (summarized in Table 3). Differences between the 1972 and 1995 monographs result from changes in nomenclature, identification of host species, and new observations. In some cases the taxonomy of the host had been revised (e.g. *Pinus californiarum*, host for *A. divaricatum*). In other cases, mistletoe populations are referred to other species, thereby "transferring" associated host species (e.g. the mistletoe on the San Francisco Peaks, AZ parasitic on *P. aristata* is transferred from *A. cyanocarpum* to *A. microcarpum*, thereby changing in host and distribution). Rarely, previous host mis-identification is corrected; Weir's unique collections of *Larix lyallii* with *A. laricis* are now determined to be additional examples of *A. laricis* on *L. occidentalis*. Most of the new reports of principal hosts and expanded distribution result from the many collections made in Mexico since 1972 (see Table 3).

Table 1. New taxa of *Arceuthobium*, species and subspecies described after Hawksworth and Wiens (1972) and subsequently recognized in Hawksworth and Wiens (1995)

A. aureum Hawksw. & Wiens, Brittonia 29:414, 1977 (*A. globosum*)

A. aureum Hawksw. & Wiens subsp. *petersonii* Hawksw. & Wiens,
Brittonia 29:415, 1977 (*A. globosum*)

A. azoricum Hawksw. & Wiens, Kew Bulletin 31:73, 1976 (*A. oxycedri*)

A. durangense (Hawksw. & Wiens) Hawksw. & Wiens,
Phytologia 66:7, 1989 (*A. vaginatum* subsp. *durangense*)

A. globosum Hawksw. & Wiens subsp. *grandicaule* Hawksw. & Wiens,
Brittonia 29:413, 1977 (*A. globosum*)

A. hawksworthii Wiens & C.G. Shaw, III,
J. Idaho Academy Sci. 30(1):25-32, 1994
(*A. aureum* subsp. *aureum*)

A. juniperi-procerae Chiovenda,
Annali di Botanica, Roma 9:134, 1911 (*A. oxycedri*)

A. littorum Hawksw., Wiens, & Nickrent,
Novon 2:206, 1992 (*A. occidentale*)

A. monticola Hawksw., Wiens, & Nickrent,
Novon 2:205, 1992 (*A. californicum*)

A. nigrum (Hawksw. & Wiens) Hawksw. & Wiens,
Phytologia 66:9, 1989 (*A. gillii* subsp. *nigrum*)

A. oaxacanum Hawksw. & Wiens, Phytologia 66:7, 1989 (*A. rubrum*)

A. pendens Hawksw. & Wiens, Brittonia 32:348, 1980

A. sichuanense (H.S. Kiu) Hawksw. & Wiens, Novon 3:156, 1993 (*A. pini*)

A. siskiyouense Hawksw., Wiens, & Nickrent,
Novon 2:204, 1992 (*A. campylopodum*)

A. tibetense H.S. Kiu & W. Ren, J. Yunnan Forestry College 1:42, 1982

A. tsugense (Rosendahl) G.N. Jones subsp. *mertensianae*
Hawksw. & Nickrent, Novon 2:209, 1992 (*A. tsugense*)

A. yecorense Hawksw. & Wiens, Phytologia 66:6, 1989

Note: name following publication date identifies the entity (if any) to which taxa had previously been referred.

Table 2. Principal hosts and distribution for new taxa of *Arceuthobium*

Arceuthobium	Principal Hosts	Distribution
A. aureum subsp. *aureum*	*Pinus montezumae* *Pinus oaxacana* *Pinus pseudostrobus*	Guatemala
A. aureum subsp. *petersonii*	*Pinus michoacana* *Pinus montezumae* *Pinus oaxacana* *Pinus oocarpa* *Pinus patula* *Pinus pseudostrobus*	Chiapas, Mexico Oaxaca, Mexico
A. azoricum	*Juniperus brevifolia*	Azores
A. hawksworthii	*Pinus caribaea*	Belize
A. juniperi-procerae	*Juniperus procera*	Kenya Eritrea Ethiopia
A. littorum	*Pinus muricata* *Pinus radiata*	California
A. monticola	*Pinus monticola*	California Oregon
A. oaxacanum	*Pinus lawsonii* *Pinus michoacana* *Pinus pseudostrobus*	Oaxaca, Mexico
A. pendens	*Pinus discolor* *Pinus orizabensis*	Puebla, Mexico San Luis Potosi, Mexico Veracruz, Mexico
A. sichuanense	*Picea balfouriana* *Picea spinulosa*	Bhutan Sichuan, China Xizang, China
A. siskiyouense	*Pinus attenuata*	California Oregon
A. tibetense	*Abies forrestii*	Xizang, China
A. yecorense	*Pinus durangensis* *Pinus herrerai* *Pinus leiophylla* *Pinus lumholtzii*	Chihuahua, Mexico Durango, Mexico Sonora, Mexico

Note: see Table 3 for additional hosts and expanded distributions of *A. durangense*, *A. globosum*, *A. nigrum*, and *A. tsugense*.

Table 3. Additional principal hosts and expanded distribution for *Arceuthobium* as determined after publication of Hawksworth and Wiens (1972) and recognized in Hawksworth and Wiens (1995)

Arceuthobium	Principal Hosts	Distribution
A. abietinum f. sp. *concoloris*	*Abies durangensis*	Chihuahua, Mexico
A. abietis-religiosae		Michoacan, Mexico Puebla, Mexico Tamaulipas, Mexico Tlaxcala, Mexico
A. blumeri	*Pinus ayacahuite*	Coahuila, Mexico Sonora, Mexico
A. cyanocarpum	*Pinus albicaulis* *Pinus longaeva*	Oregon
A. divaricatum	*Pinus californiarum* *Pinus discolor*	
A. douglasii		Texas Chihuahua, Mexico
A. durangense	*Pinus douglasiana* *Pinus michoacana* *Pinus pseudostrobus*	Jalisco, Mexico
A. gillii	*Pinus herrerai* *Pinus lumholtzii*	New Mexico Durango, Mexico
A. globosum	*Pinus maximinoi* *Pinus patula* *Pinus teocote*	Guerrero, Mexico Hidalgo, Mexico Tlaxcala, Mexico
A. guatemalense		Chiapas, Mexico Oaxaca, Mexico
A. hondurense	*Pinus maximinoi*	
A. laricis	*Tsuga mertensiana*	
A. microcarpum	*Pinus aristata*	
A. nigrum	*Pinus lawsonii* *Pinus oaxacana* *Pinus patula*	Chiapas, Mexico Guanajuato, Mexico Mexico, Mexico Michoacan, Mexico Puebla, Mexico Queretaro, Mexico Tlaxcala, Mexico Zacatecas, Mexico Guatemala
A. pusillum	*Picea glauca*	
A. tsugense	*Abies amabilis* *Abies lasiocarpa* *Abies procera* *Pinus contorta*	
A. vaginatum subsp. *vaginatum*	*Pinus patula*	Queretaro, Mexico
A. vaginatum subsp. *cryptopodum*	*Pinus durangensis*	
A. verticilliflorum	*Pinus arizonica* *Pinus durangensis*	
A. minutissimum		Bhutan
A. pini	*Pinus densata* *Pinus yunnanensis*	

Table 4. Classifications of *Arceuthobium* Based on Morphology, Physiology, Phenology, Isozyme Analysis and DNA Sequences (Hawksworth and Wiens 1995, Tables 14.1 AND 15.2)

Traditional characters only (Hawksworth and Wiens, Table 14.1)	Traditional and molecular characters (Nickrent, Table 15.2)
Subgenus *Arceuthobium*	Subgenus *Arceuthobium*
	Section *Arceuthobium*
A. oxycedri	*A. oxycedri*
A. abietis-religiosae	*A. abietis-religiosae*
A. juniperi-procerae	*A. juniperi-procerae*
	Section *Americana*
A. americanum	*A. americanum*
A. verticilliflorum	*A. verticilliflorum*
	Section *Azorica*
A. azoricum	*A. azoricum*
	Section *Chinense*
A. chinense	
A. chinense	
A. minutissimum	*A. minutissimum*
A. pini	*A. pini*
A. sichuanense	*A. sichuanense*
A. tibetense	*A. tibetense*
Subgenus *Vaginata*	Subgenus *Vaginata*
Section *Vaginata*	Section *Vaginata*
	Series *Vaginata*
A. vaginatum	*A. vaginatum*
A. durangense	*A. durangense*
A. hawksworthii	*A. hawksworthii*
A. yecorense	*A. yecorense*
	A. strictum
	Series *Globosa*
A. globosum	*A. globosum*
A. aureum	*A. aureum*
	Series *Rubra*
	A. rubrum
	A. oaxacanum
A. gillii	*A. gillii*
A. nigrum	*A. nigrum*
	Series *Minuta*
	A. douglasii
	A. divaricatum
Section *Campylopoda*	Section *Campylopoda*
Series *Campylopoda*	Series *Campylopoda*
A. campylopodum	*A. campylopodum*
A. abietinum	*A. abietinum*
A. apachecum	*A. apachecum*
A. blumeri	*A. blumeri*
A. californicum	*A. californicum*
A. cyanocarpum	*A. cyanocarpum*
A. laricis	*A. laricis*
A. littorum	*A. littorum*
A. microcarpum	*A. microcarpum*
A. monticola	*A. monticola*
A. occidentale	*A. occidentale*
A. siskiyouense	*A. siskiyouense*
A. tsugense	*A. tsugense*
	Section *Penda*
A. pendens	*A. pendens*
A. guatemalense	*A. guatemalense*
A. divaricatum	
	Section *Pusilla*
	A. pusillum
	A. bicarinatum
	A. hondurense
Series *Rubra*	
A. rubrum	
A. oaxacanum	
A. bicarinatum	
A. hondurense	
Series *Stricta*	
A. strictum	
Section *Minuta*	
A. douglasii	
A. pusillum	

A comparison of generic classification systems is presented by Hawksworth and Wiens (1995) as differences of Table 14.1 (classification based on morphology, physiology, and phenology) with Table 15.2 (classification based on molecular systematics). A simplified adaptation of these tables is reproduced here as Table 4. The classification based on traditional characters of morphology, physiology, and phenology is an update of the system presented in Hawksworth and Wiens 1972, revised in Hawksworth and Wiens 1984, and further amended with later taxa (e.g. *A. hawksworthii*). The classification based on traditional and molecular characters is proposed by Nickrent (1995) as result of studies with isozymes and DNA sequences (Nickrent 1995).

Subgenera *Arceuthobium* and *Vaginata* are recognized in both the traditional- and molecular-based classifications (Table 4). Subgenus *Arceuthobium* (species with whorled branching) includes the same species in both systems; but Hawksworth and Wiens (traditional characters only) provide no sectional division; whereas Nickrent (traditional and molecular characters) recognizes 4 sections typified by *A. oxycedri*, *A. americanum*, *A. azoricum*, and *A. chinense*. Although subgenus *Vaginata* (based on flabellate branching) is fundamentally unchanged by Nickrent, there are differences in sections, series, and species placement. Hawksworth and Wiens recognizes 3 sections--*Vaginata*, *Campylopoda*, and *Minuta*; Nickrent recognizes 4 sections--*Vaginata*, *Campylopoda*, *Penda*, and *Pusilla*. Although Nickrent retains in section *Vaginata* the same species as placed there by Hawksworth and Wiens, he establishes 4 series and includes several species from the other sections as well. To series *Vaginata* Nickrent adds *A. strictum*, transferred from section *Camyplopoda*, series *Stricta*. Series *Globosa* is established for *A. globosum* and *A. aureum*. *Arceuthobium rubrum* and *A. oaxacanum* (both formerly under section *Camyplopoda*) are associated with *A. gillii* and *A. nigrum* as a series under section *Vaginata*. The fourth series is *Minuta* composed of *A. douglasii* (from the former section *Minuta*) and *A. divaricatum* (trans-ferred from section *Campylopoda*). *Arceuthobium pusillum* which had been associated with *A. douglasii* as section *Minuta* is now included with the remaining members of the former series *Rubra* (*A. bicarinatum* and *A. hondurense*) to establish section *Pusilla*. *Arceuthobium pendens* and *A. guatemalense* are transferred from *Campylopoda* to the new section *Penda*. All these changes leave series *Campylopoda* composed of the remaining 13 species: *A. abietinum*, *A. apachecum*, *A. blumeri*, *A. californicum*, *A. campylopodum*, *A. cyanocarpum*, *A. laricis*, *A. littorum*, *A. microcarpum*, *A. monticola*, *A. occidentale*, *A. siskiyouense*, and *A. tsugense*.

References

Hawksworth, F.G.; Wiens, D. 1972. Biology and classification of dwarf mistletoes *(Arceuthobium)*. Agriculture Handbook 401. Washington, DC: U.S. Department of Agriculture, Forest Service. 234.

Hawksworth, F.G.; Wiens, D. 1984. Biology and classification of dwarf mistletoes *(Arceuthobium)*: an update. In: Hawksworth, F.G., Scharpf, R.F., tech. coord. Biology of dwarf mistletoes. General Technical Report RM-111; Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station: 2-17.

Hawksworth, F.G.; Wiens, D. 1995. Dwarf mistletoes: Biology, pathology, and systematics. Agriculture Handbook 709. Washington, DC: U.S. Department of Agriculture, Forest Service. 234 p.

Nickrent, D.L. 1995. Molecular systematics. In. Hawksworth, F.G.; Wiens, D. 1995. Dwarf mistletoes: Biology, pathology, and systematics. Agriculture Handbook 709. Washington, DC: U.S. Department of Agriculture, Forest Service: 155-170.

MOLECULAR SYSTEMATICS OF *ARCEUTHOBIUM*

Daniel L. Nickrent
Department of Plant Biology
Southern Illinois University
Carbondale, IL 62901

Although thousands of references to dwarf mistletoes exist, relatively little work has been completed on the systematics or phylogenetic relationships of the genus *Arceuthobium*. Molecular analyses of intergeneric or interspecific relationships are even fewer. The intent of this paper is to review those molecular studies that have been conducted thus far.

Isozyme Analyses of Interspecific Relationships

Isozyme electrophoresis has been extensively used to address population genetics, breeding systems, and systematic relationships in plants (Soltis and Soltis 1989). Because of the extreme reduction associated with the parasitic habit and the resulting paucity of morphological characters, isozyme electrophoresis has proven especially valuable in providing useful data for examining species relationships of *Arceuthobium*. Nickrent and others (1984) and Nickrent (1986) first examined the isozymes of 19 North American taxa of *Arceuthobium*. From those studies, it was shown that the genus has remarkably high levels of genetic diversity - 67% of the loci were polymorphic and averaged 2.23 alleles per locus. These results were surprising given the relative homogeneity of the genus with regards to morphology and flavonoid composition (Crawford and Hawksworth 1979, Hawksworth and Wiens 1972).

Many of the results from this electrophoretic study were consistent with the taxonomic classification of Hawksworth and Wiens (1972, 1984), including the recognition of two subgenera (*Arceuthobium* and *Vaginata*), the close relationship among species of section Campylopoda, and the clustering of *A. gillii* (sensu lato) and *A. vaginatum* (sensu lato). Isozyme analysis did not, however, support placement of *A. douglasii* and *A. pusillum* together (e.g. in section Minuta). An unexpected result of this study was the grouping of *A. douglasii*, a parasite of *Pseudotsuga menziesii*, with *A. divaricatum*, a parasite of pinyons. This work clearly raised as many questions as it resolved, hence further analyses were needed, especially on Mexican and Central American taxa.

More recently, an electrophoretic study was completed that included genetic data on 13 populations of seven Mexican taxa that were not included in the previous study. Inclusion of these taxa was important to better understand species and sectional relationships in *Arceuthobium*. These data were combined with isozyme data for the 19 taxa previously examined (Nickrent 1986) yielding a total of 26 taxa.

Genetic variability statistics for a total of 36 dwarf mistletoe populations is presented in Table 1. The overall mean percentage of polymorphic loci is 48.7% and the mean number of alleles per locus is 2.15. These values are lower than those reported in Nickrent (1986) because several populations of Mexican dwarf mistletoes with unusually low levels of polymorphism were included - *Arceuthobium abietis-religiosa*, *A. globosum* subsp. *grandicaule*, *A. pendens*, *A. rubrum*, *A. strictum*, and *A. verticilliflorum*. The mean number of alleles per locus for these 6 taxa (1.5) is lower than the overall mean for the genus (2.15); this reduction in allele frequency may be a consequence of their restricted distributions. However, two other Mexican taxa, *A. vaginatum* subsp. *vaginatum* and *A. durangense*, show high levels of polymorphism that are comparable

Table 1. Genetic Variability at 9 Isozyme Loci in 36 Populations of 25 *Arceuthobium* Species

Population		Taxon[1] size per	Mean sample Alleles Locus	Mean No. of Loci per locus	Percentage Expected Polymorphic[2]	Hardy-Weinberg Heterozygosity[3]
No.	Coll. No.					
1.	1917	ABC	42.2	2.0	55.6	0.206
2.	1906	ABM	54.7	2.3	44.4	0.183
3.	1983	ABR	34.3	2.0	55.6	0.250
4.	2010	ABR	61.6	1.4	33.3	0.109
5.	1932	AME	47.7	3.0	55.6	0.200
6.	1929	AME	35.8	3.8	77.8	0.351
7.	1945	APA	61.7	2.0	44.4	0.210
8.	1937	BLU	35.1	2.0	22.2	0.133
9.	1930	CAL	49.6	2.6	66.7	0.253
10.	1924	CAM	28.8	2.1	55.6	0.211
11.	1973	CYA	17.6	1.7	44.4	0.124
12.	1953	DIV	80.3	2.7	55.6	0.209
13.	1941	DOU	27.7	2.1	44.4	0.228
14.	1949	DOU	44.6	2.4	33.3	0.192
15.	1870	DUR	26.7	2.9	66.7	0.265
16.	2049	DUR	9.3	2.3	66.7	0.299
17.	2051	DUR	26.8	3.3	77.8	0.365
18.	1938	GIG	77.8	2.8	44.4	0.198
19.	1996	GLG	27.2	1.6	11.1	0.092
20.	1801	LAR	21.4	1.7	55.6	0.170
21.	1947	MIC	19.1	1.7	33.3	0.154
22.	2041	NIG	31.7	2.4	66.7	0.269
23.	1962	OCC	37.8	2.0	55.6	0.184
24.	1992	PEN	20.8	1.8	33.3	0.106
25.	1970	PUS	50.9	2.0	22.2	0.103
26.	1971	PUS	30.8	1.7	44.4	0.166
27.	1853	RUB	8.3	1.3	33.3	0.139
28.	2061	STR	24.2	1.1	11.1	0.039
29.	1927	TSM	10.0	1.9	66.7	0.290
30.	1876	VAC	53.0	2.7	44.4	0.172
31.	1964	VAC	30.2	2.8	55.6	0.256
32.	2059	VAV	8.9	2.0	66.7	0.230
33.	1980	VAV	29.8	2.4	66.7	0.274
34.	1981	VAV	15.4	1.9	66.7	0.233
35.	2001	VER	12.8	1.7	44.4	0.175
36.	2065	VER	4.6	1.3	33.3	0.169
Means			33.3	2.15	48.7	0.200

---

[1] See Table 16-2 for taxon abbreviations

[2] A locus is considered polymorphic if the frequency of the most common allele does not exceed 0.95

[3] Unbiased estimate (Nei, 1978). Direct count heterozygosity not possible given the allelic data was derived from triploid genotypes

to levels found in a related and more northern taxon, *A. vaginatum* subsp. *cryptopodum*. This contrast in species-to-species variation in polymorphism agrees with conclusions of Nickrent (1986) and Hawksworth and Wiens (1972) that section Vaginata (which includes *A. vaginatum* and *A. durangense*) is genetically and morphologically more variable than other sections in the genus. Although *A. globosum* subsp. *grandicaule* shows a low level of polymorphism and is also in section Vaginata, only 30 individuals from one population were examined electrophoretically, hence this sample may not be representative of the species' genetic diversity.

With this new isozyme data, additional insight into the phylogenetic relationships of many of the dwarf mistletoe taxa occurring in North America can be gained (Fig. 1). *Arceuthobium strictum* is distantly related to most other taxa in section Campylopoda, but is closely related to *A. pendens*. This is not totally in conflict with the classification of Hawksworth and Wiens (1972) in which the former species was placed in its own series (Stricta). It appears, however, that the majority of species in section Campylopoda are found in the United States, whereas species in section Vaginata predominate in Mexico. The two parasites of pinyons, *Arceuthobium divaricatum* and *A. pendens*, are not closely related. This conclusion is supported by the isozyme data, markedly different flavonoid chemistry, systemic broom formation in *A. pendens*, and different hosts (Hawksworth and Wiens 1980). *Arceuthobium gillii* and *A. nigrum* are clearly related but cluster at a genetic distance value that indicates they are indeed different species. The relatives of *A. vaginatum* have high levels of genetic diversity, and cluster analysis indicates a substantial genetic differentiation between populations. Further work is required to better understand apportionment of genetic variation in the *Arceuthobium vaginatum* complex.

Subgenus *Arceuthobium* shows greater within-group heterogeneity than any of the other groups. Despite the variation, cluster analysis places *Arceuthobium abietis-religiosa*, *A. americanum*, and *A. verticilliflorum* in one group that joins the remainder of the species at a genetic distance of 0.82. Thus, isozyme data support use of verticillate secondary branching (Mark and Hawksworth 1981) as a distinguishing character for the subgenus.

Additional isozyme analyses have been conducted on various members of the *Arceuthobium campylopodum* complex (Nickrent and Butler 1990, 1991, Nickrent and Stell 1990). These studies utilized diploid shoot tissue as a source of isozymes, hence a larger number of population genetic analyses could be conducted. Based upon cluster analysis, California coastal populations of *Arceuthobium* parasitic on *Pinus radiata* and *P. muricata* are genetically distinct from *A. campylopodum* (sensu stricto) and are segregated at the specific level as *A. littorum* (Hawksworth and others 1992). Examination of isozymes from allopatric and sympatric populations of *A. campylopodum* and *A. occidentale* did not reveal significant genetic differentiation, hence they could be considered a single biological species.

Nickrent and Butler (1991) examined genetic relationships among dwarf mistletoes related to *Arceuthobium campylopodum* that are parasitic on *Pinus attenuata* and *P. monticola* in Northwestern California and southwestern Oregon. The parasites of *P. attenuata* and *P. monticola* were genetically distinct from each other. These species were named, respectively, *A. siskiyouense* and *A. monticola* (Hawksworth and others 1992). This result is in accordance with the observation that the Klamath-Siskiyou Mountain region contains a highly diverse and endemic flora. These dwarf mistletoes likely represent the most recent evolutionary lines to diverge from the *A. campylopodum* complex.

The results from electrophoretic examination of the three host-forms of *Arceuthobium tsugense* (mountain hemlock, western hemlock, and shore pine) indicate that the population infecting *Tsuga mertensiana* is genetically distinct and deserving of taxonomic recognition as *A. tsugense* subsp. *mertensianae* (Nickrent and Stell 1990, Hawksworth and others 1992). *Arceuthobium tsugense* subsp. *tsugense* consists of two morphologically similar host races parasitic on *Tsuga heterophylla* (western hemlock race) and *Pinus contorta* subsp. *contorta* (shore pine race). Isozyme analysis failed to detect significant genetic differentiation between these two host-forms, hence they were retained within the same subspecies.

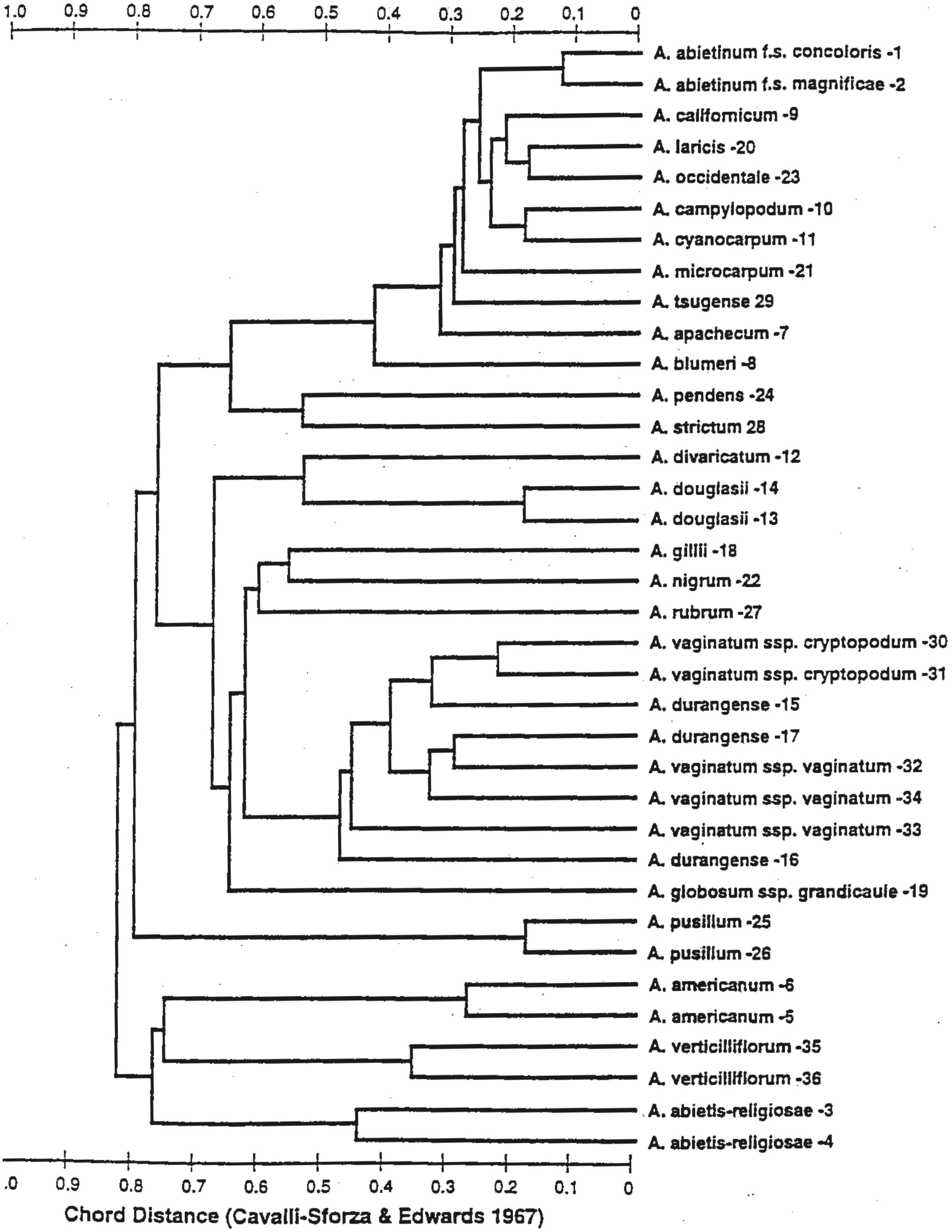


Figure 1. The UPGMA phenogram resulting from isozyme analysis of the 36 *Arceuthobium* populations shown in Table 1. Cophenetic correlation = 0.968, standard deviation 6.6%.

Species Relationships From Ribosomal DNA Spacer Sequences

Many studies addressing interspecific relationships in plants have been conducted using restriction site data from chloroplast DNA (Soltis and others 1992). Few studies have used DNA sequences to examine interspecific relationships because a gene or segment of DNA that is of adequate size and that evolves at a sufficiently fast rate is required. Recently, the internal transcribed spacer (ITS) regions of the ribosomal DNA cistron have been shown to evolve at rates appropriate for examining more recently diverging lineages (Baldwin 1993, Baldwin and others 1995). Sequences of the ITS regions and the enclosed 5.8S rDNA were analyzed for 22 species of *Arceuthobium*, thus allowing a comparison with phylogenies generated from other methods.

Based on the results from analysis of ITS sequences (Fig. 2), four members of section Campylopoda are genetically very similar - *A. abietinum* f. sp. *magnificae*, *A. apachecum*, *A. campylopodum*, and *A. microcarpum*. Sequences of *A. cyanocarpum*, *A. occidentale*, and *A. tsugense* were either very similar or identical to those of the above four taxa. Species in section Campylopoda, comparable to series Campylopoda (Hawksworth and Wiens 1972, 1984), occur mainly in the United States. Mexican and Caribbean species such as *A. guatemalense*, *A. pendens*, *A. rubrum*, *A. bicarinatum*, and *A. strictum* are not closely related to the U.S. taxa. The latter three of these species were previously segregated into series Rubra (*A. rubrum* and *A. bicarinatum*) and Stricta (*A. strictum*) by Hawksworth and Wiens (1972), thus providing some indication of their differentiation from series Campylopoda.

A strongly supported result of the ITS analysis is the association of *Arceuthobium guatemalense* with *A. pendens*. *Arceuthobium guatemalense* is confined to the mountains of Guatemala and southern Mexico, where it parasitizes *Pinus ayacahuite* (of subgenus *Haploxylon*). *Arceuthobium pendens* is known only from Puebla, San Luis Potosi, and Veracruz, Mexico and is parasitic on the *Haploxylon* pines, *Pinus discolor* and *P. orizabensis*. Both of these mistletoes and their hosts are narrow endemics indicating that these species could represent relictual taxa that diverged early during the migration and evolution of *Arceuthobium* in the New World.

As seen with isozymes, ITS data do not support a relationships between *A. douglasii* and *A. pusillum*. The relationship between this species and *A. divaricatum* is strongly supported by analysis of ITS-1 sequences only.

Analysis of ITS sequences strongly supports two clades representing section Vaginata. The first is composed of *Arceuthobium vaginatum* subsp. *vaginatum*, *A. vaginatum* subsp. *cryptopodum*, *A. durangense*, and *A. strictum*. Previous classifications (Hawksworth and Wiens 1972) and isozyme studies (Nickrent 1986) have shown relationships among the first three of these taxa. The addition of *A. strictum* is surprising, although isozyme analysis had shown genetic divergence between it and species in series Campylopoda. All four of these taxa parasitize pines of subgenus *Diploxylon* and their distributions range from the northern Sierra Madre Occidental (Durango through Chihuahua and Sonora) to the southwestern United States. The second section Vaginata clade is composed of *Arceuthobium rubrum*, *A. gillii*, and its recent segregate species, *A. nigrum*. The association of *A. gillii* with *A. nigrum* is strongly supported by ITS analysis as is the association of *A. rubrum* with this clade. Because isozyme characters also indicate a grouping of these three species, their phyletic affinity is highly probable.

A surprising, but strongly supported clade contains *Arceuthobium pusillum* and *A. bicarinatum*. The former species is a reduced parasite of spruce of the northern United States and Canada, and the latter is a relatively large parasite of *Pinus occidentalis* on the island of Hispaniola. Given these geographic distributions and the DNA sequence results, it is likely that these species' ancestor was already present in eastern North America in the early Tertiary Period and was widely distributed throughout eastern North America as well as the Caribbean region. Populations of this ancestral taxon became geographically isolated during the middle Cenozoic Era. The current genetic data on *A. bicarinatum* and *A. pusillum* suggest their ancestor likely possessed a large store of

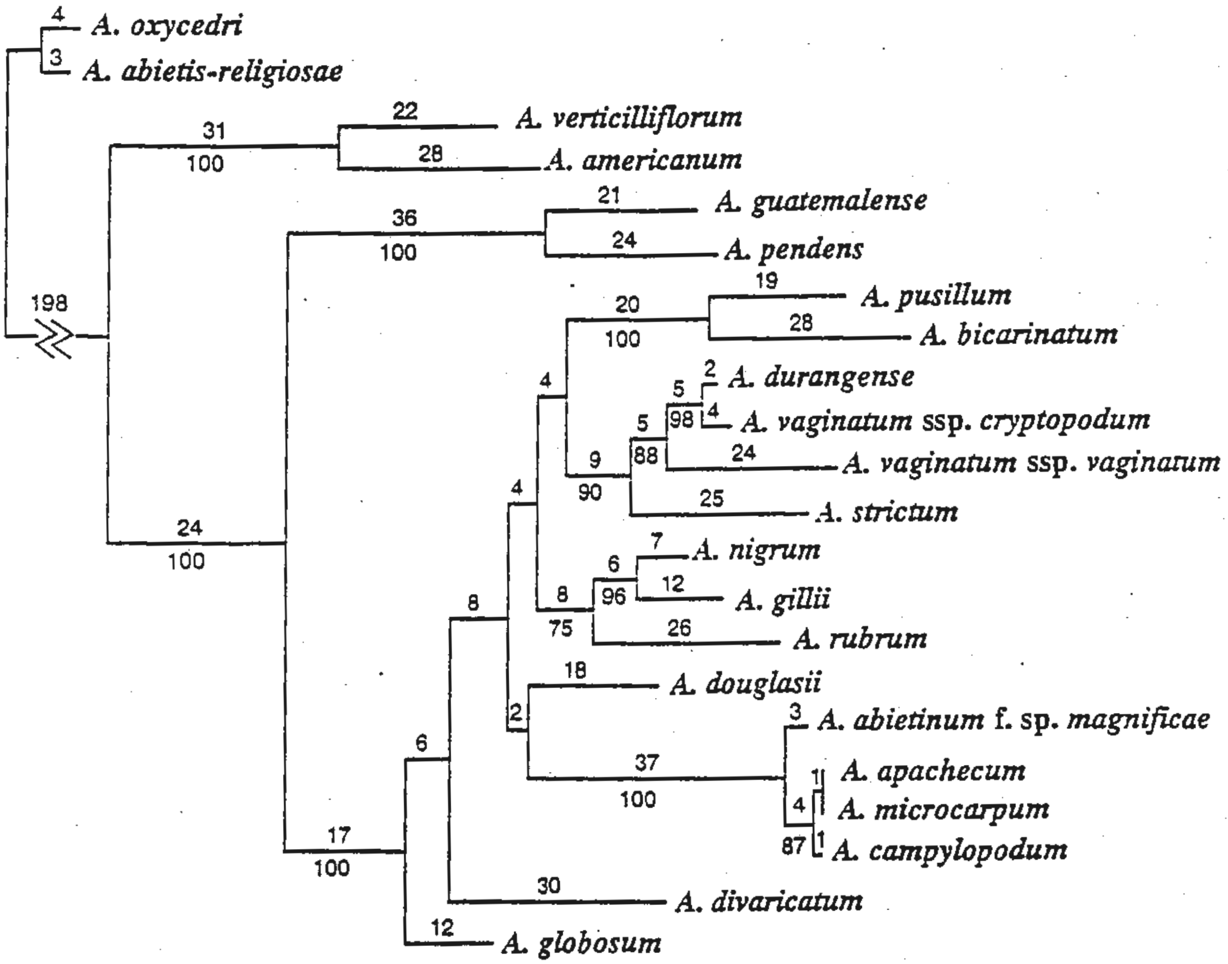


Figure 2. One of the six shortest trees (length 738) derived from analysis of *Arceuthobium* ITS-1, -2, and 5.8S rDNA sequences. The numbers above the branches indicate branch lengths (number of nucleotide substitutions) and the numbers below the branches indicate percentage values (from 200 replications) derived from the bootstrap majority rule consensus tree. Clades with no bootstrap value indicate they were supported in less than half the trees. Consistency index = 0.755, homoplasy index = 0.286, retention index = 0.726.

potential genetic variation that became manifest following diversifying selection. Increased fitness was attained by the geographically separated populations exploiting different environments and hosts. The reduction in shoot height, systemic broom formation, spring flowering, and rapid fruit maturation seen in *A. pusillum* may represent adaptations to greater winter extremes, while *A. bicarinatum* retained more characteristics of the ancestral taxon because of its subtropical distribution.

Two of the most striking results of my study of ITS variation are the extreme divergence of *Arceuthobium abietis-religiosa* and *A. oxycedri* from the other taxa sampled and the similarity of these species to each other. These results require a modification of concepts regarding relationships among the three New World members of subgenus *Arceuthobium* as well as their relationship to Old World members of this subgenus.

Arceuthobium americanum and *A. verticilliflorum* are more closely related to each other than to any other species. In addition, they have more affinity with subgenus Vaginata than with *A. abietis-religiosa* and *A. oxycedri*, thus indicating a major divergence in the verticillately branched group during their evolution in the New World. Subgenus Vaginata was apparently derived from an ancestor shared with *A. americanum* and *A. verticilliflorum*. The extreme divergence of *A. abietis-religiosa* and *A. oxycedri* from the remaining species also could be interpreted as evidence of separate migrations into the New World. Further molecular work would greatly benefit from inclusion of additional Old World species, such as *A. azoricum*, *A. chinense*, *A. juniperi-procerae*, *A. minutissimum*, *A. pini*, and *A. tibetense*.

There is no doubt that the dwarf mistletoes continue to present a challenge to the plant systematist, as do all parasitic flowering plants that follow reductional and/or convergent evolutionary paths. These plants provide the ultimate test of our abilities to reconstruct phylogenies, therefore, alternate data sets for other genes must be assembled to confirm or support proposed phylogenetic relationships.

Literature Cited

Baldwin, B. G. 1993. Molecular phylogenetics of *Calycadenia* (Compositae) based on its sequences of nuclear ribosomal DNA: Chromosomal and morphological evolution reexamined. American Journal of Botany 80: 222-238.

Baldwin, B. G., M. J. Sanderson, J. M. Porter, M. F. Wojciechowski, C. S. Campbell, and M. J. Donoghue. 1995. The ITS region of nuclear ribosomal DNA: A valuable source of evidence on angiosperm phylogeny. Annals of the Missouri Botanical Garden 82: 247-277.

Cavalli-Sforza, L. L. and A. W. F. Edwards. 1967. Phylogenetic analysis: models and estimation procedures. Evolution 21:550-570.

Crawford, D. J., and F. G. Hawksworth. 1979. Flavonoid chemistry of *Arceuthobium* (Viscaceae). Brittonia 31: 212-216.

Hawksworth, F. G., and D. Wiens. 1972. Biology and classification of dwarf mistletoes (*Arceuthobium*). USDA Agriculture Handbook No. 401, 234 p.

Hawksworth, F. G., and D. Wiens. 1980. A new species of *Arceuthobium* from central Mexico. Brittonia 32: 348-352.

Hawksworth, F. G., and D. Wiens. 1984. Biology and classification of *Arceuthobium*: an update. Pp. 2-17 In: F. G. Hawksworth and R. F. Scharpf [eds.], Biology of Dwarf Mistletoes: Proceedings of the Symposium. USDA Forest Service General Technical Report RM-111.

Hawksworth, F. G., D. Wiens, and D. L. Nickrent. 1992. New western North American taxa of *Arceuthobium* (Viscaceae). Novon 2: 204-211.

Mark, W. R., and F. G. Hawksworth. 1981. Taxonomic implications of branching patterns in dwarf mistletoes (*Arceuthobium*). Phytologia 47: 441-444.

Nickrent, D. L. 1986. Genetic polymorphism in the morphologically reduced dwarf mistletoes (*Arceuthobium*, Viscaceae): an electrophoretic study. American Journal of Botany 73: 1492-1502.

Nickrent, D. L., and T. L. Butler. 1990. Biochemical systematics of the *Arceuthobium campylopodum* complex (dwarf mistletoes, Viscaceae). I. Allozymic relationships in *Arceuthobium campylopodum* and allies in California. Biochemical Systematics and Ecology 18: 253-265.

Nickrent, D. L., and T. L. Butler. 1991. Biochemical systematics of the *Arceuthobium campylopodum* complex (dwarf mistletoes, Viscaceae). III. Genetic relationships in *Arceuthobium monticola* and *A. siskiyouense* (Viscaceae): New dwarf mistletoe species from California and Oregon. Biochemical Systematics and Ecology 19: 305-313.

Nickrent, D. L., S. I. Guttman, and W. H. Eshbaugh. 1984. Biosystematic and evolutionary relationships among selected taxa of New World *Arceuthobium*. Pp. 20-35 In: F. G. Hawksworth and R. F. Scharpf [eds.], Biology of Dwarf Mistletoes: Proceedings of the Symposium. USDA Forest Service General Technical Report RM-111.

Nickrent, D. L., and A. L. Stell. 1990. Biochemical systematics of the *Arceuthobium campylopodum* complex (dwarf mistletoes, Viscaceae). II. Electrophoretic evidence for genetic differentiation in two host races of hemlock dwarf mistletoe (*A. tsugense*). Biochemical Systematics and Ecology 18: 267-280.

Soltis, D. E., and P. S. Soltis (editors). 1989. Isozymes in Plant Biology. Advances in Plant Sciences Series, Vol. 4, T. R. Dudley, General Editor, Dioscorides Press, Portland, OR. 268 pp.

Soltis, D. E., P. S. Soltis, and J. J. Doyle (editors). 1992. Molecular Systematics of Plants. Chapman and Hall, New York, 434 pp.

SPECIAL PAPERS

Pete Angwin, Moderator

SPREAD AND PERSISTENCE OF TWO EXOTIC MELAMPSORA LEAF RUST PATHOGENS IN THE PACIFIC NORTHWEST

Gary A Chastagner and George Newcombe
Washington State University Research and Extension Center
Puyallup, WA 98371

In addition to black cottonwood and aspen, which are important components of our forest ecosystem, various poplar species and hybrids are being grown for a number of commercial and ornamental uses in the Pacific Northwest. Traditionally, poplars have been used as ornamental plantings, windbreaks, visual screens, and in efforts to stabilize soil.

Recently, there has been a rapid expansion of commercial hybrid poplar plantings in the Pacific Northwest. Genetically improved hybrids are extremely fast growing trees that can be used for a variety of wood and energy products and which potentially can be used in environmental remediation programs. For pulp fiber alone, the commercial acreage has increased from zero in 1980 to over 60,000 acres of existing and anticipated plantations. At least six forest products companies in Washington, Oregon, and British Columbia are growing hybrid poplar on a large scale and the Pacific Northwest nursery industry produced over 10 million hybrid poplar cuttings last year for establishment of commercial plantations.

It is anticipated that the demand for hybrid poplar will accelerate as its end uses become more diversified. Suited to Washington's large agricultural land base, it has been estimated that upwards of 90,000 acres in western Washington and 250,000 acres in eastern Washington, where trees are grown under drip irrigation, are available for hybrid poplar culture. Crosses of the native black cottonwood, *Populus trichocarpa*, with the eastern cottonwood, *P. deltoides*, are the most common type of hybrid poplar used, especially west of the Cascade Mountain range. Clones of hybrid poplars are typically planted in large monoclonal blocks with approximately 500-600 trees per acre.

Worldwide, there are a number of important diseases of poplars that can reduce growth or even kill trees. Leaf rusts, caused by various species of Melampsora, are generally recognized as one of the most serious diseases on poplars. Both *M. occidentalis* and *M. albertensis* are native to the Pacific Northwest. *M. albertensis* has a limited telial host range occurring only on *P. tremuloides*, while *M. occidentalis* can occur on a number of poplar species including black cottonwood. All of the commercial hybrid clones that have been planted in the Pacific Northwest are resistant to these rusts.

In 1991, rust appeared on a number of clones in several commercial hybrid poplar plantations near Woodland, WA and Scappoose, OR. The *Melampsora* spp. associated with these rusts were identified as *M. medusae* f.sp. *deltoidae*, which is native to eastern North America, and the Eurasian poplar leaf rust, *M. larici-populina*, which had not been previously reported in North America. Because of their ability to attack a relatively large number of poplar species and hybrids, these two *Melampsora* spp. are generally considered to be the most economically important poplar leaf rust pathogens. Although native to North America, *M.*

medusae f.sp. *deltoidae* had previously spread to Southwestern Europe, Australia, New Zealand, Africa, and America.

Following the detection of *M. larici-populina* and *M. medusae* f.sp. *deltoidae* in the Pacific Northwest during late 1991, a number of questions arose concerning the potential for these rusts to overwinter and cause disease during subsequent growing seasons. During the past three years, a number of experiments have been conducted relating to overwintering of these rusts and surveys have been done to monitor disease development and spread of these pathogens.

Overwintering of Telial Inoculum

The primary means of overwintering by these *Melampsora* spp. are telia that develop on fallen poplar leaves. During the spring, telia germinate and produce basidiospores which are spread via air to nearby aecial hosts where infection takes place. Aeciospores are then spread to poplar and initiate the leaf-rust phase of the disease.

During 1992 and 1993, a series of field studies were conducted to determine the viability and period of time telia of *M. medusae* f.sp. *deltoidae*, *M. larici-populina, M. occidentalis*, and *M. albertensis* germinated to produce basidiospores. These studies revealed that telia of *M. medusae* f.sp. *deltoidae* and *M. larici-populina* germinated from early March through early May. This is in contrast to telial germination of *M. occidentalis* and *M. albertensis*, which began in early April and continued through mid to late June.

Aecial Hosts

There are a number of conifers which are known to serve as aecial hosts for *M. larici-populina* and *M. medusae* f.sp. *deltoidae*. Although Ziller's work is commonly cited in relation to the aecial host range for *M. medusae*, it is uncertain whether his studies were actually done with *M. medusae* f.sp. *tremuloidae* or *M. medusae* f.sp. *deltoidae*. Reports in the literature indicate that the most common aecial host of *M. medusae* f.sp. *deltoidae* is eastern larch, while Japanese, European and, western larch, along with Monterey pine are reported to serve as aecial hosts of *M. larici-populina*.

To determine whether additional PNW conifers might be attacked by these two rusts, conifer seedlings were inoculated with natural basidiospore inoculum in a series of growth-room experiments. To identify the *Melampsora* spp. which were able to infect seedlings, aeciospores resulting from the successful infections were used to inoculate a differential set of poplars so that the *Melampsora* spp. could be identified based on urediniospore morphology.

Aecia of *M. larici-populina* were found on two previously unreported hosts, Ponderosa and lodgepole pine, while aecia of *M. medusae* f.sp. *deltoidae* were found on five previously unreported hosts, western larch, Douglas-fir, lodgepole pine, Ponderosa pine, and Monterey pine. No infections were observed on seedlings of *Picea* (3 species), *Abies* (3 species), *Chamaecyparis* (2 species), and *Tsuga, Cupressus, Thuja*, and *Cedrus* (1 species each). Although a number of conifers can potentially serve as alternate hosts to these rusts, the aecial stages of these rusts have not been detected on any coniferous host in the Pacific Northwest except larch in experimental plantings.

Spread of *M. medusae* f.sp. *deltoidae*

In 1992, *M. medusae* f.sp. *deltoidae* was first detected in commercial hybrid poplar plantations on June 30 in the area where it occurred in late 1991. During 1993, 1994, and 1995, initial appearance of this rust on hybrid poplars in western Washington and Oregon has occurred during early to mid July. Once established, the rust developed rapidly on susceptible clones during late August and early September. Initial defoliation of susceptible clones has generally been first observed during late August. Although information on the impact of this rust on the growth of susceptible clones in commercial plantations has not been determined, mortality of susceptible clones in stool beds has been associated with infection by *M. medusae* f.sp. *deltoidae*.

Following the initial detection of *M. medusae* f.sp. *deltoidae* in 1992, this pathogen rapidly spread from July through early fall. By the end of the growing season, *M. medusae* f.sp. *deltoidae* had been confirmed as far north as Bellingham, WA (204 miles), west to Astoria, OR (60 miles), south the Elkton, OR (156 miles), and east to Patterson, WA (157 miles). In 1993, *M. medusae* f.sp. *deltoidae* was detected on hybrid poplars in the Lower Mainland of British Columbia and eastward to Lewiston, ID, and by the end of 1994, *M. medusae* f.sp. *deltoidae* had spread to the Nanaimo area on Vancouver Island, BC. Although this pathogen has spread into areas east of the Cascade Mountains, in most instances only a limited amount of rust has developed on clones in commercial plantations even though susceptible clones are still being widely planted.

Spread of *M. larici-populina*

After *M. larici-populina* was first detected in two hybrid poplar plantations near Scappoose, OR and Woodland, WA during fall 1991, quarantines were placed on these sites during 1992 by APHIS, prohibiting the movement of poplars, Douglas-fir, larch and pines while steps were taken by APHIS and state regulatory personnel to obtain additional information regarding the distribution of this pathogen. *M. larici-populina* was first detected during the 1992 growing season on July 15 in one of the plantations where it occurred in 1991. *M. larici-populina* remained confined to sites near Scappoose, OR and Woodland, WA where it was detected in 1991 until late in the summer during 1992. On August 28, it was detected in a 2.5 acre experimental planting of hybrid poplars located at WSU's research unit in Vancouver, WA. By late September-early October, it had been found on Lombardy poplar and native black cottonwoods adjacent to the infected plantations near Woodland and Scappoose. It was also found on a commercial hybrid poplar planting near Goble, OR. By the end of the surveys in mid-November, *M. larici-populina* had been found in an area about 30 miles wide along the Lower Columbia River, spreading as far south as Hillsboro, OR and as far north as Kalama, WA.

During the fall of 1992, *M. larici-populina* was also detected on poplars in California. Subsequent surveys and samples of various poplars collected in California indicated that *M. larici-populina* was present in at least 18 counties. Most of these counties were along the Pacific Ocean, but a few samples came from nurseries and established plantings in the central Sacramento and San Joaquin Valleys. If the host-identification record submitted along with the samples was correct, *M. larici-populina* was found on *P. nigra, P. balsamifera, P. balsamifera* var. *subcordata, P. balsamifera* cv. *Mojave, P. fremontii, P. nigra* cv. *Italica, P. nigra* var. *caudina, P. trichocarpa,* and *P. X Canadensis.*

As a result of finding that *M. larici-populina* was widespread in California, quarantines on the hybrid poplar plantations where it had been detected in western Washington and Oregon were dropped during late 1992. The apparent widespread occurrence of *M. larici-populina* in California most likely indicates that this pathogen has been present there for a number of years. Studies using isolates from California and

Washington have revealed that race E-1 predominates in sampled locations in both of these states, while three other unnamed races occur at low frequency. Races E-2, E-3, and E-4, which are present in Europe, were not found among the sampled isolates.

In 1993, very little *M. larici-populina* developed in the plantations, but it could still be detected on hybrid poplars near Woodland, WA, and it was found on Lombardy poplars near Clatskanie, OR, and at WSU-Vancouver and Kalama, WA. By 1994, no *M. larici-populina* was detected in the hybrid poplar plantations near Scappoose, OR and Woodland, WA. In fact, it was only found on a few Lombardy poplars that had been inoculated during the early part of the 1994 growing season at WSU research facility at Vancouver, WA.

At this point in time, *M. medusae* f.sp. *deltoidae* has become established throughout the Pacific Northwest. In addition, there is no indication that more than one race of *M. medusae* f.sp. *deltoidae* is present in the Pacific Northwest. Unlike *M. medusae* f.sp. *deltoidae*, and *M. larici-populina* in California, it appears that *M. larici-populina* has failed to establish itself in the Pacific Northwest. Although it is uncertain whether the incidence of *M. larici-populina* is just so low that it cannot be readily detected or if it has failed to persist in the Pacific Northwest, the reasons for its inability to develop in an area with abundant susceptible hosts are unknown.

References

Chastagner, G.A. and G. Newcombe. 1993. Maturation of telia of *Melampsora occidentalis, M. medusae* f.sp. *deltoidae*, and *M. larici-populina* in the Pacific Northwest. Sixth International Congress of Plant Pathology, Montreal, Canada, Abstract 6.3.7, pg. 111.

Chastagner, G.A., G. Newcombe, and J.M. Staley. 1994. Effectiveness of helicopter applications of three DMI fungicides in controlling Melampsora leaf rusts on hybrid poplars. Phytopathology 84:1065.

Hsiang, T., G.A Chastagner, J.M. Dunlap, and R.F. Stettler. 1993. Genetic variation and productivity of *Populus trichocarpa* T.&G. and its hybrids. VI. Field susceptibility of celulines to *Melampsora occidentalis* Jacks. leaf rust. Can. J. For. Res. 23:436-431.

Hsiang, T. and G.A Chastagner. 1993. Variation of *Melampsora occidentalis* rust on poplars in the Pacific Northwest. Can. J. Plant Pathology 15:175-181.

Newcombe, G. and G.A Chastagner. 1993. The first report of the Eurasian poplar leaf rust fungus, *Melampsora larici-populina*, in North America. Plant Disease 77:532-535.

Newcombe, G. and G.A Chastagner. 1993. A leaf rust epidemic of hybrid poplar along the Lower Columbia River, caused by *Melampsora medusae*. Plant Disease 77:528-531.

Newcombe, G., G.A Chastagner, W. Schuette, and B.J. Stanton. 1994. Mortality among hybrid poplar clones in a stool bed following leaf rust caused by *M. medusae* f.sp. *deltoidae*. Can. J. For. Res. 24:1984-1987.

Newcombe, G., G.A Chastagner, and S.K. McDonald. 1994. Additional coniferous aecial hosts of the poplar leaf rust, *Melampsora larici-populina* and *M. medusae* f.sp. *deltoidae*. Plant Disease 78:1218.

Pinon, J., G. Newcombe, and G.A Chastagner. 1994. Identification of races of *Melampsora larici-populina*, the Eurasian poplar leaf rust fungus, in California and Washington. Plant Disease 78:101.

Shain, L. 1988. A search for aecial hosts of *Melampsora medusae* among some conifers grown in eastern United States. Plant Disease 72:904-906.

Shain, L. 1988. Evidence of formae specialis in the poplar leaf rust fungus, *Melampsora medusae*. Mycologia 89:729-732.

Ziller, W.G. 1955. Studies of western tree rusts. II. *Melampsora occidentalis* and *M. albertensis*, two needle rusts of Douglas-fir. Can. J. Bot. 33:177-188.

Ziller, W.G. 1965. Studies of western tree rusts. VI. The aecial host ranges of *Melampsora albertensis, M. medusae*, and *M. occidentalis*. Can. J. Bot. 43:217-230.

Ziller, W.G. 1974. The tree rusts of western Canada. Canadian Forestry Service Publication No. 1329. 272 pp.

THE RELATIONSHIP OF DOUGLAS-FIR DWARF MISTLETOE (*Arceuthobium douglasii*) TO ENVIRONMENTAL AND STAND CONDITIONS AND PLANT COMMUNITIES IN THE SOUTHERN OREGON CASCADES

Katy Marshall
Department of Forest Science
Oregon State University
Corvallis, OR 97331

This study examined the relationships between the frequency of occurrence and severity of Douglas-fir dwarf mistletoe (*Arceuthobium douglasii* Engelmann), environmental and stand conditions, and plant communities in the Southern Oregon Cascade Mountain Province.

Data for the study was collected from the same ecology plots that were previously used to define the plant associations in the province. A pilot study of the variability in the frequency of occurrence and severity of Douglas-fir dwarf mistletoe (DFDM) among plant associations was used to determine the sample size. The plant associations selected for the final sample were grouped into three climax series; Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco), white fir (*Abies concolor* (Gord. and Glend) Lindl. ex Hildebr.) and western hemlock (*Tsuga heterophylla* (Raf.) Sarg.). Environmental and stand conditions were sampled using the variables elevation, mean annual temperature, mean annual precipitation, dry season precipitation, site index, slope, total basal area, Douglas-fir basal area, percent basal area in Douglas-fir, number of tree canopy layers, age of each layer, diameter of Douglas-fir at breast height, aspect, topographic position, topographic shape, and soil parent material.

DFDM was present in plots at significantly higher elevations, with lower mean annual temperatures and lower mean annual precipitation. The disease was never found in plots below 1066 meters elevation or at mean annual temperatures above 8°C. It occurred significantly more often in the white fir series than in the others. Within this series it was found more often in the coldest and driest plan associations. The relative frequency of DFDM among the series appeared to be related to the differences in their elevation, mean annual temperature and mean annual precipitation.

The geographic distribution of the plots where DFDM occurred suggested that past timber harvesting, fire history and fire behavior may have influenced the present distribution of the disease in the Southern Oregon Cascades.

The severity of DFDM was significantly associated with two stand variables. Severity increased as total basal area decreased and as the age of the oldest layer increased. Multiple regression analysis indicated that the disease was most severe in old, open stands on high, dry sites.

This study suggested that plant associations and climax series were useful indicators of the relative frequency of occurrence of DFDM in the Southern Oregon Cascades, but not of its severity. However, if the current distribution of DFDM was influenced by past harvesting and fire regimes, changes in these factors may change the diseases' distribution in the future. A return to widespread partial cutting would be of particular concern because partial cutting often creates the stand conditions that were associated with severe DFDM in this study.

CAN DWARF MISTLETOE BE ELIMINATED FROM RECREATION AREAS?

John Pronos
Forest Pest Management, Stanislaus National Forest
USDA Forest Service, Sonora, CA 95370

Thomas E. Warner and Daniel M. Duriscoe
Resources Management, Sequoia and Kings Canyon National Parks
USDA National Park Service, Three Rivers, CA 93271

Abstract

Between 1984 and 1992, four campgrounds in the Cedar Grove area of Kings Canyon National Park (California) were each treated 3 times to remove western dwarf mistletoe from pines. Even though treatment guidelines were rigidly followed, the first two entries did not remove all infections. An additional survey is needed to determine if the third treatment eliminated the remaining dwarf mistletoe.

Introduction

The Cedar Grove recreation area in Kings Canyon National Park is located in the southern Sierra Nevada mountains of California. Four campgrounds are situated along the south fork of the Kings River at an elevation of approximately 1412 meters (4635 ft.). Although all the campgrounds occur within one mile of each other, there is considerable variation in site quality. The lowest elevation campground has a good, deep soil and supports fairly dense, mixed conifer stands composed of ponderosa pine, white fir, incense-cedar, Jeffrey pine and sugar pine. As you move up river to the other three campgrounds, the soil becomes dry and sandy and tree cover shifts to mainly ponderosa and Jeffrey pines and incense-cedar.

Chronic annual tree mortality in the area prompted the Park to request a biological evaluation from Forest Pest Management (FPM). The first site visit was completed in 1981 (Pronos, 1981). One year's mortality was followed and all causes of tree mortality were identified (Pronos and Schultz, 1983). Fifty trees died in the one year, and 22% of the mortality was attributed to western dwarf mistletoe (*Arceuthobium campylopodum*) in ponderosa and Jeffrey pines. Pine bark beetles, primarily the western pine beetle (*Dendroctonus brevicomis*) caused the most damage.

As a result of this information, the Park requested FPM funds to control dwarf mistletoe. The site was judged suitable for a control project based on the amount of mistletoe present and because there was enough uninfected or lightly infected trees to ensure adequate stocking after treatment. The project was approved and suppression activities began in 1984.

Objectives

The Park was willing to be very aggressive in an attempt to remove all existing dwarf mistletoe. Overall objectives of the project and future vegetation management included:

1. Protect regeneration from infection.
2. Increase longevity of overstory pines.
3. Increase species resistant to western dwarf mistletoe.
4. Prevent re-invasion by creating buffer zones.
5. Replant areas of heavy infection.

Procedures

Pre-suppression surveys and planning for the project began in 1982. All pines within the developed portions of Cedar Grove were inspected for infection and rated using the Hawksworth 6-Class System (Hawksworth, 1977). Each infected tree was numbered, tagged and mapped. Other information gathered during the surveys included: tree height, diameter at breast height (DBH), live crown ratio (LCR), and an estimate of live crown ratio after treatment.

Treatment guides were developed largely from the published report of dwarf mistletoe control efforts in the Grand Canyon (Lightle and Hawksworth, 1973). They included:

1. Trees rated 5 or 6 should be removed.
2. Trees rated 4 may be pruned if there is no mistletoe in the upper 1/3 crown.
3. Prune trees rated 1-3.
4. All pruning cuts should be made at the bole.
5. Begin pruning two branch whorls above the highest visible plants, and remove all branches below this point.
6. Remove trees with bole infections if the bole is less than 6 inches in diameter at the point of infection.
7. A minimum of 30% live crown should remain after pruning.
8. Do not remove more that 50% of the live crown.

Results

Over the duration of the project, 263 acres were treated. This included the four campgrounds (140 acres), adjacent buffer zones, Park Service housing areas, concessionaire facilities, and a pack station. All work was done by Park Service personnel. Each spring, before the facility was opened to the public, specific sites were treated, from pruning and tree removal to clean-up and site rehabilitation before going to the next treatment area. This minimized visual impact to the visitors and avoided closing sites during the summer season.

Of the 4,997 trees that were treated over the entire Cedar Grove area, 2,897 were removed and 2,100 were pruned. Tree removals averaged 11 per acre while trees pruned averaged 8 per acre.

Figure 1 compares the number of trees, either pruned or removed, by size class (DBH) in Sheep Creek Campground (32.5 acres). This campground was completed in 1984, the first year of the project. Over 900 pines were treated in one season. Twice as many trees were removed than were pruned and most of the removed trees were in the smaller size classes. About one-half of all removed trees were less than 11 inches DBH. The greatest number of pruned trees were in the 11 to 29 inch DBH class. Figure 2 shows the same two treatments in Sheep Creek Campground but displayed by Hawksworth dwarf mistletoe ratings. It was not surprising that most of the trees removed were those heavily infected with dwarf mistletoe. As indicated by the treatment guidelines, most trees rated 3 or less should have been pruned. Lightly infected trees were removed if they were in dense aggregations that would benefit from thinning.

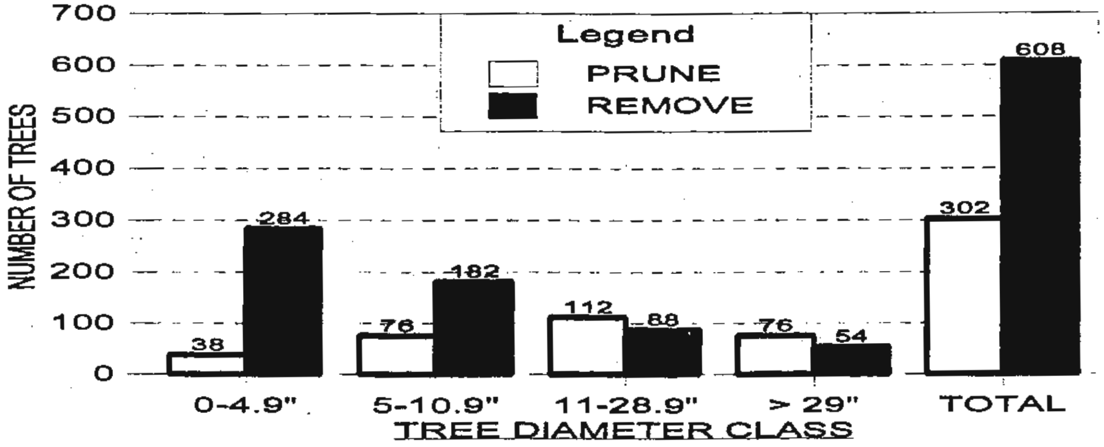


Figure 1. The number of pines pruned or removed in different diameter (DBH) size classes - Sheep Creek Campground.

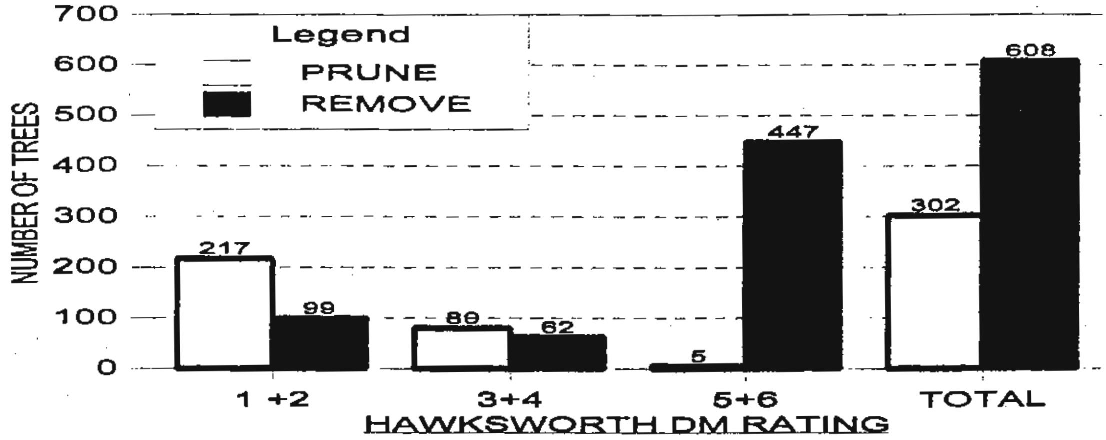


Figure 2. The number of pines pruned or removed and their Hawksworth dwarf mistletoe rating - Sheep Creek Campground.

Tree Mortality

The death of pines that were pruned was monitored and used to provide feedback to project guidelines, primarily the protocol requiring a minimum of 30% live crown after pruning. During this 8-year project, 79 trees died. Fifty -eight of these died before treatment, in other words they died after tagging but before the forestry crew was able to treat them. The remaining 21 trees died after they were pruned. Of these 21, 8 had less than 30% live crown following treatment while 13 had 30% or more live crown. When compared to the entire population of pruned trees, 3.9% of trees with less than 30% residual live crown died while 0.1% of all trees with 30% or more live crown died.

Project Effectiveness

Each of the four camp- grounds and adjacent buffer areas were entered and treated three times between 1984 and 1992. Not all of the concessionaire and Park Service administrative sites were worked three times.

Data collected for each entry into the four campgrounds is summarized in Figure 3. This information can be used to answer the question whether dwarf mistletoe can be eliminated from recreation sites. Mistletoe plants were still present in the all of the campgrounds after two entries. Our conclusion was that most dwarf mistletoe discovered after treatments was from latent infections becoming visible, and the minority were from plants missed during surveys. A survey of the campgrounds after the third entry has not been completed. This information will determine whether three treatments were successful in eradicating mistletoe.

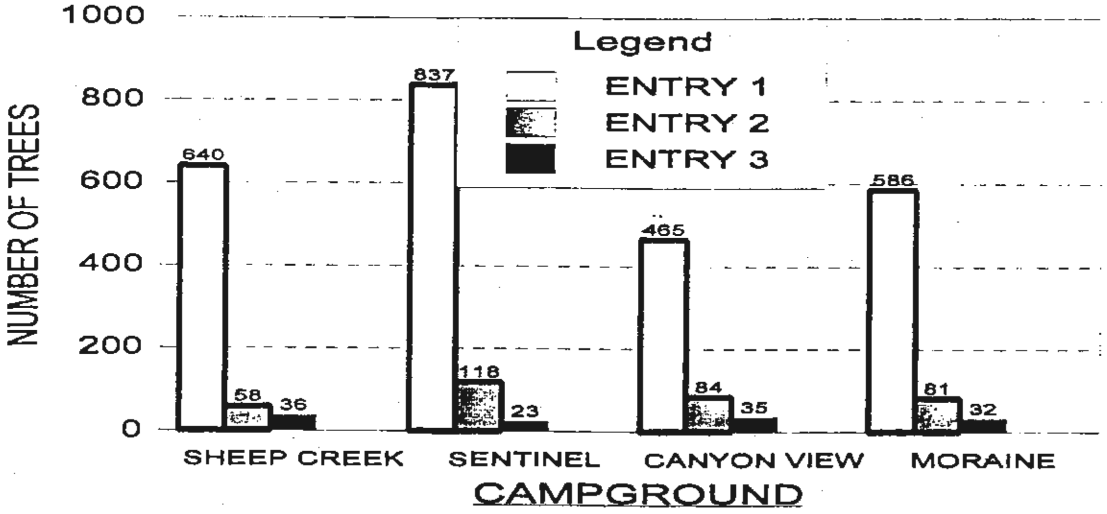


Figure 3. The number of pines treated during each entry into the four campgrounds at Cedar Grove, 1984-1992.

Conclusions

Two entries did not eliminate all dwarf mistletoe from any of the campgrounds at Cedar Grove, even though the Park Service did an excellent job of implementing the guidelines. All aspects of the project, from surveys through site rehabilitation were very well done. The inability to eradicate dwarf mistletoe illustrates the difficulty in detecting the parasite in every tree over hundreds of acres, and the complicating factor of latent infections.

With many projects, it is a challenge to complete even two entries. Recommending National Forests and Parks to do at least three entries seems unreasonable and unnecessary. More important for successful dwarf mistletoe suppression are treating sites before infection levels become too high and following established treatment guides aggressively. Both of these were done at Cedar Grove, and the mistletoe there has been reduced to such an in-significant level, that it will not be a management concern for many decades.

References

Hawksworth, F.G. 1977. The 6-class dwarf- mistletoe rating system. USDA Forest Service, Gen. Tech. Rep. RM-48. 7p.

Lightle, P.C., and Hawksworth, F.G. 1973. Control of dwarf mistletoe in a heavily used ponderosa pine recreation forest: Grand Canyon, Arizona. USDA Forest Service, Research Paper RM-106. 22p.

Pronos, J. 1981. An evaluation of dwarf mistletoe in Cedar Grove campgrounds. USDA Forest Service, Forest Pest Management, Pacific Southwest Region, Report No. 81-11. 3p.

Pronos, J. and Schultz, D.E. 1983. Biological evaluation of tree mortality in Cedar Grove campgrounds. USDA Forest Service, Forest Pest Management, Pacific Southwest Region, Report No. 83-9, 22p.

IMPROVING FOREST RESOURCE INVENTORIES: DISEASE AND INSECT INFORMATION FROM THE PACIFIC NORTHWEST REGION'S CURRENT VEGETATION SURVEY

Ellen Michaels Goheen
Southwest Oregon Forest Insect and Disease Technical Center
Medford, Oregon 97502

History

Forest Insect and Disease staff in the Pacific Northwest Region have been working closely with Regional Vegetation Inventory staff since the summer of 1992. At that time, we headed a multidisciplinary effort on the Okanogan National Forest to test inventory procedures in anticipation of the startup of a new region-wide vegetation survey. We wanted to ensure that insect and disease information gathered during this effort would be reliable and useful. We needed to test insect and disease data-gathering procedures to understand what to expect from crews who were not insect and disease specialists, to adjust detail and coding to have the information model-ready, and to put the information into the context of other resource information needs. At the closing of the Okanogan pilot study we developed a list of data elements pertaining to insect and disease information. We also developed a set of recommendations we felt would be necessary for success of the program from the insect and disease data perspective. These included:

- Clear inventory procedures, including developing priorities for disease and insect information.
- Improved contract specifications, including incentives for greater detail of disease and insect information.
- Increasing the insect and disease awareness of contract inspectors through training, written material and field visits.
- Increasing the insect and disease awareness of inventory contractors through orientations, written materials, and field visits.

Current Activities

The Current Vegetation Survey (CVS) was instituted in the summer of 1993. It is a permanent plot grid system that samples the range of vegetative conditions across all National Forest lands in the Pacific Northwest Region. The Sample Unit encompasses 1 hectare and uses a cluster of subplots of various sizes to sample existing vegetation including deciduous and coniferous trees, shrubs, indicator shrubs, forbs, and grasses, down-woody material, and standing dead trees. CVS plots are established on a 3.4 mile grid across all National Forest lands and on a 1.7 mile grid on all non-designated National Forest lands. Currently, all of the 19 National Forests in the Pacific Northwest Region have some plots established; information from Regional 3.4 mile grid plots is expected to provide the basis for the 1996 National RPA Report. A few forests have completed all plots on the 3.4-mile grid and anticipate finishing the 1.7 mile grid within the next year.

Disease and Insect Information

Disease and insect information collected on each sample unit include:

- Root Disease Severity Rating (Hagle 0-9 point scale) at each of the five .02-hectare subplots.
- Individual tree Damage and Severity.
- Tally of stumps with root disease by species and size class.

Emphasis is placed on coding observable insects, pathogens, or damage. Determining "cause of death" is no longer up to the contractor. Priority is given to bark beetles, defoliating insects, dwarf mistletoes, root diseases, and topkill or topbreak above other agents or damage categories. Group codes are allowed (bark beetles, root diseases, cankers, etc.) although additional points can be acquired by contractors for correctly identifying certain specific agents). Severity is assessed by noting observable characteristics such as proportion of crown affected, or injury to main stem rather than relating damage to volume loss.

Training and Consultations

Since 1993, much emphasis has been placed on increasing the insect and disease awareness of both inventory contractors and contract inspectors. Formal field training sessions and orientations have been held throughout the region. Follow-up sessions have occurred on some forests throughout the field season. Visits have been made to specific plots to answer questions pertaining to proper coding and grading. FID staff have been involved in resolving formal conflicts between contractors and inspectors. All crews have been provided with field guides and other literature helpful for identifying insect and disease damage.

Data Outputs

Data are available in raw form on an R-base database. Plot data can also be processed through a program written by Tom Gregg into a series of output tables. These output tables include:

- stand tables by species and 2-inch diameter classes for trees per acre and basal area per acre,
- trees per acre and basal area per acre by species, by damage codes,
- 2-inch diameter class breakdown by damage code,
- dwarf mistletoe severity by host, by 2-inch diameter classes,
- standing dead trees by snag category,
- down-woody material reported as pieces per acre and tons per acre,
- an FVS-ready tree list,
- an FVS keyword set that includes initial conditions for root disease, if present on the plot.

Challenges of Data Collection

Even with a fairly rigorous approach to training, orientation, and consultation, misidentification of insects, pathogens, or their damage, does occur during the data collection process. Root diseases and bark beetles cause the greatest amount of confusion for both contractors and inspectors; miscalls in these groups cause the greatest number of contractor errors, with root diseases leading the way. Regionally, Armillaria root disease seems to challenge the data collectors the most; they must distinguish between tree-killing *A. ostoyae* and secondary/saprophytic *Armillaria* spp. associated with suppression mortality. A great deal of effort has been spent in the field to provide examples and guidelines. Distinguishing between laminating decays caused by *Heterobasidion annosum* and *Phellinus weirii* also seems to be a problem, particularly on white and grand firs and mountain hemlock.

Crews have also had difficulty identifying stumps with root disease. Much of this error is due to missing the stumps themselves; additional error comes from the confusion associated with other fungi that inhabit stumps.

Errors related to bark beetles include difficulty identifying the year of attack; severity codes for bark beetles include categories such as successful current attack, last year's attack, and older dead. There also seems to be some difficulty distinguishing pitch streams or tubes related to bark beetles and pitch streaming associated with other causes.

Even with multi-year contracts, the beginning of the field season brings the most questions related to identification and coding. Depending on the contractor, there can be a large crew turnover, but most often crews feel more confident after refresher training and orientation. As the spring and summer progress, questions become less frequent, are more sophisticated, and related to subtle differences in the forest ecosystems being sampled.

There is a certain amount of root disease that will be missed in this inventory effort. Annosus root disease is identified based only on advanced decay characteristics or fruiting bodies. Crews do not use staining associated with incipient decay on recently killed trees to positively identify this root disease.

Results from One Forest

The Winema National Forest, located on the east slope of the Cascade Mountains in southern Oregon, has completed all field work on the 3.4 and 1.7 mile grids. Data are available for 139 3.4 mile grid plots (100%) and for 383 1.7 mile grid plots (90%). Only very preliminary analysis of these insect and disease data has occurred at this time.

A standardized (Regional CVS process) Accuracy Assessment was completed on the 3.4 mile grid plots. It showed that for 163 plots assessed, inspector data and contractor data agreed 98% of the time for plot-level Root Disease Severity Ratings, with a confidence interval between 97% and 100%. This high level of accuracy is probably related to the fact that root disease itself only occurs on 27% of plots on this grid; therefore, many plots have ratings of zero. Individual tree damage code assessments were in agreement 93% of the time (CI=90-98), for 2350 trees. Stumps with root disease presented the greatest insect/disease-related accuracy loss; stump tallies agreed only 66% of the time (CI=45-88) and identification of root disease agreed 72% of the time (CI=52-93). Some changes have been made over the last 3 years to decrease the chances of missing stumps. Assistance in identifying root diseases in stumps will have to continue.

Root disease was found on 26.6% of all 3.4 mile grid plots on the forest. Eighty-three percent of 24 plots on the Klamath Ranger District, 17% of 54 plots on the Chemult RD, and 13% of 61 plots on the Chiloquin RD were identified as having some level of root disease. A breakdown using Root Disease Severity Rating indicates that most plots fell into the low impact category. It was possible to look at the 1.7 mile grid plots in addition to the 3.4 mile grid plots for root disease. In general the proportions of plots with root disease remained very similar for each ranger district. Areas of the forest with root disease that were not identified with only the 3.4 mile grid were picked up with the higher resolution sampling.

Dwarf mistletoe is extremely common on the forest. Sixty-seven percent of all 3.4 mile grid plots had at least one tree with dwarf mistletoe. Seventy percent of the plots on the Chemult RD, 59% of the plots on the Chiloquin RD, and 75% of the plots on the Klamath RD had dwarf mistletoe recorded.

Conclusions and Recommendations

In general, the information that is coming from the inventory at the group code level of resolution seems reliable, particularly related to incidence. Pathologists and entomologists working with the data will undoubtedly have some adjusting and massaging to do, particularly related to root disease, when they attempt large scale analyses; however, that was assumed to be likely when the inventory was designed. In some respects, that close scrutiny will be valuable because it will involve the pathogen and insect specialists more closely in the planning process. The information will allow us to look at thousands of individual trees for wildlife habitat characteristics, use, and damage and severity codes. These data also afford a great opportunity for hazard analyses related to site characteristics. The plot system supplies us with another set of permanent plots to include in our own model validation and calibration efforts. It also provides us with additional information to include in our Forest Health Monitoring efforts.

Our job is not finished. The CVS effort continues n the region, and crews turnover or move into different forest ecosystems. They require our help with training and orientations related to identification, and consultation on challenging plots and will continue to do so in the future. We will be assured reliable data and fully understand its limitations only if we remain committed to the process.

PANEL
WHITEBARK PINE IN WESTERN FOREST ECOSYSTEMS

John Schwandt, Moderator

AN INTRODUCTION TO WHITEBARK PINE ECOLOGY AND STATUS

Katherine C. Kendall
USDI National Biological Service, Glacier Field Station, Glacier National Park
West Glacier, MT 59936

Ray J. Hoff
USDA Forest Service, Intermountain Research Station
1221 South Main, Moscow, ID 83843

Introduction

Whitebark pine (*Pinus albicaulis*) grows in the highest elevation forests in northwest United States and southwest Canada. It is considered a keystone species because it plays a pivotal ecological role in forests wherever it is a prominent stand component. The scale of whitebark pine's influence is broad; its presence affects animal populations, vegetation communities, and landscape processes.

The range of whitebark pine is split. One section follows the British Columbia Coast Ranges, the Cascade Range, and the California Sierra Nevada. The other extends along the Rocky Mountains from British Columbia and Alberta to Wyoming. Several isolated occurrences are evident between these main distributions, on high peaks and ridges within the sagebrush steppe of northeastern California, south-central Oregon, and northern Nevada. Elevation ranges from 1,524 m in the northwestern portion of its range and more than 3,659 m in portions of its southern range (Arno and Hoff 1989).

Taxonomy, Evolution, and Seed Dissemination

Whitebark pine is included in the Subgenus Strobus, Section Strobus, Subsection Cembrae. It also belongs to a group of pines, the "bird pines", that have wingless or nearly wingless seed. World wide, there are 21 bird pines, 20 in the Subgenus Strobus and one in the Subgenus Pinus. The bird pines are so named because the seed are cached by birds such as nutcrackers and jays. All of these pines grow and regenerate under stressful conditions. The sites are either water-limited and/or very windy in xeric woodland or alpine communities.

The pines of Subsection Cembrae are five-needled, and the cone scales don't open widely. A fibrous tissue in the cone scales of other pines shrinks when dried, causing the scales to reflex; this fibrous tissue is missing in all the Cembraen pines (Harlow, Cote, Jr. and Day 1964). However, when dried, the cone scales do open 3-4 mm and the seed can be seen.

Seed of the Cembraen pines are eaten and/or cached by several animals. However, most species are dependent on one group of birds, the nutcrackers, for regeneration (Lanner 1980, Tomback 1983). For whitebark pine there is nearly 100% dependency on Clark's nutcracker (Tomback, 1978 Lanner 1980, Hutchins and Lanner 1982). Factors that adapt whitebark pine for nutcracker use are: large seeds, high energy per seed per cone, cones are horizontal or upright on the tree so they are easily seen by birds, seed is easy to collect since they are wingless, cones are retained on tree, seed stay in cone since it is indehiscent, and the scales have a weak point at their middle--making it easier for the nutcracker to break off the scale and get the seed (Lanner 1982). Factors that adapt the nutcracker to whitebark pine are: a long, strong bill that can be driven into the cone, a throat pouch that can hold more than 100 seeds (the opening is anterior to the tongue), and long term memory (Tomback 1982). Lanner (1980) summed up the relationship between birds and pines best: "The bird pines in a sense are domesticated plants that have been bred for traits desired by the breeder; perhaps the earliest products of a tree improvement program in the genus *Pinus*".

Seed are cached in a variety of sites throughout montane habitats in loose gravelly soil, in forest litter, at the base of trees, rocks, and logs, among roots, rocky rubble, and in holes and cracks and under the bark of trees. These sites have been observed in a wide range of elevations, in burns, clearcuts, forest openings, lake shores, meadow edges, cliffs, tundra, and newly released glacial moraines.

Bird caching strategies vary. One bird may plant all seed in one area or plant in several areas. Often, groups of nutcrackers (from several to as many as 150 birds) will cache in an area from several stands. Clark's nutcrackers can carry 150 or more whitebark pine seeds in their throat pouch and have been observed caching seed up to 22 km from the seed source (Table 1). Seed is buried about 2 cm. deep; the ideal depth for whitebark pine seed germination.

Table 1. Clark's nutcracker seed dissemination parameters.

Pouch load: range = 35-150 seeds; average = 77-93 seeds.

Cache distance: Base of tree to 22 km.

Number of seeds cached: range = 1-14; average = about 4.

Cache depth: range = 1-3 cm; average = 2 cm.

Distance between caches: range = 10-300 cm; average = 67 cm.

Estimates of the number of seed cached annually per bird range from 32,000 to 98,720 (Hutchins and Lanner 1982, Tomback 1980). The data used to establish the latter estimate are listed in Table 2. Tomback (1982) estimated that 45% of the cached seed was excess to the nutcracker's needs and therefore potentially available for whitebark pine regeneration. With flocks of 10-15 or even up to 150 birds, there are enormous quantities of seeds "planted" by nutcrackers per year. Most of the data on seed dissemination and Clark's nutcracker harvest and caching rates are taken from articles by Diana Tomback, University of Colorado, Denver and Ron Lanner, Utah State University. Several of their articles are listed in the bibliography.

Importance To Animals

Whitebark pine seeds are a valuable and highly preferred wildlife food because they are large and high in fat and protein. Considering the coevolved relationship between nutcrackers and whitebark pine, it is not surprising that whitebark pine seeds are an important food source for Clark's nutcrackers. The cached seeds provide excellent nutrition for their early-hatching young, as well as, winter and spring food for adult birds. Whitebark pine seeds are a favored food and in years of cone crop failures, mass migrations of nutcrackers are reported.

Table 2. The number of whitebark pine seed harvested and cached by Clark's nutcrackers (from Hutchins and Lanner 1982).

Seed per pouch = 93.

Time to fill pouch at 8.14 seconds/seed = 757 seconds.

Flight time to cache area 7 km at 47.1 km/hr = 514 seconds.

Time to cache seed = 600 seconds.

Time for maintenance and social behavior = 900 seconds.

Time per trip = 2,546 seconds.

Average trips per 9 hour day = 13.

Harvest per year at 80 day harvest = 98,720 seed.

As with most other animals that feed on pine seeds, red squirrels prefer whitebark seeds to other, smaller seeds. In whitebark pine stands populated by squirrels, the squirrels usually harvest more seed than nutcrackers. The squirrel's competitive advantage lies in its ability to quickly cut large numbers of cones from the trees and cache them in middens on the ground where they are mostly unavailable to birds. Their well-stocked middens, however, are not secure from other seed predators.

In all areas where whitebark pine stands occur in grizzly and black bear ranges, pine seeds are a prized bear food. In fact, bears are known, at times, to prefer whitebark pine seeds to spawning salmon and abundant berries. While black bears occasionally climb trees and harvest cones, grizzly bears must rely on squirrels to make pine seeds available to them. Where whitebark pine is abundant, its seeds comprise the bulk of the fall diet. Following bumper cone crop years, when huge stores of cones remain in middens in spring, pine seeds may dominate grizzly and black bear food habits for the entire next year. In the Yellowstone area, grizzly bear survival is positively related to the cone crop size. When there are no pine seeds, mortality rates are higher because bears wander more widely, at lower elevation, and more often come into conflict with people.

A large variety of other animals eat whitebark pine seeds and use the trees for shelter (Kendall and Arno 1990). In addition to bears and red squirrels, mammals observed feeding on pine seeds include deer, coyote, golden-mantled ground squirrels, chipmunks, mice, and voles. Besides nutcrackers, avian whitebark pine seed predators include Steller's jay, common ravens, white-headed and hairy woodpeckers, Williamson's sapsucker, mountain chickadee, red- and white-breasted nuthatch, Cassin's finch, red crossbill, and pine grosbeak (Hutchins and Lanner 1982). Red squirrels, northern flickers, and mountain bluebirds, at times, use whitebark pine tree cavities for their nests. The spreading crowns of whitebark pine trees provide protected roosting sites for birds such as blue grouse.

Influence On Vegetation Patterns and Landscape Processes

Whitebark pine is an important influence on vegetative patterns and biodiversity in the high elevation of the west. Whitebark pine can tolerate harsh conditions in which few or no other plants can survive. Thus whitebark pine forms the treeline forest in many areas. In other harsh sites, whitebark pine may establish first and its presence modifies the microclimate enough to allow other plants, such as subalpine fir, to grow. Because Clark's nutcrackers tend to cache seed in open, windy sites and can transport seed long distances, high-elevation burns and other high-altitude disturbed sites, are pioneered by whitebark pine trees.

The presence of whitebark pine affects snow accumulation and retention in the drainages where it occurs. Its full crown acts as a wind break and causes snow deposition in the high country and on windswept ridges. The resultant drift patterns affect the timing of snow melt and, thus, the hydrologic characteristics across landscapes.

Management Challenges

Unfortunately, introduced disease and fire suppression have caused drastic declines in whitebark pine stands. Where it is a seral species, whitebark pine depends on crown fires to maintain stands. Shade-tolerant conifers replace whitebark pine trees in the absence of fire. The natural fire-return interval for whitebark pine stands is 50-350 years but under current fire regimes, the typical whitebark pine stand will burn at a 3,000+ year interval. In the Columbia River basin, whitebark pine stand acreage has been reduced by half this century, principally by competitive replacement.

Fire suppression is also responsible for increased insect and parasite damage in whitebark pine stands. Under natural conditions, mountain pine beetles usually cause little damage to whitebark pine stands. With wild fire suppression, the natural mosaic of varying age stands is replaced with large blocks of lodgepole pine forest, which are extremely vulnerable to mountain pine beetle epidemics. Unnaturally high populations of beetles develop which tend to spill up into high-elevation whitebark pine stands and kill many trees. Dwarf mistletoe infections primarily are kept in check by stand-replacing fire. Without it, heavy infections can develop, such as on Mt. Shasta, California, where whitebark pine mortality from mistletoe exceeds 80%.

The biggest threat to whitebark pine is from an exotic fungus, white pine blister rust (*Cronartium ribicola*). It is estimated that less than one whitebark pine tree in 10,000 is naturally resistant to blister rust. Across its northern range, 50-100% of the whitebark pine has been killed, primarily by blister rust, and the majority of remaining live trees are infected. Infection and mortality rates are lower to the south where conditions are drier, but rust infection appears to be on the increase and large die-offs are expected eventually.

High mortality of whitebark pine in the Selway/Bitterroot Mountains, Montana and Idaho and the potential for whitebark pine mortality in the greater Yellowstone ecosystem, have important implications to grizzly bear conservation efforts. Currently, grizzly bears are proposed for reintroduction to the Selway/Bitterroot

Mtns. but habitat evaluations do not account for the elimination of whitebark pine as a food source. It also has been suggested that the grizzly bear population in Yellowstone has sufficiently recovered to warrant removal from the threatened species list. Any delisting deliberations must consider the projected fate of whitebark pine in this ecosystem as they affect bear food supplies and mortality rates.

Management Options

There are several options for managing whitebark pine in the face of these threats. Because whitebark pine grows slowly and is usually about 100 years old before it produces cones, all approaches require a long-term perspective. One practical option is to create natural selection stands. These can be made by selecting 10-20 acre areas where there is good whitebark pine regeneration and thinning all competing species. This leaves a larger number a healthy seedlings on which nature can select for rust-resistant types. In contrast, in most managed forest lands today, all whitebark is removed from regenerating clear cuts and burns to favor target timber species.

A breeding program has successfully developed blister rust-resistant western white pine; the same could and, we believe, should be done for whitebark pine. To provide suitable habitat for whitebark pine to grow, we must continue efforts to once again allow fire to perform its essential role in landscape processes, especially in National Forest and Park wilderness areas. Finally, we should collect and store whitebark pine seed from throughout its range to prevent the loss of potentially unique genetic types. Once a population is 0.0001 of its original size, a catastrophic event like a mountain pine beetle epidemic or fire could easily kill the remaining individuals. We encourage managers to support all these approaches to whitebark pine conservation.

Selected Bibliography

Arno, S.F.; Hoff, R.J. 1989. Silvics of whitebark pine (*Pinus albicaulis*).USDA, Forest Service, Intermountain Research Station, General Technical Report INT-253.

Bedwell, J.L.; Childs, T.W. 1943. Susceptibility of whitebark pine to blister rust in the Pacific Northwest. Journal of Forestry 41:904-912.

Harlow, W.M.; Cote, W.A.,Jr.; Day, A.C. 1964. The opening mechanism of pine cone scales. Journal of Forestry 62:538-540.

Hutchins, H.E.; Lanner, R.M. 1982. The central role of Clark's nutcracker in the dispersal and establishment of whitebark of pine nuts. Oecologia 55:192-201.

_____. 1989. Whitebark pine seed dispersal and establishment: Who's responsible? Proceedings: Symposium on Whitebark Pine Ecosystems: Ecology and Management of a High-Mountain Resource. USDA For. Serv. Gen. Tech. Report INT-270. Pg.245-255.

Kendall, K.C. 1983. Use of pine nuts by grizzly and black bears in the Yellowstone area. Int. Conf. Bear Res. and Manage. 5:166-173.

_____; Arno, S.F. 1990. Whitebark pine--An important but endangered wildlife resource. Proceedings: Symposium on Whitebark Pine Ecosystems: Ecology and Management of a High-Mountain Resource. USDA For. Serv. Gen. Tech. Report INT-270. Pg.264-273.

_____. 1995. Whitebark pine: Ecosystem in peril. *In* LaRoe, E.T., Farris, G.S., Puckett, C.E., Doran, P.D., and Mac, M.J. eds. Our living resources: a report to the nation on the distribution, abundance, and health of U.S. plants, animals, and ecosystems. USDI National Biological Service, Washington, D.C. Pg. 228-230.

Lanner, R.M. 1980. Avian seed dispersal as a factor in the ecology and evolution of limber and whitebark pines. Proceedings Sixth North American Forest Biology Workshop, University of Alberta, Edmonton, Alberta, Canada. Pg. 15-48.

_____. 1982. Adaptations of whitebark pine for seed dispersal by Clark's nutcracker. Can. J. For. Res. 12:391-402.

_____. 1985. Made for each other: Clark's nutcracker and whitebark pine. Pacific Discovery 38:31-35.

_____. 1990. Biology, taxonomy, evolution, and geography of stone pines of the world. Proceedings: Symposium on Whitebark Pine Ecosystems: Ecology and Management of a High-Mountain Resource. USDA For. Serv. Gen. Tech. Report INT-270. Pg. 14-24.

_____. 1990. Morphological differences between wind-dispersed and bird dispersed pines of subgenus Strobus. Poster shown at Symposium on Whitebark Pine Ecosystems. USDA For. Serv. Intermountain Research Station Gen. Tech. Report INT-270. Pg.371-372.

Tomback, D.F. 1977. Foraging strategies of Clark's nutcracker. Living Bird 16:123-160.

_____. 1977. The behavioral ecology of the Clark's nutcracker *(Nucifraga columbiana)* in the eastern Sierra: How nutcrackers find their seed stores. Condor 82:10-19.

_____. 1981. Notes on cones and vertebrate-mediated seed dispersal of *Pinus albicaulis*. Madrono 2891-95.

_____. 1982. Dispersal of whitebark pine seeds by Clark's nutcracker: A mutualism hypothesis. Journal of Animal Ecology 51:451-467.

_____. 1983. Nutcrackers and pines: Coevolution or coadaptation? *In*: Nitecki, M. H., ed. Coevolution. Chicago and Longon; University of Chicago Press. Pp. 179-223.

_____; Hoffmann, L.A.; Sund, S.K. 1990. Coevolution of whitebark pine and nutcrackers: Implications for forest regeneration. Proceedings: Symposium on Whitebark Pine Ecosystems: Ecology and Management of a High-Mountain Resource. USDA For. Serv. Gen. Tech. Report INT-270. Pg.118-129.

_____.; Linhart, Y.B. 1990. The evolution of bird-dispersed pines. Evolutionary Ecology 4:185-219.

BLISTER RUST RESISTANCE IN WHITEBARK PINE DATA FROM TWO YEARS AFTER INOCULATION

Ray J. Hoff
Intermountain Research Station
Moscow, Idaho 83843

In 1989 I started a progeny test with the objectives to: 1) learn how to grow and maintain seedlings of whitebark pine and 2) to determine the level of resistance in whitebark to see if it is associated with levels of mortality in natural stands.

With much help from Jan Scheffer (manager of the Western Forest Systems, Inc. in Lewiston, Idaho) I was able to grow and maintain most of the seedlings. I lost about 300 seedlings out of 1,000 for various reasons; however I was pleased that most seedlings were killed by blister rust.

The seedlings were sown in spring 1990, inoculated in 1992, when seedlings were three-years-old. Inoculation was carried out using the detached leaf method as outlined by Bingham 1972. Seedlings were rust inspected as outlined by Hoff and McDonald 1980.

The data presented here is from the rust inspection completed in September 1994. The final rust inspection will be completed in September 1995. The data presented are stand and family means. A more complete analysis will be completed after the final inspection.

The blister rust data from this study is very encouraging. Natural stands with high levels of mortality due to blister rust, appear to have high resistance. Stands from moderate and low mortality have much lower resistance (Table 1).

Table 1. Resistance of whitebark pine seedlings artificially inoculated with blister rust.

Stand Type/	Total	No		--------------Defense	Symptoms	--------------	
Percent Mortality	Seedlings	Canker		NoSp	Shed	Shoot	Bark
	#	#	%	#	#	#	#
High Mortality, >90%	319	140	44	1	56	53	30
Moderate Mortality, 50%	136	24	18	1	6	13	4
Low Mortality, < 20%	243	10	4	6	1	1	2
Total	698	174	25	8	63	67	36

This is a lot more resistance then I expected. There will be a few more cankers showing up but I don't expect too many. More than 90% of the seedlings that had cankers in September 1994 were already cankered by September 1993. Then too, more resistance will show up--bark resistance was low in May of 1994, but by September 1994 previous cankers had become resistant bark reactions and the level of resistance took a sharp upward jump. Four resistance symptoms were evident. No Spot (NoSP) seedlings did not have needle spots--could be escapes. Premature needle shed (Shed) seedlings had spots but they were prematurely shed before the fungus could grow into the stem. Short shoot (Shoot) seedlings had spots on the needles but the fungus never showed up in the stem and the needles did not drop off earlier then the average for the test.

Bark reaction (Bark) seedlings exhibited a necrotic reaction in the stem, either before a typical normal canker was evident or at the site of a canker.

Several methods for using the resistance of whitebark pine are available, from the traditional candidate selection and seed orchard establishment system to genetic mass selection on the site of natural seedling establishment. Both are useful depending on circumstances and time lines. The seed orchard method will provide higher levels of resistance but will take several decades before a new variety is in place that is producing cones. Whereas with mass selection, a process that is going on now, will provide lower levels of resistance (but maybe better levels since nature is doing the selection) and therefore will produce a fruiting product in a few decades.

Mass selection requires a high number of seedlings that have come from trees that have survived the blister rust epidemic. In many stands that is happening; however, with more than 90% mortality it doesn't seem possible that there would be any seeds left for regeneration, but obviously there are. Maybe this is because of the behavior of Clark's Nutcracker. Clark's Nutcracker appears to be solely responsible for regenerating whitebark pine (see Kendall and Hoff, this proceedings), and it has been reported that it feeds for 15-20 minutes and then gets to work caching seed. Consequently enough seed appears to be cached and not used by the bird that germinate to become a new generation that has more resistance then the original. Several stands, adjacent to a seed source with more than 90% mortality, have been surveyed. The data varies from 132 seedlings/acre to 1,500 seedlings/acre. If these new stands of seedlings have forty percent resistance then a relatively high number of trees will probably survive to flowering time, even at the low end of the scale.

Presently, both mass selection and the seed orchard methods have been started. However, mass selection has been going on for at least a decade or two or even longer depending upon when the mortality level of a particular stand occurred and if there was a site for the Nutcracker to store seed.

What we can do to augment the mass selection method is to manage stands with a high component of whitebark pine in favor of whitebark by thinning out competing species. This probably doesn't need to continue through the life of the stand but only long enough to permit whitebark pine to grow far enough ahead of the other competing conifers so that it would remain as a viable and fruiting component for 1-200 years. Other management options are to install clearcuts or permit stand replacement fires to burn near a whitebark pine seed source. Clark's Nutcracker flies over a large range and will know what to do when the opportunity arises.

Literature Cited

Bingham, R.T. 1972. Artificial inoculation of large numbers of *Pinus monticola* seedlings with *Cronartium ribicola*. In: Biology of rust resistance in forest trees. P. 357-372. USDA For. Serv. Misc. Publ. 1221, 681 p.

Hoff, R.J. and G.I. McDonald. 1980. Improving rust-resistant strains of inland western white pine. USDA For. Serv. Res. Pap. INT-245, 13 p.

RESTORATION OF UPPER SUBALPINE WHITEBARK PINE (*Pinus albicaulis*) ECOSYSTEMS IN WESTERN MONTANA

Robert E. Keane and Stephen F. Arno
USDA Forest Service, Intermountain Fire Sciences Lab
P. O. Box 8089, Missoula, MT 59807

Cathy Stewart
USDA Forest Service, Bitterroot National Forest
88 Main Street, Stevensville, MT 59870

Abstract

Whitebark pine (*Pinus albicaulis*) is an important tree species of Pacific Northwest, upper subalpine forests. Its large nut-like seeds are a major food source for many mammals and birds including squirrels, black and grizzly bears, and Clark's nutcrackers. Whitebark pine has experienced a severe decline in the last 60 years as a result of 1) epidemics of mountain pine beetle (*Dendroctonus ponderosae*); 2) the exotic disease white pine blister rust (*Cronartium ribicola*); and 3) successional replacement by shade-tolerant conifers, subalpine fir *Abies lasiocarpa*) and Engelmann spruce (*Picea engelmannii*), presumably because of fire exclusion. Three west-central Montana study areas will be used to investigate the effect of silvicultural and prescribed burning treatments on whitebark pine growth response and regeneration. These study areas were historically dominated by whitebark pine and are currently experiencing an increase in rust infection, rust mortality and subalpine fir invasion. Prescribed burning will be used to remove competing tree species, especially subalpine fir, and promote whitebark pine growth and regeneration. Release cuttings will also remove competing conifers to improve whitebark pine health and cone production. All trees will be removed in some sites to encourage seed caching by the Clark's nutcracker. Blister rust-resistant seedlings will be planted in openings. The first results from these studies should be available by 1998 or 1999.

Background

Whitebark pine (*Pinus albicaulis*) is a critical tree species of upper subalpine forests of the northern Rocky Mountains (see Schmidt and McDonald 1990). It is an important nutritional and structural component of wildlife habitat (Arno and Hoff 1990; Schmidt and McDonald 1990). Its large, nut-like seeds are a major food source for many birds and mammals (around 105 species) including squirrels, black and grizzly bears, and Clark's nutcrackers (Hutchins and Lanner 1982). The species can protect watersheds by stabilizing soil and rock on the harshest sites, and by catching and retaining snowpack. Historically whitebark pine was a major species on 10-15 percent of the forest landscape in western Montana and central Idaho (Arno 1986); thus its perpetuation is critical for maintaining natural biodiversity and landscape structure.

A severe decline in whitebark pine has occurred during the last 60 years as a result of three interrelated factors (Kendall and Arno 1990, Keane and Arno 1993): 1) epidemics of mountain pine beetle (*Dendroctonus ponderosae*); 2) the introduced disease white pine blister rust (*Cronartium ribicola*); and 3) successional replacement by shade-tolerant conifers, specifically subalpine fir (*Abies lasiocarpa*) and Engelmann spruce (*Picea engelmannii*), probably as a result of fire exclusion policies of the last 60-80 years.

A recent 20-year remeasurement of whitebark pine inventory plots in western Montana revealed that severe blister rust mortality is "spreading" eastward and southward in the Northern Rockies (Keane and Arno 1993). Significant losses of whitebark pine have occurred due to mountain pine beetles and successional replacement in the absence of fire (Arno and others 1993), even in areas that so far have only light blister rust damage such as the Greater Yellowstone Ecosystem.

Whitebark pine benefits from wildland fire because it is better able to survive fire than its associated shade-tolerant trees (Arno 1986). Also, it readily recolonizes extensive stand-replacement burns because its seeds are brought in from distant adjacent stands and cached in the soil by Clark's nutcrackers. The nutcrackers can disperse whitebark pine seeds up to 100 times further than wind can disperse seeds of subalpine fir and spruce (Schmidt and McDonald 1990, Keane and others 1990). Most whitebark pine regeneration is from unexcavated seeds that germinate and grow. The nutcracker prefers open sites with many visual cues for seed caching, much like the conditions after stand-replacement fires (Schmidt and McDonald 1990).

Application of silvicultural cutting to favor retention of whitebark pine, along with prescribed burning and planting of rust resistant seeds and seedlings, has been suggested for restoring damaged whitebark pine communities. However, these practices have not been demonstrated or tested in research studies (McCaughey 1990). The general goal of this study, which is currently in progress, will be to test the use of prescribed burning, release cuttings, and natural and artificial regeneration methods to increase regeneration success and promote vigorous growth of whitebark pine stands. Most treatments will be implemented in 1995-1997 and the first results from this study will be available within 5 years. All research plots will be monitored for a decade or more.

Study Areas and Treatments

Three study areas have been selected to investigate the effect of silvicultural and burning treatments on whitebark pine growth response and regeneration: 1) Coyote Meadows, 2) Smith Creek, and 3) Snowbowl Ski Area (Figure 1). Additional study areas will be added contingent on funding, scientist availability, and Ranger District support. These study areas are similar in that they were historically dominated by whitebark pine. All are in the same general geographical region: west-central Montana, and have comparable fire regimes. Also these areas are currently experiencing an increase in rust infection, rust mortality, and subalpine fir invasion.

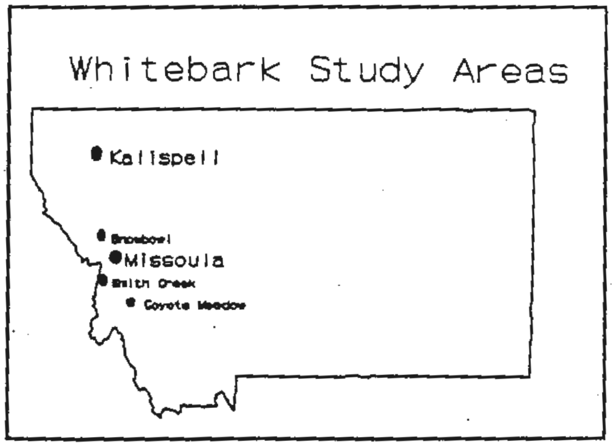


Figure 1 -- Map of Montana, USA showing locations of three whitebark pine study areas.

Since each demonstration area is different in terms of tree composition, structure, and site conditions, we developed different sets of treatments for each study area. In general, all treatments involve the use of tree cutting (silvicultural treatments) and prescribed fire (burn treatments) to accomplish the study objectives. Silvicultural treatments being tested include release cuttings, fuel enhancement, thinning, and understory removal. Differences in burning include no burn treatments, burns in natural fuels, burns in natural plus augmented (i.e., slash) fuels, burns in young and old stands, slash pile burns, and jackpot burning.

Coyote Meadows Study Area

Description -- This study area is within and immediately adjacent to a 1960's logging unit on a 2500 meter ridge in the Sapphire Range on the Bitterroot National Forest southeast of Hamilton, Montana. The site originally supported a forest of mostly large whitebark pine mixed with lodgepole pine (*Pinus contorta*), spruce, and subalpine fir. There are primarily two habitat types represented on this site: subalpine fir/woodrush (ABLA/LUHI) and subalpine fir/bluejoint (ABLA/CACA) (Pfister and others 1977). Most of this cut-over area was logged in an overstory removal treatment with no subsequent site preparation or burning, and as a result, it is dominated by patches of small subalpine fir, many of which pre-date the logging. Within the logging unit there is a 5 hectare stand of unlogged old, dying whitebark pine with an understory of subalpine fir. Fire scars on the pines indicate that the stand last underburned in 1780 at a rate of one fire every 120 years. Presumably, coverage of competing subalpine fir would have been greatly reduced if fires had continued to occur at a rate of one per century. This unlogged stand also experienced heavy mountain pine beetle mortality starting about 1927 as evident from old, large whitebark pine snags and release years dated from tree ring records of surrounding live trees.

Adjacent to and south of the logging unit are two other study stands. One is a very old (>300 years) whitebark pine stand that is dying of blister rust and giving way to fir and spruce. The other is a portion of this old stand that burned in a stand-replacing wildfire in 1919. The burn now supports a vigorous stand of young whitebark pine, lodgepole pine, subalpine fir, and spruce.

White pine blister rust infections are common in and around the Coyote Meadows Study Area, but have not yet caused much damage or mortality. There is a vigorous stand of mature whitebark pine that can provide a local seed source. Heavily blister rust infected stands with occasional live trees that may be rust-resistant are located 56 km to the west. This will provide a source of seeds from trees with apparent rust resistance.

Treatments -- The Coyote Meadows Study Area has been divided into 5 treatment areas, each having an untreated control unit and 1 or 2 silviculture or fire treatment units. The treatments are:

> Treatment Area 1 -- Low Density Fir Stand. This area is in the 1960's clearcut and contains little subalpine fir regeneration. It will be broadcast burned with no fuel enhancement treatment. Fuel enhancement is defined in Treatment 2.
>
> Treatment Area 2 -- High Density Fir Stand. This area is also in the clearcut but contains many small subalpine fir. It will receive a broadcast burn with and without silvicultural cuttings to enhance fuel loadings for improving fire spread (i.e., fuel enhancement). Subalpine fir will be selectively cut and left on the ground to cure so the fuel bed will be more continuous.
>
> Treatment Area 3 -- Mature Whitebark Pine Stand. This is the uncut patch within the clearcut boundaries. This stand will receive two prescribed underburns, with and without fuel enhancement cuttings.
>
> Treatment Area 4 -- Old Whitebark Pine Stand. This area is south of the clearcut and will be treated by release silvicultural cuttings performed at two densities (high and low). These thinnings will remove all tree species that are in direct competition with whitebark pine.
>
> Treatment Area 5 -- 1919 Whitebark Pine Stand. This stand was created when the 1919 burn spilled into Treatment Area 4. It will be treated with the same release cutting to high and low residual density.

The Darby Ranger District has finished an operational thinning project in the stands adjacent to this study area. Subalpine fir was removed in all areas where it directly competes with whitebark pine. Lodgepole pine was also removed unless there were no whitebark pine in the immediate vicinity.

Smith Creek Study Area

Description -- This demonstration area is at the head of the Smith Creek watershed near the Glenn Lake Trailhead in the Bitterroot Range, also on the Bitterroot National Forest. The site occupies a southerly aspect ranging between 2130 and 2,300 meters elevation on a ABLA/LUHI habitat type (Pfister and others 1977). Whitebark pine was a major seral component of this upper subalpine forest along with minor amounts of lodgepole pine, subalpine fir, and spruce. Whitebark pine saplings have become established in a clearcut adjacent to the study area and appear to be growing quite well. Two recent burns (1930 burn about 0.5 km west of study area and 1988 burn upslope of area) near the study area may provide additional tree regeneration information for the study. Approximately 90% of the live, mature whitebark pine are infected with blister rust and about 20-30% rust-caused whitebark pine mortality is evident in the stand. Subalpine fir has established in the understory and gaps in the overstory.

Treatments -- Three treatments and a control are implemented on one stand in this demonstration area. The stand is quite homogeneous with respect to vegetation and topography. The three treatments are:

> Treatment 1 - Prescribed Underburn: This treatment will somewhat mimic a natural underburn in whitebark pine. Burning will be done in late summer or early fall. A small amount of felling of subalpine fir may be done prior to burning to provide some red slash to promote fire spread.
>
> Treatment 2 - Nutcracker Cache Openings WITH Fire: Circular openings in the forest canopy will be created (50 meter diameter, 0.2 hectare) by removing all trees to encourage whitebark seed caching by the Clark's nutcracker. All subalpine fir, spruce, dying lodgepole pine, and dying whitebark pine trees will be removed from areas adjacent to the openings leaving an open stand of whitebark pine and lodgepole pine. Slash will be piled in the openings and burned. The areas surrounding these openings will be underburned if feasible.
>
> Treatment 3 - Nutcracker Cache Openings WITHOUT Fire: Circular openings described above be cut as in Treatment 2. Harvested trees will be delimbed at the log deck rather than on-site and no fire will be used to treat the slash in the treatment unit. However, slash may be burned at the log deck. Areas surrounding openings will not be burned.

Snow Bowl Study Area

Description -- This study area is at the headwaters of Lavalle Creek about 16 km northwest of Missoula, MT in the Snow Bowl Ski Area on the Missoula District of the Lolo National Forest. Elevation ranges from 2200 to 2320 meters and aspects are mostly southeast on ABLA/LUHI habitat types. Treatment blocks within study area lie mostly between proposed ski runs in tracts of 2-3 hectares. All have approximately the same site and vegetation conditions. This area is experiencing extensive tree mortality with approximately 60-80% of the overstory whitebark pine killed by blister rust (Keane and Arno 1993). Subalpine fir is starting to dominate the understory and parts of the overstory as a result of this mortality. However, there is a great deal of whitebark pine regeneration (2 meters tall, 20+ years old) in the study area. These seedlings and saplings have not yet been severely impacted by the blister rust. The habitat types of this study area are similar to the Smith Creek Study area being mostly subalpine fir/woodrush.

Treatments -- Three treatments and a control are also implemented in between ski runs within this demonstration site. The study area is homogeneous with respect to disturbance history, vegetation and topography. However, there is a patchy distribution of whitebark pine regeneration throughout the study area. Since this study is still in the planning stages, details of treatment location and implementation are currently lacking. The three treatments are: 1) Prescribed Burn to somewhat mimic a natural burn in whitebark pine, 2) Ecosystem Harvest WITH Fire where uninfected whitebark pine will be favored in a release cutting designed to eliminate subalpine fir and thin lodgepole pine from the area to promote the vigor of cone-bearing whitebark pine, 3) Ecosystem Harvest WITHOUT Fire similar to Treatment 2 but without burning slash where piled. Trees will be skidded whole to a central landing.

Future Study Sites

Most of the mentioned treatments attempt to reestablish whitebark pine dominance at the stand level. However, there are vast areas of whitebark pine forests where fire burned entire hillsides in stand-replacement burns. Whitebark pine had a distinct advantage in colonizing these large burns because of the great dispersal distances of the Clark's nutcracker. Currently, most whitebark pine stands in the upper subalpine are becoming dominated by subalpine fir due to accelerated succession caused by the rust. These landscapes must have fire reintroduced at a grand scale in order to mimic the ecological processes that resulted in whitebark pine dominance prior to European settlement. A viable restoration treatment is a prescribed stand-replacement fire that burns a large land area (>1000 hectares). It is hoped that a large scale, stand-replacement disturbance can be added as a treatment in this study.

The main objective of the prescribed stand-replacement fire is to create an burned area so large that wind-dispersed seeds only land in the outside boundaries of the burn. These type of fires can be small (200-1000 hectares) if the fire burns from the valley bottom to the ridge top in a wind shadow. Often, wilderness or roadless settings may provide the only landbase to successfully implement this type of treatment. Clearcutting is unavailable as a silvicultural tool because cuts of this size are against the law.

Sampling Design

Permanent sample plots will be independently located in each treatment with the first plot randomly located and subsequent plots systematically located in a pattern adequately covering treatment unit shape. The sampling approach will be to mark with concrete reinforcing rod (rebar) the centers of 10 permanent macroplots (375 m^2) in each treatment unit. These plot centers will be used as the basis for fuel, vegetation, and natural and artificial regeneration microplots described below. The vegetation and fuel characteristics shown in Table 1 will be measured on each of these plots in each of the treatment units.

Many attributes will be measured to study the effects of these treatments on whitebark pine regeneration and growth (Table 1). Seedling establishment, undergrowth vegetation response, fuel reduction and tree mortality will be monitored on 10 plots systematically located in each treatment. Treatment effects will be compared on 10 permanent macroplots in each treatment unit. Each macroplot will contain a cluster of microplots. The survival and growth of planted whitebark pine seedlings will be monitored in the treatment areas along with development of vascular plant cover and changes in ground cover (USDA Forest Service 1992). Long-term fire effects on tree growth will also be monitored as obtained from tree cores taken 5 and

	Pre-treatment	Post-treatment
Canopy coverage vascular plants	x	x
Tree seedling size & density	x	x
Overstory tree characteristics	x	x
Down woody fuel loadings	x	x
Litter loadings	x	x
Duff depth	x	x
Ground coverage (duff/mineral soil)	x	x
Release cutting measurements		x
Regeneration measurements		x

Table 1 -- Stand characteristics sampled on each plot pre- and post- treatment.

10 years after the burn and also by measuring changes in structural characteristics of all trees in the study area. Fuel consumption will be calculated by measuring fuel loads, duff depths, and litter depths before and after the burn (Brown 1970, Brown and others 1982). Selected macroplots will be photographed semi-annually to illustrate vegetative development following treatment.

Personnel Involved

These studies will be carried out under a cooperative agreement between the Bitterroot National Forest, the Lolo National Forest, and the Intermountain Research Station. Darby Ranger District personnel will either perform the prescribed burning and any operational silviculture outside of the Coyote Meadows research units or assist in the preparation of a contract to burn the area with a private company. Stevensville Ranger District personnel will perform the prescribed burning and operational silviculture at the Smith Creek study area and Missoula Ranger district personnel will have the same responsibilities at the Snow Bowl demonstration area. Researchers will conduct thinning, planting, and measurements in all research plots. Principal research cooperators will be Ward McCaughey and Clint Carlson of the silviculture unit (RWU-4151) and Robert Keane and Stephen Arno of the Fire Effects unit (RWU-4403). Other research disciplines, such as pathologists and wildlife biologists will be invited to establish collateral studies of the effects of these treatments.

References

Arno, S. 1986. Whitebark pine cone crops--a diminishing source of wildlife food? W. Jour. of Applied Forestry 1:92-94.

Arno, S. and R. Hoff. 1990. *Pinus albicaulis* Engelm. Whitebark Pine. pp. 268-279. In: Silvics of North America. Vol. I. Conifers. USDA For. Serv., Agr. Handbook 654.

Arno, S., E. Reinhardt, and J. Scott. 1993. Forest structure and landscape patterns in the subalpine lodgepole pine type: A procedure for quantifying past and present conditions. USDA For. Serv., Gen. Tech. Rep. INT-294.

Brown, J.K. 1970. A method for inventorying downed woody fuel. USDA Forest Service Gen. Tech. Rep. INT-16. 24 p.

Brown, James, K., R.D. Oberheu, C.M. Johnston. 1982. Handbook for inventoring surface fuels and biomass in the Interior West. USDA Forest Service General Technical Report INT-129. 49 pages.

Hutchins, H.E.; Lanner, R.M. 1982. The central role of Clark's nutcrackers in the dispersal and establishment of whitebark pine. Oecologia, 55:192-201.

Keane, R. and S. Arno. 1993. Rapid decline of whitebark pine in western Montana: Evidence from 20-year remeasurements. W. Jour. of Applied Forestry 8(2):44-47.

Keane, R., S. Arno, J. Brown, and D. Tomback. 1990. Modeling disturbances and conifer succession in whitebark pine forests. pp. 274-288. In: Proceedings--symposium. Whitebark pine ecosystems--ecology and management of a high mountain resource. USDA For. Serv., Gen. Tech. Rep. INT-270.

Kendall, K. C. and S. F. Arno. 1990. Whitebark pine--an important but endangered wildlife resource. Proceedings of the symposium: Whitebark pine ecosystems: Ecology and management of a high mountain resource, March 29-31, 1989, Bozeman, Montana, USA. USDA For. Serv. Gen. Tech. Rep. INT-270. Pp. 264-274.

McCaughey, Ward W. 1990. Biotic and microsite factors affecting whitebark pine establishment. Proceedings of the symposium: Whitebark pine ecosystems: Ecology and management of a high mountain resource, March 29-31, 1989, Bozeman, Montana, USA. USDA For. Serv. Gen. Tech. Rep. INT-270. Pp. 140-151.

Pfister, R. D., B. Kovalchik, S. Arno, and R. Presby. 1977. Forest habitat types of Montana. USDA For. Serv., Gen. Tech. Rep. INT-34. 174 p.

Schmidt, W. and K. McDonald, compilers. 1990. Proceedings -- Symposium on whitebark pine ecosystems: ecology and management of a high-mountain resource. USDA For. Serv., Gen. Tech. Rep. INT-270. 386 p.

USDA Forest Service. 1992. ECODATA - an ecological inventory technique for integrated resource management. Northern Region Ecosystem Management Handbook.

MANAGEMENT OF WHITEBARK PINE ON THE BITTERROOT NATIONAL FOREST, MONTANA

Cathy Stewart
USDA Forest Service, Bitterroot National Forest
88 Main Street, Stevensville, MT 59870

The occurrence of white pine blister rust is increasing on the whitebark pine on the Bitterroot National Forest. Combined with a 1920's mountain pine beetle epidemic and fire suppression, subalpine fir is replacing this valuable species. Two thirds of the potential whitebark pine habitat occurs within wilderness boundaries on the Bitterroot National Forest. Therefore, management to regenerate and maintain the species must be concentrated on the acres outside wilderness jurisdiction. Management options include prescribed burning with pretreatment slashing and precommercial thinning. Prescribed burning will reduce the amount of subalpine fir and maximize the potential for whitebark pine regeneration by nutcracker caching.

A burn project on the Stevensville Ranger District, Bitterroot National Forest, encompasses 200 acres, 150 of which were slashed to reduce subalpine fir from around existing whitebark pine and create a light fuelbed. The unit will be helitorched in the fall of 1995 or 1996, depending on weather conditions.

Precommercial thinning will reduce the competition from subalpine fir and other species and simulate a fire by favoring whitebark pine. This was accomplished on 40 acres on the Darby District, Bitterroot National Forest and will continue in the future if funds are available.

Continued management of this non-commercial species is desired but will be hindered by lack of funds and other, creative funding alternatives must be found.

REFORESTATION OF WHITEBARK PINE IN THE NORTHERN REGION

Lars Halstrom
East Zone Tree Improvement Coordinator, Gallatin National Forest
3710 Fallon St., Bozeman, MT 59715

Interest has grown substantially for managing whitebark pine sites on the National Forests of the Northern Region since the fire season of 1988. A group of cooperators has been formed to coordinate efforts for research and management of whitebark pine ecosystems that includes universities and government agencies. Several workshops and international symposiums have been held since 1990.

Cone Collecting

The Northern Region National Forests had begun collecting whitebark pine for operational planting in 1985, 1989 and 1991. Heavy cone crop intervals of 3-5 years vary with the local climate. In 1995, very few whitebark pine stands had a good crop. This is mostly attributable to the record breaking cool and wet conditions we had in 1993 when the reproductive buds would have been initiated. Heavy crops usually correspond with hot dry summers two years before harvest. There are exceptions because of the variation in local climate patterns. Southeast of Red Lodge, Montana on the Beartooth highway the trees had a heavy crop this year. West of the continental divide there also have been collectible crops this year.

The Clark's Nutcracker is our greatest adversary to collecting large quantities of mature seed. Normally they start eating some of the seed just before it gets ripe. They can't extract the whole seed from the cone before it is ripe, so most of their early feeding results in the seed coat being broken open and the contents eaten. When the seed is ripe, it can be extracted intact and stored in caches for later feeding. This year, since we had a very poor crop, the Clark's Nutcrackers started feeding on the cones in July and have eaten most of the seeds before they normally get ripe on about the third week of August. By the time Forests discovered the early predation it was too late in most instances to put protection cages, made out of hardware cloth, over the cones.

Collecting seed when it is mature enough to ensure consistent germination has been a problem. Some seedlots have had germination rates as low as 10%. Several other Stone Pine species exhibit a variable dormancy in that seed can germinate at one, two, or three years after dispersal. Some researchers are hypothesizing that this is a characteristic of increased fitness and may be genetically controlled. A good cone crop could produce seedlings every year until the next good cone crop. If climate conditions were droughty one year and germinating seedlings died from it that year, next year's germinants may survive if climate conditions are more favorable. Another hypothesis to poor germination comes from inbreeding. Tree clumps established from Clark's Nutcracker caching may all have come from the same parent. The chances of being pollinated from selfing in these clumps is increased.

There are several techniques used to harvest the seed. Falling the trees or climbing them is used for operational collections. For small collections we have been using a rifle or long extension pole pruners. Due to the early Clark's Nutcracker predation this year, we have had to place the hardware cloth cages over the cones in order to get any to collect. This also allows us to collect as late as we want and ensure maximum maturity of the cones.

Growing Whitebark Pine

The Coeur d'Alene nursery has been growing whitebark pine seedlings since 1990. The cost per seedling has ranged from 35 to 40 cents or 10 to 15 cents above the cost of traditionally planted species. Since the cones never flare open, they have to be taken apart by hand to get the seed out. The seeds are put into stratification for 100 days and then to increase the uniformity of germination, the nursery has been clipping off a portion of the hard seed coat by hand with razor blades. After the seeds have germinated in the containers, the crew removes the extra seedlings so that only one is left per container.

For the next two years the nursery grows the seedlings to a plantable size. During this time an array of pathogens affect the quantity of seedlings surviving. *Cylindrocarpon* and *Fusarium* attack immediately upon emergence of the cotyledons. A bleach bath is used to clean the surface of the seed and other pesticides are applied throughout the two year period in the greenhouse.

The nursery has had success in increasing the seedling top growth by increasing the amount of trace micronutrients in their fertilizer recipe. However, the seedlings are very sensitive to changes in the local climate and may set bud early if a cold front comes through or anything else that disrupts the growing environment for a short period.

Planting Whitebark Pine

Planting whitebark pine on operational sites was started in 1987 on the Gallatin NF and the latest one was planted in the fall of 1993 above Cooke City, Montana in the Daisy Pass road area. Seedling survival has been tracked with staked row surveys in these plantations. After three years, seedling survival is still above 90 percent. The Lewis and Clark NF has planted whitebark pine in 1989 on a burn in Falls Creek. They planted 2-3 seedlings per planting spot to look at inter-tree competition. The last survival survey at Falls Creek was at 80 percent.

Mortality in whitebark pine plantations has been attributed to frost pockets, elk browsing and pocket gophers. No mortality has been reported because of blister rust at this time. None of the stock planted comes from resistance tested stock.

A STUDY TO DETERMINE THE IMPACT OF CONE AND SEED INSECTS ON WHITEBARK PINE

Sandy Kegley
USDA Forest Service
Insect and Disease Management
Idaho Panhandle National Forests
Coeur d'Alene, ID 83814

Introduction

The mountain pine beetle (*Dendroctonus ponderosae* Hopk.) and white pine blister rust (*Cronartium ribicola* J. C. Fisher ex Rabh.) have had a dramatic affect on whitebark pine (*Pinus albicaulis* Engelm.) ecosystems. Whitebark pine mortality due to the mountain pine beetle occurs every year in Region 1. Outbreaks in whitebark pine have occurred periodically at no particular time interval but mainly following outbreaks in other pine species. Most mortality in whitebark pine occurs from outbreaks in lower elevation lodgepole pine (*Pinus contorta* Dougl. ex Loud.) moving upslope into whitebark pine ecosystems. The last major outbreak occurred in the early 1980's. During the peak, 130,000 acres of whitebark pine were infested.

White pine blister rust has also caused extensive mortality in whitebark pine. On some sites, 90% of the mature trees have been killed. Blister rust also kills the tops and branches of trees, reducing the cone producing potential.

There is a high demand for whitebark pine seed for regeneration purposes. In Region 1, eight forests are currently collecting cones for seed. These are sent to the Forest Service Nursery in Coeur d'Alene, Idaho for extraction of seed and growing seedlings. Currently, 2,000 - 4,000 whitebark pine seedlings are grown annually in containers at the nursery. They attempt to germinate all seed that is collected. However, germination is low (10-20%) and requires removal of part of the seed coat by hand. Low germination may be due to undeveloped seed since collections need to occur before Clark's nutcrackers harvest the seed or may be due in part to insect damage. The need for seed and seedlings is expected to increase in the future.

Very little is currently known about cone and seed insects on whitebark pine. However, we have some likely candidates from other pine species. In western white pine (*Pinus monticola* Dougl.), losses due to the western conifer seed bug (*Leptoglossus occidentalis* Heidemann) have been as high as 70-80%. Both adults and nymphs feed externally through the cone on the seed and nymphs have also been responsible for first year conelet abortion. Seed bugs may also feed on whitebark pine seed.

The cone beetle (*Conophthorus ponderosae* Hopkins) can also cause extensive damage. It bores into the cone to lay its eggs, killing the whole cone in the process. Losses of 90% have been documented in western white pine. In limber pine (*Pinus flexilis* James), another high elevation 5-needled pine, cone beetles have killed from 60-80% of the cones in some years.

Coneworms (*Dioryctria* spp.) have been responsible for up to 50% seed loss in western white pine. Twenty percent losses occurred in one study on limber pine.

With the reduction in cone producing potential in whitebark pine due to blister rust and mountain pine beetle, we feel that cone and seed insects may have an abnormally high impact on seed production. We did a preliminary survey of whitebark pine on 25 different sites in 1994 and found only 4 sites with current year cones. On those 4 sites, damage by coneworms was evident on 50-100% of the cones we found. The coneworm has since been identified as *Dioryctria abietivorella* (Grote). External signs of coneworm damage are obvious frass on the outside of the cone produced as the coneworm larva mines the inside.

Cone and Seed Insect Description

With this evidence of potential insect damage in whitebark pine cones, we started a technology development project to study the biology and impact of cone and seed insects in whitebark pine ecosystems. This is a cooperative project involving many regions in the west. The cooperators are Nancy Campbell and Sandy Kegley in Region 1, Julie Weatherby in Region 4, Paul Flanagan and Beth Willhite in Region 6, and John Stein at the Pacific Southwest Research Station in California. We have seven study sites in Washington, Oregon, California, Idaho, and Montana.

This is a 2 year project starting with 1st year flowers and following development until cones are mature at the end of the 2nd year. The project involves excluding insects from flowers and cones during certain intervals of time throughout the 2-year growing season. We do this by covering the branch and flower or cone with a fine mesh bag that excludes all insects. At predetermined intervals, bags are removed to expose the flower or cone to insect predation.

We know that whitebark pine does not always have a cone crop which may be due to an interruption in pollination. This could be caused by adverse weather or other factors. In order to ensure we would get cones, we collected male cones, dried and extracted the pollen, and augmented natural pollination by pollinating the flowers ourselves. We pollinated the flowers we had exposed as well as those that were bagged. The tiny holes in the mesh bags were large enough to allow pollen to enter but not insects.

On each sample tree at each site, we have 14 treatments. A treatment is simply a window of exposure to insects sometime during the 2 year cone cycle. This will allow us to determine what time of year an insect feeds on a cone. These treatments are replicated on each of 15 trees per site. During the second year we will have to cage the cones to prevent them from being destroyed by Clark's nutcrackers.

We are also testing a pheromone for attracting the cone beetle and pheromone traps are hung at each site.

Our sites range in elevation from 5400 feet in elevation to 9500 feet. There is also a wide range of blister rust infection from little to no blister rust in Montana north of Yellowstone to close to 90% mortality in some sites in north Idaho and Oregon.

Preliminary Results

We have collected some cones at our sites this year and have also observed insects on other parts of the trees. At 2 of our sites we've seen a scarab beetle (*Dichelonyx* sp.) feeding on male cones and also on needles. There is also a sawfly larvae (family Xyelidae, primitive sawflies, *Xyela* sp.) feeding in male cones.

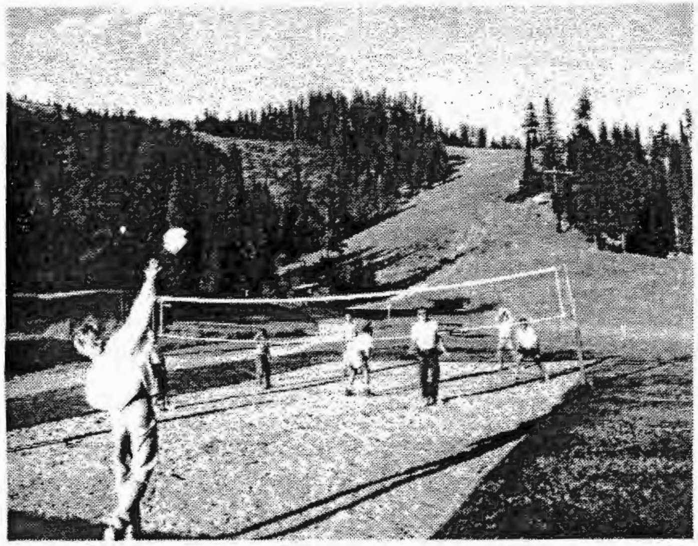
We found some damage to flowers that looks like insect damage as opposed to frost damage but haven't been able to identify the insect responsible.

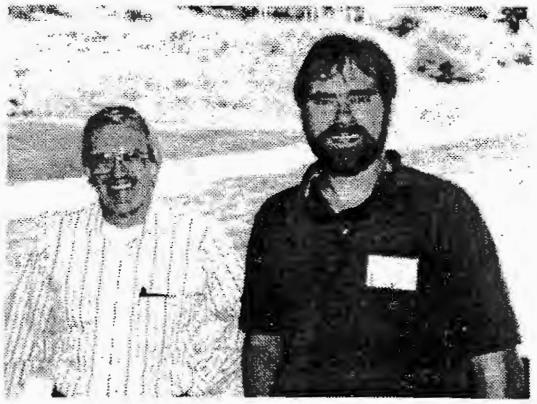
There is a twig boring caterpillar that looks like a *Dioryctria* sp. that is killing branch tips which could reduce cone and pollen production.

On the cones we are finding some adelgids (*Pineus* spp.). We've also seen evidence of coneworm (*D. abietivorella*) damage again this year.

We found attacks by cone beetles (*C. ponderosae*) for the first time in whitebark pine and have also caught beetles in our traps.

In conclusion, we are finding quite a few insects affecting cones and pollen already this year. We should have impact data on these insects by the end of the project next year and may also find other insects through rearing and dissection.





PANEL
DISTURBANCE ECOLOGY

FOREST PATHOLOGY AND DISTURBANCE ECOLOGY: IS THERE A ROLE FOR FOREST PATHOLOGISTS?

Jim Byler, Moderator
USDA Forest Service
Coeur d'Alene, ID 83814

Det Vogler
University of California
Berkeley, CA 94720

Introduction

We are undergoing a very significant change in the way we view forest pathogens and the diseases they cause. Some might argue it is a change in emphasis, but it is a significant change nevertheless. Over the past few years, words like "disturbance agents", "agents of change and stability", and "regulators of ecosystem processes" are used to describe pathogens, and the term "pest" appears to be used less-and-less. This change is largely due to the influence of forest ecologists, who call fire, floods and windstorms "disturbances", and sometimes view insects and pathogens as disturbances as well.

We believe it is appropriate to critically evaluate the meaning of "disturbance", and discuss it's implications for forest pathology before we embrace the terminology and concepts. The changes present us with an opportunity. I often think of the parallels between what is happening today and what happened back in the 70's following the publication of "Silent Spring". Most of us didn't realize that Rachael Carson provided us with an opportunity. But we had the opportunity to dialogue with people who until then weren't previously interested in pest management, spurred to reevaluate our approach, and challenged to develop a new one. The result was Integrated Pest Management", based on a more complete understanding of the ecosystem.

Now, thirty years later, we have the opportunity to dialogue with others who care about forests, particularly about the functioning of forest ecosystems, and consider questions about the ecological roles of pathogens and insects. They are still pests, and negatively affect resource production, but they can also have essential roles in succession, nutrient recycling, evolution and other ecosystem processes.

Another reason that it is appropriate to evaluate our role in disturbance ecology is because the survival of forest pathology may depend on it. The number of forest pathologists continues to decline as we heard here Tuesday morning, particularly in research and the universities. We have been unable to convince administrators to fill pest management research and teaching positions as they become vacant, and numbers are at an all-time low. The management focus has shifted from resource management to ecosystem management, and if pathology is to survive, pathologists may need to demonstrate a productive role in ecosystem function as well as in crop loss.

Our intent is to discuss the topic of disturbance ecology from both the broader sense of the concepts and in the narrow sense of terminology. We have three speakers. We have invited Dr. Thomas Hoekstra, ecologist and Assistant Director of the Rocky Mountain Forest and Range Experiment Station, to be our lead speaker. Tom is coauthor with T.F.H. Allen of "Toward a Unified Ecology", and is writing another book with Allen and Joseph Tainter on "Sustainability of Ecological Systems". He will speak to us on "What is disturbance ecology and what are the implications for forest pathology?"

Following Tom's presentation we will hear two presentations on work in-progress that address the functioning of pathogens in forests. Susan Hagle will speak on "Assessing ecological functions of pathogens and insects". John Lundquist will speak on "Developing disturbance profiles". A general discussion of the disturbance ecology terminology and forest pathologist roles will follow.

WHAT IS DISTURBANCE ECOLOGY AND WHAT ARE THE IMPLICATIONS FOR FOREST PATHOLOGY?

Thomas W. Hoekstra
USDA Forest Service
Rocky Mountain Forest and Range Experiment Station
240 W. Prospect Street, Fort Collins, CO 80526

Timothy F.H. Allen
Department of Botany
University of Wisconsin
Madison, WI 53706

Disturbance ecology should be developing a general framework for conveying, in unequivocal terms, the relationship between ecological systems and disturbances. Until that is achieved, it will be difficult to predict disturbances and the effects of various disturbance regimes. It is a requirement that the disturbance be placed in time and space relative to the ecological system that is disturbed so that there is an explicit scale for the disturbance and the system disturbed. This is not difficult to do, but if the issue is ignored, then the door is wide open for confusion and apparent contradiction, both of which rob the scientist of predictive power.

Disturbances require that we look at the system at several levels of analysis, and that is the origin of the scaling problem at the center of disturbance ecology. A disturbance comes from outside the system, according to the definition we use. Also, given the temporal dynamics of the system disturbed, the disturbance has a sharp attack. That is to say, given the normal functioning of the system at hand, the disturbance appears to come suddenly out of nowhere. It is important to realize that the scale of a system is a matter of definition, not reality, and depends on where the observer chooses to draw the boundary to both the disturbance event and the system disturbed.

We say the disturbance appears to come out of nowhere. However, we could expand the temporal or spatial boundary of the system, and then we would know exactly where the disturbance came from. It would come from inside the newly defined, larger system. At that point, the disturbance is violating part of our definition of disturbance; remember, they come from outside the system. Then, it ceases to be a disturbance and has become incorporated into normal system functioning. A scale change can rob a disturbance of its status, and that is why we must be so careful in specifying the scale of the disturbance and the system to which it applies.

To elaborate further, if we define an ecological system (i.e., a population over a short time) and a disturbance (i.e., a pest outbreak) to function at very similar spatial and temporal scales, then the epidemic occurs quickly and covers the entire population. The population is royally disturbed. If, however, we define the population over a much longer time, there is time for the numbers and age structure of the population to recover and even go through that cycle of death and recovery several times. At that point, the pestilence has become a normal part of the functioning of the population, and the disturbance would be to remove the pest altogether. This reversal of meaning is quite common in systems seen at multiple levels of analysis. There is no contradiction because the nature of disturbance is always relative to something else, and the wider scope of the larger system changes the implications of what was formerly called disturbance as opposed to normal functioning.

The organizers of the meeting identified certain questions that we were asked to answer. First, "How are disturbance and disturbance regime defined?" While an individual disturbance has an identity as an event, it sits inside a larger process of disturbance and repeated recovery. At the higher level of analysis, the character of the sequence of disturbance events describes the disturbance regime. Since the word "disturbance" occurs at part of "disturbance regime," the events are still seen as coming from outside the system. The system exists inside an environment, a regime, in which it is repeatedly thrust away from a track of slow continuous change onto a brief track of rapid change to an unusual condition. When the system is seen as having accommodated the disturbance, the disturbance regime is part of the system, and the rapid changes are seen as normal system functioning. Indeed, they are a prerequisite for the slower so-called recovery phases. The disturbance regime becomes merely a set of resets to the beginning of each new cycle.

The next question identified was, "Do pathogens qualify as disturbance agents?" They certainly can, but pathogens may also be incorporated into the system when they are seen as working processes inside normal functioning. When the ecological system, structures, or processes are unusually far from average conditions, pathogens can be responsible for taking the system down, even if the pathogen is usually a normal part of the system or back to average conditions. If the system is away from the norm, such as overpopulations of trees, pathogens are effective population mortality agents. If the system is away from the norm because of stress, pathogens can be the vehicle that transports the system over the edge to some entirely new condition and regime, in what might be seen as a metadisturbance. Thus, disturbance can be identified at several levels of analysis and can even be incorporated at yet higher metalevels.

The third questions was, "What is the importance of disturbance ecology to forest ecosystem management?" At the onset, the term forest ecosystem management needs to be qualified: as commonly used, the word ecosystem is a nontechnical term. Putting that detail aside, the importance of ecosystem management has several facets. First, forest ecological systems are not best described as steady-state equilibrium systems. They are constantly in flux and are better seen as moving from one nonequilibrium state to another. Pathogens can be effective in bringing systems particularly far from normal functioning back toward more usual configurations; populations of trees that are unusually large in number or size of individuals can be brought back inside more normal limits by pathogens. Therefore, pathogens might be a friend in ecosystem management. Disturbance ecology is important in helping us understand such happenings and their relationship to normal functioning of ecosystems. Pathogens can be effective agents of ecosystem change and play a role in a symphony of influences that challenge biota and press evolutionary development. Disturbance ecology can provide understanding for this evolutionary role of pathogens.

The last question asked was, "What are the research implications?" Forest pathology, like all areas of ecology, could benefit from research that helps establish general principles that can be used by the observer (manager, researcher, public) to interpret what they see, accurately describe the observation, and improve the power of predicting the outcome of the role of pathogens. To put it another way, research can help develop a general framework to interpret pathogen interaction with forest ecological systems as opposed to defining pathogens as only a disturbance agent in forest ecological systems.

DEVELOPING DISTURBANCE PROFILES

J.E. Lundquist
Research Plant Pathologist
USDA Forest Service
Rocky Mountain Forest and Range Experiment Station
Fort Collins, CO 80526

Introduction

Diseases and other disturbance agents impact many forest resources, but not all impacts are negative. In fact, some people consider small-scale natural disturbances to be valuable resources in themselves, and that they should, in some cases, even be used to meet management objectives (Baker 1992). Silviculturists, in particular, generally try to control stand structure and composition by mimicking natural small-scale disturbances (Oliver and Larson 1990). To use disturbances effectively, we have to be able to adequately measure them and their impact on the ecosystem.

Measures that are based on basal area, stem density, and average stem diameter may be adequate for making timber production decisions, but might not be useful for making decisions about non-timber resources. We may have to adapt or develop some new metrics. Many relatively new analytical techniques have enriched our ability to describe links between disturbance and non-timber resources. Over the last few years, we in the Pest Impact Assessment Unit at the Rocky Mountain Experiment Station in Fort Collins have been developing a method and a metric that would be flexible enough to accommodate both timber and non-timber resources, and could be used by silviculturists to formulate prescriptions at the stand level. That method is called stand profiling (Lundquist 1995).

What Is Profiling?

In stand profiling, we combine GIS, spatial and non-spatial statistics, remote sensing, and multivariate statistics to compare attributes between desired and actual stand conditions. The cornerstone of profiling is the disturbance profile (Lundquist 1995b). A disturbance profile is a "multivariate metric composed of spatial and non-spatial statistics based on crown cover, coarse woody debris, recolonizers and disturbance agents".

A profile is displayed in three columns (Table 1). The first column lists several attributes that characterized various parts of the stand or community. These variables include familiar statistics such as basal area and tree per acre; less familiar metrics such as snag frequency, gap diameter and edge length; and somewhat obscure measures such as dominance and fractal dimension. Some of these variables are so unfamiliar to decision makers and researchers alike, that their biological meaning has not yet been defined. Profiling, however, offers a way of cautiously using these statistics even before we fully understand what they mean. The second column within the disturbance profile specifies the range of values that a suitable stand would show. Suitablility is defined by the manager. The third column lists the actual values of the variables for the stand in question.

The profile is envisioned to be used similar to the way a physician uses a blood profile. Actual values are compared to desired values and the specific components that are high, low, or within the range are

Table 1. Before and after treatment disturbance profiles for a 4-ha plot in a one mixed-conifer stand (Delworth) in the Sacramento Mts, New Mexico, and a set of hypothetical desired condition for maintaining adequate diversity and abundance of small mammal prey for the Mexican spotted owl. Letter in parentheses indicate that current stand conditions are high (H) or low (L), and may need to be adjusted.

INDEX	DESIRED CONDITION	CURRENT CONDITION
Ave. stem diameter (cm)	30-40	29.8
Stem density (stems/ha)	150-250	437(H)
Basal area (m^2/ha)	25-35	30
Gap frequency (gaps/ha)	20-30	26
Mean gap diameter (m)	10-20	13.6
Skewness - gap dia distr (g_1)	0..5-2.0	0.6
Kurtosis - gap dia distr (g_2)	-0.8-0.5	-0.7
No. cause pathways (no)	40-70	68
Shannon-Weaver - causes (H')	4.0-9.0	8.8
Snag frequency (snags/ha)	50-200	211(H)
Log frequency (logs/ha)	300-400	214(L)
Ave. densiometer (%)	40-70	84(H)
Skewness - densio distr (g_1)	-2.0-2.0	-1.4
Kurtosis - densio distr (g_2)	3.0-7.0	5.9
Shannon-Weaver - densio (H')	0.5-2.0	0.7
Dominance (c)	0.1-0.9	0.7
Contagion (C)	0.5-1.5	2.0(H)
Number of edges (no)	300-500	218(L)
Ave. gap area (no)	3-7	3.2
Fractal dimension (D)	1.2-1.4	1.3
Variogram sill (semivariance)	120-200	133
Variogram range (m)	20-30	26

noted. Various combinations of these relative values may indicate specific maladies in humans. The physician interprets results by assessing the patient with respect to his environment, age, gender, and life style. Based on these interpretations, the physician prescribes management actions.

Similarly, a forest manager might use the disturbance profile to help determine whether management interventions are necessary, and to specify which actions should be taken. 'Out of range' attribute values may help guide what silvicultural decisions should be made. This procedure is still very speculative, and many pieces must still be developed and strengthened.

How Are Profiles Generated?

There are many ways to generate disturbance profiles. Figure 1 presents a flowchart showing how disturbance profiles have been generated in our recent studies. Each plot was composed of a 5 m X 5 m grid over a 4-ha area. At each grid intersection, an optical densiometer reading was taken (Grifting 1985), for a total of 1681 readings. These data were input as raster format into a GIS, and patterned isopleths were generated. Patterned isopleths are spatial models that allow us to visualize the spatial variation of canopy density over the plot. Isopleths generated from unadjusted data are busy, because of cell to cell variability that can arise from measurement error, natural variability and other sources (Figure 2, left). Generally, however, cells of similar density cluster together.

Cells with relatively low canopy density values that cluster together are gaps. In the GIS, there are various ways to manipulate data to help define the location of gaps. We used low-pass filtering to smooth the isopleth to make gaps more definable (Figure 2, middle). Subsequently, the smoothed isopleth is thresholded to produce a Boolean map (Figure 2, right). This Boolean image shows the size, shape, and spatial location of gaps. We refer to these images as gapograms.

Gapograms give a spatial context to disturbance. In this study, we use them as disturbance maps. We suggest that a disturbance map may offer a practical way of defining stand boundaries, since small scale disturbances can be major drivers of the patterns and processes driving ecosystems. Currently, for example, stand and polygon outlines are determined using aerial photos. The logic in placing borders can vary among technicians.

Recently, we have been exploring the potential for generating gapograms from aerial photos (Lundquist and Sommerfeld, unpublished).

Gapograms are subsequently used in the field as maps to relocate specific gaps, which are then assessed for snags, coarse woody debris, and recolonizing vegetation using methods described by Lundquist (1995a,b,c). Disturbance profiles are generated with these data (Beatty et al. 1995; Geils et al. 1995)

How Are Disturbance Profiles Used?

The profiling methods have been used in several forest types. In the Black Hills and the Bighorn Mts in Wyoming, we are using this method to examine the effect of small-scale disturbances on forest diversity, neotropical migratory birds, and ground beetles (Negron and Lundquist, unpublished). In the Blue Mts of Oregon, we are studying forest health (Beatty et al. 1995). In the southern Colorado Rockies, we are using these methods to measure old growth characteristics. Below, some work we are doing on the small

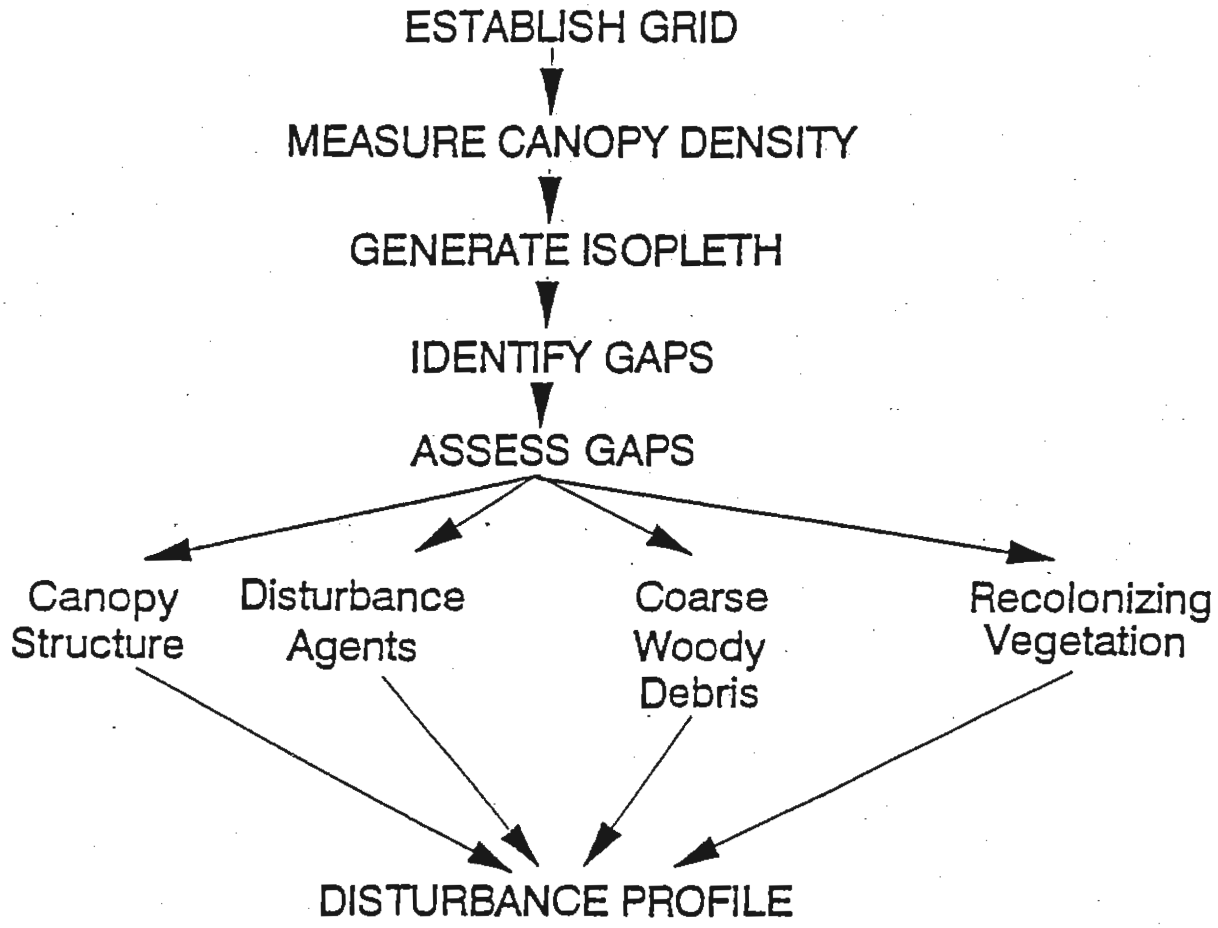


Figure 1. Procedural flowchart for field work aimed at generating data for developing disturbance profiles.

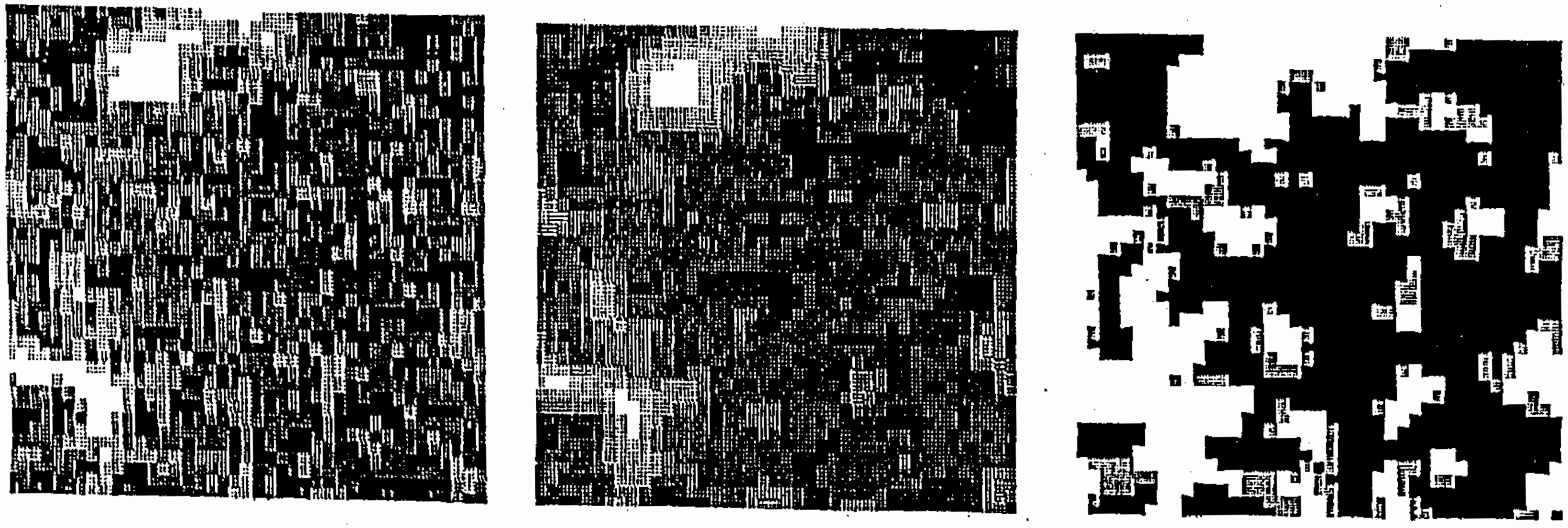


Figure 2. Patterned isopleths representing canopy-structure of the 4-ha Delworth plot. These diagrams were derived from ground observations of canopy density at 1681 points. The darker the cell, the denser the canopy. The side of each plot is 200 m long and each cell represents a 25 m^2 block of forest. Images represent unadjusted data (left), data smoothed by low-pass filtering (middle) and data thresholded to show only presence (white cells) and absence of gaps (black cells) and edges (cross-hatched cells)(right).

mammal prey of the Mexican spotted owl (*Strix occidentalis lucida*) in the Sacramento Mts in New Mexico is used to illustrate how gapograms and disturbance profiles might be used by silviculturists.

The Mexican spotted owl dwells in montane forests and canyons in Southwestern United States and Mexico. In 1993, this owl was listed as a federally threatened species in the United States (USDI Fish and Wildlife Service 1993). At that time, there was little or no knowledge about how timber harvesting or other silvicultural activities -- or natural small-scale disturbances -- affected the habitat quality of the Mexican spotted owl (MacDonald and others 1991).

We initiated a study with the Mexican spotted owl recovery team that examined the effect of small-scale disturbances (including tree harvesting) on the small mammal prey of the Mexican spotted owl (Lundquist et al 1994). We established plots in 12 stands representing the three major forest types in that region. In this discussion, data from only one of those stands is described. This stand (named Delworth) was a mixed conifer type composed primarily of Douglas fir (*Pseudotsuga menziesii* (Mirb.) Franco), white fir (*Abies concolor* (Gordon & Glend.) Lindl.) and southwestern white pine (*Pinus strobiformis* Engelm.), with some ponderosa pine (*Pinus ponderosa* Douglas ex. P. Laws).

Procedures described above were used to establish a gapogram and an associated disturbance profile for this site. In addition, the wildlife team established a 20m X 20 m grid of Sherman traps over the plot. At each grid point, the presence and abundance of small mammals was determined using trap/release methods (Ward and Block 1994).

Wildlife distribution overlays on gapograms of the Delworth stand are shown in Figure 3. Four small mammal species were found on this site: deer mice (*Peromyscus maniculatus*), long-tailed voles (*Microtus longicaudus*), Mexican voles (*M. mexicanus*), and Mexican woodrats (*Neotoma mexicana*) (Ward and Block 1994). The results suggest that different animals have different associations with gaps, and that abundance and distribution might be manipulated by silvicultural interventions. Long-tailed voles, for example, occurred mostly in fragmented parts of the stand. Deer mice seem to be indiscriminate about where they live. Mexican voles were found mostly within large gaps. Mexican woodrats, although the data are sparse, appeared to avoid gaps.

We suggest that spatial models such as gapograms might be used by the silviculturist to determine where to do what in the stand. For example, if a manager wanted to increase the abundance of Mexican voles, he might create more large gaps or enlarge the gaps that are already present. If a manager wanted to increase the long-tailed vole population, canopy fragmentation in relatively unfragmented parts of the stands might be increased. These kind of decisions can be made only by using spatially referenced data.

Is creating or enlarging gaps enough? Not all gaps are the same, because they are not all caused by the same agents. The makeup of the disturbance agents is an important element and driver of diversity within the stand community. A map showing the distribution of causal agents across Delworth (Figure 4) indicates many different agents are interacting.

One aspect of our study is to describe to what extent various disturbance agents determine the composition of snags, coarse woody debris, and recolonizing vegetation within individual gaps. The composition of individual gaps is fingerprinted in the composition of these elements. The condition of many of these elements, in turn, can influence small mammals. The entire stand is a mosaic of disturbed and less-disturbed gaps and patches. In GIS terms, stands are composed of several layers of information. Because of the huge amounts of information, describing stands can be difficult and confusing. No metric

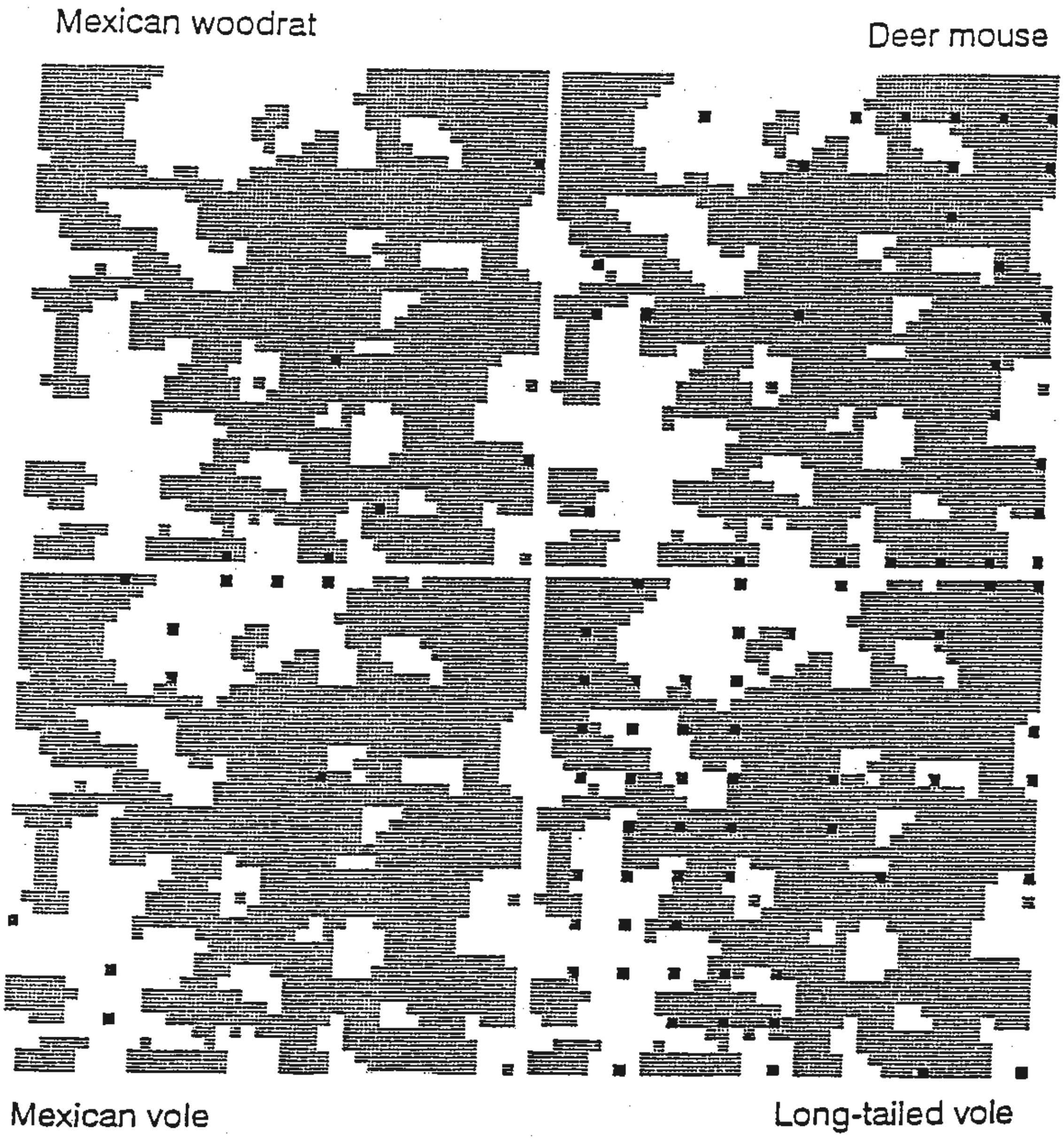


Figure 3. Composite maps of canopy-structure Delworth plot overlayed with distribution of four small mammal species. Unshaded areas are identified as canopy gaps; shaded areas include both edge and interior; solid squares indicate trap sites where at least one individual was recovered.

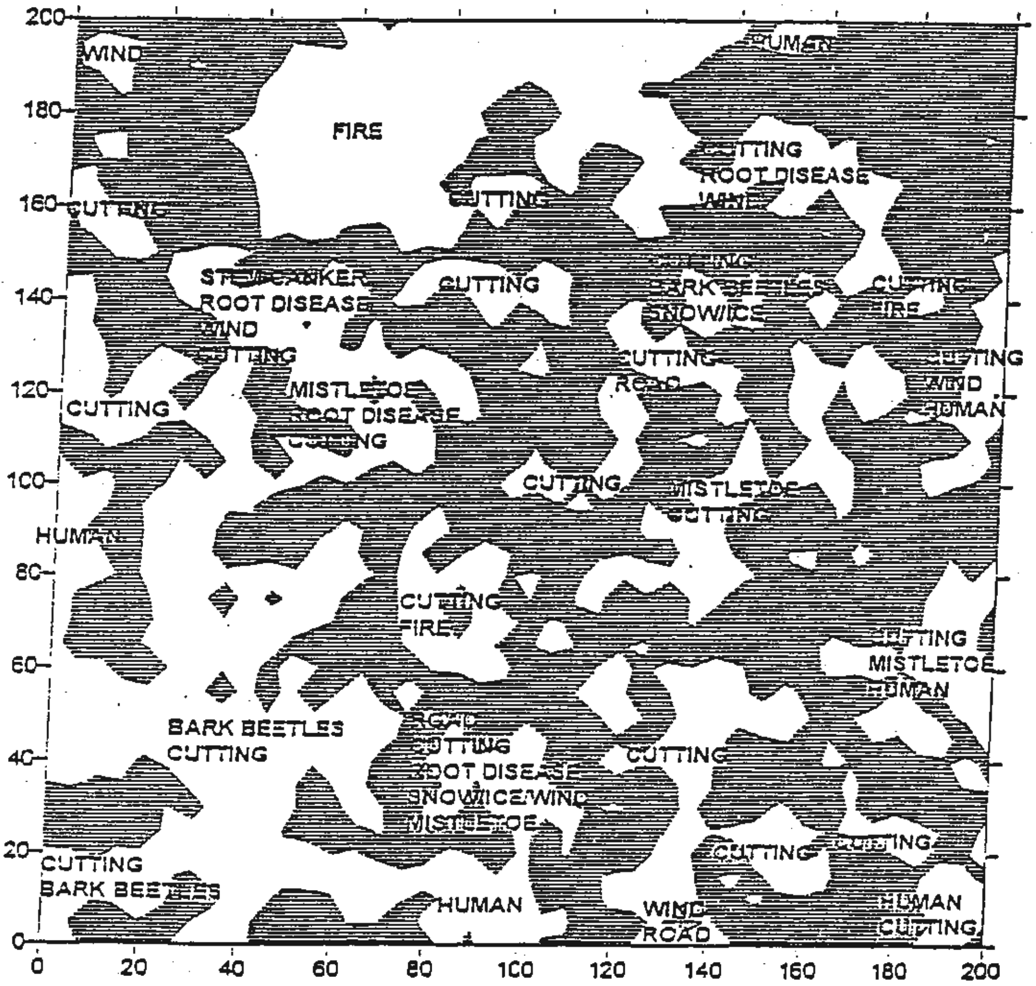


Figure 4. Distribution of disturbance agents associated with canopy gaps within Delworth.

will ever be able to capture the complexity of a forest ecosystem, but we believe that disturbance profiles can characterize this complexity adequately enough for silviculturists to use this metric operationally.

Table 1 shows the actual profile and a hypothesized desired condition profile for Delworth. Some elements are high and some low, but most fall within a suitable range. Following a field and aerial survey, a manager might be given an analysis that shows this information. To interpret it, the manager might enlist the help of specialists such as pathologists, entomologists, or soil scientists. Subsequently, the manager's interpretation might be that this stand has too many trees, too many standing snags, too few logs on the ground, too strongly clustered gaps, and not enough transitional zones between canopy openings and areas of closed canopy. The subsequent stand prescription might call for enlarging small gaps in less-gapped parts of the stand, and leaving cut trees on the ground.

A graphic display of the Delworth stand before and after prescriptive manipulation is illustrated in Figure 5. Although the two images differ in many ways, the 'before treatment' and 'after treatment' gapograms might seem the same, without close study. These differences are much more easily defined in the disturbance profiles, which show that many attributes of the stand have changed.

We have been exploring different ways to simplify data interpretation and to quantify the effectiveness of treatment. Multidimensional scaling is one way of graphically portraying the similarities among different stands (Figure 6). Each point in 2-dimensional space represents an individual stand. The distance between any two points represents the amount of dissimilarity. The further the distance, the less similar the stands. When silvicultural treatments are applied, points move. The length and direction of the trajectory of this movement is a measure of the effectiveness of the intervention.

Conclusion

Forest managers have always had to make complex decisions about systems composed of several commodity and non-commodity resources. Most of these are probably based on what they see and feel during their visits to a stand, despite the metrics and models that might be available to them. Metrics such as disturbance profiles and spatial models such as gapograms may help silviculturists make these decisions.

Literature Cited

Baker, W.L. 1992. The landscape ecology of large disturbances in the design of management of nature reserves. Landscape Ecology 7: 181-194.

Beatty, J.W., B.W. Geils and J.E. Lundquist. 1995. Disturbance and canopy gaps as indicators of forest health. Proceedings of the 1995 National Silviculture Workshop, Ruidoso, NM. May 9, 1995 (in press).

Geils, B.W., J.E. Lundquist, J. Negron, and J.W. Beatty. 1995. Disturbance regimes and their relation to forest health. Proceedings of the 1995 National Silviculture Workshop, Ruidoso, NM. May 9, 1995 (in press).

Grifting, J.P. 1985. The spherical densiometer revisited. Southwest Habitater 6: 1-2.

Lundquist, J.E. 1995a. Pest interactions and canopy gaps in ponderosa pine in the Black Hills, South Dakota, USA. Forest Ecology and Management 74: 37-48.

Lundquist, J.E. 1995b. Disturbance profiles - a measure of small-scale disturbance patterns in ponderosa pine stands. Forest Ecology and Management 74: 49-59.

Lundquist, J.E. 1995c. Characterizing disturbance in managed ponderosa pine stands in the Black Hills. Forest Ecology and Management 74: 61-74.

Lundquist, J.E. 1995d. Measuring forest health - disturbance profiles. Analysis Notes 5: 6-8.

Lundquist, J.E. and J.P. Ward Jr. 1995. Describing the conditions of forest ecosystems using disturbance profiles. Proceedings of the 1995 National Silviculture Workshop, Ruidoso, NM. May 9, 1995 (in press).

Lundquist, J.E.; Geils, B.W.; Ward, J.P. 1994. Disease-caused canopy gaps and Mexican spotted owls. Phytopathology 84: 1107 (abstract).

McDonald, C.B.; Anderson, J.; Lewis, J.C.; Ratzlaff, A.; Tibbitts, T.J.; Williams, S.O. 1991. Mexican spotted owl (Strix occidentalis lucida) status report. USDI Fish and Wildlife Service, Albuquerque, N.M. 85 p.

Oliver, C.D.; B.C. Larson. 1990. Forest Stand Dynamics. McGraw-Hill, Inc., N.Y. 467 p.

USDI Fish and Wildlife Service. 1993. Endangered and threatened wildlife and pltns: final rule to list the Mexican spotted owl as a threatened species. Federal Register 58: 14248-14271.

Ward, J.P., Jr.; Block, W.M. 1994. Mexican spotted owl prey ecology. pp 274-358. In: USDI Fish and Wildlife Service. Draft Recovery Plan for Mexican spotted owl. SW Region, Albuquerque, N.M. 646 p.

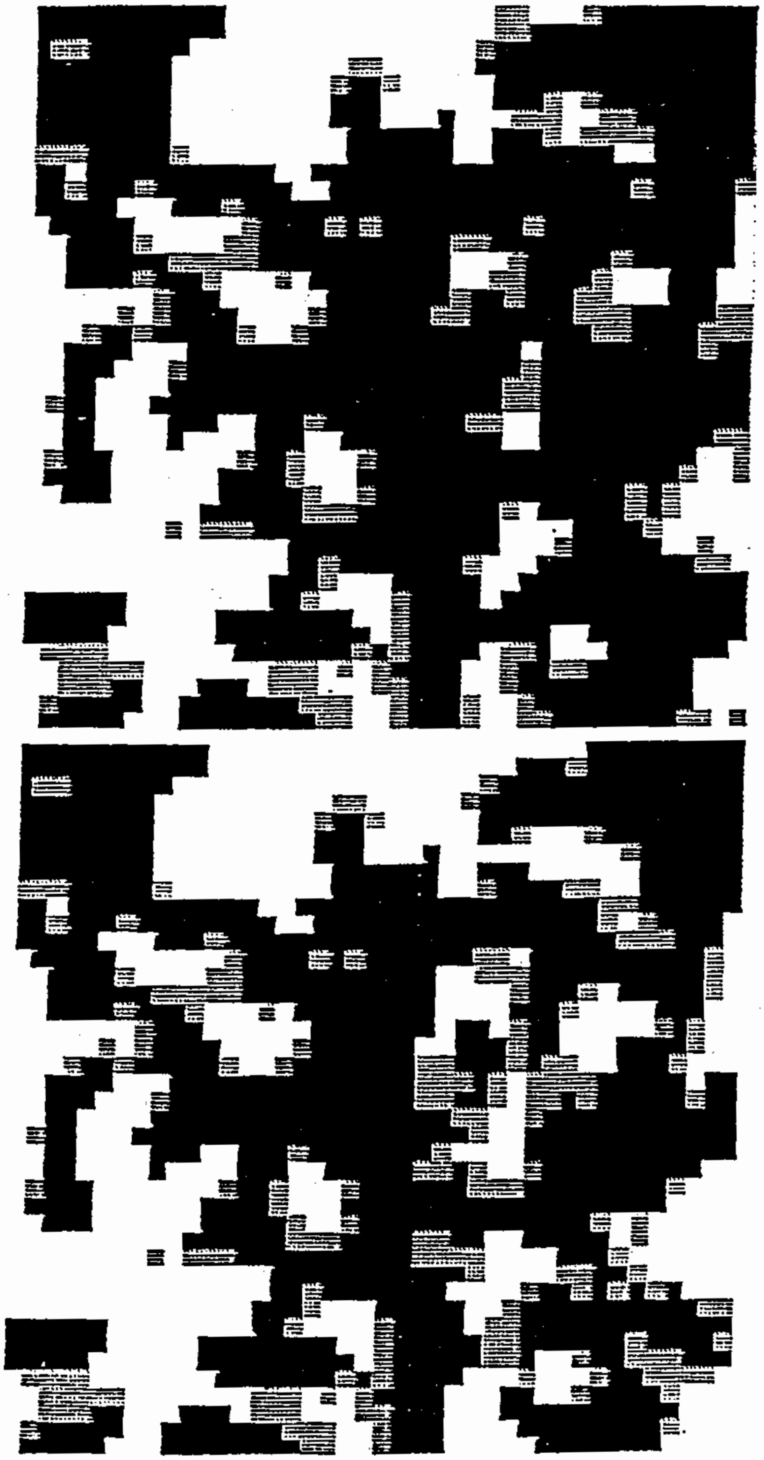


Figure 5. The upper diagram represents the plot before treatment. The lower diagram represents plot after existing gaps were enlarged and cut trees were left on the ground, as described in text.

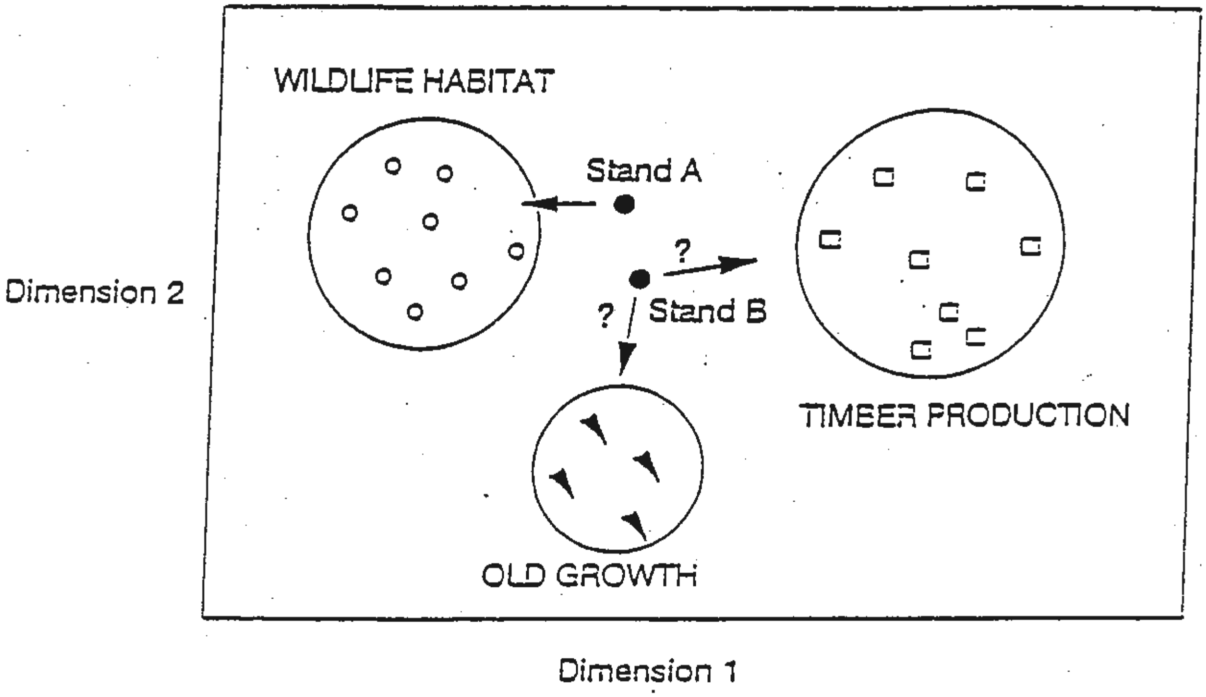


Figure 6. Hypothetical 2-dimensional clustering of the disturbance profiles associated with stands used for 3 different management objectives. Each box, triangle, or circle represents a single stand. Objectives include: forest products (boxes), old growth landscape (triangles), and enhancement of wildlife habitat (circles). The three large circles each define ranges of natural variability for each objective. The arrow signifies the trajectory or direction and magnitude of change that must be induced by silvicultural manipulations to make stands A and B suitable for one of the objectives. Stand A (which represents Delworth) is closest to the wildlife habitat cluster, and management interventions would probably best be aimed at that objective. Stand B is equidistant from the clusters for forest products and old growth landscape, and more information might be needed before developing a silvicultural prescription (Lundquist and King, unpublished).

PATHOGEN AND INSECT SUCCESSION FUNCTIONS IN FOREST ECOSYSTEMS

Susan K. Hagle
USDA Forest Service, Insect and Disease Management
Northern Region, P. O. Box 7669, Missoula, MT 59807

Abstract

The ecological functions of pathogens and insects, both endemic and exotic are important influences in determining the spatial and temporal patterns in forest ecosystems of the West. These functions may or may not be identified as disturbance types. There appear to be two major approaches to defining disturbance in western forest ecosystems. One is basically any major influence which seems opposed to the more or less linear progression of succession toward a climax. The other is the view that large influences that do not naturally occur in an ecosystem are disturbances. Neither definition would clearly identify even the most influential pathogens and insects as disturbance agents. As a practical application of current ecosystem management theory, we have been striving to understand the influences of pathogens and insects on gross vegetation patterns in forest ecosystems. These vegetation patterns in turn provide key indicators of the status of hydrologic and biotic population processes. The influences of pathogens and insects on forest succession are measured by relating succession transition rates and types to conditions for pathogen and insect activities which are expected to lead to transitions. Results of this analysis provide means to better understand historic and current functions of pathogens and insects. They also provide a basis for predictions of future trends of pathogen and insect activities with respect to specific ecological functions. More than anything, it is this ability to predict vegetation patterns which will allow this type of analysis to influence our responses to pathogen and insect actions in the future. A symptom of our efforts to we deal with the reality of our becoming endemic in ecosystems to which we only recently introduced ourselves!

Distinctions between succession and disturbance functions are vague at best where the most common actions of pathogens and insects are concerned. For the past several years I have worked with a team of pathologists, entomologists and other specialists to analyze the successional affects of pathogens and insects in Idaho and Montana forests (Hagle and Williams 1995, Hagle, Kegley and Williams 1995). Most common among the functions resulting from insect and pathogen actions in northern Idaho have been 1) a slowing of the pace at which early seral species such as ponderosa pine and western larch are replaced by more shade or competition tolerant species or 2) acceleration of the pace at which climax composition and structures are reached. In application it was fairly impossible to clearly distinguish between disturbance functions of pathogens and insects and their activities which determine the course and timing of succession. There are dramatic actions such as the mountain pine beetle outbreaks of the 1970's which would seem easily distinguishable as disturbances. But rather than reset the successional time as fires often do, the most common function of the beetle outbreak has been to accelerate the rate at which sites converted to climax subalpine fir or grand fir compositions. Most of the activities of pathogens and insects are so integral to the rates and trends of vegetation succession as to be indistinguishable from the process of succession.

Even structural stages, referred to as "successional stages" in Harris' "The Fragmented Forest" (Harris 1984), are difficult to predict if we attempt to map development in the absence of significant insect and pathogen influences. What causes a stand of trees to loose canopy closure? At what rate without pathogens and insects? This is all the more difficult when considering the whole of plant succession. In addition to structural stage changes, species composition changes take place through time.. There are often a number of alternative pathways and a range of rates of change. Since these changes do not take place in the absence of pathogens and insects, it is of only academic interest to be able to estimate changes in the absence of pathogens and insects. So it is important not to loose sight of the fact that succession is not restricted to the vegetative components of forest communities. All of the organisms of the forest are busily participating in the process of succession, pathogens and insects included. So it has increasingly been necessary for us to abandon our original plan to analyze the disturbance functions of pathogens and insects in favor of studying their succession functions.

The concept of disturbance as an influence which does not normally occur in an ecosystem was recommended by Tom Hoekstra at this meeting (Hoekstra, these proceedings). It will be worth considering the possible utility of this approach in our current efforts to understand the ecological significance of pathogens and insects in Northern Region forests. It is, at first glance, appealing because it allows some distinction between succession and disturbance. With this definition of disturbance, it would be unusual for native insects and pathogens to be considered disturbance agents. This is consistent with our findings that their affects are generally indistinguishable from "natural" succession.

An introduced pathogen or insect would likely be considered a disturbance agent in the ecosystem into which it has been introduced. Taking the view of Spurr and Barnes (1973), that because of the ongoing process of species migration and elimination, ecosystems exist "only at a given instant of time and a given instant in space", the distinctions between endemic and exotic are ephemeral. It does then require that we grapple with when a disturbance ceases to be a disturbance. Is it when the exotic has become established? Perhaps it is when affected ecosystems will have adapted to presence of the introduced pathogen or insect. By either of these definitions, larch casebearer and it's imported parasites may be ready for endemic status. But what of white pine blister rust? It certainly has established, but have the ecosystems adapted to the presence? They certainly have changed in response to the loss of white pine, whitebark pine, sugar pine and other susceptible species.

Even the most severe outbreaks of root diseases, bark beetles, defoliating insects and fungi may be considered not to be disturbances. This would presumably be based on understanding that they represent events which are essential functions of healthy ecosystems. We must also consider that actions of pathogens and insects which can be considered disturbances are not necessarily undesirable from the standpoint of human society. Even in damaged or unhealthy ecosystems, such outbreaks may represent mechanisms to re-establish normal functions. For example in forests which have progressed to severely overstocked levels pathogens and insects may be the best means to lower stocking and redistribute canopy structure to improve the health of the ecosystem. In other cases it may be a means to increase fuel loading thereby providing hot burning conditions to carry broad stand-replacement fires. It is probably not terribly important, in this case, whether the events represent disturbances or not. This brings us back to examining the actions of pathogens and insects with respect to their ecological functions, whether we label them succession, disturbance, or some other class of function. The salient point is that we strive to understand the ecological significance of pathogens and insects, whether endemic or exotic, whether inside or outside of natural ranges of variability, so that we can predict their actions and consequent future conditions of forest ecosystems.

Pathogens and insects recycle far more biomass over the course of stand development than is typically consumed in fires in even the most fire-intensive ecosystems. Epidemics of diseases and insect herbivory have occurred throughout history. Veblen and others (1991) described a series of spruce beetle outbreaks in subalpine forests in Colorado which altered the species composition of forests as far back as 1810. Similar history has been described for western spruce budworm outbreaks (Swetnam and Lynch 1989). Root disease epidemics have been common and enduring in large areas of the western United States (Filip and Goheen 1984, Hagle and Byler 1993, Hagle and others 1994).

Less extensive and intensive activity by pathogens and insects occur on every hectare of forest, every year and form much of the character of forests (Williams and others 1992). Both epidemic and endemic types of activities are characteristic of the forests in which most of our native species evolved or to which they have adapted (Amman 1977).

This effort to analyze succession functions of pathogens and insects in Idaho and Montana began in 1991. The team of nine pathologists and entomologists, and four database, GIS and statistical specialists has completed the bulk of the analysis and generated an Oracle/ArcInfo-based analysis system (Hagle 1992, Hagle and Williams 1995). These efforts are aimed at describing how pathogens and insects affect spatial and temporal patterns of succession, describing current and historic pathogen and insect regimes (the spatial and temporal patterns of pathogen and insect actions), and predicting future successional trends that reflect the role of pathogens and insects.

For each of these agents the actions and the functions have been defined. The "actions" on the part of the pathogen or insect, in conjunction with the physical conditions of the polygons, determine the most likely functions of the pathogen or insect. These include, the potential vegetation type, cover type, structural stage, elevation, and so on. By focusing only on functions which are expected to be significant at this broad scale, many of the actions of pathogens and insects were eliminated from consideration. The outline of the analysis system used (below) was excerpted from Hagle, Kegley and Williams 1995. The analysis methods and pilot results are discussed in greater detail in Hagle and Williams 1995 and Hagle, Kegley and Williams 1995.

Analysis Structure

The analysis consists of three general phases. In the first phase we:

1) selected a stratified random sample to represent a broad range of conditions on each Forest,
2) identified significant pathogen and insect succession functions associated with the represented forest types,
3) identified actions which lead to the significant functions and the conditions under which they occur,
4) analyzed the data from 1975 surveys to assign probability index values for each identified action,
5) characterized polygon classes according to their average, range and frequency distributions of pathogen and insect action indices.

In the second phase we:

1) analyzed successional changes from 1935 to 1975 in polygons covered in surveys from both years.
2) assign pathogen and insect action probability indices to polygons based on their 1935 classes,
3) compared 1935 and 1975 pathogen and insect action probability indices,
4) analyzed successional stage changes from 1935 to 1975,
5) calibrated FVS (Wykoff and others 1982) and pest models (Bukema and others 1994, Stage and others 1990) to reflect actual successional transitions according to polygon classes and pathogen and insect action probability indices.

In the third phase we:

1) used actual transitions for well-represented classes and calibrated FVS simulations for poorly-represented classes to produce factors for types and rates of successional transitions,
2) entered the factors into transition matrices as appropriate for two landscape successional models which are currently under development.

Analysis Team

Carol Bell (Forest and Rangeland Management), Jim Byler (FRM), Nancy Campbell (FRM), Ken Gibson (FRM), Susan Hagle, (FRM), Teri Johnson (on detail from the Lolo NF), Sandra Kegley (FRM), Lowell Lewis (Management Systems Corporation of America), Blakey Lockman (FRM), Michael Marsden (MACA), Ross Pywell (Methods Applications Group), John Schwandt (FRM), Chuck Siefke (MACA) Larry Stipe (FRM), and Jane Taylor (FRM), Steve Williams (MAG).

The project is supported in part by a Technology Development Special Project grant through the USDA-Forest Service, Washington Office, Forest Health Protection.

Literature Cited

Amman, G.D. 1977. The role of mountain pine beetle in lodgepole pine ecosystems: impact on succession. In: W.J. Mattson, ed. The role of arthropods in forest ecosystems. Springer-Verlag, New York, New York, USA.

Beukema, S.J.; Kurz, W.A.; Greenough, J.A. 1995. Annosus root disease model: user's guide and model description. Prepared by ESSA Technologies Ltd., Vancouver, B.C.

Byler, J. W.; Marsden, M. A.; Hagle, S.K. 1992. The probability of root disease on the Lolo national Forest, Montana. Can. J. For. Res. 20:987-994.

Filip, G.M.; Goheen, D.J. 1984. Root diseases cause severe mortality in white and grand fir stands of the Pacific Northwest. Forest Science 30: 138-142.

Goheen, D.J.; E.M. Hansen. 1993. Effects of pathogens and bark beetles on forests. In: Beetle- pathogen interactions in conifer forests. Academic Press Ltd. PP. 176-196.

Hagle, S.K.; Byler, J.W.; Jeheber-Matthews, S.; Barth, R.; Stock, J.; Hansen, B.; Hubbard, C. 1994. Root disease in the Coeur d'Alene river basin: An assessment. In: Interior Cedar-Hemlock-White pine forests: Ecology and Management, 1993, March 2-4; Spokane, WA: Washington State University, Pullman, WA. pp. 335-344.

Hagle, S.K. 1993. Forest Health in Ecosystem Management. In: Frankel, S., comp. Western International Forest Disease Work Conference proceedings. USDA- forest Service, Pacific Southwest Region. pp. 112-116.

Hagle, S.K.; Byler, J.W. 1993. Root diseases and natural disease regimes in a forest of western U.S.A. In: Johansson, M.; Stenlid, J., eds., Proceedings of the Eighth International Conference on Root and Butt Rots, Wik, Sweden and Haikko, Finland, August 9-16, 1993. pp. 606-617.

Hagle, S.K.; S.B. Williams. 1995. A methodology for assessing the role of insects and pathogens in forest succession. In: Thompson, J. comp. Methods for Analysis in Support of Ecosystem Management, Symposium proceedings. Ft. Collins, CO, March 1-4, 1995. In press.

Hagle, S.K. ; Kegley, S.; Williams, S.B. 1995. Assessing pathogen and insect successional functions in forest ecosytstems. IN: Proceedings of the National Silviculture Symposium, March 1995, Mescalero, NM. In press.

Harris, L.D.; Maser, C. 1984. Animal community characteristics. pp.44-68. IN: Harris, L.D., The fragmented forest. Island biogeography theory and the preservation of biotic diversity. The University of Chicago Press, Chicago, 211 pp.

Kurz, W.A.; Beukema, S.J.; Robinson, D.C.E. 1994. Assessment of the role of insect and pathogen disturbance in the Columbia River Basin: a working document. Prepared by ESSA Technologies, Ltd., Vancouver, B.C. USDA Forest Service, Coeur d'Alene, ID, 56 pp.

O'Laughlin, J., J.G. MacCracken, D.L. Adams, S.C.Bunting, K.A. Blatner, and C.E. Keegan, III. 1993. Forest Health conditions in Idaho. Idaho Forest, wildlife and Range Policy Analysis Group, Report No. 11. 244 p.

Spurr, S.H. ; Barnes, B.V. 1973. Forest Ecology. The Ronald Press Company. 571 pp.

Stage, A.R. and eight others 1990. User's manual for western root disease model. USDA-FS Intermountain Research Station, Gen. Tech. Rep. INT-267. 49 p.

Swetnam, T.W.; Lynch, A. 1989. A tree-ring reconstruction of western spruce budworm history in the southern Rocky Mountains. For. Sci. 35:962-986.

Veblen, T.T.; Hadley, K. S.; Reid, M. S.; Rebertus, A. J. 1991. The response of subalpine forests to spruce beetle outbreak in Colorado. Ecology 72(1):213-231.

Williams, C.B.; Azuma, D.L.; Ferrell, G.T. 1992. Incidence and effects of endemic populations of forest pests in young mixed-conifer forest of the Sierra Nevada. USDA- Forest Service, Research Paper PSW-RP-212, Pacific Southwest Research Station, 8 p.

Wykoff, W.R.; Crookston, N.L.; Stage, A.R. 1982. User's guide to the Stand Prognosis Model. Gen Tech Rep. INT-133. Ogden, UT, USDA Forest Service, Intermountain Forest and Range Exp. Station. 112 p.

FOREST PATHOLOGY AND DISTURBANCE ECOLOGY: IS THERE A ROLE FOR FOREST PATHOLOGISTS?

Jim Byler and Det Vogler

Discussion and Conclusions

Tom set the stage for our discussion by discussing disturbance ecology concepts and terminology. He stressed the importance of scale and of the viewpoint of the observer. He suggested that the term disturbance should be reserved for events that come from outside the system. By that definition, most pathogens do not cause disturbances, since they are agents working within the system to cause slower rates of change. From most viewpoints, only introduced pathogens might cause the rapid changes from outside the system that would qualify as disturbance.

Table 1 is a framework for discussion of the relevance of forest pathology to disturbance ecology, and the roles for forest pathologists. Our traditional role has been to address the function of diseases as they impact resources, commodities and amenities. We considered ourselves ecologists, because disease was the interaction of the host, pathogen and environment. We worked at various scales, but like most of our research and management counterparts, we generally focused on stands or smaller spatial scales, and decades or shorter time frames.

Table 1. Forest pathology and disturbance ecology: a framework for discussion of the roles of pathogens.

FUNCTION	INTERACTIONS	SPATIAL SCALE	TEMPORAL SCALE
Impact Resources Etiology	Pathogen	Molecular	Hours
Epidemiology Damage	Host	Population	Days
Control	Environment	Stand	Years
	Insects	Project	Decades
Regulate Processes Succession	Fire	Watershed	Centuries
Decomposition Evolution	Many others	River Basin	Millennia
		Continent	

Disturbance ecology has added a whole new dimension in terms of disease function, and broader and longer spatial and temporal scales. It is now necessary to address the function of pathogens in ecosystem processes, whether we call them disturbance agents, ecosystem regulators, or something else. And we have the need to evaluate the interactions of pathogens with other factors, particularly fire, at the scales of assessment and research that are featured today. These scales tend to track events and changes in watersheds and river basins over decades and centuries.

Sue Hagle illustrated successional roles of pathogens, and described a Northern Region analysis to understand how pathogen function has changed during past decades and to quantify effects on forest composition and structure. The scale of the analysis will make it useful for predicting successional effects at the watershed and area scales of assessment.

John Lundquist presented results of research to develop disturbance profiles, a representation of the dynamic forest community as a mosaic of living and dead trees interacting with a sequence of factors and agents. They are visual displays and descriptions of current conditions in comparison to reference conditions with ranges of variability. They are for use in prescription development.

General Discussion

A lively discussion took place during the meeting, dealing with terminology and with pathologist's appropriate roles. We regret that we were not able to capture that discussion. What we have done, however, is to invite several participants who made comments from the floor to prepare short written statements. These are reproduced below.

Everett Hansen's Comments

This was a valuable session. It clarified a number of issues for me, although they weren't necessarily the points the speakers were trying to make.

1. Language is all important. Disturbance Ecology means something very specific to Hoekstra. I appreciated his coherent set of definitions. It showed the need for clear thinking. Unfortunately, his definitions are very limiting, and not useful for the pathologists. It is important to realize that there are many other definitions of "disturbance", and that this is an area of active ferment among ecologists. Pathologists are usually naive ecologists (and vice versa). This was an excellent reminder that we need to be careful that our language means the same things to our audience that it does to us.

2. Questions of scale were highlighted, again as a useful reminder to be clear in our thinking. Much of the discussion was focused at the landscape spatial scale, and long term temporal scales, and it is important to think this way sometimes. But we should not forget that disease management (dare we still talk this way?) is usually practiced at the stand or tree level, and in the here and now, not the distant future or forgotten past.

Finally 3. We must constantly strive to understand the objectives of management, at whatever scale. Native pathogens **are** part of the system, functioning as regulators or disturbance agents, or mortality agents, whatever term we choose, within the ongoing ecosystem process. Under some definitions of ecosystem management, and in some site specific management objectives, these same organisms cause economic, or aesthetic, or personal damage, and are legitimately subject to our best efforts at disease and loss prevention.

Fields Cobb's Comments

I had come to the session prepared to battle with our guest ecologist from the Rocky Mountain Station. He disarmed me completely with his views that pathogens are as much a part of the natural forest ecosystem as are the trees, wildlife, etc. I and my colleague Dick Parmeter at Berkeley have long taught, and preached a bit too, that endemic pathogens are a totally natural component of the forest and that they should be viewed as regulators, not as "disturbance factors".

I view disturbance factors as those things or events normally outside of the system that might impact upon the system suddenly (eg volcanic eruption, rare hurricanes or rare, naturally occurring fires) and not occur again for millennia, or may be introduced into the system from afar (eg blister rust). It is not only a wrong use of the terms but a sadly misguided concept to refer to endemic pathogens as disturbance factors. To base major analyses of systems on pathogens (and insects too) as disturbance factors rather than as naturally occurring regulators will lead to serious and potentially devastating errors.

I enrolled in college with the goal to become a forester (which I think I did). Along the way, I discovered that to be a good forester I needed to understand the ecology" of the forest, ie to see the forest and ALL of its components as a functioning system, hence, I became an ecologist of sorts. But I learned that to be a good ecologist, as well as a good forester, I had to learn the pathogens, and how they influenced the forest, and how human activities in the forest influenced them. I do believe that I can pass as a forester, a forest pathologist, and an ecologist in spite of what my friend and colleague from OSU has to say about it.

Because of this background, I have not taught "forest pathology" as a forest mycology course. I have had students call the course the best class in silviculture that they had taken and others the best class in ecology. I tried to show them how pathogens function in the natural system and how human activities were most often the disturbance factors that unbalanced the system and caused the pathogens to become problems. In other words, disease diagnosis is not complete until we have determined how humans have contributed to the problem in the first place.

I suspect that most of you know the functions or characteristics of forests that are regulated at least in part by pathogens, and I am sure that there are good additions to the following list: (1) stand composition and succession; (2) stand density; (3) age structure of trees and other perennials; (4) gene selection and conservation (=fitness); (5) nutrient cycling; (6) wildlife habitat creation and maintenance (eg gap and habitat formation for other plants and wildlife).

As for human impacts, they range from introduction of pathogens such as *Cryphonectria parasitica*, which not only eliminated chestnut but set up a situation for oak wilt, to high grade mixed conifers which intensified true fir mistletoe and other pathogens.

Bob Edmonds' Comments

With the current emphasis on ecosystem management in forestry it appears that the agricultural image of pathology, where we focus on the disease triangle (i.e., host, pathogen, and environment), is not appropriate for forest pathology. Exceptions might be intensively managed hybrid poplar plantations that are managed on very short rotations for pulpwood. This practice, however, is more like agriculture than modern forestry. Forest pathologists need to take a more ecological approach. Ecologists recently developed the concept of disturbance ecology recognizing that ecosystems are rarely if ever in steady state and are continually changing. They initially considered disturbance to be caused by physical agents such as fire, floods and windstorms. Biological agents such as insects and pathogens can also be considered disturbance agents because they influence species succession, forest structure and function and wildlife habitat like the physical agents. Disturbances, however, are generally considered by ecologists as coming from outside the system and occurring rapidly and dramatically like fire and wind. Time and space scales are important in the definition of ecological disturbance. Native insects and pathogens are typically inside the system and act more slowly, although introduced or exotic insects and diseases could be considered as disturbances? Probably not in the strict definition of disturbance ecology although they are certainly agents of change.

Despite this I would strongly argue that forest pathologists need to take an ecological approach to the study of forest diseases. We need to view our major disease agents, i.e. fungi, bacteria, viruses, dwarf mistletoes and nematodes, as biological components of ecosystems. Disturbance ecology has been important in illustrating to both ecologists and pathologists the importance of pests and pathogens in ecosystems. However, the space and time scaling problems of determining whether pests and pathogens are actually disturbance agents and whether they act from inside or outside the system makes the concept difficult to grasp for both ecologists and pathologists. Introduced agents, like white pine blister rust, may originate from outside the system, but eventually they become part of the system. If the space scale is increased then everything can be considered inside the system. It may be more appropriate to consider pests and diseases as producer, consumer and decomposer organisms in ecosystems. They are acted upon by the physical components of ecosystems and interact with each other. Individual pathogens, tree species, and loss of productivity can still be studied in this context.

As a member of the American Phytopathological Society, the Ecological Society of America and the Soil Science of America I am concerned that forest diseases are rarely discussed in the latter two societies. For example, at the 1995 Annual Meeting of the Ecological Society of America in Snow Bird, Utah there were several thousand attendees and only two papers on forest diseases. Soil biology, however, receives a deal of attention in both societies. I believe that involvement of soil scientists and ecologists in forest pathology and vice versa is extremely important in the survival and future development of the field of forest pathology.

Will Littke's Comments

I will comment on this issue from my perspective as a University of Washington post-doc member of a multidiciplinary forest ecology/pest team studying fire-fungi-bark beetles (NFS-funding for 3 years) and as a industrial forest pathologist (12 years). First let me define our role and later describe the steps to develop it.

Our role as scientists with specific backgrounds in the interaction of hosts, biological agents and the environment is central to any study described as disturbance ecology. This expertise can best be used in multidiciplinary studies of ecosystems in several ways, namely: (a) through descriptive floristic studies of lower cryptograms (often not covered in biological surveys of ecosystem or floristic diversity); (b) through quantitative determinations of agents that can be used as markers or indicators of past disturbance frequency (i.e. fire dependent fungi, decay columns, mistletoe, rust levels) and previous stand history; (c) through integration of pest-host interactions (to explain individual or group selection by other pest agents such as bark beetles); and (d) through input from a scale and temporal perspective of agents across stands and landscapes.

(a) Floristic Diversity: Disturbance agents modify the successional gradients of pests as they do other larger ecosystem components. Harvest patterns, like other disturbances, have affected pathogen distribution (both positively and negatively) and also serve to begin new successional gradients. The same can be said about other microorganism groups representing symbionts (mycorrhizae) and decomposers (wood-decaying basidiomycetes). Past stand or landscape histories can be better understood by reading successional patterns of these diverse groups (which are often overlooked). Future needs include management of stands for diverse forest products (edible mushrooms), indicators of maintenance of long term site productivity, conservation of genetic diversity of lower cryptograms for bioengineering, and potential for some forested lands as bio-recyclers of wastes.

(b) Disturbance Agents and Pests: We as pathologists need to develop more information on the successional gradients of certain pest groups (i.e. decay fungi, rusts etc.) and disturbance agents. This could be specific to landowners be it mostly fire, wind, or harvesting events. Terms such as "natural disturbances" should be inclusive of man-caused events, since in the past 20,000+ yours we have impacted ecosystems and ecosystems have integrated our impacts in their structure and function. This information will better enable ecologists to piece together systems ecology. Our learning will be to look at the pest from the context of the system, rather than our usual "gloom and doom" approach which often takes the pest out of context with its surrounding.

(c) Pest Complexes: Focus must be placed on the dynamics of the interrelationship of pest groups. Major pest outbreaks such as Mountain Pine Beetle have their roots in less interesting developments which preceded these events by several decades. This can be accomplished by working with other field experts in endemic pest conditions rather than as "coroners" following system collapse. We have the expertise to study stands and to determine the trajectory from current conditions and to predict future events. Our role is to provide the pulse of the stand or watershed relative to the management guidelines. We must point out where pest and host conditions might clash to limit full site expectations and make recommendations to correct them.

(d) Spatial and Temporal Scales: We must point out the relative nature of pathological situations such as root-disease, where the age of root-rot clones may be 3-5 times older than the current stand (who is encroaching on whom?). We need to promote (where appropriate) intermediate changes to pest conditions which get us to the end result rather than to focus on the same prescription for every site and every acre. On the landscape, tools such as GIS will allow us to identify and for the first time utilize the distribution of root-disease in management plans for diversity and wildlife (rather than create these conditions artificially).

How do we get there if we aren't there already? To put it simply, the pathologist or pest specialist must become an integral part of the management team. You must understand the objectives and constraints of the management unit ("clients") and be able to prioritize those problems of greatest importance or limitation to the unit. Several questions come to mind. Who is your client? What needs do they have? How are these needs being addressed or limited by specific pest groups? How can you help? What communication tools are indicated? How must you educate yourself and your client to be able to speak the same language?

Education is the key to continued success in our field, but in addition to our yearly meetings we must strive to communicate with our peers in other units/diciplines. Soils, silviculture, entomology, fire science, genetics, and ecology should be as familiar to us as are morphological keys to specific pathogens. The role of the pest specialist is slowly being replaces by the specialist with the ability to integrate the pest into the situation and who can make the diagnosis and recommendations. The importance of pathology is not diminishing merely evolving and we must evolve with it or be left behind.

Closing Comments

We sense that most forest pathologists are comfortable with the concepts of pathogens playing ecosystem roles, in addition to their functioning as "competitors" with us in terms of resources. It also appears that we are in general agreement with Tom's definition of disturbance as coming from outside the system. Native pathogens will most often be viewed as part of normal system functioning, thus will not be considered disturbances. "Regulators" is a term used to describe pathogens with ecosystem functions, but there may be a need to revisit terminology. Terminology **is** important.

The degree to which we devote our time and efforts to ecological roles of pathogens, and to which we maintain our traditional "pest" research and extension, is a question that we could discuss in greater detail. The ongoing dialogue about "forest health" centers on whether forest health means the ability to produce resources and other immediate human needs, or whether it is about ecosystem function. It must be about both. Both short term needs of people and long term functions of the systems that provide for those needs are management goals. Pathologists must address the effects of disease on both.

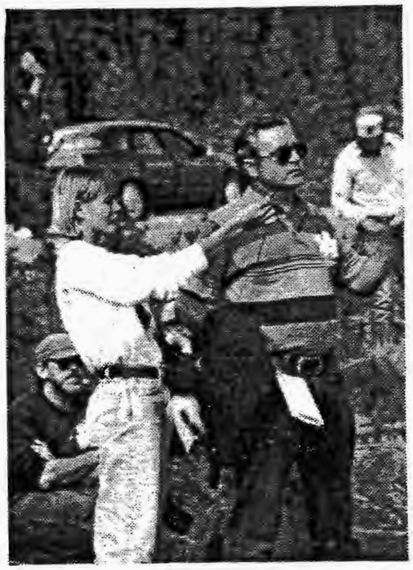
From the political standpoint, it is crucial that we maintain our relevance to questions and issues of the day, which are largely ecological in nature. But we think most would agree that something very valuable would be lost if we neglected the traditional work altogether. One theory suggests that revolutions in science and technology make everything that came before obsolete. We don't see it this way. Our challenge is to allocate our efforts so that we are relevant to today's questions while maintaining the ability to accomplish critical, traditional functions that may not be in-vogue. The scale of today's questions poses a particular challenge to research, the question of how research done in days or weeks in the lab can be made relevant to broader questions about long-term effects.

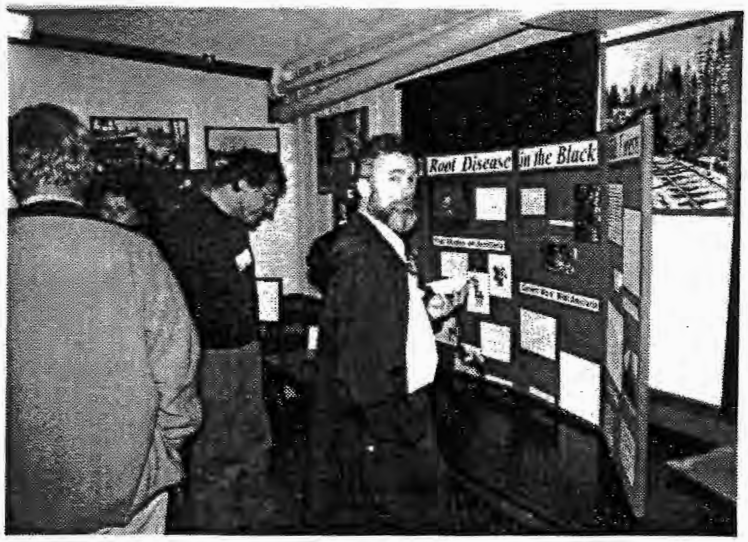
Time did not allow a discussion of the "unique roles" for forest pathologists. But we'd like to share a couple of ideas for your consideration. First, one is to research, assess, and interpret the functions of pathogens as regulators of ecosystem processes. Vegetation ecologists most commonly **characterize** the processes, such as succession or carbon cycling. Fire ecologists describe fire regimes, and how they affect vegetation. We have some depth of knowledge of the ecology and effects of pathogens that drive change and promote stability of the systems, including succession and carbon cycling. Together, we pathologists, entomologists, vegetation ecologists, and fire ecologists can provide a complete picture of the process, and only then will we have the understanding necessary to predict future trends.

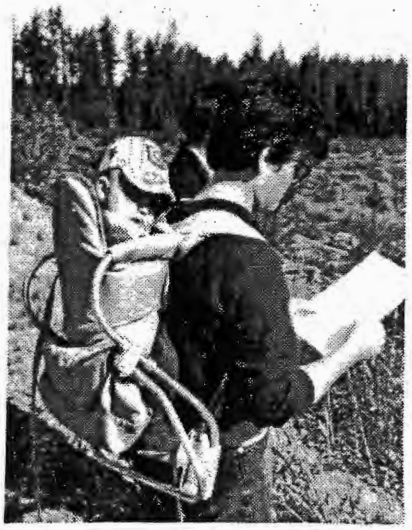
We can play another key role that no one else is likely to play, by maintaining some of our traditional activities. We'll give just one example of many. For example, we heard two excellent panels on taxonomy of pathogens at this meeting. Taxonomy is important, not just for communication, but to show relationships between organisms which may function in different ways. Forest pathologists are familiar with the pathology literature, much of which is not well known to ecologists and others. We have a knowledge of methods for research, monitoring, assessment and prediction of disease. And we have access to herbaria, which are not only needed to answer questions of identity, but can provide material for new research on population genetics, among other things.

Pathologists and entomologists have been quite effective in integrating pest considerations into stand prescriptions, given the size of that job and the small number of pathologists. We did this through a conscious effort to train and assist silviculturists who wrote those prescriptions. We were not so successful in planning. Most of the current forest health problems can be traced to policy decisions, such as to defer consideration of diseases and insect management until we had a problem, to deal with problems at the project level, and to consider insects and diseases only on lands where resource production was a major goal. These policies are now being re-evaluated, and plans will be changed. Forest ecologists are leading many of these assessments that will be used for plan revisions. We have another opportunity to affect management through policy decisions, and can leverage our influence by close cooperation with forest ecologists and others involved in planning at various scales.

Finally, we hope that, rather than closing the case, this session serves as a catalyst for a continuing WIFDWC discussion on the mission and role of forest pathology and pathologists. Disturbance ecology is just one theme that impinges on our profession; there are many others. The fields of evolutionary biology, conservation biology, population genetics, parasitology, and molecular biology (plus many more) are all changing the way we do, or should, think about what we know and how we know it. (If you don't believe in these fields, check the job listings in the back of Science for a refresher course in what academia thinks it wants today). The need for what we know and do will not go away, no matter how badly our numbers decline, but we must also be knowledgeable about the rapid changes in biological sciences that form the landscape in which we function.







POSTERS

Blakey Lockman, Coordinator

ARMILLARIA ROOT DISEASE IN THE BLACK HILLS

Jeri Lyn Harris
USDA Forest Service
Forest Health Management
Rapid City, SD 57701

Melanie Kallas
Department of Forest Resources
Colorado State University
Fort Collins, CO 80523

This display about Armillaria provides information about the disease and latest research on it in the Black Hills to a general public audience. Hopefully, displays such as this will inform the public about Forest pest and health work. The display is available to various offices of the Forest Service and State Forestry Depts., state and county fair booths, and classroom or conference presentations.

This poster also describes a current research project about the incidence of Armillaria root disease in relation to site and disturbance factors. The incidence and severity of Armillaria root disease may be related to various site factors of productivity, soils, past management activity, climatic variation or other environmental factors. The purpose of the three-year study is to develop a hazard-rating system for Armillaria root disease in the Black Hills, This will help forest managers to predict the incidence and severity of the disease for many sites. Preliminary results at this time indicate that more Armillaria-infected trees were found on less productive sites, and on sites with moister soils and lower temperatures.

MERIA LARICIS, AN ANAMORPH OF RHABDOCLINE

David S. Gernandt, Francisco J. Camacho, and Jeffrey K. Stone
Department of Botany and Plant Pathology
Oregon State University, Corvallis, OR 97331.

Meria laricis is a moderately serious needle cast pathogen of *Larix* spp. in North America and Europe. *Meria laricis* has no known ascigerous state, possibly having permanently lost the ability to reproduce sexually and thus representing an obligately asexual "anamorphic holomorph." We present evidence here to show that *M. laricis* is closely related to and probably derived from the ascomycete genus *Rhabdocline*.

DOES *FUSCOPORIA HEINRICHII* CAUSE LAMINATED ROOT ROT IN DOUGLAS-FIR?

E. M. Hansen
Department of Botany and Plant Pathology
Oregon State University
Corvallis, OR 97331

What is the correct name for the fungus that causes laminated root rot on Douglas-fir? Not only must we decide the biological question of species limits, but there is a nomenclatural challenge as well. We need both a specific epithet, and a genus name. Neither are obvious. Here is an annotated chronological listing of some of the taxonomic literature that must be sorted through to find a good name for our favorite fungus.

1. Murrill, W. A. 1907. Family 5. Polyporaceae. North American Flora 9:1- 131.

Hymenophore resupinate
    Tribe Porieae
        Hymenophore brown
            Hymenophore annual
                Spores hyaline *Fuscoporia*
            Hymenophore perennial
                Spores hyaline *Fomitiporia*

Now what could be simpler?

2. Murrill, W. A. 1914. An enemy of western red cedar. Mycologia 6:93-94.

Fomitiporia weirii Murrill New species

Poria weirii Murrill New Combination

Murrill offered two names for the fungus, in the same paper. The type is from western red cedar. Wouldn't it have been nice if Weir had crawled under a root rotted DF tree and sent that specimen to Murrill at the same time?

3. Pilat, A. 1932. Additimenta ad floram Sibiriae Asiaeque orientalis mycologicam. Pars prima. Bull. Soc. Mycol. France. 48:28.

Xanthochrous glomeratus (Peck) subspecies ***heinrichii*** Pilat New Subspecies.

"ad truncum Abietis sibiricae."

X. glomeratus is a North American hardwood Phellinus. Pilat first saw this Asian resupinate fungus as a variant.

4. Pilat, A. 1934. Additamenta ad floram Siberiae Asiaeque orientalis mycologicam. Pars secunda. Bull. Soc. Mycol. France. 49:272.

Xanthochrous heinrichii Pilat New Combination

Pilat now recognizes *heinrichii* as a distinct species. There is no comparison with *weirii.*

5. Pilat, A. 1935. Additamenta ad floram Sibiriae Asiaeque orientalis mycologicam. Bull. Soc. Mycol. France. 51:372.

Phellinus sulphurascens Pilat New Species

> "Fungus maxime insignis......
> ad ligna Larix sibiricae semicarbonista."

Same. man, a new fungus. He does not even compare it to his earlier species *heinrichii.* The type specimen is small, and later judged to be immature. No other specimens are cited.

6. Pilat, A. 1936. Polyporaceae- Houby chorosovite. p. 576, In Kavina and Pilat, eds. Atlas Hub Europskych, Vol. 3. 624 p.

Inonotus heinrichii Pilat, New Combination

I have not seen this reference, but it is apparently the first recognition of the *Inonotus* connection. Bondartsev and Singer are sometimes cited for the combination, but their publication (Ann. Mycol. 39:56) was later, in 1941.

7. Mounce, I., J. E. Bier, and M. K. Nobles. 1940. A root-rot of Douglas fir caused by *Poria weirii.* Can. J. Res. C. 18:522-533.

> " Although differing somewhat from *Poria weirii* as it is found on western red cedar, the fungus would seem to be that species or a form of it occurring on Douglas-fir."

If Ms. Mounce had emphasized the differences instead of the similarities, we would be in a much clearer position today. A number of authors have since emphasized the differences between cedar and DF forms of *P. weirii*, but until Larsen et al. (1994), there was no taxonomic proposal.

8. Aoshima, K. 1953. Wood rotting *Poria* from Japan. II. Bull. Govt. Forest Exp. Sta., Tokyo, 59:57-64.

Fuscoporia weirii (Murr.) Aoshima new Combination.

"Causes a root and butt rot......."

This is the first report of similarities between an Asian fungus and North American *P. weirii.* Aoshima clearly describes a pathogen, in contrast to the earlier strictly morphological descriptions. His discussion refers to *P. weirii* on both cedar and DF, and he lists a combined host range, sensu Mounce et al. (1940). He stresses empty decay pockets and encrusted setae, features that I do not associate with DF *P. weirii.* There is no reference to *heinrichii* or *sulphurascens.* Because Aoshima did not reference the original genus name (*Fomitiporia* or *Poria*) the new combination is not validly published.

9. Kotlaba, F. and Z. Pouzar. 1970. Revision of the original material of *Phellinus sulphurascens* Pil., *Xanthochrous glomeratus* ssp *heinrichii* Pil. and *Polyporus rheades* Pers. Ceska Mycologie 24:146-152.

Inonotus weirii (Murrill) Kotlaba and Pouzar New Combination

"According to our opinion, *Poria weirii* and *Inonotus heinrichii*, (incl. *Phellinus sulphurascens*) are specifically identical."

The plot thickens. This thorough taxonomic treatment amounts to a name change for the Aoshima species, to the genus *Inonotus.* They are saying that the Japanese fungus, *heinrichii*, *sulphurascens*, and *weirii* (both DF and cedar forms?) are one and the same thing, based on basidiocarp morphology. They suggest that *heinrichii* is the preferred name over *sulphurascens*, but both names are made synonymous with *weirii* Murrill. They examined original material, including the types in most cases, for all of the taxa concerned. All North American specimens were from cedar, except one Priest River hemlock specimen. "The American population prefers *Thuja plicata*, whereas the Eurasian population occurs on the wood of almost all conifers in the region." They were clearly saying that the Asian species were similar to the cedar form of *P. weirii.*

This new combination was picked up quickly by European mycologists, but largely ignored in North America.

10. Gilbertson, R. L. 1974. Fungi That Decay Ponderosa Pine.

Phellinus weirii (Murr.) Gilbertson New Combination.

Now we can start the argument about generic placement of our fungus. *Phellinus weirii* sensu Gilbertson includes both DF and cedar forms, although his generic placement relies heavily on the perennial nature of the cedar form. European authors picked up *Inonotus* (ie Donk, Pegler), and relied more on hyphal structure.

11. Fiasson, J.L., and T. Niemela. 1984. The Hymenochaetales: a revision of the European poroid taxa.

"The distinction between *Inonotus* and *Phellinus*, based originally on the color of the spores, then on the hardness and perenniality of the basidiocarp in *Phellinus*, now rests on the miticity. The demarcation between the generative and skeletal hyphae is often vague to nonexistent in this group, and so the distinction between *Inonotus* and *Phellinus* again appears to be a problem."

Fuscoporia Murrill "...a very homogeneous genus. The spores are extremely thin-walled and acyanophylous, and mostly allantoid in shape. The context is very soft corky,....."

These authors looked only at European specimens, and do not mention *weirii* or any synonyms. They really aren't part of the story, except to illustrate the instability in generic nomenclature in this group of fungi.

12. Larsen, M. J., F. F. Lombard, and J. W. Clark. 1994. *Phellinus sulphurascens* and the closely related *P. weirii* in North America.

Inonotus sulphurascens (Pilat) Larsen, Lombard et Clark. New Combination

"....we conclude that the correct name for the Douglas-fir form is *Phellinus sulphurascens*."

They go on to make the new combination. If the DF form is a different species from the cedar form, then it should be called *sulphurascens*. *Weirii* stays with the type, from cedar. Furthermore, both cedar and DF forms, and the Asian taxa, are monomitic, they say, and thus belong in *Inonotus*, not *Phellinus*.

The next (but not the last) chapter is unfolding at this meeting. I am wondering several things:

1. Is the Asian fungus (fungi?) really the same as either of our forms of *P. weirii*?

2. Why doesn't *heinrichii* Pilat have priority over *sulphurascens* Pilat?

3. What genus best holds these species? Strong cases are made for *Inonotus*, and *Phellinus*, but the forces are gathering to split both of these genera into smaller, hopefully more useful groups.

4. Why not *Fuscoporia heinrichii*? Or do you prefer *Phellinus*, or *Inonotus*, or ***Fuscoporia*** (insert your own species name here)? Maybe we could get away with *Phellinus weirii var. heinrichii*, and *P. weirii var. weirii*. Do you miss the old days when a simple call of "***PORIA***" was understood throughout the west?

Or perhaps we had best stick with "***the laminated root rot fungus***", for now.

DOUGLAS-FIR RESISTANCE TO BLACK STAIN ROOT DISEASE

W.R. Jacobi and J.R. zumBrunnen
Department of Plant Pathology and Weed Science and Department of Statistics
Colorado State University, Fort Collins CO 80523

Abstract

A provenance trial of Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) planted in 1969 on southern Vancouver Island, British Columbia was surveyed for the occurrence of black stain root disease (*Leptographium wageneri var pseudotsugae* Harr. & Cobb). The chance of a tree being diseased was positively related to the incidence and proximity of surrounding trees with black stain root disease. Average tree diameter and latitude of a provenance's source were respectively negatively and positively related to number of diseased trees within a provenance. There was more variation among the provenances in amount of disease than could be explained by the number of surrounding disease trees, tree diameter, geographic location, elevation, and longitude of the provenance's source. Thus, it appears that these provenances vary in resistance to the black stain root disease pathogen. Further work with direct inoculations is needed to confirm the variation in resistance among Douglas-fir selections.

Introduction

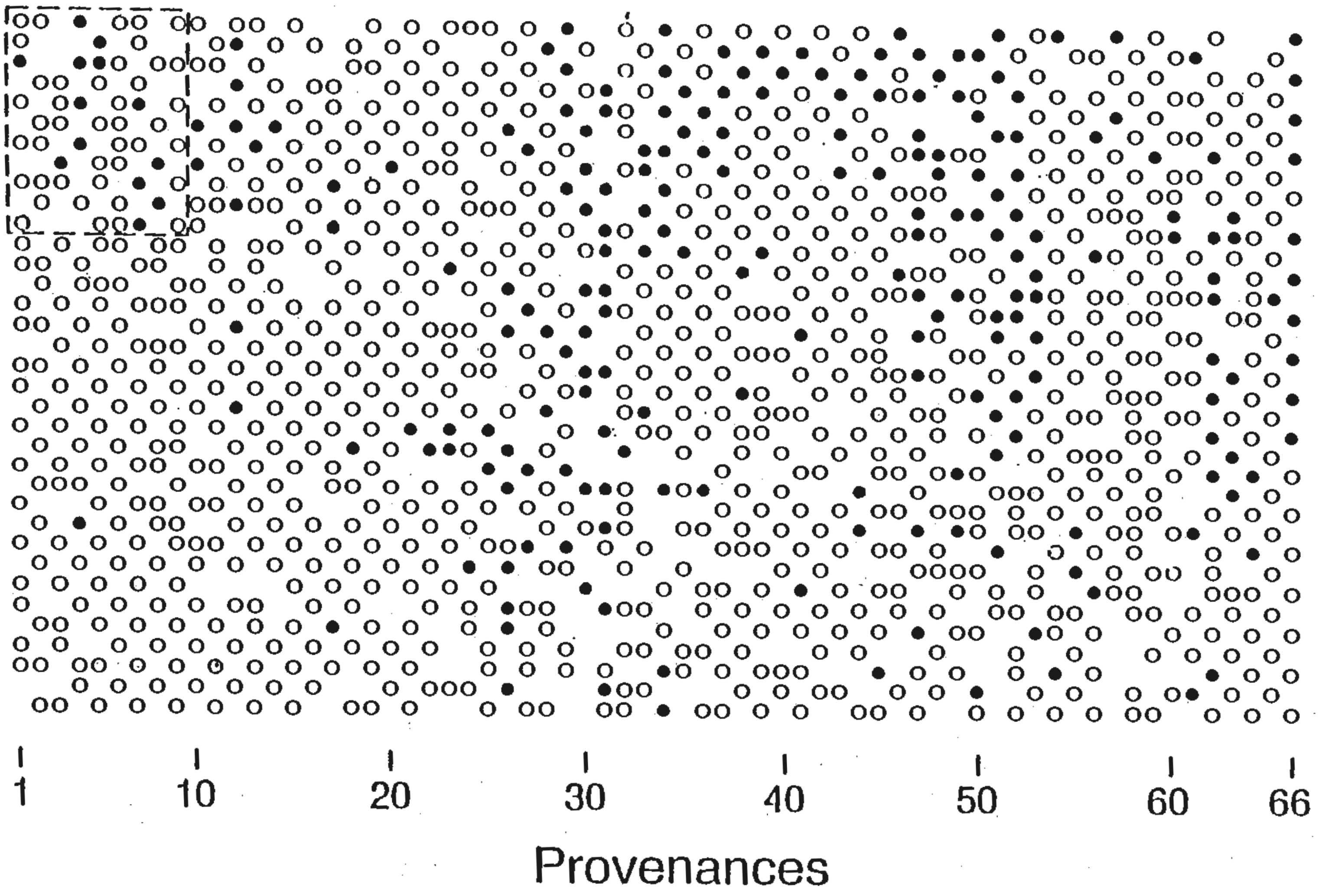
Black stain root disease (BSRD) of Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco), caused by the fungus *Leptographium wageneri* var. *pseudotsugae* Harr. & Cobb, is a serious management problem in western U.S.A.. 1983). Similarly, the disease is causing pockets of mortality on Vancouver Island and the adjacent coastal mainland in British Columbia. Once the fungus is present in a stand, disease management options are limited. Genetically resistant Douglas-fir would be useful to plant on high hazard sites or fill-in plantings in BSRD infested sites where species conversion is not feasible. Thus the objective of this study was to determine if there is evidence of resistance to the black stain pathogen by assessing disease incidence in a provenance trial of Douglas-fir on Vancouver Island. Further pathogenicity testing would be warranted if resistance is indicated by this study.

Methods

The British Columbia Ministry of Forests established a provenance trial of four reps (blocks) with 66 selections of Douglas-fir in 1969 near Port Renfrew on the west coast of southern Vancouver Island, British Columbia. Because of restrictions in suitable planting sites, one block was located 10 km away from the other three blocks. BSRD affected only the one block that was distant from the other three in the trial. Each of the 66 provenances was randomly assigned to a single row in each block, with each row having 35 trees of a single provenance. Trees were planted at 3.6 m spacing between rows and 3 m within rows (Fig. 1).

A thinning removed half of the trees in each row, leaving about 18 trees in a row for a total of 1,341 trees. In fall 1989, the block was surveyed for root disease by assessing foliar and root conditions. Trees with yellow foliage or partial defoliation were partially root-excavated and evaluated for root diseases. Trees with yellow/green needles were not excavated and evaluated for root disease because this provenance trial was still being used by the Ministry of Forests. We assumed all trees with yellow/green foliage in 1989 were affected by BSRD since: of the confirmed mortality, 84% was associated with BSRD and, similarly, four

Figure 1. Location of Douglas-fir trees within the provenance trial showing symptoms of root disease (foliar symptom categories 2-6). Dark circles are trees with symptoms of root disease, open circles are healthy trees. Trees removed in thinning or that died prior to 1984 are blank spaces.



other root disease monitoring plots within 1 km of this site had trees with similar symptoms and all these trees had roots with BSRD symptoms. Since disease incidence of BSRD was not uniform, we accounted for differences in inoculum potential by taking into account the number of infected trees surrounding a tree in three circles. A SAS program searched the data for unhealthy trees in close proximity to each provenance tree, calculating the distance to each nearby unhealthy tree, and calculating the percent of unhealthy trees within each of three successive concentric circles with radial distances away from the tree of 0-4.7, 4.7-7.8, 7.8-10.7 m.

To adjust the apparent resistance of a provenance to BSRD, an analysis of covariance was used. Percent of infected trees in the three circles, geographic group, average tree diameter, elevation, latitude, and longitude of each provenance were used as covariates.

Results

* Provenances varied in the number of trees with BSRD, Armillaria and laminated root diseases (Fig. 1,2).

* The occurrence of resistance was suggested by provenances, such as 25, 32, and 65, that had little disease but were next to rows with heavily infected trees (Fig. 2).

* There were 907 healthy trees, 59 BSRD, 1 BSRD and laminated root disease, 16 BSRD and Armillaria, 130 with foliar symptoms of root disease of undetermined cause, 14 Armillaria alone, and zero trees with laminated root disease alone.

* Thus, the major disease in the stand was BSRD with a few trees affected by Armillaria and laminated root diseases.

* The probability of trees having BSRD was positively related to the percent of unhealthy trees in primarily the first circle.

* No significant relationship existed between the estimated resistance of provenances and the geographic location, elevation or longitude of their origins (Table 1).

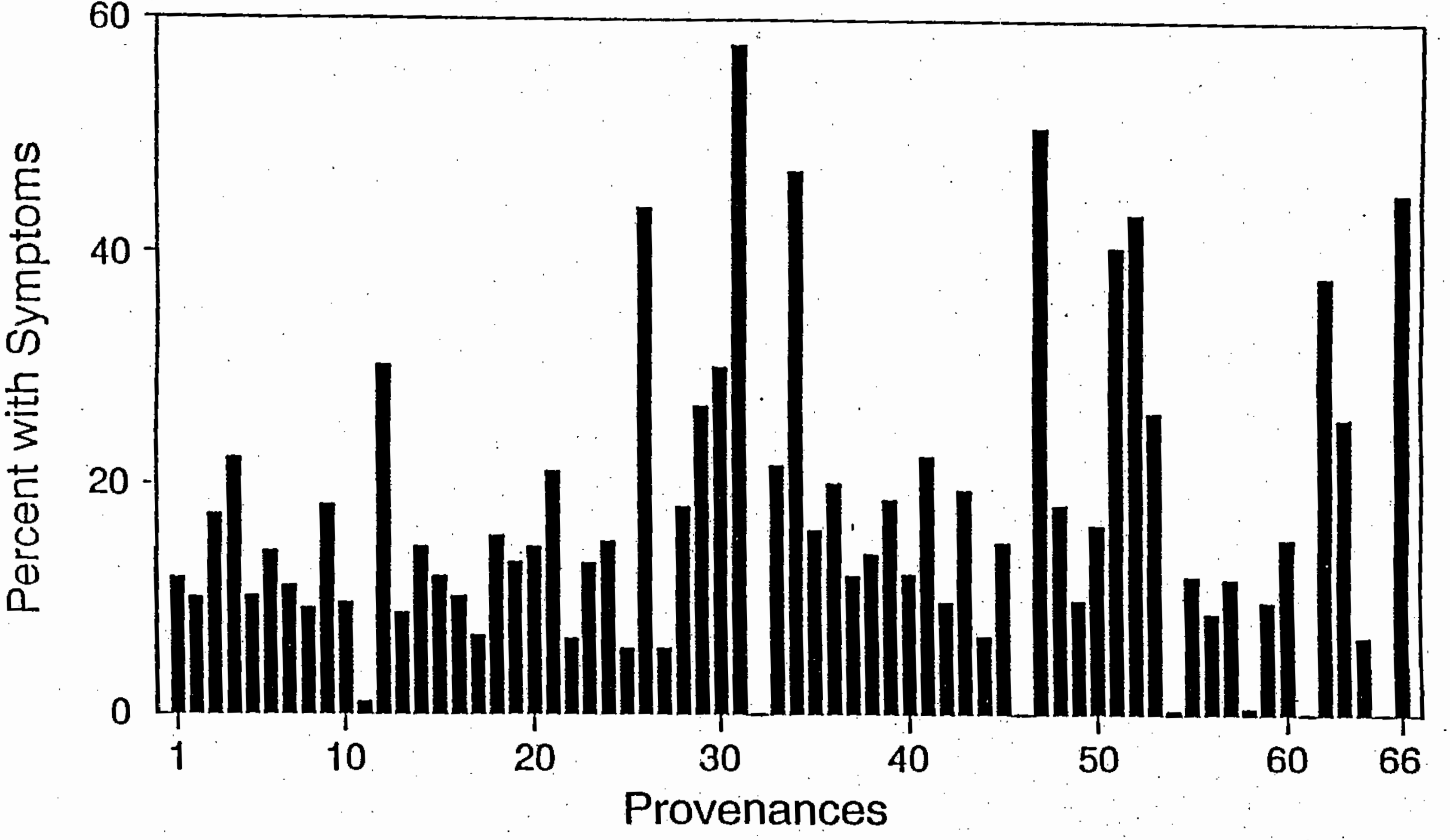
* Latitude of tree origin was weakly associated with disease incidence.

* Tree diameter had a significant negative relationship with resistance (Model 3 & 4, Table 1).

Discussion

Variation in percent of unhealthy trees exists among provenances that is greater than can be explained by parameters describing the source of the provenances, tree diameters and percent of unhealthy trees (inoculum pressure) around each tree. Larger trees are less likely to have the disease, presumably by being more resistant, vigorous or less attractive to insect vectors rather than being exposed to less inoculum. It is unlikely that infected trees have grown slower since infection, as BSRD kills young trees quickly before much impact on tree growth occurs. The existence of rows with few infected individuals between rows with many infected individuals is additional evidence suggesting possible resistance in Douglas-fir. It also

Figure 2. Adjusted mean percentages of Douglas-fir trees within each provenance with symptoms of root disease in 1989 (disease categories 2-6). Means are adjusted for amount of surrounding disease in circle one and average tree diameter of each provenance, thus a provenance may have a mean incidence higher or lower than observed.



appears that movement of the black stain pathogen from tree to tree is more probable as trees are spaced closer together. This study adds further evidence that it would be worth while to set up inoculation studies to further investigate Douglas fir resistance to the black stain pathogen. Thus, the provenances should not be assumed resistant until tested further.

Acknowledgements

We would like to thank Dr. John Muir, B.C. Ministry of Forests, Protection Branch, for support of this survey, and Dr. Cheng Ying, Research Branch, for use of the provenance trial and related growth data.

Table 1. Variation in percent of trees with black stain and root disease symptoms among Douglas-fir provenances related to the influence of average tree diameter, elevation, latitude, longitude and geographic area of origin and proximity of unhealthy trees.

Variation source[a]	DF[b]	Coef[c]	Type I[d] sum of sq.	F value	PR>F
MODEL 1					
Provenances	65		398,982	5.23	0.0001
Radii 0-4.7 m	1	0.29±0.07	116,200	98.93	0.0001
4.7-7.8 m	1	0.23±0.09	13,323	11.34	0.0008
7.8-10.7 m	1	0.14±0.06	5,947	5.06	0.0246
Error	1065		1,250,942		
MODEL 2					
Geographic Area	4		9,440	1.82	0.1230
Provenances w/in G.A.	61		389,542	4.92	0.0001
Error	1068		1,386,414		
			Type III sum of sq.		
MODEL 3					
Radius 0-4.7 m	1		113,367	107.35	0.0001
Diameter	1	-0.26±0.02	136,190	128.96	0.0001
Elevation	1		1,408	1.33	0.2484
Latitude	1	1.74±0.58	9,356	8.86	0.0030
Longitude	1		1,127	1.07	0.3017
Error	1078		1,138,403		
MODEL 4					
Provenances	65		181,769	2.94	0.0001
Diameter	1	-0.26±0.02	84,798	89.05	0.0001
Radius 0-4.7 m	1	0.34±0.04	53,034	55.69	0.0001
Error	1016		967,469		

[a] Provenances = the 66 Douglas-fir provenances.
Geographic area = the five geographic categories for the provenance sources.
Diameter = the average diameter (mm) of all living trees in each provenance in 1988.
Elevation (m), Latitude (degrees), and Longitude (degrees) = the location of the sources.
Radii: 0-4.7, 4.7-7.8, 7.8-10.7 m = the percentage of unhealthy trees found within those circles around a particular tree.

[b] Degrees of freedom. Unequal total degrees of freedom between models results from missing diameter data.

[c] Coefficients with standard errors of significant variables in each model.

[d] Type III sum of squares = the adjusted SS for each variable with all other variables taken into account.
Type I sum of squares= sequential SS explained by the effects in the order in which they entered the model.

LONG TERM FLOODING STRESS AND THYRONECTRIA CANKER OF HONEYLOCUST TREES

S.T. Kerbs and W.R. Jacobi
Department of Plant Pathology and Weed Science,
Colorado State University, Fort Collins, Colorado 80523

Abstract

Four-or-five year-old Honeylocust trees (*Gleditsia triacanthos*) were inoculated the fungus *Thyronectria austro-americana* and exposed to long term flooding over an entire growing season. Experiment 1 utilized ten trees that were flooded and ten trees that were adequately watered. All trees were inoculated with two fungal isolates in mid-June 1994. Experiment 2 also contained ten trees per treatment and were inoculated in early September of 1994. Canker sizes were recorded to determine the effects of the treatments. Water potentials of the trees, dry root weight measurements and percent water roots were also used to analyze the overall health of the trees. Canker expansion did not significantly differ between treatments in either experiment.

Introduction

Honeylocust trees are very common and important shade trees in the United States. Honeylocusts have very few disease and insect problems, but in Colorado they are affected by fungal caused cankers. Expansion of Thyronectria canker caused by the fungus *Thyronectria austro-americana* seems to be influenced by the degree of stress the tree is under. Research on other tree-fungal systems indicates an increase in tree susceptibility to canker expansion from water saturated soils and a reduction in oxygen available to roots. Saturated soils with low oxygen content can damage and kill roots which causes stress. Saturated soils are common in many blue grass landscapes with honeylocusts. Thus, the aim of this project was to determine the effect of long term soil flooding on Thyronectria canker expansion.

Material and Methods

Common thornless honeylocust trees were grown in a shade house in 19 L black pots. Trees were watered by a drip irrigation system. The flooded "wet" trees received approximately 9.6 L per week. The adequately watered "dry" trees received 4.8 L per week.

Two isolates of *Thyronectria austro-americana* were grown in culture and applied to two wounds on trunks of ten trees per treatment. Canker sizes were measured as the sum of the horizontal and vertical size of discolored bark surrounding each wound every two to four weeks for two months after inoculation. Two repetitions of this experiment were completed in June and September 1994.

Water potentials (measure of drought stress) of four trees per treatment were recorded weekly utilizing a pressure bomb. At the end of each experiment root systems were washed, percent of the root system that were water roots (morphologically altered roots as a result of saturated soils) was subjectively rated, and dry weights of root systems obtained.

Results

There was no significant difference between canker expansion on flooded trees and normally watered trees. In fact, the "dry" trees experienced a greater degree of expansion than the "wet" trees. Another interesting finding was that trees inoculated in the summer (Expt. 1) were more susceptible to the expansion than the trees inoculated in the fall (Expt. 2). Water potentials were not significantly different between treatments thus none the trees were drought stressed (Figure 1).

Visually the flooded trees appeared to have fewer roots and more water roots than the adequately watered trees. However, the average ratings for percent water roots were opposite for each experiment and there was no significant difference in dry root weights between treatments (Table 1).

Discussion/Conclusions

Further studies should be completed using trees planted in the field and not pots with the irrigation system utilized in this experiment. The pots allowed to much variation in water applications, root development and health. Ratings of percent water roots should also be taken differently. Subjective measurements were unsuccessful.

Water potentials were not significantly different as was expected since both treatments received enough water to keep them from being drought stressed.

One final thought, during the summer of the experiment (1994) both treatments were further stressed by approximately equal infestations of mites. This additional stress could have caused an increase in expansion for both samples.

In conclusion, we were unable to prove that flooded tress are more susceptible the Thyronectria canker than normally watered trees under our system.

Table 1. Effects of long term flooding of Honeylocust trees on root and canker size.

Experiment	Treatment	Isolate	Mean Dry Root Weight[1] (g)	% Water roots[1]	Mean canker size[1] (mm)
1	Wet	2	20.5x	12.0x	158.4x
1	Wet	3	20.5x	12.0x	182.5z
1	Normal	2	25.2x	21.5z	188.0x
1	Normal	3	25.2x	21.5z	204.7z
2	Wet	2	25.6x	26.0z	58.8x
2	Wet	3	25.6x	26.0z	53.7x
2	Normal	2	28.4x	14.7x	63.6x
2	Normal	3	28.4x	14.7x	65.0x

1-Mean dry root weight, Percent water roots and Mean canker size- means follow similar letters within an experiment. Measurements were not significantally differently when found by an analysis of variation. (P value greater than or equal to .05)

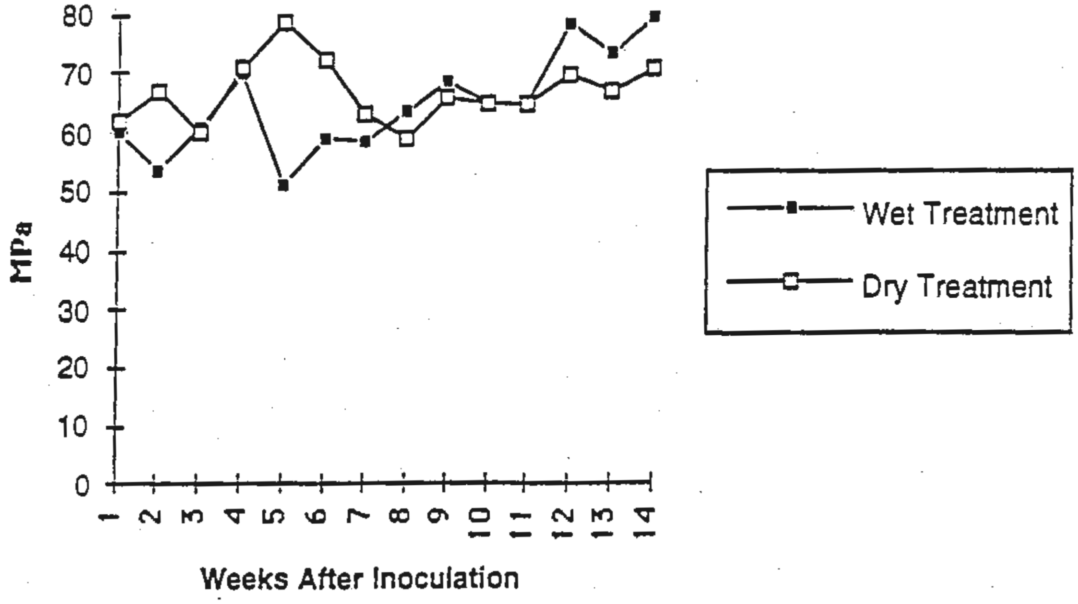


Figure 1. Mean water potentials measured at 4 am once per week beginning June 21, 1994 and ending September 30, 1994.

SUSCEPTIBILITY OF PACIFIC YEW (*TAXUS BREVIFOLIA* NUTT.) TO *PHYTOPHTHORA LATERALIS*

Marion S. Murray and Everett M. Hansen
Department of Botany and Plant Pathology
Oregon State University
Corvallis, OR 97331

In 1991 Pacific yew (*Taxus brevifolia* Nutt.) was reported as a new host for *Phytophthora lateralis* Tucker and Milbrath, an aggressive root rot pathogen thought previously to be specific to Port-Orford-cedar (*Chamaecyparis lawsoniana* (A. Murr.) Parl.). This study was designed to compare the pathogenicity of *P. lateralis* on the two hosts through seedling, stem, branch, and rootlet inoculations, and to characterize sites where Pacific yew mortality occurs. Seedling mortality averaged 58% for cedar and 4% for yew, and root colonization of *P. lateralis* was significantly greater in cedar seedlings than in yew seedlings. Lesion length on the cedar seedling stems was twice the lesion length on yew stems, and cedar branches had lesions four times longer than yew branches. Abundant zoospore aggregation occurred on cedar rootlets along the zone of elongation and the region of maturation. In comparison, far fewer zoospores encysted along the yew rootlets, and were concentrated on the root hairs. A stream survey of three infested drainages in southwest Oregon and northwest California revealed a total of 1199 dead Port-Orford-cedar (46% mortality), and 86 dead Pacific yew (10% mortality). At sites where *P. lateralis*-induced mortality occurred, the interaction of slope and distance from the stream was negatively correlated with tree death. Based on results of this study, we conclude that Pacific yew is less susceptible to *P. lateralis* than Port-Orford-cedar, and that mortality of Pacific yew occurs most often on level sites that are frequently exposed to slow-moving, *P. lateralis*-infested water.

INSECTS AND DISEASES SHAPE OUR FOREST ENVIRONMENT.

Judith E. Pasek
USDA Forest Service
Forest Health Management
Rapid City, SD 57701

An educational display was developed to illustrate examples of the roles and functions that insects and diseases play in changing forest environments. Photos and text introduce concepts of disturbance events and their relationship to stand conditions and fire dynamics, effects on tree growth and form, microclimate changes, nutrient recycling, creation of patchiness, creation of bird habitat, pollination, forest regeneration, and predation. Simple wording was chosen to make the display suitable for a general public audience. The display was developed in response to repeated requests from Forest Service districts for materials pertaining to insects and disease that could be used at fair booths and other public and educational events. The display will also be used during presentations to school and scout groups, which are in high demand in the Rapid City School System. The display was designed to fit on table-top display panels that can be easily transported and set up in a matter of minutes.

IMPACT OF GYPSY MOTH ON ASPEN

John H. Hart
Forestry Department
Michigan State University
East Lansing, MI 48824

The objectives of this research were (1) to compare the reaction of bigtooth and quaking aspen to defoliation by gypsy moth, and (2) to determine how long dead aspen snags remain standing. In late June, species, DBH % defoliation and condition were recorded for each ramet. Average 10 year defoliation of quaking and bigtooth aspen was 22 (0.5-84%) and 10.8 (0-54%), respectively. Mortality of quaking aspen (10%/yr) was 4 times higher than that of bigtooth aspen (2.6%). *Armillaria* sp. occurred on 91% of the dead trees. Mortality was correlated with defoliation >80% for one or two subsequent years but not thereafter. Ramets initially coded subdominant died at 2 to 3 times the rate of ramets coded co-dominant or dominant, although defoliation rates were similar. Five years after death, 78% of the dead snags were still standing.

TREE VIGOR AND THE SUSCEPTIBILITY OF DOUGLAS-FIR TO ARMILLARIA ROOT DISEASE

Pablo Rosso and Everett Hansen
Department of Botany and Plant Pathology
Oregon State University
Corvallis, OR 97331

In this study we explored the effects of thinning, fertilization and pruning on tree vigor and susceptibility to Armillaria root disease. Tree vigor was defined as the relative capacity for tree growth, expressed as the aboveground biomass increment per unit of photosynthetic tissue, or growth efficiency (Waring 1983). It has been hypothesized that trees with higher GE can better resist pathogen attack, and that GE can be used as a predictor of tree susceptibility to disease (Waring 1983).

In a previous study, four Douglas-fir (*Pseudotsuga menziesii* {Mirb.} Franco var. *menziesii*) plantations were thinned, fertilized and pruned in all combinations, and the effects of these treatments on tree vigor were measured after 10 years (Velazquez-Martinez et al. 1992). Root disease was not a factor in the initial study, and mortality was not noted in the plantations until 8 years after the treatments were applied. In the current study, we sought to correlate current Armillaria root disease incidence with the continuing effects of the stand treatments on tree growth.

This work was done at the H.J. Andrews Experimental Forest, in the central portion of the western Cascade Mountains in Oregon. All sites were situated within the Tsuga heterophylla Zone (Franklin and Dyrness 1973), where Douglas-fir occurs in large areas as a dominant, sub-climax species. Four sites, previously uncut, were harvested and slash-burned between 1958 and 1965 and planted with Douglas-fir. In 1981, when treatments were applied, sites were densely stocked (3,000-4,000 stems/ha).

Each of the four harvest units ("sites") was considered a replicate in a split plot design. Each replicate was divided into three plots. One plot was thinned to 300 trees/ha (low density), one thinned to 604 trees/ha (medium density), and one left unthinned (high density), averaging 3459 trees/ha. Each thinning plot was then split into four subplots, and the following treatments were applied: 1) fertilized only, 2) pruned only, 3) pruned and fertilized, and 4) untreated control. All subplots initially contained 50 trees, and thus, varied in area. The total experimental area of the sites ranged from 4.1 to 6.8 ha. Radial growth increment (RG) and growth efficiency (GE) were calculated on an individual tree basis (Waring et al. 1982, Cholz et al. 1979).

Thinning had the most influence on growth response among all the silvicultural treatments. On all sites, lower densities resulted in faster RG and larger tree diameters, and greater values of GE across all time periods. Neither pruning nor fertilization had a significant effect on GE or RG.

Armillaria ostoyae was the primary mortality agent in the study area. None of the 12 subplots on one site had infected trees, although A. ostoyae was found in buffer areas. On the remaining 3 sites, 23 of the 36 subplots were infested. Disease incidence on these subplots ranged from 2 to 20%. Armillaria incidence was the highest at medium density (6.1%), slightly lower on the low density (5.6%), and lowest on the control plots (3.8%). There were no significant correlations between disease incidence on subplots in 1993 and tree growth responses in the first and last periods of the experiment.

It is evident that on these sites that incidence of Armillaria root rot in Douglas-fir is not regulated by tree growth. Thinning produced a significant increase in tree vigor, even at the first time period, but enhancement of tree vigor at low tree densities did not correspond with low root disease incidence on either plots or subplots. Rather, the lowest amount of root disease was on the low vigor, unthinned plots. Furthermore, the vigor of trees that became symptomatic or died by 1993 was not different in 1983-1985 from vigor of trees that remained asymptomatic.

These results contradict the widely held view of Armillaria as an opportunistic, or even secondary pathogen, capable of killing only trees weakened by some other stress. On these sites, in areas of infestation, A. ostoyae is killing the largest, fastest growing trees, as well as less vigorous trees. Armillaria in our sites continues to cause mortality, regardless of the growth efficiency or growth rate of the host. We suggest that the location of disease centers is principally determined by the distribution of inoculum sources. Size and intensity of disease centers may depend on the number of contacts among root systems of young trees and old-growth stumps and the opportunities for increased inoculum potential presented by stumps from thinning.

References

Gholz, H.L., Grier, C.C., Campbell, A.G., and Brown, A.T. 1979. Equations and their use for estimating biomass and leaf area of plants in the Pacific Northwest. Forest Research Laboratory, Oregon State University, Corvallis. Research Paper 41.37 pp.

Velazquez-Martinez, A., Perry, D.A., and Bell, T.E. 1992. Response of aboveground biomass increment, growth efficiency, and foliar nutrients to thinning, fertilization and pruning in young Douglas-fir plantations in the central Oregon Cascades. Can. J. For. Res. 22: 1278-1289.

Waring, R.H. 1983. Estimating forest growth and efficiency in relation to canopy leaf area. Adv. Ecol. Res. 13: 327-354.

Waring, R.H., Shroeder, P.E., and Oren, R. 1982. Application of the pipe model theory to predict canopy leaf area. Can. J. For. Res. 12: 556-560.

THE WIND RIVER CANOPY CRANE
A FACILITY FOR STUDY OF THE FOREST CANOPY

David Shaw
College of Forest Resources
University of Washington
Wind River Canopy Crane
Carson, Washington 98610.

The Wind River Canopy Crane is a user facility located in the Wind River Experimental Forest of the Gifford Pinchot National Forest. The facility is composed of a construction tower crane, 73 meters tall with a jib arm 79 meters long, capable of accessing 2.3 ha of an old-growth Douglas-fir/western hemlock forest (top heights 62 meters, maximum age 500 years). The purpose of the facility is to provide researchers access to the difficult to reach upper and outer canopy of forest trees. Some aspects of our understanding of forest science have been limited due to the difficulty in accessing the canopy of tall trees. The facility is ideally suited to study foliage and stem diseases of Douglas-fir, western hemlock, and western red cedar. In addition the facility can be used to investigate relationships of root disease and stem decays to tree physiology and overall health. Integrated studies that link forest disease to spatial pattern of trees, stand dynamics, other biota, and various environmental conditions are also possible. An infestation of western hemlock dwarf mistletoe also provides unprecedented potential to study the ecology of this important disease. The facility is cooperatively managed by the University of Washington, USFS PNW Research Station, and the Gifford Pinchot National Forest. An operations committee reviews all research proposals for site impacts and availability of crane time. Cost of facility use ranges from $160 to 185/hour. For more information please contact David Shaw, Site Director, Wind River Canopy Crane, 1262 Hemlock Road, Carson, WA 98610.

COMMITTEE REPORTS

RUST COMMITTEE REPORT

Brian W. Geils

The rust committee breakfast was held on Tuesday morning and attended by nine members; verbal and written reports were accepted. In spite of program changes in a number of organizations, work continues on systematics, epidemiology, genetics, distribution, effects, and control of stem rusts.

Pacific Forestry Centre

(Extracted From Biennial Report Submitted by Rich Hunt)

Although program support is reduced with the departure or transfer of Meagher, Dronzek, White, and Ekramoddoullah, a small program including Rich Hunt remains at Victoria. Operations and research are reviewed here.

Operational selection and screening completed by 1995 now includes 291 and 216 trees for the Coastal and Interior areas, respectively. Examination of the 1995 stock will require another 6 years. Selected interior stock will add to the BC Forest Service seed orchard at Vernon (the third such orchard resulting from the program).

Research studies have involved both genetic field trials and various molecular techniques. Field trails examined: 1) potential for Idaho seed in BC, 2) geographic variation of blister rust, and 3) family contrasts in spotting and cankering incidence. The molecular studies of foliar proteins, bark proteins, and monoclonal antibodies are used to investigate resistance and susceptibility. DNA markers, isozymes, and virulence phenotypes are used to examine rust population structure and breeding system. Recent findings confirm previous results that the rust is heterothallic and out-breeding, changes in virulence may occur as result of reassortment of virulence determinants during sexual reproduction, there is no association with geographic region, and variation in restriction-site pattern is low. Results are consistent with the view that blister rust in BC originated from a single introduction and has limited genetic base. Clones of two disease-response genes have been isolated; work with these is continuing.

In other notes, comandra blister rust continues to cause serious concern in southern British Columbia.

Ekramoddoullah, A.K.M.; Davidson, J.J. 1995. A method for the determination of conifer foliage protein extracted using sodium dodecyl sulfate and mercapoethanol. Phytochemical Analysis 6: 20-24.

Hunt, R.S. 1994. The transferability of western white pine to and within British Columbia - blister rust resistance. Can. J. Plant Pathol. 16: 273-278.

Hunt, R.S. 1995. A new portable fungal spore collector. Can. J. Plant Pathol. 17: 90-91.

Hunt, R.S. 1995. Disease incidence can be used to rank families or provenances for relative resistance. Abstr. Can. J. Plant Pathol. [in press].

Hunt, R.S.; Jensen, G.A. 1995. Conifer tree and plot labels. Abstr. Can. J. Plant Pathol. [in press].

Sun, L-J.; van der Kamp, B.J.; Carlson, J.E.; White, E.E. 1995. Preliminary study of genetic variation in western gall rust populations in British Columbia, Canada, using molecular markers. Proc. Fourth IUFRO Rusts of Pine Working Party, Tsukuba, Japan, Oct. 2-4, 1994.

Southwest Region

(Report Submitted by Mark Schultz)

We are planning a white pine blister rust survey of the Sacramento Mts., Lincoln N.F. as part of a forest inventory for a 20,000 acre ecosystem management area. This will give us a fairly intensive survey of a small area. We hope to survey more of the Southwest white pine habitat and related habitats, that have southwestern white pine as a component, by contributing to the National Forest Inventory Analysis (inventory, monitoring, and evaluation research working unit, Ogden, UT). The inventory teams are expected to be in New Mexico sometime in 1996 and/or 1997. These efforts are contingent on whether we can support this through general operating funds, or in combination with other funds.

Dave Conklin and Mark Schultz have located 75 putatively resistant southwestern white pine within the 160 acre area where Hawksworth made his first sighting of WPBR in the Southwest, Bradford Canyon, Sacramento District. Bro Kinloch, of the PSW Forest and Range Experiment Station accompanied us on a trip to look at the feasibility of doing selections. We will probably be sending seed to the Placerville, CA IFG for testing.

Dave Conklin is cooperating with Paul Zambino, North Central Forest Experiment Station, on the collection of uredospores for Paul's molecular systematics studies of the rust.

University of California, Berkeley

(Report Submitted by Det Vogler)

The isozyme study of western hard pine stem rusts led by Det Vogler, University of California, Berkeley, in cooperation with Fields Cobb, Brian Geils, and Dave Nelson (USDA, FS, Shrub Sciences Lab, Provo, Utah), has been accepted for publication in the Canadian Journal of Botany and will be published in early 1996. Results of further work using DNA sequences to explore these same western rusts and other related *Cronartium* and *Peridermium* species in the U.S. have been submitted to Mycologia for publication. *Cronartium* and *Peridermium* species from Eurasia are now been sequenced, and a world-wide phylogeny of these genera of pine rusts will be prepared for submission in late 1995. Collections of spores and infected host material for these studies and analyses of the data have been carried out in close collaboration with the above-mentioned individuals, and with consultations with Roger Peterson, Yasu Hiratsuka, and other rust experts world-wide.

Rocky Mountain Forest and Range Experiment Station

(Submitted by Brian Geils, attending)

The research on stem rusts conducted by the Pest Impact Assessment unit at Fort Collins has always involved partnership with other researchers. Although this unit will be abolished, John Lundquist and Brian Geils intend to continue with these cooperative efforts. We plan to continue with our spring expeditions to collect aeciospores from isolated populations in the western United States; these collections will support studies on rust distribution, phenology, host range, and systematics. The Rocky Mountain Region (Jeri Lyn Harris) has assumed responsibility for re-measurement of comandra blister rust plots established 1982-86 by the RMS and Colorado State University. The Northern (Jane Taylor) and Intermountain Regions (John Guyon) plan to assist with this effort by setting up additional plots as part of the PTIPS system. John Lundquist and Brian Geils continue their interest along with the Southwestern Region in the blister rust outbreak on southwestern white pine. We are especially involved with assessment of the ecological interactions and impacts.

Intermountain Research Station

(Submitted by Donna Dekker-Robertson, attending)

Both genetics and blister rust research continues at the Moscow Lab. Ray Hoff is still active collecting seeds and screening for rust resistance, especially in the whitebark pine-blister rust pathosystem. Geral McDonald is still assigned 25% of his time to research on blister rust and working on a general blister rust hazard model (formerly with Tom Rice).

Pacific Southwest Forest and Range Experiment Station

(Submitted by Bro Kinloch, attending)

Research at the Pacific Southwest Station is investigating both the genetics of the rust and the host. Some of the interesting results are: success with culture of haploid clones, confirmation the rust is heterothallic, outcrossing, but with low genetic variability, and that virulence is not a nuclear trait. Work with host has focused on the hypersensitive reaction and has found high levels of resistance in some southwestern white pine.

In other notes: the Sequoia National Park is conducting an intensive impact study of blister rust.

Oregon State Department of Forestry

(Submitted by Alan Kanaskie, attending)

Current work with white pine blister rust involves operational assessment by remeasurement of stock deployed in the Coast Range.

Northern Region

(Submitted by John Schwandt, attending)

We have recently evaluated silvicultural methods for reducing blister rust losses in western white pine. We found that pruning greatly increases survival of treated trees (reduces mortality by nearly 50%) by reducing the amount of infection. Although thinning alone can result in higher losses of white pine, twenty-two years after treatment, 65-75% of trees with no infections were in plots that had been both pruned and thinned. Pruning not only improves survival but also lumber quality, therefore the forest industry considers the pruning to be economically worthwhile.

Utah State University

(Submitted by Fred Baker, attending)

Limb rust is a serious disease of ponderosa pine in southern Utah and through a cooperative study with the Rocky Mountain Forest and Range Experiment Station, we established a series of growth and yield plots on the Dixie National Forest. These plots are due for re-measurement in 1996.

Retirees

The meeting was also attended by Roger Peterson who maintains an active interest in life cycles and taxonomy and by Fields Cobb who didn't get much chance to say anything before we had to adjourn.

DWARF MISTLETOE COMMITTEE REPORT

Jerome S. Beatty and Robert L. Mathiasen

I. Taxonomy, Hosts, and Distribution

a. A short research note reporting new hosts for hemlock dwarf mistletoe and summarizing the host range of this taxon was published in December, 1994 by the Rocky Mountain Forest and Range Experiment Station (Natural infection of new hosts by hemlock dwarf mistletoe, Research Note RM-RN-350). (See last years committee report Parts a, b, c, and d under Taxonomy, Hosts, and Distribution). (R. Mathiasen, Idaho Dept. of Lands, Cd'A, ID)

b. A short research note pertaining to the reports of larch dwarf mistletoe on alpine larch was published in April, 1995 by the Rocky Mountain Forest and Range Experiment Station (Larch dwarf mistletoe not found on alpine larch, Research Note RM-RN-533). Reports of larch dwarf mistletoe on alpine larch were based on two collections of larch mistletoe made by J. R. Wier in the early 1900's. A detailed examination of the collections indicated the host material is western larch and not alpine larch for both collections. Therefore, we feel there are no valid reports of larch dwarf mistletoe parasitizing alpine larch at this time. (R. Mathiasen, Idaho Dept. of Lands, Cd'A, ID and B. Geils, USFS, RM Sta., Ft. Collins, CO)

c. *Arceuthobium hawksworthii* has been found hiding out in Belize and described by Del Wiens and Terry Shaw: "*Arceuthobium hawksworthii* (Viscaceae), a new species of dwarf mistletoe from Belize." Journal of the Idaho Academy of Science 30(1): 25-32. Here's the abstract: A new species, *Arceuthobium hawksworthii*, is described from Belize, where it is a parasite of *Pinus caribaea* var. *hondurensis*, and possibly *P. oocarpa*. Presently it is known only from the Mountain Pine Ridge area of Cayo District. *Arceuthobium hawksworthii* is compared with *A. aureum* subsp. *aureum*, a Guatemalan species that parasitizes *Pinus pseudostrobus* and *P. montezumae*, and with which it is has been previously confused. In addition to the host differences, the shoots of *A. hawksworthii* are yellow-green, and taller (10-30 cm), the staminate flowers are dark red, the pistillate flowers are brownish-gray, the stigma is included, the flowers and fruit are generally larger, it produces witches' brooms, and exhibits multiple, periodic flowering. On the basis of morphological and physiological characters *A. hawksworthii* is assigned to section Vaginata. (Del Wiens, Univ. of Utah and Terry Shaw, USFS, PNW Sta., Juneau, AK)

d. Several cases of dual parasitism by lodgepole pine dwarf mistletoe and larch dwarf mistletoe on lodgepole pine were observed in the Okanagan Highlands in northern Washington. Evidently dual parasitism by these dwarf mistletoes on lodgepole pine is more common than previously believed. Several specimen collections were made and have been deposited at the Forest Pathology Herbarium in Fort Collins, CO. (R. Mathiasen, Idaho Dept. of Lands, Cd'A, ID)

e. Over 80 specimen collections were made during 1994 for several dwarf mistletoe/host combinations from the Pacific Northwest. Specimens collected represented new host reports, new geographic locations, or unusual host/parasite situations such as dual parasitism by two dwarf mistletoes on the same tree. These specimens have been added to the extensive herbarium collection of dwarf mistletoes established by Frank Hawksworth at the Rocky Mountain Station in Ft. Collins, CO. (USDA Forest Service, Forest Pathology Herbarium).

I encourage all members of the dwarf mistletoe committee to continue collecting specimens of dwarf mistletoes for deposit at Ft. Collins or other herbaria.

Collections of dwarf mistletoes from new geographic areas or on secondary, occasional, rare, or what were thought to be immune hosts are all useful contributions to herbaria and constitute important reports for future studies of dwarf mistletoe taxonomy, hosts, and distribution. Even collections of dwarf mistletoes made from known localities at different times of the year may be valuable additions to herbaria. Collections made during the peak of anthesis or seed dispersal are needed from many localities and at different elevations. Many botanical herbaria have poor representation of dwarf mistletoes or only have old, poorly preserved specimens with non-specific information on the location where the mistletoe was collected.

The host range tables, maps of geographic distribution, and list of specimens examined (Appendix) in the revised monograph of dwarf mistletoes should be consulted to determine if your observations of a dwarf mistletoe could be a new host combination or a new geographic location worthy of a specimen collection and report. Collections of dwarf mistletoes that are at their peak of anthesis or seed dispersal can be made from any location. For information on making specimen collections consult the monograph revision or contact B. Geils or R. Mathiasen. (R. Mathiasen, Idaho Dept. of Lands, Cd'A, ID)

f. Some noteworthy specimen collections of dwarf mistletoes made during 1995 are:

Douglas-fir dwarf mistletoe on Engelmann spruce and subalpine fir. Washington, Okanagan Co, 8 mile creek canyon.

Douglas-fir and larch dwarf mistletoes both parasitizing the same subalpine fir. Washington, Okanagan Co., Northwest of Wauconda.

Lodgepole pine and larch dwarf mistletoes both parasitizing the same lodgepole pine. Washington, Okanagan Co., several locations.

Mountain hemlock dwarf mistletoe on grand fir. Oregon, Lane Co., Pat Saddle, south of McKenzie Bridge.

Mountain hemlock dwarf mistletoe on western hemlock. Oregon, Linn Co., Wildcat Mountain Natural Area.

Western hemlock dwarf mistletoe on Engelmann spruce. Oregon, Linn Co., 12 miles West of Santiam Pass on US Highway 20.

Larch dwarf mistletoe on grand fir. Washington, Kittitas Co., South of Leavenworth near US Highway 97.

(R. Mathiasen, Idaho Dept. of Lands, Cd'A, ID)

g. In February 1995, I observed two species of mistletoe near San Carlos de Bariloche, Argentina (41 degrees south latitude). *Tristerix tetrandrus* was found on *Lomatia hirsuta* and *Maytenus boaria*. This mistletoe has relatively large leaves (often larger than the host leaves) and produces colorful flowers. In fact, host trees are artificially inoculated to grow the mistletoe for its floral display. Another mistletoe species, *Myzodendron* sp., is very common throughout the Andes especially on *Nothofagus dombeyi* and *N. pumillio*. Unlike *Tristerix*, *Myzodendron* has pale yellow stems and rudimentary leaves, and as such, resembles *Arceuthobium* in North America. Although some work has been done on habit, flowers, and fruits of *Myzodendron* spp. (Kuijt 1969), relatively little is known about the pathology of mistletoes in Patagonia. (G. M. Filip, Associate Professor, Oregon State University, OR)

h. During our recent surveys for the illusive mountain hemlock dwarf mistletoe in southern Washington (Gifford Pinchot National Forest) we discovered lodgepole pine dwarf mistletoe infecting subalpine fir on the southeast slopes of Mount Adams (Yakima County). We observed a total of 14 heavily infected subalpine fir scattered among heavily infected lodgepole pine. Infected subalpine fir were heavily broomed, but few shoots were observed on infected branches. In addition, infected branches usually were extremely swollen. The infected subalpine fir were growing in close proximity to heavily infected lodgepole pine and the few shoots we did observe were morphologically similar to the shoots of lodgepole pine dwarf mistletoe. This is the first report of lodgepole pine dwarf mistletoe on subalpine fir. Prior to this report subalpine fir was thought to be immune to lodgepole pine dwarf mistletoe.

We also discovered larch dwarf mistletoe infecting Pacific silver fir northwest of Trout Lake, WA. Infected Pacific silver fir were growing near heavily infected mountain hemlock and old, residual dead western larch with signs of heavy, past larch dwarf mistletoe infection. Subalpine fir were occasionally infected in the area as well. Observations in other nearby stands indicates that Pacific silver fir is best classified as an occasional host of larch dwarf mistletoe. This is the first report of larch dwarf mistletoe on Pacific silver fir and the first report of larch dwarf mistletoe parasitizing mountain hemlock in the Cascade Mountains. (R. Mathiasen, ID Dept. Lands, J. Beatty, USFS, FPM-R6, and D. Hildebrand USFS, FPM-R6).

II. Physiology and Anatomy

III. Life Cycles

IV. Host-parasite Relations

a. A study initiated in 1991 to determine the approximate ages and heights at which young western larch are first infected by larch dwarf mistletoe in the Inland Empire is continuing. Over 200 additional larch saplings were sampled during 1994. Results indicate that most western larch saplings are infected by the time they are nine years old when growing near heavily infected overstory trees. However, small larch are not generally infected until they are slightly older when growing near lightly infected overstory trees. Most larch saplings are taller than breast height before they are infected. The study has been expanded to include infection of young larch near infected seed trees. So far only twelve seedlings have been found growing near infected seed trees. The saplings ranged from 6 to 8 years old. Infection of larch regeneration in the plots around several larch seed trees will be monitored for several years.

Information on whether or not there is a "lag" period for aging larch dwarf mistletoe infections is being obtained from artificial inoculations. From 1992-1995 several hundred larch dwarf mistletoe seeds were placed on young western larch near Priest River, Idaho. Successful infections will be dissected after several years to determine how long it takes before annual rings become distorted as a result of mistletoe infection in larch. (R. Mathiasen, Idaho Dept. of Lands, Cd'A, ID)

b. Quantitative data is being collected on the host relationships of mountain hemlock and western hemlock dwarf mistletoes in Oregon and Washington. Temporary circular plots (6 m radius) are placed around heavily infected hemlocks in mixed conifer stands and the following data recorded for each tree larger than 2 cm in diameter at breast height: species, dbh and DMR. This information will be used to better evaluate the natural host susceptibility classifications for hemlock dwarf mistletoe in the Pacific Northwest.
(R. Mathiasen, Idaho Dept. of Lands, Cd'A, ID)

c. Additional quantitative data is being collected on the host relationships of larch dwarf mistletoe in the Pacific Northwest. This information will be used to better evaluate the natural host susceptibility classifications for larch dwarf mistletoe. (R. Mathiasen, Idaho Dept. of Lands, Cd'A, ID)

d. A study to quantify the level of parasitism on subalpine fir by Douglas-fir dwarf mistletoe in the Pacific Northwest was started in 1993. Quantitative data was collected from new areas where Douglas-fir dwarf mistletoe was discovered on subalpine fir in Washington. In 1994 and 1995 additional data was collected from areas where this host-parasite combination has been previously reported in Idaho, Utah, Arizona, and from new locations in Washington. (R. Mathiasen, Idaho Dept, of Lands, Cd'A, ID)

V. Effects on Hosts

VI. Ecology

a. In April 1994, *Arceuthobium tsugense*, hemlock dwarf mistletoe, was listed as a species needing protective management in the Record of Decision and Standards and Guidelines for Land Management within Range of the Northern Spotted Owl (ROD) published jointly by the USDA Forest Service and the USDI Bureau of Land Management. This came as a surprise to pathologists, foresters, and silviculturists, especially since Forest Disease Management Notes, published by the Pacific Northwest Region, states that hemlock dwarf mistletoe infests 21% of the western and mountain hemlock types in the Pacific Northwest. In the rush to complete the Northwest Forest Plan, apparently a small group of people gathered information and opinions, and developed lists of species and protective management schemes that were hurried through without internal review. The intent was to protect species associated with late-successional and old-growth forests, and whose habitat or populations are strongly limited or at high risk of becoming limited due to management activities. Hemlock dwarf mistletoe was apparently included based on one individual's recollections of conversations with Frank Hawksworth that mountain hemlock dwarf mistletoe populations were hard to find in Washington.

Beginning in May of 1994, we attempted to inform the people involved of the widespread occurrence and broad host range of hemlock dwarf mistletoe. Tommy Gregg and Diane Hildebrand retrieved the data from the timber inventory and Diane wrote a fairly comprehensive summary of the biology and distribution of hemlock dwarf mistletoe. In February 1995, Jerry Beatty and Diane Hildebrand were able to come to consensus with key individuals in support of a request for a change in status for hemlock dwarf mistletoe. Finally, at the end of July 1995, the Regional Interagency Executive Committee and the Regional Ecosystem Office decided to change the listing. We succeeded in reducing the requirements to "conduct general regional surveys" for mountain hemlock dwarf mistletoe, *Arceuthobium tsugense* subsp. *mertensianae*, in the State of Washington. This will save our land managers from a lot of meaningless extra work.
(D. Hildebrand, USFS, FID-R6).

b. Several hundred ponderosa pine seedlings (natural regeneration) are being monitored for dwarf mistletoe infection in a large (1993) clearcut on the Mescalero Apache Indian Reservation. An initial report will be prepared this winter. (D. Conklin, USFS, FPM-R3, New Mexico Zone).

VII. Genetics

a. Sixty-two ponderosa pine parent trees were selected as dwarf mistletoe resistance candidates within east-side forest stands of the Lassen and Plumas National Forests. In addition, ten heavily infected parent trees were selected as controls. Open pollinated seed were collected from all ten controls and forty resistance candidates. Seed is being produced through controlled crosses between six previously selected candidates. Twelve of 21 crosses have been completed within a modified half diallel which includes selfs and reciprocals. Evaluation of parent selections is planned through artificial inoculation of grafted ramets. Both artificial and natural inoculation will be used in field evaluations of open and control-pollinated materials. Selection of sixty Jeffrey pine candidates will take place in the summer of 1995. (Dr. James Allison, Pathologist, Forest Pest Management; Chuck Frank, Zone Geneticist, Genetic Resource Program (GRP); Lynne Hartman, Director, Genetic Resource Center; Dr Jay Kitzmiller, Region Geneticist, GRP; Dr Safiya Samman, Sugar Pine Program Manager, GRP; Dr Robert Scharpf, Research Pathologist, emeritus, PSW Forest Research Station; Paul Stover, Zone Geneticist, GRP.)

VIII. Control

a. Plans are to treat 1,308 acres of dwarf mistletoe infested stands on the White River; Grand Mesa, Uncompahgre and Gunnison; Medicine Bow; Pike and San Isabel; and Routt National Forests, and the Southern Ute Indian Reservation. (P. Angwin, D. Johnson, USFS, R-2).

b. Approximately 690 acres on four National Forest Ranger Districts, and 4100 acres on five Indian Reservations are being treated in Forest Pest Management-funded dwarf mistletoe control projects in New Mexico in 1995. The majority of this acreage is being treated with low intermediate thinnings, shelterwood seed cuts, or clear cuts. (D. Conklin, USFS, FPM-R3, New Mexico Zone).

c. Dwarf mistletoes (*Arceuthobium* spp.) are the most serious diseases of pines in Mexican forests; 20 species are found in this nation's forests and these represent more than half of the known species in this genus. The principle problem with using the shelterwood system for regeneration in infested stands is that infected seed trees perpetuate the mistletoes by infecting regeneration. The objective of this study is to obtain better information on timing and dosage in applying Ethephon for dwarf mistletoe control. The experiment was established near the community of San Juan Nuevo using a design of divided plots where the large plot is the season of application (summer vs. winter), and the smaller plots are the different doses of the Ethephon (500, 1000, 1500, or 5000 ppm and water). The treatments were replicated 3 times. Ethephon was applied directly to the mistletoe plants to the point of run off. Data collected were: percent of shoot abscission per treatment, the rate of shoot abscission, the percent of re-sprouting, and the final infection severity rating. Preliminary results show that there is a difference in abscission depending upon the season of application and the dose. Summer applications needed a smaller dose to insure 100% abscission and the rate of abscission was faster than in the winter application. New shoots of the parasite appear within 6 months of treatment and the appearance of new shoots is directly affected by tree height, DBH, and level of infection. (Ignacio Vasquez C., CEFAP URUAPAN, Michoacan, Mexico).

d. In the Intermountain Region in 1994, 2270 acres of dwarf mistletoe infested stands were treated in seven National Forests. In 1995, treatments are planned for 5560 acres in eleven National Forests. (J. Guyon, USFS, FPM-R4).

IX. Surveys

a. Presuppression surveys for dwarf mistletoe are planned for 54,392 acres on the Arapaho and Roosevelt; Medicine Bow; Pike and San Isabel; Routt; and White River National Forests, and the Southern Ute Indian Reservation. (P. Angwin, D. Johnson, USFS, FPM-R2).

b. In 1995, investigations were begun in Mexico on methods of forest inventory in stands infected with dwarf mistletoes, with emphasis on the use of aerial photos. The data sheets, types and intensity of sampling have all been modified over the years but the goal was always to evaluate volume estimates based on stocking density. Methods for inventorying stands infested with the dwarf mistletoe, *Arceuthobium globosum*, have not been developed, therefore the goal of this study was to define the optimum sampling intensity to evaluate these stands. The work was done in the local community of San Juan Nuevo, in stand XXII. First the stand was delineated and inventoried; second, sample points were selected systematically (100 meters between lines and 100 meters between points). At each sampling point both a fixed area plot (SDF) and a variable area plot (SDV) were established. The sampling intensities for the two plots were 1,2,3,4,5, and 7 percent. The following data were collected: DBH, level of dwarf mistletoe infection, species and class. Data were analyzed using DBASE III and the results compared using a paired t test (p .05). The results show that at low sampling intensities (1,2, and 3 percent), there was a significant difference between the plots and the stand inventory, at the 4% level there was no significant difference between the census and the SDV plots, and at the 5% sampling intensity there was no significant difference between the census and the SDF results for species and the species and class grouping. (Ignacio Vasquez C., CEFAP URUAPAN, Michoacan, Mexico).

c. In the Intermountain Region in 1994, 7438 acres were surveyed for dwarf mistletoe in the Bridger-Teton, Wasatch-Cache-Uinta, and Payette National Forests. In 1995 7500 acres are scheduled for survey in the same Forests as above plus the Caribou National Forest. (J. Guyon, USFS, FPM-R4)

X. Modeling

a. At a dwarf mistletoe modeling workshop in November of 1992 a question arose as to how dwarf mistletoe is allocated to the crown thirds of host trees using the Hawksworth 6 class system. Answering this question will be useful in determining default values for the DMCRTHRD keyword in the Dwarf Mistletoe Impact Modeling System linked to the Forest Vegetation Simulator (FVS). A better understanding of how mistletoe "fills up" in the crown of a host will also help in general model design and may change the way DMR data is recorded on permanent monitoring plots.

Data derived from 17 permanent mistletoe monitoring plots from 4 states (Utah, Arizona, Wyoming, and Idaho) were sorted by species and age structure (uneven vs even age structures) and statistically analyzed. All of these plots, which were installed under the auspices of the Pest Trend/Impact Plot System, had DMR ratings recorded by crown third. The plots were located in lodgepole pine infected with *Arceuthobium americanum*, Douglas-fir infected with *A. douglasii*, and ponderosa pine infected with *A. vaginatum* subsp. *cryptopodum*.

Data in each DMR class (1-6) were sorted into subsets for all possible permutations allowed by the 6 class system. For example, a DMR class one tree could result from the mistletoe infections occurring in the bottom, middle, or top crown third. Thus a DMR of one could result from data recorded as 1-0-0, 0-1-0 or 0-0-1, with the first digit representing the bottom crown third, the second digit representing the middle crown third, and the last digit representing the top crown third.

Analysis revealed that DM appears to primarily fill the bottom crown third first. This trend exists for the all three species examined and for both uneven and even aged plots. This is contrary to the popular opinion that dwarf mistletoe spreads to the bottom crown third first in the even aged condition and from the top down in the uneven aged condition. Differences in DM distribution by crown third exist between the different species, but the significance of these differences is unknown pending further statistical analysis.

b. In 1995, we have been involved with Beta testing the new and interim dwarf mistletoe subroutines to the Forest Vegetation Simulator (FVS) model for the Southwest. (M.L. Fairweather, USFS, FPM-R3, Arizona Zone).

XI. Miscellaneous

Special Projects

a. PROJECT TITLE: Montezuma County Ponderosa Pine Assessment; INVESTIGATORS: Pete Angwin and Bernie Raimo; Forest Health Management, Rocky Mountain Region; COOPERATORS: Phil Kemp and Bob Vermillion, Dan Greene and Bruce Short, San Juan National Forest, Mike Preston, Fort Lewis College. YEARS: Begun- 1993; End- 1994

PROJECT DESCRIPTION: In 1993, Montezuma County, Colorado, was awarded a rural development grant to study the ponderosa pine vegetation cover type on the Dolores and Mancos Ranger Districts, San Juan National Forest. As part of the analysis, the staff of the Gunnison Service Center was asked to perform an assessment of the health of the cover type, which encompassed an area of approximately 116,000 acres. Cursory examination of stand examination data revealed that the greatest threat to these stands was from mountain pine beetle (*Dendroctonus ponderosae*), ponderosa pine dwarf mistletoe (*Arceuthobium vaginatum* subsp. *cryptopodum*) and Armillaria root disease (*Armillaria* sp.). Once these major impacts were identified, additional data was gathered by aerial survey, ground-truthing and on-site stand examinations.

Evaluation of the conditions within the project area revealed that the stands are at risk for a substantial mountain pine beetle outbreak. At least 41% of the area is at moderate-to-high risk. Fire suppression, which has created stand conditions which are favorable to the beetle, was cited as a major reason for the elevated risk factor. Controlling tree density on a large number of acres was recommended to reduce the risk of a major outbreak.

Ponderosa pine dwarf mistletoe is widespread throughout the project area, and was identified on approximately 31% of the acres that were rated for infection. However, only 3.1 of the mistletoe-rated acres were in the medium or high infestation classes. A number of silvicultural techniques were recommended to be applied on a case-by-case basis.

Although there is currently little information regarding the distribution of Armillaria root disease in the project area, it was identified in a few stands. While specific measures aimed at root disease control may be necessary in a few instances, in most cases the potential effects of root disease may be minimized by addressing the effects of other stand-stressing agents, such as mountain pine beetle and dwarf mistletoe. A biological evaluation report (#R2-94-1), detailing the survey results and management recommendations, is available from the Gunnison Service Center.

b. PROJECT TITLE: Piney River Analysis- White River National Forest; INVESTIGATORS: Pete Angwin, Tom Eager, Dave Johnson, Forest Health Management, Rocky Mountain Region; Wendy Bailey, Dave VanNorman, White River National Forest; Eric Smith, FPM Methods Application Group. COOPERATORS: Matt Thompson, FPM Methods Application Group. YEARS: Begun- 1993; End- 1995

PROJECT DESCRIPTION: At the request of the White River National Forest and the Holy Cross Ranger District, the forest health of the Piney River/Red Sandstone Area was examined. Because of the history of mountain pine beetle and lodgepole pine dwarf mistletoe activity in the lodgepole pine cover type (15,184 acres), that forest component was chosen for detailed evaluation. However, some attention was also given to the impacts of spruce beetle in the spruce-fir cover type (14,956 acres).

Analysis of existing stand exam data confirmed that the greatest potential threat to the lodgepole pine stands in the area was from mountain pine beetle, lodgepole pine dwarf mistletoe and Armillaria root disease. Once these major impacts were identified, a systematic survey was performed in which 20% of the lodgepole pine stands in the analysis area were examined. Stands were stratified and chosen for additional survey according to mountain pine beetle risk (high, medium and low), dwarf mistletoe incidence (high, medium, low, none), and geographic location within the analysis area (north, south and east). During the 1994 field season, standard stand exams were repeated in these stands, but a number of additional data items were added to address information gaps with regard to the three major pests of interest.

The analysis area is at risk for a substantial mountain pine beetle outbreak. Approximately 96% of the lodgepole pine cover type is at moderate to high risk levels. Controlling tree density over large acreages is the only feasible way to reduce the beetle risk. At least 80% of the spruce/fir acres are at moderate to high risk for a spruce beetle outbreak. The opportunistic nature of this insect requires that managers be vigilant regarding potential outbreaks.

While lodgepole pine dwarf mistletoe is widespread throughout the Analysis Area (present on 17% of surveyed acres), it is less prevalent than on the White River NF as a whole (approximately 36% of surveyed acres). Thirteen percent of the acres were in the medium or high infestation classes. Appropriate treatments must be determined on a case-by-case basis, according to the individual stand conditions and the intensity and distribution of the dwarf mistletoe infestation.

Armillaria root disease was found in over half of the surveyed stands, and 19% of the acres were in the moderate or high infestation classes. While treatment options exist, in most cases the limited potential impact of the disease does not justify the cost of treatment.

A Biological Evaluation Report detailing the findings of the surveys and presenting management recommendations is currently in the final stages of preparation.

Pest Trend/Impact Plots System Plots

In the Intermountain Region in 1995, 8 plots are scheduled for remonitoring and 8 new plots are planned. The new plots will be installed in Idaho and southern Utah ponderosa pine. (J. Guyon, USFS, FPM-R4).

In the Southwestern Region in 1995, previously established plots were monitored and new plots were established in fire-treated areas. (M.L. Fairweather, USFS, FPM-R3, Arizona Zone).

DISEASE CONTROL COMMITTEE REPORT

Robert L. James

The Disease Control Committee of WIFDWC held their annual meeting on Thursday, August 31st at 7:30AM. The following people were in attendance: Don Goheen, Walt Thies, George Howe, Alan Kanaskie, Jim Hoffman, Ken Russell, Will Littke, Greg DeNitto, Bill Woodruff and Bob James. The following is a summary of discussions held during the 1 hr. meeting:

Kanaskie: discussed problems with carryover of *Fusarium* on containers used to grow several crops of high value conifer seedlings. Strategies for reducing or eliminating this carryover were discussed.

Howe: indicated that much of the Region One tree improvement program has begun to focus on resistance to insect and disease problems. He outlined how rooted cuttings and grafting are being used in the program. The white pine program has been centered around obtaining seed that has some level of resistance to blister rust.

DeNitto: discussed problems with control of *Pseudomonas* canker and dieback on *Camptotheca* which is grown at the Chico Genetics Res. Cen. This crop is a potential source of taxol. Discussion centered around Kocide (fixed copper) and potential problems with phytotoxicity.

Woodruff: discussed pruning sugar pine for blister rust control and planting both resistant and some susceptible stock to reduce selection pressure on the blister rust fungus to avoid mutation to more virulent strains. The discussion centered around using areas of high and low infection in determining efficacy of pruning. Optimal pruning was considered to be at least two whorls of 50-60% of the crown.

Russell: discussed tree pulling for root disease control and increased utilization of wood; discussed the "tree max".

Kanaskie: discussed swiss needle cast (*Phaeocryptopus*) control and indicated that direct control was ineffective.

Littke: stated that ammonia produced by chicken farms increased disease susceptibility of nearby trees.

Time ran out before we could continue this interesting topic about chicken byproducts!

HAZARD TREE COMMITTEE REPORT - 1995

John Pronos

The Hazard Tree Committee met for lunch on Thursday, August 31, 1995; 33 people attended. Chairperson John Pronos began the meeting by briefly summarizing the Hazard Tree Workshop that was held in May of 1995 in Visalia, California. A collection of abstracts, list of attendees, and a hazard tree bibliography prepared by Mike Schomaker and Bob Mathiasen, are all available upon request.

Jana Albers, Minnesota Department of Natural Resources, announced that they will be hosting a national "train the trainer" session in Minneapolis during April, 1996. The 2-day session is intended to include about 2 people from each state, and will focus on urban hazard tree situations.

The rest of the meeting was devoted to discussing a Technology Development Proposal that Dr. Alison Berry, University of California - Davis, Environmental Horticulture Department, will submit to FPM-WO for funding in FY 96. The proposal is to establish a national tree failure reporting system modeled after the project that has been in place for 8 years in California. In general, the Hazard Tree Committee was very supportive of this effort. We generated the following list of people who were willing to be included as cooperators or sponsors of the project.

USDA FOREST SERVICE

Region 1: John Schwandt
Region 2: Dave Johnson, Pete Angwin
Region 3: Terry Rogers
Region 4: Jim Hoffman, John Guyon
Region 5: John Pronos
Region 6: Keith Sprengel
Region 8: Bill Sites
Region 10: Paul Hennon
Northeast Area: Joe O'Brien

STATE/UNIVERSITY/CANADIAN

California: Dave Adams
Colorado: Mike Schomaker
Idaho: Bob Mathiasen
Minnesota: Jana Albers
Oregon: Alan Kanaskie
Washington: Ken Russell
Oregon State University: Greg Filip
Canadian Forest Service: Rona Sturrock
British Columbia Ministry of Forests: Stefan Zeglan

ROOT DISEASE COMMITTEE REPORT

Gregory M. Filip

The root disease committee met and discussed several topics pertaining to root disease biology and management. At the end of the committee meeting, Greg Filip announced that he would no longer be committee chair and that Ellen Goheen would assume this position.

The following reports were submitted this year:

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

INVESTIGATORS: Pete Angwin, Dave Johnson, Jeri Lyn Harris, and Bernard Benton, Forest Health Management, Rocky Mountain Region

COOPERATORS: Bov Eav, Renee Platz, Julie Williams-Cipriani, Judy Adams, FPM Methods Application Group; 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- 1990; End- indeterminate

PROJECT DESCRIPTION: For the past 5 years, Region 2 Forest Health Management has been actively involved with the westwide technology development project, "Pest Trend Impact Plots In The West". 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. To date, most of our work has concentrated on the installation of plots to monitor the spread of Armillaria, annosus and blackstain root diseases. Prior to 1994, plots were established in 23 ponderosa pine, white spruce, mixed conifer and lodgepole pine stands throughout the Region. During the 1994 field season, additional root disease plots were established in 9 spruce/fir and pinyon pine/juniper stands. In addition, one permanent plot was installed in a dwarf mistletoe-infested ponderosa pine stand that was about to be placed in unevenage management. A canopy gap analysis plot was also placed around the dwarf mistletoe plot by John Lundquist, Brian Geils and Jose Negron of the Rocky Mountain Station.

In addition to the installation of permanent plots, Region 2 Forest Health Management participated in the beta-testing of the PTIPS (Pest Trend-Impact Plot System) data entry programs. In the spring of 1994, the PTIPS database was installed on the Data General System at the R2 Regional Office. 1991 and 1993 remeasurement data from three of the mixed conifer stands (total of six data sets) were manually entered onto ASCI files, run through data translation programs and placed in the PTIPS database. Following this, the PTIPS data error and data reporting systems were tested. Recommendations from the beta test are currently being used to fine tune the database system.

In 1995, we plan to remeasure the permanent plots that were installed in 1991 and 1993. These include plots in mixed conifer, lodgepole pine, and ponderosa pine cover types. In addition, personnel from the Rapid City Service Center will remonument and remeasure comandra blister rust plots that were installed in the 1980s.

PROJECT TITLE: Survey of biological species of *Armillaria* and *Heterobasidion* in Region 2

INVESTIGATORS: Pete Angwin, Dave Johnson, and Yun Wu, Forest Health Management, Rocky Mountain Region

COOPERATORS: Terry Shaw, Dan Omdal and John Lundquist, Rocky Mountain Forest and Range Experiment Station; Geral McDonald, Intermountain Research Station; Alice Ratcliff, Pacific Southwest Forest and Range Experiment Station; various Forest and Ranger District personnel.

YEARS: Begun- 1993; End- indeterminate

PROJECT DESCRIPTION: The objective is to determine the biological species of *Armillaria* and *Heterobasidion* root diseases in various hosts and ecosystems in the Rocky Mountain Region. This information will then be used to develop better root disease management strategies for our various customers. Starting in 1993, diseased wood samples containing *Armillaria* and *Heterobasidion*, collected from throughout Region 2, were sent to the diagnostic lab at the FHM Lakewood Service Center. The pathogens were isolated from the host material and identified by pairing unknown isolates with known tester strains in culture. Though identification of the isolates is not yet complete, all that have been done to date have been *A. ostoyae*. The isolates have been catalogued and kept in cold storage (along with the various tester strains) as part of the Region's new fungal reference collection. A technical report detailing the survey results is currently in preparation.

PROJECT TITLE: Ski Area Vegetation Management

INVESTIGATORS: Pete Angwin, Tom Eager and Dave Johnson, Forest Health Management, Rocky Mountain Region

COOPERATORS: Jon Morrissey, Taylor River/Cebolla Ranger District, Grand Mesa, Uncompahgre and Gunnison National Forest; Jim Stark, Aspen Ranger District, White River National Forest; Dick Myhre and Barry Russell, FPM Methods Application Group.

YEARS: Begun- 1993; End- 1995

PROJECT DESCRIPTION: For the past six years, forest health in developed recreation areas has been a major focus of attention for the Forest Health Management Staff in the Rocky Mountain Region. Until recently, forest health management efforts have concentrated on vegetation management in campgrounds, picnic areas and along scenic byways. However, at the request of the Aspen and Taylor River/Cebolla Ranger Districts, the Gunnison Service Center became involved in the development of vegetation management plans for the Aspen Mountain and Crested Butte Mountain Resort ski areas. Detailed forest health assessments were needed at both areas. In August 1993, an aerial photo mission was flown by Dick Myhre, of the Forest Pest Management Methods Application Group. Low altitude color infrared photos were taken, covering the ski areas, and surrounding public and private lands. From the photos, areas containing dead and dying trees were identified. In October 1993 and August 1994, the areas were visited and assessed for disease and insect pests. Armillaria root disease (*Armillaria* sp.) and western balsam bark beetle (*Dryocetes confusus*) were found to be major causes of mortality in the spruce/fir stands of both areas. Lodgepole pine dwarf mistletoe (*Arceuthobium americanum*) was also found to be affecting lodgepole pines in one large area at Crested Butte. Most of the aspen stands at both ski areas were in good condition, though cankers and stem decays were identified in some of Crested Butte's older stands. Root samples from 16 spruce/fir stands were sent to the Forest Health Management diagnostic lab in Lakewood for isolation and analysis of the root disease fungus. In addition, permanent plots to monitor root disease spread characteristics were installed in two stands at Crested Butte. Survey results and management recommendations were summarized in two biological evaluation reports. Recommendations from the reports are being incorporated into the ski area vegetation management plans. In the future, similar assessments will be done at Snowmass, Aspen Highlands, Tiehack/Buttermilk and Wolf Creek ski areas.

PROJECT TITLE: GIS-Based Landscape-Scale Root Disease Hazard Rating System.

INVESTIGATORS: Jeri Lyn Harris, Judy Pasek, and Dave Johnson, Forest Health Management, Rocky Mountain Region

COOPERATORS: William Jacobi, Dept. of Plant Pathology and Weed Science, Colorado State University (CSU), Robin Reich, Dept. of Forestry, CSU, Melanie Kallas, Graduate Student, Dept. of Forestry, CSU.

YEARS: Begun- 1995; End- 1997

PROJECT DESCRIPTION: Existing data on Armillaria root disease occurrence, supplemented with new field data, will be coupled with SCS soil classification, stand inventory, site disturbance, habitat type, and meteorological data in a GIS data base. Utilizing spatial statistical analysis, an Armillaria root disease hazard rating system will be developed for the Black Hills National Forest.

REGIONAL REPORTS

ROCKY MOUNTAIN REGION REPORT

1. New and Continuing Projects

A. Root and Soil Diseases or Relationships (including Mycorrhizae) 95-D-1 GIS-Based Landscape-Scale Root Disease Hazard Rating System (W. Jacobi, M. Kallas, R. Reich, J.L. Harris).

3-D-1 Survey of biological species of *Armillaria* and *Heterobasidion* in Region 2 (P. Angwin, D. Johnson, Y. Wu).

90-D-2 Root disease impact monitoring (P. Angwin, D. Johnson)

79-D-1 Surveys of root diseases in managed conifer stands in R-2 (P. Angwin).

79-D-5 Spread of *Armillaria* spp. disease centers in managed pine stands (P. Angwin).

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

85-F-5 Silvicultural control of dwarf mistletoe in young lodgepole pine stands (B. Geils, D. Johnson).

C. Miscellaneous Studies

92-K-1 Effectiveness of fire for site preparation in seral aspen in western Colorado (P. Angwin, W. Shepperd).

90-K-1 Vegetation management planning in developed recreation sites (D. Johnson, P. Angwin, T. Eager).

2. Terminated Projects

A. Forest Disease Surveys-General

88-A-1 Evaluation of site factors involved with aspen sprout mortality (P. Angwin, W. Jacobi).

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

86-F-1 Evaluation of ethephon as a control of dwarf mistletoes in high use recreation forests (D. Johnson, Y. Wu).

94-A-1 Evaluation of a dieback of bitterbrush in western Colorado (A. Hayes, P. Angwin, D. Nelson).

Recent Publications
(As of August 1995)

Angwin, P.A. 1995. Pest Conditions at Crested Butte Mountain Resort, Taylor River/Cebolla Ranger District, Gunnison National Forest, Colorado. USDA For. Serv., Renewable Resources, Rocky Mountain Region Biol. Eval. R2-95-1. 19 p.

Angwin, P.A. 1995. Pest Conditions at Aspen Mountain Ski Resort, Aspen Ranger District, White River National Forest, Colorado. USDA For. Serv., Renewable Resources, Rocky Mountain Region Biol. Eval. R2-95-3. 15 p.

Angwin, P.A. and B.J. Raimo. 1994. Ponderosa pine rural development project- forest health assessment. USDA For. Serv., Renewable Resources, Rocky Mountain Region Biol. Eval. R2-94-1. 27 p.

Angwin, P.A., D.W. Johnson, T.J. Eager, E. Smith and W. Bailey. 1995. Piney Analysis Area, Holy Cross Ranger District, White River National Forest- Forest health assessment. USDA For. Serv., Renewable Resources, Rocky Mountain Region Biol. Eval. R2-95-2. 71 p. (In preparation)

Berisford, C.W., T.J. Eager and D.C. Allen. 1994. Meeting tomorrow's challenges in forest entomology. Journal of Forestry. Vol. 92, 11:10-15.

Johnson, D.W. 1994. Effects of application rate and timing of ethephon treatments on abscission of ponderosa pine dwarf mistletoe. USDA For. Serv., Renewable Resources, Rocky Mountain Region, Forest Health Mgmt. Tech. Rep. R2- 55a. 12 p.

Johnson, D.W. 1994. Catalog of specimens located in the herbarium, Lakewood Service Center, Rocky Mountain Region USDA Forest Service. USDA For. Serv., Renewable Resources, Rocky Mountain Region Tech. Rep. R2-56. 14 p.

Johnson, D.W. 1995. *Quercus gambelii* Nutt. *IN*: Enzyklopedie der Holzgewachse (Encyclopedia of Woody Plants). (In press).

Johnson, D.W. 1995. *Picea pungens* Engelm. *IN*: Enzyklopedie der Holzgewachse (Encyclopedia of Woody Plants). (In press).

Johnson, D.W. 1995. *Picea engelmannii* Parry ex Engelm. *IN*: Enzyklopedie der Holzgewachse (Encyclopedia of Woody Plants). (In press).

Johnson, D.W., J.S. Beatty and T.E. Hinds. 1995. Cankers on Western Quaking Aspen. USDA For. Serv., Forest Insect and Disease Leaflet 152. 8 p.

Johnson, D.W. and Y. Wu. 1995. A survey for Melampsora rusts along the Colorado Front Range. USDA For. Serv., Renewable Resources, Rocky Mountain Region Tech. Rep. R2-57. 7 p.

Pasek, J.E. 1995. Rocky Mountain aerial survey program, pp. 22-23. *IN*: McConnell, T. J. [ed.]. Proceedings: Aerial Pest Detection and Monitoring Workshop, Las Vegas, NV, April 26-29, 1994. USDA For. Serv., Northern Region, Forest Pest Mgmt., Report 95-4, 103 p.

Schaupp, W.C., Jr. 1994. Biological control of forest pests in the Great Plains: Regulatory, industrial, and extension status, needs, and issues, pp. 28-35. *IN*: Proceedings of the Great Plains Agricultural Council, June 7-9, 1994, Bismarck, ND.

Sharon, E.M. 1994. Spotting potential failures. Arbor Age 14(10):10-12.

Wu, Y., D.W. Johnson, and P. Angwin. 1995. Identification of Armillaria species in the Rocky Mountain Region. USDA For. Serv., Renewable Resources, Rocky Mountain Region Tech. Rep. R2- . (In preparation)

BUSINESS MEETING MINUTES

Prepared by Robert L. Mathiasen and Jerome S. Beatty

Chairman Susan Frankel convened the business meeting at 4:10 p.m. on Thursday, August 31 in Whitefish, Montana. Susan began by thanking the executive committee for all of the hard work they had done for the 1995 meetings.

The business meeting minutes for the 1993 WIFDWC meeting in Boise, ID were approved as written, but the business meeting minutes for the 1994 WIFDWC meeting in Albuquerque, NM were tabled until the next business meeting in 1996.

Greg Filip reported that Mark Schultz had informed him that the Proceedings for the 1994 combined WIFDWC/WFIWC meeting should be completed in 3-4 months.

Ken Russell, the out-going WIFDWC treasurer, reported that the transfer of the WIFDWC treasury to John Schwandt, the in-coming treasurer, had been delayed because Ken wished to complete transactions for the Hazard Tree Conference that had been held in Visalia, CA in the spring of 1995. Ken reported he has sold two copies of previous Proceedings in the past year. The cost of printing the Proceedings for the 1993 Boise meetings were about $2300.00. There was $1877.83 left over from the Visalia Hazard Tree Conference which Ken is keeping in a separate account for now. As of August 31, 1995 there is $1366.20 in the WIFDWC treasury.

Ken reported that the attendance for the 1995 meeting in Whitefish was 88 fully registered members, 10 students, 9 retirees, and there were 12 guest speakers who were not required to pay registration costs. One hundred and nine individuals had paid for the banquet. Ken's entire treasurer's report is included below.

Committee Reports

Bob Mathiasen, dwarf mistletoe committee chair gave the following brief report: Diane Hildebrand updated the committee members on the current status of hemlock dwarf mistletoe in the Pacific Northwest. Brian Geils discussed the future of the dwarf mistletoe herbarium, Frank Hawksworth's literature files, and the dwarf mistletoe database relative to Brian's pending move to Flagstaff, AZ. Bob Scharpf reported on dwarf mistletoe resistance work which is ongoing in CA. There was a discussion on the current status of Forest Insect and Disease Leaflets (FIDL's), especially those for dwarf mistletoes and a decision was made to try to get several western states, Forest Service regions, and other federal agencies to fund reprints of Western Dwarf Mistletoes FIDL.

Bob James, disease control committee chair reported that eleven people attended the disease control committee meeting and that they had a good discussion session.

John Pronos, hazard tree committee chair gave the following report: A national tree failure reporting system technology development project will be submitted for FY 1997. There was interest expressed for another hazard tree workshop in the next couple of years, perhaps in the Pacific Northwest.

Brian Geils, rust disease committee chair reported that ten people attended the meeting. .

Greg Filip, root disease committee chair reported that he will no longer be the chair of this committee. Committee members breathed a sigh of relief.

(Written committee reports are included in the 1995 Proceedings.)

The nomination committee for selecting officers for the 1996 WIFDWC meeting to be held in Hood River, OR were Everett Hansen, Pete Angwin, and Gregg DeNitto. Everett reported the following individuals had gracefully "volunteered" to serve as officers:
Chair - John Kliejunas; Secretary - Jerry Beatty; Program - Sally Campbell; Treasurer - John Schwandt
Local Arrangements - Ken Russell

Interim Program Chairman, Sally Campbell reported that suggestions for next years program had been received from:

Brian Geils: Suggested WIFDWC invite Dr. Clyde Calvin from Portland State University to give a presentation on the anatomy and histology of dwarf mistletoes.

Ken Russell and Willis Littke: Have a panel on mushroom identification, mushroom collection as special forest product and include information on the impact of commercial mushroom collection on forest fungi in general. This could include a table display of common commercial mushrooms found in the Pacific Northwest and an evening poster session.

Willis Littke: Suggested we have a panel on the effects of fire on fungi, one on shrub diseases and one on recent tree health evaluation methods/survey technologies.

Bob Mathiasen: Would like to see a panel put together to discuss the effects of long-term fire suppression activities on forest diseases or forest health in general.

Alan Kanaskie: Suggested we have a panel on tree resistance to root diseases.

Fields Cobb: Would like to see a discussion of changes in APHIS regulations regarding log imports included in the next program.

Ken Russell, acting as local arrangements coordinator, reported that the next WIFDWC meeting (1996) would be in Hood River, OR at the Hood River Inn. At this point in time the Inn had all weeks in September, 1996 available. Ken said that several possibilities for interesting field trips were available in the Hood River area, including trips to the Glenwood Armillaria plots, the Wind River Canopy Crane, and the Mount St. Helens Devastation Area.

Jeff Beale reported that the British Columbia individuals hosting the 1997 WIFDWC in Prince George, B.C. were concerned about the fact that there was an IUFRO root disease meeting during the summer of 1997 in France which would be competing for attendance with the 1997 WIFDWC meeting and that the distance up to Prince George might limit WIFDWC members from attending. A brief discussion ensued, but it was decided that despite these possible conflicts the 1997 WIFDWC meeting should still be held in Prince George. Suggestions were made that the local arrangements committee for Prince George work around the

IUFRO meeting dates. Several members mentioned that people attended the Juneau WIFDWC despite the large distance involved.

Jim Hoffman and John Guyon offered to have the Intermountain Region host the 1998 WIFDWC meeting in the Carson City/Reno Nevada area. Their invitation was accepted unanimously. So the 1998 WIFDWC meeting will be held somewhere in Nevada, exact location to be announced at a future WIFDWC meeting.

Old Business

It was suggested that we continue to work with the forest entomologists on arranging future joint meetings. There had been a proposal to explore more ways to interact with entomologists during WIFDWC, from increasing the frequency of combined meetings to more insect/pathogen related programs. This proposal had been tabled during the 1994 business meeting and was again tabled at this meeting with no opposition or discussion.

New Business

A discussion concerning the WIFDWC mailing list was initiated by Bob Mathiasen. The question is whether or not we should distribute the WIFDWC membership mailing list to anyone who requests it. After a short discussion a motion was made and seconded to leave the distribution of the mailing list up to the organizing committee of each WIFDWC meeting. The motion was voted on and approved. Bob mentioned that he had worked on updating the mailing list and that everyone should check the mailing list he had placed in the meeting room and make any needed corrections in their address.

The next item discussed was the nomination and approval of new Honorary Life Members (HLM's) of WIFDWC. Several names were nominated based on recent and not so recent retirements. Individuals nominated for Honorary Life Membership in WIFDWC included:

Dick S. Smith, Tom Nicholls, John Laut, Bob Scharpf, Dick Parmeter, Norm Alexander, Dave French, Mike Sharon, Earl Nelson, Fields Cobb and Ray Hoff.

No one knew for sure if any of these individuals were already approved as life members or not, so all the names were approved unanimously by a vote of the membership. John Kliejunas, Susan Frankel and Bob Mathiasen agreed (later) to look into the process of selecting individuals for Honorary Life Membership, whether or not any of the individuals approved for HLM had already been approved during past WIFDWC meetings, and to send letters to the newly approved HLM's. (Bob Mathiasen has prepared a listing of living and deceased Honorary Life Members for inclusion in the 1995 WIFDWC Proceedings.)

John Hart suggested we increase our involvement with the Society of American Foresters (SAF) which will next meet in Albuquerque, NM. Log imports will be discussed at this SAF meeting and John Hart requested that people wishing to volunteer to participate in the log imports debate please let him know.

Bob Mathiasen asked if anyone at the 1995 WIFDWC meeting had enrolled for continuing forestry credit through SAF. No one had and Bob suggested discontinuing this effort. Fred Baker pointed out that if we wanted to obtain free advertising in the Journal of Forestry, which is published by SAF, we would need to allow WIFDWC members to obtain continuing forestry credits. Bob Mathiasen agreed (after finally recalling the process he went through to get an announcement about the 1995 WIFDWC meeting in the

Journal of Forestry) that Fred was correct and it was decided that the next WIFDWC secretary, Jerry Beatty, contact SAF again. (Bob Mathiasen has forwarded the SAF material to Jerry Beatty)

The last topic discussed at the business meeting was related to should WIFDWC continue to bring in guest speakers who are not WIFDWC members and pay for their travel, lodging and meals from WIFDWC registration monies.

The pre-WIFDWC poll had indicated a 50/50 split on this subject.

Diane Hildebrand thought this was a good idea and suggested we continue this practice.

Jane Taylor pointed out that depending on the distance traveled it could be quite costly to bring in outside speakers.

John Schwandt indicated that it would probably cost about $1000.00 per speaker.

Ken Russell indicated that he had reimbursed past speakers from $350.00 to $500.00 each for travel, lodging, and meals related to speaking for WIFDWC meetings.

Everett Hansen suggested that we definitely should not rely on outside experts and there seemed to be a general agreement on this point by the membership.

Jim Hoffman warned the membership about becoming what he termed "pathocentric" and that we should be open to expanding our horizons. (Pathocentric will soon appear in the next edition of Webster's New Collegiate Dictionary and be defined as "pertaining to eccentric forest pathologists, example: Jim Hoffman.")

Don Goheen agreed that we should expand our topics and that we should make a concerted effort to include more entomologists as participants and speakers at WIFDWC meetings.

Fields Cobb stated that the dwarf mistletoe panel which included two non-WIFDWC speakers, Dan Nickrent and Del Wiens, had gone well and that we should continue to invite speakers, but that we should not have the entire program or even a major portion of it presented by non-WIFDWC speakers.

After the discussion was over a motion was made and seconded that it be left to the Executive Committee of each WIFDWC to decide who and how many outside speakers they wanted to invite to WIFDWC and that they could pay travel costs from WIFDWC registration fees. The motion was approved unanimously by the membership.

Susan Frankel adjourned the business meeting at 4:57 p.m.

Respectfully submitted by,

Robert L. Mathiasen and Jerome S. Beatty
1995 WIFDWC Secretary 1996 WIFDWC Secretary

TREASURER'S REPORT, 42 nd WIFDWC

Ken Russell

This report closes WIFDWC transactions at the Washington State Employees Credit Union opened on November 13, 1975 and closed on November 17, 1995. The account was managed through this period by Kenelm Russell.

Transactions for the Whitefish meeting are shown separately beginning with the final balance shown below.

Balance recorded at close of 41st meeting in Boise:	1431.55
Deposits:*	
Interest paid to account from July 1, 1993 to June 30, 1995 (2 years)	189.32
Proceedings sales from July 1, 1993 to June 30, 1995 (2 copies at $10.00 each)	20.00
Reimbursement for start-up Albuquerque combined insect and disease meetings (4/24/94)	500.00
Total deposits from Hazard Tree Conference, Visalia, CA (May, 1995)	6365.28
Interest paid to account July 1 to November 17, 1995	23.31
Total Deposits:	7097.91
Payments:	
Adjustment for printing 41st Proceedings Total cost was $2358.71. Original estimate for printing 41st Proceedings was $2000.00	358.71
Payment to local arrangements for start-up for Albuquerque, NM meeting November 30, 1993	500.00
WIFDWC contribution to CSU Frank Hawksworth Memorial Scholarship	800.00
Total payments for Hazard Tree Conference, Visalia, CA July 7, 1995	4487.45
Whitefish meeting start-up fund, July 14, 1995	1000.00
Check writing fee for Hazard Tree Conference payments July 14, 1995	3.00
Error Correction to make this report agree with Credit Union balance**	0.49
Total Payments:	7149.65
Balance:	1379.81

*Additional funds will be sent to the account from the Albuquerque meeting as soon as the Proceedings have been printed. Remaining funds to be split 50/50 between WIFDWC and WFIWC.

**This small error may have been accumulating for several years, and who knows where to find it!

Ken Russell, WIFDWC Treasurer November 13, 1975 to November 17, 1995. "It's been fun!"

TREASURER'S REPORT, 43rd WIFDWC

John Schwandt

Balance from 42nd Report (Ken's Final Report)	1,379.81

WIFDWC Transactions at Whitefish, Montana Meeting:

Start Up Funds From Ken	1,000.00
Gross Receipts	10,966.95

Meeting Participants

Regular members	69
Students	10
Retirees	9
Guest Speakers	12
Spouses	21
Totals	121

The banquet was attended by 109 people, and over 90 people (plus several future WIFDWC-ers) went on the field trip into Glacier Park.

Expenses at Whitefish Meeting		8,238.51
Estimated Cost For Proceedings		1,500.00
	Total	9,738.51
Balance At The Close of the 43rd Meeting at Whitefish, MT		3,608.25