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Predicting Decay and Degrade Rates in Stad-ning and Fallen Trees Killed b Mountain Pine Beetle: A Literature Review

Barb Sharp and Kathy Lewis

Mountain Pine Beetle Initiative
Working Paper 2005–15

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Abstract

This paper is a review of the existing literature on degrade, decay and fall rates of trees killed by bark beetles. Most of the references are from studies of pine (lodgepole, western white, and ponderosa) killed by mountain pine beetle. A reference and abstract are provided for each listed paper.

Résumé

Le présent article constitue un examen de la littérature existante concernant le processus de dégradation, de décomposition et de chute au sol d'arbres tués par des scolytes. La plupart des études mentionnées portent sur des essences de pins (pin tordu latifolié, pin argenté et pin ponderosa) tués par le dendroctone du pin ponderosa. Une bibliographie et un résumé accompagnent chaque document relevé.

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SECTION 1. LODGEPOLE PINE

1. Brown, P.M.; Shepperd, W.D.; Mata, S.A.; McClain, D.L. 1998. Longevity of windthrown logs in a subalpine forest of central Colorado. Canadian Journal of Forest Research 28:932-936.

Keywords: longevity, logs, subalpine forests, specific gravity, dead wood, forest, windthrown

The number of years since tree death for wind-thrown logs of lodgepole pine (*Pinus contorta* var. *latifolia*) and Engelmann spruce (*Picea engelmannii*) was used to examine the longevity of this component of coarse woody debris in an old-growth subalpine forest in the Fraser Experimental Forest, central Rocky Mountains. Death dates of downed logs were determined by dendrochronological cross-dating methods for 73 out of 104 logs collected (which included both species). The oldest log was from a lodgepole pine dead 139 years. Sound lodgepole pine and Engelmann spruce logs lying on the ground persisted for many decades with a majority of their volume intact. No difference was seen in decay classes of logs collected from two primary study sites on opposite (north and south) exposures. There was also no significant difference in decay classes between the two species, although lodgepole pine logs were in general older than Engelmann spruce logs within any decay class. There was little decrease in the specific gravity of wood remaining in logs with time, although there was a corresponding greater loss of wood volume.

2. Busse, M.D. 1994. Downed bole-wood decomposition in lodgepole pine forests of central Oregon. Soil Science Society of America Journal 58: 221-227.

Key words: decaying wood, lodgepole pine, bole-wood decomposition, nutrients

Impact of decaying wood from natural disturbances may benefit nutrient cycling processes in lodgepole pine [*Pinus contorta* var. *murrayana* (Grev. & Balf.) Engelm.] forests of central Oregon by supplementing detrital C and nutrient pools. This study was conducted to determine the decomposition rate and nutrient retention of downed lodgepole pine boles, and to characterize their effects on soil biological and chemical properties. Three sites, in stands recently damaged by insects, had an average downed wood biomass of 38.7 Mg ha^{-1}. Bole-wood decay was rapid once in contact with the soil surface. The decomposition rate constant based on the single-exponential decay model was 0.027 yr^{-1} and the turnover time of C was 37 yr. Nitrogen content per unit volume was 75% greater for downed boles after 38 yr of decay compared with their initial content. A net release of Ca (38%), Mg (54%), and K (42%) was found, but P content remained constant during decomposition. With the exception of Mg, however, downed boles comprised <3% of the combined mineral soil, O horizons, and downed wood nutrient pool. In comparison, downed boles comprised 23.5% of the detrital C. Microbial biomass C (C_M) and the ratio of microbial C to total organic C (C_M/C_T) were significantly greater in the surface 0 to 4 cm of soil beneath rapidly decaying boles than in soil without a bole-wood component. The C_M/C_T ratio remained elevated throughout the advanced stages of wood decomposition, indicating a long-term change in the efficiency of C utilization by soil microbial communities associated with decaying wood.

There is a brief discussion on wood density of live, standing dead and down dead stems of lodgepole pine.

3. Byrne, T.; Woo, K.; Uzunovic, A.; Watson, P. 2005. An annotated bibliography on the effect of bluestain on wood utilization with emphasis on mountain pine beetle vectored bluestain. Mountain Pine Beetle Initiative Working Paper 2005-4. Natural Resources Canada, Canadian Forest Service, Pacific Forestry Centre, Victoria, BC.

Keywords: bluestain, bibliography, lodepole pine, solid wood, pulp

This bibliography provides a summary of studies on the effect of bluestain fungi on wood quality and forest products, particularly studies relevant to the bluestain vectored by the mountain pine beetle, *Dendroctonus ponderosae*. The references are given in three sections: 1) mountain pine beetle and associated bluestain fungi, 2) bluestain and solid wood utilization, and 3) bluestain and pulp quality. Research on the biology of the associated bluestain fungi is evolving and there is now a solid body of scientific literature on this subject. In terms of bluestain and solid wood there is little specifically on mountain pine beetle-killed lodgepole pine with the exception of some recent work on lumber properties. Recently killed bluestained lodgepole pine appears to be sound but may pose a marketing problem in some markets because of its colour. References on the dryness of trees initially induced by bluestain fungi are given. The splits and checks that occur as the trees dry cause processing problems and volume and grade recovery are reduced. These references are old and the modern economics of producing products from dry logs are unknown. Due to substantial reduction in moisture content, bluestained wood generates more pins and fines during chip production. Literature detailing the effects of mountain pine beetle-associated bluestain on pulp quality is limited and the results are inconsistent. In general, kraft pulping studies have suggested that pulp yield and paper strength properties are not significantly affected by bluestain. Mechanical pulp produced from bluestain wood exhibits acceptable quality; however, brightening costs are expected to be significantly affected, as bluestain pulp is more difficult to bleach.

4. Dobie, J. 1978. An overview of dead timber potential in Canada. *In* Symposium: the dead softwood timber resource. Engineering Extension Service Washington State University, Pullman, Washington.

Keywords: utilization, dead timber, allowable cut, salvage, value, lumber yield, market forces

Stands devastated by insect, disease, or fire quite often have been included in allowable cut calculations so cannot be used to augment allowable cuts. In fact, indications are that unless they're salvaged in relatively few years, they may not yield sufficient values even for pulp manufacture. However, if salvaged soon enough, they yield perfectly good lumber and render positive conversion returns. The question of the potential dead timber inevitable boils down to a question of supply, demand, and market forces. The more buoyant the market, the more we can afford to spend to utilize dead timber. The general strategy would be to use it as soon after death as possible, because the longer it's dead, the more it deteriorates, and the fewer are the options for its utilization.

5. Dobie, J.; Wright, D.M. 1978. Lumber values from beetle-killed lodgepole pine. Forest Products Journal 28(6): 44-47.

Key words: lodgepole pine, mountain pine beetle, *Dendroctonus ponderosae*, foliage, checking

The study of lodgepole pine attacked by mountain pine beetle (*Dendroctonus ponderosae* Hopk.) in the East Kootenay region of British Columbia, Canada, shows that positive conversion returns for lumber manufacture can be obtained unless trees have started to shed their bark and develop severe checking. Quality classes were derived using tree foliage characteristics as well as bark characteristics for trees dead many years. Trees with green and red foliage yielded similar values per 100 cubic feet of logs with positive conversion returns. Trees with no foliage but tight bark also yielded positive returns, but at a lower level. For trees sloughing bark the returns were negative.

6. Eades, H.W.; Roff, J.W. 1959. Red heart stain of lodgepole pine logs in the southern interior of British Columbia. Government of Canada Department of Northern Affairs and National Resources. Forest Branch. Vancouver, BC.

Keywords: lodgepole pine, fungi, red heart stain, decay

While the study determined that several fungi caused red heart stain in lodgepole pine, it was noted that *Fomes pini* was isolated in 66 percent of the stained samples and it was responsible for all the advanced decay.

7. Eades, H.W.; Roff, J.W. 1957. Red heart stain of lodgepole pine logs in the northern interior of British Columbia. Government of Canada Department of Northern Affairs and National Resources. Forest Branch. Vancouver, BC.

Keywords: lodgepole pine, fungi, red heart stain, decay, degrade, rot

The study found that three fungi, *Fomes pini, Stereum pini,* and *Stereum sanguinolentum* are almost entirely responsible for red heart stain in lodgepole pine in the northern interior of British Columbia. It is not known if the strength and serviceability of lodgepole pine products differ in relation to the three main causal fungi. The red stain caused by the fungi is usually only considered to relate to appearance in lumber and results in some degrade. However, in other products, such as poles and railway ties, it is often assumed to indicate the early stages of decay, which may eventually develop into typical rot under service conditions. For this reason, lodgepole pine having red heart stain are sometimes rejected.

8. Eng, M.; Fall, M.; Hughes, J.; Shore, T.; Riel, B.; Hall, P.; Walton, A. 2005. Provincial-level projection of the current mountain pine beetle outbreak: An

overview of the model (BCMPB v2) and results of year 2 of the project. Mountain Pine Beetle Initiative working paper 2005-20. Natural Resources Canada, Canadian Forest Service, Pacific Forestry Centre.

Keywords: shelf-life, mountain pine beetle, lodgepole pine, sawlogs, chips, beetle-killed timber, BC

A summary prepared specifically for the 2005-03-10 'Meeting to discuss the "shelf-life of beetle-killed timber in BC.' This document attempts to project the quantity of available beetle-killed timber in relation to time since death.

9. Fahey, T.D. 1980. Evaluating dead lodgepole pine for products. Forest Products Journal 30(12): 34-39.

Key words: lodgepole pine, forest products, market, dead timber

Dead lodgepole pine is a resource currently abundant in the intermountain West. Possible uses for dead pine range from small power poles to fuel and fiber. Values for products that can be produced from dead trees are evaluated based on ovendry tons of fiber for both logs and products. The technique can be adapted by the reader to make allocation choices among products for any species. Specific products evaluated as uses for roundwood products are power poles, house logs, and corral poles. These products return high values per unit of log, but have restrictive specifications and limited markets. Solid wood products include random length dimension, studs, and core veneer. Values are lower than roundwood products but specifications are less restrictive and markets are much larger. Fiber products generally return low values per unit of volume and values vary from never feasible to feasible under some conditions. The techniques are applicable by the reader to such diverse questions as, 1) Should Economy lumber be chipped under current market conditions? to 2) What is the best investment possibility for using a timber resource?

10. Fahey, T.D.; Snellgrove, T.A.; Plank, M.E. 1986. Changes in product recovery between live and dead lodgepole pine: a compendium. United States Department of Agriculture, Forest Service Research Paper PNW 353. Pacific Northwest Research Station, Portland, OR.

Keywords: lumber recovery, veneer recovery, dead timber, lodgepole pine, *Pinus contorta*

Six studies were used to compare differences in recovery of volume and value among live, recent dead, and older dead lodgepole pine (*Pinus contorta* Dougl. ex Loud.) in the Western United States. The products studied included boards, random-length dimension studs, and veneer. For the average size log (12 cubic feet) absolute values were highest for boards, followed by dimension, veneer, and studs for both live and dead timber. The percentage change in value from live to dead, however, showed the reverse order; studs lost the least values and boards the most.

11. Giles, D.R., 1986. Harvesting and processing of beetle-killed pine. *In* Harvesting and processing of beetle-killed timber. Forintek Canada Corp., Vancouver, BC.

Keywords: beetle-killed, pine, grade yield, lumber recovery, log handling, moisture content

Interior sawmill operations will continue to process beetle-killed timber for many years to come. Efforts to contain the extent of attack have had limited success. Accelerated cutting of affected timber resource is presently being proposed in at least one forest district. Long term storage of logs, using underwater storage or water spraying techniques, have been suggested. Conversion of the resource will result in lower product recovery and value in sawmill operations compared with normal green log mix. Changes in mill operating practices can help offset some of these anticipated losses. Presorting of beetle-killed logs can help reduce losses during barking, drying, and planning by adjusting these operations to handle dry wood. Product diversification, such as production of ties and mine timbers, may create new markets for beetle-killed timber. Machine stress rating of lumber has value-added potential.

12. Harvey, R.D. Jr. 1986. Deterioration of mountain pine beetle-killed lodgepole pine in northeast Oregon. United States Department of Agriculture, Forest Service R6-86-13. Pacific Northwest Region, Portland, OR.

Keywords: beetle-killed, lodgepole pine, *Pinus contorta,* mountain pine beetle, *Dendroctonus ponderosae,* rate of deterioration, salvage

The mountain pine beetle, *Dendroctonus ponderosae* Hopkins, is a periodic forest pest in most mature lodgepole pine (*Pinus contorta* Dougl. ex Loud.) stands. Outbreaks develop in lodgepole pine stands after the trees reach 80 to 100 years of age. Mountain pine beetle outbreaks typically start in large-diameter trees because they provide the food and living space necessary for brood development. Outbreaks continue until the large-diameter component of the stand is killed; the average diameter of the living residual is usually below 8 inches DBH (Safranyik 1974). The trees smaller than 4 inches in diameter are attacked only occasionally.

Stands in the Blue Mountain outbreak became established in the 1860s following fires that destroyed the former stands. Losses to mountain pine beetle were estimated to be in excess of 16 million board feet in this area between 1972 and 1974.

The rate of deterioration of beetle-killed lodgepole pine is an important consideration in developing salvage and fire management plans. This information was lacking when the outbreak erupted. Consequently, an evaluation that could provide some of this information was designed and initiated in 1975. The evaluation included portions of the Wallowa-Whitman and Umatilla National Forests.

13. Harvey, R.D. Jr. 1979. Rate of increase of blue stained volume in mountain pine beetle killed lodgepole pine in northwestern Oregon, U.S.A. Canadian Journal of Forest Research 9: 323-326.

Keywords: lodgepole pine, mountain pine beetle, *Pinus contorta, Dendroctonus ponderosae*, blue stain, salvage, beetle killed

Recently killed lodgepole pine (*Pinus contorta* Dougl.) were examined to determine rate of spread of blue stain fungi introduced by mountain pine beetle (*Dendroctonus ponderosae* Hopk.). Trees were felled, dissected at 2.5 m intervals, and photographed at each cross section to determine area of stain. Rate of spread is so rapid that salvaging mountain pine beetle killed lodgepole pine prior to severe staining is difficult.

14. Hawkes, B.; Taylor, S.W.; Stockdale, C.; Shore, T.L.; Alfaro, R.I.; Campbell, R.; Vera, P. 2004. Impact of mountain pine beetle on stand dynamics in British Columbia. *In* T.L. Shore; J.E. Brooks; J.E. Stone, eds. Mountain Pine Beetle Symposium: Challenges and Solutions. Natural Resources Canada, Canadian Forest Service, Pacific Forestry Centre, Report BC-X-399. Victoria, BC.

Keywords: mountain pine beetle, lodgepole pine, stand dynamics, fuel dynamics, stand structure, British Columbia, impacts

A three-year research project was established in 2001 to examine the impact of mountain pine beetle on stand dynamics in British Columbia and southern Alberta. The project had three components: assessments of the effects of mountain pine beetle on stand dynamics; projections of mountain pine beetle impacts on stand and fuel dynamics with Prognosis^{BC} and the Fire and Fuel Extension; and estimation of mountain pine beetle outbreak and fire return intervals.

Permanent sample plots were re-measured after 10-19 years since establishment in 31 mountain pine beetle-affected stands in the Chilcotin Plateau, Kamloops and Nelson Forest Regions, and Kootenay and Waterton Lake National Parks. New permanent plots were established in 15 currently affected stands in Manning Provincial Park and Entiako Protected Area.

In total, 1631 lodgepole pine and non-host tree species cores were used to determine growth-release periods. In total, 272 tree cross-sections were examined and cross-dated for mountain pine beetle scars with 127 identified. This paper provides a summary of the project results.

15. Ince, P.J. 1982. Economic perspective on harvesting and physical constraints on utilizing small, dead lodgepole pine. Forest Products Journal 32(11/12): 61-66.

Key words: dead trees, small wood, lodgepole pine, utilization, dead wood

Costs, energy requirements and physical characteristics of the wood were investigated for small dead lodgepole pine harvested from the Umatilla National Forest in eastern Oregon during a 3-month demonstration harvest. An informal market survey of several dozen local timber buyers was conducted in order to ascertain the current problems and potential in utilization. Results showed that the cost of producing chips alone was lower and less variable than the cost of producing roundwood and chips. Market prices of both roundwood and chips varied considerably with time. Harvesting presented no major difficulties and small dead lodgepole pine wood was generally acceptable to buyers and used for a variety of products. Energy inputs to harvesting were small (6-7%) relative to the recoverable heat if the deadwood is used as fuel. The cost-to-energy-value ratio of delivered dead lodgepole pine chips was less than the price-to-energy-value ratio of oil and gas, but not coal. However, the price-to-energy-value ratio of dead lodgepole pine chips is likely to be higher and more variable than the cost ratio, due to alternative and competing end uses and variable market prices.

16. Ince, P.J.; Henley, J.W.; Grantham, J.B.; Hunt, D.L. 1984. Cost of harvesting beetle-milled lodgepole pine in eastern Oregon. United States Department of Agriculture, Forest Service General Technical Report PNW 165. Pacific Northwest Forest and Range Experiment Station, Portland, OR.

Keywords: logging enterprise costs, lodgepole pine (dead), wood utilization, energy, insect damage, forest products, mountain pine beetle

The cost of harvesting and recovering round wood logs and whole-tree chips from small diameter lodgepole pine *(Pinus contorta)* infested by mountain pine beetle *(Dendroctonus* sp.) was studied in the Blue Mountains of eastern Oregon in 1979. Mechanized harvest operations were conducted on six study sites totaling 134 acres. The average cost of producing chips was $31.30 per ton, wet, delivered 50 miles from harvest sites. The average cost of logs was $50.28 per ton, wet, delivered the same distance. A gross energy balance indicates that energy required by harvesting was about 3.4 percent of the gross energy content of the delivered products.

17. Kim, J.; Allen, E.; Humble, L.; Breuil, C. 2005. Ophiostomatoid and basidiomycetous fungi associated with green, red and grey lodgepole pines after mountain pine beetle (*Dendroctonus ponderosae*) infestation. Canadian Journal of Forest Research 35: 274-284.

Keywords: bluestain, decay, basidiomycete, ophiostomatoid, moisture content, fungi

The mountain pine beetle (MPB) is a major concern for lodgepole pine forests in British Columbia, Canada. MPB and the ophiostomatoid staining fungi they vector have a close, mutualistic relationship. In this work, we determined which fungi colonized MPB-killed standing trees with green, red and grey crowns, and quantified how rapidly the fungi stained and reduced the moisture content of sapwood. Green trees were mainly colonized by *O. clavigerum, O. montium, O. nigrocarpum, O. minutum,* and unknown *Leptographium* species. In red and grey pines (two and three years after the original MPB attack, respectively), the frequency of the original fungal colonizers decreased and other sapstaining fungal species were encountered. Among basidiomycetous fungi, decay fungi were rarely present in green trees but were isolated more frequently in red and grey trees. The frequency and type of decay fungi isolated vary between harvesting sites.

18. Lemaster, R.L.; Troxell, H.E.; Sampson, G.R. 1983. Wood utilization potential of beetle-killed lodgepole pine for solid wood products. Forest Products Journal 33(9): 64-68.

Keywords: lodgepole pine, thinning, dead materials, products, beetle-killed

Several areas in the Rocky Mountains are experiencing bark beetle attacks in lodgepole pine stands. Removing dead and dying material and thinning to advise prescribed stocking levels is necessary to reduce wildfire hazards and restore vigor to the stands. The silvicultural practices required to cope with this problem call for developing appropriate markets for this resulting material. In this study the technical suitability of this material for traditional and potential products was evaluated. As a basis for comparing the dead and small thinning material with that cut from living sawtimber, various physical tests were conducted on selected 2 by 4's. The test results were then combined into property groupings that were considered to represent the most important qualities for a given product. In all, 13 products were considered. All values for dead trees and small thinnings were expressed as a percentage of the accepted value for live lodgepole pine sawtimber. The summary of properties produced a comparative index value for each material class for the various products considered.

19. Lieu, P.J.; Kelsey, R.G.; Shafizadeh, F. 1979. Some chemical characteristics of green and dead lodgepole pine and western white pine. United States Department of Agriculture, Forest Service Research Note INT 256. Intermountain Forest and Range Experiment Station, Ogden, Utah.

Keywords: chemical components, combustion characteristics, dead trees, lodgepole pine, western white pine, utilization of dead trees

The chemical components and combustion characteristics of dead and live lodgepole pine and western white pine were determined. Except for small variations, the chemical composition and burning characteristics of sound dead wood were nearly identical to the corresponding live wood for both species. Therefore, dead wood could be utilized as a source of chemicals, fuel, and as a substitute for live timber in the manufacture of wood products.

20. Loman, A.A. 1962. The influence of temperature on the location and development of decay fungi in lodgepole pine logging slash. Canadian Journal of Botany 40: 1545-1559.

Keywords: decay, lodgepole pine, logging slash, fungi, fungi decaying abilities

In an investigation to determine the fugal flora of lodgepole pine logging slash and the growth rates and decaying abilities of the principal fungi in vitro as contrasted with conditions in nature, four hymenomycetes were isolate consistently and proved to cause most of the decay; *Lenzites saepiaria* Wulf. ex Fr., *Peniophora phlebioides* Jacks. and Dearden, *Stereum sanguinolenium* Alb. And Schw. ex Fr., and *Coniophora puteana* (Schum. ex Fr.) Karst. These four fungi comprised 80% of the basidiomycetes isolated from slash, *Lenzites saepiaria* in the center, and *Coniophora puteana* and *Stereum sanguinolentum* in the lower portions. Relatively broad temperature ranges and high temperature optima were demonstrated for *P. phlebioides* and *L. saepiaria* to grow and cause decay, in contrast with the narrower temperature ranges and lower optimal temperatures of slash were proved to fluctuate between wider extremes in the upper portions of slash than in the lower portions. This is believed to be a partial explanation of the characteristic distributions of individual fungi within slash. The relative decaying abilities of the four main fungi as indicated by woodblock tests, in decreasing order of importance were: *L saepiaria, C. puteana, P. phlebioides, S. sanguinolentum.* Because of its greater frequency, however, *P. phlebioides* probably ranks higher in the scale of slash decayers than *C. puteana.*

21. Loman, A.A.; Paul, G.D. 1963. Decay of lodgepole pine in two foothills sections of the boreal forest in Alberta. Forestry Chronicle 39(4): 422-435.

Keywords: cull losses in the forest, decay in trees, decay, fungus diseases, heartwood stain, *Pinus contorta*

Cull in lodgepole pine (*Pinus contorta* Dougl. var *latifolia* Engelm.) is highly variable in the B19a and B19c Sections of the Boreal Forest in Alberta, depending upon whether the wood is used for pulp or sawed for products. Sixty-nine percent of 2,436 sample trees were suspected of containing volumes of red heartwood stain and advanced decay on the basis of the presence of external defects. Fifty-three percent of the suspects were sound, 36 percent had red heartwood stain and 11 percent were partly or entirely decayed. Sixty percent of the trees without external defects were sound, and 40 percent had red heartwood stain. In cubic-foot measure decay was unimportant in stands less than 100 years old. In older stands a few infested trees accounted for most of the decay. In foot-board measure 62 of 2,746 sample trees were totally culled and 122 were partially culled. Considerable loss occurred in 90-year old and older stands near Whitecourt and in 170-year old stands in the other sample areas. *Fomes pini (*Thore) Lloyd and *Polyporus tomentosus* Fr. Were the principal fungi isolated from white pitted trunk rots. *P. tomentosus* and *Flammula alnicola* (Fr.) Kummer were isolated most frequently from white pitted root and butt rots, and *Coniophora puteana (*Schum. Ex Fr.) Karst. from brown cubical root and butt rots. *Peniophora pseudo-pini* Weres. and Gibson was the most frequently isolated fungus but was always associated with red heartwood stain. Scars of all kinds were the most important points of entry for decay fungi.

22. Lowery, D.P.; Pellerin, R.F. 1982. Evaluation of dimension lumber made from dead-tree logs. United States Department of Agriculture, Forest Service Research Paper INT 286. Intermountain Forest and Range Experiment Station, Ogden, Utah.

Keywords: lodgepole pine, western white pine, dimension lumber, dead trees, modulus of elasticity, strength properties

Dimension lumber made from dead lodgepole and western white pine was evaluated nondestructively by the E-computer, and stress-wave testing methods. The same material was then tested on edge to failure. Analysis of the test data showed that the modulus of elasticity could be predicted fairly well by the nondestructive methods, and the results showed no marked differences in moduli of elasticity between lumber cut from dead trees and lumber cut from live trees.

23. Lowery, D.P.; Hearst, A.L. Jr. 1978. Moisture content of lumber produced from dead western white pine and lodgepole pine trees. United States Department of Agriculture, Forest Service Research Paper INT 212. Intermountain Forest and Range Experiment Station, Ogden, Utah.

Keywords: lodgepole pine, western white pine, moisture content, disease, insect-killed

One of the Rocky Mountain area's major problems is the utilization of insect- and disease-killed timber. More and more of these trees are being harvested as a part of green timber sales. The efficient handling and processing of this material depends to a large extent on its moisture content.

In the two studies reported here, the moisture content of lumber sawed from dead western white pine and lodgepole pine logs was determined using both a moisture meter and the ovendry test method. In both studies the moisture content of lumber from dead trees was about half that reported for green lumber of the same species. Test sections cut from a sample of the boards showed that the dead log lumber had essentially no moisture gradient and only a slight amount of drying stress.

This information indicates the kiln drying time for dead log lumber should be about half the time required to dry green lumber. A dry kiln operator can determine the appropriate drying conditions for a charge of dead lumber by measuring its moisture content with a moisture meter.

24. Maloney, T.M.; Talbott, J.W.; Strickler, M.D.; Lentz, M.T. 1978. Composition board from standing dead white pine and dead lodgepole pine. *In* Symposium: the dead softwood timber resource. Engineering Extension Service Washington State University, Pullman, Washington.

Keywords: western white pine, *Pinus monticola,* lodgepole pine, *Pinus contorta,* composition board, dead standing, wood characteristics

Dead trees of western white pine (*Pinus monticola*) and lodgepole pine (*Pinus contorta*), while normally unacceptable for plywood and with limited acceptance for lumber, constitute an important potential resource for wood construction materials in the form of dry-process composition boards. It was demonstrated that, even after standing dead many years, the wood of such trees changed very little from that of live trees in characteristics important to composition board manufacture. A wide spectrum of desirable particles, ranging from flakes to fiber, can be produced. Compatibility with commercial composition board resin appears to be retained, as determined by chemical tests of the wood and internal-bond strength tests.

25. Mitchell, R.G.; Preisler, H.K. 1998. Fall rate of lodgepole pine killed by the mountain pine beetle in central Oregon. Western Journal of Applied Forestry 13(1): 23-26.

Key words: mountain pine beetle, lodgepole pine, fall rate

The fall rate of nearly 600 lodgepole pines (*Pinus contorta*) killed by the mountain pine beetle (*Dendroctonus ponderosae*) in central Oregon was investigated in thinned and unthinned stands. Estimates were obtained by fitting a complementary log-log model to the conditional probabilities of trees falling within a given year. Snags began falling 3 yr after death in thinned stands and 5 yr in unthinned stands. Small trees fell slightly faster than large trees in thinned stands, but tree size was not a factor in the fall rate in unthinned stands. In thinned stands, 50% were down in 8 yr and 90% were down in 12 yr. In unthinned stands, 50% were down in 9 yr and 90% were down in 14yr. No particular calendar year had tree fall that was significantly greater than average. All beetle-killed trees broke off at the ground when they fell. The rate that trees fall in different environments may be related to the speed of bole decay at the ground level.

26. Nielson, R.W. 1986. Beetle-killed pine processing problems and opportunities a British Columbia perspective. *In* Harvesting and processing of beetle-killed timber. Forintek Canada Corp., Vancouver, BC.

Keywords: lodgepole pine, beetle-killed, mountain pine beetle, moisture loss, blue-stain, checking, British Columbia

This paper is based on a study carried out at Forintek's Western Laboratory. The overall purpose of the study was to review the processing of mountain pine beetle-killed lodgepole pine in various forest products operations; to examine the particular problems this presents, and determine further work that might be carried out to help alleviate any of the problems identified. The study concentrated on sawmilling, but also covered veneer and plywood, pulp, particleboard, and treated wood products manufacturing.

27. Nielson R.W. 1979. Processing dead timber into solid wood products. *In* Proceedings of the Society of American Foresters 1978 national convention. Society of American Foresters, USA.

Keywords: lodgepole pine, dead, lumber, beetle-killed, salvaged, mountain pine beetle

This paper examines the problems associated with processing beetle-killed lodgepole pine into solid wood products. Problems result from the dry wood condition, the development of blue-stain in the sapwood and checks and splits in stems. Lumber and plywood operations are most severely affected by yield losses due to splits that develop within two to three years of death. Trees must be salvaged and processed quickly to minimize problems.

28. Nielson, R.W.; Wright, D.M. 1984. Utilization of beetle-killed lodgepole pine. Forintek Canada Corp., Vancouver, BC.

Keywords: lodgepole pine, beetle-killed, salvage, utilization, dead timber, mill operations, British Columbia

The study took the form of a literature review and survey of mills currently processing dead timber. A total of 15 operations were visited to observe and discuss the effects of beetle-killed pine on mill operations. These included sawmilling, plywood, pulp, finger-jointing, lumber remanufacturing and preservative treating operations. Discussions were also held with B.C. Ministry of Forests staff, Canadian Forestry Service scientists, and other Forintek staff concerning the salvage and use of beetle-killed timber. A report has been developed reviewing the subject and providing a rationale for the conclusions drawn and recommendations made.

29. Reid, R.W. 1961. Moisture changes in lodgepole pine before and after attack by the mountain pine beetle. Forestry Chronicle 34:368-375.

Key words: moisture content, sapwood, lodgepole pine, mountain pine beetle

The moisture content of the outer sapwood of non-infested lodgepole pine is normally about 85 to 165 per cent of oven dry weight. In trees that have been infested by the mountain pine beetle for one year, the sapwood moisture content can be as low as 16 per cent. There is a steep moisture gradient from about 160 per cent in the outer sapwood to about 30 per cent in the heartwood. The moisture content in the centre is slightly higher than in the adjacent wood. In infested trees the sapwood moisture is greatly reduced within a year after the attack but moisture in the heartwood is not altered appreciably. Trees infested early in the season drop to a lower moisture content by fall than trees infested later in the season. In non-infested trees there is a diurnal and a seasonal moisture march; these do not occur in infested trees. The rapid moisture loss in the sapwood of infested trees is associated with blue-stain infection and successful establishment of bark-beetle broods.

30. Roff, J.W.; Whittaker, E.I. 1963. Relative strength and decay resistance of red-stained lodgepole pine. Department of Forestry Publication No. 0131. Forest Products Research Branch, Ottawa, ON.

Keywords: lodgepole pine, red stain, heartwood, fungi, decay, specific gravity, strength

The heartwood of lodgepole pine commonly exhibits a red coloration which may lead to rejection of this wood for certain uses. In this report, both the strength and decay resistance of firm red-stained lodgepole pine heartwood, grown either in British Columbia or in Alberta, have been compared with that of unstained material of similar origin.

No reduction either in specific gravity or in strength in impact bending was observed, nor was the durability of the wood in stake plot tests reduced on account of the stain. No further development of decay associated with red stain occurred during the service test. The causal organisms remained alive in air-dry wood for over four years, but were quickly killed in wood which was steamed.

Strength of material from different regions varied to the extent that values for red-stained wood from area often averaged higher than those of unstained material from another. By comparison, however, average strength values in static bending and in toughness of red-stained wood were lower than those of corresponding clear material grown on the same site.

Three fungi, namely, *Stereum pini, S. sanguinolentum* and *Fomes pini,* proved to be responsible for over 80 percent of all red stain in the wood. Under laboratory test conditions, specimens cut from logs which exhibited this red stain developed typical advanced decay and, when red stain was introduced into previously sound wood, resistance to subsequent attack by fungi associated with decay in buildings was reduced.

The decay capacity and colour reaction of twelve other fungi, occasionally isolated from red-stained logs, but considered of minor importance, were examined. These fungi included members of the Basidiomycetes, Ascomycetes and Fungi Imperfecti.

31. Snellgrove, T.A.; Ernst, S. 1983. Veneer recovery from live and dead lodgepole pine. Forest Products Journal 33(6): 21-26.

Key words: veneer, lodgepole pine, time-since-death, mountain pine beetle

Recovery of dead lodgepole pine for core-stock veneer is probably feasible but varies with time-since-death and size. Volume recovery for 1-year dead was not practically different from live trees, but 3-year dead recovery was about 30 percent less. Recovery by grade of veneer was not related to time-since-death, but a higher percentage of random strip was produced from the older dead logs.

32. Solheim, H. 1995. Early stages of blue-stain fungus invasion of lodgepole pine sapwood following mountain pine beetle attack. Canadian Journal of Botany 73:70-74.

Key words: lodgepole pine, *Dendroctonus ponderosa,* fungal succession, blue-stain fungi

Invasion of lodgepole pine sapwood by blue-stain fungi was followed for 7 weeks after infestation by the mountain pine beetle, *Dendroctonus ponderosae.* During this period all sapwood was heavily stained blue and blue-stain fungi were always isolated close to the front of visible occlusion. *Ophiostoma clavigerum* and *Ophiostoma montim* were commonly isolated, both of which are known to be carried in the mycangia of the mountain pine beetle. *Ophiostoma montim* was most frequently isolated, but when both fungi were present *O. clavigerum* was always at the leading edge of fungal penetration. On average *O. montium* trailed 7.3 mm behind *O. clavigerum.* Other microorganisms were seldom isolated.

33. Tegethoff, A.C.; Hinds, T.E.; Eslyn, W.E. 1977. Beetle-killed lodgepole pines are suitable for powerpoles. For. Prod. J. 27(9): 21-23.

Keywords: beetle-killed, lodgepole pine, decay, moisture content, time after death

Of 30.8 dead, standing, pole-size lodgepole pines per acre in southeastern Idaho, 38 percent yielded 35- to 40-foot-long poles that met ANSI standards for size and form. Decay prevented the utilization of 12 percent of the trees for poles. Basal decay, responsible for rejecting over 50 percent of the trees, usually could be eliminated by long-butting trees from 4 to 8 feet. Trees dead for 3 years or longer attained an EMC of about 30 percent at 1 foot, and 14 percent at 16 feet, and higher, above the ground.

34. Thomas, P.R. 1986. Infestation of pine and spruce bark beetles in British Columbia and its effect on kraft and mechanical pulping. *In* Harvesting and processing of beetle-killed timber. Forintek Canada Corp., Vancouver, BC.

Keywords: beetle-killed wood, spruce, pine, pulp quality, wood characteristics, kraft pulping, mechanical pulping

Samples of pine and spruce beetle-killed wood were collected at various stages of time since attack. Wood characteristics, debarking wood losses and chip quality were measured. The furnishes were kraft cooked and pulping characteristics determined. Kraft pulp quality, drainage, drying and bleaching characteristics were addressed. Blue stain, which occurs in beetle-attacked wood, was evaluated for its effect on kraft and mechanical pulp quality and bleachability. Chemithermomechanical pulping and bleaching were carried out on both the spruce and pine. The effect of including beetle-killed wood chips with unattacked wood on chip pile deterioration has been assessed. This report presents the general findings of this study.

35. Waterhouse, M.; Armleder, H. 2004. Windthrow in partially cut lodgepole pine forests in west-central British Columbia. Extension Note 70. British Columbia Ministry of Forests, Research Branch. Victoria, BC.

Keywords: windthrow, northern caribou, *Rangifer tarandus caribou*, partial cutting, lodgepole pine, *Pinus contorta*

This study assessed whether partial cutting could increase levels of windthrow in stands to a point that would reduce the quality of caribou habitat. It also discussed the impact of partial cutting on stand stability because of potential economic loss and forest health risk.

36. Willits, S.; Brunner, C.; Morrell, J.J. 1997. Timber salvage and utilization in the Inland Northwest. Blue Mountains Natural Resources Institute Tech. Note 8. Blue Mountains Natural Resources Institute.

Key words: wood defects, deterioration, salvage, product potential

Uses for salvage lumber are characterized; however, it must be recognized that there are important limitations associated with dead and dying logs. Wood defects and deterioration affect log value. The rate of deterioration in dead and dying trees depends on wood species, tree size, local climate conditions, time of year, and cause of mortality

37. Woo, K., Watson P., and Mansfield S. 2003. The effects of mountain pine beetle and associated blue staining fungi on wood morphology and chemistry. Paprican University Report 831. Paprican and Department of Wood Science, University of BC, Vancouver, BC.

Key words: insects, blue stain, fungi, *Pinus contorta,* life cycle, wood properties, sapwood, heartwood, tree dimensions, moisture content, wood density, extractive content, lignin content, carbohydrates, permeability

The mountain pine beetle, *Dendroctonus ponderosae* Hopkins, is currently devastating the lodgepole pine resources in Western Canada, and in an attempt to deal with the problem, significant volumes of wood are being harvested. In order to fully use the mountain pine-beetle killed wood, it is crucial to understand how the pine beetle affects wood quality. A thorough analysis of beetle-killed and a sound lodgepole pine tree indicated that the infested sapwood and heartwood had substantial moisture loss, and that moisture content decreased with increasing tree height when compared to sound wood. Additionally, wood density analysis showed that infested wood was less dense than sound wood, and tended to decrease with increasing tree height. Chemical analysis indicated that infested sapwood contained significantly lower concentrations of extractives when compared to sound sapwood, and that extractives content increased toward the crown. Chemical analysis also revealed that infested sapwood had a lower lignin and hemicellulose content than sound sapwood. Wood permeability showed that infested sapwood was more permeable than sound sapwood, while sound heartwood was more permeable than infested heartwood. Permeability in both sapwood and heartwood varied with tree height and correlated with extractives content. These chemical and morphological changes significantly influence the quality of wood and fibre obtained from this substantial resource.

38. Woodfin, R.O. Jr. 1979. Dead western softwood timber – a resource to be utilized. *In* Proceedings of the Society of American Foresters 1978 national convention. Society of American Foresters, USA.

Keywords: lumber recovery, dead timber, utilization, lodgepole pine, losses, time since mortality, grade yield

This paper looks at various western softwoods and the potential for product recovery from dead standing timber. Areas of potential volume loss are also discussed, as well; lumber grade recovery is examined.

39. Woodward, Ben. 2005. Value recovery study of mountain pine beetle-killed trees on veneer processing. Report for Canfor-North Central Plywoods.

Keywords: veneer, mountain pine beetle, drying, wood quality

Mill studies at Canadian Forest Products - North Central Plywoods (NCP) were performed to quantify the impacts of processing mountain pine beetle-killed (MPB) logs on veneer processing.

These studies revealed that: 1) Prior to harvesting, green attack MPB-tree sapwood contains approximately 30% less MC than green healthy pine tree sapwood. Since MC has such a profound effect on veneer recover, maximum veneer recovery will occur when MPB-logs are processed immediately after arrival; 2) Veneer recovery values were 47.3%, 44.0%, and 41.7% when processing 25%, 50% and 75% MPB-logs decked for 4-5 months respectively. The veneer recovery value increased to 50.3% when processing 25% MPB-logs within one week after arrival; 3) The amount of random width veneer ranged from 6.2% to 9.4% when processing MPB-logs. Darker blue-stain was seen as a defect by the clipper camera, resulting in an excess amount of random width veneer produced; 4) MPB veneer contains less mc than control logs resulting in 0.35" less veneer width shrinkage per sheet than control veneer. The rotary clipper already takes MC into account prior to veneer clipping resulting in maximum veneer recovery; 5) Overall, MPB ribbons are rougher, containing more peaks and valleys between thickness measurements than control ribbons; 6) The veneer dryers are where cost benefits can occur when processing high percentages of MPB veneer; however, the age of NCP veneer dryers will not capitalize on production levels necessary for maximizing profit.

40. Work, L.M. 1978. Dead timber evaluation and purchase – firewood or lumber. *In* Symposium: the dead softwood timber resource. Engineering Extension Service Washington State University, Pullman, Wash.

Keywords: dead timber, harvesting, wood losses, epidemics, insect attack, value

Harvesting dead timber creates unique problems that are associated with dead trees and increases problems that are inherent in all log processing activities. It is important to allow for these problems in terms of cost allowances and to hasten the processes of making dead timber available to prospective buyers. Procrastination through study teams, red tape, or improper allowances will only succeed in compounding the problems. The best solution for minimizing wood losses due to mortality is to practice preventive maintenance (silviculture) in green stands and impede epidemic flare-ups of insects.

SECTION 2. OTHER PINE SPECIES

41. Barron, E.H. 1971. Deterioration of southern pine beetle-killed trees. Forest Products Journal 21(3):57-59.

Key words: moisture content, specific gravity, southern pine beetle, beetle-killed trees

Regression equations were developed from measurements of specific gravity and moisture content from 1 through 6 months following beetle attack. Values obtained were used to measure wood substance loss and changes in moisture content. Specific gravity reductions after 6 months varied from 5 to 16 percent. Moisture content declined 29 to 52 percent within the first month, but quickly tapered off. Reduction in both specific gravity and moisture content depend on initial treatment and season the trees are killed. Felling trees soon after attack reduced moisture loss by one-half, but approximately doubled wood substance loss.

42. Basham, J.T. 1957. The deterioration by fungi of jack, red, and white pine killed by fire in Ontario. Canadian Journal of Botany 35: 155-172.

Keywords: pine, deterioration, sapwood, heartwood, sap rot, heart rot, fungi, salvage, fire

The nature, causes, and rate of pathological deterioration of jack, red, and white pine killed by fire in the Mississagi region of Ontario in 1948 were studied to determine the practicability and probable duration of profitable salvage operations in such stands. Blue and brown sapwood stains appeared in all species 1 year after the fire, and became extensive during the succeeding 3 years. Sap rot was first noted 2 years after the fire; 5 years after the fire most of the sapwood was affected, and in some cases this rot extended into the heartwood. Three fungi, *Pemiophora gigantean* (Fries) Massee, *Polyporus anceps* Peck, and *Polyporus abietinus* Dicks. ex Fries, were isolated consistently from white sap rots, while *Fomes pinicola* (Sw.) Cooke and *Fomes subroseus* (Weir) Overh, were recovered from many of the brown sap rots. The increase in the volume of heart rot encountered during the course of the study, chiefly associated with *Fomes pini* (Thore) Lloyd, was much greater than that observed in living pine over a similar period, and for this reason the excess was considered as a form of deterioration. The average rate of radial penetration of visible deterioration was significantly faster in trees with widely spaced annual rings in the outer portion of the bole than in slow-growing trees. Variations in the severity of burn in individual trees or stands apparently had little effect on the rate of pathological deterioration.

43. Chapman, A.D.; Scheffer, T.C. 1940. Effect of blue stain on specific gravity and strength of southern pine. Journal of Agriculture Research 61(2): 125-133.

Keywords: blue stain, fungi, strength, toughness, pine, specific gravity

Although all strength properties of pine appeared to be lowered when the sample was inoculated with blue stain causing fungi, only toughness was affected to an extent of general practical significance. There was some evidence of a broad relation between the abundance of direct cell-wall penetration by the fungi and reduction in toughness. The intensity of the discoloration caused by the different fungi was not indicative of the severity of attack or of the comparative weakening caused by each. The frequency of association between a particular blue stain fungus and a certain kind of wood apparently does not necessarily indicate the inherent ability of the fungus to attack the wood and to affect its strength.

44. Dahms, W.G. 1949. How long do ponderosa pine snags stand? United States Department of Agriculture, Forest Service Research Notes PNW 57. Pacific Northwest Forest and Range Experiment Station, Portland, OR.

Keywords: snags, ponderosa pine, rate of snag fall

A plot on the Pringle Falls Experimental Forest was installed to determine how long ponderosa pine snags remain standing. A burn killed most of the snags however snags resulting from insect kill are also discussed. Smaller snags tend to fall sooner than larger snags. Snags killed by fire have a tendency to stand longer then those killed by insect.

45. Fahey, T.D. 1980. Beetle-killed pine can be salvaged, but for how long? Forest Industries. 107(5): 60-61.

Keywords: beetle-killed pine, salvage, lumber yield, value

Salvage opportunities are abundant; but before salvaging, an operator needs to know the values retained and the length of time trees will remain salvageable.

46. Findlay, W.P.K.; Pettifor, C.B. 1937. The effect of sap-stain on the properties of timber. Forestry. 11: 40-52.

Keywords: *blue stain, fungi, pine, specific gravity, toughness, strength, hardness, sapwood*

Experiments are described in which the specific gravity, toughness, compressive strength, bending strength, and hardness of pine sapwood infected with blue stain caused by *Ceratostomella coerulea* or by other similar organisms have been compared with those of clear unstained sapwood. Two series of tests were carried out – the first on matched samples, some of which were sterilized by steaming and in which infection was artificially produced, and the second on samples selected from naturally stained planks. It was found that the presence of the staining fungi had no appreciable effect on the compressive strength, or the bending strength, but that it caused a marked reduction in toughness and also slight reduction in hardness.

47. Fritz, C.W. 1952. Brown stain in pine sapwood caused by *Cytospora* sp. Canadian Journal of Botany 30(4): 349-359.

Keywords: Cytospora sp., brown stain, red pine, pine, toughness, bending strength

A fungus isolated from naturally brown-stained red pine sapwood was found to produce characteristic chocolate brown stain in sterilized red pine sapwood in culture; it is identified as a species of *Cytospora*. The fungus develops in the ray parenchyma, may proliferate in the tracheids, but penetrates the walls only through the pits. A technique is described for producing brown stain in culture in sticks of the size required for static bending and toughness tests. Two series of sticks were subjected to each test; the samples used were end-matched sticks in groups of three, which provided a green control, sterilized control, and a specimen stained in culture by *Cytospora* sp. The results showed some variation in the relative strength of samples in different groups, but a statistical analysis indicated that the effect of *Cytospora* sp. On both bending strength and toughness is negligible.

48. Govett R.L.; Sinclair, S.A.; Bowyer, J.L. 1983. Lumber grade yields from spruce budworm-damaged balsam fir. Forest Products Journal 33(5): 46-50.

Keywords: balsam fir, budworm-killed, dimension lumber, grade yields, standing dead

In two grade yield studies conducted at a commercial sawmill in northern Minnesota, 383 100-inch bolts, bucked from 149 balsam fir trees, were processed into lumber. Production of 2- by 4-inch and 2- by 6-inch dimension lumber was maximized. The sample of trees, which were harvested, included balsam fir which were healthy, stressed, or dying as a result of spruce budworm defoliation and dead standing trees which had been killed by the spruce budworm. Budworm-killed trees were harvested which had been standing dead approximately 6 months or less (including recently killed trees), 12 months, and 18 months. Results indicate that healthy balsam fir is capable of producing relatively high percentages of Standard or No. 2 and Better grades of dimension lumber. Over 56 percent of all dimension lumber sawn from bolts of healthy and budworm-stressed trees graded as Standard or No. 2 and Better. The rapid onset and advance of decay in the dead standing tree quickly erodes the potential for recovery of large percentages of dimension lumber in grades of No. 2 or Standard and Better from budworm-killed balsam fir. Budworm-killed balsam fir continues to remain reasonably well suited to the production of dimension lumber grades of Stud or Utility or No. 3 and Better for up to 1 year after death. Over 63 percent of all dimension lumber produced from balsam fir standing dead 12 months was in grades of Stud or Utility or No. 3 and Better. Progression of decay with increasing time after death caused increasing downfall of lumber into the Economy grades.

49. Hunt, K. 1979. Kraft pulping of jack pine killed by the Swaine sawfly. Canadian Journal of Forest Research 9:149-153.

Key words: pulp, jack pine, *Pinus banksiana*, Swaine sawfly, time since death, pulp strength, insect attack

Kraft pulping studies were done on jack pine (*Pinus banksiana* Lamb.) defoliated by Swaine jack pine sawfly (*Neodiprion swainei* Midd.). Trees dead as long as 7 years, dead and living trees sprayed with Lindane insecticide, and dead trees wrapped in cotton to prevent secondary insect attacks were tested. There was a statistically significant decrease in unscreened pulp yield (adjusted to screened pulp permaganate No. 20) with length of time since death, e.g. 44.6% (1 year) to 43.4% (7 years); but sufficient variation exists between the trees in any category such that, from a practical viewpoint, all trees tested could be used for pulp manufacture. There were no apparent differences in pulp yield between treated and untreated trees dead for the same length of time. Pulp strength decreased approximately linearly with length of time since death. A decrease in the chip thickness range of –6 mm to +2 mm (total laboratory accepts) and an increase in the –2 mm (pan) thickness range with length of time since death were observed.

50. Ifju, G.; Oderwald, R.G.; Ferguson, P.C.; H.J. Heikkenen. 1979. Evaluation of beetle-killed southern pine as raw material for pulp and paper. Tappi Journal 62(2): 77-80.

Key words: southern pines, insects, kraft pulping, yield, tear strength, tensile strength, break resistance, Canadian standard freeness

Southern pine trees left dead on the stump for up to 3 years following southern pine bark beetle infestation in the Virginia piedmont and coastal regions were felled, chipped, and pulped in an experimental kraft digester. The trees included in the study were stratified according to the length of time they had been standing dead after infestation. Chips from each tree were cooked, the yield was determined, and handsheets were prepared and tested for tear and breaking length after five different beating periods. In spite of apparent decay, no drop in kraft pulp yield was found compared with green control material. However, tearing resistance of the handsheets decreased after 0-6 months following death. Paper tensile strength increased slightly after 6 months following death and then decreased to a small loss after 24 months. Dead southern pine trees left on the stump for as long as 2 years after a beetle attack may be safely used as raw material by kraft mills without affecting yield and with only a slight effect on paper properties. However, quick removal of the dead material is recommended because of easy breakage of branches and tops of dead trees.

51. Keen, F.P. 1955. The rate of natural falling of beetle-killed ponderosa pine snags. Journal of Forestry. 53(10): 720-723.

Key words: ponderosa pine, natural fall rate, snags, beetle-killed

The rate of natural fall of beetle-killed ponderosa pine is dependant on time elapsed since death, but this rate is modified by tree size, soil conditions, and several unpredictable variables. In the study conducted, 85 percent of the snags were still standing after 5 years, but as the effects of wood rots and wood borers accumulated, the snags fell at an increasingly rapid rate. After 15 years the rate of fall decreased, and the larger more resistant trees stood for a long time. After 25 years, 10 percent of the snags were still standing.

52. Kelly, M.W.; Barefoot, J.E.; Swint, W.H.; Levi, M.P. 1982. Properties of particle and hardboard made from healthy and beetle-killed southern pine. Forest Products Journal 32(3): 33-39.

Keywords: shortleaf pine, southern pine beetle, particleboards, hardboards, yield of wood fiber

Particleboards were prepared from wood of: (a) healthy shortleaf pine trees; (b) shortleaf pine trees that had been killed by southern pine beetle (*Dendroctonus frontalis*) 3 months previously; and (c) trees that had been killed by beetles 30 months previously. Results of tests showed that particleboards produced from beetle-killed pines met industry specifications for MOR, MOE, IB, screw withdrawal, hardness, water absorption and thickness swelling. However, in these tests, linear expansion (LE) was not adequate for (a), (c) or a 50/50 mixture of (a) and (b). Hardboards made from (a), (b) and (c) also met industry specifications for all properties except LE; boards prepared from 100% (b) or (c) failed this specification, but when 50% (a) was added they met the specifications. The yield of wood fibre from beetle-killed wood was slightly lower, the percentage of fines was higher, and the m.c. was lower, than that for healthy trees.

53. Levi, M.P.; Dietrich, R.L. 1976. Utilization of southern pine beetle-killed timber. Forest Products J 26(4): 42-48.

Key words: beetle-killed trees, utilization, southern yellow pine

Over 600 buyers of pine in North Carolina were questioned on their attitudes regarding purchase and utilization of southern yellow pine beetle-killed trees. Five of the 11 responding pole, piling, and post buyers stated that they would not purchase beetle-killed trees, whereas only six of the 76 responding pulpwood buyers refused to accept dead trees. Manufacturers of lumber, dimension stock, railroad ties, and reconstituted wood products were intermediate in their attitudes. A survey of the literature on the utilization of beetle-killed, blue-stained, decayed, and insect-attacked southern yellow pine indicates that trees recently beetle-killed could be used economically for dimension lumber and pulp production, even when purchased at the same price as sound wood. However, as the length of time the trees have been dead increases, their value and usefulness to the wood products manufacturer decreases. The survey also showed that there is an urgent need for further information on the rate of deterioration of beetle-killed trees and its effect on utilization, and for development of a simple field method for estimating time since beetle-kill.

54. McNab, W.H. 1983. Total tree and product weight of beetle-killed loblolly pines in northeast Georgia. Georgia Forest Research Paper 42. Georgia Forestry Commission, Macon, Georgia.

Keywords: loblolly pine, pines, beetle-killed, moisture content, weight-scaling factors, product weight, total tree weight

Pines killed by beetles are merchantable for various products if harvested soon after attack. In the south, however, significant weight loss occurs quickly, especially during the summer months, and will affect accurate conversion of weight to volumes if factors for live trees are used. For example, the main stem and branch moisture content of live loblolly pines is almost double the amount measured in beetle-killed trees. Tables for estimating the weight of the total tree and products, and weight-scaling factors were developed for beetle-killed loblolly pines.

If markets are not available or if excessive deterioration lowers good quality for conventional products, beetle-killed trees can be harvested for fuelwood chips.

55. Patterson, D.W.; Murphey, W.K.; Massey, J.G. 1983. Moisture content of beetle-killed southern pine timber in eastern Texas. For. Prod. J. 33(1): 67-68.

Key words: moisture content, time since death, beetle-killed, southern pine

In October 1981, beetle-killed southern pine trees were harvested to provide data for validating a sawmill decision model. As part of that study, moisture content samples were taken at the butt of the tree, at the top of the butt log, and above the last log if more than one log was taken. Analysis of variance showed that moisture content varied significantly by time since death and position in the tree. The data are presented in tabular and graphic form.

56. Raphael, M.G.; Morrison, M.L. 1987. Decay and Dynamics of Snags in the Sierra Nevada, California. Forest Science 33(3): 774-783.

Keywords: snags, decay, falling rates, *Pinus jeffreyi, Abies concolor,* wildlife habitat

A study on the rates of decay, falling, and recruitment in a population of snags (standing dead trees) in Sierra Nevada, California, during 1975-83 showed that large-diameter (>38 cm dbh) snags fell slower than small-diameter snags. Firs (*Aibes* spp.) fell at a lower rate than pines (*Pinus* spp.). Snags lost all needles and twigs within five years; 75% of pines and 66% of firs had lost most larger limbs within five years. Compared with the numbers of live trees in the parent stand, rates of new mortality were highest among Jeffrey pine (*Pinus jeffreyi* Grev. and Balf.) <15 cm dbh. Live-tree mortality exceeded the rate that snags fell during our study, causing an increase in the snag population from 1978 to 1983. A Leslie matrix model of this snag population was developed that accounted for falling rates, transitions among decay stages, and recruitment of snags. Use of the model was illustrated using field data from five unburned study plots.

57. Schmid, J.M.; Mata, S.A.; McCambridge, W.F. 1985. Natural falling of beetle-killed ponderosa pine. United States Department of Agriculture, Forest Service Research Note RM 454. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.

Keywords: Dendroctonus ponderosae Hopkins, *Pinus ponderosa* Larson, beetle-killed, ponderosa pine, mountain pine beetle, rate of falling, direction of falling

Beetle-killed trees in the Front Range of Colorado were observed for their rate and direction of falling. No trees fell within the 2 years following infestation. Thereafter, trees generally fell at the rate of 3-5% per year unless winds exceeded 75 mph. Most trees fell to the east and broke off between ground level and 2 feet above ground.

58. Shamoun, S.F.; Levi, M.P. 1985. A chemical and microscopic study of decayed earlywood and latewood of loblolly pine killed by the southern pine beetle. Wood and Fiber Science. 17(1): 22-28.

Keywords: decay, chemical analysis, microscopy, loblolly pine, southern pine beetle, earlywood, latewood

Chemical and anatomical changes in the wood of loblolly pines (*Pinus taeda* L.) killed by southern pine beetles (*Dendroctonus frontalis* Zimm) were examined. The trees had been dead for approximately 20 months, and were harvested near Jacksonville, North Carolina. Decay occurred in both earlywood and latewood although the rate of deterioration was greater in the earlywood. The dominant patterns of decay in earlywood were dissolution of the secondary walls from the lumen outward towards the middle lamella, and finally a total destruction of cell-wall structure. Decay in latewood was characterized by localized dissolution of the secondary walls, and the formation of "soft-rot" type cavities in the S_2 layer of the secondary walls. Chemical analysis showed little or no difference in proportions of holocellulose and lignin in earlywood and latewood of sound and beetle-killed wood. One percent NaOH solubility of both earlywood and latewood was significantly greater in beetle-killed wood than in sound wood. These characteristics suggest that the primary fungus responsible for decay may be *Peniophora* sp., a fungus commonly found in stored southern pine logs. The results indicate that the beetle-killed wood could be used successfully as a furnish for pulp and reconstituted board products.

59. Sinclair, S.A.; Ifju, G. 1979. Lumber quality of beetle-killed southern pine in Virginia. Forest Products Journal 29(4): 18-22.

Keywords: beetle-killed, southern pine, foliage fade, dimension lumber, decay, grade yields, lumber recovery

Test sawings of beetle-killed southern pine were conducted to determine the potential grade yields of dimension lumber at various times after foliage fade. Trees were harvested at periods of 12 months, 20 months (2 winters and 1 summer), and 20 months (2 summers and 1 winter) after foliage fade. The amount of lumber in grades No. 2 and better decreased rapidly with increasing time after foliage fade. Green, control trees had 96 percent of their dimension lumber in grades No. 2 and better, while trees on the stump 12 months after foliage fade retained approximately 55 percent of their dimension lumber in grades No. 2 and better, and trees on the stump 20 months (2 summers and 1 winter) had only 24 percent of their dimension lumber in grades No. 2 and better. Major causes of degrade were decay and large borer holes. The lumber recovery factor was also lower for beetle-killed trees. This was due to increased slabbing by the sawyer and greater amounts of cull boards. It was found that an average 12-inch small-end-diameter upper log from beetle-killed pine, which was left on the stump for 20 months (2 summers and 1 winter) between foliage fade and harvesting, retained less than half the value of a similar log cut from healthy green pine when processed into dimension lumber.

60. Sinclair, S.A.; McLain, T.E.; Ifju, G. 1979. Strength loss in small clear specimens of beetle-killed southern pine. Forest Products Journal 29(6): 35-39.

Keywords: beetle-killed, shortleaf pine, loblolly pine, crushing strength, bending strength, MOR, MOE, foliage fade

Beetle-killed shortleaf and loblolly pine trees with known dates of foliage fade, as well as normal healthy trees, were harvested and processed into lumber. Small clear specimens were prepared from the lumber meeting the current grading specifications for dimension lumber as determined by quality supervisors of the Southern Pine Inspection Bureau. MOR and MOE in bending and ultimate crushing strength were determined for both the dead and the healthy material. Significant reductions in mean MOR and MOE were noted in the material harvested within 12 months of foliage fade as compared to control material from the same stands. A mean reduction of 19 percent in MOR and 11 percent in MOE were noted for wood taken from trees standing for two full warm seasons after foliage fade. The relationship between MOR and MOE of small clear specimens was significantly affected due to a differential reduction in these two properties. Mean ultimate crushing strength was reduced but not to the same degree of severity as MOR and MOE. Examination of the sample lower 5 percent tolerance limits indicated that both mean and variance of MOR and MOE were significantly affected while those of ultimate crushing strength were relatively insensitive.

61. Sinclair, S.A.; McLain, T.E.; Ifju, G. 1979. Toughness of sap-stained southern pine salvaged after beetle attack. Wood and Fiber. 11(1): 66-72.

Keywords: southern pine beetle, toughness, blue stain, structural lumber, incipient decay, beetle-killed, utilization

Approximately 1,200 small clear specimens were machined from visually graded dimension lumber and tested for toughness. Dimension lumber was obtained from green healthy southern pine and beetle-killed southern pine at various times after foliage fade. The specimens machined from beetle-killed material were free from defects with the exception of sap stain, which is not currently considered in grading rules. Toughness generally decreased with increasing time between foliage fade and the harvesting of the beetle-killed sawtimber. Most of the loss in toughness occurred during the first year after foliage fade. For certain structural applications where toughness or shock resistance of wooden members may be of some importance, caution should be exercised in the utilization of beetle-killed southern pine.

62. Sinclair, S.A.; Johnson, J.A.; Ifju, G. 1978. Changes in toughness of wood from beetle-killed shortleaf pine. Forest Products Journal 26(7): 44-47.

Keywords: shortleaf pine, *Pinus echinata,* bark beetle attack, traditional toughness, fracture toughness, fungi, decay, strength

Matched groups of specimens from healthy green shortleaf pine (*Pinus echinata* Mill.) and from dead shortleaf pine killed by the effects of a bark beetle attack were tested for traditional and fracture toughness. Traditional and fracture toughness appeared to be related through four groups of specimens; normal or control, lightly stained, heavily stained plus incipient decay, and partial decay. Fracture toughness proved sensitive to the effects of early fungal sap stain and incipient decay, but appeared less sensitive than traditional toughness. Both measures of toughness indicated strength losses due to the effects of stain and decay fungi.

63. Sinclair, S.A.; Ifju, G.; Heikkenen, H.J. 1977. Lumber yield and grade recovery from southern pine sawtimber after beetle attack. Southern Journal of Applied Forestry 1(4):17-20.

Keywords: southern pine, beetle-killed, lumber yield, grade recovery, sawtimber, foliage fade, volume loss

Dead southern pine sawtimber previously attacked by bark beetles was harvested 12 months after foliage fade and converted into lumber. Lumber yield on a volume and grade basis was significantly less for the beetle-killed trees than for a similar set of normal green trees. Upper logs of the beetle-killed trees showed a more serious grade and volume loss than the lower logs. Decay and borer damage were the main cause of grade yield loss.

64. Snellgrove, T.A., and Cahill, J.M. 1980. Dead western white pine: characteristics, product recovery, and problems associated with utilization. United States Department of Agriculture, Forest Service Research Paper PNW 270. Pacific Northwest Forest and Range Experiment Station, Portland, OR.

Keywords: dead timber, lumber recovery, lumber yield, wood utilization, deterioration, western white pine, *Pinus monticola*

When a western white pine (*Pinus monticola* Dougl. Ex D. Don) tree dies, it undergoes a series of physical changes. The effects of these changes on product recovery are evaluated. Tabular information and prediction equations provide the tools necessary for using this resource.

65. Snellgrove, T.A.; Fahey, T.D. 1977. Market values and problems associated with utilization of dead timber. Forest Products Journal 27(10): 74-79.

Key words: dead timber, utilization, loss, market value, pine

Dead timber suffers a series of incremental losses: 1) logging and handling losses in the woods and mill yard, 2) decreases lumber volume from logs sawed, and 3) degrade of lumber due to deterioration defects. Dollars per hundred cubic feet of gross tree volume is used to express value losses. There was a 24 percent average value loss for true fir dead from zero to 2 years. For western, white pine of average value that had been dead zero to 2 years, losses were 26 percent; for that dead 3 to 6 years, 55 percent; and for that dead more than 7 years, 69 percent.

There are a number of factors that can affect utilization of dead timber including inherent bias against utilization, handling problems created by increased breakage, manufacturing problems in mills, and market considerations.

66. Troxell, H.E.; Tang, J.; Sampson, G.R.; Worth, H.E. 1980. Suitability of beetle-killed pine in Colorado's Front Range for wood and fiber products. United States Department of Agriculture, Forest Service Resource Bulletin RM 2. Rocky Mountain Forest and Range Experiment Station. Fort Collins, Colorado.

Key words: beetle-killed wood, mountain pine beetle, ponderosa pine, blue-staining

Front Range beetle-killed ponderosa pine wood is suitable for most traditional uses of the species. Differences are: the beetle-killed timber is drier, usually blue-stained, and may contain wood borers and decay. Mechanical properties may be affected.

67. Willits, S.; Woodfin, R.O.; Snellgrove, T.A. 1990. Lumber recovery from dead ponderosa pine in the Colorado Front Range. United States Department of Agriculture, Forest Service Research Paper PNW 428. Pacific Northwest Research Station, Portland, OR.

Keywords: Lumber recovery, ponderosa pine, *Pinus ponderosa,* Colorado Front Range, beetle-killed pine, blue stain

Lumber recovery information from live and beetle-killed ponderosa pine *(Pinus ponderosa* Dougl. ex Laws) in the Colorado Front Range is presented. No significant difference in lumber volume was found among the samples. Significant differences were found in lumber value among the live, 1-year-dead, and 3- to 5-year-dead samples. About 10 percent of the value was lost in the first year after death, primarily because of blue stain. Checks and splits, wood borers, and rot caused additional loss in subsequent years.

68. Woodson, G. 1985. Utilization of beetle-killed southern pine. United States Department of Agriculture, Forest Service General Technical Report WO 47. Washington Office, Washington, DC.

Keywords: southern pine, beetle-killed, utilization, SAMTAM, moisture content, product yields

Beetle-killed timber has been underutilized because its value has been misjudged. Reluctance on the part of timber buyers to use such material has left mill managers with the option of either suppressing prices or refusing to process this type of wood. But recent research has shown that beetle-killed pulpwood and sawtimber can be utilized for a wide variety of wood products if trees are harvested and processed soon after attack. Lumber grade in beetle-killed trees is lower than for healthy ones, but yields of particleboard, hardboard, and pulp are similar for both types. In addition, a lower moisture content makes beetle-killed pine an economical purchase for those who buy wood on a weight basis, since it yields more fiber per dollar than healthy pine. The development of SAMTAM and SAMTAM II sawmill analysis models now takes the guesswork out of profit and loss determinations in processing beetle-killed logs and can make their increased utilization an attractive option for many wood products.

SECTION 3. OTHER SPECIES

69. Basham, J.T. 1986. Biological factors influencing stem deterioration rates and salvage planning in balsam fir killed after defoliation by spruce budworm. Canadian Journal of Forest Research 16: 1217-1229.

Key words: balsam fir, *Abies balsamea*, spruce budworm, bark beetles, saprot, salvage

Balsam fir (*Abies balsamea* (L.) Mill.) trees dead between 0 and 5 years were sampled in three widely separated areas that had distinctly different population levels of the secondary, stem-attacking, balsam fir bark beetle (*Pityokteines sparsus* (Lec.)). The percentage of stem volume affected by sap rot increases significantly with the number of years since tree death. The wood volume lost in debarking tests, simulating pulp mill conditions, averages 23% in trees dead 4-5 years in the two areas with the most sap rot, and in individual trees, debarking losses were significantly correlated with the extent of sap rot. Sap rot developed most quickly where stems had the most bark beetle activity, whereas where the bark beetle population was very low, sap rot development was significantly slower. These results are consistent with those of many earlier studies and observations in which a close relationship has been noted between the extent of sap rot and the intensity of bark beetle attack in stands of budworm-killed balsam fir. Evidence is presented indicating that stem deterioration rates and beetle activity frequently change with time in specific regions during any one budworm outbreak. It is postulated that inoculum levels of *Polyporus abietinus* (Dicks ex Fr.), the fungus responsible for the sap rot, and population levels of the balsam fir bark beetle are similarly and greatly affected by earlier occurrences of balsam fir mortality in a region. The average density of bark holes, caused by bark beetle tunnelling in recently killed trees, can be used as a non-destructive and quick indicator of the average rate of development and probable extent of stem sap rot in budworm-damaged balsam fir stands. This information can be useful in assessments of the economic feasibility of proposed salvage operations.

70. Basham, J.T. 1984. Degradation and loss of wood fibre in spruce budworm-killed timber, and effects on utilization. Forestry Chronicle 60:10-14.

Key words: spruce budworm, balsam fir, stem deterioration, sap rot, dead trees, salvage, utilization, pulp quality

Far more investigations of the deterioration and utilization of the stems of trees killed following spruce budworm (*Choristoneura fumiferana* [Clem.]) defoliation have been, or are being, carried out during the current budworm outbreak in eastern and central North America than in all previous outbreaks combined. Unfortunately, the results are dispersed in a wide variety of publications, some of which are relatively obscure and difficult to find. This report is an attempt to assist the forest manager faced with salvage decisions, by reviewing and summarizing current knowledge and by identifying some of the potentially useful literature.

71. Bernes, D.P.; Sinclair, S.A. 1983. Time-related changes in specific gravity and moisture content of spruce budworm killed balsam fir. Canadian Journal of Forest Research 13:257-263.

Keywords: dead trees, moisture content, wood density, spruce budworm, balsam fir

Variation in density and m.c. was investigated in healthy firs and firs killed by *Choristoneura fumiferana* in northern Minnesota. Discs were removed at 100-inch intervals along the merchantable boles of 31 healthy trees, 16 trees dead 6 months, 42 trees dead 12 months, and 18 trees dead 22 months. Knot-free wedges were cut from the discs and separated into outer and inner sections. Av. values of density for outer and inner sections of healthy (control) fir varied within trees, decreasing then increasing with height. This trend was not apparent for av. values of outer section density in the dead tree categories. However, av. densities of the 4 tree categories were not significantly different. Av. m.c. decreased rapidly with time after death, and significant differences were detected within months of tree death. Significant moisture losses occurred within 6 months after death, while significant inner section losses developed after 12 or more months.

72. Dobie, J.; Wright, D.M. 1978. Lumber yields and values from dead, standing alpine fir. Forest Products Journal 28(5): 27-30.

Keywords: alpine fir, lumber yields, lumber value, dead, recovery, economically recoverable

An interim classification system used by the British Columbia Forest Service (BCFS) for dead, standing alpine fir recognizes two groups: 1) trees with broken tops or with tops broken at a point in the stem smaller than 4.0 inches DIB, and with no conks visible; and 2) trees with tops broken at a pint in the stem larger than 4.0 inches DIB. Trees in group 1 are considered to have wood product potential, whereas those in group 2 are considered useless. Group 1 is further divided into two quality groups, with the better being considered suitable for lumber manufacture, and the other suitable only for the manufacture of chips for pulping. Recovery studies of both these quality groups indicated that the classification system performed adequately in distinguishing lumber quality. Average lumber yields in the first quality group of the dead potential class were 39 percent greater than in the second group; product values per unit of logs were 32 percent greater, based on BC Firmwood Cubic Scale. However, the values recovered indicate that only the largest diameter at breast height classes of the better quality group are likely to yield positive conversion returns at current costs and prices. Thus, unless there is a real scarcity of fiber, this potential source of additional supply would not appear on the average to be economically recoverable.

73. Giles, D. 1986. Salvage and storage of beetle-killed timber. *In* Harvesting and processing of beetle-killed timber. Forintek Canada Corp., Vancouver, BC.

Keywords: beetle-killed, timber, storage, wood destroying insects, fungi, wood deterioration, temperature, moisture, oxygen

Salvage of beetle-killed timber can reduce the loss of timber by the forest industry. Protection of logs from wood destroying insects and fungi, after initial attack has occurred will increase the period over which the resource may be converted to marketable products. Moisture, oxygen and temperature are the factors which determine the rate and extent of physical and biological deterioration of wood. Control of one or more of these factors is required for effective long-term storage.

74. Hadley, K.S.; Veblen, T.T. 1993. Stand response to western spruce budworm and Douglas-fir bark beetle outbreaks, Colorado Front Range. Can. J. For. Res. 23:479-491.

Key words: western spruce budworm, Douglas-fir beetle, stand characteristics, stand development, forest pests

The montane forests (i.e. below about 2900 m altitude) of the Colorado Front Range have experienced repeated outbreaks of western spruce budworm (*Choristoneura occidentalis*) and Douglas-fir bark beetle (*Dendroctonus pseudotsugae*), both of which locally attack Douglas-fir (*Pseudotsuga menziesii*). The effects were studied of (historically documented) outbreaks of these insects on succession, stand structure, and radial growth of host and non-host species in Rocky Mountain National Park; the most recent budworm (1974-85) and bark beetle (1984-present) outbreaks resulted in the most severe and widespread disturbance of these forests since the late 19th century. Studies were carried out during 1987 and 1988 in 11 stands representing a wide range of environmental conditions, and dominated by ponderosa pine (*Pinus ponderosa*) and Douglas-fir, in order to investigate the responses of stands to repeated outbreaks of these pests. The stands were either old (>250 yr) with relatively open understories or young (<130 yr), dense, even-aged post-fire stands. Cores were taken from some Douglas-fir, ponderosa pine and lodgepole pine (*Pinus contorta*) for dendrochronological analyses. Young, vigorous post-fire stands showed minimal budworm defoliation, and in these stands only remnant trees from the pre-fire generation appeared to be susceptible to beetle-caused mortality. Dense stands exhibited higher budworm-induced mortality, which hastened the natural thinning process and shifted dominance towards the non-host species. The stands most severely disturbed by these insects were multi-storied stands with high host densities and a wide range of stem sizes. The stand response to these disturbances included the growth release of shade-intolerant, seral species, and in some cases, a higher survivorship among mid-sized individuals of Douglas-fir. The net result of the combined insect outbreaks is the temporary slowing of the successional trend towards a steady-state Douglas-fir forest. Fire suppression, by increasing the density of suppressed Douglas-fir, has previously been shown to favour increased outbreak severity of western spruce budworm in the N. Rocky Mountains. However, in the Front Range, recent increases in outbreak severity and their synchronicity may also be the result of large areas of forest (burned during the late 19th century during European settlement) simultaneously entering structural stages susceptible to insect outbreak.

75. Hatton, J.V. 1981. Utilization of dead wood in pulping: Current studies on the processing of spruce budworm-killed balsam fir. Pulp & Paper Canada. 82(3): 81-82, 85-87, 89-90.

Key words: dead wood, utilization, pulping, age, storage, stumps, *Abies balsamea*, density, losses, barking, chips, quality, alkalis, solubility, economic factors, questionnaires, insects, forest pathology

Initial results are presented of a four-year study on the effects of length of time since death on the processing characteristics of stump-stored budworm-killed balsam fir from two regions in Ontario and one in Minnesota. As length of time since death increases, wood density decreases, wood losses in debarking increase, chip quality decreases and 1% caustic solubility of chips increases. All these effects combine to increase the net cost of fibre at the processing point. Principles for evaluating dead or diseased wood in general are described and are applied to budworm-killed material to indicate the importance of a comprehensive evaluation prior to decision making on the use of budworm-killed wood in pulping and the salvaging strategy to be followed. The highlights of a questionnaire on mill operating experience in the use of budworm-killed wood in North America are summarized. Although several mills use this material in pulping, little is known concerning the differences between processing of 100% budworm-killed and 100% sound wood. A number of possible strategies for salvaging budworm-killed wood are described and their advantages and disadvantages are indicated. They all, however, result in increased wood costs relative to sound wood and, therefore, work must continue to combat the incidence and activity of spruce budworms not only to reduce processing costs, but to maintain required timber supplies to all areas of the industry.

76. Hinds, T.E.; Hawksworth, F.G.; Davidson, R.W. 1965. Beetle-killed Engelmann spruce: its deterioration in Colorado Journal of Forestry 63: 536-542.

Key words: Engelmann spruce, lodgepole pine, windthrow, deterioration, decay, spruce beetle, beetle-killed

An estimated 4.3 billion board feet of Engelmann spruce and lodgepole pine sawtimber was killed by the Engelmann spruce beetle during a major Colorado epidemic from 1941 to 1952. A study on the rate of deterioration in these stands was begun in 1951. Results indicate that about 40 percent of the original cubic-foot volume has been lost 20 years after kill. About one-third of this loss is due to decay in standing trees, two-thirds to windthrow. It is anticipated that windthrow will be a progressively more important deterioration factor in the future.

77. Keepf, C.J. 1978. Industry product recovery experience in operating a sawmill on dead timber. *In* Symposium: the dead softwood timber resource. Engineering Extension Service Washington State University, Pullman, Washington.

Keywords: product recovery, Engelmann spruce, checking down material, blowdown

Realization from selected dead Engelmann spruce logs can be as high as 87 percent of the value, of live Engelmann spruce, to as low as 69 percent. Spiral checked and down material have considerable less value than standing material with a straight check.

78. Kupferschmid Albisetti, A.D.; Brang, P.; Schonenberger, W.; Bugmann, H. 2003. Decay of *Picea abies* snag stands on steep mountain slopes. Forestry Chronicle 79(2): 247-252.

Key words: Norway spruce, bark beetles, decay process, rockfall, avalanche, mountain forest, Switzerland, decomposition, coarse woody debris

In a 30-ha *Picea abies* mountain forest in the Swiss Alps, almost all trees were killed by bark beetles (*Ips typographus*) between 1992 and 1996. Snag decay was studied using full-callipering within transects, and the height of lying logs above ground level was studied using the line transect method. None of the dead trees had been uprooted, but 75% were found broken in 2000. The probability of snag breakage was independent of both tree diameter and time since stand death, but 28% of the snags broke close to the ground during a storm in December 1999. The log sections that were not in direct contact with the ground (73% of the log length sampled) were on average 85 cm above the soil surface in 2001. The orientation of the logs could be explained with the prevailing wind direction even on this steep slope. Leaving snag stands unharvested in *P. abies* forests on such slopes is likely to result in effective protection against rockfall and avalanche release for about 30 years.

79. Mielke, J.L. 1950. Rate of deterioration of beetle-killed Engelmann spruce. Journal of Forestry. 48:882-888.

Key words: beetle-killed trees, Engelmann spruce, deterioration, decay, windthrow, rate of fall

In an attempt to determine how long beetle-killed trees would remain standing in a sound condition, studies were conducted in Utah where the spruce beetle had killed stands 25 years prior. Of the trees studied, 84 percent were still standing and 16 percent had fallen. Windthrow was not a major factor and degree of slope, aspect, and character of the soil were not significant factors in the rate of fall of dead trees. Checking occurred at a fairly rapid rate and started when the trees still had green needles attached. In standing trees that had been dead for 3 or more years, the moisture content of both the heart and sapwood was below 22 percent, which is too low for decay.

80. Murley, R. Effects of dead wood on pulp quality. 1979. *In* Proceedings of the Society of American Foresters 1978 national convention. Society of American Foresters, USA.

Keywords: dead wood, pulp quality, sap rot, pulping properties

This paper includes data indicating the effects on pulp quality as sap rot increases after a tree dies. Recommendations are included to minimize the effect of dead wood on the quality of newsprint. The economics of utilizing dead wood is briefly covered. Ultimately it is the economic and not the quality of pulp, which dictates how much dead wood, can be used and how long after death a tree can be harvested.

81. Newstein, S.A. 1971. Damage to forests in relation to topography soils and crops. *In* Windthrow of Scottish forests in January 1968 – report of the windblow action group. Forestry Commission Bulletin No. 45, UK.

Keywords: windthrow, topography, soil, windsnap, gale

After a gale the influence of topography and site on the extent and distribution of damage was investigated on a sample of affected forests by means of various survey methods. In more mountainous forests windthrow was mainly influenced by topography. Soils did not play a dominant role. Windthrow, and to a lesser extent, windsnap occurred on all soil types.

82. Parry, D.L.; Filip, G.M.; Willits, S.A.; Parks, C.G. 1996. Lumber recovery and deterioration of beetle-killed Douglas-fir and grand-fir in the Blue Mountains of Eastern Oregon. United States Department of Agriculture, Forest Service General Technical Report PNW 376. Pacific Northwest Research Station, Portland, OR.

Key words: Douglas-fir, *Pseudotsuga menziesii,* grand fir, *Abies grandis,* lumber recovery, utilization, dead timber, western spruce budworm, *Choristoneura occidentalis,* Douglas-fir beetle, *Dendroctonus pseudotsugae* Hopkins, fir engraver, *Cryptoporus volvatus, Trichaptum (Polyporus) abieinum, Fomitopis pinicola*

The purpose of this study was to determine the effect of time since death over a 4-year period on the amount of usable product volume and value, and to determine the species of fungi associated with wood deterioration in the stems of Douglas-fir and grand fir trees killed by bark beetles in northeastern Oregon. Sap rot, caused principally by *Cryptoporus volvatus,* increased significantly with years dead for both Douglas-fir and grand fir, but there were no significant differences in sap rot among d.b.h. (diameter at breast height) classes. Few insects were associated with defective wood, probably because of the relatively dry condition of the wood. Log breakage during logging in the live samples was less than 0.5 percent of the gross volume, and the amount of wood too defective to remove from the woods was about 2.5 percent in the dead Douglas-fir and 3.8 percent in the dead grand fir. Two-year-dead Douglas-fir recovered about 8 percent less lumber volume than live and 1-year dead Douglas-fir and all classes of dead grand fir. Three and four-year dead Douglas-fir combined lost another 7 percent in lumber volume. Average lumber value (dollars per thousand lumber tally) and average log value (dollars per hundred cubic feet) analysis showed no difference among the live and 1-year-dead Douglas-fir samples. Average log value decreased about $60 from the live class to the grand fir dead class and another $60 for the Douglas-fir dead. Contrary to popular belief, the grand fir did not deteriorate as fast as the Douglas-fir or lose as much value as expected.

83. Peterson, C.J. 2004. Within-stand variation in windthrow in southern boreal forests of Minnesota: Is it predictable? Canadian Journal of Forest Research 34: 365-375.

Key words: windthrow, wind damage, boreal forests, tree diameter, tree fall

Wind damage to forests in determined by numerous factors that interact to produce complex, seemingly random damage patterns. However, the complexity may lie mostly among stands and be less within stands: in this study, I attempted to discern how predictable tree fall risk is within five southern boreal forest stands in northeastern Minnesota. I sampled five stands in the Boundary Waters Canoe Area Wilderness, following a July 1999 catastrophic windstorm. Levels of damage varied from 29.5% to 86.8% of basal area fallen and 23.3% to 63.4% of stems fallen. In all sites, the disturbance reduced mean trunk diameter of standing trees. In general *Abies balsamera* (L.) Mill. Was the most vulnerable species. I split the data set from each site into predictor and test portions and used the predictor data sets to derive logistic regression parameters for the relationship of tree size (trunk diameter) to probability of tree fall. Models based on these parameters allowed quite accurate predictions of the levels of damage in the test portion of each stand. For the five sites, the proportion of test trees predicted to fall differed from the proportion observed to fall by 5.7%, 3.9%, 8.3%, 1.4%, and 3.7% of the total test sample size. This suggests that while numerous factors indeed influence tree fall risk, the sizes and identities of trees may account for most of the within-stand variation in damage.

84. Putz, F.E., Coley, P.D., Lu, K., Montalvo, A., and Aiello, A. 1983. Uprooting and snapping of trees: structural determinants and ecological consequences. Canadian Journal of Forest Research 13: 1011-1020.

Key words: snapped, uprooted, growth rate, density, stem diameter, disturbance

The influence of mechanical and architectural properties of tress on growth rates, mortality rates, and relative probabilities of snapping and uprooting were examined on Barro Colorado Island, Republic of Panama. Of 310 fallen trees, 70% snapped, 25% uprooted, and 5% broke off at ground level. Stepwise discriminate analysis between snapped and uprooted trees indicated that of the variable measured, wood properties were the most important factors determining the type of death in trees. Uprooted trees tended to be larger, shorter for a given stem diameter, and to have denser, stiffer, and stronger wood than snapped trees. There were no significant differences between trees that snapped and trees that uprooted in the extent of buttress development or in the slope of the ground upon which they grew. Trees with low density wood grew faster in stem diameter than those with high density wood but also suffered higher mortality rates. After damage, many of the snapped trees sprouted; small trees sprouted more frequently than large trees. Sprouting is proposed as a means by which weak-wooded fast-growing trees partially compensate for being prone to snapping.

85. Reiter, R. 1986. Processing beetle-killed timber into veneer and plywood. *In* Harvesting and processing of beetle-killed timber. Forintek Canada Corp., Vancouver, BC.

Keywords: veneer, plywood, beetle-killed timber, bark beetles, moisture content, sapwood, blue-stain, spruce

This article is a summary of results of veneer peeling tests carried out at North Central Plywood. The talk by R. Reiter was largely based on a slide presentation which illustrated the difficulties in manufacturing veneer and plywood for spruce killed by bark beetles in the Prince George region.

86. Scott, G.M.; Bormett, D.W.; Sutherland Ross N.; Abubakr, S.; Lowell E. 2000. Beetle-killed spruce utilization in the Kenai Peninsula. Tappi Journal 86(3): 48.

Key words: pulp, utilization, beetle-killed, *Dendroctonus rufipennis*, white spruce, hybrid lutz spruce

Beetle-killed spruce can be used as a fiber source for papermaking. The presence of sap rot is a key indicator of pulpability, but other factors may also be important.

87. Schmid, J.M.; Hinds, T.E. 1974. Development of spruce-fir stands following spruce beetle outbreaks. United States Department of Agriculture, Forest Service Research Paper RM 131. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.

Keywords: Picea engelmannii, Abies lasiocarpa, Dendroctonus rufipennis, insect outbreaks, forest succession

Logged and unlogged stands of Engelmann spruce-subalpine fir were evaluated in spruce beetle outbreak areas infested about 15, 25, 50, and 100 years ago. Seedling regeneration was generally adequate except in heavily logged areas, although seedlings were often damaged, apparently by animals. Species composition was dramatically altered in favor of fir in the unlogged spruce-fir type. In the overstory, fir may predominate for many years but eventually the spruce will replace it. When the forest reaches a basal area of 150 to 200+ ft^2 per acre in predominantly large spruce, the potential for spruce beetle outbreaks increases. Changes in species composition with different intensities of beetle infestations and over several centuries are hypothesized.

88. Sinclair, S.A. 1979. Insect-damaged balsam fir: lumber quality and marketability. *In* Proceedings of the Society of American Foresters 1978 national convention. Society of American Foresters, USA.

Keywords: grade-yield, consumer acceptance, retail lumber dealer, balsam fir, tree death

Healthy balsam fir can produce relatively good yields of high quality stud-size lumber. Grade yields of budworm-killed balsam fir drop rapidly after tree death with more than half of the dimension lumber being lower than No. 2 or Standard as soon as one year after tree death. Balsam fir lumber is readily accepted, even preferred, in areas where the species is familiar to retail lumber dealers. Problem with reliability of supply, inconsistent quality and retail dealer misconceptions apparently hinder wider marked acceptance.

89. Thomas, G.P.; Craig, H.M. 1958. Deterioration by fungi of killed Douglas-fir in interior British Columbia. Department of Agriculture. Forestry Biology Laboratory. Victoria, BC.

Keywords: Douglas-fir, saprot, heartrot, fungi, decay, volume loss, Douglas-fir beetle, deterioration

It appears that most Douglas-firs are seriously deteriorated within 5 years of being killed. Saprot accounted for a volume reduction of 12.4 percent in the 217 dead trees sampled, whereas in the same trees the loss resulting from heartrot was only 4.3 percent. Losses from saprot may be expected to increase with increasing tree size as well as with the length of time trees are exposed to deterioration processes. There seems to be a relationship between deterioration and infestation by the Douglas-fir beetle. While 65 percent of lightly-infested logs were infected by saprotting fungi, 87 percent of heavily-infested logs were infected.

90. Veblen, T.T. 1986. Treefalls and the coexistence of conifers in subalpine forests of the Central Rockies. Ecology. 67(3): 644-649.

Key words: Abies lasiocarpa, Colorado forests, forest ecology, *Picea engelmannii*, species coexistence, subalpine forests, treefalls, tree mortality

Differences in replacement patterns and frequencies of treefalls were investigated for subalpine fir (*Abies lasiocarpa)* and Engelmann spruce (*Picea engelmannii*) in the Colorado Front Range. In sever old-growth unlogged stands, data were collected on age and size of trees, frequencies of fallen trees, growth rates of trees, and sizes and abundances of occupants of treefall gaps. Subalpine fir accounted for 74.5% of the potential successors in the 125 treefall gaps sampled. The much greater abundance of subcanopy trees of subalpine fir implies more frequent recruitment into the canopy. However, its greater recruitment rate into the canopy is approximately balanced by its greater loss from the canopy; even though subalpine fir accounted for only 37% of the canopy trees it accounted for 76% of the fallen trees. The consistently lower frequency of Engelmann spruce as treefalls and its greater longevity compared to subalpine fir imply a lower adult mortality rate for the spruce. Consequently, the greater proportion of young subalpine fir does not imply that it will gradually replace Engelmann spruce in old-growth stands unaffected by large-scale exogenous disturbance. The results of this study provide empirical support for the coexistence of ecologically similar species by means of different life history strategies.

91. 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. 71(1): 213-231.

Key words: Abies lasiocarpa, age structure, Colorado Rocky Mountains, *Dendroctonus rufipennis,* dendroecology, disturbance, *Picea engelmannii*, spruce beetle outbreak, spruce-fir forest, subalpine forests, succession

Spruce beetle (*Dendroctonus rufipennis* Kirby) outbreaks are important disturbances affecting subalpine forests of Engelmann spruce (*Picea engelmannii)*, supalpine fir (*Abies lasiocarpa*), and lodgepole pine (*Pinus contorta*) in the southern Rocky Mountains. However, little is known about the influences of these outbreaks on overall forest dynamics. We used age-structure analyses and dendrochronological techniques to investigate the effects of a major spruce beetle outbreak on stand composition, dominance, tree age and size structures, radial growth, and succession in subalpine forests in Colorado. This outbreak, which occurred in the 1940s, caused a shift in dominance from spruce to fir and a reduction in average and maximum tree diameters, heights, and ages. The outbreak did not favor new seedling establishment of the seral lodgepole pine. Thus, in seral stands spruce beetle outbreak accelerates succession towards the shade-tolerant tree species.

The predominant response to the outbreak was the release of previously suppressed small-diameter spruce (not attacked by beetle) and subalpine fir (a non-host species). Following the 1940s outbreak, growth rates of released trees remained high for >40 yr. The relative increases in growth rates were similar for both species. Both spruce and fir will continue to codominate the affected stands. The predominance of accelerated growth following a spruce beetle outbreak, instead of new seedling establishment, is a major contrast to the pattern of stand development following fire. In some Colorado subalpine forests the effects of disturbance by spruce beetle outbreaks appear to be as great as those due to fire.

92. Walser, D.C. 1986. Processing beetle-killed timber into veneer and plywood. *In* Harvesting and processing of beetle-killed timber. Forintek Canada Corp., Vancouver, BC.

Keywords: veneer, plywood, beetle-killed, western white spruce, moisture content

This article discusses a peeling study of beetle-killed western white spruce conducted at Forintek. The results of this study showed that the veneer blocks from three-year-dead trees were extremely dry with an average moisture content of 27.6 percent and contained numerous splits and checks. In addition, the sapwood in many blocks was completely rotten and broke up when peeled.

93. Werner, R.A.; Elert, E.E.; Holsten, E.H. 1983. Evaluation of beetle-killed white spruce for pulp and paper. Canadian Journal of Forest Research 13:246-250.

Keywords: pulping material, dead trees, dead wood, spruce beetle

A kraft pulping study on wood from standing white spruce killed by *Dendroctonus rufipennis* in south central Alaska showed no difference in pulp yield between trees dead for 1 yr and those dead for as long as 50 yr. Strength properties of beetle-killed white spruce remained extremely high in all dead trees regardless of how long they had been dead, so they apparently could be used for producing high-quality kraft pulps. These are the first results reported in which standing trees dead for so long produced high-quality bleached and unbleached pulps.

94. Wright, K.H.; Harvey, G.M. 1967. The deterioration of beetle-killed Douglas-fir in Western Oregon and Washington. United States Department of Agriculture, Forest Service Research Paper PNW 50. Pacific Northwest Forest and Range Experiment Station, Portland, OR.

Keywords: Douglas-fir beetle, rate of deterioration, dead timber, salvage, Douglas-fir

The Douglas-fir beetle sporadically kills large volumes of Douglas-fir sawtimber in western Oregon and Washington. Salvage of dead timber before it deteriorates beyond economic use is often a major problem for forest-land owners and managers. A study was started in 1952 to determine how fast beetle-killed trees deteriorate, the factors influencing the rate of deterioration, and the causal agents.

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