FLEXURAL PROPERTIES OF SALVAGED DEADYELLOW-CEDAR FROM SOUTHEAST ALASKA

DAVID W. GREEN*
KENT A. MCDONALD*
PAUL E. HENNON
JAMES W. EVANS
JOHN H. STEVENS

ABSTRACT

A decline and mortality problem is affecting yellow-cedar trees on more than a half-million acres in southeast Alaska. Because of the high decay resistance of yellow-cedar, dead snags may remain standing for 100 years or more. Currently, this wood is primarily used for firewood. The results of the study reported here indicate that the flexural properties of wood from dead yellow-cedar snags is little affected by how long the trees have been dead. Living yellow-cedar trees are sometimes infected with "black stain," which remains in the trees after they die. Black stain does not reduce the flexural properties of wood from either live or dead trees. Thus, utilization options for wood from dead cedar snags can be broadened to higher value uses consistent with those for wood from live cedar trees.

Natural stands of yellow-cedar *(Chamaecyparis nootkatensis* (D.Don) Spach) are distributed in the coastal forests from northern California, British Columbia, and southeast Alaska (17). Also referred to as yellow cypress, this species has been planted in plantations in Canada (16). A typical yellow-cedar tree in a natural forest is about 80 feet (24.4 m) tall with a diameter of 2 to 3 feet (0.6 to 0.9 m), although trees may attain 120 feet (36.6 m) in height and a diameter of up to 6 feet (1.8 m). In mature trees, the sapwood is narrow and sometimes slightly lighter in color than the heartwood. The wood is fine textured and generally fine-grained (7). Yellow-cedar has a number of outstanding characteristics, including high decay resistance and superior strength. Its common name is derived from the bright yellow color of the heartwood. This color and the familiar aroma of yellow-cedar are a result of compounds such as nootkatin (3) that produce natural durability. Yellow-cedar from live trees has historically been the most valuable wood in Alaska and is a highly desirable product in Pacific Rim markets, especially Japan.

A decline and mortality problem affects yellow-cedar trees on more than a half-million acres in southeast Alaska **(Fig. 1)** (15). On average, 65 percent of the basal area of yellow-cedar is dead on these sites (12). The decline of yellow-cedar is believed to be primarily the result of naturally induced forest decline (11). Extensive research over the last 20 years has shown the following:

- The high rate of mortality appears to have begun around 1880.
- Yellow-cedar has been the principal victim.
- All ages of trees are affected.
- All affected sites have cedar snags dating to the time of onset of the high mortality rate.
- No biotic factor appears to be a primary cause of death.
- Root system mortality appears to be the initial symptom.
- Mortality occurs on wet, poorly drained soil.

The authors are, respectively, Supervisory Research General Engineer and Research Wood Scientist (retired), USDA Forest Serv., Forest Prod. Lab., Madison, WI; Pathologist, USDA Forest Serv., State and Private Forestry, Pacific Northwest Res. Sta., Juneau, AK, Supervisory Mathematical Statistician, USDA Forest Serv., Forest Prod. Lab., Madison, WI; and Silviculturist, USDA Forest Serv., Tongass National Forest, Wrangell District, Wrangell, AK.
The authors wish to acknowledge D. Witter, USDA Forest Serv., State and Private Forestry, Juneau, AK, for the graphics presented in Figure 1 of this paper and for assistance in the field. This paper was received for publication in August 2000. Reprint No. 9168.
*Forest Products Society Member.

Forest Prod. J. 52(1):81-88.

- Mortality is concentrated in open-canopy stands where trees and soil are exposed.
- A high rate of mortality does not occur on either high- or low-elevation sites that have good drainage.
- Local spread is limited to short distances and occurs along a slope gradient.

Extensive climatic warming in the late 1800s which apparently coincided with the onset of extensive mortality, could be responsible for triggering some stress factors that led to yellow-cedar decline (8,10). For example, warmer temperatures could change winter precipitation from snow to rain, which could alter the decomposition rate, perhaps resulting in the formation of soil compounds toxic to yellow-cedar. If climate change is the trigger, a long-lived species that does not reproduce often (such as yellow-cedar) may be less able to adapt to a changing environment. Research is continuing on possible linkages between climate change and cedar decline.

Most declining stands contain a mixture of long-dead trees, recently dead trees, dying trees, and healthy trees **(Fig. 2).** The high decay resistance of yellow-cedar retards the rate of deterioration and snags can remain standing for a century or more after death. A classification system **(Table 1, Fig. 3)** developed for yellow-cedar snags in various stages of deterioration can be used to estimate the average time since death for each class **(12,13).**

Unlike the wood of live yellow-cedar trees, which readily sells for high prices, the wood from snags is underutilized because of the lack of knowledge about its properties. As snags accumulate in the forest, they make up an increasing percentage of the stand. Because snags have relatively low commercial value, their removal would be economically justified only if the wood retains some of the desirable characteristics of wood from live trees. Establishment of some higher value uses for wood from snags could help pay for ecological improvement and help support the local economy. A key element in establishing better use options is knowledge of the properties of dead yellow-cedar.

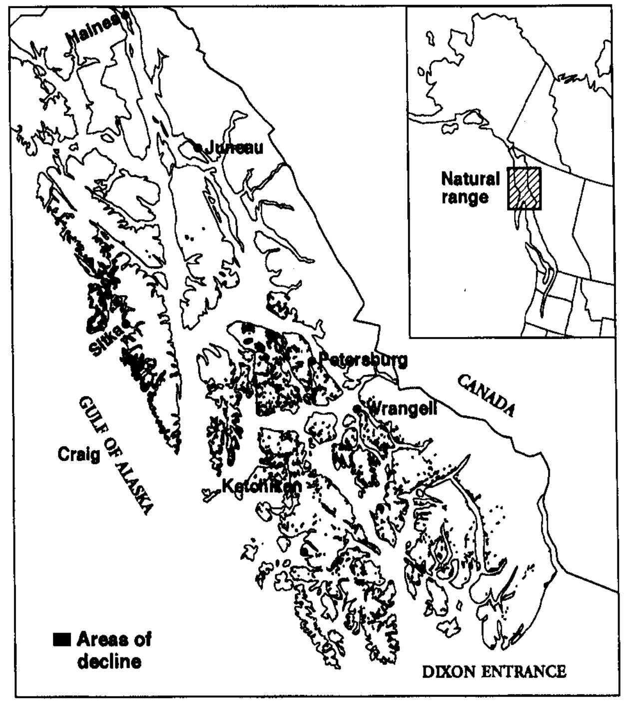

Figure 1. - Area of southeast Alaska affected by yellow-cedar decline.

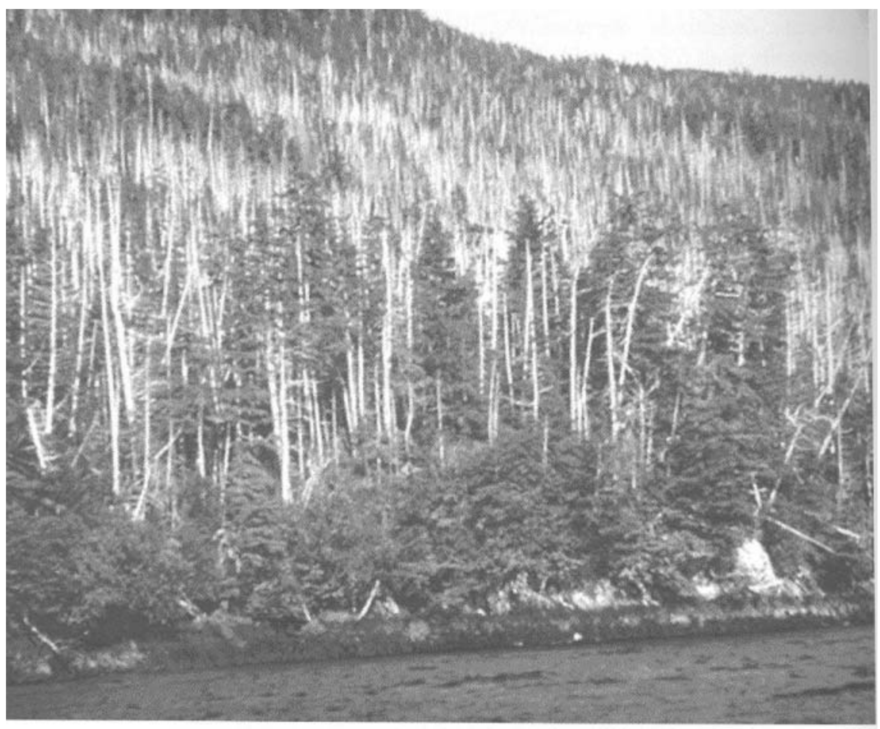

Figure 2. - Stand affected by yellow-cedar decline and mortality.

Objectives

The primary objective of this study was to determine whether the mechanical properties of yellow-cedar snags vary with the length of time the dead snags have been standing. The expectation was that older snags would have less utility and possibly yield lower strength wood than does wood from younger snags or live trees.

Materials and methods

Site selection

All material was collected near Nemo Point (latitude 56°17') on the west side of Wrangell Island in southeast Alaska

TABLE 1. – Classification system for yellow-cedar snags.[a]

Snag class	Average time since death	Foliageand branches	Bark	Bole	Sapwood	Heartwood
	(yr.)					
1	4	Dead foliage; twigs retained	Intact	Intact	Stained	Unaltered
2	14	Twigs retained	Sloughing	Intact	Decaying	Unaltered
3	26	Secondary branches retained	Mainly sloughing	Intact	Decayed	Unaltered
4	51	Primary branches retained	Gone	Intact	Mainly gone	Checking, 1.2-in. deep
5	81	No primary branches	Gone	Intact	Gone	Checking, 1.5-in. deep

[a]References 12 and 13. 1 inch = 25.4 mm.

(Fig. 1). The site included a mix of yellow-cedar, western hemlock *(Tsuga heterophylla* (Raf.) Sarg.), and western redcedar *(Thuja plicata* Donn ex. D.Don) as well as small amounts of Sitka spruce *(Picea sitchensis* (Bong.) Cart-.) and shore pine *(Pinus contorta* Dougl. ex Loud. var. contorta).

Sampling design

Sampling for this study was conducted in two phases, about 2 years apart. Phase 1 provided an initial evaluation of the change in properties with the length of time the, trees had been dead. Control samples were taken from live trees with healthy crowns. Test samples were selected from snag classes 2 through 5 **(Table 1);** class 1 was not sampled because few trees of this class were in the study area. All sample trees were larger than 15 inches (380 mm) in diameter at breast height. Six control trees and six trees from each snag class were collected **(Table 2).** Trees with internal heart rot and trees with noticeable spiral grain of more than a few degrees of spiral were not included. One 4-foot-(1.22-m) bolt was removed from the top of the first merchantable 11-foot-(3.35-m-) long log.

Phase 2 provided information on factors other than time since death that might cause a change in mechanical properties. The number of trees sampled was increased for phase 2; 40 additional live trees were selected for controls and 19 additional trees were selected in each of snag classes 3 and 5 **(Table 2).** The trees were chosen in much the same manner as the trees selected for phase 1. In phase 1, many of the samples cut from live trees contained "black stain" (9,20), a stain that occurs in the live tree, as opposed to "blue stain," which may occur in green lumber that has been stored too long before drying. Recent work suggests that black stain is caused by a dark-colored fungus, perhaps vectored to trees by insects, that infects the sapwood. This stain remains in the sapwood as it is converted to heartwood. Because phase 1 results indicated that black stain might be affecting properties, we biased our selection so that half the live trees would have considerable black stain and the other half would

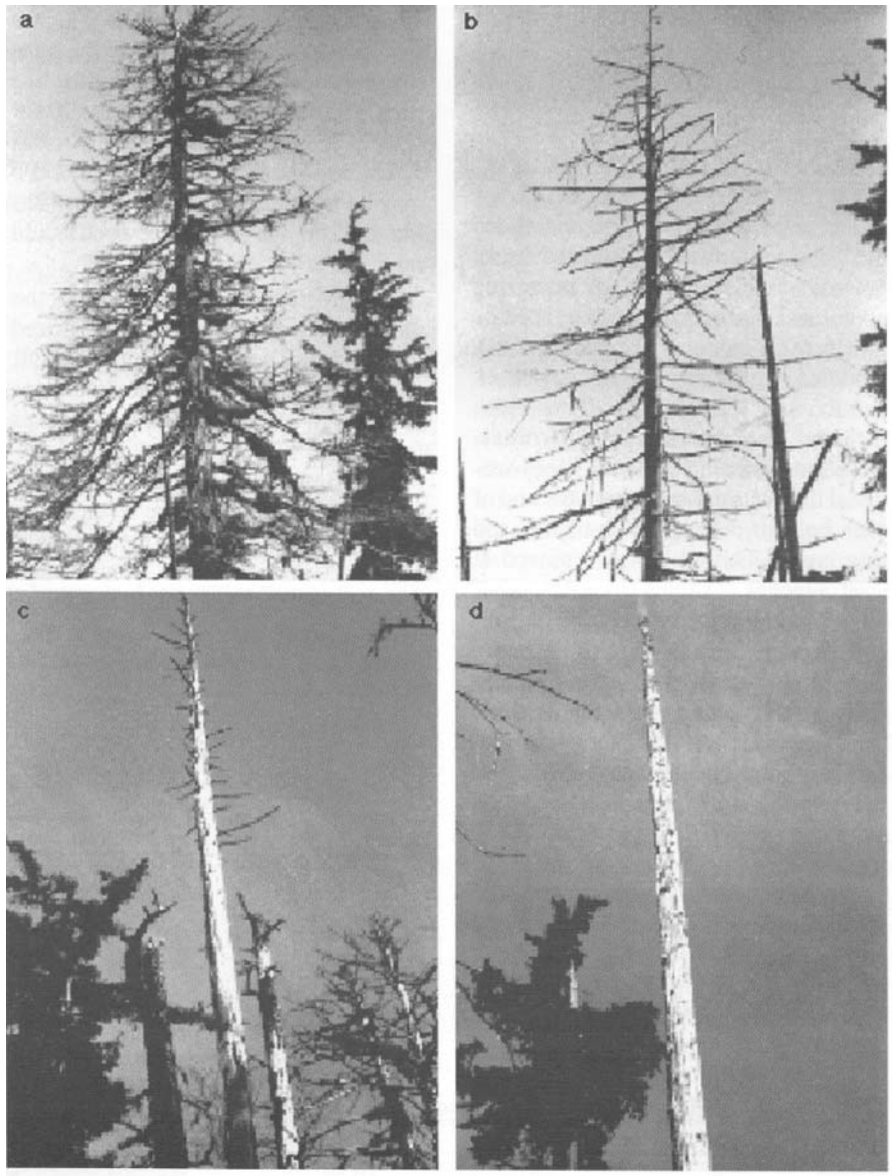

Figure 3.- Examples of snags in four snag classes (class number and average time since death): a. Class 2, 14 years; b. Class 3, 26 years; c. Class 4, 51 years; d. Class 5, 81 years.

have little. The selection of stained and unstained trees was based on presence or absence of stain on the cut end of felled trees.

Preparation for Shipment

Each numbered 4-foot (1.22:m) bolt was split lengthwise down the middle and one-half the bolt was removed from the forest. All the half-bolts removed from the forest were palletized for shipment to the Forest Products Laboratory (FPL), USDA Forest Service, in Madison, Wisconsin. Bark (if present) was kept intact to retard drying during shipment. At FPL, each section was stored to minimize additional drying or staining.

Specimen preparation and testing

The wood properties determined and the physical attributes evaluated were: presence or absence of black stain, ring count, moisture content (MC), specific gravity (SG), modulus of rupture (MOR), modulus of elasticity (MOE), and work to maximum load (WML). Phase 1 also included hardness tests, but the results are not reported here (18). A cross-sectional disk was removed from the end of each bolt for determination of MC and ring count. This disk was removed at least 3 inches (75 mm) from the end of the bolt to minimize the effects of bolt-end drying during shipping. Rough, edge-grain boards were sawn from the bolts. After sawing, the rough boards were stacked in a conditioning room for equilibration to an anticipated MC of 12 percent; layers of boards were separated by stickers. ASTM D 143 (1) bending specimens were selected and prepared from the dry boards. The specimens were selected to be clear of knots and straight grained. They were machined to 1 by 1 by 16 inches (25.4 by 25.4 by 406 mm). The presence of black stain was noted on both the bolts and the individual bending specimens.

Results and discussion

Phase 1

The results of phase 1, including those of the hardness tests, are discussed in detail in McDonald and others (18). The live controls and the snags in classes 2 and 3 exhibited very minor checking in the bolts. Class 4 snags had surface checks 1 to 2 inches (25 to 50 mm) deep, while bolts from class 5 snags showed some surface checks as deep as 4 inches (102 mm). The average age of the trees (by ring count) was 390 years for the live trees, 435 for snag class 2 trees, 420 for class 3,268 for class 4, and 219 for class 5. The lower counts for classes 4 and 5 may be the result of sapwood loss (Table 1). The age of the sapwood could represent 50 to 100 years (14).

The average properties of all the pieces tested in phase 1 are summarized in **Table 3.** The lowest average MOR and MOE were found for the specimens cut from live trees. The same trend was found with SG. This result was unexpected. Because of the small number of trees, it is possible that the results from one tree could bias the mean trends. Trends in median values would minimize this effect. The MOR and MOE trends by snag class are shown in **Figures 4** and **5** for median values. **Figures 4** and **5** also show mean values and range limits where 50 percent of the outlying data are excluded. **Figure 6** explains the format used to display the data. In general, the trends show that both MOR and MOE decreased slightly with an increase in the number of years since tree death. For classes 2 through 5 snags, MOR and MOE decreased about 7 and 9 percent, respectively. Because of the small number of trees, statistical estimates of within- and between-tree variability are not appropriate.

Black stain was noted in many of the bending specimens from live (control) trees but not from the dead specimens (18). For example, about 69 percent of specimens from live trees contained black stain, whereas less than 10 percent of specimens from any of the dead snag classes contained black stain. The lack of a sufficient number of total trees sampled per class, coupled with the possible effect of black stain on test results, suggested the need for the follow-up study that was conducted in phase 2.

Phase 2

The properties of all the specimens tested in phase 2, without regard to presence or absence of black stain, are summarized in **Table 3.** Inspection of the wood cut from' the bolts indicated that selected trees would not be totally free of black stain, Therefore, individual

TABLE 2. - Sample sizes for live trees and snag classes for bending tests.

	Phase 1		Phase 2		Total	
Group	Trees	Samples	Trees	Samples	Trees	Samples
Live	6	216	40	1,370	46	1,586
Class 2	6	155	--	--	6	155
Class 3	6	199	19	680	25	879
Class 4	6	146	--	--	6	146
Class 5	6	125	19	542	25	667

TABLE 3. - Average flexural properties by tree class for each study phase.'

	Phase 1						Phase 2							
	SG		MOE		MOR		SG		MOE		MOR		WML	
Group	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD'	Mean	SD
			- - (× 10^6 psi) - -		- -(× 10^3 psi)- -				- -(× 10^6 psi) - -		- - (× 10^3 psi) - -		- - (in.-lbf./in.^{3}) - -	
Live	0.45	0.03	1.50	0.26	12.13	1.43	0.48	6.04	1.55	0.31	13.10	1.76	17.94	4.6
Class 2	0.49	0.04	1.97	0.33	14.66	1.94	--	--	--	0.00	--	--	--	--
Class 3	0.49	0.02	1.75	0.38	13.91	1.41	0.46	0.04	1.50	0.37	12.80	1.59	17.50	5.1
Class 4	0.46	0.04	1.88	0.33	13.52	1.85	--	--	--	0.00	--	--	--	--
Class 5	0.46	0.04	1.78	0.24	13.17	1.96	0.46	0.04	1.60	0.31	12.65	1.63	15.67	4.9

[a] Average MC at time of test was 12 percent. SG = specific gravity; MOE = modulus of elasticity; MOR = modulus of rupture; WML = work to maximum load; SD = standard deviation. 1 psi = 6.894 kPa; 1 in.-lbf./in^3 = 6.89 kJ/m^3.

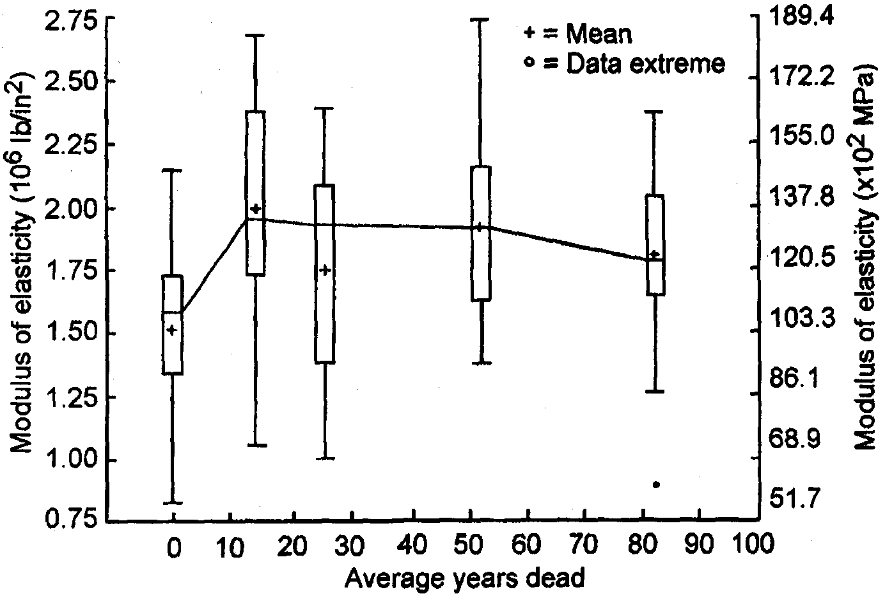

Figure 4. -Clear wood MOE for individual pieces tested in phase 1

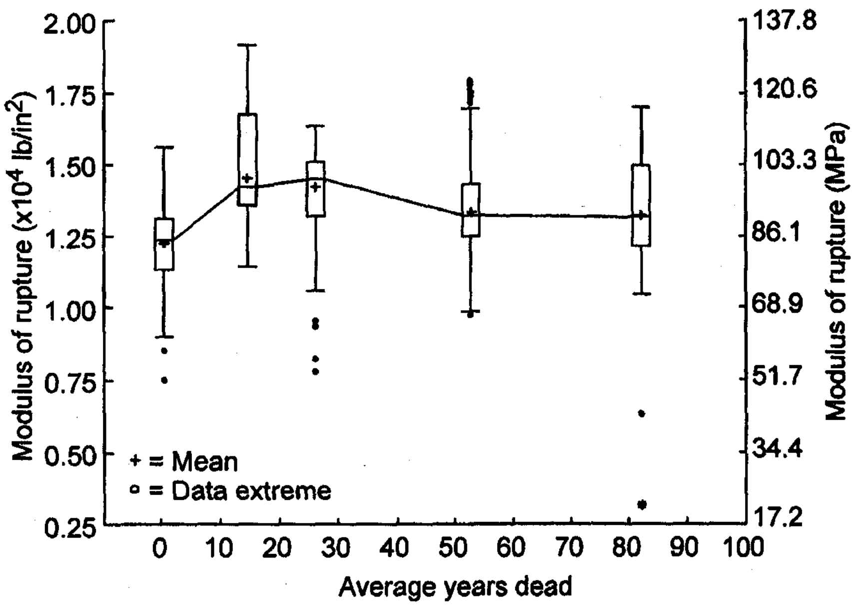

Figure 5. - Clear wood MOR for individual pieces tested in phase 1.

pieces with stain were identified during the testing process regardless of whether the tree (half-bolt) had been designated as "stained" or "unstained." **Table 4** gives ovendry SG values and the ratio of mean MOE and MOR values of stained to unstained wood by snag class. Before calculating the ratio, it was necessary to reduce the effect of differences in SG between stained and unstained wood. The MOR and MOE values were adjusted by linear regression between property and SG values developed from the data to the mean SG. Within any given snag class, there was no indication that stain caused a significant reduction in flexural properties. When the SG adjusted values for stained and unstained specimens were combined, phase 2 results actually indicated a slight increase in flexural properties with higher snag class. For MOE, the values for snag class 3 were about 1 percent higher than control values; for class 5, MOE was about 8 percent higher. For MOR, the values for class 3 were about 2 percent higher than control values and the values for class 5 were about 3 percent higher.

WML in static bending is the ability to absorb energy or shock from slowly applied loads. It is a measure of the combined strength and toughness of wood under static bending loads (7). Toughness, the ability to absorb energy or shock under impact bending loads, is generally considered the mechanical property most sensitive to early stages of decay, and WML in static bending is considered the next most sensitive property (21). WML was determined only in phase 2 of the study. Overall WML values, without regard to presence or absence of black stain, are presented in **Table 3.** The results indicate about a 2.5 percent reduction in WML for class 3 snags and a 12.7 percent reduction for class 5 snags. However, because WML is a more variable property than is MOR or MOE, even the apparent reduction for class 5 snags is not statistically significant. Stained and unstained specimens showed little difference in WML **(Table 4).** This indicates that any potential change in WML is not due to the presence of black stain. The WML values for unstained specimens from unstained live trees and from unstained specimens from class 3 and class 5 snags were 18.31, 18.23, and 16.41 in.-lbf./in.^{3}, respectively. Thus, there is some indication that wood from class 5 snags might be less shock resistant than that from live trees. Shock resistance of wood from class 3 snags would be the same as that from live trees. Generally speaking, WML does not affect utilization of most products, because they do not need to resist impact loads. (A baseball bat is an example of a product that *would* have to resist impact loads). The data are only suggestive of a difference in WML for wood from class 5 or older trees.

Combined Phase 1 and Phase 2 Data

Table 5 summarizes the results of combined data from both study phases. The values in **Table 5** are based on all the individual pieces tested. For live trees, flexural properties were higher (17% higher for MOR and 9% higher for MOE) than those given in the *Wood Handbook (7).* This was expected because the SG of the samples from the live trees was about 4 percent higher than the *Wood Handbook* value of 0.46, after it was adjusted to an ovendry basis. For all properties, the variability of the

TABLE 4. - Effect of black stain on flexural properties of yellow-cedar adjusted to a common SG. [a]

Group	Trees	Pieces	Sample size	SG	Ratio (stained/unstained) MOE	MOR	WML
Live	Unstained	Unstained	510	0.469	--	--	--
		Stained	125	0.466	1.00	1.01	1.00
	Stained	Unstained	203	0.490	--	--	--
		Stained	532	0.493	0.96	0.97	0.96
Class 3	Dead	Unstained	443	0.461	--	--	--
		Stained	237	0.464	1.07	1.01	0.96
Class 5	Dead	Unstained	219	0.452	--	--	--
		Stained	323	0.460	0.98	1.01	1.01

[a] SG based on ovendry weight and volume.

TABLE 5. - Average flexural properties by tree class for all lumber tested. [a]

Group	Sample	MC	SG Mean	SG SD[b]	MOE Mean	MOE SD	MOR Mean	MOR SD
	(no.)	(%)			-------($\times 10^6$ psi)-------		-------($\times 10^3$ psi)-------	
Live	1,586	12.4	0.48	0.04	1.55	0.31	12.97	1.75
Class 2	155	11.9	0.49	0.04	1.97	0.33	14.66	1.94
Class 3	879	11.9	0.49	0.03	1.56	0.38	13.06	1.62
Class 4	146	11.9	0.46	0.04	1.88	0.33	13.52	1.85
Class 5	667	12.5	0.46	0.04	1.64	0.31	12.74	1.71

[a] Average MC at time of test was 12 percent.

data about the mean was generally a little less than would be expected. Of the static properties, only the MOR of class 5 snags was lower than that of pieces cut from live trees, and the difference between class 5 snag MOR and live piece MOR was only 2 percent. Because the number of test trees in each class differed widely **(Table 2),** and even greater differences occurred in the total number of specimens tested per class, the average MOE and MOR were calculated for each tree tested. This allowed us to use between-tree variation for our statistical tests. These mean values are plotted in **Figures 7** and **8.** Because there were only six trees each in snag classes 2 and 4, the median, rather than the mean, values per tree were connected to aid in identifying trends. Median values are less sensitive than mean values to an extreme value for one tree. As for properties for individual pieces, median MOE values of all the dead snags were equal to or higher than those of the live controls. For median MOR, the values for classes 4 and 5 were only slightly lower than those for the live controls; class 4 MOR was about 3.8 percent lower than control MOR and class 5 MOR was about 1.5 percent lower. Thus, flexural properties of dead snags were not significantly lower than those of wood cut from live trees.

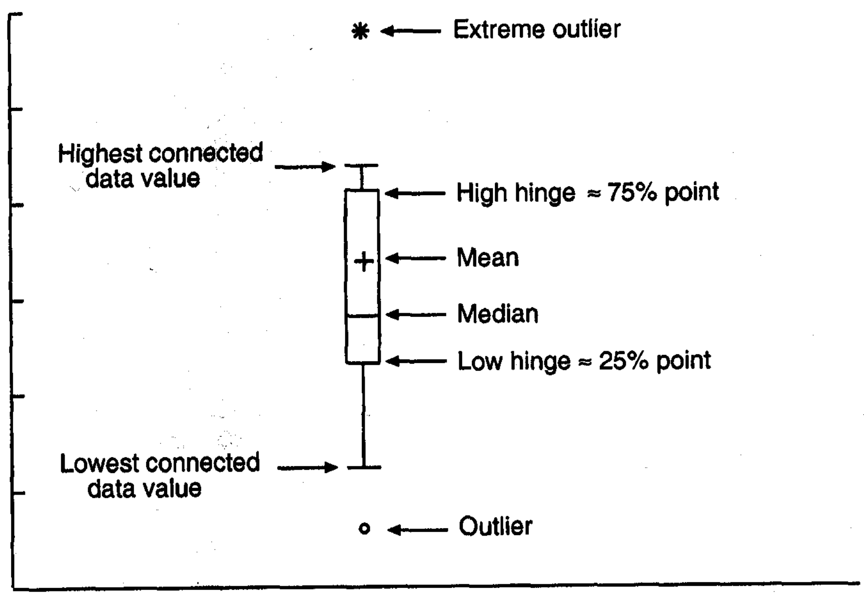

Figure 6. - Format used to display mean, median, and range of MOE and MOR values.

Currently, allowable properties for yellow-cedar are derived from clear wood properties such as those given in this report. Although all the cedar for this study came from one geographic location, recent data on the properties of Alaskan species are sparse (6). Thus, it might be advantageous to compare the clear wood results of our study with those from historical sources. The *Wood Handbook* (7) values for yellow-cedar are from a combination of samples taken in Alaska and Oregon. As **Table 6** indicates, our results are considerably higher than those given in the *Wood Handbook* and slightly lower than the

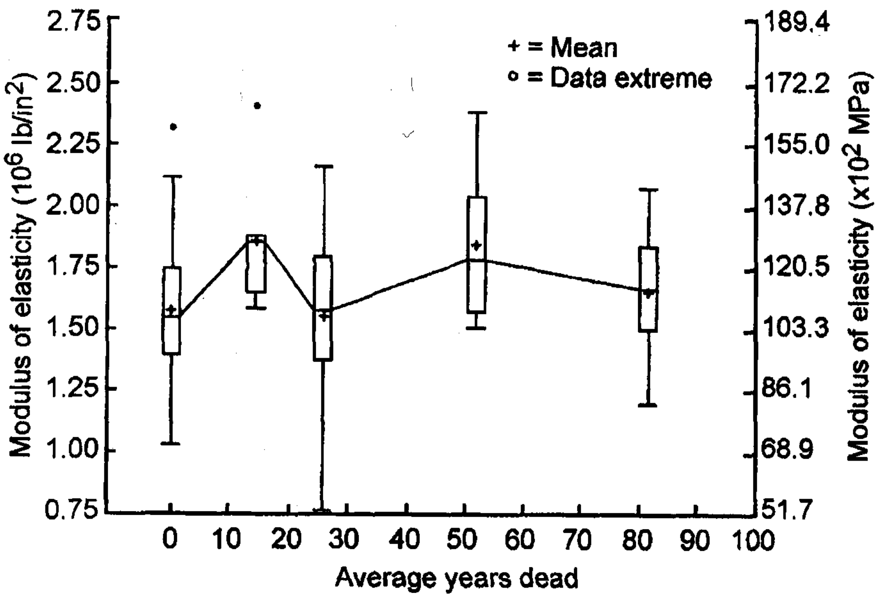

Figure 7. - Overall clear wood MOE for test trees.

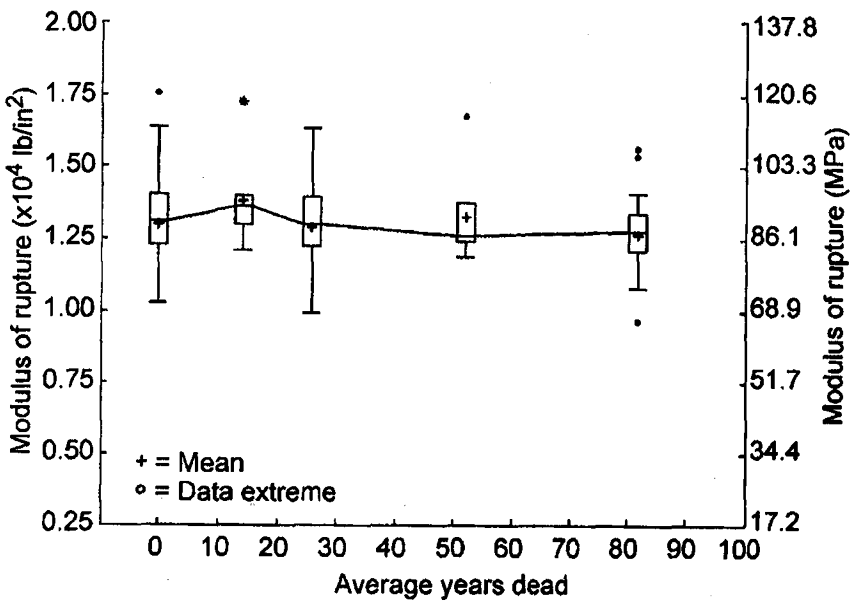

Figure 6. - Overall clear wood MOR for test trees.

TABLE 6. - Flexural properties of yellow-cedar and other selected species, at 12 percent MC, based on historical sources.

Source	Species	Average value	
		MOE	MOR
		($\times 10^6$ psi)	($\times 10^3$ psi)
Current study	Yellow-cedar	1.55	12.97
Reference 7	Yellow-cedar	1.42	11.10
	Incense cedar	1.04	8.00
	Port-Orford cedar	1.70	12.70
	Western redcedar	1.11	7.50
Reference 6	Yellow-cedar	1.70	13.20
	Western redcedar	1.04	8.00

values sampled from Ketchikan and reported in 1963 (6).

For marketing purposes, yellow-cedar structural lumber is sold as part of the Western Cedars grouping. The four species that make up this grouping are yellow-cedar, incense-cedar, Port-Orford cedar, and western redcedar. The properties of this grouping are calculated by the clear wood procedures of ASTM D 245 (2) and are determined by the properties of incense-cedar and western redcedar. There are no recent data on the properties of western redcedar. However, the older data **(Table 6)** suggest that the properties of a yellow-cedar/redcedar marketing group might be controlled by the properties of western redcedar. Whether these properties would be higher than the currently assigned properties is impossible to determine. The results do suggest that if tests were conducted only on yellow-cedar from Alaska, there would be a good chance for establishing allowable properties that are higher than those currently assigned. Whether this is desirable from a marketing perspective is beyond the scope of this study.

CONCLUSIONS

The results of this study led to the following comments and conclusions.

1. All wood in the dead yellow-cedar trees tested in this study, regardless of the number of years the trees were dead, had maintained its MOR and MOE over time. No snag classes were identified as having property losses that would limit potential utilization options.

2. The presence of "black stain" did not reduce static MOR or MOE of wood from either living or dead trees. Thus, there is no reason to reduce the structural grade of yellow-cedar lumber when black stain is present. Black stain might be a limiting characteristic for uses where appearance is the primary criterion.

3. The results somewhat suggest that WML, an indicator of the ability to resist impact loads, is lower for wood from class S snags. Although-the difference is not statistically significant, if impact toughness is important for a particular application, additional toughness testing is recommended. The WML values of wood from class 3 snags were about the same as those from live trees. The presence or absence of black stain did not seem to be a factor in WML differences.

4. The clear wood results suggest that increases in allowable properties might be obtained if yellow-cedar from Alaska were sampled and tested according to ASTM procedures. Funding for such a program for several Alaskan species, including yellow-cedar, is currently being pursued by Alaskan interests.

Our results thus indicate that decisions about salvage and use of yellow-cedar snags should be based on traditional utilization considerations such as yield of usable product and total value of product recovered from the log.

Related Research and Recommendations for Future Work

Gluing

Since the initiation of the phase 1 research, several other studies have been completed that relate to utilization of the dead cedar resource. Initially, concerns had been raised that yellow-cedar could not be glued successfully. Research has now shown that cedar, if properly dried, can be glued with common adhesives (19).

Decay Resistance

A laboratory evaluation of decay resistance of yellow-cedar heartwood indicated that wood from both live trees and trees from snag class 5 is adequate for practical application in products used above the ground and subjected to intermittent wetting, such as millwork, outdoor steps, balconies, and seating (4). This study suggests that the heartwood of class 5 trees may have less durability in belowground exposures. However, the laboratory evaluation to date contains some anomalous results. Additional laboratory evaluations, as well as in-ground field tests in Alaska, are in progress.

Lumber Grade Recovery

A study on the pattern of deterioration and recovery of lumber grades of yellow-cedar snags showed only about 0.5 inch (13 mm) of sapwood in live trees and dead snags through snag class 3. This small amount of sapwood would be typical for these old, slowly growing trees (14,18). Little sapwood remained in snag classes 4 and 5. Stain and decay occurring radially inward from the bark was mainly limited to sapwood through class 3. Radial checking, potentially one of the most damaging defects in dead cedar snags, extended to a depth of 0.25 inch (6.4 mm) through class 3. For domestic and export lumber grades, grade recovery did not differ greatly by tree/snag class (14). The lower grades tended to have greater volume recovery from older snag classes.

Recommendations

Utilization of a dead timber resource can present a number of technical and marketing challenges not faced by producers of lumber from live trees (5,22). However, the high durability of yellow-cedar, coupled with its potentially high economic value, make this a unique opportunity to extend the available wood resource within the context of sustainable forest practices. In addition to continued evaluation of durability, we recommend development of the following information.

1. A more detailed survey of the dead yellow-cedar resource in southeast Alaska (one of the most pressing needs). Ultimately, volume estimates by snag class and estimates of the extent of severe spiral grain in the tree would be invaluable to potential users of this resource.

2. Assessment of the environmental contributions, if any, of dead cedar snags to the ecosystem.

3. Continuation of product yield studies when use options and commercial interests become clearer.

Literature Cited

1. American Society for Testing and Materials. 1999. Standard methods of testing small clear specimens of timber. ASTM D 143-94. Annual Book of Standards, Volume 04.10. ASTM, West Conshohocken, PA.
2. _________. 1999. Standard practice for establishing structural grades and related allowable properties for visually graded lumber. ASTM D 245-88. Annual Book of Standards, Volume 04.10. ASTM, West Conshohocken, PA.
3. Carlsson, B., H. Erdtman, A. Frank, and W.W. Harvey. 1952. The chemistry of the natural order Cupressales. VIII. Heartwood constituents of *Chamecyparis nootkatensis* – carvacrol, notkatin, and chamic acid. Acta Chemica Scandinavica 6:690-696.
4. De Groot, R.C, B. Woodward, and P.E. Hennon. 2000. Natural decay resistance of heartwood from dead, standing yellow-cedar trees: Laboratory evaluations. Forest Prod. J. 50(1):53-59.
5. Ernst, S., M.E. Plank, and D.J. Fahey. 1986. Sitka spruce and western hemlock beach logs in southeast Alaska: Suitability lumber, pulp, and energy. Res. Pap. PNW-352. USDA Forest Serv., Pacific Northwest Forest and Range Expt. Sta., Portland, OR.
6. Forest Products Laboratory. 1963. Characteristics of Alaska woods. Res. Pap. FPL-RP-1. USDA Forest Serv., Forest Prod. Lab., Madison, WI.
7. _________. 1999. Wood Handbook: Wood as an Engineering Material. Forest Prod. Soc., Madison, WI.
8. Hamilton, T.D. 1965. Alaskan temperature fluctuations and trends: An analysis of recorded data. Arctic 18:105-117.
9. Hennon, P.E. 1990. Fungi on *Chamaecyparis nootkatensis*. Mycologia 82:59-66.
10. _________ and C.G. Shaw, III. 1994. Did climatic warming trigger the onset and development of yellow-cedar decline in southeast Alaska? European J. of Forest Pathology 24:399-418.
11. _________ and _________. 1997. The enigma of yellow-cedar decline: What is killing these long-lived, defensive trees? J. of Forestry 95(12):4-10.
12. _________, E.M. Hansen, and C.G. Shaw, III. 1990. Dynamics of decline and mortality of *Chamaecyparis nootkatensis* in southeast Alaska. Canadian J. of Botany 68: 651-662.
13. _________, C.G. Shaw, III, and E.M. Hansen. 1990. Dating decline and mortality of *Chamaecyparis nootkatensis* in southeast Alaska. Forest Sci. 36:502-515.
14. _________, D.T. Wittwer, J.H. Stevens, and K. Kilborn. 2000. Pattern of deterioration and recovery of wood from dead yellow-cedar in southeast Alaska. Western J. of Appl. Forestry 15(2):49-58.
15. Holsten, E, P.E. Hennon, D. Wittwer, and K. Matthews. 1996. Forest insect and disease conditions in Alaska, 1995. Gen. Tech. Rept. R10-TP-61. USDA Forest Serv., Forest Health Management, Anchorage, AK. 40 pp.
16. Jozsa, L.A. 1991. Yellow cypress wood quality and Hinoki connection. *In*: Proc. Yellow cypress: Can we grow it? Can we sell it? Canada-British Columbia Partnership Agreement on Forest Resource Development; FRDA II, Co-published by B.C. Ministry of Forests, Vancouver, BC, Canada. pp. 9-12.
17. Little, E.L., Jr. 1979. Checklist of United States trees (native and naturalized). Agri. Handb. 541. USDA Forest Serv., Washington, DC.
18. McDonald, K.A., P.E. Hennon, J.H. Stevens, and D.W. Green. 1997. Mechanical properties of salvaged dead yellow-cedar in southeast Alaska: Phase I. Res. Pap. FPL-RP-565. USDA Forest Serv., Forest Prod. Lab., Madison, WI. 9 pp.
19. Okkonen, E.A. and C.B. Vick. 1998. Bondability of salvaged yellow-cedar with phenol-resorcinol adhesive and hydroxymethylated resorcinol coupling agent. Forest Prod. J. 48(11/12):81-85.
20. Smith, R.S. 1970. Black stain in yellow-cedar heartwood. Canadian J. of Botany 48: 1731-1739.
21. Wilcox, W.W. 1978. Review of literature on the effects of early stages of decay on wood strength. Wood and Fiber 9(4):252-257.
22. Woodfin, R.O., Jr. and E.M. Estep. 1978. Proc. The dead softwood timber resource. Engineering Ext. Serv., Washington State Univ., Pullman, WA. 206 pp.