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Mechanical Properties of Salvaged Dead Yellow-Cedar in Southeast Alaska

Phase I

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Abstract

An intensive decline and mortality problem is affecting yellow-cedar trees in southeast Alaska. Yellow-cedar snags (dead trees) could be important to the economy in southeast Alaska, if some high-value uses for the snags could be established. Due to the high decay resistance of yellow-cedar, the rate of deterioration is so slow that snags may remain standing for a century or more after death. Obtaining information on wood properties from these snags is necessary to correctly assess the utilization potential of the yellow-cedar. Initial property analyses, Phase I, showed no evidence that even the oldest snags have lost strength. Black stain in the heartwood of live yellow-cedar may have an effect on strength, which will be analyzed through additional study.

Keywords: Yellow-cedar, Alaska yellow-cedar, snags, cedar decline, bending strength, stiffness, modulus of rupture, modulus of elasticity, specific gravity, age, salvage

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Research Highlights

Yellow-cedar (*Chamaecyparis nootkatensis* (D. Don) Spach) is understood to be an important and valuable tree species in the rainforest region of coastal Alaska. Yellow-cedar wood from live trees has historically been the most valuable wood grown in Alaska and is a highly desirable product in Pacific-rim markets. An intensive decline and mortality problem affects yellow-cedar on more than a half-million acres in southeast Alaska (Holsten and others 1996). The increasing percentage of snags in the forest may prevent regeneration of healthy trees and may constitute a forest health problem. One key element in improving use options of the snags is knowledge of wood properties after tree death. The primary objective of this study is to determine if mechanical properties vary with the length of time the yellow-cedar snags have been standing dead. All wood tested from the dead yellow-cedar trees, regardless of the number of years the trees had been dead, appeared to maintain strength with time. Not one of the snags, in any class, had lost enough strength to prevent it from potentially being used. Therefore, decisions about salvage and use of dead yellow-cedar snags should include the yield of sound logs and lumber and the total value of products that can be obtained from the snags. The average bending strength values obtained for clear yellow-cedar wood in most snag classes were above the strength values recorded in the literature. In addition, the average bending strength of all dead yellow-cedar equaled or exceeded the values reported for coast Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco var. *menziesii*). The hardness test values obtained for this cedar essentially supported the bending test results. Black stain was found to be prevalent in the live trees tested as our control. We believe this stain contributed to the lower strength values recorded, relative to the snags. Additional research to investigate these initial observations is planned.

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Phase I

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Introduction

Yellow-cedar (*Chamaecyparis nootkatensis* (D. Don) Spach) is an important and valuable tree species in the rainforest region of coastal Alaska (Holsten and others 1996). This species has a number of outstanding wood characteristics, the most outstanding being its high decay resistance. The bright yellow color and unique aroma of its heartwood come from compounds such as nootkatin (Carlsson and others 1952) that produce great natural durability (Barton 1976). Yellow-cedar wood from live trees has historically been the most valuable wood grown in Alaska and is a highly desirable product in the Pacific-rim markets.

An intensive decline and mortality problem affects yellow-cedar on more than a half-million acres in southeast Alaska (Holsten and others 1996). Other species are not similarly affected. On average, 65% of the yellow-cedar basal area is dead on these sites (Hennon and others 1990a). Most declining stands contain a mixture of long-dead trees, recently killed trees, dying trees, and some healthy yellow-cedar trees (see cover photo). 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. 1) has been developed for yellow-cedar snags in various stages of deterioration (Hennon and others 1990a,b) to represent average time since death for each class.

Table 1—Classification of yellow–cedar snags

Snag class	Characteristics of deterioration	Average time since death (years)
1	Dead, foliage retained	4
2	Dead, foliage missing, but twigs retained	14
3	Dead, twigs missing, but secondary branches retained	26
4	Dead, secondary branches missing, primary branches retained	51
5	Dead, all branches missing, but top intact	81

Research has not been able to identify a contagious agent (e.g., fungus, insect, nematode) responsible for the decline (Hennon 1990, Hennon and others 1990c), and the primary cause of this unusual mortality is not completely understood. Poorly drained soils and semiopen canopies are site and forest factors that are typically associated with the decline and mortality in southeast Alaska (Hennon and others 1990a). The early onset of the decline (about 1880 (Hennon and others 1990b)) and remote locations of mortality suggest that this yellow-cedar problem is a naturally occurring process (Hennon and Shaw 1994).

Figure 1—Examples of snags in four snag classes included in this study: (a) Class 2 (dead ~14 years), (b) Class 3 (dead ~26 years), (c) Class 4 (dead ~51 years), and (d) Class 5 (dead ~81 years).

Unlike live yellow-cedar trees, which have readily been sold for high prices, the wood from snags is used principally for firewood. As they accumulate in the forest, the snags make up an increasing percentage of the stand density. This may prevent regeneration of healthy trees and may represent a forest health problem. Because of the relatively low commercial value of the firewood and lack of road access, removal of the snags is presently not economically justified. Establishment of some higher value uses for wood from the snags could help pay for ecosystem improvement and help support the local economy. A key element in establishing better use options is knowledge of wood properties after tree death.

Background

Accurate data on physical and mechanical properties are essential when evaluating the suitability of wood for specific purposes. Testing the mechanical properties of small, clear specimens cut from yellow-cedar provides an efficient tool to judge the effects of potential deterioration of the wood within each snag class.

Tree and wood characteristics and use concerns for Alaskan species are summarized in a report by the Forest Products Laboratory (1963). This report, based on previously published material from many sources, was compiled to provide a convenient reference on Alaskan woods.

Natural stands of yellow-cedar are distributed in the coastal forests through northern California, British Columbia, and southeastern Alaska (Fig. 2) (Little 1979). Yellow-cedar is generally ~80 ft (24.4 m) tall with diameters of 2 to 3 ft (0.6 to 0.9 m). Yellow-cedar (also referred to as yellow cypress) has also been planted in plantations in Canada (Jozsa 1991). The sapwood is narrow and sometimes slightly lighter than the pale yellow heartwood (Alden 1997). The average moisture content (calculated on the ovendry basis) of the sapwood in live yellow-cedar is 166%, but that of heartwood averages only 32% (Forest Products Laboratory 1987). The wood is moderately heavy, soft, and fine textured. It tends to be straight grained and easily worked with both hand and machine tools. When dry (<12% moisture content), yellow-cedar is easily glued and holds stains and finishes well. It is rated as moderate in mechanical properties, shrinks little in drying, and is stable in use after seasoning. The heartwood is very resistant to decay.

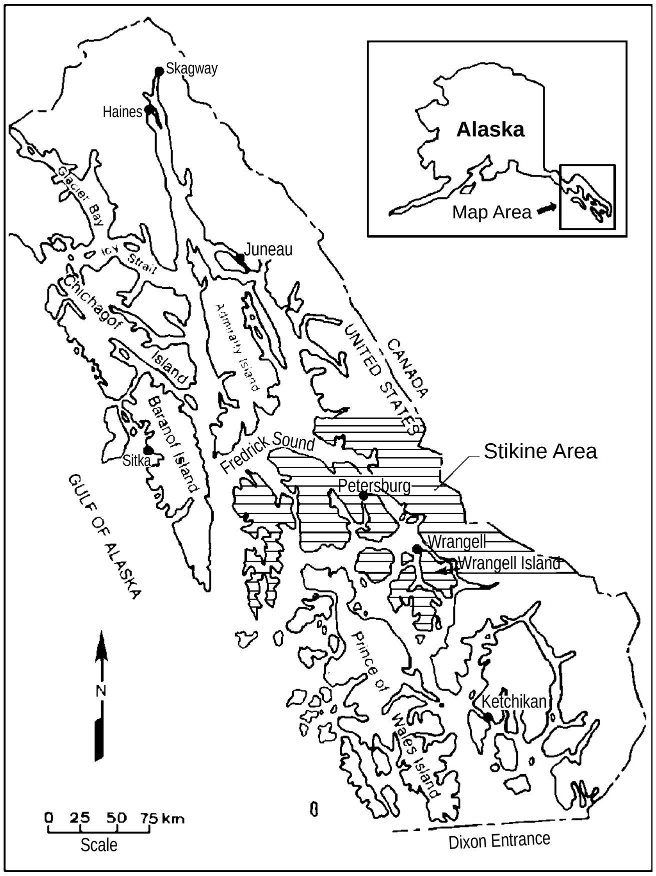

Figure 2—Stikine area, in Tongass National Forest, located within the range of yellow-cedar in southeast Alaska. Sample trees were selected from Wrangell Island.

The yellow-cedar used for clear wood tests reported by the Forest Products Laboratory (1963) came from three representative trees cut at an elevation of less than 400 ft (122 m) near Ketchikan, AK. The logs from these trees were shipped (prior to 1931) to Madison, WI. Standard test specimens were prepared according to specifications given in Standard D143 established by the American Society for Testing and Materials (ASTM) (ASTM 1996). Tests were conducted on both green material and material conditioned to 12% moisture content. Table 2 presents average results of these early tests made on yellow-cedar. Data on some other selected species are also given for comparison. When dry (12% moisture content), yellow-cedar from Alaska had properties more like those of coast Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco var. *menziesii*), and the property values were generally higher than those of the other species shown in Table 2. Thus, yellow-cedar seems to be an ideal species to use where a combination of durability and high strength is required. Wood from plantation-grown trees may average only 2.5 rings per inch (1 ring per centimeter), compared with more than 40 rings per inch (16 rings per centimeter) for old growth yellow-cedar (Jozsa 1991). The specific gravity of plantation-grown material would be expected to be lower than that from old growth trees.

Table 2—Average mechanical properties of yellow-cedar from Alaska and selected other species[a]

				Bending[c]		Compression			
Common name[b]	Area sampled from	Moisture content	Specific gravity	MOR (×10^3 lb/in^2 (MPa))	MOE (×10^6 lb/in^2 (GPa))	Parallel (×10^3 lb/in^2 (MPa))	Perpen-dicular (×10^3 lb/in^2 (MPa))	Shear parallel (×10^3 lb/in^2 (MPa))	Side hardness (lb (kg))
Yellow–cedar	Alaska	Green	0.44	6.90 (47.6)	1.42 (9.79)	3.33 (23.0)	0.47 (3.2)	0.88 (6.1)	500 (227)
		12%	0.47	13.20 (91.0)	1.70 (11.72)	7.52 (51.8)	0.91 (6.3)	1.38 (9.5)	690 (313)
Western hemlock	Alaska	Green	0.36	5.60 (38.6)	1.12 (7.72)	2.78 (19.2)	0.39 (2.7)	0.77 (5.3)	380 (172)
		12%	0.40	9.20 (63.4)	1.38 (9.52)	5.70 (39.3)	0.62 (4.3)	1.16 (8.0)	530 (240)
Sitka spruce	Alaska	Green	0.39	5.80 (40.0)	1.14 (7.86)	2.71 (18.7)	0.42 (2.9)	0.76 (5.2)	300 (136)
		12%	0.42	11.30 (77.9)	1.62 (11.17)	6.34 (43.7)	0.69 (4.8)	1.11 (7.7)	520 (236)
Coast Douglas-fir	Lower 48	Green	0.45	7.70 (53.1)	1.56 (10.76)	3.78 (26.1)	0.38 (2.6)	0.90 (6.2)	500 (227)
		12%	0.48	12.40 (85.5)	1.95 (13.45)	7.23 (49.8)	0.80 (5.5)	1.13 (7.8)	710 (322)
Western hemlock	Lower 48	Green	0.42	6.60 (45.5)	1.31 (9.03)	3.36 (23.2)	0.28 (1.9)	0.86 (5.9)	410 (186)
		12%	0.45	11.30 (77.9)	1.63 (11.24)	7.20 (49.6)	0.55 (3.8)	1.29 (8.9)	540 (245)
Western redcedar	Lower 48	Green	0.31	5.20 (35.9)	0.94 (6.48)	2.77 (19.1)	0.24 (1.7)	0.77 (5.3)	260 (118)
		12%	0.32	7.50 (51.7)	1.11 (7.65)	4.56 (31.4)	0.46 (3.2)	0.99 (6.8)	350 (159)
Port-Orford cedar	Lower 48	Green	0.39	6.60 (45.5)	1.30 (8.96)	3.14 (21.6)	0.30 (2.1)	0.84 (5.8)	380 (172)
		12%	0.43	12.70 (87.6)	1.70 (11.72)	6.25 (43.1)	0.72 (5.0)	1.37 (9.4)	630 (286)

[a] Forest Products Laboratory (1963, 1987).

[b] Scientific names given in text except for Port-Orford cedar, which is *Chamaecyparis lawsoniana* (A. Murr.) Parl.

[c] MOR, modulus of rupture; MOE, modulus of elasticity.

Objective

The primary objective of this study is to determine if mechanical properties of yellow-cedar snags vary with the length of time the snags have been standing dead. The expectation is that older snags would have less utility and possibly yield lower strength wood than younger snags. By identifying the year at which there is strength loss, salvage negotiations could include important contracting decisions and only useful snags would be harvested.

Methods

Site Selection

All material was collected near Nemo Point (Latitude 56°17') on the west side of Wrangell Island in southeast Alaska in the Stikine Area of the Tongass National Forest (Fig. 2). This site included a mix of yellow-cedar, western hemlock (*Tsuga heterophylla* (Raf.) Sarg.), western redcedar (*Thuja plicata* Donn ex. D. Don), and small amounts of Sitka spruce (*Picea sitchensis* (Bong.) Carr.) and shore pine (*Pinus contorta* Dougl. ex Loud. var. contorta).

Sampling Design

Live trees with healthy crowns were used as a control, and sample trees were selected from Snag Classes 2 through 5 (Hennon and others 1990a,b). Snag Class 1 was not sampled because there were very few trees of this class on the study site.

All sample trees were larger than 15 in. (381 mm) in diameter at breast height. Six controls and six trees from each snag class (2–5), 30 trees total, were collected. Trees with internal heartrot and trees with noticeable spiral grain were not included because only clear, straight-grained specimens can be included in the standard tests. One 4-ft (1.22-m) bolt from the top of the first merchantable 11-ft (3.35-m) log of each selected tree was removed.

Preparation for Shipment

Each numbered 4-ft (1.22-m) bolt was split lengthwise down the middle, and one bolt half was removed from the forest and palletized for shipping to the Forest Products Laboratory in Madison, WI. Bark (if present) was kept intact, and each section was stored to minimize additional drying or staining.

Specimen Preparation and Testing

The wood properties noted and physical conditions evaluated were annual ring count, green moisture content, wood density, static bending modulus of rupture (MOR) and modulus of elasticity (MOE), and side hardness. A cross-sectional disk was removed from the end of each bolt for determining green moisture content and ring count for each tree. This disk was removed at least 3 in. (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 using stickers separating each layer for equilibration to 12% moisture content. From the dry boards, the ASTM Standard D143 bending and hardness specimens were selected and prepared (ASTM 1996). The maximum number of available clear, straight-grained, standard 1- by 1- by 16-in. (25.4- by 25.4- by 406-mm) bending and 1- by 2- by 6-in. (25.4- by 50.8- by 152-mm) hardness specimens were selected for testing (Fig. 3).

Results and Discussion

Of the 30 trees selected and cut, none of them broke up when felled. This indicated substantial residual strength in their wood. The live controls and the snags in Classes 2 and 3 exhibited very minor surface checking, whereas Class 4 snags had surface checks that were 1 to 2 in. (25 to 50 mm) deep and Class 5 snags showed some surface checks as deep as 4 in. (102 mm).

The age (ring count) of the trees sampled (Table 3) shows the average age within class tended to be higher for the live than for the longest dead trees. Some of this difference could be due to the missing sapwood on the Class 4 and 5 dead trees. The age of the sapwood could represent 50 to 100 years. The average properties of the specimens tested are shown in Table 4. There were 841 bending specimens and 467 hardness specimens from the 30 bolts processed. The result was unanticipated—the lowest average bending MOR and MOE was found for the control specimens cut from the live trees. This trend also held true for specific gravity but not for side hardness. Because of the small number of trees tested, it is possible for the results from one tree to bias the mean trends observed. Median values (Table 5) have a

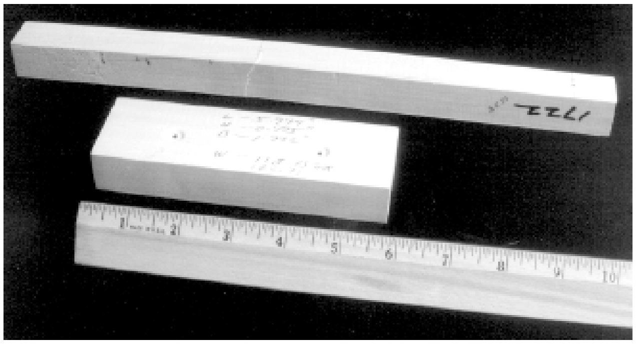

Figure 3—Samples of standard bending and hardness testing specimens.

Table 3—Annual ring count for yellow–cedar trees sampled

Class	Tree no.	Ring count
Live	13	425
	21	356
	22	490
	23	230
	26	426
	30	412
	Average	390
2	6	400
	7	500
	15	480
	27	442
	28	353
	29	437
	Average	435
3	1	390
	2	420
	3	461
	4	404
	14	417
	16	430
	Average	420
4	5	215
	8	343
	9	204
	10	269
	11	280
	12	298
	Average	268
5	17	444
	18	127
	19	152
	20	297
	24	183
	25	113
	Average	219

minimizing effect on this influence. The bending (MOR) and stiffness (MOE) data are viewed for trends by plotting the average values and the median values by class (Figs. 4 and 5). Also plotted are the range limits where 50% of the outlying values are omitted (50% exclusion). Generally, the trends show that both MOR and MOE decrease very slightly with increasing years dead (Figs. 4 and 5). The decrease from Class 2 to 5 is only about 7% for MOR and 9% for MOE (Table 5). Because of the small number of trees, statistical estimates of within and between tree variability are not appropriate. When data from additional trees are available, estimates of statistical significance will be made.

Black stain was noted in many of the live (control) bending specimens but not in the dead specimens. Table 6 shows the percentage of bending specimens with stain in each class. The high percentage of the stained specimens (69%) for the live controls may have contributed to the lower strength values observed. In the snag classes, less than 10% of the specimens were stained. The black or dark-stained heartwood of yellow-cedar is caused by fungi, according to Smith (1970) and Smith and Cserjesi (1970), which could have an effect on strength. This effect may be caused indirectly by the fungi-detoxifying heartwood compounds allowing true heartrot fungi to begin to break down wood cells. Additional research on the identity of the fungi and their effect on strength and durability is in progress.

The resulting values for live trees in this study are generally lower than those reported for yellow-cedar sampled in Alaska by the Forest Products Laboratory (1963) (Table 7). For the snag classes, our results for bending MOR and MOE are generally higher than, or approximately equal to, those reported by the Forest Products Laboratory (1963). The properties from our study are definitely higher than those reported for yellow-cedar from the lower 48 states. In fact, the bending MOR of our data for Classes 2, 3, 4, and 5 appear to be generally as high as those of coast Douglas-fir. Again, the number of trees sampled in our study is much less than that represented in property estimates for Douglas-fir.

Conclusions

All wood in the dead yellow-cedar trees tested, regardless of the number of years the trees were dead, maintained strength with time. No snag classes were identified as having strength loss that would prohibit potential utility. Therefore, decisions about salvage and use of yellow-cedar snags should include the yield of sound logs and lumber and the total value of products that can be obtained from the snags. The bending strength values obtained for clear yellow-cedar wood in most snag classes were above the strength values recorded in the literature. In addition, the bending strength of all dead yellow-cedar equaled or exceeded the values reported for coast Douglas-fir. The hardness test values obtained for this cedar essentially supported the bending test results. Black stain was found to be prevalent in the live trees tested as our control. This stain is believed to have contributed to the lower strength values recorded for the live trees relative to the dead trees.

Table 4—Average results of bending and hardness tests by tree class (Specimens had 12% moisture content.)

	Bending tests[a]				Hardness tests	
Class	Speci-mens	SG	MOR ($\times 10^3$ lb/in^2 (MPa))	MOE ($\times 10^6$ lb/in^2 (GPa))	Specimens	Hardness (lb (kg))
Live	216	0.45	12.13 (83.6)	1.503 (10.36)	95	637 (289)
2	155	0.48	14.66 (101.1)	1.971 (13.59)	98	609 (276)
3	199	0.49	13.92 (95.9)	1.749 (12.06)	98	766 (348)
4	146	0.46	13.52 (93.2)	1.885 (13.00)	120	636 (288)
5	125	0.46	13.17 (90.8)	1.783 (12.29)	56	563 (255)
Wood handbook[b]		0.44	11.10 (76.5)	1.42 (9.79)		580 (263)

[a] SG, specific gravity; MOR, modulus of rupture; MOE, modulus of elasticity.
[b] Forest Products Laboratory (1987), p. 4–12 (See Cedar: Alaska- data).

Table 5—Median values of bending tests by tree class (Specimens had 12% moisture content.)

	Bending tests[a]			
Class	Specimens	SG	MOR ($\times 10^3$ lb/in^2 (MPa))	MOE ($\times 10^6$ lb/in^2 (GPa))
Live	216	0.45	12.22 (84.3)	1.552 (10.70)
2	155	0.48	14.04 (96.8)	1.915 (13.20)
3	199	0.49	14.30 (98.6)	1.886 (13.00)
4	146	0.46	13.06 (90.0)	1.874 (12.92)
5	125	0.46	13.02 (89.8)	1.745 (12.03)
Wood handbook[b]			11.10 (76.5)	1.42 (9.79)

[a] SG, specific gravity; MOR, modulus of rupture; MOE, modulus of elasticity.
[b] Forest Products Laboratory (1987), p. 4–12 (See Cedar: Alaska- data).

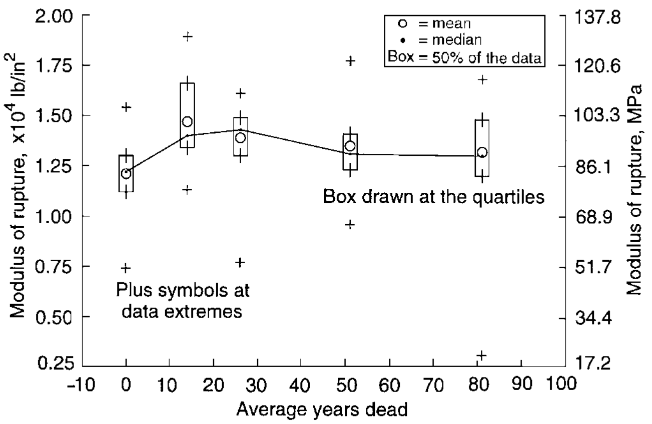

Figure 4—Clear wood modulus of rupture of dead yellow-cedar.

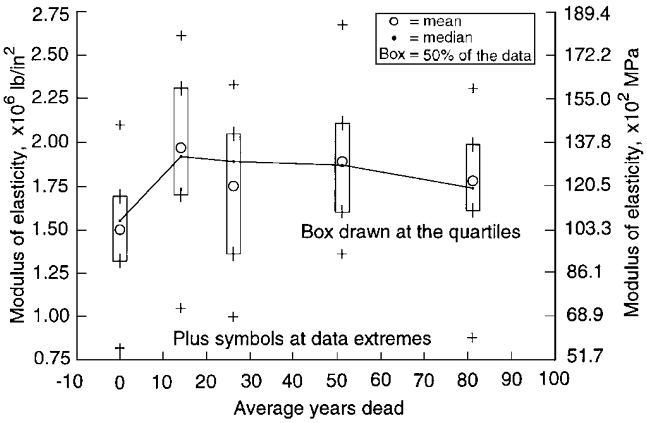

Figure 5—Clear wood modulus of elasticity of dead yellow-cedar.

Table 6—Occurrence of black stain in bending specimens

Class	Stained no.	Total no.	Percentage stained
Live	150	216	69
2	13	155	8
3	19	199	10
4	3	146	2
5	6	125	5

Recommendations for Future Work

Initial results on the properties of dead yellow-cedar from Alaska are very encouraging. These results suggest that wood cut from salvaged yellow-cedar would be superior to other species in applications where a combination of strength and durability is important. It is important, therefore, to anticipate what additional information would be needed to use this resource. Our recommendations are as follows:

1. Perform a more detailed survey of the dead yellow-cedar resource (one of the most pressing needs). Ultimately, we will need volume estimates by snag class and an estimate of the extent of severe spiral grain and checking in the tree.

2. Conduct additional studies to quantify the effects of black stain on the strength of wood from live trees. (These studies have already been initiated.)

3. Obtain information on the quality of dead cedar from other locations, including assessment of the occurrence of black stain in live trees.

4. Assess the environmental contribution of the dead cedar to the ecosystem.

5. Study the product yield, including mechanically graded lumber, when use options and commercial interests become clearer.

Table 7—Ratio of yellow–cedar test results from this study (Table 4) to average test results (Table 2) reported at 12% moisture content for yellow-cedar and coast Douglas-fir

			Ratio				
Species	Source; area sampled from	Property[a]	Live	Class 2	Class 3	Class 4	Class 5
Yellow–cedar	Forest Products	SG	0.95	1.02	1.04	0.98	0.97
	Laboratory 1963; Alaska	MOR	0.92	1.11	1.05	1.02	1.00
		MOE	0.88	1.16	1.03	1.11	1.05
		Hardness	0.92	0.89	1.11	0.92	0.82
	Forest Products	SG	1.06	1.14	1.17	1.10	1.09
	Laboratory 1963; Lower 48	MOR	1.20	1.45	1.38	1.34	1.30
		MOE	1.18	1.55	1.38	1.48	1.40
		Hardness	1.22	1.17	1.47	1.22	1.08
Coast Douglas-fir	Forest Products	SG	0.93	0.99	1.02	0.96	0.95
	Laboratory 1987	MOR	0.98	1.18	1.12	1.09	1.06
		MOE	0.77	1.01	0.90	0.97	0.91
		Hardness	0.90	0.86	1.08	0.90	0.79

[a] SG, specific gravity; MOR, bending modulus of rupture; MOE, bending modulus of elasticity.

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