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Lumber Recovery From Insect-Killed Lodgepole Pine in the Northern Rocky Mountains

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Abstract

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A total of 496 logs from lodgepole pine (*Pinus contorta* Dougl. ex Loud.) trees killed by the mountain pine beetle (*Dendroctonus ponderosae* Hopk.) were compared with 189 logs from similar live trees. Logs were processed through a stud mill. In most cases lumber recovery from trees dead 1 to 3 years was the same as that from live trees. Less cubic volume was recovered from trees dead 4 or more years. Recovery tables and curves are shown.

Keywords: Lumber recovery, lumber yield, dead timber, insect damage (-forest products, lodgepole pine, *Pinus contorta*, Rocky Mountain area.

Summary

A sample of lodgepole pine (*Pinus contorta* Dougl. ex Loud.) trees from the Bridger-Teton National Forest in Wyoming and the Targhee National Forest in Idaho that had been killed by the mountain pine beetle (*Dendroctonus ponderosae* Hopk.) was processed through a stud mill. Logs from similar live trees were sawn to compare their product recovery with that of logs from the dead trees. Generally, volume recovered from logs of trees dead 1 to 3 years was the same as that recovered from live trees. Less cubic volume was recovered from trees dead 4 or more years.

Average stud grade recovery was 86 percent of the volume in the live sample compared with 73 percent in the dead sample. The value per unit of lumber volume recovered was lower for the dead sample, but there was no clear distinction between values of any of the time-since-death classes in that respect.

Lumber volume recovery is based on long log Scribner scale and on gross cubic scale.

Introduction

In the mid-1970's the mountain pine beetle (*Dendroctonus ponderosae* Hopk.) killed millions of board feet of timber in the Targhee National Forest in Idaho and the Bridger-Teton National Forest in Wyoming. Many dead and dying trees remain from past attacks in lodgepole pine (*Pinus contorta* Dougl. ex Loud.) stands. In western Wyoming and eastern Idaho, estimates of accessible dead lodgepole pine range as high as 1.25 billion board feet, most of which has been killed by the mountain pine beetle. These stands are esthetically unpleasant, management of the lodgepole pine resource is difficult, and the huge amounts of fuel are a fire hazard.

In 1977, the USDA Forest Service (Rocky Mountain and Intermountain Regions and the Timber Quality Research unit of the Pacific Northwest Forest and Range Experiment Station) and the forest products industry cooperated in a study to: (1) determine the lumber recovery of a sample of beetle-killed lodgepole pine trees, (2) compare the lumber recovery and value of beetle-killed lodgepole pine with a similar sample of live trees, and (3) evaluate time-since-death classes of the beetle-killed trees to determine their relationship to recovery and value.

Field Procedures

Timber Sample

Timber was sampled from the Bridger-Teton and Targhee National Forests, an area representative of the range in size and quality of lodgepole pine in western Wyoming and eastern Idaho. Local foresters familiar with the lodgepole pine resource participated in selecting sample areas.

The three areas selected contained sizes of sawtimber trees normally encountered. The areas also contained trees that had been attacked by the mountain pine beetle at different times during the 11 years prior to the study. Trees on each area were selected to insure that all diameter classes were included in the sample. A total of 448 trees were designated on the three areas; when study trees were selected they were placed into classes based on estimated time since death. These classes were determined by the color of the needles and on the percentages of needles, small branches, twigs, and bark retained. Three classes of dead trees were defined, based on these estimates: dead 1 to 3 years, dead 4 to 7 years, and dead longer than 7 years.

Table 1 shows the range of diameters and heights and the average diameter and height for the sample trees by area. Analyses were run collectively on all areas.

Table 1—Diameters and heights of sample lodgepole pine trees, by area

Area and class of trees	Range of diameters	Average diameter	Range of heights	Average height
	- - - - Inches - - - -		- - - - Feet - - - -	
Area 1:				
Live	7.2-13.9	10.1	67- 86	78
Dead	8.0-16.4	11.4	58- 89	74
Area 2:				
Live	8.0-17.2	13.0	61- 95	78
Dead	9.1-22.3	13.6	60-102	80
Area 3:				
Live	7.0-13.3	9.6	52- 84	68
Dead	8.4-20.9	12.9	44-101	70

Felling and Identification	Study trees were felled and bucked following normal industry practice. Diameter and length of each bucked log were recorded along with tree height for each sample tree. Each log was tagged to identify tree number and log within the tree.
Scaling	When all logs had been delivered to the mill yard, they were rolled out and scaled. Net scale of all dead logs was determined according to the National Forest Log Scaling Handbook (USDA Forest Service 1973) rules; however, no deduction was made for drying or weather checks. This estimate should approximate the net scale of live logs for realistic recovery percentages. Reasons for each scale deduction were documented. Cubic volumes based on Scribner diameters and Smalian's formula were also determined for all logs. After the logs were bucked into 8-foot lengths, they were again scaled by Scribner log rule.
Lumber Manufacturing	Each log was sawn to recover its optimum value through manufacture of the mill's usual lumber items. About 94 percent of the total volume is made up of studs. The major equipment in the mill included a band head saw, a four-saw scragg, double arbor edger, and a hula trim saw. There was a reclaim area where lumber could be ripped, trimmed, or resawn. An automatic stacker was used for 8-foot 2x4's. A Western Wood Products Association grading inspector either graded or supervised the grading of lumber on the planer chain. Lumber was graded under the Western Wood Products Association (1977), "Grading Rules for Western Lumber." Lumber volumes were based on a surfaced-dry shipping tally.
Cubic Calculations	The gross cubic volume of logs was computed by Bruce's (1970) formula for butt logs and Smalian's formula for all other logs. Bruce's formula: $\text{Volume} = 0.0054545 (0.3677 D_s^2) + 0.6688 (D_s \times D_L) - 0.000148 (D_s \times D_L)L;$ Smalian's formula: $\text{Volume} = 0.002727 (D_s^2 \times D_L^2)L;$ where: D_s is the log scaling diameter (inches) of the small end, D_L is the log scaling diameter (inches) of the large end, and L is the log scaling length (feet). The cubic-foot volumes of lumber were based on measurements of surfaced-dry lumber. The cubic foot volumes of sawdust were calculated from the average saw-kerf thickness and the rough-green surface area of the lumber from each log. Shrinkage and planer shavings were determined by subtracting the volume of surfaced-dry lumber from the volume of rough-green lumber. The residue volume was the gross log volume minus volumes of lumber, sawdust, shrinkage, and planer shavings. Thus, the residue volume includes a small amount of sawdust from the production of slabs, edgings, trim ends, and some defect.

Analysis Model Selection

Five regression models were compared. Volume and value were expressed as functions of different combinations of the independent variables D , $1/D$, $1/D^2$. The final model for each response variable was selected based on the statistics of the regression (s_{y-x} , the standard deviation about regression, and R^2 , the coefficient of determination), each coefficient being significant ($P < 0.05$), and on information obtained from fitting these models in previous studies.

Results

Dependent variables used were:

1. Cubic recovery percent (CR%) ^{1/}
2. Lumber recovery factor (LRF).
3. Recovery ratio.
4. Dollars per thousand board feet of lumber tally (\$/MLT).
5. Dollars per hundred cubic feet of gross log volume (\$/CCF).

From the model that best fit all the response variables,

$$(y = b_0 + b_1(d) + b_2(1/d) + b_3(1/d^2),$$

where d = diameter,

covariance analysis was used to compare the three classes of dead material. If differences occurred, the individual classes were compared to isolate the differences. Classes not significantly different were combined and compared with live material.

The analysis indicated a significant difference ($P < 0.05$) among the three classes, except in \$/MLT. Further analysis of the other four response variables indicated no difference between the two older groups of logs from dead trees, so they were combined. Next, the 1- to 3-year-dead group and the combined group were compared and found to be significantly different ($P \leq 0.05$). The final comparison was between the logs from trees dead 1 to 3 years and the logs from live trees. This analysis showed a significant difference, but differences in the curves did not appear to be practically important relative to the variation in the data. The y_m criterion (Draper and Smith 1981) was used to determine if the significant difference between the logs from trees dead 1 to 3 years and logs from live trees was of practical importance. This criterion requires observed F values at least four times the tabled value for the regression coefficients to be practically useful compared with just statistically significant. By use of this criterion, logs from trees dead 1 to 3 years and logs from live trees were combined for all response variables, except \$/MLT. Separate means for the logs from the live sample and logs from all the dead samples were retained since there was no significant relationship of \$/MLT to diameter.

Tables 2 and 3 present summaries of log scale, lumber tally, and cubic volumes obtained from the study logs. Lumber yields are shown in both board feet and cubic feet of surfaced-dry lumber (shipping tally volume). The cubic-foot volume of the logs, lumber, sawdust, shrinkage, and planer shavings and residues calculated by 1-inch diameter classes is also shown.

^{1/} Cubic recovery percent = rough-green cubic-foot lumber volume divided by gross cubic foot of log volume times 100.

Table 2—Log scale, lumber tally, and cubic volumes by scaling diameter for logs from live lodgepole pine trees and logs from trees dead 1 to 3 years

Log scaling diameter <u>1/</u>	Number of logs	Scribner log scale		Lumber tally		Volume <u>3/</u>					
		Gross	Net	Volume	Recovery ratio <u>2/</u>	Log	Surfaced-dry lumber	Lumber recovery <u>4/</u>	Green sawdust	Shrinkage and planer shavings	Chippable volume
Inches		--- Board feet ---			Percent	--- Cubic feet ---			Percent		
5	43	1,795	1,725	2,698	156	373.07	145.65	39	13	11	37
6	114	6,255	6,005	9,008	150	1,267.74	486.86	38	13	11	38
7	72	4,120	3,870	5,036	130	726.15	272.80	38	12	10	41
8	36	1,460	1,340	1,908	142	333.38	102.31	31	11	9	49
9	38	2,090	1,960	2,656	136	431.69	143.11	33	11	10	46
10	29	2,430	2,330	2,756	118	430.65	147.79	34	11	9	46
11	15	2,090	1,940	2,644	136	345.69	141.76	41	13	10	36
12	8	1,010	1,010	1,330	132	181.89	71.53	39	13	10	38
13	8	1,790	1,790	2,257	126	293.51	121.42	41	12	10	37
14	4	1,100	1,020	1,401	137	187.28	75.55	40	13	9	37
Total or average	367	24,140	22,990	31,694	138	4,571.05	1,708.78	37	12	10	40

1/ In accordance with National Forest Log Scaling Handbook (USDA Forest Service 1973) rules.

2/ Equals lumber tally volume divided by net log scale times 100.

3/ Lumber volume based on surfaced-dry dimensions. Chippable volume gross log volume minus volume of lumber, sawdust, and shrinkage and planer shavings.

4/ Equals cubic lumber volume divided by cubic log volume times 100.

Table 3—Log scale, lumber tally, and cubic volumes by scaling diameter for logs from lodgepole pine trees dead 4 years or more

Log scaling diameter <u>1/</u>	Number of logs	Scribner log scale		Lumber tally		Volume <u>3/</u>					
		Gross	Net	Volume	Recovery ratio <u>2/</u>	Log	Surfaced-dry lumber	Lumber recovery <u>4/</u>	Green sawdust	Shrinkage and planer shavings	Chippable volume
Inches		--- Board feet ---			Percent	--- Cubic feet ---			Percent		
5	7	560	530	694	131	96.75	37.49	39	13	10	38
6	67	3,215	3,035	4,032	133	676.96	218.11	32	10	8	49
7	69	4,270	4,120	4,975	121	786.12	268.43	34	11	9	46
8	44	2,360	2,230	2,933	132	512.34	158.24	31	9	8	51
9	36	2,690	2,580	3,105	120	518.63	167.47	32	10	8	49
10	39	3,520	3,230	3,809	118	640.99	204.66	32	10	8	50
11	21	2,820	2,650	3,224	122	506.97	174.44	34	10	8	47
12	13	2,020	1,860	2,344	126	351.10	127.03	35	8	9	47
13	11	2,010	1,820	2,360	130	332.37	127.27	38	11	9	42
14	4	920	860	1,000	116	148.96	53.95	36	9	9	46
15	4	1,130	1,090	1,277	117	182.06	69.11	38	9	8	45
16	2	710	710	819	115	120.58	44.23	37	7	8	48
17	1	410	390	548	141	64.84	29.72	46	15	10	29
Total or average	318	26,635	25,105	31,120	124	4,938.67	1,680.15	34	10	9	47

1/ In accordance with National Forest Log Scaling Handbook (USDA Forest Service 1973) rules.

2/ Equals lumber tally volume divided by net log scale times 100.

3/ Lumber volume based on surfaced-dry dimensions. Chippable volume gross log volume minus volume of lumber, sawdust, shrinkage and planer shavings.

4/ Equals cubic lumber volume divided by cubic log volume times 100

Cubic Recovery

Percentage of cubic log volume produced as rough green lumber is plotted over diameter for all logs in figure 1 for the two classes of logs. The general trend is a slight increase in recovery as diameter increases. Average recovery of cubic volume in percent for the logs from live trees and logs from trees dead 1 to 3 years was 47 percent, and for logs from trees dead more than 3 years, 44 percent.

This cubic recovery differs from that observed from other studies in that generally curves from other studies start out with low recovery in the lower diameters, rise as diameter increases, and then flatten. The explanation for this curve to drop and then rise again is probably that most logs were processed on a 4-saw scragg where the major product was 4-inch cants. Apparently in the 6- to 7-inch logs, the cant size was not increased relative to the increase in log volume, so a greater proportion of the logs of that size was chipped.

Lumber Recovery Factor

Figure 2 presents the relationship between lumber recovery factor (LRF^{2/} and diameter. The shapes of the curves are similar to the curves for recovery of cubic volume. The mean LRF for the logs from live trees and from trees dead 1 to 3 years was 6.3, whereas that for logs from trees dead 4 or more years was 5.6.

Recovery Ratio^{3/}

Figure 3 shows the relationship between recovery ratio (overrun) and diameter. Recovery ratio for the logs from live trees and logs from trees dead 1 to 3 years is high in the small diameters but decreases as diameter increases to about 8 inches where it levels off. The variance in recovery of small diameters was much greater than that of larger diameters, but no techniques to overcome this problem were explored. There was no significant relationship for the logs from trees dead 4 years or more where the average recovery was 124 percent.

Recovery ratio of the logs from dead trees was analyzed two ways; when a deduction for check was included in the total defect and when it was excluded. When a deduction for checks was included, many of the logs were culled and recovery ratios were as high as 600 percent. Because it appeared that excluding the deduction for checks on the logs from dead trees would give net scales that approximated logs from live trees, a decision was made to exclude the deduction for checks.

^{2/} Lumber recovery factor = board feet of lumber tally per cubic foot of gross log volume.

^{3/} Recovery ratio is overrun plus 100 percent.

Figure 1.—Percentage of cubic volume of lodgepole pine logs produced as rough-green lumber, by log diameter:

Logs from live trees and logs from trees dead 1 to 3 years—
Cubic recovery (percent)
= $-99.66 + 7.32(d) + 817.95(1/d) - 1,308.07(1/d^2)$.
Coefficient of determination = 0.057.
Standard deviation from regression = 11.3.

Logs from trees dead 4 or more years—
Cubic recovery (percent)
= $119.95 - 1.62(d) - 944.34(1/d) + 3,022.90(1/d^2)$.
Coefficient of determination = 0.059.
Standard deviation from regression = 11.7.

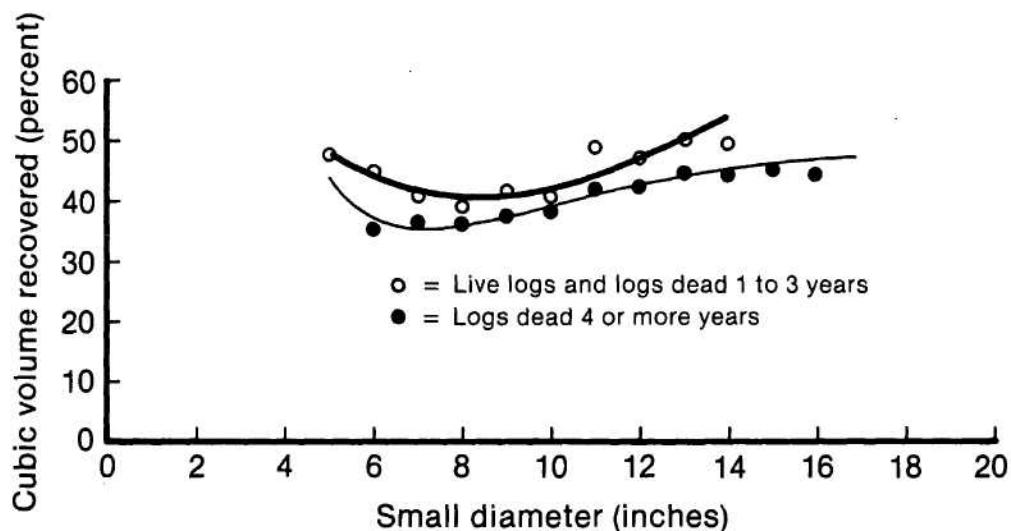


Figure 2.—Lumber recovery factor: Board feet of lumber tally per cubic foot of gross log scale, by diameter:

Logs from live lodgepole pine trees and from trees dead 1 to 3 years—
LRF= $18.27 + 1.257(d) + 142.95(1/d) - 241.27(1/d^2)$.
Coefficient of determination = 0.064.
Standard deviation from regression = 1.69.

Logs from lodgepole pine trees dead 4 years or more—
LRF= $16.76 - 0.18(d) - 136.09(1/d) + 445.70(1/d^2)$.
Coefficient of determination = 0.071.
Standard deviation from regression = 1.85.

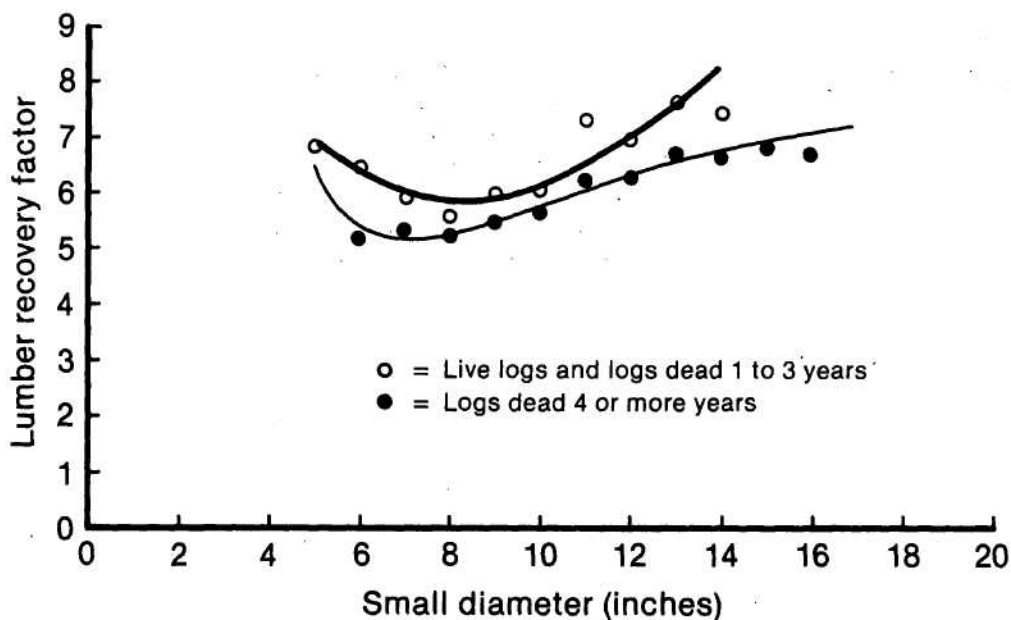
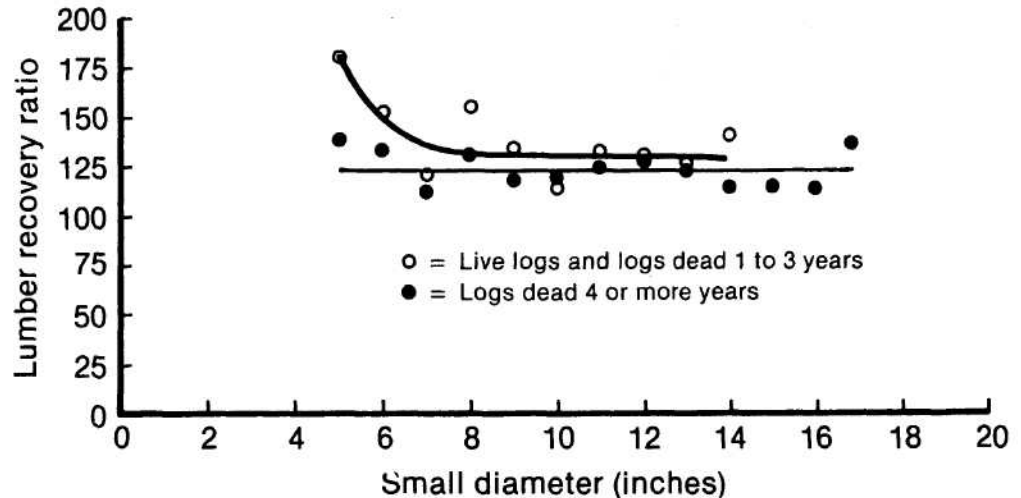


Figure 3.—Lumber recovery ratio from lodgepole pine logs, by diameter:

Logs from live trees and from trees dead 1 to 3 years—
Recovery ratio = $384.18 - 8.12(d) - 2,646.67(1/d) + 9,186.17(1/d^2)$.
Coefficient of determination = 0.113.
Standard deviation from regression = 44.8.

Logs from trees dead 4 years or more—
Recovery ratio = 124.
Standard error of the mean = 2.2.



Grade Yields

Tables 4-6 show percentage of recovery for each lumber grade by 1-inch diameter class. Grade yield varied by time since death. For the logs from live trees together with the logs from trees dead 1 to 3 years, 79 percent of the total volume was produced as Stud grade; 13 percent, Economy Stud. For logs from trees dead 4 or more years, 73 percent of the total volume was graded Stud and 22 percent Economy Stud.

Value (\$/MLT)

The \$/MLT relationship to diameter was not statistically significant. There was also no difference in recovery among the dead logs. For this relationship, all the dead logs were grouped together. The average \$/MLT for the live logs was \$201.51; for the dead logs, \$181.48. These relationships are based on 1978 lumber prices (table 7) furnished by the Intermountain Region (Region 4) of the USDA Forest Service. A significant change in price between the lumber grades could change the difference in average values.

Table 4—Lumber grade recovery as a percentage of surfaced-dry lumber tally for logs from live lodgepole pine trees

Log scaling diameter	Number of logs	Lumber tally	Moulding	Common				Stud	Economy Stud
				No. 2 and better	No. 3	No. 4	No. 5		
<u>Inches</u>		<u>Board feet</u>		<u>Percent</u>					
5	21	1,119	0	2.23	6.34	2.50	0	82.04	6.88
6	59	3,920	.43	.74	8.09	2.07	.05	83.37	5.26
7	37	1,901	.58	.47	7.42	1.84	.47	80.69	8.52
8	16	832	2.52	1.80	6.49	2.16	0	82.81	4.21
9	19	1,471	1.56	1.56	5.30	1.90	0	84.84	4.83
10	19	1,869	1.82	.32	3.32	.54	0	89.57	4.44
11	11	1,698	2.89	.88	2.06	.88	0	89.10	4.18
12	2	212	3.77	0	3.77	0	0	87.26	5.19
13	3	942	.96	0	.53	.21	0	94.06	4.25
14	2	610	.98	0	0.82	1.64	0	92.46	4.10
Total or average	189	14,574	1.22	.84	5.32	1.56	.08	85.63	5.36

Table 5—Lumber grade recovery as a percentage of surfaced-dry lumber tally for logs from lodgepole pine trees dead 1 to 3 years

Log scaling diameter	Number of logs	Lumber tally		Common				Stud	Economy Stud
				No. 2 and better	No. 3	No. 4	No. 5		
<u>Inches</u>		<u>Board feet</u>		<u>Percent</u>					
5	22	1,579	0.13	5.13	3.74	0.51		78.21	12.29
6	55	5,088	.04	4.72	3.46	.41		72.66	18.71
7	35	3,135	.06	3.44	2.65	.06		77.19	16.59
8	20	1,076	.19	4.93	6.23	.46		71.10	17.10
9	19	1,185	0.25	4.73	6.08	.51		71.31	17.13
10	10	887	0	1.24	1.92	.56		60.88	35.40
11	4	946	0	.63	1.27	0		72.41	25.69
12	6	1,118	.45	1.34	2.68	0		76.92	18.60
13	5	1,315	0	.84	1.22	.23		72.78	24.94
14	2	791	0	0	.76	0		79.65	19.60
Total or average	178	17,120	.09	3.39	3.14	.29		73.80	19.28

Table 6—Lumber grade recovery as a percentage of surfaced-dry lumber tally for logs from lodgepole pine trees dead 4 years or more

Log scaling diameter	Number of logs	Lumber tally	Common				Stud	Economy Stud
			No. 2 and better	No. 3	No. 4	No. 5		
Inches		Board feet	Percent					
5	7	694	0	3.17	3.89	0.29	61.38	31.27
6	67	4,032	.24	3.22	2.98	.20	71.60	21.75
7	69	4,975	.10	2.91	3.70	.18	71.08	22.03
8	44	2,933	0.34	3.95	3.72	.48	72.93	18.58
9	36	3,105	.39	2.67	3.06	.29	73.88	19.71
10	39	3,809	.24	2.02	2.55	.29	73.64	21.27
11	21	3,224	0.09	1.46	1.99	.19	80.09	16.19
12	13	2,344	0.13	1.24	2.90	.21	72.18	23.34
13	11	2,360	.08	1.23	1.14	.42	68.43	28.69
14	4	1,000	0	.60	3.00	.42	70.30	26.10
15	4	1,277	0	.47	.47	.39	74.94	23.73
16	2	819	0	.37	1.83	0	67.16	30.65
17	1	548	0	0	.91	0	87.77	11.31
Total or average	318	31,120	.17	2.23	2.72	.25	72.84	21.79

Table 7—Average yearly lumber prices for white woods, 1978

Lumber grade	Item			
	1 inch	2 x 4	2 x 6	2 x 8
Dollars per thousand board feet lumber tally				
Moulding	381.78			
No. 2 and Better Common	381.78			
No. 3 Common	212.73			
No. 4 Common	162.46			
No. 5 Common	91.19			
Standard and Better		219.45		
Utility		167.62		
Economy		89.87	89.87	89.87
Stud		204.64		
Economy Stud		90.45		
No. 2 and Better			207.77	213.92
No. 3			146.26	146.26

Source: Intermountain Region, USDA Forest Service.

Value (\$/CCF)

Figure 4 shows the relationship of dollars per hundred cubic feet of gross log volume (\$/CCF) to diameter for the two classes of logs.

The \$/CCF and \$/MLT relationships were expected to exhibit similar trends, but they did not. Although average lumber value (\$/MLT) was the same for all logs from dead trees, the LRF was higher for the logs from trees that recently died. This caused the value per unit of log volume (\$/CCF) for logs from trees recently dead to be much higher than for logs from trees dead longer. Dollars per unit of log volume is considered the most important single indicator of value.

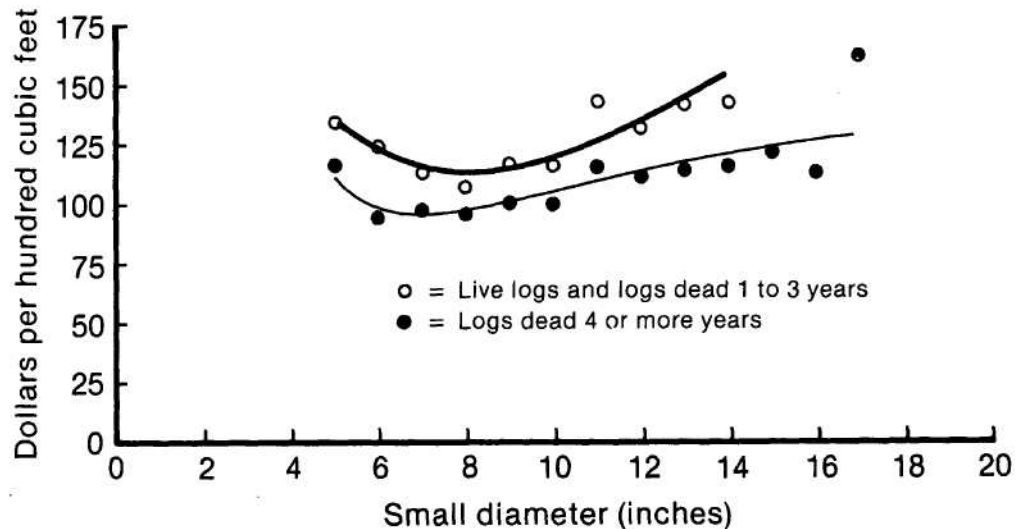


Figure 4.—Dollars per hundred cubic feet of gross log scale over diameter.

Logs from live lodgepole pine trees and from trees dead 1 to 3 years—

$$\$/\text{CCF} = -193.52 + 17.77(d) + 1,501.31(1/d) - 1,487.22(1/d^2).$$

Coefficient of determination = 0.063.

Standard deviation from regression = 33.06.

Logs from lodgepole pine trees dead 4 years or more—

$$\$/\text{CCF} = 224.86 - 1.21(d) - 1,624.33(1/d) + 5,417.63(1/d^2).$$

Coefficient of determination = 0.048.

Standard deviation from regression = 31.89.

Conclusions

Overrun for the logs from live trees and the logs from trees dead for 3 years was 44 percent, whereas the logs from trees dead 4 years or more had an average overrun of 24 percent. Because the logs did not have a wide range of diameters, there was not a strong correlation between overrun and diameter, even in the live and 1- to 3-year-dead classes.

Cubic recovery of surfaced-dry lumber by diameter class varied from 35 percent to 56 percent. Comparable figures for rough-green material were 43 to 61 percent. Average cubic recovery was about 10 percent more when it was based on rough-green lumber than when based on surfaced-dry lumber.

Stud recovery for the live sample was 86 percent of the total volume. For all the dead samples combined, it was 73 percent. For lumber grade distribution only, all the dead material could be combined. This is reflected in the \$/MLT values where there was no significant difference among time-since-death classes in the sample of dead trees.

This report indicates that for volume recovery only, less lumber was recovered from the older dead material than from the combined samples of logs from recently dead trees and from live trees. This relationship also holds for the value per unit volume of log (\$/CCF). For average value of the lumber produced, there was no difference among any of the dead samples; however, there is a clear distinction between the dead and the live samples.

Metric Equivalents

1 inch = 2.540 centimeters
1 foot = 0.305 meter
1 cubic foot = 0.028 cubic meter

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A total of 496 logs from lodgepole pine (*Pinus contorta* Dougl. ex Loud.) trees killed by the mountain pine beetle (*Dendroctonus ponderosae* Hopk.) were compared with 189 logs from similar live trees. Logs were processed through a stud mill. In most cases lumber recovery from trees dead 1 to 3 years was the same as that from live trees. Less cubic volume was recovered from trees dead 4 or more years. Recovery tables and curves are shown.

Keywords: Lumber recovery, lumber yield, dead timber, insect damage (-forest products, lodgepole pine, *Pinus contorta*, Rocky Mountain area.

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