Determining the Processed Cut Stock Recovery Rate from Standing Dead Beetle-Killed Lodgepole Pine Timber

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Abstract

Colorado's forests have been decimated by a mountain pine beetle outbreak. The mountain pine beetle introduces a blue-stain fungus into the trees, lowering the economic value of the wood. As a result, forest product manufacturing opportunities using beetle-killed trees are limited. One possibility is to use beetle-killed trees to make cut stock, which is lumber that has been cut into specified length, width, and thickness requirements from a cant, lumber, or glued-up panels. The White River Conservation District commissioned this study to determine if a relationship existed between the amount of time beetle-killed trees remain standing dead and the recovery rate for cut stock material from those trees. Conducted in north-central Colorado and south-central Wyoming, this study found that enough material does exist in beetle-killed lodgepole pine trees to produce cut stock but that a tree's diameter at breast height is a better predictor for the cut stock recovery rate from the logs rather than the time spent standing dead on the stump. Given the increasing likelihood that beetle-killed trees will blow down as time passes, incentives for increased beetle-killed wood utilization should be developed quickly.

The current mountain pine beetle (MPB; *Dendrochtonus ponderosae*) epidemic began over a decade ago and has impacted 3.3 million acres of Colorado's pine forests (Colorado State Forest Service [CSFS] 2014), which is an area approximately the same size as Connecticut. Across the western United States, the MPB has affected more than 23 million acres (Hubbard et al. 2014) or an area about the size of Indiana. The beetles initially attacked most of the state's lodgepole pine (*Pinus contortus* Douglas) trees. Aerial surveys conducted in 2012 recorded nearly imperceptible MPB activity levels in high elevation lodgepole pine forests as the state's supply of suitable host trees has been nearly exhausted; noticeable activity declined in the north-central part of the state and on the Western Slope. However, the MPB epidemic continues to spread through lower elevation ponderosa pine (*Pinus ponderosa* Douglas ex. C Lawson), lodgepole pine, and limber pine (*Pinus flexilis* E. James) stands along the northern Colorado Front Range. In 2013, 87 percent of MPB activity was recorded in Larimer County, in the north-central part of the state (CSFS 2013, 2014).

The swath of the epidemic is substantial and so are its related impacts (Mackes et al. 2010). Costs to remove beetle-killed trees and to remediate impacted forests remain high. Public safety is threatened by tree blowdowns and increased risk of fire. Recreation and tourism revenues are negatively impacted. Wildlife habitat is substantially altered, while watershed quality is degraded from increased sediment pollution. Furthermore, leftover insecticides from treating trees have been dumped down sewer drains by applicators or washed off of recently sprayed trees by rain; in Summit County, Colorado, carbaryl concentrations in the local run-off water were so high that they killed water fleas (Haythorn 2008). Given that the water is eventually released into the Blue River, these insecticides can kill water-borne insects that are relied upon by trout and other fish in prize-winning waters. Homeowners have also suffered as each MPB-killed tree within a 0.1-km (0.06-mi) radius around the home can lower property values by $648 (Price et al. 2010). However, real estate advertisements in Grand County, Colorado, have quickly adapted—instead of describing homes located in the forests, some realtors now promote homes with amazing open views.

Perhaps the most significant impact from the MPB epidemic is the loss of economic value in the beetle-killed trees. Timber value loss is assessed in terms of stumpage price, where stumpage is the raw material from which forest

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products are derived after felling, skidding, transporting, and milling. The stumpage price is based on its utility after a tree is cut and removed from the land and the current strength of the product markets. Stumpage is considered part of the land prior to being logged or cut. Stumpage losses can be severe. Estimates of stumpage losses caused by the MPB in Grand County, Colorado, conservatively approach $1 billion (Mackes et al. 2010).

Many reasons exist for the decreased value of wood products made from MBP-killed trees. Foremost, MPBs introduce a fungus into the wood that causes a bluish discoloration in the sapwood (Leatherman et al. 2007). This blue stain does not significantly alter the strength and stiffness properties of the wood because the fungus feeds on material inside the cell and not on the cell wall. However, discolored wood differs markedly in appearance from clearwood. Subsequently, consumers equate the blue stain with a defective product, similar to the way consumers might avoid selecting bruised produce.

Additionally, wood moisture content decreases rapidly as needles fade from green to dull red after the tree is killed. Within a period of months, wood moisture content can drop from 85 percent or more to 40 percent on an oven-dry basis (Lewis and Hartley 2006). Within 1 year, moisture content can drop below the fiber saturation point (FSP). After the wood's moisture content level drops below the FSP, the wood begins to shrink and significant checking will generally start to occur within 1 to 3 years after the tree dies. Rot is not a serious threat to the wood structure provided the tree has not blown over; once on the ground, however, the rate of decay progresses more rapidly (Lewis and Hartley 2006).

A number of responses for the MPB epidemic exist. Forestland owners and managers can attempt to safeguard valued trees by applying preventative chemical sprays or attaching anti-aggregating pheromone packets to the trees. However, sprays and packets have disadvantages. They are expensive and are only highly effective when applied or installed properly. Thinning forest stands through active forest management can help but it is time and labor-intensive and thus expensive. If active forest management occurs without generating revenue from product manufacture, then public and/or private managers may not recoup all or even some of their costs.

Alternatively, one way to reduce the impacts of the current MPB epidemic is to develop a sustainable, market-based model for reducing forest stand density using beetle-killed trees. By developing a product or products from the removed material, forest management costs may be partially or entirely offset. Using MPB-killed trees to produce cut stock that is finished with a transparent, semi-transparent or even a solid color where the blue stain is concealed is another possibility for reducing the amount of standing dead timber in Colorado. Cut stock is solid wood that has been cut into specified length, width, and thickness requirements from a cant, lumber, or glued-up panels.

Yet questions persist. How much of a standing-dead MPB-killed lodgepole tree can be used for cut stock? Does the amount of time the tree spends standing dead influence the rate of cut stock recovery? If not, what other factors may influence the recovery rate? The objective of this study was to determine what relationship, if any, exists between the amount of time an MPB-killed tree spends standing dead and the recovery rate for cut stock production from said trees.

To help answer these questions, this project tested two hypotheses:

- Hypothesis 1: Clear defect-free material exists within the standing-dead lodgepole pine that could be used in the millwork industry.
- Hypothesis 2: The recovery rate of defect-free material in a lodgepole pine tree changes based on how long that tree has been standing dead.

To test these hypotheses, the White River Conservation District (WRCD), which covers roughly the eastern two-thirds of Rio Blanco County in western Colorado, commissioned this study. The WRCD was interested in using MPB-killed lodgepole pine trees to make cut stock as a way to help offset the costs of tree removal and wanted to know what factors would help predict maximized cut stock recovery.

Methodology

The WRCD selected trees from the epicenter of the mountain pine beetle epidemic. Two sites were chosen: the Pelton Creek Collection Site located just north of Jackson County in south-central Wyoming and the Green Ridge Collection Site in south-central Jackson County, Colorado. These areas could be considered somewhat climatically similar, given the cold weather and similar annual precipitation totals, although the Wyoming collection site is comparatively dryer as it receives less precipitation (Prins 2011). The two collection sites were used in order to obtain a sufficiently large and diverse sample, and not for purposes of comparing results between sites.

An attempt was made to visually select and harvest a total of 40 trees from these two collections sites. Beetle-killed lodgepole pine trees were selected for each category based on cues from visual inspection (e.g., bark sloughing, checking, presence of needles or lack of needles) in addition to consultation with locally based US Forest Service personnel. Only five green trees were initially located for the control group because the supply of suitable green trees was scarce. Another 31 trees killed by MPBs that were estimated to have been standing dead from 1 to 9 years were identified and harvested. All 36 trees were felled over a 3-day period in September 2011. They were subsequently delimbed and topped.

To determine the length of time that the 31 noncontrol trees spent standing dead, cross-sections (''cookies'') were taken from the butt-end of each tree, and dendrochronological analyses were completed (see Fig. 1 for a sample rough plot of Tree 27). These analyses determined more precisely how old the trees were and, for the noncontrol trees, how many years the tree had been standing dead on the stump by pattern matching against the green trees. For example, in Figure 2, the Tree 27 plot shows the most recent 30 years for a green tree. The tree was harvested during 2011 and the first minimum point, i.e., where the increase in growth increment size, occurred during the year 2006. This point matched well with other trees that had been standing dead for several years, as shown with Trees 33 and 21. However, not all trees could be successfully pattern-matched, and subsequently seven trees were excluded from the analysis to determine if a relationship exists between recovery factor and length of time standing dead (see Table 1).

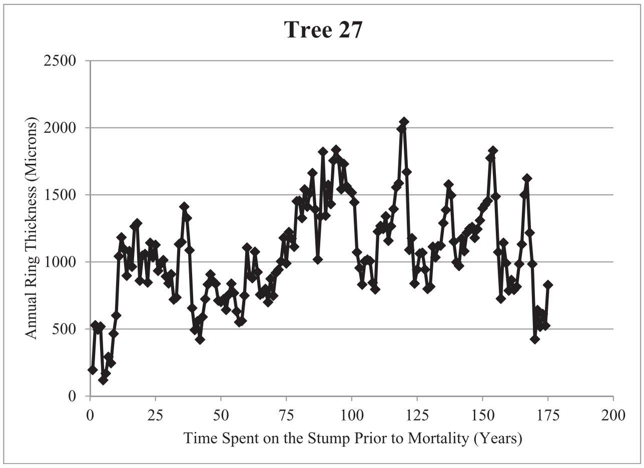

Figure 1.—Ring thickness versus time spent on the stump for Tree 27.

After verifying the times of death for the remaining trees, the tree-length logs were transported to Morgan Timber Products in Fort Collins, Colorado, for processing. For this project, the tree length log was considered the experimental unit. Both log segments and boards cut from these segments were considered to be replications, subsequently requiring a nested design. The reason for adopting this nested design is that defects within the tree, such as checks, tended to impact multiple boards (cut stock) cut from the same tree. For instance, some checks often went through three or four

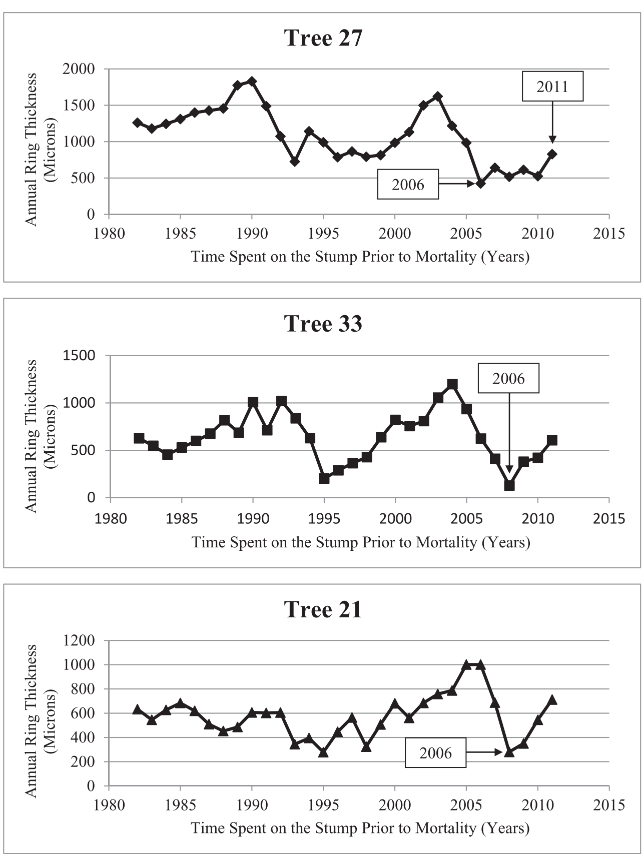

Figure 2.—A comparison of three tree plots from three different trees.

Table 1.—Time spent standing dead for the 36 harvested trees.[a]

Tree ID no.	Year killed (determined by dendrochronology)	No. of years beetle-killed tree spent standing dead
1	2011	0
2	2003	8
3	2011	0
4	2004	7
5	2003	8
6	2004	7
7	2007	4
8	2008	3
9	ND	ND
10	ND	ND
11	ND	ND
12	2010	1
13	2010	1
14	2004	7
15	2009	2
16	2010	1
17	2002	9
18	2010	1
19	2009	2
20	ND	ND
21	2009	2
22	2011	0
23	ND	ND
24	2009	2
25	2010	1
26	2011	0
27	2011	0
28	2011	0
29	2011	0
30	ND	ND
31	2003	8
32	2011	0
33	2009	2
34	ND	ND
35	2009	2
36	2009	2

[a] ND = the time of the tree's death could not be determined.

boards, so they were impacted by the same defect; thus, these boards were not independent samples. Each tree-length log was subsequently bucked into four, five, or six 8.5-foot-long segments, and then multiple boards were made from each segment.

The boards were then evaluated to determine how much cut stock product could be recovered. Log volumes, measured in cubic feet, were calculated by measuring the large-end and small-end diameters and using Smalian's formula, which assumes that the basal area of logs vary uniformly over their length:

$$V = [(BA_1 + BA_2)/2] \times L$$

where

V = log volume,

BA_1 = basal area of log's small end,

BA_2 = basal area of log's large end, and

L = log length in feet (8 feet in all cases).

Log segments were then sawn into cants using a custom Skragg mill with a 5/16-inch saw kerf; boards were recovered from slabs whenever possible. Cants were then sawn into boards that were 8.5 feet long by 1 inch thick and of random widths. The processed boards were then transported to the CSFS Foothills Campus in Fort Collins, for estimating the percentage of 1-inch-thick by 2-inch-wide cut stock present in the boards. These dimensions were selected because they would most accurately estimate cut stock volume in terms of quantity and quality for high-value end-uses in the millwork industry.

Forestry students from Colorado State University (CSU) and trained volunteers with the CSFS assessed the percentage of defects in the boards. To assess the defect percentage, a five-step process was used. First, the cubic foot volumes of the tree-length logs and of each log segment were determined. The length of each log segment was assumed to be 8.5 feet. After breakdown, boards were also assumed to be 8.5 feet in length, and the widths and thicknesses of each board were measured using hand calipers to determine nominal dimensions. Second, using these dimensions, the gross nominal cubic foot volume of merchantable lumber was determined. Third, the nominal volumes of any wood defects present were measured. Blue stain was not considered a defect. In the case of cut stock, especially when painted, stained, or even naturally finished, blue-stained product can sometimes carry a premium. However, in the case of visually graded boards, blue stain is considered a defect and earns a lower grade. Knots, cracks (checks), rot, and borer holes were also evaluated as defects. Fourth, defect volumes were subtracted from gross merchantable volume to arrive at the net volume of cut stock recovered for each piece. Finally, after deducting for various defects, the net volume (board feet) of clear wood (1-in.-thick by 2-in.-wide boards) was determined for each log and divided by the original gross log volume (cubic feet) to determine the cut stock recovery factor.

Then, a statistical analysis (ANOVA) was conducted to determine if relationships existed between the length of time timber spent standing dead and clear wood (1-in.-thick by 2-in.-wide boards). The length of time the tree spent standing dead was compared with cut stock yield for each tree as a unit and log segment. After the boards were evaluated, they were transported to a sawmill in Ault, Colorado, operated by Andy Hinz and were converted into various products. Mr. Hinz roughly determined the board volume that was actually useable for cut stock products.

Results

- Hypothesis 1: Clear defect-free material exists within the standing-dead lodgepole pine that could be used in the millwork industry.

The small-end diameter, the log length, gross cubic foot volume, defect volume, net board foot volume, and cut stock volume were calculated for each segment for all trees. Also, the average cut stock recovery factor was also calculated. Table 2 shows the aggregate data for each tree. For the volumes, the table shows the total volume per tree. For the cut stock recovery factor, the table shows the average number of board feet recovered per cubic foot for the total log. On average, roughly 3.6 board feet of cut stock material (recovery factor range: 2.65 to 4.66 bf/cf) can be removed for every cubic foot of beetle-kill lodgepole pine wood.

- Hypothesis 2: The percentage of defect-free material in a lodgepole pine tree changes based on how long that tree has been standing dead.

Using the nested design with the tree as a sample unit did not provide a significant benefit ($P = 0.210$). Therefore log segment data were considered independently in subsequent analyses. Based on an ANOVA test comparing the amount of time a tree spent standing dead compared with the amount of cut stock recovered, there was a statistically insignificant relationship ($P = 0.318$). Concluding that there was an insignificant relationship between the cut stock recovery factor and the time a tree spent standing dead allowed for the use of all data in the final analysis of the cut stock recovery factor and small-end log diameter. Analysis results revealed that there was a weakly correlated relationship ($R^2 = 0.356$) that was highly significant ($P = 0.000$). The following quadratic equation fit the data best:

$$y = -0.698 + (0.587 \times \text{tree diameter}) + (-0.917 \times \text{tree diameter squared})$$

Figure 3 shows this equation plotted on a chart that compares the diameter class of a tree in inches to the cut stock recovery factor.

Discussion

The data above indicate that material exists in beetle-killed lodgepole pine trees to make cut stock products, which supports Hypothesis 1. The data also disprove Hypothesis 2. The amount of time that a tree stands dead was not significant, which does not support the general premise that increasing the amount of time spent dead on the stump would lead to more checking and other defects, thus reducing the amount of cut stock recovered from the tree. Generally, beetle-killed trees that were standing dead for over a year had a much higher incident of checking than green trees or recently killed trees. While this might present a serious problem for recovering widths greater than 2 inches (particularly 8- to 10-in. widths), it was often possible to minimize the impact of the check when recovering relatively short lengths of narrower width. For the majority of trees, as a log's small-end diameter increases, cut stock yield increases, too.

After completing the analysis, the boards were transported to a small sawmill in Ault, Colorado, where they were milled into finished products. To corroborate the study's results, the mill owner was asked to measure the reported cut stocky recovery yield. Mr. Hinz reported that only about 60 percent of the material could actually be made into product, a slight reduction from the measured finding (average cut stock recovery percentage was 74%). The unusable 40 percent consisted of 25 percent lost due to checking and 15 percent due to variations in the material thickness. In the original analysis, material thickness variability was not considered to be a defect. Had the material thickness been more uniform, the percentage of material would have increased to 75 percent, which is very close to the measured 74 percent average.

These data apply to beetle-killed trees with comparatively recent mortality that remain standing on the stump. The oldest tree in this study had been dead for 9 years, but most trees had been standing dead for considerably less time. Furthermore, beetle-killed trees typically begin to blow down between 3 and 7 years after mortality. Within 15 years after mortality, about 90 percent of beetle-killed trees will

Table 2.—*Cut stock volume measurements and percentages for the 36 harvested trees.*

Tree ID no.	Small-end diam. (in.)	Total log length (ft)	Gross lumber vol (bf)	Lumber defect vol (bf)	Net vol of 1×2 cut stock (bf)	Cut stock recovery factor (bf/cf)	Percentage of cut stock recovered from lumber
1	8.50	42.50	126.08	29.71	96.38	3.41	76.44
2	9.20	34.00	141.67	33.13	108.54	3.05	76.62
3	8.00	34.00	120.42	32.32	88.10	3.50	73.16
4	6.80	42.50	144.50	42.08	102.42	3.73	70.88
5	8.50	34.00	151.58	30.22	121.36	4.63	80.06
6	7.00	34.00	87.83	23.27	64.57	3.70	73.51
7	7.30	51.00	151.58	39.04	112.54	3.17	74.24
8	7.40	42.50	96.33	21.16	75.17	3.88	78.04
9[a]	7.20	34.00	96.33	26.40	69.93	3.50	72.59
10[a]	6.60	34.00	87.83	24.65	63.18	3.41	71.93
11[a]	7.20	34.00	96.33	22.20	74.13	3.46	76.95
12	8.40	51.00	269.17	59.94	209.22	3.92	77.73
13	11.40	42.50	235.17	44.10	191.07	4.00	81.25
14	6.50	34.00	109.08	37.44	71.65	3.66	65.68
15	8.30	34.00	96.33	29.11	67.23	3.08	69.79
16	8.50	42.50	154.42	44.79	109.63	3.42	70.99
17	6.60	34.00	87.83	21.36	66.47	3.29	75.68
18	6.40	51.00	36.83	14.12	22.72	2.65	61.67
19	6.00	42.50	168.58	39.21	129.37	3.54	76.74
20[a]	7.40	51.00	161.50	52.28	109.22	3.51	67.63
21	9.00	34.00	124.67	30.22	94.45	3.33	75.76
22	8.30	42.50	189.83	48.92	140.91	4.01	74.23
23[a]	7.20	42.50	117.58	40.37	77.22	3.66	65.67
24	6.30	51.00	155.83	42.24	113.60	4.51	72.90
25	9.50	42.50	127.50	38.09	89.41	3.26	70.13
26	7.90	42.50	148.75	31.51	117.24	4.18	78.81
27	5.70	51.00	133.17	35.08	98.08	3.16	73.66
28	6.50	42.50	87.83	22.62	65.22	3.59	74.25
29	7.40	51.00	147.33	38.72	108.61	3.93	73.72
30[a]	10.00	51.00	254.93	40.85	210.08	4.13	82.41
31	5.80	42.50	124.67	33.02	91.65	2.99	73.51
32	7.00	42.50	113.33	26.35	91.23	4.23	80.50
33	12.20	34.00	228.08	50.57	177.51	4.66	77.83
34[a]	7.80	51.00	157.25	43.70	113.55	3.21	72.21
35	7.90	42.50	162.92	35.76	127.16	3.52	78.05
36	6.50	42.50	107.67	30.35	77.32	3.12	71.81

[a] The tree was not considered in regression analysis of cut stock yield versus time standing dead, but was included in analysis comparing diameter class to cut stock yield.

be on the ground. Because the current MPB epidemic has raged for over a decade, the amount of blowdown will increase dramatically in the immediate future. Once on the ground, beetle-killed trees will deteriorate faster.

These data suggest that material from beetle-killed trees exists in quantity that cut stock producers could utilize, but they should look for larger diameter class trees and act quickly as the epidemic is approaching the 15-y/90% mark. It is still uncertain that cut stock would have enough value to offset the costs associated with felling, transporting, and processing. To reduce the costs for hazardous fuels reduction, producers should develop the full-value product chain so that more of the tree is usable, and do so as quickly as possible while trees remain standing. Co-locating solid wood product facilities with wood energy product producers (i.e., pellet mills) makes sense as transportation costs can approach half or more of total treatment costs; co-locating facilities minimizes transportation distances and reduces the amount of handling required, subsequently reducing manufacturing costs (e.g., Pan et al. 2007). The residue or ''waste'' material from one operation would become the feedstock for the other. Waste material produced when manufacturing higher value solid wood products, like cut stock, could be used to manufacture other wood products, such as mulch for landscaping, shavings for animal bedding, or sawdust for wood pellets. Carl Spaulding, president of the Colorado Timber Industry Association, remarked that ''the cheapest wood chip rides on the back of a 2 × 4,'' indicating that wood product producers should strive for increased utilization of wood material whenever possible to minimize expenses and maximize revenues (Gaul 2010).

Cut stock producers may need assistance with processing costs and financing/capital for facilities. To help further incentivize cut stock and wood product manufacturing, statewide policies could help. Developing projects and incentives that encourage the use of Colorado-produced wood products from beetle-killed trees would further decrease continued reliance on imported wood products and increase demand for domestic timber sources. In Colorado, between 90 and 100 percent of forest products

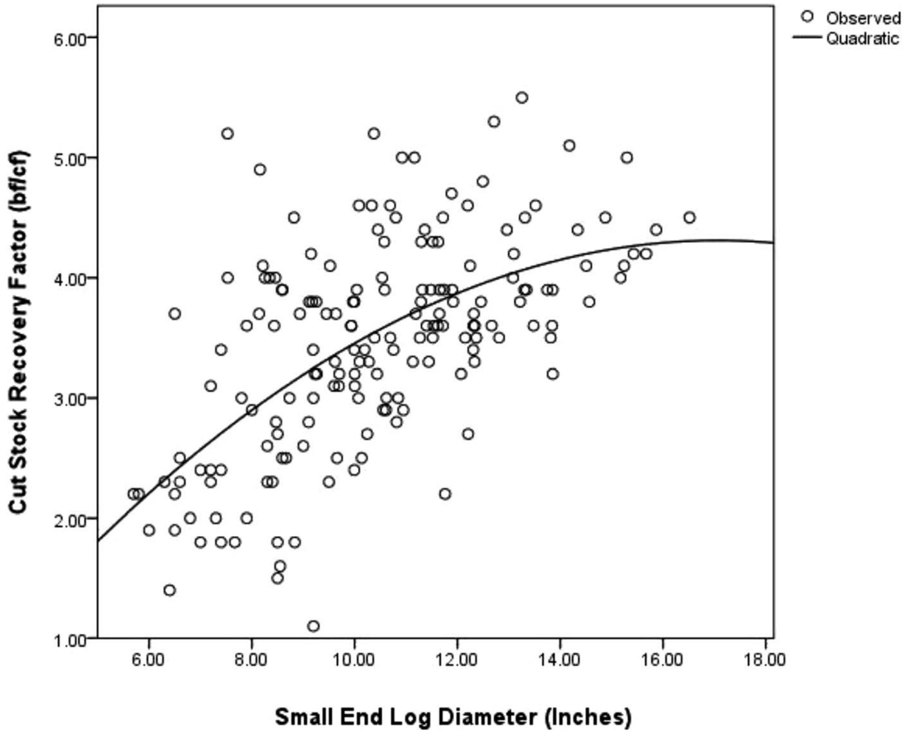

Figure 3.—Cut stock recovery factor versus small end log diameter.

are imported, depending on the product segment (Lynch and Mackes 2001). Encouraging domestic forest product manufacture and consumption in Colorado using beetle-killed trees would help with active management while reducing this impact. To Colorado's credit, the Colorado General Assembly passed House Bill 12-1045, which exempts wood products made from MPB-killed trees from sales tax until July 1, 2020.

Another possible approach is for the state to strengthen programs already in existence. For example, the CSFS operates a ''Colorado Forest Products'' (CFP) program, a companion program to the Colorado Department of Agriculture's ''Colorado Proud'' program, which is a branding program for the state's agricultural products. The CFP program is a free marketing and branding program available to any forest products producer whose finished product obtained at least 50 percent of its wood from Colorado forests. CFP members have access to a logo to use on their packaging, listing on a free, searchable database and raised visibility through the program's statewide advertising efforts such as its recent public service announcements.

By using branding to convey product information to consumers, the increased awareness of the link between poor forest health conditions and the decline of the state's forest products industry may help reverse the deteriorating conditions. By increasing utilization among beetle-killed trees to reduce forest fuel loads, produce wood products sustainably for market while lessening the taxpayer burden would provide the greatest return on public investment while improving public safety and local economies. Using MPB-killed trees to manufacture cut stock and complementary wood products represents one possibility for achieving forest management objectives while reducing costs.

Conclusions

This study evaluated what relationship, if any, exists between the amount of time an MPB-killed tree spends standing dead and the recovery rate for cut stock production from said trees. Findings from this study revealed that material exists in beetle-killed trees capable of being processed into 1 by 2-inch cut stock. No statistically significant relationship exists between the percentage of cut stock yield from green living trees and beetle-killed trees that had been standing dead for up to 9 years, which suggests that there is a longer window of opportunity for utilizing beetle-killed trees to produce cut stock than wider dimensional lumber. However, the data support a weakly correlated yet significant relationship between the small-end log diameter and the amount of cut stock that can be recovered from the tree. Finally, finding ways to incentivize cut stock production from MPB-killed trees quickly, such as through policy incentives or marketing assistance, would help ensure the opportunity to utilize MPB-killed trees is not wasted as the epidemic in Colorado persists.

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