YELLOW-CEDAR SALVAGE LOGGING IN SOUTHEAST ALASKA:

Case studies reveal large variation in producer efficiency and profitability

December 2019

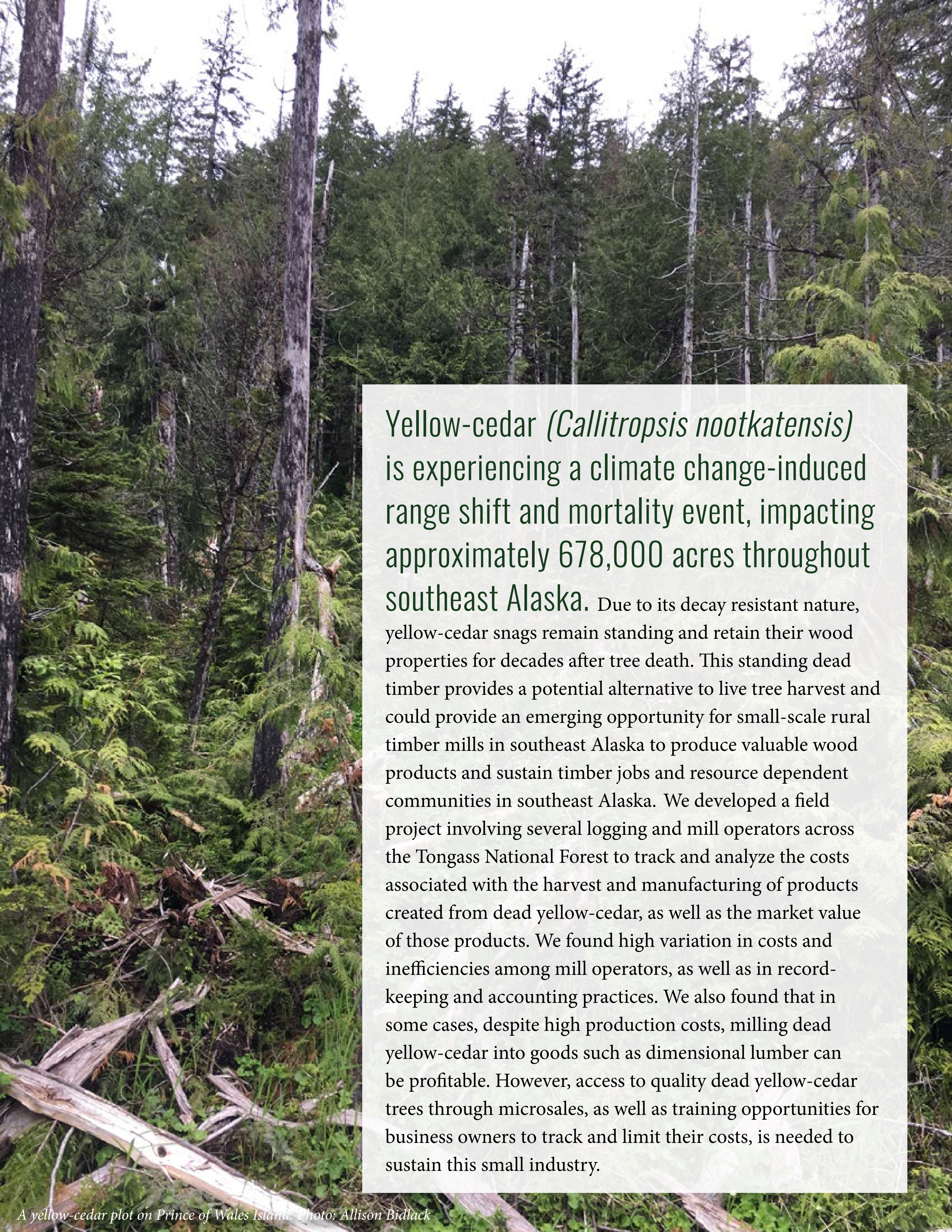
Allison Bidlack[1], Brian Buma[2], Sarah Bisbing[3], Brian Vander Naald[4]

[1] Alaska Coastal Rainforest Center, University of Alaska Southeast, 11066 Auke Lake Way, Juneau, AK 99801; albidlack@alaska.edu

[2] Department of Integrative Biology, University of Colorado – Denver, 1151 Arapahoe St, Denver, CO 80204

[3] Department of Natural Resources & Environmental Science, University of Nevada – Reno, 1664 N. Virginia St, Reno, NV 89557

[4] College of Business and Public Administration, Drake University, 2507 University Ave, Des Moines, IA 50311



Yellow-cedar *(Callitropsis nootkatensis)* is experiencing a climate change-induced range shift and mortality event, impacting approximately 678,000 acres throughout southeast Alaska. Due to its decay resistant nature, yellow-cedar snags remain standing and retain their wood properties for decades after tree death. This standing dead timber provides a potential alternative to live tree harvest and could provide an emerging opportunity for small-scale rural timber mills in southeast Alaska to produce valuable wood products and sustain timber jobs and resource dependent communities in southeast Alaska. We developed a field project involving several logging and mill operators across the Tongass National Forest to track and analyze the costs associated with the harvest and manufacturing of products created from dead yellow-cedar, as well as the market value of those products. We found high variation in costs and inefficiencies among mill operators, as well as in record-keeping and accounting practices. We also found that in some cases, despite high production costs, milling dead yellow-cedar into goods such as dimensional lumber can be profitable. However, access to quality dead yellow-cedar trees through microsales, as well as training opportunities for business owners to track and limit their costs, is needed to sustain this small industry.

A yellow-cedar plot on Prince of Wales Island. Photo: Allison Bidlack

INTRODUCTION

Yellow-cedar (*Callitropsis nootkatensis*) is a culturally and economically important tree species in Alaska and the Pacific Northwest. The tree has been used by Native peoples for millennia, with its bark used in weaving and its naturally decay-resistant wood carved into house posts and totem poles, paddles, containers, and other items. In recent decades, the species has acquired commercial value as well, particularly for use in outdoor applications such as decking and fencing, to replace chemically-treated lumber in applications such as play structures, and as a substitute for overharvested Hinoki cypress (*Chamaecyparis obtusa*) in Asia. Yellow-cedar is used by small mill operators and personal users throughout southeast Alaska to produce dimensional lumber, posts, countertops, siding, decking, flooring, shingles/shakes, cabinets/furniture/trim, totem poles, wood paneling, bentwood boxes, and outdoor furniture.

Yellow-cedar populations are currently experiencing climate change-induced mortality, impacting approximately 678,000 acres throughout southeast Alaska (USFS 2018). Decreasing snowpack leads to shallow root freezing and tissue mortality during spring frosts in trees that are growing in wet soils. One or more freezing events can ultimately lead to tree death (Hennon et al. 2012). However, due to its decay-resistant nature, dead yellow-cedar remain standing and retain their wood properties for decades after tree death (MacDonald et al. 1997; Hennon et al. 2000; Green et al. 2002; Kelsey et al. 2005). This standing dead timber provides a potential alternative to live-tree harvest, as old-growth logging in the region continues to provoke controversy. The salvage harvest of dead yellow-cedar could provide an emerging opportunity for small-scale rural timber mills in southeast Alaska to produce value-added wood products and provide another means of sustaining timber jobs and resource dependent communities surrounded by the Tongass National Forest. This is timely given the challenges of maintaining an industry as the US Forest Service (USFS) transitions to predominantly young-growth management and harvest in the Tongass over the next 15 to 20 years.

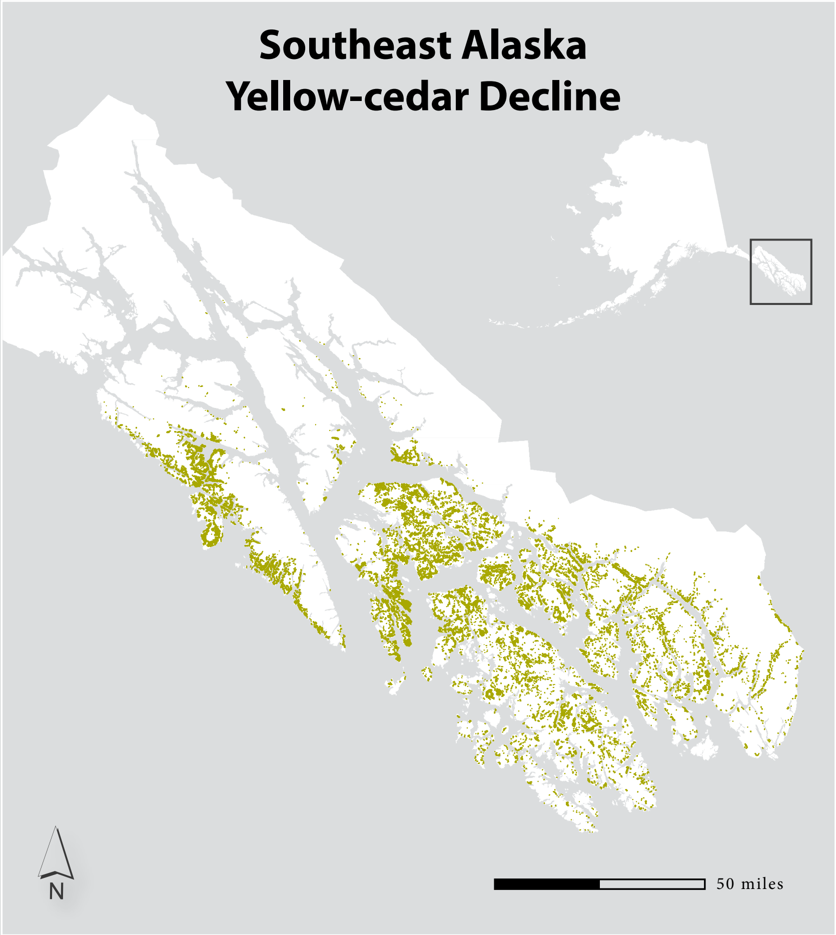


Figure 1. Cumulative yellow-cedar decline in southeast Alaska as of 2018 (USFS 2018).

Yellow-cedar trees remain standing long after tree death due to their decay-resistant wood.

Yellow-cedar is one of four commercial species of trees found in the region; of those four species it has the smallest forest presence based on volume, and its market value has varied widely over time (USFS 2019a). Over the past five years the majority of live yellow-cedar harvested in southeast Alaska has been exported in the round to Asia (USFS 2019b), but round log export markets are hesitant about, and generally have not purchased, logs from standing dead trees (Clark pers. comm.). In contrast, many small-scale mills in southeast Alaska are interested in and willing to salvage and process dead yellow-cedar. However, because most yellow-cedar is exported in the round, there has been little ability for the USFS to track costs associated with processing live or dead yellow-cedar or to examine the market for value-added products created by small mills. Over the past several years, we repeatedly met with researchers, agency managers, and mill operators to better understand the economics of yellow-cedar salvage in southeast Alaska. One outcome of these discussions was the realization that the data to address questions about the supply and demand sides of the yellow-cedar salvage market do not exist.

Here we examine the feasibility of harvesting, transporting, and manufacturing products from standing dead yellow-cedar. We set up a demonstration project with the following objectives: 1) track the volume and kinds of timber products created from salvaged yellow-cedar; 2) record and analyze the costs associated with the harvest and manufacturing of these products; 3) examine the market value of those products and the revenue generated; and 4) provide mill operators with a basic understanding of cost accounting to improve their business skills. By gathering cost and revenue data, this project acts as a case study for determining whether it is feasible for southeast Alaskan small mill operators to create value-added wood products from standing dead yellow-cedar, and to what market extent this feasibility exists. We seek to grow a deeper understanding of the value-added yellow-cedar product market in southeast Alaska. We identify inefficiencies on the producer side of the market, and determine some of the economic challenges and benefits to communities of further developing these markets in the region.

METHODS

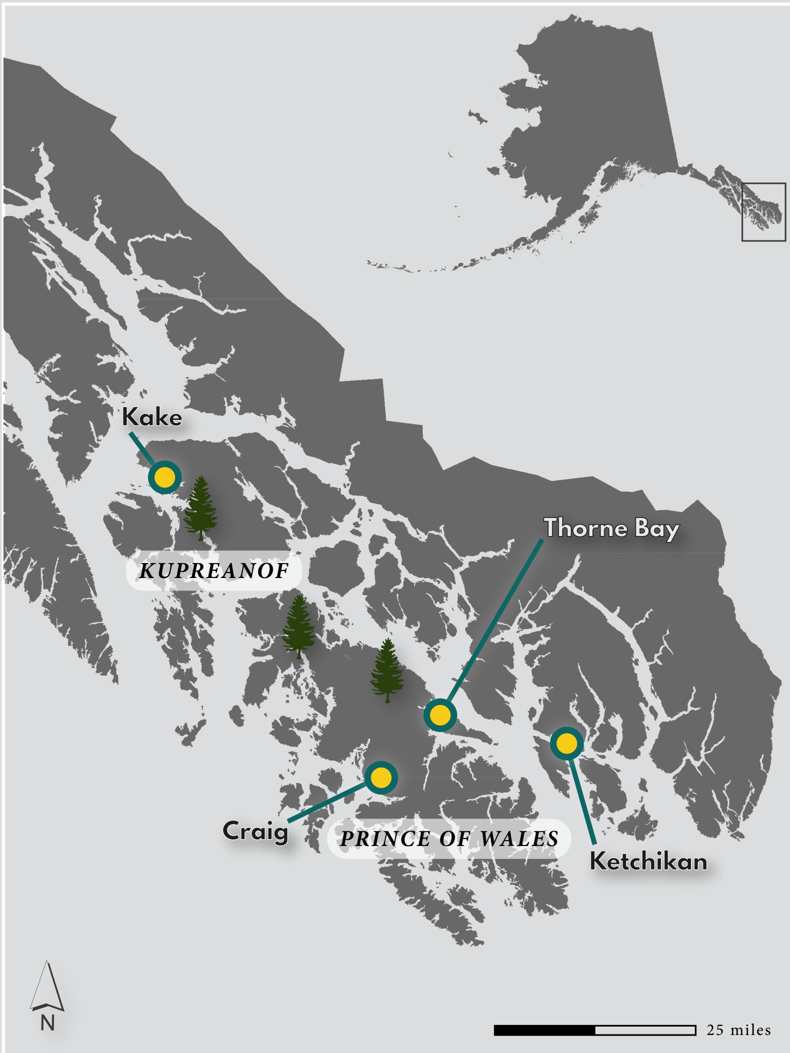


Figure 2. Location of salvage logging sites (trees) and mill operations (circles).

We focus on two islands in southeast Alaska with large areas of yellow-cedar decline: **Kupreanof** and **Prince of Wales** islands.

Kupreanof Island is part of the Tongass Special Treatment Area designated under Section 8204 of the 2014 USDA Farm Bill due to the large areas of yellow-cedar decline. It has one community on it, Kake, and two small mills. Prince of Wales Island (POW) is home to several small logging and mill operations in the communities of Thorne Bay, Naukati, and Craig. Suitable roadside salvage logging areas were chosen by identifying zones of yellow-cedar decline within 250 feet of roads which contained trees at least 12 inches in diameter at breast height and a range of snag age classes. These distance and size criteria were used to limit the salvage stands to those easily accessible to small operators and which would have trees large enough for traditional milling equipment. Percentage of basal area of these stands in yellow-cedar ranged from 7% to 67%, with a mean of 41%, and the proportion of yellow-cedar that were dead ranged from 4% to 99%. Despite mortality occurring over varying ecosystem types and conditions, forested wetlands and steep slopes were avoided to reduce the probability of impacts to soils and watercourses (FRPA, AS 41.17). All trees on Kupreanof were within a timber sale unit NEPA-cleared under the Central Kupreanof ROD (USFS 2011), and those from POW met the requirements for eligibility to be harvested under the Roadside Salvage EA. Additional dead trees were harvested from off the POW road system and were part of the ongoing US Forest Service Big Thorne timber sale (USFS 2013; Figure 2). For the roadside logging, we contracted two loggers, one from each island. The logger from Kupreanof personally marked each tree to be harvested (he was also the mill operator of Mill E; see below); Petersburg Ranger District foresters then cruised the trees, estimating the volume of timber (gross and net Scribner scale). Trees on Kupreanof were harvested by hand and by using a self-loading log truck.

On POW, we marked trees for harvest, and then Craig Ranger District foresters marked and cruised trees in the same general area that we marked trees; however, this included trees we did not mark and did not include all of the trees marked by us due to other resource concerns. Trees on POW were harvested by a logger (who was not affiliated with any mill) by hand and by using a rubber-tired shovel loader with choker and hydraulic drum and cable. For cost comparison with road-based methods, additional, non-roadside accessible trees on POW were selected and cruised by Viking Timber and logged using helicopters for extraction.

Detailed data on all trees harvested were kept by loggers on log sizes, number of personhours needed for the logging operation, gallons of fuel used, and other consumables. Actual costs were calculated using these data. Distinct from actual costs were contracted logging costs, which was the agreed upon amount of money the loggers would be reimbursed by us for their efforts. Transportation costs from logging site to mill, such as gallons of fuel used, mileage, and person-hours, were included in the contracted logging costs with the exception of the costs to barge logs from POW to a mill in Ketchikan. Contracted logging costs (as opposed to actual costs) were used in the mill revenue calculations (below). Logs were delivered to five southeast Alaska mills that represent a suite of operation sizes and product capabilities. Number of logs delivered to each mill were based on capacity. Mills A and B are located in Thorne Bay on POW; Mill C is located in Craig on POW; Mill D is located in Ketchikan; and Mill E is located in Kake on Kupreanof. Mill operators tracked the size and estimated volume of logs received, volume milled, and types and amounts of resulting products (e.g., dimensional lumber, beams, and firewood). Overrun was used as an indicator of milling efficiency: the larger the number, the more efficient was the milling operation at extracting value-added products from the lumber they received. Operators also tracked the entire suite of explicit costs along the production process, including cost of labor and cost of operating machinery. Once milled, operators noted the market value of products created from the milling process, and provided qualitative comments on products and potential markets, the quality of the wood, the business opportunities around dead yellow-cedar, and any lessons learned.

One of the mills involved in the study.. Photo: Allison Bidlack

RESULTS

Table 1. Number of trees logged, mean lengths and small-end diameters of logs, mean Gross Scribner (Northwest Log Rules Advisory Group 1969) scale per tree, and costs for logging (MBF; thousand board feet).

Location	# trees salvaged	Mean log length (ft)	Length range	Mean log dia (in)	Diameter range	Gross Scribner scale	Logging cost/MBF*
Kupreanof	48	18	8 - 40	13	6 - 34	110	$159 ($316)§
POW road	195	29	10 - 40	11	6 - 34	120	$350 ($400)
POW helicopter	61	30	16 - 40	13	6 - 26	180	$700 ($600)

*Costs/MBF include actual costs with contracted costs in parentheses. § Actual costs do not include equipment (capital).

Logging

Kupreanof Island

Sixty-six dead yellow cedar trees were marked for harvest on Kupreanof Island near the community of Kake. Petersburg Ranger District foresters cruised the 66 trees and estimated the volume to be 8.79 thousand board feet (MBF) gross Scribner and 4.10 MBF net Scribner. Of the 66 marked trees, 48 were harvested. The remainder were culled or left standing due to defect or because if felled they would be beyond the ability of the logger to yard with the available equipment. All logs were transported by the logger via truck to his mill in Kake (Mill E). Logging costs were calculated at $159/MBF and included time, fuel, and materials, but excluded capital costs such as depreciation and equipment maintenance, thus underestimating actual costs. The up-front contract price paid for logging was $316/MBF (Table 1).

Prince of Wales Island -harvested by ground-based methods

We marked 106 dead yellow-cedar trees for harvest on POW (Table 1). The USFS marked and cruised 182 trees in the same general area that we marked trees and estimated that these 182 trees contained 27.99 MBF gross Scribner volume and 13.20 MBF net Scribner volume. 195 yellow-cedar were ultimately logged within the cruised area, with eleven more trees, which were not marked by us or the USFS, cut during harvest operations for safety purposes or to allow for the harvesting of marked trees. Eleven of the cut yellow-cedar were culled and left on the ground due to rot or other deficiencies. Logs were delivered to two mills on POW (Mills A and B) via truck and to one mill in Ketchikan (Mill D) via commercial barge. Actual costs were calculated at $350/MBF; contractual costs equaled $400/MBF.

Prince of Wales Island - harvested by helicopter

Viking Lumber harvested 61 dead yellow-cedar trees by helicopter on POW (Table 1). The gross volume equaled 13.8 MBF Scribner, while the net volume was estimated at 9.6 MBF Scribner. All of this volume was provided to a single small mill on POW (Mill C). True costs were calculated at $700/MBF and included helicopter time, labor, capital equipment, and commodities; invoiced costs were $600/MBF.

Milling

Mill A (Thorne Bay, POW) received logs from the ground-based logging operation on POW, with an estimated volume of 9.40 MBF gross Scribner. They milled 1.77 MBF of 1x and 2x dimensional lumber, 1.33 MBF in other dimensional products, and 5.28 MBF in firewood, for a total of 8.38 MBF. Gross revenue equaled $6,457, while total costs equaled $9,029. This equated to a net negative return of $307/MBF (Table 2).

Mill B (Thorne Bay, POW) received logs from the ground-based logging operation on POW, and calculated a volume of 3.38 MBF gross Scribner. They milled 2.09 MBF of 1x and 2x dimensional lumber, 1.63 MBF in other dimensional products including live edge slabs, and 0.1 MBF in firewood, for a total of 3.82 MBF. Gross revenue equaled $5,377, while total costs equaled $2,933. This equated to a net positive return of $639/MBF (Table 2).

Mill C (Craig, POW) received all the logs from the helicopter-based logging operation on POW, and calculated this volume at 8.2 MBF gross Scribner. They milled 2.65 MBF 1x and 2x dimensional lumber; 5.74 MBF other dimensional products; 3.77 MBF firewood, for a total of 12.16 MBF. Gross revenue equaled $16,118, while total costs equaled $11,893. This equated to a net positive return of $348/MBF (Table 2).

Mill D (Ketchikan) received logs from the ground-based operation on POW and measured a volume of 16.53 MBF gross Scribner. They milled 7.44 MBF 1x and 2x dimensional lumber, some of which was subsequently used for fencing and oyster farm floats, 10.52 MBF in other dimensional products, and 5.00 MBF in firewood, for a total of 22.96 MBF. Gross revenue equaled $55,806, while total costs equaled $21,676. This equated to a net positive return of $1,488/MBF (Table 2).

Mill E (Kake) calculated that 16.16 MBF gross Scribner were harvested and brought to the mill. They milled 5.80 MBF 1x and 2x dimensional lumber, 0.59 MBF in other dimensional products plus slabwood for counters, and 5.74 MBF in firewood, for a total of 12.13 MBF. Gross revenue equaled $13,790, while total costs equaled $14,233. This equated to a net negative return of $37/MBF (Table 2).

Stacks of yellow-cedar dimensional lumber. Photo: Clarence Clark

Table 2. Volume of timber processed at each mill, and associated costs and revenue.

Mill	A	B	C	D	E
Estimated Gross Volume (MBF)	9.40	3.38	8.20	16.53	16.16
Dimensional Volume (1X, 2X; MBF)	1.77	2.09	2.65	7.41	5.80
Volume Other Products (MBF)	1.33	1.63	5.37	10.52	0.59
Total Volume Sawn (MBF)	3.09	3.72	8.39	17.94	6.39
Firewood (MBF)	5.28	0.10	3.77	5.00	5.74
Total Manufactured Volume (MBF)	8.37	3.82	12.16	22.94	12.13
Overrun §	0.75	1.14	1.89	1.56	0.61
Gross Revenue	$6,457	$5,377	$16,118	$55,806	$13,791
Contracted Logging Cost *	$3,848	$1,537	$5,748	$6,940	$5,104
Contracted Logging Cost/MBF	$400	$400	$600	$400	$316
Milling Cost	$2,803	$1,396	$4,695	$6,751	$5,628
Milling Cost/MBF	$906	$375	$560	$376	$880
Firewood Processing Cost	$2,379	$0	$1,450	$375	$3,502
Barge Transportation Cost¥	$0	$0	$0	$7,610	$0
Total Costs	$9,029	$2,933	$11,893	$21,676	$14,234
Net Revenue	-$2,572	$2,443	$4,225	$34,131	-$443
Net Revenue/MBF	-$307	$639	$348	$1,488	-$37

§Overrun is equal to the volume sawn divided by the estimated gross volume minus the firewood volume. It is a measure of log quality and reflects the amount of product that is milled in excess of the estimated gross volume (based on the small end diameter of a log).

*Contacted logging costs were the agreed upon amounts of money the loggers would be reimbursed by us for their work, including transportation from logging site to mill. This differs from the actual logging costs that include labor, equipment ownership costs, consumables, and helicopter time (see Table 1).

¥Barge transportation costs are from POW to Ketchikan.

Discussion

Cost analysis and wood products

This study allowed us to compare costs and returns from different harvest methods, types of mills, and locations to assess the economic viability of dead yellow-cedar harvest and the capacity of the industry to take advantage of this resource. The most striking result was the heterogeneity in net return among mill operators, ranging from -$307/MBF to $1488/MBF. This resulted from several factors, one being that the two mill operators with negative returns (Mills A and E) were those that produced a large amount of firewood from their logs (63% and 47% of manufactured volume, respectively), which has a relatively low value compared with dimensional lumber. It is hard to determine whether this was due to lower-quality wood, higher individual standards for wood quality, or to time and mill constraints. Because Mill A received logs from the same site as Mills B and D, it is unlikely that the quality of the wood was an issue. However, the operator of Mill A expressed a desire to mill only the highest quality wood. Operator E on the other hand reported that the quality of the wood on the site he was allowed to log was not high, and he indicated that he was in a rush at the end of the project period and so may have converted more of the logs to firewood than normal.

Another factor contributing to the large differences in net revenue was the value assigned to finished products. All mills except for Mill D assessed or sold dimensional products for approximately $1.50/BF. Mill D assessed value at $3/BF, but because these products were not sold on the open market and used internally for co-owned businesses, this raises questions about their real market value. If the value assigned to Mill D's products were brought in line with the other mills at $1.50/BF, their net return would equal $315/BF, more similar to Mill C. However, it should be noted that Ketchikan is a larger market and it is possible that dimensional yellow-cedar products can be sold for higher prices there than on POW or in Kake.

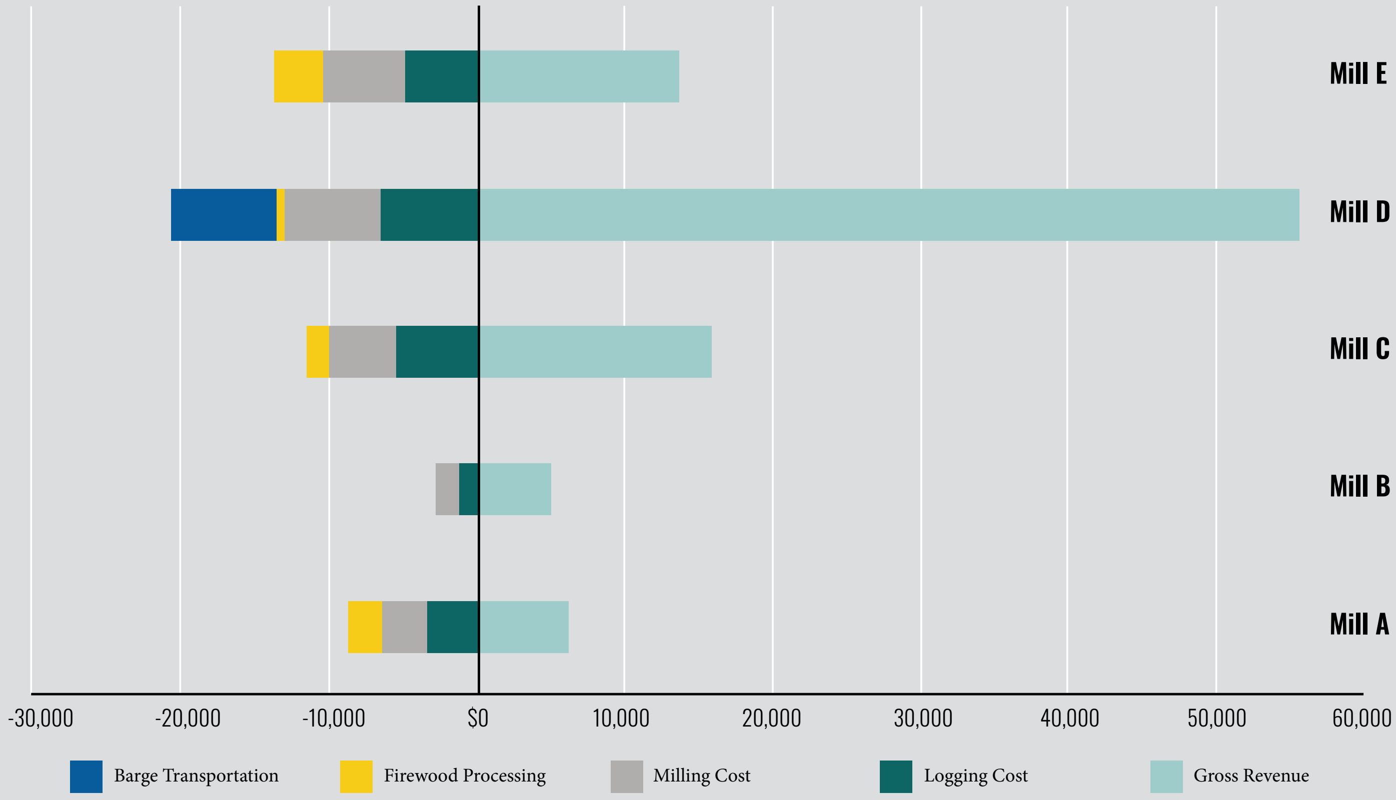


Figure 3. Cost and gross revenue breakdowns for each mill involved in the study.

Cost factors among mills that lead to differences in revenue included logging, milling, and transportation costs, and method of firewood processing. Logging costs were highest for Mill C since these trees were obtained using selective helicopter logging, while transportation costs were highest for Mill D, as these logs were shipped from POW to Ketchikan via barge. Going into this project we assumed that helicopter logging costs and barge transportation costs would provide the largest obstacles to profitability for mill operators. Although helicopter logging is substantially more costly than road-based logging, our data suggest that the ability to selectively log the highest quality trees leads to higher sawlog volume and less waste. Similarly, transportation costs from POW to Ketchikan did not seem to affect Mill D's bottom line. More data from additional mills are necessary to determine if these cost-to-benefit ratios are the rule and not the exception. Milling costs varied substantially among mills, from a low of $375/MBF (Mill B) to over $900/MBF (Mill A). Whether this range is attributable to poor cost tracking or real differences in mill efficiencies is impossible to say. Costs for producing firewood also varied widely, and again may be due to poor cost tracking or to real efficiency differences. For example, Mill D used low-quality milled wood as firewood, rather than bucking and splitting logs especially for that purpose.

There was surprisingly little variation among mills in finished wood products. All mills produced dimensional lumber, the majority of which was 1x and 2x boards, with some nonstandard and larger beams (4x, 6x). One mill made a picnic table, another milled some live-edge slabs for countertops and tables, but overall very little value-added or specialty products were made. However, this was not an unusual practice for these particular mills or a result of using salvaged trees instead of live wood. Several mills only manufactured wood products in response to specific orders from customers, and these orders were mostly (if not entirely) from local consumers. Mill E in Kake sold boards locally, but also occasionally took products to sell in larger towns. No mill had a contract to provide another business with manufactured wood products on a consistent basis. Firewood was made from lower quality or smaller logs (Mills C and E; data not shown), from portions of logs that were deemed unsuitable for lumber (Mill A) or from milled wood that was later rejected for sale (Mill D).

Operator experiences and data collection

One objective of this study was to provide mill operators with a basic understanding of cost accounting to improve their business skills. A recurring theme throughout the project was the inexperience of many of the businesses with correctly tracking their costs and revenues over the course of time. None of the mills were tracking their operational costs at the time that the project started and in fact one operator stated that he did not keep track of expenses, but that if he had money in his checking account at the end of the year, then he must have made money. We developed a user-friendly calculator in Microsoft Excel that allowed operators to input relevant cost and revenue information throughout the study. Output from this calculator provided a rough measure of profitability based on the inputs and underlying assumptions. It was hoped that this tool could help small operators to track costs, improving their business planning and reducing inefficiencies. Most businesses in the study did not properly account for

Yellow-cedar logs in a mill yard. Photo: Allison Bidlack ownership costs of their equipment, including the cost of purchase, operating, and replacement or upgrades, depreciation costs, fuel, insurance, repairs and maintenance, downtime, and the cost of borrowing money if the purchase of the equipment is financed. For example, the logger on POW first used hourly rental rates for equipment (yarder/loader & log truck) as the cost of operating that equipment. His initial logging cost spreadsheet showed a loss of $290.00/MBF. When hourly rental rates were replaced with actual operating costs and an estimated cost/MBF for initial purchase and replacement of the equipment, the spreadsheet showed a profit of $52/MBF. For him and other participants in the study we had to explain and help them fill out the spreadsheet, but despite our best attempts at data collection training and oversight, some of the data may be incomplete, likely biasing the costs low, or questionable, which would have unpredictable effects on the direction of bias.

In addition to cost data, there were inconsistencies in how individual logs were tracked through the milling process, and some operators even had problems with determining volume delivered to the mill. One mill was estimating volume by adding the diameters of the large and small ends of a log and dividing by two instead of basing the volume on the diameter of the small end of the log (Scribner scale; this was corrected for in our analyses). This same mill produced a significant amount of overrun from their milling operation and beams of a size that are questionable based on the size of logs (length and taper) milled. This is symptomatic of the uncertainties in the data collected from each operator. Despite these caveats, the data provide a reasonable picture of small mill costs and revenues when working with salvaged yellow-cedar. Additionally, all participants informed us that they learned a great deal from this study and felt more knowledgeable about the real cost of running their businesses.

The grey "ghost" trees visible on North Kupreanof Island are dead yellow-cedar stands. Photo: Allison Bidlack

Opportunities and challenges

Interestingly, there were discrepancies between the cruised gross and net volume and the volume that was ultimately logged and milled. On Kupreanof, the logger salvaged approximately twice the gross volume that was cruised, even while only logging 48 of 66 marked trees. However, the sawlog volume he was able to extract mirrored the relatively poor quality of the timber estimated in the cruised net volume. In contrast, the gross volume cruised on POW was reflected in the mill volume, but the quality was higher than estimated (Table 3). Yellow-cedar tends to have a lot of hidden defect and can be difficult to cruise. The quality of yellow-cedar timber also varies with site conditions, with small differences in wetness or slope impacting the amount of defect even with a stand. Standing dead trees, particularly of older snag classes, may bias cruiser's volume estimates simply because they are already dead and an assumption is made that something must be defective with the tree. A cruiser's experience with yellow-cedar may play a large role in the reliability of the pre-salvage volume estimates.

Table 3. Cruised gross and net volume of logged stands, mill gross volume and volume sawn (MBF).

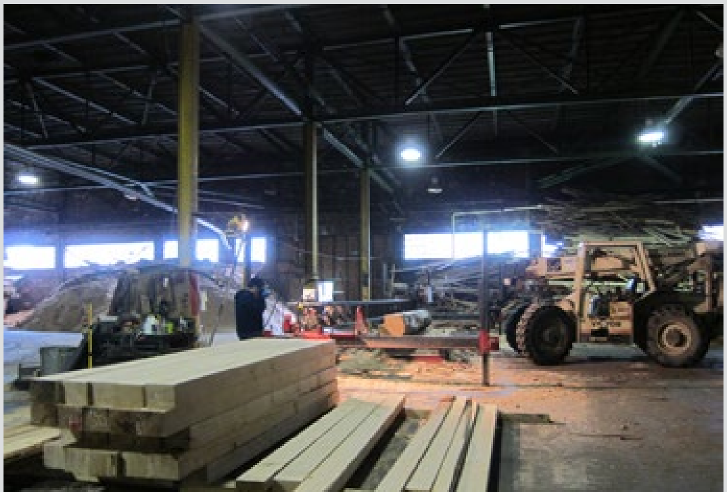
	Cruised Gross	Cruised Net	Mill Gross	Sawn Volume
Kupreanof	8.79	4.1	16.16	6.39
POW Ground	27.99	13.2	29.31	24.75
POW Helicopter	13.8	9.6	8.2	8.39

Salvage logging, like any management activity, has an ecological impact, and understanding the scope of that impact is important in terms of judging the overall value of salvage (Lindenmeyer et al. 2012). Minimal negative impact to remaining vegetation, fauna, and successional trajectories is typically desirable. Yellow-cedar (dead or alive) does not typically provide much wildlife habitat because of its decay-resistance (with the notable exception of bats, which tend to preferentially use both yellow-cedar and western redcedar (*Thuja plicata*) for diurnal roosting sites; Boland et al. 2009); therefore, selective and seasonal harvesting of dead trees may have a minimal impact to wildlife (Hutto 2006). Salvage logging, however, is still disruptive to the local ecosystem and can significantly impact the forest community following additional removal of unmarked trees for access/safety reasons, alteration of the light and establishment environment for plants, and compaction or disruption of soils and plants along access or skid trails (Saint-Germain and Greene 2009). These associated impacts can lead to changes in the regenerating community and result in long-term shifts in community composition and stand dynamics (Royo et al. 2016) which may not be desirable (Thorn et al. 2018). The effects are highly dependent on the intensity of harvest (Peterson and Leach 2008). In the context of southeast Alaska, a region characterized by high precipitation and an abundance of saturated soils, skidding can alter stand drainage significantly by creating compact trenches (personal observation); potential soil compaction by logging in wet conditions is well known (Sidle and Drlica 1981) and likely avoidable in practice. In this case, because the harvests were all close to the road system and small in extent, impacts were relatively minor outside of the directly harvested zones.

Regardless of the potential impacts of this small-scale salvage harvest, the short- and long-term ecological impacts are likely minor in comparison to clearcutting, the most commonly used silvicultural system in the region. Selective salvage logging can also minimize impact to old-growth (versus clearcutting) while the region waits for young-growth forest to mature and produce merchantable products. Furthermore, small-scale salvage logging may reduce conflict around old-growth logging and allow operators to tap into sustainably-sourced timber markets. Value-added yellow-cedar producers may consider marketing yellow-cedar products from standing dead trees as eco-friendly products, by highlighting products made from them as a substitute for live old-growth trees. Considering how politically unpopular old-growth logging has become over the last few decades, this type of marketing may make products produced from dead yellow-cedar attractive to some consumers in the regional market. A similar example exists for "blue stained" mountain pine beetle killed wood – while largely disliked for aesthetic reasons, a niche market exists as a result of the unique story and look of the wood (Byrne et al. 2006) and products in a variety of dimensions are currently available around mountain pine beetle affected areas. For yellow-cedar, a contingent valuation study found that consumers are willing to pay a premium for yellow-cedar over treated softwood of another species because of its natural decay-resistant properties (Donovan and Hesseln 2004). This was corroborated by the owner of Mill E, who stated that some consumers prefer buying yellow-cedar planks over treated lumber for decking, both because of transportation cost savings, but also potentially for health and environmental reasons.

Timber Availability

Salvaged yellow-cedar may have potential to help sustain small mills in southeast Alaska, but this nascent industry is constrained by an inconsistent supply of timber. In general, insufficient supply is one of the primary barriers to developing value-added wood product markets in southeast Alaska (DCCED 2012a), and current sawmill capacity is highly underutilized (Parrent and Grewe 2018). Yellow-cedar usually represents a small percentage of a timber stand's total volume, and many stands that look promising for salvage at first glance are actually made up of widely scattered trees and are not practical sites for efficient harvesting. Conversely, if stands are dominated by dead yellow-cedar they are often too wet for ground-based equipment, and environmental/soil impacts are likely to be higher on wetter ground (Sidle and Drlica 1981). However, approximately 125,072 acres of dead yellow-cedar (18% of the total decline area) is situated on lands that allow timber harvest to occur per the Forest Plan within the Tongass National Forest (USFS 2016), and this number may rise in the coming decades as climate change continues to affect this species (Buma et al. 2016; Buma 2018). Given that both ground- and helicopter-based logging resulted in useable timber and positive revenue, it is possible that dispersed and selective logging for this species across the Tongass provides a viable opportunity for small and medium sized mill operators.


Yellow-cedar lumber in a mill warehouse. Photo: Allison Bidlack

Whether the current USFS microsale process (sales of down or dead timber less than or equal to 50 MBF that the District Ranger agrees to offer for bidding in response to a proposal by a prospective purchaser) is capable of maintaining a sufficient supply of dead yellow-cedar available for purchase is another consideration. The current study took longer than anticipated due to administrative backlog within the USFS, and mill operators told us that a consistent supply of yellow-cedar through microsales was problematic. Another barrier to the development of a yellow-cedar salvage industry is the fact that dead yellow-cedar is also the preferred wood for local firewood gatherers. Harvesters of dead-yellow cedar along roadsides are in competition with locals gathering firewood and thus may not be considered priority users on some ranger districts. As stated above, many small mill operators may not have the business skills (or financial capacity) to sustain a long-term salvage operation in the face of USFS bureaucratic timelines and priorities. The fact that three of the mills in this study did not regularly carry liability insurance, which prevents them from bidding on state timber sales in lieu of Forest Service sales, speaks to the lack of capacity within the industry.

Conclusions

"Our new climate reality, driving yellow-cedar mortality across much of the Tongass, presents an opportunity for a new approach to forest management and a forest products industry in southeast Alaska."

There currently exist a handful of southeast Alaska mill operators producing value-added yellowcedar products on a small scale for commercial and residential use, as well as for specialty purposes. In addition to the mills in this study, Icy Straits Lumber in Hoonah, Alaska creates cabin kits, beams and other large structural pieces, as well as smaller items, including custom furniture and carvings, while Alaska Specialty Woods in Craig, Alaska is milling high grade yellow-cedar (among other species) for use in musical instruments. To aid in the success of southeast Alaska manufacturers of value-added wood products, organizations such as the Southeast Alaska Conservation Council and Sitka Conservation Society have engaged in public relations campaigns to try and shift consumer demand toward locally-produced products.

Dead yellow-cedar presents an opportunity for some southeast Alaska loggers and mill operators to maintain a supply of valuable timber in the face of declining availability of live trees (of any species) of marketable size. The Tongass National Forest is currently transitioning from a regime of old-growth logging to one dominated by young-growth logging, a transformation that necessitates changes in equipment, products, and markets. Many mills have gone out of business in the past two decades (Parrent and Grewe 2018), and there is high turnover in the industry. While the harvest of dead yellow-cedar may not sustain the full gamut of traditional forest industry jobs or provide a bridge in the transition from old-growth logging to young-growth logging, increasing supply and creating niche markets for dead yellow-cedar products may help small mill operators and loggers to survive (DCCED 2012b). This will, however, likely only be in combination with other economic opportunities: most of the owners of the businesses in this study worked for wages at least part-time during the study in addition to operating their mill. Salvage logging and milling of dead yellow-cedar will not by itself sustain this industry. This study exposed the variation among mill operations in southeast Alaska in regards to harvest and milling capacity, cost assessment/valuation ability, and market accessibility. Despite the differences among operations, our data suggests that logging and milling dead yellow-cedar can be a profitable enterprise, despite high logging and transportation costs. Access to quality dead yellow-cedar trees through microsales, as well as training opportunities for business owners to track and limit their costs, and a preference for lumber over firewood salvage, will help sustain small family-run logging and milling operations in southeast Alaska. Our new climate reality, driving yellow-cedar mortality across much of the Tongass, presents an opportunity for a new approach to forest management and a forest products industry in southeast Alaska.

Acknowledgments

This work was supported through the USFS Wood Innovations Fund, grant no. 15-DG11100106-807, by the Alaska Department of Commerce, Community and Economic Development, and by the Alaska Department of Natural Resources Division of Forestry. We thank Clarence Clark for assistance in the field and for help interpreting and analyzing the logger and mill operator data. We also thank the Petersburg and Craig Ranger Districts for their cooperation, and Viking Lumber for providing logging cost information. Thank you to Justin Crotteau and Su Alexander for helpful comments on the manuscript. Lastly, we thank the participants for their patience answering our questions and for tracking all of their costs through this process.

References

Boland, JL, Hayes, JP, Smith, WP and Huso, MM. 2009. Selection of day-roosts by Keen's myotis *(Myotis keenii)* at multiple spatial scales. Journal of Mammalogy. 90: 222-234.

Buma, B. 2018. Transitional climate mortality: Slower warming may result in increased climateinduced mortality in some systems. Ecosphere. 9(3): e02170.

Buma, B, Hennon, PE, Harrington, CA, Popkin, JR, Krapek, J, Lamb, M, Oakes, LE, Saunders, SC and Zeglen S. 2016. Emerging broad-scale mortality driven by climate warming and loss of snowpack. Global Change Biology 23: 2903-2914.

Byrne, T, Stonestreet, C and Peter, B. 2006. Characteristics and utilization of post-mountain pine beetle wood in solid wood products. *The Mountain Pine Beetle: A Synthesis of Biology, Management, and Impacts on Lodgepole Pine*, pp. 233-254.

Department of Commerce, Community and Economic Development. 2012a. Report to the Alaska Timber Jobs Task Force. Administrative Order 258, Task 8: Alaska's Timber Resource and Wood Products.

Department of Commerce, Community and Economic Development. 2012b. Report to the Alaska Timber Jobs Task Force. Administrative Order 258, Task 6: Southeast Wood Product Business and Timber Supply Need.

Donovan, G and Hesseln, H. 2004. Consumer willingness to pay for a naturally decay-resistant wood product. Western Journal of Applied Forestry 19: 160-164. FRPA 2018. Alaska Forest Resources and Practices Act, AS 41.17.

Green DW, McDonald KA, Hennon PE, Evans JW and Stevens JH. 2002. Flexural properties of salvaged dead yellow-cedar from southeast Alaska. Forestry Products Journal 52: 81–88.

Hennon, PE, Wittwer, D, Stevens, J and Kilborn, K. 2000. Pattern of deterioration and recovery of wood from dead yellow-cedar in southeast Alaska. Western Journal of Applied Forestry 15: 49-58.

Hennon, PE, D'Amore, DV, Schaberg, PG, Wittwer, DT, and Shanley, CS. 2012. Shifting climate, altered niche, and a dynamics conservation strategy for yellow-cedar in the north pacific coastal rainforest. BioScience 62(2): 147-158.

Hutto, RL. 2006. Toward meaningful snag-management guidelines for postfire salvage logging in North American conifer forests. Conservation Biology, 20(4), pp.984-993.

Kelsey, RG, Hennon, PE, Huso, M, and Karchesy, JJ. 2005. Changes in heartwood chemistry of dead yellow-cedar trees that remain standing for 80 years or more in Southeast Alaska. Journal of Chemical Ecology 31: 2653-2670.

Lindenmayer, DB, Burton, PJ and Franklin, JF. 2012. *Salvage logging and its ecological consequences.* Island Press.

McDonald, KA, Hennon, PE, Stevens, JH and Green, DW. 1997. Mechanical properties of salvaged dead yellow-cedar in southeast Alaska. USDA, Forest Products Lab. Research Paper FPL-RP-565.

Northwest Log Rules Advisory Group. 1969. Official Rules for the following Log Scaling and Grading Bureaus - Columbia River, Grays Harbor, Northern California, Puget Sound, Southern Oregon and Yamhill. Reprinted January 1, 1995.

Parrent, D and Grewe, N. 2018. Tongass National Forest 2017 Sawmill Capacity and Production Report. USDA Forest Service, Alaska region.

Peterson, CJ and Leach, AD. 2008. Limited salvage logging effects on forest regeneration after moderate-severity windthrow. Ecological Applications 18(2): 407-420.

Royo, AA, Peterson, CJ, Stanovick, JS and Carson, WP. 2016. Evaluating the ecological impacts of salvage logging: can natural and anthropogenic disturbances promote coexistence? Ecology 97(6): 1566-1582.

Sidle, RC and Drlica, DM. 1981. Soil Compaction from Logging with a Low-Ground Pressure Skidder in the Oregon Coast Ranges 1. Soil Science Society of America Journal 45: 1219-1224.

Saint-Germain, M. and Greene, DF. 2009. Salvage logging in the boreal and cordilleran forests of Canada: inte grating industrial and ecological concerns in management plans. The Forestry Chronicle 85(1): 120-134.

Thorn, S, Bässler, C, Brandl, R, Burton, PJ, Cahall, R, Campbell, JL, Castro, J, Choi, CY, Cobb, T, Donato, DC and Durska, E. 2018. Impacts of salvage logging on biodiversity: A metaanalysis. Journal of Applied Ecology 55(1): 279-289.

USFS. 2011. Central Kupreanof Timber Harvest, Petersburg Ranger District, Tongass National Forest. Record of Decision. U.S. Forest Service, Alaska Region. Publication R10-MB704.

USFS. 2013. Big Thorne Project, Thorne Bay Ranger District, Tongass National Forest, Record of Decision. U.S. Forest Service, Alaska Region. Publication R10-MB-736e.

USFS. 2016. Tongass National Forest Land and Resource Management Plan. U.S. Forest Service, Alaska Region. Publication R10-MB-769j.

USFS. 2018. Forest Health Conditions in Alaska 2018. Anchorage, Alaska. U.S. Forest Service, Alaska Region. Publication R10-PR-44.

USFS. 2019a. Forest Products Cut and Sold from the National Forest and Grasslands. https://www.fs.fed.us/for estmanagement/products/cut-sold/index.shtml. Accessed 11 September 2019.

USFS. 2019b. Summary Tables: Log Exports and Interstate Shipments (updated June 2019). https://www.fs.usda. gov/detail/r10/landmanagement/resourcemanagement/?cid=fsbdev2_ 038785. Accessed 11 September 2019.