Radiata Pine Bark Removal Associated with Two On-Landing Log-Processing Methods

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Abstract

Bark accounts for about 9 percent of the weight of the boles of mature radiata pine (*Pinus radiata* D. Don) trees. The presence of bark can be considered as either a cost or benefit depending on the participant in the forest-to-customer supply chain. Understanding how much bark is lost or removed by different processing methods should help with managing bark quantities and with the design of harvesting systems and equipment.

Bark loss was measured in autumn in New Zealand on radiata pine logs processed using two methods; delimbing and bucking with a mechanized, dangle-head processor fitted with spiked rollers, and delimbing with a static, pull-through delimber and manual bucking using a chainsaw. The line intersect method and photographic images were used to measure areal bark loss on a total of 302 logs. Equal numbers of logs were measured for each log-processing method.

No difference in bark removal was found between methods for log grades cut from the lower portion of the stem. However, there were significant differences for grades cut from the upper portion of the stem. For the total stem, bark removal was greater with the mechanized processor method (75%) than with the static delimber and manual bucking method (48%).

Bark is made up of two types of tissues: inner bark and outer bark. The role of the inner bark is to transport sugars around the plant for growth. The role of the outer bark is one of protection. While bark plays important roles for the growth and survival of living trees, it has little economic value in most species once felled, other than serving as a source of energy, tannins, and landscape mulch, and it may be a net financial loss to the forest industry (Marshall et al. 2006). The inclusion of bark can be a serious problem in many of the forest product manufacturing processes, and it is normally removed before entering any type of wood processing mill.

Bark makes up 5 to 30 percent of the overbark volume and weight of trees (Meyer 1946, Prince 1973, Philip 1994). The proportion of the stem that is bark is dependent on species, site quality, age, tree size, and location on the stem. Bark makes up about 9 percent of the weight (Webber and Madgwick 1983) and 13 to 16 percent of the volume (Harris and Nash 1973) of mature radiata pine (*Pinus radiata* D. Don) stems.

Tree- and log-handling activities (felling, extracting, delimbing, bucking, storing, loading, transporting, and unloading) result in some bark being lost. The type of harvesting system (chainsaw vs. mechanized delimbing and bucking) and the type of feed rollers on mechanized delimbing heads affect bark loss. Lee and Gibbs (1996) found that there was much less bark loss on logs that had been manually delimbed and bucked (13% and 1%), at two Corsican pine (*Pinus nigra* J.F. Arnold) study sites in Great Britain, than on logs that had been mechanically delimbed and bucked with rubber rollers (29% and 6%) or with spiked rollers (39% and 8%). The consistently higher bark loss at one site was likely owing to thinner bark at this site. Uzunovic et al. (1999) also reported much less bark loss with manual delimbing and bucking (<5%) than with mechanical delimbing and bucking with rubber rollers (5% to 45%) in Corsican pine. Granlund and Hallonborg (2001) report that bark loss by five harvesters, all fitted with rubber rollers, ranged from 0 to 5 percent. Murphy and Pilkerton (2011a) reported average bark loss of 34 percent for Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) and 13 percent for ponderosa pine (*Pinus ponderosa* Douglas) from mechanical delimbing and bucking with chains over rubber

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rollers. They also noted that bark loss tended to be evenly distributed along the stem for Douglas-fir but concentrated toward the top of the stem for ponderosa pine.

Bark is more easily knocked off stems, logs, and wood chips in spring, when the sap is rising, than at other times of the year (Wilcox et al. 1954, Neville 1997). Harder et al. (1978) found that for the 42 species they studied in the United States, the bonding strength of the bark increased dramatically during the dormant season, and the chance of bark abrasion was much reduced during this time period. Murphy and Pilkerton (2011a) found that there was a substantial (up to five times) increase in bark loss during late spring and early summer compared with the winter season for mechanically delimbed and bucked Douglas-fir and ponderosa pine. Woollons and Powell (1984) reported 50 to 60 percent more bark arriving on logs on a daily basis to a large radiata pine mill (>600,000 tonnes of wood per yr) in New Zealand during winter months than during summer months. Chainsaw delimbing and bucking was common during the 1980s in New Zealand.

The line intercept method (also known as the line intersect method) was introduced by Canfield (1941) as a means of determining the areal coverage of terrestrial plant species. To use this method, a tape is extended to create a transect across the site. The observer proceeds along the line-transect, identifying plants intercepted by the tape, and recording intercept distances. Cover is calculated by adding all intercept distances and expressing this subtotal as a proportion of the total transect length. The line intercept method today finds many uses, such as determining coverage of marine plants (Nakajima et al. 2010) and harvest-related soil disturbance (Miller et al. 2010). It has also been modified for determining the volume of logging waste on harvesting sites (Warren and Olsen 1964).

Harris and Nash (1973) used the line intercept method for determining bark lost during extraction of radiata pine, Corsican pine, and Douglas-fir stems to landings in New Zealand. A metallic tape was placed along the upper surface of each log to measure lengths of bark lost and, hence, to estimate percentage of bark lost. Murphy and Pilkerton (2011a) found that bark loss estimates were not sensitive to transect location; no significant difference in bark loss estimates was found for transects running along the upper surface of a stem or along the right or left sides of the stem.

The primary objective of this study was to compare bark removal associated with two delimbing and bucking methods carried out on a landing: (a) mechanized delimbing and bucking of stems with a dangle-head processor, and (b) delimbing with a static pull-through delimber and manual bucking into logs using a chainsaw. The secondary objective was to determine if the type of log being handled, and by implication location on the stem, affects bark removal.

Methods

Study location, equipment used, and stand details

The study was carried out in April 2014 (mid-autumn) at two radiata pine sites, both located in the East Coast region of New Zealand. Site A is located at 38.31°S, 177.78°E. Site B is located at 38.44°S, 177.74°E.

Trees on Site A were manually felled using a chainsaw, extracted to a landing by a Caterpillar 525 skidder, and then delimbed and bucked into logs using a Woodsman Pro 800 processor head fitted to a Komatsu PLC 450 carrier. Trees on Site B were manually felled using a chainsaw, extracted to a landing by a Caterpillar D6H tractor with rubber-tired arch, and then delimbed using a Harvestech S3000 static pull-through delimber and manually bucked into logs using a chainsaw. A Hyundai excavator fitted with a grapple was used to pull logs through the static delimber.

The 24-year-old trees at Site A were pruned and averaged 1.57 m^3 per tree. Stocking was 250 stems per hectare, and volume was estimated to be 393 m^3 per hectare. The 26-year-old trees at Site B were pruned and averaged 2.12 m^3 per tree. Stocking was 305 stems per hectare, and volume was estimated to be 647 m^3 per hectare.

Log specifications

Five log grades were being processed at both sites. Two grades, A grade and K grade, have been further split into two classes: longs and shorts (Table 1). Pruned logs are found at the base of each tree. KI logs, with larger branches and stem diameters, are also usually found toward the bottom of the tree. A grade, K grade, and Pulp logs are found above the pruned zone and higher up in the tree. This is mentioned because it has implications for interpreting the results of the study.

Sampling, measurement method, and analyses

One hundred fifty-one logs per harvesting site, 302 in total, were measured. The distribution of these by grade is shown in Table 1. Each log was photographed immediately after processing on the landing and then digitally analyzed in the office. Photographs were taken at a point that was approximately perpendicular to the midpoint of the long axis of each log. Photography was used for three reasons: to minimize disruption to the normal working procedure of the harvesting crew, to maximize safety of the observer while gathering data near working harvesting machines, and to minimize bias in the selection of logs (logs sampled for different grades frequently came from the same trees).

Initially a camera on a tripod was considered for capturing photo images. However, this was abandoned for practical reasons. A hand-held digital camera provided fast response times and zoom features for capturing whole logs as they were

Table 1.—Log specifications and sample size.

	Log grades:						
	Pruned	A Long	A Short	K Long	K Short	KI	Pulp
Knot size (mm)	0	100	100	110	110	250	No limit
Minimum small-end diam. (mm)	300	300	300	200	200	260	100
Length (m)	3.7–4.8	5.9	3.9	5.9	3.9	3.0–3.9	3.0–6.0
No. of logs measured/harvesting site	20	24	23	15	24	21	24

being bucked and during situations when the observer needed to act quickly so as not to inhibit the harvesting crews' production. It was also easier than moving a tripod when walking around log stacks and standing on logging debris while photographing. The grade of each log photographed was determined by the log-processor operator and recorded by the observer.

Digital photographs were analyzed using line intercept procedures and Adobe Photoshop software. After loading an image into Adobe Photoshop, a line joining the midpoint of the small end of the log with the midpoint of the large end of the log was drawn. The Ruler tool, in Photoshop's Measurement Tools, was then used to measure the total line length (in pixels) and the intercept lengths (in pixels) along the line for segments where bark was present. The intercept lengths were summed and expressed as a percentage of total line length. Bark removed was calculated as 100 minus the percentage of bark present.

Comparisons between processing (delimbing and bucking) methods for each log grade were made using the "*t* test with unequal variances" procedure in Microsoft Excel. Additionally, comparisons were made between processing methods and position in the tree after pooling data into two groups: data from A, K, and Pulp grades and data from Pruned and KI grades. Comparisons were considered to be significantly different if they did not exceed the two-tail probability at 0.05 level.

Results

On average, significantly more bark was removed when delimbing and bucking was carried out using a dangle-head processor (75%) than when delimbing was carried out using a static pull-through delimber and manual bucking (48%). The differences between methods were not statistically significant for every log grade, however (Table 2). There was no significant difference between methods for Pruned and KI grade logs, nor between these two grades; bark removal was 53 percent on average. There were significant differences, however, for A, K, and Pulp grade logs, with dangle-head delimbing and bucking removing 20 to 36 percent more bark on average than static pull-through delimbing and manual bucking.

Grades are an indication of where in the tree logs are found. As noted in the "Methods" section, Pruned and KI grades are generally found toward the bottom of the tree, and A, K, and Pulp grades are generally found higher up the tree. Figure 1 shows the bark removal for the two delimbing systems (dangle-head and static pull-through) for the lower portion and upper portions of the stem. Dangle-head processing of logs in the upper portion of the stem resulted in significantly more bark removal (82%) than static delimbing and bucking of logs on any portion of the stem (47% to 50%) or dangle-head processing of logs on the bottom portion of the stem (58%).

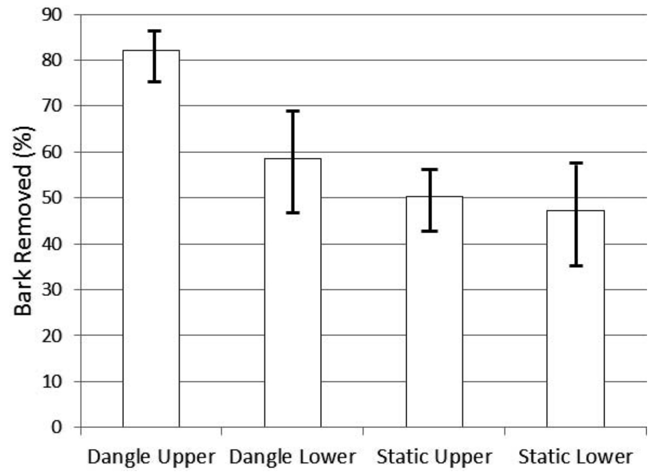

Figure 1.—Effect of processing method and location of logs on the stem on bark removal. Error bars show 95 percent confidence limits. Dangle = logs delimbed and bucked by a mechanized dangle-head processor; Static = logs delimbed by a static pull-through delimber and manually bucked; Lower = log grades generally found in the pruned or large-stem diameter or large branch zones; Upper = log grades generally found above the lower zone.

Discussion and Conclusions

Depending on where you are located in the forest-to-buyer supply chain, the presence or absence of bark can be seen as a cost or benefit (Marshall et al. 2006, Lowell et al. 2010, Murphy and Pilkerton 2011b). It can affect transport costs, storage capacity at mills and ports, energy availability, landscaping mulch availability, degradation owing to sapstain, fumigation for export market phytosanitary purposes, and log-drying rates, among other things. For most harvesting operations, bark removal is not intentionally carried out.

On average half to three quarters of the bark was removed from radiata pine stems at the two study sites when harvesting was undertaken in autumn. The amount of bark removed was dependent on the log-processing system used, with bark removal being greater when delimbing and bucking were undertaken with a mechanized dangle-head processor fitted with spiked rollers (75%) than when delimbing was

Table 2.—Average and range of the areal percentage of radiata pine bark removed by two log-processing methods.

	Log grades:							
Delimbing and processing method	Pruned	A Long	A Short	K Long	K Short	KI	Pulp	All grades
Dangle-head delimbing and processing								
Avg.	55.9	85.5	75.1	82.2	75.0	53.6	85.5	74.6
Range	21–100	52–100	30–100	42–100	12–100	8–100	14–100	8–100
Static pull-through delimbing and manual processing								
Avg.	51.0	49.4	55.2	46.0	43.1	38.8	49.0	48.3
Range	10–100	8–89	10–93	13–99	7–85	8–99	10–91	7–100
Statistical significance (*P* value)	0.57	<0.01	<0.01	<0.01	<0.01	0.08	<0.01	<0.01

undertaken with a static pull-through delimber and bucking was carried out manually using a chainsaw (48%).

Radiata pine bark removal with the spiked roller mechanized processing head was considerably higher (75%) than when the same type of processing equipment was used in Corsican pine (8% to 39%; Lee and Gibbs 1996) and when mechanized processing heads with chains over rubber rollers were used in ponderosa pine (13%), and Douglas-fir (34%; Murphy and Pilkerton 2011a).

No studies quantifying bark loss associated with static pull-through delimbers were found in the literature. McConchie and Evanson (1995) observed that ''considerable'' amounts of bark were removed when delimbing radiata pine with a static delimber; however, ''considerable'' was not quantified in their report. The radiata pine bark removal found in this study from static delimbing was substantially higher (48%), however, than that found for manual processing and delimbing (1% to 13%) and mechanized processing with rubber rollers in Corsican pine (5% to 45%; Lee and Gibbs 1996, Uzunovic et al. 1999). It cannot be determined whether the comparatively greater bark removals found in this study are related to the equipment being used or to the tree species and characteristics of the trees being harvested.

Removal of radiata pine bark was greater higher up the stem (82%) than toward the bottom of the stem (58%) when delimbing and bucking were carried out using a dangle-head processor with spike rollers. Murphy and Pilkerton (2011a) reported a similar finding for ponderosa pine, but not for Douglas-fir, when stems were mechanically processed using chains over rubber rollers. Use of a static delimber, however, resulted in no difference in radiata pine bark removal at different heights on the tree.

There are a number of limitations associated with this study. First, study results relate to harvesting in a single month, April (autumn). Work by Woollons and Powell (1984) indicates that log-handling bark loss from radiata pine stems in New Zealand follows a parabolic pattern being highest in January (summer) and lowest in June (winter). Carrying out the study at a different time of the year may have affected the total amount of bark loss and where on the stem the bark loss was occurring.

Second, the line intersect method provides an estimate of the areal extent of the bark loss, but not the bark volume loss. Bark thickness and stem taper also need to be taken into account to obtain estimates of bark volume loss. Future work should incorporate measures of these parameters so that bark volume loss estimates can be made.

Third, only two harvesting crews, each using a single type of log-processing system, were studied under slightly different stand conditions. Different machine operators, different stand conditions, and different harvest extraction systems may have resulted in different findings. A wider range of operating conditions and a greater number of machine operators should be included in future studies.

Despite these limitations, this research has provided a better understanding of how two alternative log-processing methods affect rates of bark loss. This information could be of use to harvesting equipment manufacturers, forest companies, and harvesting contractors for designing or buying debarking and log-processing equipment with the intention of either maximizing the amount of bark left on logs after processing or minimizing the amount of bark moved along the forest-to-customer wood supply chain.

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