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PILOT STUDY TO EXAMINE DAMAGE LEVEL IN GRADE 2 SCALED SPRUCE BARK BEETLE KILLED LOGS

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Twelve SBB (spruce bark beetle killed) grade 2 logs were received by FPInnovations, three were confidently assigned a grade 2, but nine were considered suspicious, as the scalers suspected that some internal defects could not be correctly identified visually. CT (computer tomography) scanning and analysis revealed that decay and checking were more extensive than externally visible defects indicated, which led to downgrading 2 logs to grade 4. Pressure treating one of the apparently good quality logs with water and re-scanning enhanced the visibility of the number and depth of checks in CT images and led to downgrading that log as well. Two of the suspicious logs were warmed for 24 hours at 22 degrees to simulate exposure to one summer day in BC Interior, but unlike typical dry pine logs, the many fine checks around these logs opened evenly, without revealing the true depth of any. Another two suspicious logs with signs of decay were cut to analyse decay extent. The decay was far more extensive than even visible in CT images, leading to downgrade of both logs. Overall, 4 of the nine logs considered suspicious and one of the 3 considered good quality SBB killed grade 2 logs were downgraded due to checks and decay not visible to scalers on the study. Although these results are neither statistically significant nor comprehensive, they point to the challenge of scaling SBB logs correctly, without knowledge of internal defects.

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1 PURPOSE

Studies of sawmill lumber recovery, debarking, and tree stems have indicated significant fiber damage due to decay after spruce bark beetle (SBB) attack. Although the extent of decay in the study (Uzunovic, 2019) samples was related to time since mass attack of the beetle, this information is not available during scaling. Scalers must rely only on the external indicators of log quality. However, scalers have expressed concern that some grade 4 logs may be misidentified as grade 2, due to the difficulty in detecting the extent of defects. The purpose of this study was to examine some of these "suspicious" SBB killed logs using CT (Computed tomography) scanning and destructive testing to determine if potential grade reducing internal defects, such as decay, micro checks, and deeps checks that are not visible during scaling, result in some grade 4 logs being scaled as grade 2.

2 STUDY METHODS

Three green and 15 dry SBB killed 8-foot spruce logs with large end diameters in the 16"-20" range were scaled by FPInnovations' industrial partner. The logs were photographed, the downgrading features were noted, before being shipped to FPInnovations' Vancouver lab for CT scanning and analysis of internal defects. The SBB killed logs were selected by scalers to include three grade 4 logs, three grade 2 logs considered as good quality, and nine suspicious grade 2 (i.e., potentially grade 4) logs. Figure 1 shows the log pile after arrival at FPInnovations.

Figure 1. Scaled logs after arrival at FPInnovations

All logs were visually inspected to note the defects, and CT scanned. Figure 2 shows one of the logs (#26) set up for scanning in the CT bay. The CT images were analyzed by FPInnovations researchers and the partner scalers. The green logs and grade 4 logs were used as a reference. Based on the level and type of defects such as check depth and decay extent found in the CT images, a few of the grade 2 logs were selected for additional study using three different strategies to verify or measure the extent of the defects.

1- Pressure treatment with water.

Fully open checks are easily visible in CT images due to density contrast between air and wood. When dried and checked log surfaces absorb moisture (from rain, snow, etc.) wood cells expand and check gaps close, which diminishes their visibility in CT images. The depth of checks that are easily detectible near log surface may also be difficult to measure, as check width decreases towards the pith. On the other hand, the additional water mass due to moisture inside checks and surrounding fiber acts as a contrast material (as in medical imaging) to enhance check appearance in x-ray/CT images. However, during natural re-wetting, moisture is absorbed from log surface inwards and surface expansion seals the checks and limits water entry. Pressure speeds water seepage inside check openings before check closure. One grade 2 log, identified as good quality, was subjected to pressure treatment (40 psi for 10 seconds) and CT scanned again to determine if the subtle check indicators observed in the original scans were due to checks.

2- Gentle warming/conditioning.

Check closure due to moisture re-absorption is particularly detrimental to detection of checks and their depths (especially under bark) during scaling. A common observation in mills and lab tests for dry pine logs is that checks re-open quickly, even with the gentle warming of one summer day in the logyard. Two grade 2 logs that were considered suspicious were subjected to the warming conditions of an BC Interior average simmer day (24 hours at 22 ℃ and 35% RH) before a second visual inspection and CT scan to determine if check visibility is enhanced.

3- Destructive testing.

Cutting cookies (discs) at key locations selected, based on CT images, and analysing them for presence of decay using the mycological expert approach (Uzunovic, 2019), allows verification of the extent of the decay radially and along the log. Two suspicious logs with signs of decay in the CT scans were selected for this test.

Figure 2. Examples of log set up in the CT bay to be scanned

3 RESULTS

The following table summarizes the initial logyard scaling grade of the 12 grade 2 logs (2G = Good and 2S = Suspicious) and the new grade assigned after various methods utilized to enhance the detectability of the key defects. Overall, 5 out of the 12 grade 2 logs were downgraded to grade 4 with the additional information. Further details are provided in the following sections.

Table 1. Log Grade Summary for Grade 2 Logs Before and After Inspection Steps

Log ID / Grade	2	6	9	12	13	14	15	16	17	18	25	26
Logyard Scale	2G	2S	2S	2S	2S	2S	2S	2G	2S	2G	2S	2S
Adding CT Images	2G	2S	2S	4	2S	2S	2S	2G	2S	2G	4	2S
Water Pressure Treatment & CT Imaging										4		
24 Hr Gentle Warming & CT Imaging		2M										2S
Cutting & Incubation Based on CT images			4		4							
Final	2G	2S	4	4	4	2S	2S	2G	2S	4	4	2S

3.1 Initial Inspection

Inspection of the CT scan images of the green and grade 4 logs did not reveal any unexpected results, but some of the grade 2 logs images showed more extensive decay and checking than indicated by external appearance. These logs were re-evaluated by scalers based on the extent of rot and checking visible in the CT images and two of the suspicious grade 2 logs were subsequently downgraded to grade 4. Figure 3 shows one of these logs (left) with two CT cross section images (right) that demonstrate the unexpected depth of the checks and extent of the decay. In these images, the higher density is shown with brighter intensity. Therefore, air gaps in checks, severely decayed/shattered fiber, or insect galleries appear as black (very low density), while areas with heavy water content, or high density due to knots appear as white. For dry logs, any moisture in the sapwood area is generally trapped moisture in decayed fiber. The white areas can also indicate moisture in other internal rot (heart rot, ring rot, etc.), or seeping into checks or insect galleries and neighbouring fiber. In the images of the two checks extending to the log surface, some parts of the check appear as white due to the water and some as black due to the air gap. Several checks were observed in this and other logs that did not extend to the surface. Since checks typically form by stress due to drying and shrinkage of log surface, further study is needed to determine if these internal checks are related to fiber weakened by decay.

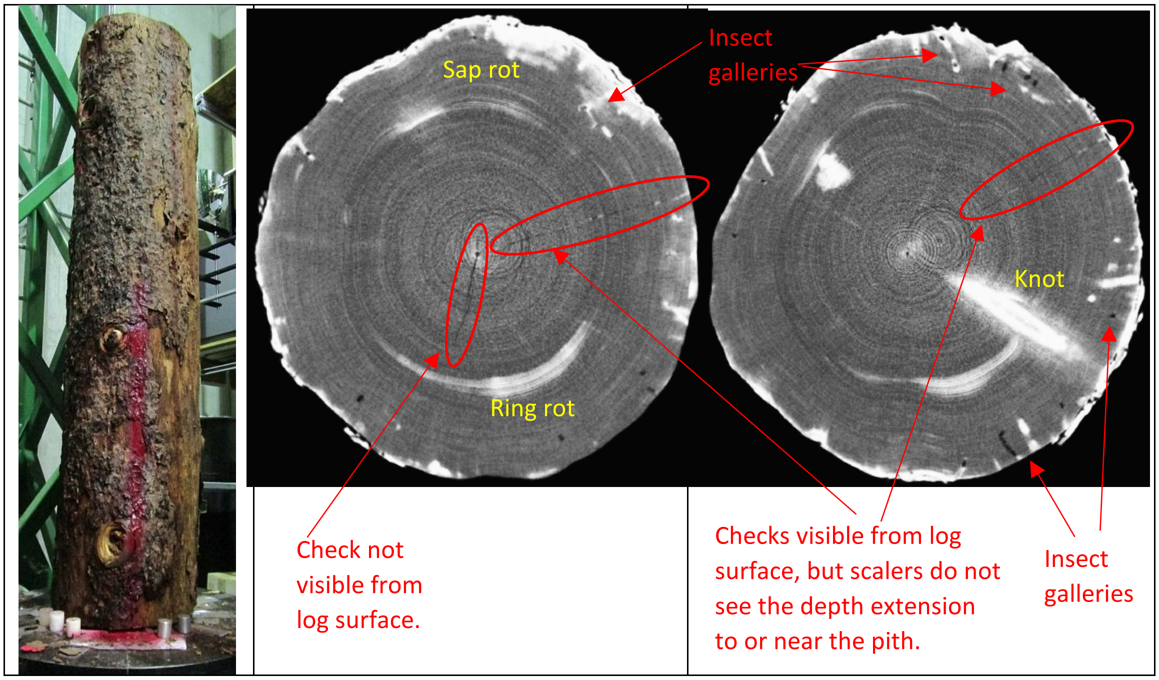

Figure 3. CT cross section images reveals check extending to pith, and extensive ring and sap rot

3.2 Pressure Treatment with Water

In several CT images, partially closed or narrow checks appeared as faint or segmented lines caused by low density of air gaps or high density of absorbed moisture. Since such fine checks were also observed in logs that were identified by scalers as good quality, it was important to eliminate the possibility of mistaking imaging artifacts or other natural features for checks. It was hypothesized that water would seep into checks with a standard water pressure treatment process (similar to preservatives seepage into incised lumber) to enhance their appearance in CT images with the added water mass.

To test this hypothesis, one of the good quality grade 2 logs with deep, but narrow checks visible in the CT images was pressure treated with water to force water into the checks. Figure 4 shows one cross section image for the log before and after the pressure treatment. Even though only 40 psi was applied for 10 seconds, the comparison for this cross section verifies one check that was barely visible before and confirms another to be much deeper than the portion clearly visible in the initial image. A longer treatment may reveal more extensive checking. On the other hand, this method is only effective for checks that reach the surface and are not covered with bark. Furthermore, it is not certain that the full depth of the check is visible after treatment. However, this was sufficient to verify the depth and the existence of enough checks for the scaler to determine that this log was grade 4, and not a good quality grade 2 as initially thought.

It should be noted that no other log was rescaled based on this process and any similarly faint check indicators in other logs were not considered in their grade.

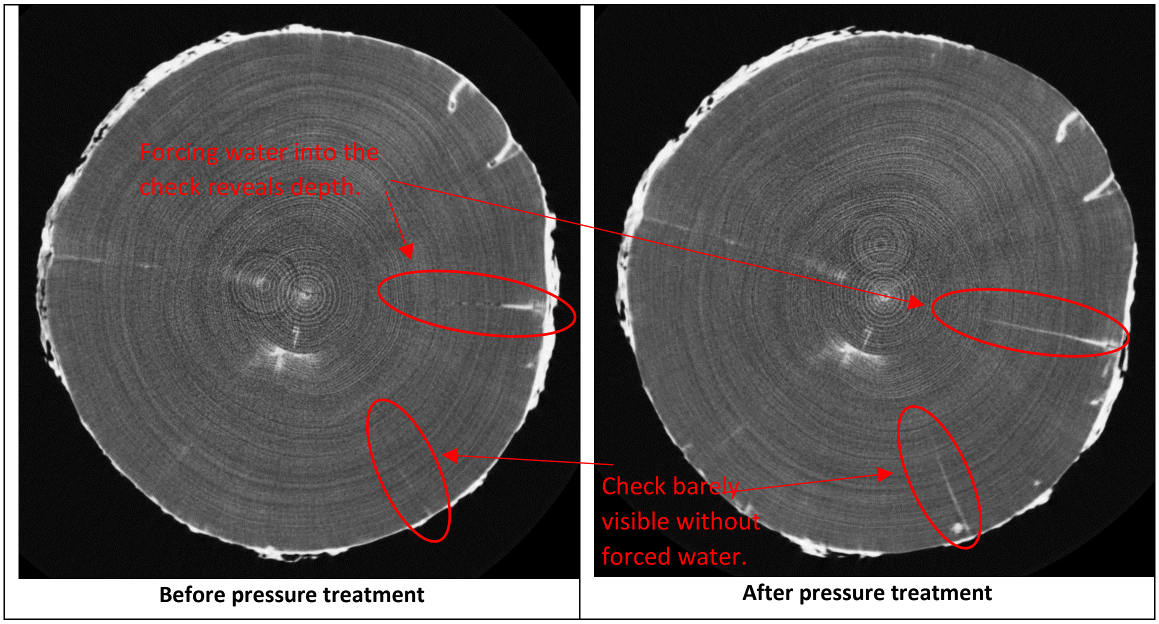

Figure 4. Pressure treatment with water revealed more and deeper checks

3.3 Gentle Warming/Conditioning

Since log scaling is often performed on rain-soaked or wet logs, the inspections and CT scanning were also performed when the logs were rain-soaked, and their checks were likely to be closed. Two suspicious grade 2 logs (#26 and #6) with multiple checks were selected for gentle warming to determine if warming opens the existing checks for better visibility. The warming strategy was based on common industry knowledge and previous lab tests that showed checks in dry pine logs close due to rain and moisture, but open after exposure to one summer day in the yard. Therefore, a very conservative warming strategy (24 hours at 22 °C and 35% RH, simulating a single summer day in BC Interior) was used to ensure no new checks are formed.

However, unlike dry pine logs, which typically have 1-2 major checks that open significantly on warm/dry days, the SBB killed logs examined had numerous fine checks around the log, which in this test seem to only open evenly and moderately after one day of warming. Multiple checks on one of the logs (log #26) can be seen Figure 5. Even the transition from them rain-soaked state in the yard to the lab on a dry winter day enhanced the appearance of surface check but did not reveal their depth. In the CT 3D image (bottom) the blue shades indicate high density, which in this case is likely due to moisture absorbed in surface fiber or trapped in decayed fiber and checks. This helps reveal surface and end checks and trapped moisture in and around them, which are hard to see on the rough-sawn ends. The brown shades indicate low density, which is likely due to decay.

Figure 5. Log 26 rain-soaked in yard (left), in lab before warming (right), 3D CT image (bottom)

Figure 6 shows log #26 after warming (left) when some checks opened sufficiently to insert a feeler gauge (up to 1” into the log). After about one month under similar temperature and RH conditions one of the major checks opened extensively (right image), likely due to over-drying. Although this has no bearing on the log grade, the rapid deterioration emphasises that that such logs should be processed quickly during summer months.

Figure 6. Log 26 after warming (left) and one month in the lab with similar temperature and RH (right)

Figure 7 shows one CT cross section image before (left) and after the initial warming (right). The blue ovals mark some areas where moisture near the surface is reduced after warming. The green ovals show checks that were not visible before warming, and red ovals show checks with change in the water presence, but do not change in size. The log remained a grade 2 log after rescaling. However, with the current information it is not possible to determine if this method was successful in revealing the true check depths.

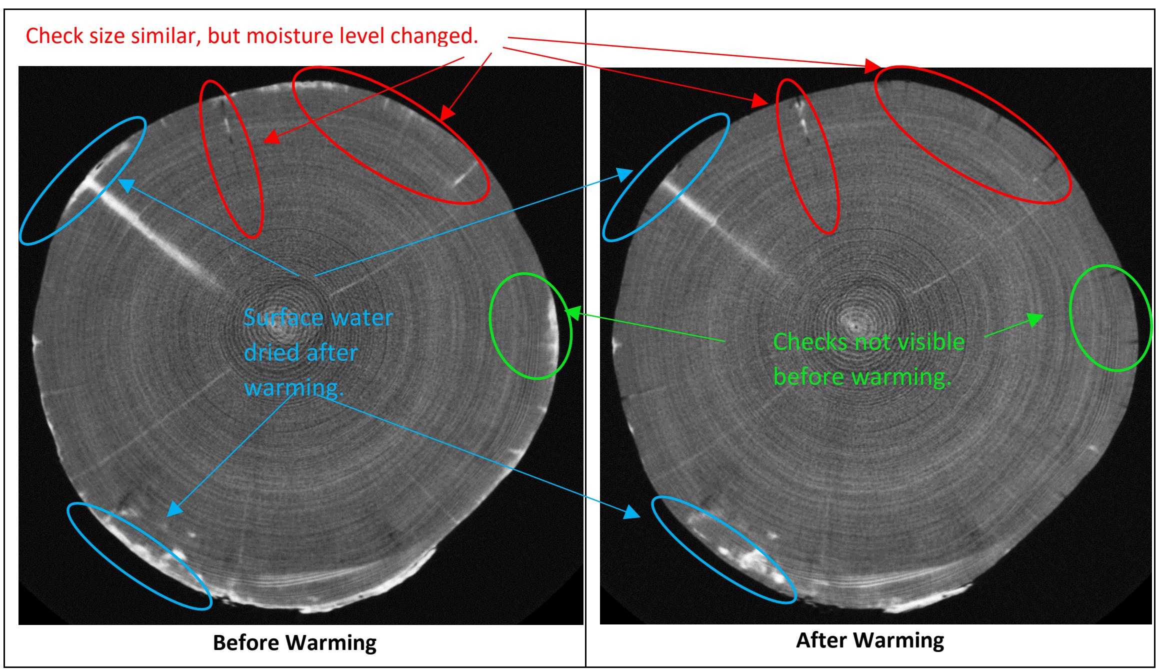

Figure 7. Log 26 CT images of the same cross section before (left) and after warming (right)

The other log (#6) warmed had fewer and shallower checks, which opened after warming, but the apparent check depth remained the same (CT images not shown) and the log grade remained as grade 2 after rescaling. Figure 8 shows the log before warming (left), after warming (middle), and after one month under similar temperature and RH conditions in the lab (right). Even after one month in the lab, the check depth did not appear to increase.

Figure 8. Log 6 before (left) and after (middle) warming and one month stay in the lab(right)

3.4 Destructive Testing

Two of the grade 2 logs that were considered suspicious (#9 and #13) and had signs of decay were cut at locations corresponding to CT cross section images indicating low-density severely decayed and crumbled fiber (darker in CT images) or trapped water in decayed areas (white in CT images). One CT cross section of log #13 is shown on the left of Figure 9, where red ovals mark the low-density areas. The back side of the corresponding disc (within 0.5") in the log is shown on the right, with manually identified decay delineated in black, which extends further than detectible in the CT image.

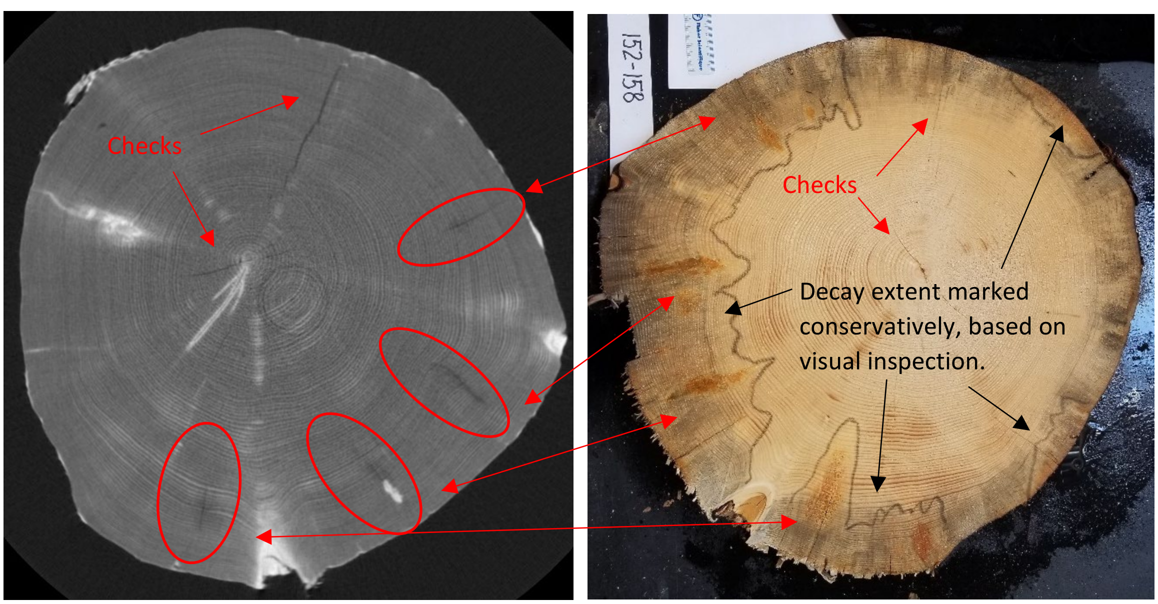

Figure 9. Decayed areas visible in a CT cross section image do not show the full extent of the decay

The extent of moderate decay/saprot cannot be depicted in CT images given no density change due to damaged fibers or trapped water. However, even the decay signs apparent in the CT images are more extensive than detectible on the log surface. Figure 10 shows the log photo with two CT 3D external log models (different orientations) and two longitudinal cross sections, where brown colour indicates low density and dark blue indicates high density (trapped water and knots). Comparing the surface and internal views demonstrates how only a small fraction of the density loss or trapped water, which are only partial indicators of decay, is visible to the scalers for estimating decayed volume in the log. Furthermore, as discussed in section 3.1, the checking apparent in the CT image is more extensive than visible to the scalers, especially checks deep inside the log (linked to decay process) that are not extended to the log surface.

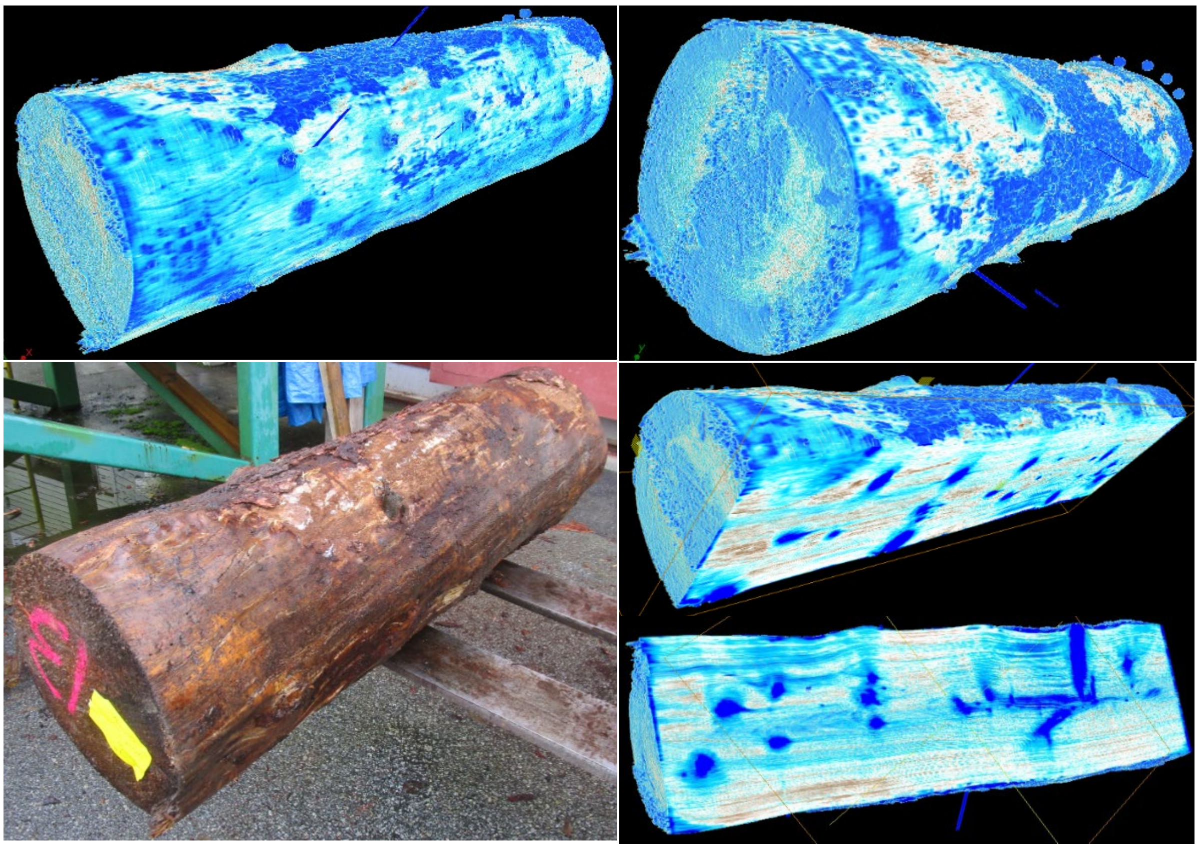

Figure 10. Log 13 and its 3D CT log models- blue representing high density and brown for low density

To verify the visual estimate of the decay boundary, another lab method (Uzunovic, 2019) was used where the discs were individually bagged and stored in a wet warm location to incubate for 2 weeks. With optimal incubation conditions, the live decay present in the wood grows out on the surface of the incubated disc in the form of white mycelium, clearly indicating where it is present in the wood. Figure 11 shows one disc (left) with both the original estimate of decay boundary marked in black and the revised boundary based on mycelium growth marked in red. This shows that the true extent of the active decay was more than the original visual estimate. Better incubation conditions may have led to more growth and further extension of boundaries marked in black. The corresponding CT image with markings approximately matching both decay boundaries are shown on the right, which are significantly more extensive than suggested by the CT images. This indicates that CT scanning may be a good tool to detect the existence of some decay but should not be used as tool for estimating the extent of decay. Detailed lab work and analysis of decay led to both logs being downgraded to grade 4 after rescaling.

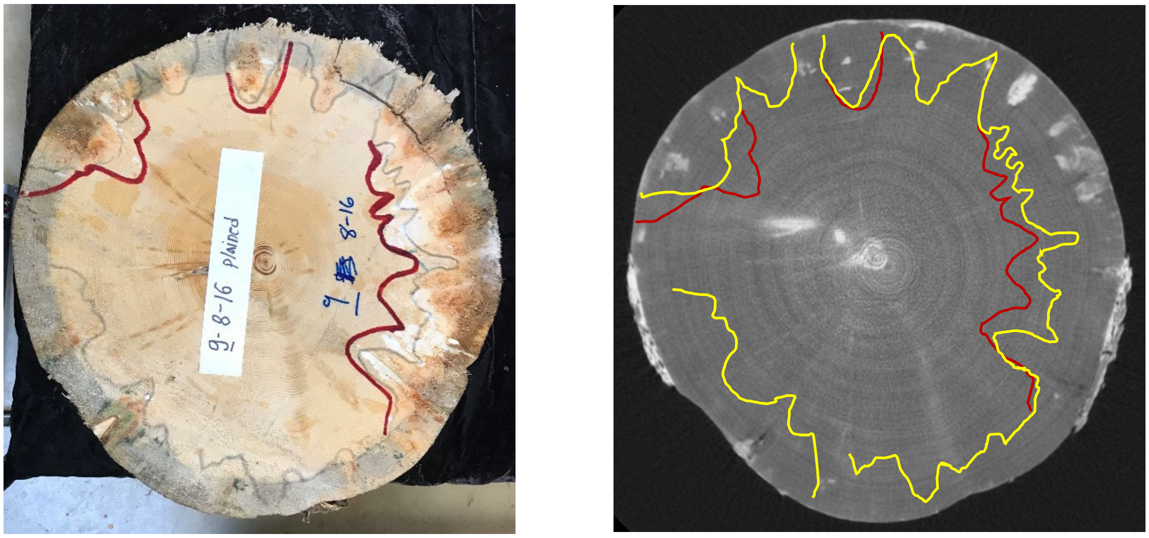

Figure 11. Better estimate of decay extension after mycelium growth marked on disk and CT image

4 CONCLUSION

Nine SBB killed grade 2 spruce logs identified by scalers as suspicious (potentially not grade 2), and three identified as good quality (confidently grade 2) were CT scanned and analyzed. Both direct inspection of the CT images and subsequent analysis revealed more extensive checking and decay than indicated by log appearance. The dry spruce logs appeared to have multiple fine checks distributed around the perimeter with individual checks openings narrower than typical for the 1-2 checks in dry pine logs. This makes depth measurement difficult during scaling and in the CT images. However, based on the CT inspection alone, two of the suspicious grade 2 logs were downgraded to grade 4. Forcing water into the checks of one good quality grade 2 log enhanced their appearance in CT images and confirmed that the depth and number of checks were more than initial conservative estimates. This led to the log being rescaled as grade 4, but checks in all other logs were measured conservatively, without the application of this method.

While warming to simulate one summer day in Interior BC enhanced the appearance of the checks, it did not help in measuring their depth. Both suspicious grade 2 logs examined in this way remained as grade 2 after rescaling. Destructive testing and lab analysis of another two suspicious grade 2 logs with decay appearance on the surface and CT images, confirmed the signs of decay (low density and trapped water). However, analysis showed that the depth and extent of decay was far greater than visible on the logs or in the CT images and as a result, both logs were downgraded to grade 4.

Overall, 5 logs from the 12 grade 2 SBB killed logs inspected were downgraded to grade 4 based on closer inspection of internal defects. Four of the downgraded logs were from the 9 identified as suspicious by the scalers. However, one of the 3 logs selected as examples of good quality grade 2 logs was also downgraded. Despite the small sample size and not being comprehensive, this study shows that much of the internal decay and checking of the SBB killed logs is difficult to detect visually, which can lead to some grade 4 logs being scaled as grade 2.

5 REFERENCES

Uzunovic, Adnan (2019). *Investigating Decay in Hybrid Spruce After Mortality due to Bark Beetle Attack in Anzac Prince George TSA*. FPInnovations.

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