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Assessing wood quality of 30-year-old regrowth karri from Nairn Block, Pemberton

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ABSTRACT

Extensive areas of even-aged regrowth karri (*Eucalyptus diversicolor*) are regenerated in Western Australia each year. As these stands mature they constitute an increasing proportion of the resource available for timber production. Thirty-year-old regrowth karri trees were harvested from a stand with a site index of 44, representing the most common site type in the regrowth karri estate, and logs were assessed for sawn recoveries and timber grade. Timber from logs cut from different dominance classes and different height positions in the tree (butt, mid and crown) were compared.

Part I of this paper describes the extent of mechanical damage (e.g. end splits, under and over sizing and want), biological attack (insect and fungal damage) and the physical nature of the stand (e.g. knots and heart) and the effect of each of the different types of damage on recovery into graded products. Part II relates the log external features to timber grade and defect.

Sawn recovery was directly related to log size (r^2=0.7) and, as expected, larger logs from the most dominant trees produced higher recoveries than the smaller logs from the least dominant trees. Defects caused by biological attack were the major cause of downgrade timber sawn from the logs of dominant, co-dominant and sub-dominant trees, whereas the problems associated with the physical nature of the stand were the main cause of timber downgrade in suppressed trees. Biological problems tended to downgrade boards while problems caused by the physical nature of the stand tended to cause boards to be rejected. Defects caused by mechanical damage resulted in equal amounts of timber being downgraded or rejected.

The mean surface area (percentage) of defects and defect combinations assessed on the internal slabs was low, but frequencies of occurrence were high, indicating that defects were scattered along the slabs and throughout the logs. For example, the mean percentage area of insect galleries for logs from the most dominant trees was 1.1 per cent and the mean frequency was 54.3 occurrences per log. For the external features, limbs (green, dry or occluded) were associated with a dry or green limb and encased bark. Dry limbs generally had more brownwood, rot and insect galleries associated with them than did green limbs. Swellings were the most common external feature (52 per cent of features assessed), with 33 per cent associated with insect galleries and about 20 per cent with brownwood. Using external features to accurately determine the type and extent of internal damage is difficult because they may relate to different types of internal damage. For example, a swelling could be related to an insect gallery, brownwood, gum or a green knot.

INTRODUCTION

Karri (*Eucalyptus diversicolor* F. Muell.) forest occurs naturally in areas of the south-west of Western Australia, from Wheatley on the Donnelly River in the north to Walpole in the south. Outlier populations occur around Margaret River and Karridale to the west and the Porongurup Range to the east of the main forest area. Forty-six per cent of the karri forest is managed primarily for nature conservation (CALM 1994), therefore approximately 54 per cent is managed for multiple uses, including timber production. Karri is regenerated after logging for timber production by either natural seeding from residual seed trees, or by hand planting with nursery-raised seedlings. In 1993 approximately 2000 ha of even-aged karri was regenerated, principally for timber production purposes (CALM 1994). As these stands mature, they will constitute an increasing proportion of the resource available for harvest from Western Australian forests. By 2020 it is estimated that about 40 per cent of the State's hardwood sawlog supply will be regrowth karri (CALM 1987).

Previous studies looking at sawmilling and wood quality of regrowth karri have been carried out by White (1989), Brennan *et al.* (1991) and White and Siemon (1992). White (1989) milled 40- to 45-year-old regrowth karri and found that more than 80 per cent of the sawn production was Structural Grade 3 or better, i.e. F11 stress grade or above, and the recovery of structural timber was 30.2 per cent. As regards appearance grades, little furniture grade material was produced, with a rejection rate in excess of 50 per cent owing to insect damage and associated brownwood. Brennan *et al.* (1991) assessed regrowth karri logs from a range of sites, age classes (49- to 70-years-old) and dominance classes (dominant to suppressed). White and Siemon (1992) conducted a sawmilling trial assessing sawn graded recoveries from two grades of regrowth jarrah (*E. marginata* Donn ex Sm.) and one grade of regrowth karri. The karri component consisted of 50-year-old first grade logs, harvested in two diameter classes (15–19.9 cm small end diameter under bark (s.e.d.u.b.) or 20–30 cm s.e.d.u.b.) and two length classes (2.4 m or 3.6 m). They found recoveries from these karri logs were poor in the 2.4 m x 15–19.9 cm size class because of the very small diameter of the logs, but the other three dimension classes tended to give similar results to those from first grade regrowth jarrah logs in those classes. Knots and insect attack were the major reasons for docking. The data on insect galleries showed a greater incidence in the larger diameter classes, which indicated that more vigorous trees are more susceptible to insect attack, i.e. the bulls-eye borer (*Phoracantha* — formerly *Tryphocaria* — *acanthocera* Cerambicidae) and others. Similarly, knots were more pronounced in the larger diameters overall.

Donnelly *et al.* (1994) conducted sawmilling surveys of medium karri sawlogs from regrowth stands, and first grade sawlogs of which at least half came from mature stands. Results showed that the incidence of incipient rot (brownwood) and/or rot were significantly greater in medium sawlogs than in first grade sawlogs. The most common symptom of fungal attack in both log classes was incipient rot. The most frequent infection points were branch stubs, borer galleries and fire damage, and *Armillaria* scars would be included in this latter category. In both log classes scattered pockets of incipient rot and/or rot were most frequently associated with borer galleries. Davison and Tay (1990) presented results on the incidence of brownwood in regrowth karri trees and concluded that brownwood is widespread in regrowth stands throughout the karri forest.

Abbott *et al.* (1991), in a study of the infestation of regenerated stands of karri by the bulls-eye borer, found that the insect attack occurs within a wide range of karri forest but no damage was recorded in fully stocked stands younger than 14 years. Damage tended to be associated with the proximity of even-aged regrowth to old growth forest or non-clearfelled stands, and also with the unsuitability of sites for pure karri, small coupe size and drought. Infestation was linked to fire damage. Abbott *et al.* (1991) suggested thinning regrowth karri stands may be a management option for reducing infestation by bulls-eye borer, but further research on the influence of site factors on karri physiology and borer ecology is needed before this control measure can be justified.

McKenzie and Donnelly (1993a, and 1993b) studied *Phoracantha* spp. damage in regrowth jarrah. Assessments in two different site types showed that between 78 per cent and 60 per cent of jarrah trees had medium to heavy attack, with the dominant and co-dominant trees in Havel type S having heavier attack than found in T type, but attacks in suppressed and sub-dominant trees were similar for each type. A sawmilling study on a sample of trees from these two site types showed each grub track had a gum vein or gum pocket associated with it. For every two lineal metres of board, there was an average of one grub track with 1.34 lineal metres of associated gum damage, mostly in the form of gum veins. Some brownwood and rot were also observed. Tucek (1991) looked at knot size and associated distribution of degraded timber in regrowth karri.

This survey looks at the sawn recoveries and wood quality of logs cut from trees of different dominance class from a 30-year-old regrowth karri stand in Nairn Block, Pemberton. It had the following major objectives :

(1) To assess the extent of internal damage by pathogens, insects and other factors in each tree dominance class, and in different log positions, and the effect on recovery of sawn products in regrowth karri logs.

(2) To assess the effect of features (e.g. dry limbs, green limbs, occluded limbs and swellings), caused by the physical nature of the stand (e.g. spacing, limb size, growth stress) on wood quality in regrowth karri logs.

The Nairn Block site was selected because it represented the most common site type in the regrowth karri estate and 30-year-old trees were studied because previous sawmilling studies had assessed wood quality of trees 49- to 70-years-old.

Other aspects are also discussed. This report is in two parts. Part I discusses the extent of damage features caused by mechanical damage, biological attack and the physical nature of the stand and their effect on recovery into graded products. Part II discusses the internal damage and also includes a discussion on the relationship between external features and internal damage.

PART I

Extent of damage features caused by mechanical damage, biological attack and the physical nature of the stand, and their effect on recovery into graded products

MATERIALS AND METHODS

Site History

Logs were extracted from Nairn Block, Pemberton District. The trees were naturally regenerated in 1963 and were 30 years old at time of felling. The site index was 44

(Rayner 1991), which represents the most common site type in the regrowth karri estate. Site index is based on stand top height at different ages. Stand top height for 30-year-old karri trees growing on the Nairn Block site indicated a site index of 44. Trees were randomly selected from each dominance class. All the selected trees showed external evidence of borer damage, but were considered representative of the amount of damage occurring on trees growing in this stand. The following site parameters were measured, (with the measurement in parentheses) :

- Stand top height of the two tallest trees (37 m)
- Site type (site index 44)
- Stand basal area (36 $m^2 ha^{-1}$)
- Stocking density (~ 300 stems per hectare — s.p.ha)
- Diameter distribution before logging (mean 27.6 cm d.b.h.o.b., S.D. 14.4 and range 11.2–51.5 cm)
- Sample size 21 trees (5 dominant, 6 co-dominant, 5 sub-dominant and 5 suppressed trees).

Diameter at breast height over bark (d.b.h.o.b.) was measured before logging and top height after logging.

Logs were harvested on 9 February 1994 and delivered to the then Wood Utilisation Research Centre (WURC) — now CALM Timber Technology — at Harvey on the same day, where they were stockpiled under water spray before milling. Eighteen logs were from dominant trees, thirteen from co-dominants, twelve from sub-dominants and eight from suppressed trees and all were subsequently cut into slabs and assessed for wood quality. In this report, logs from the different tree dominance classes are referred to as dominant logs, co-dominant logs, sub-dominant logs and suppressed logs. The slabs were sawn into boards and graded to structural grades 1, 2, 3 or below grade, before drying, dressing and grading to an appearance grade standard. In the data analysis, results from dominant and co-dominant (most dominant) logs were combined, and sub-dominant and suppressed (least dominant) logs were combined.

Cutting Pattern — Log Breakdown

Logs were placed on the Forester '150' deck with any major external defect, i.e. knot, bump or limb, in a vertical position. Commencing from the large end, logs were cut into 28 mm slabs after an initial sizing cut was made to reduce log taper. The 28 mm slabs and initial sizing sections were assessed for log defects, but the sizing sections were too small to recover any sawn timber. The slabs were cut from one side of the logs to between 40 mm and 50 mm from the heart. The logs were then turned and 28 mm slabs cut from the other side, leaving residual centre cants of 80 mm to 100 mm thick. These centre cants were then cut into 28 mm slabs on a circular saw, from the outer log section to the inner or heart side of the centre cant, and depending on its size either two or three slabs were produced (Fig. 1). The guard on this circular saw is 32.5 cm high, therefore slabs which were any wider were cut in half or trimmed on an edge, then fed vertically through the saw. The cutting pattern used in this trial generally would not be used in a commercial sawmill. The trimmed edges from the centre cant were usually wasted, because they were too small for assessment and difficult to relate to their original positions. With a 3 mm saw kerf on the 'Forester 150' and 8 mm kerf on the circular saw, the former was used where possible to maximize recovery.

Slab Resawing and Grading

Part II describes the assessment of internal damage on the boards and their relationship to log external features. After the full slabs were assessed for defects and damage, they were resawn on the 'Jonsereds' band resaw into the following widths: 109 mm, 75 mm or 58 mm. Boards were graded and docked to lengths ranging from 0.9 m to 4.8 m (in increments of 0.3 m), and with some 5.0 m lengths, aiming at producing the longer lengths in a lower grade instead of shorter lengths of a higher grade. After structural grading boards to Grades 1, 2, and 3 and below grade, according to AS 2082 — 1979 (Standards Association of Australia 1979), and recording the reasons for down grade or rejection, boards longer than 3.6 m were docked to this length for drying. Short boards (0.9 m or 1.2 m) are generally not suitable for structural purposes but were included because they may make an appearance grade based on the WA Industry Standard (FIFWA 1992), or a VALWOOD® core grade (CALM 1989). Material that was docked when structural grading was below appearance or VALWOOD® core grade.

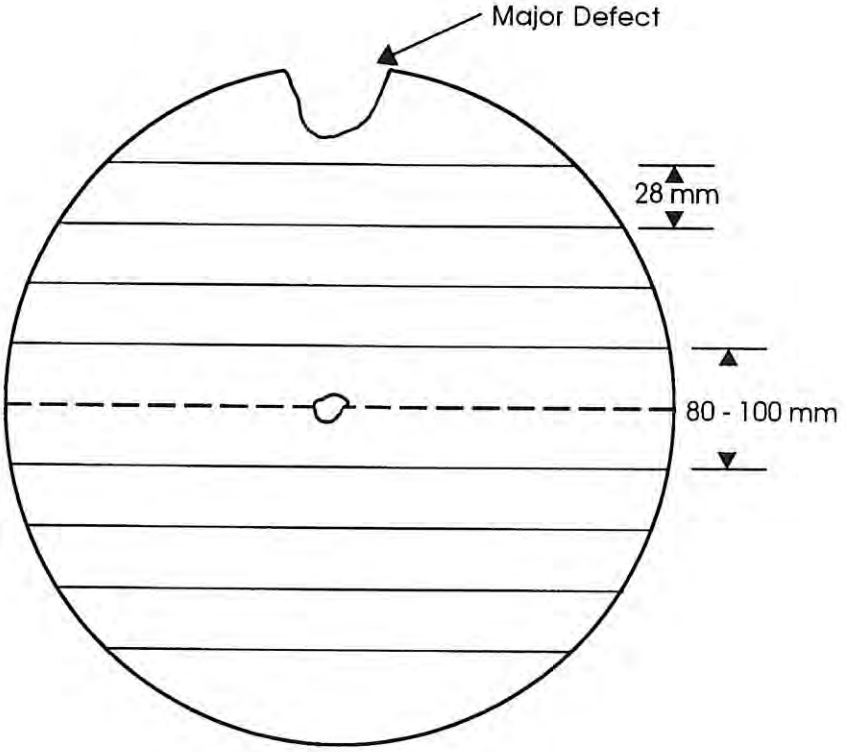
All the boards that made structural grade timber were dried and dressed to 19 mm and re-graded into appearance grade timber or VALWOOD® core grade. The results from both grading exercises are considered separately because they were carried out independently.

Defects resulting from sawing or drying, e.g. spring, bow, twist and cupping, were not taken into account when grading for structural or appearance grades. Definitions of log characteristics associated with sawn timber and rots are listed in Clarke and Ellis (1989).

RESULTS AND DISCUSSION

Log Recovery

Table 1 shows the tree and log parameters, structural timber graded recovery and percentage lost owing to sawing/trimming and docking of logs from the different dominance classes, and Table 2 shows the log parameters and structural recoveries by log position, grouping dominant and co-dominant, and sub-dominant and suppressed trees. Figure 2 shows the percentage recovery by small end diameter under bark (s.e.d.u.b.) classes (cm). As expected, the larger logs were generally from the most dominant trees and produced higher recoveries (32.9 cm mean s.e.d.u.b. and 34.9 per cent green sawn recovery) than the smaller logs from the least dominant trees (19.3 cm mean s.e.d.u.b. and 15.1 per cent green sawn



Circular saw cutting pattern

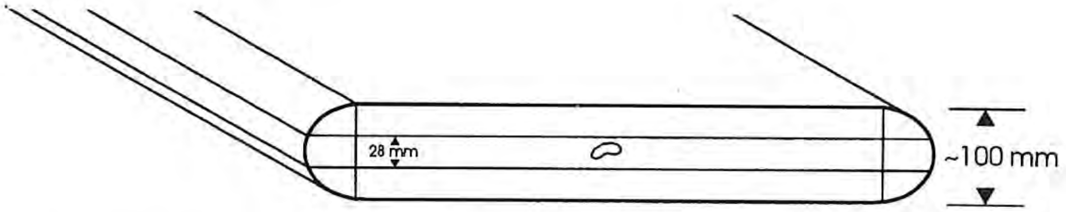


Figure 1. The cutting pattern for cutting 28 mm slabs on a Forestor 150 bandsaw and circular saw.

recovery). For all classes, sawing and trimming resulted in three to four times the loss in recovery compared with docking defects.

Of the 51 logs assessed, a mean of 56.7 per cent of log volume was lost in conversion, with a range from 48.8 per cent loss for dominant logs to 67.6 per cent for suppressed logs. Docking defects resulted in a mean loss of 17.6 per cent which ranged from 13.1 per cent for dominant trees to 21.8 per cent for suppressed trees (Table 1). The high recovery loss in logs from suppressed trees resulted from the small diameter logs producing a high proportion of boards with wane requiring trimming and large knots requiring docking.

Table 2 shows the recovery lost when converting logs to sawn boards, by log position. Recoveries by log position for the most dominant (dominant and co-dominant) trees showed only a slight difference in the recovery of the butt and mid logs, but crown logs had a mean difference between 6 and 10 per cent lower than the butt logs. With the least dominant (sub-dominant and suppressed) trees, there was a slight difference in recovery of 0.4 per cent between butt and crown logs, which is small considering the small number of logs assessed. The mid logs had slightly higher recoveries because they were produced from the larger sub-dominant trees. The butt and crown logs were from both sub-dominant and suppressed trees. Similarly, comparing recoveries by dominance class, the smaller crown logs from the most dominant trees and the butt, mid and crown logs from the least dominant trees produced lower recoveries than the butt and mid logs of the most dominant trees. This would have resulted from the smaller log size producing a high proportion of boards with wane requiring trimming, and large knots in the crown logs requiring docking.

Brennan *et al.* (1991) conducted a study on regrowth karri logs from a range of sites, age classes (49–70 years

TABLE 1

Tree and log parameters and sawn recovery by tree dominance class.

DOMINANCE CLASS	No. OF TREES	MEAN d.b.h.o.b. (cm)	MEAN TOP HEIGHT (m)	RATIO UTILISABLE BOLE TO TOTAL HEIGHT	No. OF LOGS	S.E.D.U.B. (cm)			SAWN RECOVERY (%) (on log vol.)		RECOVERY LOST (%) OWING TO			
											SAWING/ DOCKING		TRIMMING	
						Mean	S.D.	Range	Mean	S.D.	Mean	S.D.	Mean	S.D.
Dominant	5	52.2	36	0.50	18	35.2	5.3	26.7–46.2	38.1	6.7	48.8	8.0	13.1	6.7
Co-dominant	6	44.2	33	0.40	13	30.6	4.4	24.0–38.8	34.1	6.1	50.6	6.2	15.3	6.6
Sub-dominant	5	32.7	30.3	0.43	12	21.8	6.9	13.2–35.5	20.1	7.6	59.9	8.6	20	6.5
Suppressed	5	17.5	19.3	0.39	8	14.7	2	17.8–12.5	10.6	5.2	67.6	8.0	21.8	8.9

Note: Docking involved cross-cutting boards to length or removing defects.
Trimming involved resawing along boards, which reduced their widths.

TABLE 2

Log parameters and recovery by log position.

LOG POSITION	No.OF LOGS	S.E.D.U.B. (cm)			SAWN RECOVERY (%)		RECOVERY LOST (%) OWING TO			
							SAWING/TRIMMING		DOCKING	
Most dominant		Mean	S.D.	Range	Mean	S.D.	Mean	S.D.	Mean	S.D.
Butt	10	37.8	4.9	31.5–46.2	36.2	6.0	53.1	5.1	10.6	4.3
Mid	13	33.5	3.7	28.2–40.0	39	5.0	44.6	5	16.4	6.3
Crown	8	27.3	2.4	24.0–31.5	29.6	5.8	53.2	8.4	17.2	7.6
Least dominant										
Butt	10	19.5	6.6	12.8–35.5	14.8	9.8	65.8	9.1	19.4	6.4
Mid	4	22.2	6.3	18.5–29.5	16.1	8.4	60.2	10.1	23.7	7.5
Crown	6	16.3	5.8	12.5–27.8	14.4	3.8	60.6	9.9	25	9.3

Note: For the least dominant trees, the suppressed trees did not produce any mid logs, resulting in mid logs having a slightly higher s.e.d.u.b. than butt logs. Also, the butt logs for the least dominant trees were from both sub-dominant and suppressed trees, which reduced the combined s.e.d.u.b.

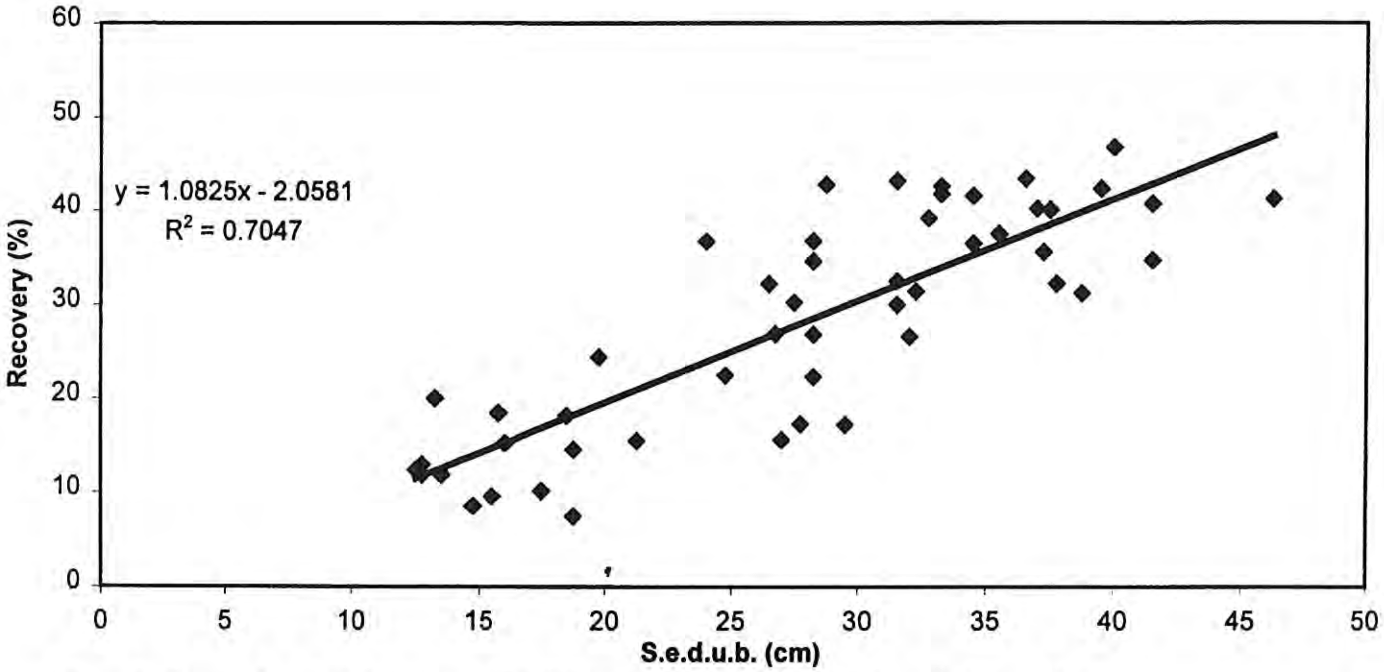


Figure 2. Structural grade timber recovery (%) of 30-year-old regrowth karri logs by s.e.d.u.b. (cm) class.

old) and dominance classes (dominant to suppressed), milling boards that were 20 mm, 30 mm, 40 mm or 50 mm thick. They found that logs with a mean s.e.d.u.b. of 35.8 cm from a high quality site had a mean recovery of 36.6 per cent (based on log volume) and logs with a mean s.e.d.u.b. of 24.6 cm had a recovery of 25.0 per cent. As confirmed in this trial, recovery was directly related to log diameter, i.e. increased s.e.d.u.b. of a log generally resulted in an increased recovery. The mean recovery across all stands was 26.6 per cent, of which 23.5 per cent met Structural Grades 1, 2 or 3 specifications and 3.1 per cent met Appearance Grade specifications. The assessment of defects within logs from the different sites indicated that under-sized boards, owing to the high shrinkage, were the most frequent defect causing downgrade, followed by knots, gum veins and pockets, surface checks and borer holes.

White (1989) recorded a structural graded recovery of 30.2 per cent for regrowth karri logs with a mean s.e.d.u.b. of 32.0 cm. White and Siemon (1992) found that recoveries from first grade regrowth karri logs were poor in the 2.4 m length and 15–19.9 cm diameter class, because of the very small log size. The other size classes, i.e. 2.4 m x 20–30 cm, 3.6 m x 15–19.9 cm and 3.6 m x 20–30 cm gave higher recoveries and similar results to those from first grade regrowth jarrah logs in those classes. White and Siemon (1992) reported that first grade regrowth karri logs in the smallest size class (2.4 m x 15–19.9 cm) required 11.6 per cent to be docked because of heart and 5.3 per cent because of gum pockets (which may have resulted from insect damage). They referred to an additional class of defect as a 'multiple' which was used when grading because some samples had 2 or 3 major defects of equal importance. This study found that knots and insect attack were major reasons for docking.

The dominant trees in this trial had a higher proportion of utilizable bole in relation to tree height, with 50 per cent of the bole utilizable for sawlogs. The trees from other classes had only about 40 per cent of their boles with a suitable size and quality for sawlogs (Table 1). Obviously the ratio of height to crown break compared with top height in dominant trees would be larger than in the other classes, and more of the tree could be utilized for sawlogs. In addition, larger diameter logs would be produced from the dominant trees and this would also improve utilization.

Figure 3 gives, by dominance class, the percentage recovery based on log volume of each structural grade. The dominant trees produced the highest Structural Grade 1 recovery while the less dominant trees produced substantially lower recoveries in Grade 1, particularly suppressed trees which had a recovery below 1 per cent. The less dominant trees had the highest amount of boards below grade with approximately 20 per cent in that category. Logs from the most dominant trees generally had less inherent defects, which would have increased recoveries into the higher grades. In a previous trial, Brennan *et al.* (1991) found that there was no significant difference for recoveries from butt and mid logs, but both were significantly higher than from crown logs. Recoveries from dominant/co-dominant logs were significantly higher than those from sub-dominant/ suppressed logs and the results showed that log size was the overriding factor in determining recovery.

Appearance Grading

Figure 4 shows, by dominance class, the percentage recovery based on log volume of each appearance grade in

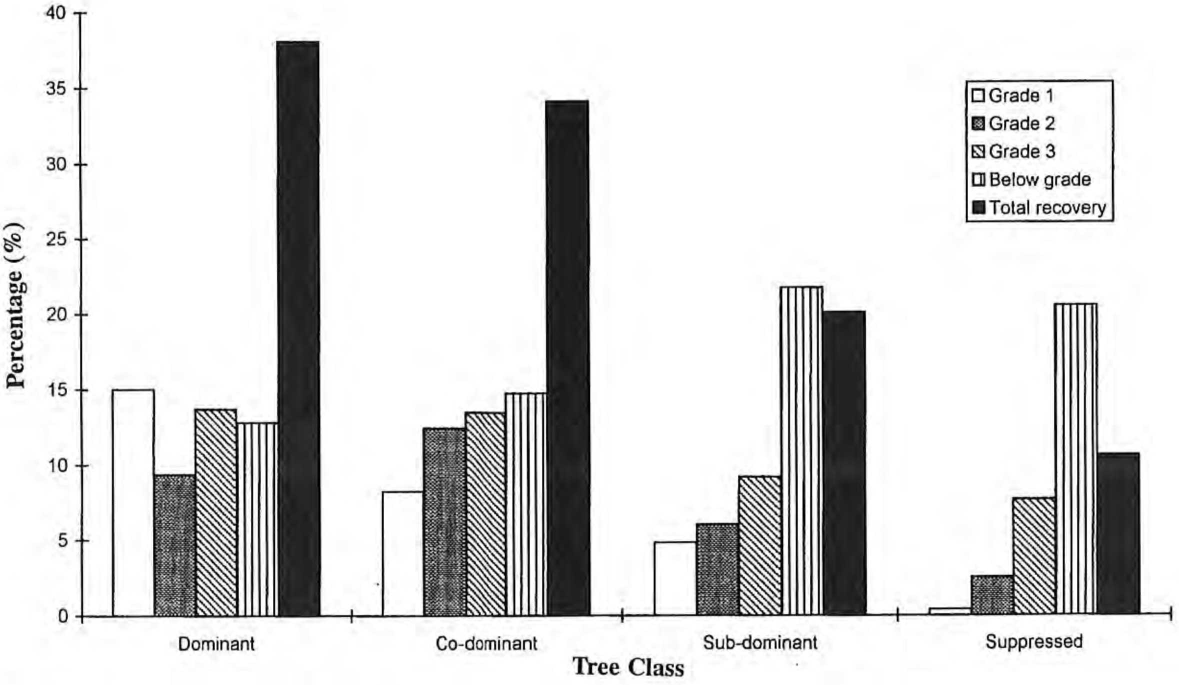


Figure 3. Percentage recovery by dominance class and structural grade (compared with log volume).

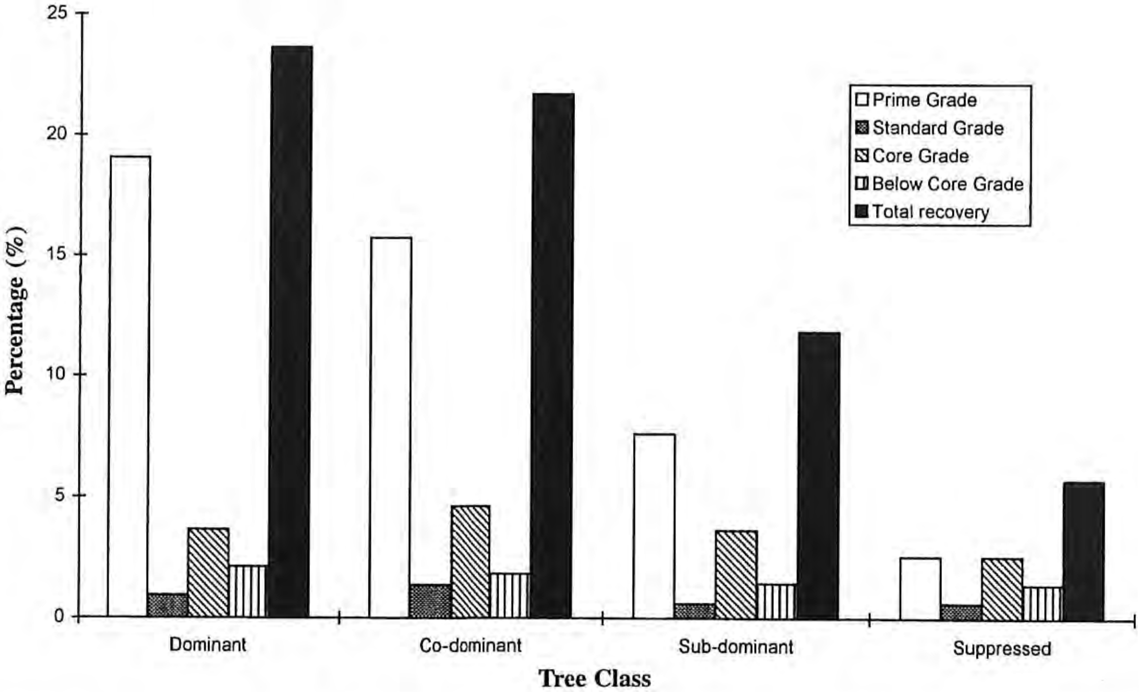


Figure 4. Percentage recovery by dominance class and appearance grade (compared with log volume).

each dominance class. As stated previously, the structural and appearance grading results are independent, because the structural timber was subsequently dried, dressed and re-graded. Prime Grade is based on the best face and two edges, and Standard Grade is based on four sides. This grading exercise aimed at maximizing recovery in the highest grade and longest lengths. VALWOOD® core grade boards are structurally sound and suitable for filler laminates in panels or products to be used without further manufacture.

The grading rules allowed a greater tolerance of imperfections for Standard Grade than for Prime Grade, but the requirement to grade on all four sides in Standard Grade is a restriction. The dominant and co-dominant trees had 19.1 per cent or 15.8 per cent of Prime Grade respectively because many boards were clear or the imperfections could be concealed on one face. Grading was to a minimum length of 0.9 m and this allowed many imperfections to be docked from longer boards, increasing the recovery into Prime Grade.

The sub-dominant and suppressed trees had a higher proportion of VALWOOD® core grade and below grade boards than the most dominant trees, owing to a high proportion of imperfections and characteristics that downgrade appearance timber. The Prime Grade boards were generally from the larger butt logs. These results are comparable to those of 64-year-old regrowth jarrah, where 12 per cent of Clear Grade and 32 per cent of Feature Grade were recovered (Brennan and Pitcher 1992).

Effect of Defects on Recovery

Appendix 1 shows the percentages of defects causing downgrade to Structural Grades 2 and 3 and below grade for each dominance class. A summary of these defects into those caused by mechanical damage, physical nature of the tree/stand, and biological problems is given in Table 3. Where defects are listed as a combination, e.g. borer/knot, or end split/knot, then that board or piece could have been downgraded or rejected for either defect. Defects in the mechanical group included end splits, under or over sizing, wane, want, cross grain and combinations of these defects. Physical nature of the tree/stand included knots, heart, encased bark and their combinations, and biological problems included borers, gum, brownwood, rots and their combinations.

Borers and knots tended to downgrade a board from Grade 1 to Grade 2 or 3, rather than cause it to be rejected. Heart is not accepted in structural timber, therefore boards with heart or heart associated with another defect resulted in more rejection than downgrade to Grades 2 and 3. The grading rules for Structural Grade 3 state that knots and borer holes (not associated with decay and over 3 mm in diameter) are permissible defects provided they do not exceed one third of the width of the surface on which they occur. In most cases the size and location of borer holes and galleries did not exceed these limits.

Table 3 shows the loss of recovery owing to docking or log breakdown and resawing for each dominance class. Mechanical damage was the cause of most docking in the dominant and co-dominant trees. Faults caused by the physical nature of the stand were the major causes of docking in the least dominant trees, particularly suppressed trees, where heart and knots were the main problems. Faults resulting from biological damage were similar for dominant and co-dominant trees, but damage caused by biological attack was higher in sub-dominant trees than in suppressed trees.

Table 4 gives the loss of recovery owing to docking or log breakdown and resawing for each log position. The high recovery in the mid logs compared with that in butt logs would be because there were no smaller mid logs from suppressed trees, which would result in increased overall recovery in this log position. These recoveries are slightly different from those shown in the data in Table 2 for the most and least dominant trees, because of different log numbers involved. Mechanical damage was the major reason for docking in butt and mid logs, and the physical nature of the stand (knots and heart) in crown logs.

TABLE 3

Comparison of recoveries and losses to docking and log breakdown/resawing by dominance class (percentages based on log volume).

CLASS	SAWN RECOVERY (%)	LOSS (DOCKING) (%)				LOSS (BREAKDOWN/ RESAWING (%)
		MECH. DAMAGE	PHYSICAL NATURE OF STAND	BIOL. PROBLEM	TOTAL	
Dominant	38.1	5.6	3.8	3.7	13.1	48.8
Co-dominant	34.1	7.3	4.6	3.5	15.4	50.5
Sub-dominant	20.1	4.9	8.8	6.4	20.1	59.8
Suppressed	10.6	3.9	13.0	2.3	19.2	70.2

TABLE 4

Comparison of recoveries and losses to docking and log breakdown/resawing by log position (percentages based on log volume).

CLASS	RECOVERY (%)	LOSS (DOCKING) (%)				LOSS (BREAKDOWN/ RESAWING) (%)
		MECH. DAMAGE	PHYSICAL NATURE OF STAND	BIOL. PROBLEM	TOTAL	
Butt	26.2	6.0	3.9	3.0	12.9	60.9
Mid	34.1	7.0	5.4	4.6	17.0	48.9
Crown	23.7	5.7	9.5	2.2	17.4	58.9

Appendices 2 to 5 give the percentage of defects and ranking according to the percentage causing rejection or downgrade by dominance class or log position. The highest ranked defects causing rejection were generally knots, wane, want and heart. For example, heart in logs from suppressed trees resulted in 14.5 per cent of the log being docked (Appendix 2). Knots were the major cause of rejection in crown logs. The major cause of downgrade to Grades 2 and 3 for dominance classes were borers, knots and gum (Appendix 3). In all log classes defects resulting from biological attack were clearly causing the highest amount of downgrade, and problems associated with the physical nature of the stand were generally causing more rejection (Appendices 4 and 5). Mechanical damage resulted in similar amounts being downgraded or rejected.

Similar results occurred when looking at the different log positions, i.e. problems caused by biological attack generally caused the boards to be downgraded, whereas the defects caused by the physical nature of the stand caused the most rejection. Borers were causing the highest downgrade in butt and mid logs, and knots caused the highest downgrade in crown logs (13.1 per cent) (Appendix 5). Gum ranked either second or third in importance in all log positions and knots were ranked highly in butt and mid logs. As with dominance classes, heart caused the greatest amount of rejection in butt and mid logs and the second highest in crown logs.

PART II

The relationship between log external features and timber grade and defect

Slabs produced in log breakdown were re-sawn and the resulting boards graded into structural and appearance grade boards as described in Part I. Before resawing, the slabs were assessed for internal damage and the outer wings were examined for external features, e.g. limbs, swellings and knots, which is described here. The objective of Part II is to quantify the extent of damage by pathogens and insects, in different tree dominance classes and the extent of external features, such as limbs, bumps, and knots, and their effect on wood quality.

Slab Assessment Methods

The following method was used to assess the slabs and relate the external features to internal damage.

(1) After cutting the logs through-and-through, the resulting slabs were stacked in the order they were cut. The slabs were then stacked in a drying shed, in the order they were cut, on metal supports 1.5 m above the ground and then assessed on the outer face. Slabs from one side of the log were identified numerically and from the other alphabetically. The centre slab was assessed on both sides because defects on either side of the slab related to different sides of the log. A plastic template 5 m long marked with 200 x 40 mm rectangles was placed on each slab, with the centre of the plastic sheet corresponding to the centre of the slab. The surface area of individual defects was assessed using a small overlaying grid with either 20 x 25 mm or 5 x 100 mm rectangles, with each grid square on the overlay representing 5 cm^2. Defects were measured from the butt to the crown end of each slab.

(2) Assessment of both halves of the log was from the outside to the inside of the log. This allows comparison of defects observed on the outside of the log with those on the sawn faces of the slabs. If the slab surface had dried, making it difficult to see brownwood and other discolorations, water was applied to improve assessment.

(3) The following slab dimensions were recorded: length, thickness at both ends, and width (measured at 1 m intervals along the slabs). Slab surface area (m^2) and volume (m^3) were then calculated, and the percentage surface area and frequency for each defect was determined on a per log basis.

(4) The following defects were assessed on each 25 mm slab:

- presence of grub tracks (galleries) or holes, pupation chambers and bulls-eyes;
- associated damage caused by the tree's response to the insect's activities (gum veins, gum pockets, callus formation and overgrowth);
- signs of fungal activity, e.g. discoloured sapwood, brownwood, white pocket rot, and white rot and any fungal activity associated with insect galleries, branches or mechanical damage;
- other features, e.g. heart, knots, limbs, included sapwood, etc. were also recorded.

An association was considered to occur when defects were visually connected or could be related to each other. When associations occurred between defects, they were assessed for presence, area and location. Some of the associations included insect galleries and brownwood, insect galleries and gum, knots and brownwood. In some cases three or occasionally four defects were in association, e.g. insect galleries, knots and brownwood or insect gallery, brownwood and rot. To simplify the data, only the individual defect occurrences have been included.

Total surface areas for features or defects were extracted from field sheets, by summing the surface area of a particular defect on the same slab and across the slabs. Where a defect occurred across a number of slabs the frequency was one, and the surface area was the sum of the surface areas for all those defects. Percentage surface area was expressed as the proportion of that defect occurring over the whole slab area, and frequency as the mean number of occurrences of that particular defect on a per log basis. In some cases, particularly with insect galleries, the area of the defect was not large enough to be measured with the grid squares, therefore no area was recorded but a note made about its presence.

Incipient rot (brownwood) and rot in regrowth karri can be caused by at least two fungi, *Stereum hirsutum* and *Hymenochaete* spp. (Davison and Tay 1990). Brownwood is incipient rot and consequently was not classed as a defect when structurally grading karri timber.

RESULTS AND DISCUSSION

Ranking of Defects by Percentage Surface Area and Mean Frequency for each Dominance Class

The major features observed on the slabs are ranked by dominance class (Table 5) and log position (Table 6).

Table 5 shows the ranking of defects by mean percentage surface area and frequency, based on the slab assessment results. For percentage surface area, brownwood was either the first or second highest ranked defect in all dominance classes, and in the suppressed trees it is ranked equally with knots and insect galleries. Knots and insect galleries were ranked second or third in the most dominant trees and either first or third in the least dominant trees. Gum, rot and heart were overall ranked fourth, fifth or sixth in the dominant and sub-dominant trees, but heart was second highest in suppressed trees. The percentage surface areas affected by defects are very low, for example, brownwood in co-dominants has the greatest value with 2.7 per cent of the slab surface area affected. The areas of some of the defects are insignificant, for example, heart in the dominant trees affected a mean 0.07 per cent of the surface area.

For mean frequencies, insect galleries and knots were the most frequent defects, whereas brownwood was ranked lower. Gum and heart were ranked fourth or fifth and rot was so infrequent it is not listed. As stated above, brownwood was generally the defect with the largest surface area overall, tending to occur in the centre slabs of many butt logs (Table 5). Although this area is small, brownwood has the potential to develop into rot and decay as the tree grows. Rot development is affected by compartmentalization as defined by Shigo (1979), i.e. the vertical spread of rot is considerably greater than the horizontal spread. The individual areas affected were small, but the large number of occurrences per log reduces recoveries into high grade structural and appearance grade timbers.

Table 6 shows the mean percentage surface area, frequencies and ranking of defects based on log position. For mean percentage surface area, brownwood was the highest ranking defect in butt and mid logs and third highest in the crown logs. Insect galleries were ranked second in all log positions, and knots were ranked first in the crown logs and third in the butt and mid logs. Rot, gum and heart were ranked fourth, fifth or sixth in all log positions. The ranking of mean frequencies showed that insect galleries were the most frequent defect in butt and mid logs, and the second highest in crown logs. For example, in mid logs the mean frequency was 66.6 occurrences per log. Knots were the most frequent defect in crown logs, and second in butt and mid logs. Generally insect galleries and knots were the most frequent, and gum, brownwood and heart the least frequent defects in all log positions.

Tables 7 and 8 show the pairwise associations of mean frequency of defects assessed on the slabs by log position and dominance class. For all log positions, insect galleries were generally not associated with another defect, but were associated occasionally with brownwood. For example, in mid logs an average 20.9 occurrences of insect galleries were associated with brownwood, because it is likely that borers carried fungal spores into the wood. Knots also tended to not be associated with another defect. When an association did occur, knots were equally associated with insect galleries, brownwood or gum, but occurrences were low with only between 1.8 and 4.3 occurrences per log in all log positions. Heart in all log positions was not associated with any other defect.

Similar trends can be seen when the associations are compared by dominance class, with insect galleries and knots tending not to be associated with another defect. For example, in the most and least dominant class, trees

TABLE 5

Mean percentage surface area (SA) and frequency, and ranking of defects on slabs, by tree dominance class (% SA and frequency on per log basis).

DEFECT	DOMINANT		CO-DOMINANT		SUB-DOMINANT		SUPPRESSED	
	SA %	RANK	SA %	RANK	SA %	RANK	SA%	RANK
Brownwood	1.5	1	2.7	1	1.4	2	0.8	1
Knots	1.0	2	0.9	3	0.6	3	0.8	1
Insect Gallery	0.7	3	1.7	2	1.5	1	0.8	1
Gum	0.6	4	0.3	5	0.3	4	0.1	3
Rot	0.2	5	0.3	4	0.2	5	-	-
Heart	0.1	6	0.2	6	0.1	6	0.2	2
	FREQ.	RANK	FREQ.	RANK	FREQ.	RANK	FREQ.	RANK
Insect Gallery	53.7	1	37.1	1	55.2	1	16.3	2
Knots	33.8	2	23.7	2	23.8	3	30.0	1
Brownwood	25.4	3	14.8	3	25.2	2	10.3	3
Gum	12.3	4	10.6	4	18.7	4	2.6	4
Heart	2.6	5	3.1	5	3.3	5	3.1	5

TABLE 6

Mean percentage surface area (SA) and frequency, and ranking of defects on slabs, by log position (% SA and frequency on per log basis).

DEFECT	BUTT		MID		CROWN	
	MEAN %SA	RANK	MEAN %SA	RANK	MEAN %SA	RANK
Brownwood	1.7	1	1.9	1	1.2	3
Insect Gallery	0.9	2	1.4	2	1.3	2
Knots	0.6	3	0.7	3	1.4	1
Rot	0.3	4	0.2	4	0.1	6
Gum	0.1	5	0.2	6	0.4	4
Heart	0.1	6	0.2	5	0.1	5
	MEAN FREQ.	RANK	MEAN FREQ.	RANK	MEAN FREQ.	RANK
Insect Gallery	38.0	1	66.6	1	28.3	2
Knots	20.2	2	30.7	2	30.8	1
Gum	11.7	3	14.4	3	9.9	4
Brownwood	8.8	4	27.8	4	11.6	3
Heart	2.9	5	3.1	5	3.1	5

TABLE 7

Pairwise associations of mean frequencies of defects assessed on slabs, by log position.

	PAIRWISE ASSOCIATIONS OF DEFECT (MEAN PERCENTAGE PER LOG)					
	INSECT GALLERIES	KNOTS	BROWNWOOD	GUM	HEART	OVERALL MEAN FREQUENCY PER LOG
BUTT LOGS						
Insect Gallery	18.9	1.8	13.6	6.5		40.8
Knots		20.9	1.8	2.0		24.7
Brownwood			8.1	-		8.1
Gum				7.7		7.7
Heart					2.9	2.9
MID LOGS						
Insect Gallery	34.0	4.3	20.9	9.4		68.6
Knots		21.4	2.8	2.7		26.9
Brownwood			5.2	-		5.2
Gum				8.4		8.4
Heart					3.1	3.1
CROWN LOGS						
Insect Gallery	14.6	2.5	8.8	4.3		30.2
Knots		23.4	3.4	3.1		29.9
Brownwood			1.4	-		1.4
Gum				6.0		6.0
Heart					3.1	3.1

TABLE 8

Pairwise associations of mean frequencies of defects assessed on slabs, by dominance class.

	PAIRWISE ASSOCIATIONS OF DEFECT (MEAN PERCENTAGE PER LOG)					
	INSECT GALLERIES	KNOTS	BROWNWOOD	GUM	HEART	OVERALL MEAN FREQUENCY PER LOG
MOST DOMINANT						
Insect galleries	25.8	3.3	12.6	8.2		49.9
Knots		21.8	3.0	4.0		28.8
Brownwood			6.2	-		6.2
Gum				8.0		8.0
Heart					2.8	2.8
LEAST DOMINANT						
Insect galleries	14.6	2.3	15.0	5.4		37.3
Knots		21.8	2.5	2.6		26.9
Brownwood			3.6	-		3.6
Gum				6.0		6.0
Heart					3.2	3.2

had an average of 25.8 per cent and 14.6 per cent respectively of insect galleries per log which were not associated with another defect. When insect galleries were associated with another defect, they tended to be associated with brownwood. Generally knots were not associated with another defect, but when they were, it was equally with insect galleries, brownwood and gum. Neither gum nor heart were associated with another defect, and their overall frequencies were low.

Analysis of Variance

Analysis of variance was used to compare the differences between various defects and the proportion of one defect associated with a second.

Fourteen comparisons of different defects and defect combinations were made between logs from different dominance classes and log positions using analysis of variance (Appendix 6). Comparing logs from the most and least dominant trees showed that the proportion of knots associated with rot was significantly greater in logs from the most dominant trees. All the other comparisons indicated no significant difference.

For logs cut from butt, mid and crown positions, four comparisons were significantly different. They were :

- Insect galleries, either by themselves or associated with another defect, were significantly more frequent in mid logs than in butt and crown logs and there was no significant difference between butt and crown logs.
- Brownwood, either by itself or associated with another defect, was significantly more prevalent in butt and mid logs than in crown logs.
- The proportion of brownwood associated with knots compared with the total amount of brownwood indicated that crown logs had a significantly higher proportion than butt and mid logs.
- Knots, either by themselves or associated with another defect, indicated that crown logs had a significantly greater surface area of knots and associated defects than did butt and mid logs, but no significant difference occurred between log positions for frequency of knots.

In general, the analysis of variance for the different defects and defect associations indicated that the mean percentage surface areas affected were low, but their frequencies were higher, indicating that defects were scattered along the slabs and throughout the logs. For example, the percentage surface area of insect galleries not associated with another defect for logs from the most dominant trees was 1.07 per cent, but the mean frequency was 54.3 occurrences per log, indicating that insect galleries are small in comparison with the slab surface areas, but are frequently scattered throughout the log. The results also showed high standard deviations for both percentage surface area and frequency in many of the defects and defect associations, indicating large variations between the logs assessed.

Association of External Defects with Internal Damage

The external features, e.g. swellings and green, dry or occluded limbs, were initially assessed on the whole log before milling, or on the outer slabs or wings after cutting the logs. These were visually associated with any damage found on the inner slabs, e.g. if a limb was associated with a green or dry knot or a bump with an insect gallery. Table 9 shows the number of external defects, separating those that relate to an internal defect, i.e. dry knots, green knots, brownwood, rot and insect galleries.

A limb observed on the external part of the log was associated with a dry or green knot and encased bark as

TABLE 9

Number of external features related to an internal defect (percentages in parentheses) for 51 regrowth karri logs assessed.

EXTERNAL FEATURE		INTERNAL DEFECTS					FUNGAL ATTACK		INSECT DAMAGE
	TOTAL	DRY KNOTS	GREEN KNOTS	ENCASED BARK	GUM	VOID	BROWNWOOD	ROT	INSECT GALLERIES
Dry limb	133	26 (19.5)	44 (33.1)	23 (17.3)	4 (3)	1 (0.75)	11 (8.3)	11 (8.3)	13 (9.8)
Green limb	70	10 (14.3)	30 (42.9)	14 (20.0)	4 (5.7)	1 (1.4)	5 (7.1)	1 (1.4)	5 (7.1)
Occluded limb	100	15 (15)	28 (2.8)	24 (24.0)	5 (5.0)	1 (1.0)	11 (11)	6 (6.0)	10 (10.0)
Swelling	330	17 (5)	54 (16.4)	42 (12.7)	49 (14.8)	7 (2.1)	62 (18.8)	6 (1.8)	93 (28.2)

expected. The dry limbs generally had more associated brownwood, rot and insect galleries than did the green limbs. Swellings were the most common external feature (52 per cent), with 30 per cent associated with insect galleries and about 20 per cent with brownwood. Dr Janet Farr, based on external and internal assessment of regrowth karri trees, has suggested that there is a 75 per cent probability that external damage is an indication of internal *Phoracantha* (formerly *Tryphocaria*) spp. damage (Farr[1] personal communication). However, to reliably assess the amount of insect damage within the tree using external features, evidence of exit holes associated with fresh kino is required.

Using external features to accurately estimate the internal damage that is inside the log is difficult, because they relate to different types of internal damage. For example, a swelling could be related to insect galleries, brownwood, gum or a green knot. External signs of branches are a more reliable indicator of internal problems because they tend to be associated with either a green or dry knot.

White and Kile (1991) have demonstrated that stem wounds inflicted during mechanical thinning operations can lead to the development of substantial columns of decay. Fire has also been commonly associated with stem damage, allowing the establishment of decay and termites in eucalypts. Wilkes (1985) found that decay columns in eucalypts often originated from sources other than those external agencies which mechanically damage the stem cambium. Apart from stem wounds originating from logging damage, he found that branch stubs and wood boring insects were also common origins of wood decay columns in dry sclerophyll eucalypt forests in northern New South Wales. White and Kile (1991) similarly found that a high proportion of trees had decay columns originating from branch stubs in a young eucalypt regrowth forest in Victoria, although their findings were based on a relatively small sample from one area.

This study showed that the external features of limbs and swellings were associated with internal fungal and insect attack (Table 9). External swellings were the highest indicator of internal brownwood, rot or insect galleries, while about 10 per cent of dry and occluded limbs were associated with fungal or insect attack. Green limbs were an indication of the least amount of fungal and insect attack, with 7 per cent associated with brownwood and insect galleries and 1 per cent associated with rot.

Wardlaw (1996) identified almost 600 columns of discoloration and decay in 213 Tasmanian eucalypt trees sampled. Ninety-three per cent of the columns originated from above ground sources. Branch origins accounted for 55 per cent of the columns, with the columns starting either at the fracture point of an improperly shed branch (either occluded or open) or in the branch proper. In the latter case some of the columns had already established while branches were still alive. Columns of decay arising from branches tended to be larger than the other above ground origins and their contribution to the total decay volume was greater than 60 per cent in both butt and crown logs. Branch crotches accounted for the origin of 16 per cent of the decay columns. Fifteen per cent of the decay columns were associated with galleries of stem-boring insects. The remaining 7 per cent of the decay columns originating above ground were from wounds (commonly abrasion), dead tops or were of indeterminate origin. Decay columns associated with these origins tended to be smaller than all but columns of branch crotch origin and their contribution to the total decay volume was small in both the butt and crown logs. Butt rots evidenced by discoloration and decay arising from below ground accounted for the remaining 7 per cent of the decay columns.

Similarly, in 7-year-old *Acacia mangium* plantations grown in Malaysia, the most frequent entry points for fungi causing heart rot were pruning wounds (either natural or mechanical), thinning damage (38.6 per cent) and dead branch stubs (38.4 per cent) (Lee[2] personal communication).

Wardlaw (1996) also found that the proportion of trees with extensive decay was quite low, but those trees were concentrated on two of the four sites assessed. This indicates that the impact of decay on sawlog recovery would be likely to become significant on some sites targetted for intensive management for wood production.

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REFERENCES

Abbott, I., Smith, R., Williams, M. and Voutier, R. (1991). Infestation of regenerated stands of karri (*Eucalyptus diversicolor*) by bullseye borer (*Tryphocaria acanthocera*, Cerambycidae) in Western Australia. *Australian Forestry* **54** (1 and 2), 66-75.

Brennan, G.K. and Pitcher, J.A. (1992). Sawing regrowth jarrah grown under different silvicultural prescriptions. Department of Conservation and Land Management, *WURC Technical Report* No. 32.

Brennan, G.K., Glossop, B.R. and Rayner, M.E. (1991). Sawmilling regrowth karri of differing age and dominance class from a range of site types. Department of Conservation and Land Management, *WURC Technical Report* No. 29.

CALM (1987). *Timber production in Western Australia: A strategy to take W.A.'s south-west forests into the 21st century*. Department of Conservation and Land Management, Western Australia.

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[1] Dr J Farr, Department of Conservation and Land Management, Manjimup, Western Australia.

[2] Dr Su See Lee, Forest Research Institute, Kepong, Malaysia.

CALM (1989). Grading criteria for VALWOOD® core material. Department of Conservation and Land Management, Western Australia.

CALM (1994). *Annual Report:* July 1993 to June 1994. Department of Conservation and Land Management, Western Australia.

Clarke, J. and Ellis, G. (1989). *Log faults: A glossary of defects and other characteristics of trees and logs in the south-west of Western Australia.* Department of Conservation and Land Management, Western Australia, Information Booklet.

Davison, E.M. and Tay, F.C.S. (1990). Brownwood in karri. Unpublished Interim Report, Department of Conservation and Land Management, Western Australia.

Donnelly D.J., Rule, R. and Davison, E.M. (1994). Incidence of brown wood (incipient rot) and rot in regrowth karri: comparison of medium and first grade sawlogs. Department of Conservation and Land Management, Western Australia, unpublished report.

FIFWA (1992). Industry standard for seasoned, sawn and skip-dressed W.A. hardwoods. Forest Industries Federation of Western Australia.

McKenzie, J.W. and Donnelly, D.J. (1993a). *Tryphocaria* attack in regrowth jarrah — pilot study. Department of Conservation and Land Management, WURC Internal Report.

McKenzie, J.W. and Donnelly, D.J. (1993b). *Tryphocaria* damage in jarrah appearance grade timber. Department of Conservation and Land Management, WURC Internal Report.

Rayner, M.E. (1991). Site index and dominant height growth curves for regrowth karri (*Eucalyptus diversicolor* F. Muell.) in south-western Australia. *Forest Ecology and Management* **44**, 261–283.

Shigo, A.L. (1979). Tree decay. An expanded concept. United States Department of Agriculture, Forest Service, *Agricultural Information Bulletin* No. 419.

Standards Association of Australia (1979). *Visually stress-graded hardwoods for structural purposes.* AS 2082–1979.

Tucek, M.E. (1991). Knot size and associated distribution of degraded timber in karri. Department of Conservation and Land Management, *WURC Technical Report* No. 35.

Wardlaw, T. J. (1996). The origin and extent of discolouration and decay in stems of eucalypts in southern Tasmania. *Canadian Journal of Forest Research* **26**, 1–8.

White, K.J. (1989). Sawmilling of regrowth karri logs. Department of Conservation and Land Management, *WURC Technical Report* No. 8.

White, D.A. and Kile, G.A. (1991). Thinning damage and defect in regrowth eucalypts. In: *The Young Eucalypt Report.* Eds C.M. Kerruish and W.H.M. Rawlins. CSIRO, Canberra.

White, K.J. and Siemon,G.R. (1992). Sawn recoveries from regrowth jarrah and karri graded logs. Department of Conservation and Land Management, *WURC Technical Report* No. 39.

Wilkes, J. (1985). Host attributes affecting patterns of decay in a regrowth eucalypt forest. I. Patterns of natural decay. *Holzforschung* **39**, 17-22.

APPENDIX 1

Defects causing downgrade to Structural Grades 2 and 3 and below grade (percentages are based on log volume).

	DOMINANCE CLASS											
	DOMINANT			CO-DOMINANT			SUB-DOMINANT			SUPPRESSED		
GRADE	2	3	B.G.	2	3	B.G	2	3	B.G.	2	3	B.G.
Borers	2.4	6.2	0.6	1.2	5.2	3.07	4.4	2.08	4.8		3.7	
Borers/knots	0.1	0.7	0.1	2.8	1.8	2.7	6.3	7.4	0.5			
Borers/gum	0.2	0.7	-	-	3.2	-						
Borers/heart	-	-	-	-	-	1.9						12.7
Borers/rot	-	0.1	0.4	-	-	-						
Brownwood	-	-	0.2	-	-	-						
Cross grain	-	-	0.1	-	-	-						
End splits	0.1	0.5	1.4	-	0.8	0.9		1.0	0.6			
End splits/knots	0.2	0.3	0.5	-	1.9	-						
End splits/borers	-	0.4	0.1	-	-	0.2						
Gum	1.9	0.5	0.1	2.2	3.7	1.0	2.7	2.2	1.6			
Gum/wane	0.2	0.2	-	-	-	-						
End splits/gum	0.4	0.3	0.1	-								
Knots	4.2	3.6	2.1	3.0	3.2	1.29	4.6	6.8	0.9	3.6	11.9	
Knots/gum	0.2	0.3	0.1	-		-						
Knots/wane	0.2	0.1	0.3	-		-			1.4			3.0
Heart	-	-	0.6	-		9.4			10.8			12.1
Heart/knots	-	-	0.3	-		3.3			3.9			
Heart/rot	-	-	0.1	-		-						
Undersize	-	-	0.9	-		6.9			4.6			
Oversize	-	-	0.1	-		-						
Rot	-	0.1	0.4	-		0.8			2.7			
Wane	0.4	1.1	1.2	-		12.5		2.7	3.8			4.6
Undersize/ heart	-	-	0.2	-		5.1						
Undersize/knots	-	-	0.3	-								
Borer/wane	-	0.3	0.1	2.0				1.9	5.3			
Rot/wane	-	-	-									
End splits/checking	-	0.2										
End split/undersize		-	0.1									
Knots/want			0.2									
Rot/want			0.1									
Want/end splits			0.1									
Want			0.1			0.3						
Undersize/borers			0.1									
Borers/want			0.1									
Knots/rot			0.1									
Included sapwood												1.7
TOTALS	10.4	15.5	10.1	11.2	19.9	49	18	24	40.7	3.65	15.5	34.2

B.G. = Below grade.

APPENDIX 2

Percentage of defects causing board rejection and ranking (by dominance class) when grading to AS 2082 (percentages based on log volume).

DEFECTS	DOM	RANK	CO-DOM	RANK	SUB-DOM	RANK	SUPP.	RANK
Knots/combination	3.0	1	1.6	5	0.8	8	0.5	5
Wane/want	2.2	2	2.8	3	3.5	3	3.2	2
Heart/combination	2.2	3	4.1	1	7.6	1	14.5	1
End splits	2.1	4	1.4	6	1.4	5	0.2	8
Borers/combination	1.9	5	3.5	2	4.4	2	1.9	3
Sizing	1.2	6	2.2	4	2.8	4	-	-
Heart/rot	0.4	7	0.2	8	1.1	6	1.1	4
Rot	0.4	8	0.2	10	0.2	>10	-	-
Gum/combination	0.2	9	0.5	7	0.5	9	-	-
Brownwood	0.2	10	0.1	>10	-	-	0.3	6
Cross grain	0.1	>10	-	-	0.4	>10	-	
Gum	0.1	>10	0.2	9	0.2	>10	-	
Borers/brownwood	0.1	>10	0.1	>10	0.3	10	0.2	7
Rot/brownwood	-		-	-	0.9	7	0.1	9
Gum/brownwood	-		0.1	>10	0.1	>10	-	
Rot/gum	-		0.1	>10	-	-	-	
Included sapwood	-		-	-	-	-	-	
Mechanical Damage	5.4		6.5		7.8		6.8	
Physical Effects	5.2		5.1		8.4		15.2	
Biological Attack	2.6		4.7		8.8		3.1	

X/combination: that defect and their combinations, e.g. knots/combination is knots and knots associated with other defects.

APPENDIX 3

Percentage of defects causing downgrade to Structural Grades 2 and 3 and ranking (by dominance class) when grading with AS 2082 (percentages based on log volume).

DEFECT	DOMINANT		CO-DOMINANT		SUB-DOMINANT		SUPPRESSED	
	% DG	RANK	%D.G	RANK	%D.G	RANK	%D.G	RANK
Borer/combination	9.8	1	11.2	1	6.8	1	2.7	2
Knots/combination	7.9	2	8.7	2	4.8	2	5.2	1
Gum/combination	3.7	3	5.7	3	3.2	3	-	-
Wane/combination	2.8	4	3.5	5	1.9	6	2.8	2
Gum	2.4	5	4.8	4	2.2	4		
End splits/comb.	1.6	6	-	-	2.0	5	0.6	3
End splits	0.5	7	0.5	6	0.4	8	0.2	5
Borers/rot	0.1	8	-	-	0.4	7	-	-
Heart	-		-	-	-	-	0.5	4
Mechanical Damage	4.8		5.8		3.9		3.4	
Physical Effects	8.0		8.7		4.8		5.7	
Biological Attack	13.5		17.1		10.0		2.7	

X/combination: that defect and their combinations, e.g. knots/combination is knots and knots associated with other defects.

APPENDIX 4

Percentage of defects causing rejection when grading to AS 2082 for butt, mid and crown logs (percentages based on log volume).

DEFECT	BUTT		MID		CROWN	
	% REJECTED	RANK	% REJECTED	RANK	% REJECTED	RANK
Heart/combination	4.3	1	4.3	1	5.3	2
Want & wane	3.8	2	3.3	3	3.3	3
Borer/combination	2.1	3	3.7	2	2.7	4
Rot/combination	2.0	4	2.5	6	0.6	7
End splits/combination	1.9	5	3.0	5	1.8	6
Sizing	1.3	6	2.4	7	2.3	5
Brownwood/comb.	0.7	7	0.2	9	0.1	9
Knots/combination	0.4	8	3.2	4	8.1	1
Gum/combination	0.2	9	0.8	8	0.5	8
Mechanical Problems	6.8		8.4		7.4	
Physical Effects	4.7		7.1		11.8	
Biological Attack	3.8		6.0		3.6	

X/combination: that defect and their combinations, e.g. knots/combination is knots and knots associated with other defects.

APPENDIX 5

Percentage of defects causing downgrade to Structural Grades 2 and 3 for butt, mid and crown logs.

DEFECT	BUTT		MID		CROWN	
	% DOWNGRADE	RANK	% DOWNGRADE	RANK	% DOWNGRADE	RANK
Borer/combination	9.2	1	13.2	1	2.8	3
Gum/combination	6.5	2	8.0	3	3.1	2
Knot/combination	2.8	3	11.2	2	13.1	1
Want/wane	2.2	4	3.4	4	2.5	4
End splits/combination	1.7	5	2.6	5	2.3	5
Rot/combination	0.1	6	0.3	6	-	-
Brownwood/combination	0.1	7	0.1	7	-	-
Heart/combination	0.1	8	-	-	-	-
Sizing	-	-	-	-	-	-
Mechanical Problems	3.8		6.0		13.8	
Physical Effects	3.0		11.4		13.1	
Biological Attack	13.6		19.0		5.8	

X/combination: that defect and their combinations, e.g. knots/comb is knots and knots associated with other defects.

APPENDIX 6

Analysis of variance.

COMPARISON	DOMINANCE (MOST vs. LEAST DOMINANT)	LOG POSITION
IG or IG/other defects	NS	Sig (M >B, C) ($p < 0.01$)
IG/BW to total BW	NS	NS
K/IG to total IG	NS	NS
IG/no other defect to total IG	NS	NS
IG/BW to total IG	NS	NS
IG/G to total IG	NS	NS
IG/K to total K	NS	NS
BW or BW/other defects	NS	Sig (B, M >C) ($p < 0.05$)
BW/K to total K	NS	N S
BW/K to total BW	NS	Sig (C > B, M) ($p < 0.05$)
BW to total BW	NS	NS
K or K/other defect	NS	Sig (C > B, M) ($p < 0.05$)
K/G to total K	NS	NS
K/R	Sig (M > L) ($p < 0.05$)	NS

Codes:

IG = insect galleries
BW = brownwood
K = knots
G = gum
K = knot
IG/BW = insect galleries associated with brownwood.