INCIDENCE OF BROWN WOOD (INCIPIENT ROT) AND ROT IN REGROWTH KARRI.

COMPARISON OF MEDIUM AND FIRST GRADE SAWLOGS.

D. J. DONNELLY[1], R. RULE[1] AND E. M. DAVISON[2]

[1]Timber Utilisation and Inspection Service
[2]Science and Information Division

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Abstract

Sawmill surveys of medium sawlogs from regrowth stands and first grade sawlogs of which at least half came from mature stands, were carried out in 1987 and 1992 respectively. These surveys showed that the incidence rot and of incipient rot (brown wood) and/or rot was significantly greater in medium sawlogs than first grade sawlogs. The commonest symptom in both log classes was incipient rot. The most frequent infection points were branch stubs, borer galleries and fire damage; *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. In regrowth sawlogs, when at least two thirds of the whole cross section of the log was affected by incipient rot and/or rot it was associated with fire and/or *Armillaria*.

Introduction

Karri (*Eucalyptus diversicolor* F. Muell.) is the second most important timber tree in Western Australia. Its wood is used for general construction, engineering, shipbuilding, railway sleepers, flooring and roof trusses (Bootle 1983). The karri forest covers an area of 175 100 ha, of which approximately 54 per cent is available for timber production. Karri is harvested by clear felling, with coupes being regenerated by either natural seeding from residual trees or by hand planting with nursery raised seedlings. This forest is thus a mosaic of more or less even aged stands with regenerating karri comprising about 46 per cent of the area available for timber production. As these stands mature they will constitute an increasing proportion of the resource harvested from all WA forests; by 2020 it is estimated that about 40 per cent of the state's sawlog supply will be regrowth karri (CALM 1987).

Although regrowth karri appears sound when growing, a proportion of sawlogs from these stands are affected by rots, as well as by a discolouration known as brown wood. Brown wood is associated with fungal invasion, and pathogenicity testing has shown that this symptom is incipient rot, and can be caused by at least two fungi (*Stereum hirsutum* (Willd.) Pers.: Gray and a *Hymenochaete* sp.); if left long enough, white rot or white pocket rot will develop (Davison and Tay 1990).

CALM's timber inspectors have been concerned that the abundance of both brown wood and rot is greater in regrowth than mature karri. In 1987 they carried out a sawmill survey of regrowth sawlogs to record the incidence and extent of brown wood and rot, and to identify any association of these symptoms with potential entry points. A similar survey of sawlogs from mature trees was carried out in 1992. The results of these surveys are presented in this report.

Method

The surveys were carried out at two sawmills, Monier's mill at Busselton which cuts medium sawlogs which come mainly from regrowth stands, and Bunnings' mill at Pemberton which cuts first grade sawlogs. Size specifications for medium logs are a small end diameter (underbark) of 200 to 300 mm and length of 2.4 to 5.0 m (e.g. Contract of Sale N^{o} 756); size specifications for first grade sawlogs are a minimum small end diameter of 300 mm and minimum length of 2.4 m (CALM 1989). Log quality relevant to this study are, for medium sawlogs: that they will meet the established sawlog quality standards set by the Forest officer in Charge (e.g. Contract of Sale N^{o} 756); first grade logs must have at least 50 per cent millable wood on the worst face, as assessed by the Forest officer in Charge (CALM 1989).

The Monier's survey was carried out at about monthly intervals between March and September 1987, and the Bunnings' survey was carried out in July and August 1992

Logs were measured and then observed at the breakdown saw. All logs were cut into tile battens. At the Monier mill medium sawlogs were cut into 25 mm boards at the breakdown saw, whilst at the Bunnings mill first grade logs were cut into 50 mm boards at this saw. The occurrence of brown wood (incipient rot), straw rot, brown rot and kino in these boards were recorded. The suspected infection point(s), the position of infection within the log and the log length affected were also recorded.

The survey data were analysed using the STATVIEW statistical package (Abacus Concepts 1992). Comparisons of log diameters and volumes were made on ln-transformed data because of inequality of variances in the raw data.

Results

The logs

The Monier's survey comprised 253 medium sawlogs from at least ten regrowth coupes (Dombakup 16, Treen Brook 1, 2, 4, 5, 6, 8, 11 12 and 14) and one mature coupe (Dombakup 14); the origin of one log was not determined. The largest sample came from Treen Brook 6 (31.2 per cent), the smallest sample came from Dombakup 14 (0.4 per cent). The Bunnings survey comprised 64 first grade sawlogs from at least ten coupes including logs from mature trees from Brockman 12, Collins 5, Gardner 6, Sutton 20, Treen Brook 4, Weld 14. Other logs came from Denmark, Dombakup, and Wheatley. The origin of 48.4 per cent of the logs could not, however, be determined. The samples comprised both butt and other logs (Table 1).

The first grade sawlogs were significantly longer ($t=-10.27$, $p<0.0001$), of greater mid-point diameter ($t=-50.75$, $p<0.0001$) and greater volume ($t=-52.74$, $p<0.0001$) than the medium sawlogs (Table 1). The mean volume of the first grade sawlogs was 11.13 times greater than the volume of medium sawlogs.

Table 1.
Log samples used in the survey. The Monier's survey was carried out between March and September 1987, the Bunnings' survey was carried out in July and August 1992.

Means compared by unpaired t-test; n.s. not significant; * significant at $p<0.05$; ** significant at $p<0.01$; ***significant at $p<0.001$.

Sawmill	Log type	Sample size	Proportion of butt logs (%)	Length (m)	Mid-point diameter (m)[a]	Volume (m^3)[a]
Monier	Medium	253	38.7	4.79***	0.32***	0.38***
Bunnings	First grade	64	53.1	5.94	0.96	4.23

[a] Means calculated from ln-transformed data

Brown wood and rot were present in both medium and first grade sawlogs. The first grade sawlogs which had no brown wood or rot were of similar length, mid-point diameter and volume, to those which had (Table 2). This was not, however, the case with the medium logs. Logs which had no brown wood or rot were of smaller mid-point diameter ($t=2.80$, $p=0.005$) and smaller volume ($t=3.31$, $p=0.001$) than those with these symptoms. Further analysis showed that these logs were of smaller mid-point diameter and smaller volume than logs with brown wood only, and logs with brown wood and rots (Table 3).

Table 2
Comparison of the size of first grade sawlogs with and without incipient rot and rot from Bunnings' mill, Pemberton.

Means compared by unpaired t-test; n.s. not significant; * significant at p=0.05; ** significant at p=0.01; ***significant at p <0.001.

Symptoms	Sample size	Length (m)	Mid-point diameter (m) [a]	Volume (m^3)[a]
No brown wood or rot	7	5.63 n.s.	0.99 n.s.	4.31 n.s.
Brown wood and/or rot	57	5.98	0.96	4.22

[a] Means calculated from ln-transformed data

Table 3
Comparison of the size of medium sawlogs with and without brown wood and rot, from Monier's mill, Busselton.

Symptoms	Sample size	Log length (m)	Mid-point diam. (m)[a]	Log volume (m^3)[a]
No brown wood or rot	75	4.72	0.305	0.34
Brown wood	119	4.88	0.322	0.40
Brown wood & rot	59	4.68	0.328	0.41

[a] Means calculated from ln-transformed data

Means compared by ANOVA; n.s. not significant; * significant at p=0.05; ** significant at p=0.01; ***significant at p <0.001.

Comparisons	Log length	Mid-point diameter	Log volume
None vs brown wood	n.s.	*	**
None vs rot	n.s.	**	**
Brown wood vs rot	*	n.s.	n.s.

Incidence of brown wood, rots and kino

As brown wood is incipient rot, these symptoms were combined for many of the following analyses.

There was no straw rot or brown cubical rot, either singly or together, in 59.38 per cent of first grade logs and 76.68 per cent of medium logs (Table 4). As first grade sawlogs are eleven time the volume of medium logs (Table 1) probability theory has been used to calculate the predicted incidence in each log type from the observed incidence in the complementary log type. If logs free from rot occurred equally frequently in both log types the predicted and observed incidence would not differ significantly. The predicted incidence of first grade logs with no rot is $0.7668^{11}=0.0539$, and the predicted incidence of medium logs with no rot is $\sqrt[11]{0.5938}=0.9537$ (Table 4). The observed and predicted incidence differ significantly; the incidence of rot in medium logs is higher than would be predicted from the survey of first grade sawlogs, and the incidence of rot in first grade logs is lower than would be predicted from the survey of medium logs (Table 4).

Similar calculations have been made for the predicted incidence of medium and first grade sawlogs free from brown wood and/or rot (Table 4). These calculations also show that the incidence of brown wood and/or rot is significantly higher in medium logs than that predicted from the survey of first grade sawlogs, and the incidence of brown wood and/or rot in first grade sawlogs is significantly lower than that predicted from the survey of medium sawlogs (Table 4).

Table 4
Observed and predicted incidence of medium and first grade sawlogs with no rot, or no brown wood and/or rot.

Symptom	Proportion of medium logs (%)		Proportion of first grade logs (%)	
	Observed (Monier survey)	Predicted (from Bunnings survey)	Observed (Bunnings survey)	Predicted (from Monier survey)
No rot	76.68	95.37	59.38	5.39
Rot	23.32	4.63	40.63	94.61
	DF=1, χ^2=13.5, p=0.0002		DF=1, χ^2=67.0, p<0.0001	
No brown wood and/or rot	29.64	75.83	10.94	0.0002
Brown wood and/or rot	70.36	24.17	89.06	99.9998
	DF=1, χ^2=42.5, p<0.0001		DF=1, χ^2=11.6 p=0.0006	

Brown wood was the most common defect, occurring in almost half of the medium and first grade sawlogs (Table 5). It was present by itself, or in combination with both brown cubical rot and straw rot (Table 5).

Table 5
The incidence of brown wood, brown cubical rot and straw rot in medium and first grade sawlogs.

Defect	Medium sawlogs		First grade sawlogs	
	Proportion (%)	Rank	Proportion (%)	Rank
Brown wood	47.0	1	48.4	1
No brown wood or rot	29.6	2	10.9	3
Brown wood & straw rot	17.0	3	9.4	4
Brown wood & brown cubical rot	2.4	4	14.1	2
Straw rot	2.0	5	0	8
Brown cubical rot	1.2	6	7.8	5
Brown cubical rot & straw rot	0.4	7	1.6	7
Brown wood & brown cubical rot & straw rot	0.4	7	7.8	5

Medium sawlogs. The large sample size of medium sawlogs and their small volume allowed more detailed analysis of this data than was possible with the first grade sawlogs.

In medium sawlogs, brown wood and/or rot were less common in butt logs than other logs (Table 6). Kino was present in 49.8 per cent of all medium sawlogs, it was equally common in both butt and other logs (n=253, DF=1, χ^2=0.53, p=0.47) and was significantly associated with the presence of borers (Table 7).

Table 6
The incidence of brown wood and/or rot in butt medium sawlogs.

Symptom	**Butt logs**		**Other logs**		**Totals**
	Observed	Expected	Observed	Expected	
No brown wood and/or rot	36	29.1	39	45.9	75
Brown wood and/or rot	62	68.9	116	109.1	178
Totals	98		155		253
DF=1, χ^2=3.96, p=0.05					

Table 7
The incidence of kino and borers in medium sawlogs.

Symptom	**Borers**		**No borers**		**Totals**
	Observed	Expected	Observed	Expected	
No kino	19	33.7	108	93.2	127
Kino	48	33.2	77	91.8	125
Totals	67		185		252
DF=1, χ^2=17.7, p<0.0001					

Suspected infection point(s) were recorded whenever they were seen. In medium sawlogs, brown wood and rots were most frequently associated, either singly or in combination, with branch stubs (52 per cent), borers (43.2 per cent) and fire damage (14.4 per cent) (Table 8). *Armillaria* scars were not distinguished from fire damage and therefore would have been included in this category. Infection points associated with fire were more common on butt logs than other logs, whilst infection points associated with borers and branch stubs were more common on other logs.

Table 8
Association of infection point in medium sawlogs with log type. Only logs with brown wood and/or rot, and where the infection point could be distinguished were used in this analysis.

Infection point	**Butt logs**		**Other logs**		**Totals**
	Observed	Expected	Observed	Expected	
Branch stubs	15	16.9	34	32.1	49
Borers	10	12.4	26	23.6	36
Fire damage	12	4.8	2	9.2	14
Mechanical damage	2	1.7	3	3.3	5
Branch stubs & borers	3	4.5	10	8.5	13
Branch stubs & fire damage	0	0.7	2	1.3	2
Branch stubs & mechanical damage	0	0.3	1	0.7	1
Borers & fire damage	0	0.7	2	1.3	2
Borers & mechanical damage	1	1.0	2	2.0	3
Totals	43		82		125
	DF=8, χ^2=20.8, p=0.008				

First grade sawlogs. Data from the first grade sawlog survey was not as comprehensive as those from the medium sawlog survey. Brown wood and/or rot were equally common in butt and other logs (n=64, DF=1, χ^2=1.06, p=0.30). Kino was present in 89.1 per cent of first grade sawlogs, and was equally common in both log types (n=64, DF=1, χ^2=1.06, p=0.30). It was marginally associated with borers (n=64, DF=1, χ^2=3.46, p=0.06).

In first grade sawlogs brown wood and rots were most frequently associated, either singly or in combination, with borers (84.5 per cent), branch stubs (30.4 per cent), and fire damage (21.7 per cent) (Table 9). As mentioned above, *Armillaria* scars were not distinguished from fire damage and therefore would have been included in this category. There was no association between infection points and log type.

Table 9
Association of infection point in first grade sawlogs with log type. Only logs with brown wood and/or rot, and where the infection point could be distinguished were used in this analysis.

Infection point	**Butt logs**		**Other logs**		**Totals**
	Observed	Expected	Observed	Expected	
Borers	15	12.0	7	10.0	22
Branch stubs	2	1.6	1	1.4	3
Mechanical damage	0	1.5	1	0.5	1
Borers & branch stubs	2	4.9	7	4.1	9
Borers & fire damage	3	3.8	4	3.2	7
Borers & pinholes & fire damage	1	0.5	0	0.5	1
Branch stubs & fire damage	1	0.9	1	1.1	2
Pinholes & fire damage	1	0.5	1	0.5	1
Totals	25		21		46
	DF=7, χ^2=8.9, p=0.26				

Distribution and extent of brown wood and rot in sawlogs

During the surveys the distribution of brown wood and rot in the cross-section of the log was recorded i.e. whether in scattered pockets, central third, central two thirds, or all of the log. In medium sawlogs, the distribution of brown wood and rot was independent of log type (DF=5, χ^2=6.2, p=0.29, n=175), and independent of branch stub infection points (DF=5, χ^2=3.3, p=0.66, n=175). Scattered pockets of brown wood and rot were associated with borers (Table 10) and when two thirds or the whole of the cross-sectional area was affected, it was associated with fire damage (and possibly *Armillaria*) (Table 11).

Table 10
Association of the distribution of brown wood and rots with borers in medium sawlogs. Only logs with brown wood and/or rot were used in this analysis.

Distribution of symptoms	Borers		No borers		Totals
	Observed	Expected	Observed	Expected	
Scattered pockets	26	18.2	33	40.8	59
Central 1/3 of log	16	16.4	37	36.6	53
Central 2/3 of log	9	15.1	40	33.9	49
All cross section of log	1	2.5	7	5.5	8
Scattered pockets + central 1/3	1	1.5	4	3.5	5
Scattered pockets + central 2/3	1	0.3	0	0.7	1
Totals	54		121		175
	DF=5, χ^2=12.2, p=0.032				

Table 11
Association of the distribution of brown wood and rots with fire damage (and possibly *Armillaria*) in medium sawlogs. Only logs with brown wood and/or rot were used in this analysis.

Distribution of symptoms	Fire damage		No fire damage		Totals
	Observed	Expected	Observed	Expected	
Scattered pockets	1	6.1	58	52.9	59
Central 1/3 of log	4	5.5	49	47.5	53
Central 2/3 of log	7	5.0	42	44	49
All cross section of log	5	0.8	3	7.2	8
Scattered pockets + central 1/3	0	0.5	5	4.5	5
Scattered pockets + central 2/3	1	0.1	0	0.9	1
Totals	18		157		175

DF=5, χ^2=12.2, p=0.032

In first grade sawlogs the distribution of brown wood and rots was independent of log type (DF=4, χ^2=7.2, p=0.12, n=57). Scattered pockets of infection were associated with presence of borers (Table 12). Sample sizes relating to branch stubs and fire damage were too small for analysis.

Table 12
Association of the distribution of brown wood and rots with borers in first grade sawlogs. Only logs with brown wood and/or rot were used in this analysis.

Distribution of symptoms	Borers		No borers		Totals
	Observed	Expected	Observed	Expected	
Scattered pockets	23	17.8	3	8.2	26
Central 1/3 of log	5	15.1	13	6.9	22
Central 2/3 of log	4	3.4	1	1.6	5
All cross section of log	0	0.7	1	0.3	1
Scattered pockets + central 1/3	3	2.1	0	0.9	3
Totals	39		18		57
	DF=4, χ^2=16.4 p=0.0025				

Frequency distributions of the proportion of log length affected by brown wood and rot are shown in Fig. 1 for medium sawlogs and Fig.2 for first grade sawlogs. There were fewer medium sawlogs than first grade logs with symptoms along their whole length. As mean log lengths are significantly different (Table 1), these observations are not easily compared.

Figure 1
Frequency distribution of medium sawlog length affected by brown wood and rot. Sample size: 176.

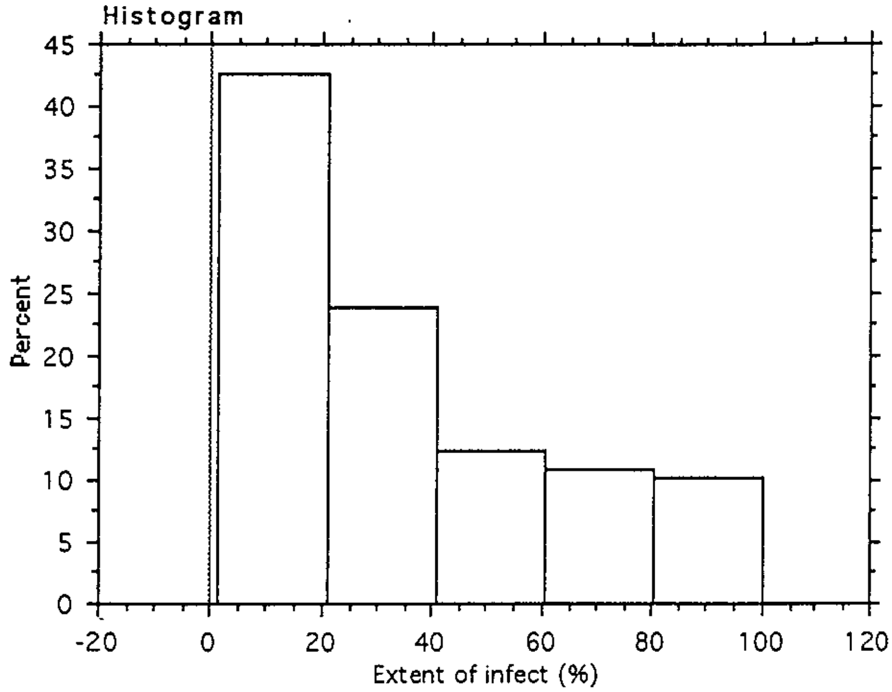
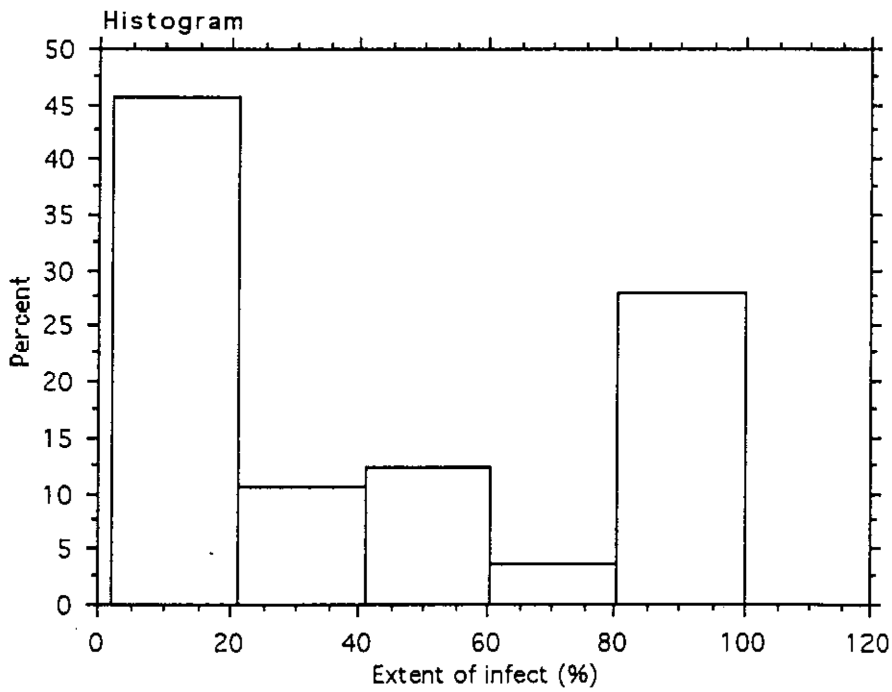


Figure 2
Frequency distribution of first grade sawlog length affected by brown wood and rot. Sample size: 57.



Discussion

The logs used in these surveys fall within the size specifications for medium and first grade sawlogs current at that time, i.e. medium logs must have a small end diameter (underbark) of 200 to 300 mm and length of 2.4 to 5.0 m, whilst first grade sawlogs must have a minimum small end diameter of 300 mm and minimum length of 2.4 m (Table 1). We assume that log quality also conformed to current specifications. Medium sawlogs came from regrowth stands in Treen Brook and Dombakup blocks whilst those first grade sawlogs of known origin came from Brockman, Collins, Denmark, Dombakup, Gardner, Sutton, Treen Brook, Weld and Wheatley blocks. As logs are classed on size, not on origin, some first grade sawlogs may have been from regrowth stands.

In 1987, Monier was the only sawmill cutting medium sawlogs. Our survey of 253 logs which came from at least eleven coupes, would constitute a representative sample of the quality of regrowth logs at that time. Similarly the survey of first grade sawlogs carried out at Bunnings in 1992 included logs from at least ten coupes and would be a representative sample of the quality of mature karri. We are not aware of any other surveys of the quality of karri logs. As both medium and first grade sawlogs were cut into similar size products the visual sampling of all logs would be comparable. However, because of differences in log diameters and lengths (Table 1), and because our survey results were expressed on a per log basis, we can only make general comparisons between these two log classes.

Comparisons of the incidence of brown wood and rot between regrowth and mature logs was made on a volume basis; the mean volume of the logs from mature trees was over eleven times the volume of regrowth logs. Probability theory was used to estimate the proportion of logs with no rot or no brown wood and/or rot in each log class, based on the observed incidence of these symptoms. These calculations showed that the incidence of both rot, and brown wood and/or rot was significantly greater in regrowth than mature logs (Table 4).

The sample of regrowth logs with either brown wood only or brown wood and rot was of larger mid-point diameter and volume than logs without these symptoms (Table 2), and may therefore indicate increased incidence of incipient rot and rot with higher dominance class or increased tree age.

Brown wood was the most common symptom in both regrowth and mature logs (Table 5). Brown wood is incipient rot, which can be caused by *Stereum hirsutum* and *Hymenochaete* sp., it will eventually develop into white rot or white pocket rot (Davison and Tay 1990). In the survey, all white rots were recorded as straw rot, an advanced stage of white pocket rot, so the association of brown wood with straw rot in many logs is to be expected. We do not know whether brown wood is also an early stage of brown cubical rot. In karri brown cubical rot is associated with *Piptoporus australiensis* (Wakef.) G. Cunn. (Tamlyn 1936, Shivas 1989).

Fungi which cause wood rots in live trees invade through damaged bark (Rayner and Boddy 1988). In all surveyed logs where infection points could be seen, brown wood and rots were mainly associated with branch stubs, borers and fire damage (Tables 8 and 9). In the surveys, *Armillaria* scars may also have been recorded as fire damage; brown wood and rot are frequently associated with these scars in regrowth trees (Davison, Pearce and Tay unpublished). In regrowth logs, infection points were associated more commonly than expected with fire damage (and possibly *Armillaria* scars) in butt logs, and more commonly than expected with borers and branch stubs in other logs (Table 8). Thus there appear to be different infection points at different distances up the stem, which may reflect differences in borer infestation, and in the frequency or size of branch stubs, between butt and other logs. Further survey work e.g. SPP 93/0161, may substantiate this observation.

Scattered pockets of brown wood and rot were more likely to be associated with borers than other entry points in logs from both regrowth and mature trees (Tables 10 and 12), whilst in regrowth logs, when two thirds or the whole cross-section of the log was affected, it was most likely to be associated with fire damage (and possibly *Armillaria* scars) (Table 11).

These surveys show that the symptoms of incipient rot and rot in regrowth karri logs are similar to, but have a higher incidence, than these symptoms in logs from mature trees. These symptoms are associated with similar infection points (borers, branch stubs and fire scars), but whereas brown wood and rot is most commonly associated with borers in logs from mature trees, these symptoms are more commonly associated with branch stubs in regrowth logs.

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