

# Comparison of the occurrence of rot in sawlogs from regrowth and mature stands of *Eucalyptus diversicolor* (karri)

D.J. Donnelly<sup>1,2</sup> and E.M. Davison<sup>3,4,5</sup>

<sup>1</sup>Timber Utilisation and Inspection Service, Department of Conservation and Land Management, Bunbury, WA 6230, Australia

<sup>2</sup>Current address: 4 Allen Rd., Gelorup, WA 6230, Australia

<sup>3</sup>Science and Information Division, Department of Conservation and Land Management, Kensington, WA 6151, Australia

<sup>4</sup>Current address: Department of Environmental Biology, Curtin University, GPO Box U1987, Perth, WA 6845, Australia

<sup>5</sup>Email: E.Davison@curtin.edu.au

Revised manuscript received 10 January 2008

## Summary

Karri (*Eucalyptus diversicolor*) timber from old-growth forest has been highly valued for heavy engineering construction, special purpose rail track timbers, scantling for housing, mine guides, joinery, furniture and flooring. With changes to forest management, sawlogs from mature stands have been supplemented by sawlogs from regrowth stands. A survey was conducted to compare the quality of sawlogs from mature and regrowth stands in relation to incipient rot, established rot, other defects and market expectations for this species. Sawmill surveys of sawlogs from regrowth and mature stands were carried out in 1987 and 1992 respectively. These surveys showed that there was significantly more incipient rot, known locally as brown wood, and or wood rot in regrowth sawlogs than in sawlogs from mature stands, while there was significantly less kino in regrowth sawlogs. The most common defects in both log classes were the presence of kino and incipient rot. The most frequent infection points for wood rot fungi were branch stubs, borer galleries and scars (which may have been caused by *Armillaria* infection, fire damage or mechanical damage). Infection associated with branching was more common in regrowth sawlogs than in sawlogs from mature stands. In both log classes, scattered pockets of incipient rot and or established 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 established rot, it was associated with scars resulting from fire, *Armillaria* or mechanical damage. Since this survey was conducted, changes in Western Australian government policy have resulted in only regrowth forest being available for harvest.

**Keywords:** sawlogs; log grades; surveys; regeneration; decay; decay fungi; wood defects; decayed wood; kinos; wood borers; karri; *Eucalyptus diversicolor*; *Phoracantha acanthocera*

## Introduction

Karri (*Eucalyptus diversicolor* F.Muell.) is endemic to wet sclerophyll forest in the extreme south-west of Western Australia (WA). The karri forest covers an area of about 167 100 ha, where it grows in either pure stands or in association with marri (*Corymbia calophylla* (Lindl.) K.D.Hill and L.A.S.Johnson). Karri stands are

interspersed with stands of jarrah (*E. marginata* Donn ex Smith), jarrah-marri, or treeless flats and swamps. Its occurrence, together with a description of past management of the karri forest, was reviewed by Bradshaw and Lush (1981).

Karri is one of the tallest eucalypts, commonly reaching heights of 50–70 m. Its clear straight bole, freedom from defects and great strength have made it ideal for general construction, engineering, shipbuilding, railway sleepers, flooring and roof trusses in both Australia and overseas (Bootle 2005). Karri timber in service is not resistant to decay, and as such should not be recommended for use in ground contact applications. When exposed to weather it gives best results when suitably treated and protected. The species is also susceptible to termite attack.

Karri stands were initially harvested by clear felling, but this harvesting method was replaced by selection cutting in about 1938. This trial of selection cutting resulted in problems with regeneration burns for ashbed formation, fire protection, declining health of residual trees and difficulties in carrying out further harvests. Consequently, selection cutting was replaced by clear felling in 1967 (Bradshaw and Lush 1981). The karri forest is therefore a mosaic of old-growth stands, regenerating even-aged stands and uneven-aged stands resulting from selection cutting.

Extensive research into karri regeneration has been summarised by Breidahl and Hewett (1995). After coupes have been logged and burnt, seed from retained seed trees falls within a few days onto the resulting ashbed, with germination occurring after the next substantial rainfall. If there is no mature seed in the canopy at the time of logging, the coupe is replanted with nursery-raised seedlings. Regenerating stands are managed on a 100-y rotation, with first thinning occurring at 15–25 y, depending on site quality.

Regrowth karri is an important, fast growing, future native timber resource for WA. A review of timber production in the 1980s estimated that by 2020 about 40% of WA's supply of sawlogs would be from regenerated karri stands, that is about 220 000 m<sup>3</sup> per annum (Department of Conservation and Land Management 1987). However, as a result of political decisions to incorporate almost 48% of the karri forest within national parks, nature

reserves and conservation reserves, there has been a significant decrease in the projected supply of karri sawlogs. Present forest management plans estimate an annual average yield of 54 000 m<sup>3</sup> of first- and second-grade sawlogs, plus 117 000 m<sup>3</sup> of lower-grade bole logs from 2004 to 2013 (Conservation Commission of Western Australia 2004).

There have been concerns about the quality of wood from regrowth karri stands. When utilisation of thinnings started in the 1960s, foresters and sawmillers observed that many logs had discoloured heartwood, a defect that was known locally as brown wood. This defect was thought to either be new or much more abundant than in sawlogs from old-growth stands. As there was no obvious mycelium in brown wood and it split like sound wood, it was treated as sound wood, even though there were concerns that brown wood was incipiently rotted wood.

Several samples of brown wood were sent to CSIRO Division of Forest Products in Melbourne for examination. Preliminary investigations by Greaves and Barnacle (1970) showed that brown wood was more permeable to impregnation with creosote than was unaffected wood from regrowth karri, and this change was associated with fungal attack. These investigations did not identify the fungi or determine whether the fungi could cause rot.

A more extensive investigation of brown wood was conducted by Davison and Tay (submitted<sup>1</sup>). They isolated a large number of fungi from brown wood and other defects of established rot in regrowth karri. In vivo pathogenicity tests showed that two of the most common fungi, *Stereum hirsutum* (Willd.) Pers. and *Hymenochaete semistupposa* Petch, could cause discolouration in the heartwood followed by white rot and white pocket rot respectively within 4 y. Davison and Tay<sup>1</sup> concluded that brown wood was incipient rot and its presence in regrowth karri reduced the quality of timber from regrowth trees.

Incipient rot and rot are not the only defects in regrowth karri (Clarke and Ellis 1989). Attack by bullseye borer (*Phoracantha acanthocera* (Macleay) = *Tryphocaria acanthocera* (Macleay)) is also widespread. Farr *et al.* (2000) have shown that both incipient rot and kino are significantly associated with the borers' galleries.

Timber inspectors in WA were concerned that the incidence of incipient rot was higher in regrowth logs than in logs from old-growth stands. The sawmill surveys reported in this paper were designed to compare the incidence of incipient rot and other defects in medium-quality sawlogs from regrowth stands with those in first-grade sawlogs from old-growth forest. This paper also reports the most likely entry points for the fungi that cause incipient rot and rot.

This survey is part of a large study on the quality of regrowth karri which started in the 1980s. It includes the cause of brown wood and established rot (Davison and Tay<sup>1</sup>), the incidence of insect borer damage in regrowth stands (Farr *et al.* 2000), the incidence of defects in sawlogs (this paper) and regrowth stands (Hewett and Davison 1995), the effects of defects on sawn

recovery (Brennan *et al.* 1999) and the durability of brown wood (Johnson *et al.* 1993).

## Methods

### Definitions of log type

The logs used in these surveys fell within the size specifications for medium- and first-grade sawlogs current in 1987 and 1992 (Department of Conservation and Land Management 1989).

Size specifications for medium logs, almost all of which would have come from regrowth stands, were a small-end diameter (underbark) (sedub) of 200–300 mm and minimum length of 2.1 m. Log quality specifications were that logs must have at least 70% clear wood on the worst end-section face, the maximum allowable dryside was 50% girth (this would include *Armillaria* scars), the maximum allowable gum ring was one complete ring, and if pinholes were present these had to be clean with no macroscopically determined rot (D. Swain, Department of Conservation and Land Management, *pers. comm.* 28 September 1994).

Size specifications for first-grade sawlogs, all of which would have come from mature stands, were a minimum sedub of 300 mm and minimum length of 2.4 m; first-grade logs must have at least 50% millable wood on the worst face, as assessed by the Forest Officer in Charge (Department of Conservation and Land Management 1989).

### Medium sawlog survey

This survey was conducted at Monier's Sawmill, Busselton, between March and September 1987. It involved 253 medium sawlogs from at least ten unburnt 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%); the smallest sample came from Dombakup 14 (0.4%).

Logs were measured and then observed at the breakdown saw, where they were cut into boards 25 mm thick. The presence of any incipient rotted wood (brown wood), white rot (including straw rot, white rot and white pocket rot), brown rot and kino in each board was recorded. The suspected infection point(s) (bullseye borer, pinhole borer, other insects, fire, mechanical damage, wind damage, branch stubs, unknown) were also recorded. The position of infection within the log (scattered pockets, confined to the central one-third, central two-thirds, or all of the heartwood affected) and the estimated proportion (%) of log length affected were measured.

### First-grade sawlog survey

The survey of first-grade sawlogs was conducted at Bunnings' Sawmill, Pemberton, in July and August 1992. It involved 64 logs from at least ten coupes: Brockman 12, Collins 5, Gardner 6, Sutton 20, Treen Brook 4, Weld 6, Weld 14, and from Denmark, Dombakup and Wheatley. The origin of 48% of the logs could not be determined.

<sup>1</sup>Davison, E.M. and Tay, F.C.S. Causes of incipient rot and rot in regrowth *Eucalyptus diversicolor* (karri) trees. *Plant Pathology* submitted

Logs were measured and then observed at the breakdown saw, where they were cut into boards 50 mm thick. The presence of defects, suspected infection point(s), position and extent of infection, as described above, were recorded for each board.

### Statistical analysis

Survey data were analysed using the STATVIEW statistical package (Abacus Concepts 1992). Data were transformed as necessary.

## Results

### Logs

Thirty-nine per cent of the medium sawlogs were butt logs, while 53% of first-grade logs were butt logs. The mean log length of the medium sawlogs was 4.8 m, and of the first-grade sawlogs, 5.9 m. The first-grade sawlogs were about 11 times the volume of medium sawlogs, as shown in Table 1.

Incipient rot and established rot were present in both medium and first-grade sawlogs. The first-grade sawlogs which had no incipient rot or established rot were of similar length, mid-point diameter and volume, to those which had these defects (Table 1). This was not the case with the medium logs. Logs which had no

incipient rot or established rot were of similar length, but smaller mid-point diameter and volume than medium sawlogs with these defects (Table 1).

### Comparison of the incidence of defects in medium- and first-grade sawlogs

There was no white rot or brown rot, either singly or together, in 58% of first-grade sawlogs and 77% of medium logs. As first-grade sawlogs were about 11 times the volume of medium logs, the predicted number of medium logs with no established rot, based on the survey of first-grade sawlogs, was the eleventh root of the proportion of the logs with no rot multiplied by the total sample size ( $^{11}\sqrt{0.58 \times 253} = 240.9$ ). If logs free from established rot occurred equally frequently in both log types, the predicted and observed numbers would not differ significantly. Table 2 shows that this is not so, as the number of medium sawlogs with established rot is significantly higher than predicted from the survey of first-grade sawlogs.

Similar calculations have been made for the predicted number of medium sawlogs free from incipient rot and or established rot (Table 2), and indicate that the number of medium sawlogs with incipient rot and or established rot is significantly higher than that predicted from the survey of first-grade sawlogs.

**Table 1.** Comparison of the size of first-grade sawlogs and medium sawlogs with and without incipient rot and advanced rot. Comparisons of mid-point diameters and log volumes were on ln-transformed data; back-transformed values are presented. Within columns, for each log type, values with the same superscript do not differ significantly ( $P > 0.05$ ).

Log grade and defects	Sample size	Length (m)	Mid-point diameter (m)	Volume (m <sup>3</sup> )
First-grade sawlogs				
No incipient rot or rot	7	5.63 <sup>a</sup>	0.99 <sup>a</sup>	4.31 <sup>a</sup>
Incipient rot and or rot	57	5.98 <sup>a</sup>	0.96 <sup>a</sup>	4.22 <sup>a</sup>
Total	64			
Medium sawlogs				
No incipient rot or rot	75	4.72 <sup>ab</sup>	0.305 <sup>a</sup>	0.34 <sup>a</sup>
Incipient rot	119	4.88 <sup>a</sup>	0.322 <sup>b</sup>	0.40 <sup>b</sup>
Incipient rot and or rot	59	4.68 <sup>b</sup>	0.328 <sup>b</sup>	0.41 <sup>b</sup>
Total	253			

**Table 2.** Observed and predicted number of medium sawlogs with advanced rot, incipient and or advanced rot and kino. The predicted numbers of logs are calculated from the  $^{11}\sqrt$  of the proportion of first-grade sawlogs with the relevant defects.

Defect	Observed (from medium sawlog survey)	Predicted (from first-grade sawlog survey)
No rot	194	241
Rot	59	12
	DF = 1, $\chi^2 = 346.7$ , $P < 0.0001$	
No rot and or incipient rot	75	207
Rot and or incipient rot	178	46
	DF = 1, $\chi^2 = 143.4$ , $P < 0.0001$	
No kino	127	207
Kino	126	46
	DF = 1, $\chi^2 = 101.4$ , $P < 0.0001$	

Kino is the other defect that was recorded in the survey. Similar calculations have been made for this defect (Table 2), and show that the number of medium sawlogs with kino is significantly lower than that predicted from the first-grade sawlog survey.

Kino was the most common defect in both medium and first-grade sawlogs (Table 3), and the second most common defect was incipient rot. Brown rot was more common in first-grade sawlogs than in medium logs.

### Medium sawlogs

The large sample size of medium sawlogs allows more detailed analysis of the data than is possible with the first-grade sawlogs.

Incipient rot and established rot were less common in butt logs than other logs (Table 4). Kino was present in half of all medium sawlogs; it was equally common in both butt and other logs and was significantly associated with borers (Table 5).

Possible infection point(s) were recorded whenever they were seen or suspected. In medium sawlogs, incipient rot and established rot were most frequently associated, either singly or in combination,

with branch stubs (52%), borers (43%) and scars resulting from *Armillaria* cankers, fire or mechanical damage (14%). Infection points associated with these scars were more common on butt logs than other logs, while infection points associated with borers and branch stubs were more common on other logs.

### First-grade sawlogs

Data from the first-grade sawlog survey were not as comprehensive as those from the medium sawlog survey. Incipient rot, established rot and kino were equally common in butt and other logs.

Suspected infection points for incipient rot and established rot, either singly or in combination, were borers (85%), branch stubs (30%), and scars resulting from *Armillaria*, fire or mechanical damage (22%). There was no association between infection point(s) and log type.

### Distribution and extent of incipient rot and rot in sawlogs

During the surveys, the distribution of incipient rot and established rot in the cross-section of the log was recorded — that is, whether

**Table 3.** Incidence of kino, incipient rot, brown rot and white rot in medium and first-grade sawlogs

Defect	Medium sawlogs		First-grade sawlogs	
	Proportion (%)	Rank	Proportion (%)	Rank
Kino	49.8	1	89.2	1
Incipient rot	47.0	2	48.4	2
No incipient rot or advanced rot	29.6	3	10.9	4
Incipient rot and white rot	17.0	4	9.4	5
Incipient rot and brown rot	2.4	5	14.1	3
White rot only	2.0	6	0	9
Brown rot only	1.2	7	7.8	6
Brown rot and white rot	0.4	8	1.6	8
Incipient rot, brown rot and white rot	0.4	8	7.8	6

**Table 4.** Medium sawlog survey - incidence of incipient rot and/or advanced rot in butt logs

Defect	Butt logs		Other logs	
	Observed	Expected	Observed	Expected
No incipient rot and or rot	36	29	39	46
Incipient rot and or rot	62	69	116	109

DF = 1,  $\chi^2 = 3.96$ ,  $P = 0.05$

**Table 5.** Medium sawlog survey — incidence of kino and borers

Defect	Borers		No borers	
	Observed	Expected	Observed	Expected
No kino	19	34	108	93
Kino	48	33	77	92

DF = 1,  $\chi^2 = 17.7$ ,  $P < 0.0001$

in scattered pockets, central third, central two-thirds, or the entire log. In medium and first-grade sawlogs, scattered pockets of incipient rot and established rot were associated with borers. In medium sawlogs, when two-thirds or the whole of the cross-sectional area was affected, the incipient rot and established rot was associated with *Armillaria*, fire or mechanical damage.

## Discussion

Logs used in these surveys fell within the size specifications for medium and first-grade sawlogs current at those times (1987 and 1992) (Department of Conservation and Land Management 1989). Since then there have been changes to the sawlog specifications for karri, with logs now being classed as first-grade, second-grade and other bole logs (Department of Conservation and Land Management 1999). The specifications for first-grade sawlogs remain the same as those prescribed in Department of Conservation and Land Management (1989). Medium sawlogs would now be classed as first-grade sawlogs, with specific specifications for particular sawmills. These sawlogs must have a sedub of 200 mm, but specifications relating to length, sweep and millable wood vary with the sawmill (Department of Conservation and Land Management 1999).

In 1987, Monier's Sawmill was the only mill cutting regrowth karri, so the sample of 253 medium sawlogs from at least ten coupes would have been representative of the regrowth logs at the time. Similarly, the survey of first-grade sawlogs carried out at Bunnings' Sawmill in 1992 included logs from at least ten old-growth coupes; although the origin of about half of the first-grade sawlogs was not known, the mean mid-point diameter of logs of unknown origin — almost 0.98 m (range 0.69–1.43 m) — indicates that most would have also come from mature stands. The Bunnings' survey therefore encompassed a sample representative of the quality of logs from mature stands at that time. We are not aware of any other surveys of the quality of karri sawlogs from old-growth stands.

As sawlogs of both types were cut into comparable products, the visual sampling of all logs would be comparable. Because of differences in diameters and lengths (Table 1), however, it is possible to make only general comparisons between the log classes.

The surveys show that, as suspected by the timber inspectors, incipient rot and established rot are significantly more abundant in regrowth sawlogs than in sawlogs from old-growth forest (Table 2). The main difference between these sawlogs is in relation to the entry points for wood rot fungi. These infect through wounds; they cannot invade through undamaged bark (Kile and Johnson 2000). The most common entry point in regrowth sawlogs was branch stubs, although other entry points were borer galleries and scars resulting from *Armillaria* attack, fire or mechanical damage. This contrasts with the logs from old-growth stands where the most common entry point was borer galleries. A survey of regrowth karri trees has also shown that incipient rot and established rot are most commonly associated with branches, although they are also associated with insect galleries (Hewett and Davison 1995). Options for reducing numbers of entry points in regrowth trees are discussed in Hewett and Davison (1995).

Brennan *et al.* (1999) assessed the quality of karri timber in a sawing trial of 30-y-old regrowth trees of different dominance classes. They recorded the surface area of boards affected by biological agents (insect and fungal damage) as well as the extent of mechanical damage. They found that incipient rot was the defect affecting the largest surface area of slabs sawn from butt, mid-point and crown logs, observations that are consistent with the Monier survey. Incipient rot was associated with knots, especially in the crown logs, as well as with insect galleries. As incipient rot is not classed as a defect, it did not reduce recovery.

Although incipient rot is not classed as a defect, it does affect durability. Using an accelerated field simulator, Johnson *et al.* (1993) have shown that incipient rot reduces durability. They estimated the median specimen life (MEDSL) value of regrowth karri affected by incipient rot as 44 weeks, significantly less than that of unaffected regrowth karri, which had not decayed sufficiently within 184 weeks' exposure to be able to calculate a MEDSL.

Incipient rot may also affect the density and strength of regrowth karri. Yang *et al.* (2000) compared the density, modulus of elasticity (MOE) and modulus of rupture (MOR) of discoloured and clear regrowth *E. obliqua* L'Hérit. They showed that clear wood had a higher density, MOE and MOR than discoloured wood. No similar measurements have been made for regrowth karri wood affected by incipient rot (G.R. Siemon, Forest Products Commission, *pers. comm.* 16 January 2007).

One observation from our surveys is that kino is the most common defect in both medium- and first-grade sawlogs (Table 3), and it is less common in medium sawlogs than would be expected from the first-grade sawlog survey (Table 2). Kino is formed following damage to the cambium (Tippett 1986); common causes include insect damage, damage as branches are shed and mechanical damage. In regrowth karri, kino is associated with borers (Table 5; Hewett and Davison 1995; Farr *et al.* 2000) and with branches (Hewett and Davison 1995). We do not know whether the high incidence of kino in first-grade sawlogs indicates a higher incidence of mechanical damage and or borer attack than in medium sawlogs.

The results of this study are consistent with those of other research. The quality of wood from regrowth karri trees is inferior to that from mature stands. Incipient rot is widespread (Davison and Tay<sup>1</sup>); its incidence is higher in dominant and co-dominant trees than in subdominant and suppressed trees (Hewett and Davison 1995). Incipient rot is mainly associated with branching, although borer galleries are also important infection points (Hewett and Davison 1995; Brennan *et al.* 1999; Farr *et al.* 2000; Davison and Tay<sup>1</sup>). It is also associated with scars caused by *Armillaria*, fire or mechanical damage. Incipiently affected wood is less durable than sound wood (Johnson *et al.* 1993), and as rot develops it will reduce sawn recovery (Brennan *et al.* 1999). Sawn timber from regrowth karri may not be of adequate quality to replace timber from old-growth forests in its traditional markets.

## Acknowledgements

We thank staff from Monier's Sawmill, Busselton, and Bunnings' Sawmill, Pemberton, for their co-operation, and R. Rule, D. Jackson and J. Martin for conducting the surveys. We are grateful to M.J. Williams for statistical advice, and to P. Shedley and G.R. Siemon for constructive criticism of this report.

## References

- Abacus Concepts (1992) *StatView*. Abacus Concepts, Inc., Berkeley, California.
- Bradshaw, F.J. and Lush, A.R. (1981) *Conservation of the Karri Forest*. Forests Department, Perth, Western Australia.
- Breidahl, R. and Hewett, P.J. (1995) Silvicultural research in the karri forest. *CALMScience* **2**, 51–100.
- Bootle, K.R. (2005) *Wood in Australia: Types, Properties and Uses*. Second edition. McGraw-Hill Book Company, Sydney, New South Wales.
- Brennan, G.K., Smith, E.L., Stratico, S.C. and Pitcher, J.A. (1999) Assessing wood quality of 30-year-old regrowth karri from Nairn Block, Pemberton. *CALMScience* **3**, 1–19.
- 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, Perth, Western Australia. 26 pp.
- Conservation Commission of Western Australia (2004) *Forest Management Plan 2004–2013*. Conservation Commission of Western Australia, Perth, Western Australia.
- Department of Conservation and Land Management (1987) *Timber Production in Western Australia*. Department of Conservation and Land Management, Perth, Western Australia.
- Department of Conservation and Land Management (1989) *Manual of Hardwood Logging Specifications*. 2nd edition. Department of Conservation and Land Management, Perth, Western Australia.
- Department of Conservation and Land Management (1999) *Manual of Management Guidelines for Timber Harvesting in Western Australia*. Department of Conservation and Land Management, Perth, Western Australia.
- Farr, J.D., Dick, S.G., Williams, M.R. and Wheeler, I.B. (2000) Incidence of bullseye borer (*Phoracantha acanthocera* (Macleay) *Cerambycidae*) in 20–35-year-old regrowth karri in the south-west of Western Australia. *Australian Forestry* **63**, 107–123.
- Greaves, H. and Barnacle, J.E. (1970) A note on the effect of microorganisms on creosote penetration in *Pinus elliottii* sapwood and *Eucalyptus diversicolor* heartwood. *Forest Products Journal* **20**, 47–50.
- Hewett, P.J. and Davison, E.M. (1995). Incidence of brown wood (incipient rot) and rot in regrowth karri. Comparison of 12 to 14-year-old trees on two community vegetation types. Unpublished report, Department of Conservation and Land Management, Perth, Western Australia.
- Johnson, G.C., Thornton, J.D. and Nguyen, N-K. (1993) An accelerated field simulator study of the natural durability of heartwood from mature and regrowth trees. Proceedings *24th Forest Products Research Conference*, Melbourne, Australia, 15–18 November 1993, Topic 2/21, 9 pp.
- Kile, G.A. and Johnson, G.C. (2000) Stem and butt rot of eucalypts. In: Keane, P.J., Kile, G.A., Podger, F.D. and Brown, B.N. (eds) *Diseases and Pathogens of Eucalypts*. CSIRO Publishing, Australia, pp. 307–338.
- Tippett, J. (1986) Formation and fate of kino veins in *Eucalyptus* L'Hérit. *IAWA Bulletin n.s.* **7**, 137–143.
- Yang, J.-L., Wardlaw, T. and Scott, L.H. (2000) Density and strength characteristics of discoloured and pencil-streaked Tasmanian regrowth eucalypts: a preliminary study. *Australian Forestry* **63**, 188–193.