Decay and other defects associated with pruned branches of *Eucalyptus nitens*

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Abstract

Fifty-two Eucalyptus nitens *trees, aged 12–16 years, from five pruned stands in Tasmania were dissected and assessed for decay and other defects associated with the pruned branches. In four of the five stands, 13.5–16.2% of the pruned branches were associated with columns of discolouration and decay spreading from the pruned stub into the main stem. The risk of a pruned branch being associated with spreading decay columns increased with increasing branch diameter and increasing height up the pruned stem. Other defects associated with the pruned branches are described.*

Introduction

Throughout Australia, social pressures are demanding that an increased proportion of the future sawn timber requirements be met by trees grown in plantations (Cameron and Penna 1988; Clark 1990). The conversion of plantation-grown *Pinus radiata* D. Don to sawn timber is well established in Australia. Until recently, however, there has been little attention given to the establishment and silvicultural treatment of eucalypt plantations specifically for sawn timber production. In Tasmania, approximately 7000 ha of *Eucalyptus nitens* (Deane and Maiden) Maiden were planted on State forest between 1991 and 1996 with the specific goal of producing high quality sawn timber and veneer. Forestry Tasmania aims to increase the sawlog eucalypt plantation estate by a further 56 000 ha during the next decade (Forestry Tasmania 1999).

Trials have been conducted recently to evaluate the quality of sawn timber from older eucalypt plantations in Tasmania and Victoria that were established primarily for pulpwood production (Yang and Waugh 1993, 1996). Those trials have established that *E. nitens* timber has many of the characteristics desired for end-uses demanding high quality. However, they found that only 5% of the recovered sawn timber volume met select grade (*sensu* Waugh and Rozsa 1991), with 75% of the recovered volume being down-graded because of excessive knots. If knots were not present, Yang and Waugh (1993) estimated that more than 50% of the recovered volume could meet select grade specifications. It was concluded that to produce acceptable volumes of high quality sawn timber from *E. nitens* plantations a silvicultural regime that involved pruning would be required.

The studies of Yang and Waugh (1996) showed that decay associated with branches in unpruned *E. nitens* was rare in comparison with *E. regnans* F. Muell. from unpruned plantations. Glass and MacKenzie (1989) found that pruned branches rarely became sources of stem decay in a New Zealand plantation of *E. regnans.* Similarly, Gadgil and Bawden (1982) found that pruned branches were no more likely to be the source of stem decay than unpruned branches in a New Zealand plantation of *E. delegatensis* R.T. Baker. However, Mohammed *et al*. (1998) showed that pruned *E. nitens* trees had substantially more columns of decay than paired unpruned trees in an eight-year-old plantation in southern Tasmania.

In this study, we examined the incidence of decay and other defects arising from branches in five plantations of *E. nitens* which had been pruned between one and nine years earlier.

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Table 1. Summary of pruned Eucalyptus nitens *stands assessed for decay associated with pruned branches.*

	Barnback	Camden	Goulds Country	Peak Hill Farm	St Georges Road
Altitude (m)	250	580	150	440	350
Year planted	1986	1982	1984	1986	1979
Provenance	Unknown	Toorongo	Toorongo	Toorongo	Toorongo and Sth NSW
Age at 1st pruning (years)	4	7	6	5	7
Age at 2nd pruning (years)	8	-	-	-	?
Season of 1st pruning	?	March	Nov-Dec	March	March
Season of 2nd pruning	?	-	-	-	?
Height of pruned stem (m)	6	6	6.4	4.5	6
Pruned trees sampled	10	10	14	11	7
Pruned branches assessed	451	129*	628	423	236†
Unpruned trees sampled	0	5	0	3	0

* Assessment was confined to the section of the pruned stem above 2 m.
† Assessment was confined to the section of pruned stem above 1.3 m.

Materials and methods

Study sites

Four stands of *E. nitens* in northern Tasmania and one in the south (Figure 1) were sampled and assessed for defects associated with pruned branches. These stands represented a large proportion of the pruned *E. nitens* estate present at that time in Tasmania and were established primarily for experimental purposes rather than on an operational basis for sawlog production. The silvicultural treatments used in these stands pre-dated the development of regimes for the silvicultural treatment of the plantation sawlog estate recently established in Tasmania. As a result, the stands, with the exception of Barnback, were pruned at a later age than currently prescribed (Pinkard *et al.* 1999). Details of the pruned stands assessed for defect are given in Table 1.

Defect assessment

Within each of the pruned stands, trees for defect assessment were selected randomly except at Goulds Country where trees were selected from among pruned buffer trees surrounding pruned experimental plots. At Camden and Peak Hill Farm, five and three trees respectively from adjacent unpruned stands were also selected for decay assessment. Selected trees were felled and cross-cut into 30 cm billets from the stump (approximately 30 cm) to the end of the pruned stem or 6 m (unpruned trees). In each billet, pruned branches were exposed with radial–longitudinal cuts through the centre of the branch stub (or occlusion scar) to the pith.

The diameter of each branch stub was measured and its condition was assessed as:

(i) *clear* (no evidence of discolouration and decay in the pruned branch stub);
(ii) *confined* (discolouration and decay present but confined to within the stub of the pruned branch); and
(iii) *decay escape* (discolouration and decay spreading out of the pruned branch stub into the stem above and/or below the branch).

No attempt was made to differentiate discoloured wood from decayed wood although a greyish discolouration sometimes present in the crotch of branches was not assessed because previous studies have shown such discolouration not to be associated with wood decay fungi (Wardlaw 1996). Other defects were described and classified as they were encountered.

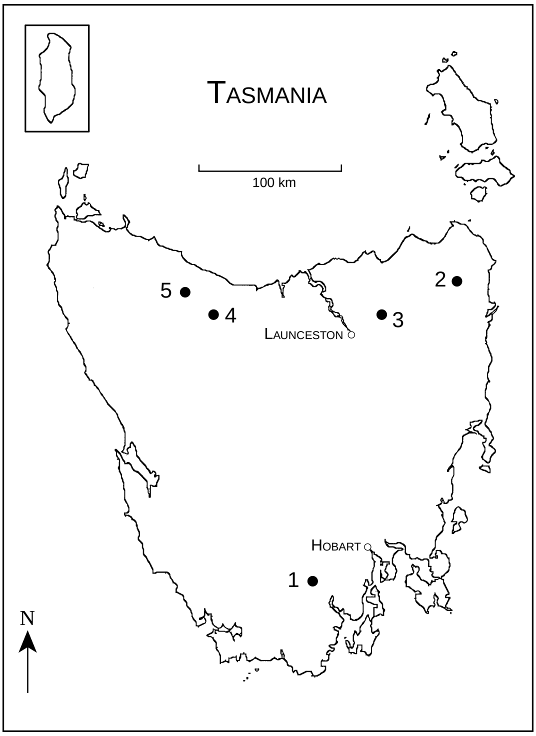


Figure 1. Location of pruned stands of Eucalyptus nitens *in Tasmania which were sampled for decay. (1 = Barnback, 2 = Goulds Country, 3 = Camden, 4 = Peak Hill Farm, 5 = St Georges Road)*

Table 2. Counts of Eucalyptus nitens *pruned branch stubs (pruned stands) or unpruned branches (unpruned stands) which had either no decay (or confined to branch stub) or decay spreading into the main stem. Figures in parentheses are percentages of total branches assessed with decay spreading into the main stem. Values for pruned stands or treatments (pruned – unpruned) with different superscripts are significantly different ($P < 0.05$) based on least significant difference range tests of arcsine transformed data.*

Plantation	Clear or confined to stub	Decay spreading into stem
Pruned stands		
Barnback	383	68 (15.1)[a]
Camden	125	4 (3.1)[b]
Goulds Country	526	102 (16.2)[a]
Peak Hill Farm	362	62 (14.6)[a]
St Georges Road	205	32 (13.5)[a]
Unpruned stands		
Camden	71	0 (0)
Peak Hill Farm	118	4 (3.3)
Treatments overall		
Pruned	1601	268 (13.2)[a]
Unpruned	189	4 (1.3)[b]

Data analysis

Each branch assessed for decay was classified into one of six diameter classes (≤ 10 mm, 11–20 mm, 21–30 mm, 31–40 mm, 41–50 mm and > 50 mm) and one of four height classes (0–1.5 m, 1.5–3 m, 3–4.5 m, 4.5–6 m). Analysis of variance was used to test the significance of differences in the proportion of branches with decay escapes between pruned and unpruned trees, among pruned stands and among branch diameter and height classes. Where necessary, an arcsine transformation was applied to the data to stabilise variances.

Results

The range of defects associated with pruned branches is shown in Photo 1. A well-occluded, defect-free branch is shown in Photo 1A. Columns of discolouration and decay spreading out of the pruned branch into the stem (Photo 1B) were the most common defect encountered. At Goulds Country, pruned branches that had died and formed a natural abscission zone (Photo 1D) prior to pruning were associated with a kino trace defect (Photo 1C). This type of defect appears to occur as a result of a small section of the branch between the natural abscission zone and the pruning cut being strongly held in the bark and, instead of being occluded, is drawn radially outwards with diameter growth. This results in the formation of a kino-filled void. High angle branches which had died and formed natural abscission zones prior to pruning sometimes produced stubs which hinged at their abscission zone and, instead of occluding, were pushed downwards with increasing diameter growth (Photo 1D). High angle branches also presented difficulties with access for pruning that occasionally resulted in cambial damage to the branch collar around the base of the branch (Photo 1E).

All of the decay columns arising from the pruned branches were confined to the knotty core (i.e. had not spread outwards into wood formed subsequent to pruning). There was, however, little visible evidence of kino vein formation in response to pruning except where cambial damage to the branch collar occurred. Instead, it was common for a narrow tangential–longitudinal band of intense purplish discolouration to form at the outer boundary (adjacent to sapwood) of columns of discolouration and decay (Photo 1F).

Pruned trees had a significantly ($P < 0.001$) greater proportion of branch stubs associated with decay escapes than branches/branch stubs in unpruned trees. Only one of the eight unpruned trees had decay escaping from dead branches/branch stubs compared with 45 of the 52 pruned trees. In the pruned stands, there were highly significant differences ($P < 0.001$) among sites in the proportion of pruned branches with decay escapes. These differences were due to the significantly lower proportion of pruned branches with decay escapes at the Camden site compared with the other four sites (Table 2).

There was a strong and statistically significant ($\chi^2_{[5\ \text{d.f.}]} = 280.5$; $P > \chi^2 < 0.001$) trend of an increasing proportion of branches associated with spreading columns of decay with increasing branch diameter (Figure 2). This trend was consistent across all of the sites except Camden. This relationship could be expressed satisfactorily by the linear regression model $y = 0.0126x - 0.0313$, where y is the proportion of branches in the branch diameter class associated with decay escapes, and x is the mean diameter (in mm) of the branch diameter class. This model accounted

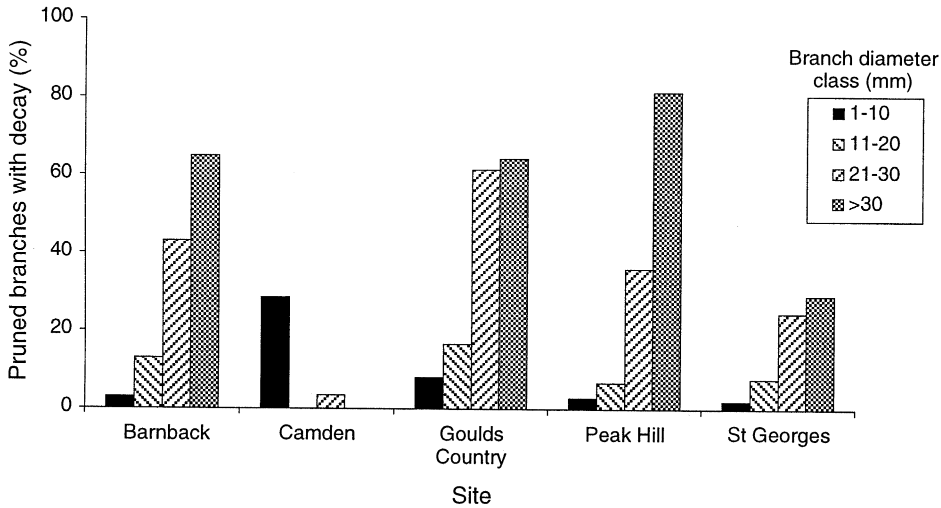
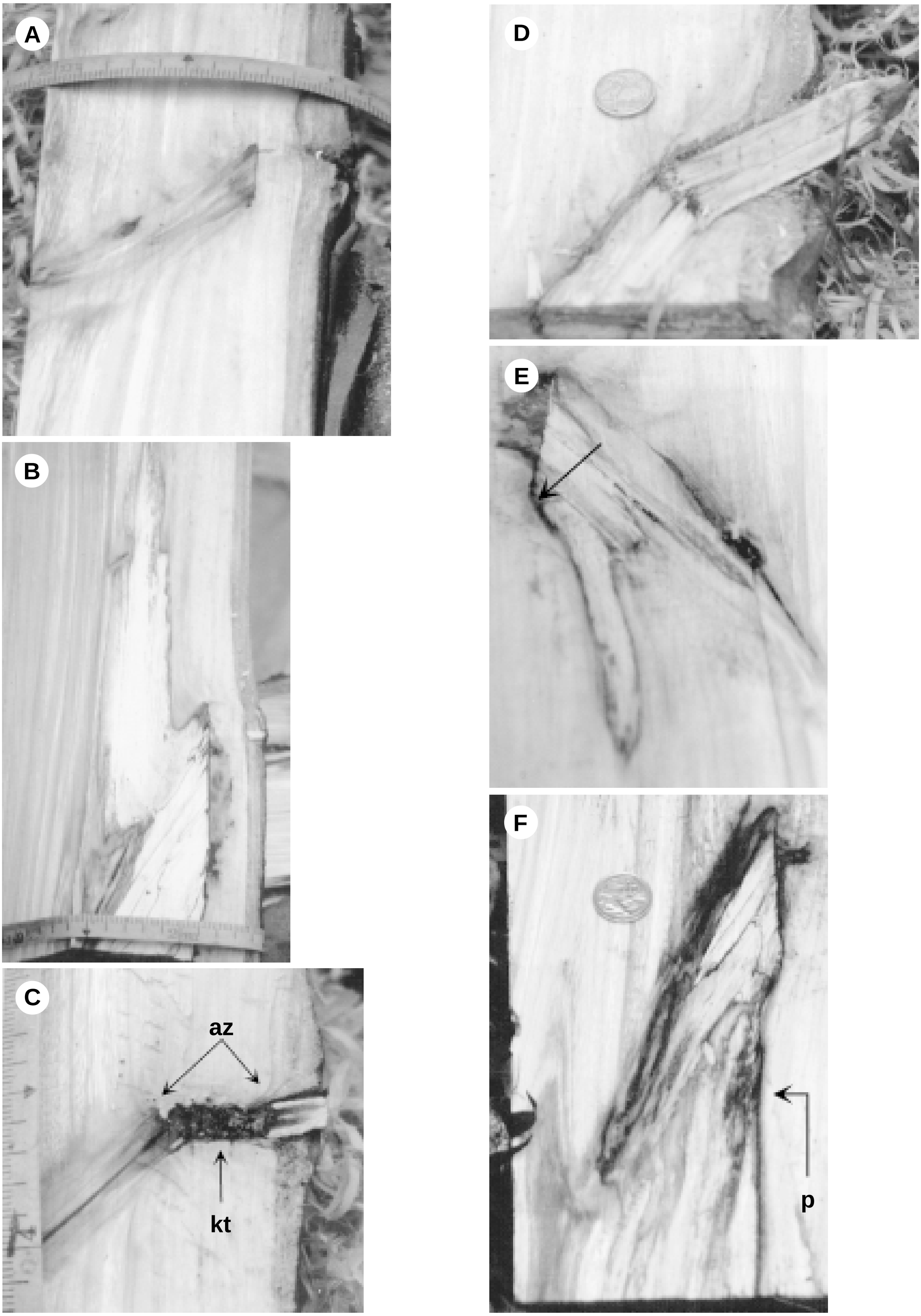


Figure 2. Proportion of pruned Eucalyptus nitens *branches associated with spreading columns of decay, partitioned according to branch diameter class within sites.*

Photo 1. Longitudinal sections through pruned branches of Eucalyptus nitens. *(A, A well-occluded pruned branch with discolouration confined to the branch trace; B, a large diameter pruned branch with decay spreading into the main stem; C, a pruned dead branch showing a kino trace defect (az – abscission zone, kt – kino-filled void); D, a pruned high-angle dead branch showing a retained stub (between abscission zone and pruning cut) being pushed downwards with new diameter growth instead of occluding; E, the cambium below this pruned branch was damaged (arrow) during pruning, causing a decay column to develop; F, purple discolouration (p) has formed at the interface of a decay column and sapwood.)*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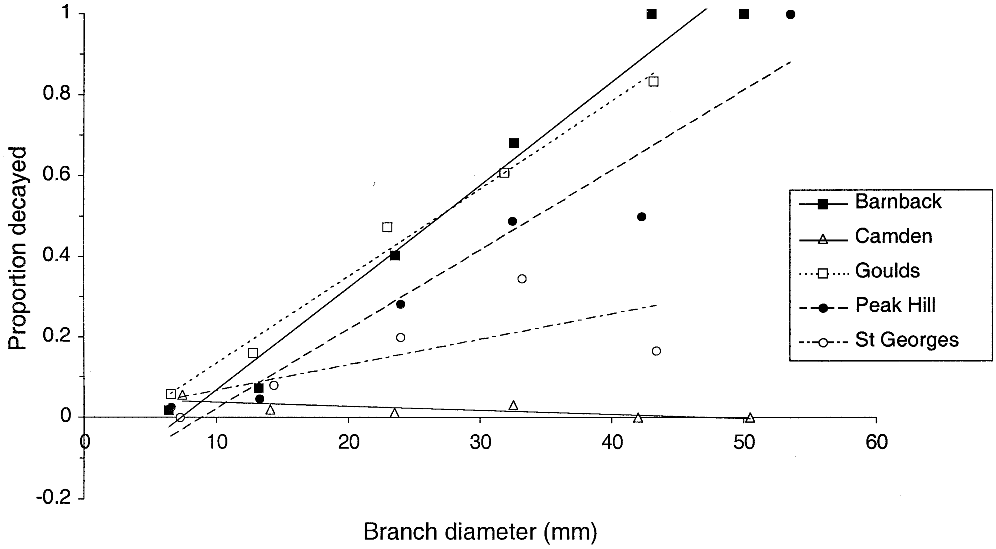

Figure 3. Least squares linear regressions of average branch diameter (within diameter classes) versus proportion decayed for each of the five pruned stands assessed.

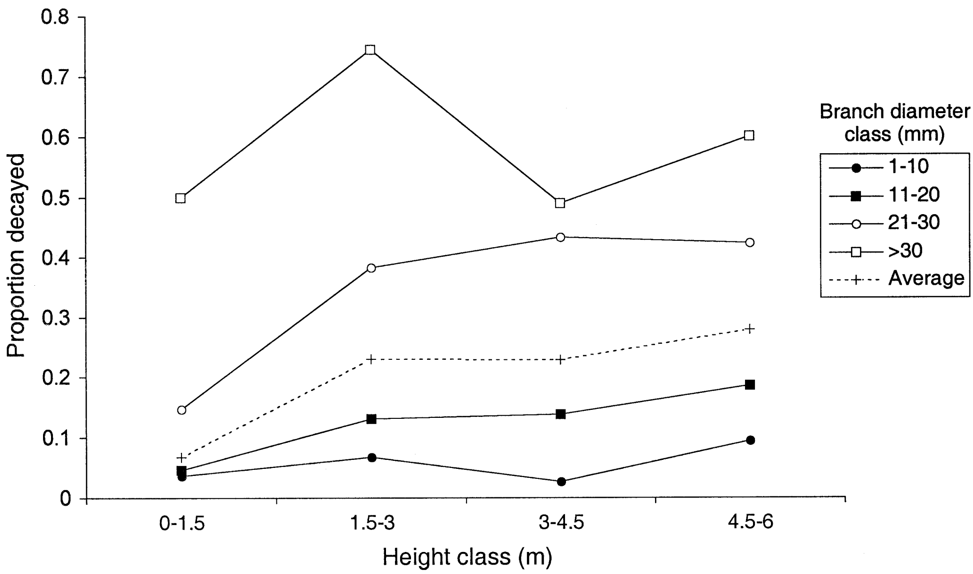

Figure 4. Proportion of pruned Eucalyptus nitens *branches associated with spreading columns of decay, partitioned according to branch diameter class within stem height classes.*

for 94% of the variation in the dependent variable ($P < 0.001$). However, the slopes of the linear regressions differed significantly ($P < 0.001$) among sites. Both the Camden and St Georges sites had significantly lower slopes than the other three sites (Figure 3).

The proportion of pruned branches with decay escapes increased sharply above the 0–1.5 m pruned section and then stabilised ('Average' in Figure 4). This trend occurred across all branch diameter classes below the > 30 mm class.

Discussion

This study has shown that a high proportion of pruned branches in *E. nitens* formed the source of decay columns spreading out of branch traces into the main stem. A substantially higher proportion of pruned branches formed the source of stem decay compared with unpruned branches. However, insufficient comparable unpruned trees were sampled to be confident that pruning, *per se*, increased the risk of the branch becoming a source of stem decay. Mohammed *et al.* (1998) found that pruned branches had a considerably higher risk of initiating columns of stem decay than unpruned branches in an *E. nitens* plantation in southern Tasmania. However, an assessment of stem decay in an unpruned *E. nitens* stand adjacent to the St Georges Road site found the incidence of decay arising from dead attached branches was very high (T. Wardlaw, unpublished data). In that study, columns of decay were found in all eight trees sampled, with between four and 14 (average 8) independent decay columns occurring in each tree. It is likely that differences in the risk of decay associated with pruning exist between sites. Surveys in native forests found significant differences in the incidence and severity of stem decay originating primarily from branches (Wardlaw 1996; Wardlaw *et al.* 1997). The significant difference, among sites, in the regression slopes of the proportion of branches with decay escapes versus branch diameter provides evidence that there are significant differences in decay risk among the sites.

The incidence of decay spreading into the stem from pruned branches of *E. nitens* found in this study and the study of Mohammed *et al.* (1998) was considerably higher than incidences reported by Gadgil and Bawden (1982) for *E. delegatensis* and Glass and McKenzie (1989) for *E. regnans*. In the latter work, however, a fungicidal treatment was applied to pruned stubs and therefore the study was not comparable with our study.

There is little published information to indicate that plantation-grown *E. nitens* is decay-prone. Previous studies have found unpruned *E. nitens* plantations had very little decay (Yang and Waugh 1996). However, as discussed previously, there is evidence that high levels of decay occur in *E. nitens* on some Tasmanian sites. Other factors that could be contributing to the high incidence of decay found in this study include:

- Stands were pruned at an older age than is currently prescribed in Forestry Tasmania's eucalypt plantation sawlog regime (Pinkard *et al.* 1999). Because of this, trees selected for pruning would have had larger branch diameters (particularly in the top half of the 6 m pruned section) than trees pruned under current prescriptions.
- Sites sampled in this study were among the first eucalypt plantations to be pruned in Tasmania and some mistakes due to inexperience could be expected. Some examples of inappropriate tree selection and poor pruning technique (particularly of large and/or high angle branches) were seen during the study.

Our study has found that the risk of decay columns that escape the confines of the branch trace increases with increasing branch diameter. Glass and McKenzie (1989) found a similar trend in pruned *E. regnans*. A matching trend also exists for naturally shed branches in naturally regenerated eucalypt forests (Marks *et al.* 1986; Wardlaw *et al.* 1997). Because we found the risk of decay escape increases linearly with increasing branch diameter, a management strategy to reduce the risk of decay should be to set the maximum allowable diameter threshold as small as possible while at the same time allowing sufficient 'within-specification' trees for pruning. On the basis of trees sampled in this study, a maximum allowable diameter threshold of 40 mm would enable nearly three-quarters of the trees pruned to 6 m to meet this specification (Table 3). However, the branch diameters measured in this study were considerably larger than would be expected using the current pruning prescriptions that stipulate pruning some three to four years earlier. If this is taken into account, it is estimated that 85% of branches in the 30–40 mm

Table 3. Percentage of pruned sample trees that met the indicated branch diameter specifications for three pruning heights.

Pruned height (m)	Branch diameter limit (mm)		
	< 20	< 30	< 40
3	15	51	88
4.5	7	22	78
6	0	15	73

diameter class would still be in the 20–30 mm diameter class if pruning were done according to current prescriptions. On this basis, a maximum allowable branch diameter of 30 mm is proposed for pruning *E. nitens*.

We did not differentiate branches that were live at the time of pruning from those that were dead. The branches that were dead at the time of pruning would be expected to be concentrated in the lower section of the pruned stem and in the lower branch diameter classes. The sharp rise in the proportion of pruned branches with decay escape above the 0–1.5 m pruned section coincides with an expected transition from pruning predominantly dead to pruning predominantly live branches. This would suggest that live-branch pruning has a higher risk of decay escape than dead-branch pruning.

Our study found a high proportion of pruned trees had decay spreading out of the traces of pruned branches. However, decay will only impact on future timber yields if it escapes the confines of the knotty core and spreads into clear wood formed following pruning. Somerville and Davies-Colley (1998) found a very low incidence of decay in the clearwood zone compared with the knotty core zone of 22-year-old pruned *E. regnans* in New Zealand. In our study, all of the columns of discolouration and decay remained confined to the knotty core. However, the trees were sampled mid-rotation and would still need to grow for at least a further 10 years to reach target size for sawing.

The formation of an effective barrier zone (*sensu* Shigo 1979) is widely regarded to be the main mechanism in trees to confine any discolouration and decay to wood present at the time of wounding; in this case, the pruning wound (Shigo *et al.* 1979). In eucalypts, this barrier zone typically develops as a kino vein (Tippett 1986). In the *E. nitens* dissected in this study, kino veins were rarely seen, although kino-filled voids were a common defect at the Goulds Country site. Many of the trees assessed in this study had a zone of intense purple discolouration at the outer boundary (sapwood side) of the decay column in freshly cut billets (Photo 1F). We have never seen similar zones of discolouration in more than 1000 young *E. regnans*, *E. delegatensis* and *E. obliqua* regrowth trees assessed for stem decay. The purple zone of discolouration matches the description of 'aniline wood' by Shain (1971) who found it associated with reaction zones bounding columns of decay in Norway spruce. Pearce (1996) speculated that reaction zones were analogous to Wall 1 of the CODIT model (Shigo *et al.* 1979) and form a cap to limit the axial (and to some extent, radial) spread of decay into functional sapwood. K. Barry, R.B. Pearce and C. Mohammed (pers. comm.) found that the zone of purple discolouration bounding decay columns at the sapwood interface had several properties that characterise reaction zones and provided an effective barrier to the spread of decay.

This study aimed to provide basic information about the risk of decay associated with pruning *E. nitens*. It has shown that pruning has a high risk of initiating stem decay on sites representative of a substantial proportion of the *E. nitens* plantation estate in Tasmania. The study has shown the importance of branch size as a conditioner of decay risk. This has resulted in maximum branch size specifications being included in the current pruning prescriptions. The results from this study form the basis for identifying gaps in our knowledge requiring further research. These include:

(i) Whether the risk of initiating decay columns in pruning live branches differs from that in pruning dead branches;

(ii) Are there differences between sites in the risk of decay from pruning;

(iii) Does pruning at different times of the year influence the risk of decay and, if so, are those differences related to weather patterns;

(iv) How does *E. nitens* respond to wounding and invasion by wood decay fungi; and

(v) Can *E. nitens* contain decay arising from pruning to within the knotty core until trees are harvested?

Many of these questions are being addressed through research being conducted by Caroline Mohammed and Karen Barry at the Co-operative Research Centre for Sustainable Production Forestry.

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