Forestry Tasmania
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Native Forest Silviculture

TECHNICAL BULLETIN No. 13

2001

# Thinning Regrowth Eucalypts

ISSN 1034 - 3261

November, 2001.

The suggested citation for this bulletin is:

Forestry Tasmania (2001). Thinning Regrowth Eucalypts.
Native Forest Silviculture Technical Bulletin No. 13,
Forestry Tasmania.

*Acknowledgments:*

Assistance in the production of the second edition was provided by John Cunningham, John Hickey, Tim Wardlaw and Leigh Edwards.

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# Thinning Regrowth Eucalypts


Second edition (2001): Revised and prepared by Ann LaSala.

First edition (1998): Prepared by Gary Brown, John Cunningham and Mark Neyland.

Division of Forest Research and Development
Forestry Tasmania

## Part A: Thinning as a Silvicultural Treatment



## Part B: Silvicultural Principles Of Thinning

# PART A: Thinning as a Silvicultural Treatment

## 1. Introduction

Thinning is a silvicultural treatment applied to overstocked, even-aged regrowth stands to release potential sawlogs from competition. As applied by Forestry Tasmania, about one-half the basal area is kept after thinning. There is no intention to encourage regeneration, because sufficient trees are retained so that all the growth potential of the site is added to the retained stems.

Thinning does not increase the productivity of a stand, it merely concentrates wood production onto the retained trees. This results in either a shorter rotation or larger trees at harvest. Wood that would otherwise be lost through death due to natural suppression in the forest is harvested, providing an interim return to the forest owner. Thinning also increases the sawlog component of the final stand by removing stems with poor form, and by allowing a greater number of trees to grow to sufficient size to be sawn.

### 1.1 Suitable stands

Thinning is mainly conducted in stands dominated by one or more of the ash species, *Eucalyptus obliqua, E. regnans* and *E. delegatensis,* as these tend to dominate high-quality sites. Suitable stands have a eucalypt height potential of E1, E2 or E+3 (average mature height at least 34 m), and are situated at altitudes of less than 600 m. An overview of the process used in deciding whether a particular stand should be thinned is given in Figure 1.

### 1.2 Suitable ages

Thinning should be employed at times of canopy closure, that is, when the crowns of the dominant and co-dominant trees touch one another and form a continuous canopy layer. Thinning opens up space into which the crowns of the retainers, or "crop trees", can expand. This crown expansion results in increased tree growth rates until the next time the stand reaches canopy closure. The two main types of thinning operations are Pre-Commercial Thinning (PCT), which is done between 10 and 25 years, and Commercial Thinning (CT) which is done between 25 and 40 years. As a general rule, stands older than 40 years which have not been thinned previously should not be thinned, because the growth response will be slow and the investment is not likely to be recouped before clearfell age.

## 2. Crop Tree Selection

Crop tree selection in stands of any age should aim to maximise eventual sawlog production. To that end, crop trees should be selected on the basis of form, size, spacing and species, in that order.

### 2.1 Form

Trees containing potential sawlog should make up at least half the crop trees in PCT, and four out of five crop trees in CT. Potential sawlog trees must contain at least one 2.5 m length which is free of large branches or wounds, and which does not sweep away from its centre-line by more than half its diameter for PCT or one-quarter of its diameter for CT.

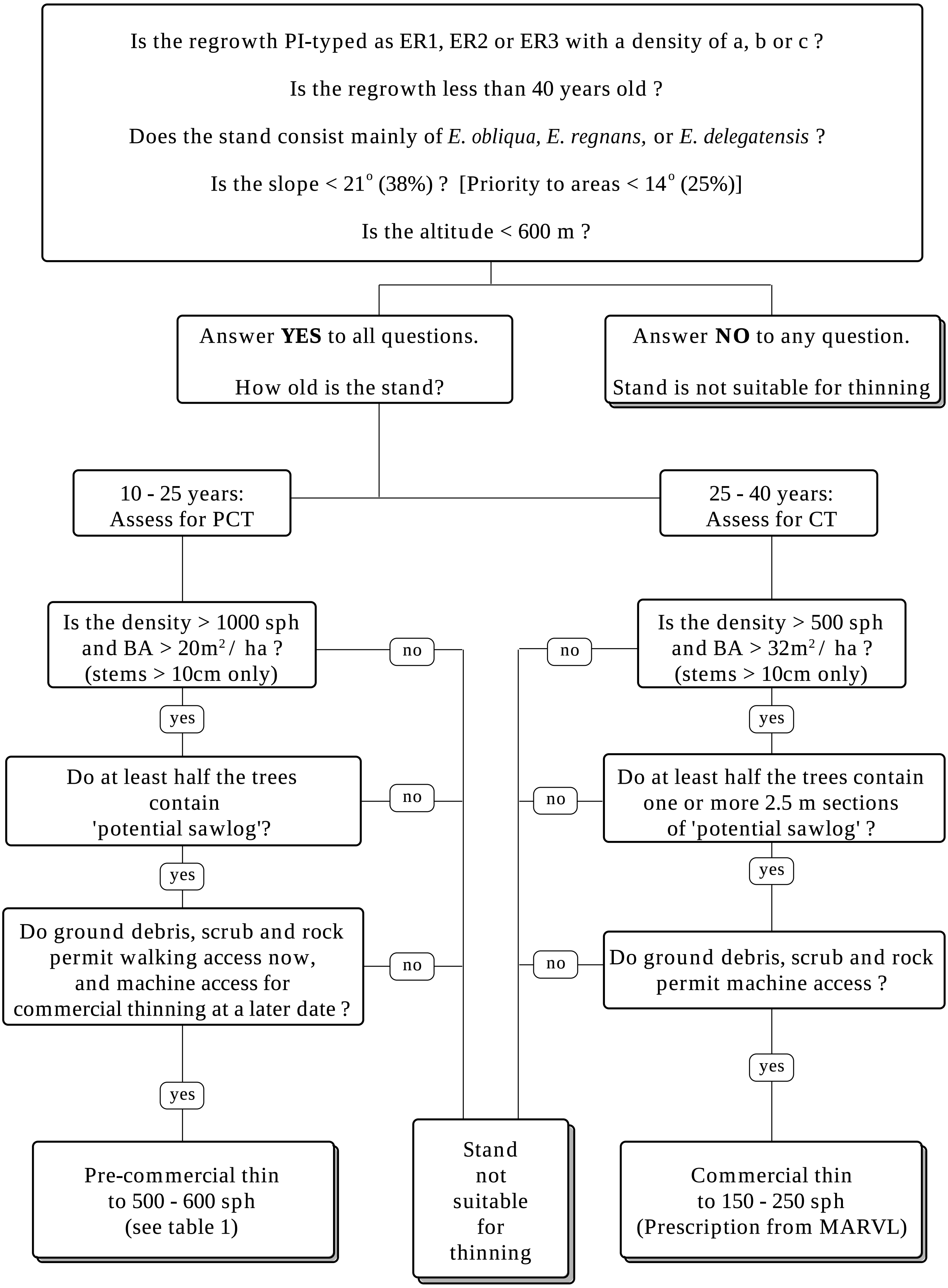
### 2.2 Size

Crop trees should be dominant and co-dominant trees, with subdominants being retained only when needed for spacing. They should have dense, healthy crowns, and no sign of epicormic stem shoots. Ideally only single-stemmed trees should be kept, but if it is necessary to retain a double-leader tree, both leaders should be retained.

### 2.3 Spacing

Retaining the correct number of stems per hectare can be most easily achieved by picturing the correct spacing needed between trees. Crop tree selection is based on the concept of 'key' trees. Having selected a crop tree (the 'key tree') the operator should select the next crop tree visually at the correct distance from the 'key' tree, before the competing trees are removed. The second crop tree then becomes the 'key' tree and the process is repeated.

**Figure 1. Selection of Stands for Thinning.**




**Trees for retention should be selected on the basis of Form, Size, Spacing and Species.**
**Damage to retained trees must be minimised.**

## 2.4 Species

The species mix of the retained stand should be similar to that of the original stand. Any *Acacia melanoxylon* (blackwood) present should be retained as they are shade tolerant and will reach maturity by final harvest. *Acacia dealbata* (silver wattle) may be retained for spacing purposes in a PCT operation, but should be removed in CT operations as they are likely to die prior to final harvest.

# 3. Pre-Commercial Thinning

PCT is generally used in stands between 10 and 25 years old (Figure 1). Treatments are currently implemented using stem injection of glyphosate, and trees are thinned to waste. PCT is used to prepare the stand for subsequent commercial thinning, by increasing both growth rates of retainers and access for machinery. (The term PCT covers all operations previously referred to as both "Early Age Spacing" and "Mid Age spacing").

## 3.1 Selection of areas

Areas potentially suitable for PCT are determined through local knowledge, the regeneration survey system and the use of aerial photographs. Stand characteristics should match the criteria given below. Selected areas are then subjected to a formal field assessment, and the decision as to whether to proceed with PCT is made based on stand density, basal area, canopy height, patchiness, and ease of access.

**Screening Criteria for Potential PCT areas**

**Age:** • 10 to 25 years
**PI typing:** • ER1 and ER2, with density 'a' or 'b'
**Site index:** • 30 or greater
**Min. area:** • 5 hectares
**General:** • Trees have shed their lower branches
• Ground debris and understorey do not significantly impede walking progress

Areas selected for PCT operations should have a minimum basal area (BA) of 20 $m^2$/ ha and a minimum density of 1000 stems per hectare (sph) larger than 10 cm in diameter.

## 3.2 Prescriptions

The standard PCT prescription stipulates a basal area (BA) reduction of about 50%, to no less than 12 $m^2$/ ha. This should result in a retention rate of no less than 500 crop trees/ha, at a spacing of about 5 m. Thinning prescriptions which stipulate retained numbers of crop trees and basal area will generally conform to Figure 2. Stands which have a basal area of close to 35 $m^2$/ ha and tree densities close to 1000 sph prior to thinning may warrant leaving for a few years until they are suitable for a commercial thinning instead of PCT.

*Figure 2. Typical stand characteristics and their corresponding PCT prescriptions. All figures refer to stems larger than 10 cm dbh over bark (dbhob).*

| Pre-thin density (sph) | Pre-thin BA ($m^2$/ ha) | Retained BA ($m^2$/ ha) | Retained sph | Avg. crop tree dbhob (cm) | Spacing (m) |
|---|---|---|---|---|---|
| c. 1400 | 20-25 | 12 | 600 | 16.0 | 4.4 |
| c. 1400 | 25-30 | 12-15 | 550 | 18.0 | 4.6 |
| c. 1400 | 30-35 | 15-17 | 500 | 20.0 | 4.8 |

### 3.3 Treatment method

The stem injection unit consists of a small backpack containing glyphosate herbicide, connected with plastic tubing to the injection hammer. The claw end of the hammer (Figure 3) has a single blade, and is used to strike the tree, penetrate the bark and lodge in the sapwood. A lever is then squeezed to compress the plastic tubing and inject the chemical into the small "well" created. Too shallow or too deep a cut will result in ineffective dosing. The unit is calibrated to release 1 ml of undiluted herbicide per compression. Injections are spaced evenly around the stem at 15 cm intervals at about shoulder height. Operators generally work in small teams, each covering a narrow strip and moving in parallel through the bush. Retained trees are marked with a band of spray paint.

*Figure 3. Using a stem injection hammer to treat an unwanted tree.*

Trees less than 10 cm dbhob are considered "non-competing" and do not need to be injected. Occasionally, very young stands with high stem density and relatively small size will be considered for PCT, and the prescription would stipulate that stems between 5 and 10 cm dbhob be injected.

The best time for injecting eucalypt regrowth is in its most active growing season, provided there is adequate moisture available. Recommended seasons for injection are spring and summer for wet sclerophyll forests (although it is effective year-round), and autumn and winter for dry sclerophyll forests. This introduces the herbicide into the tree's system during or just prior to the season in which it is most effective (LaSala and Dingle, 2000).

Further information can be found in the "Pre-commercial Thinning, Contractor and Supervisor Manual" (Cunningham and Pena, 2000).

### 3.4 A Field Operators Guide To Pre-Commercial Thinning (PCT)

***General aim***

To identify and retain trees at the time of PCT which have stem and crown characteristics likely to result in specification sawlogs at final harvest. Trees that do not meet these characteristics are thinned out of the stand, generally with herbicide.

**A. Tree form**

- Crop trees are to be single stemmed up to at least 2.5 m above stump height;
- Trees forming multiple stems at ground level should not be selected;
- Selected trees may have kinks within a potential sawlog section, provided the kink has a displacement of no more than half the diameter of the tree (Figure 4.);
- Ignore dead branches and branch stubs <30 mm diameter when assessing the suitability of trees for retention;
- Trees containing branches >30 mm in more than one quadrant in the bottom 4 metres of the stem should not be selected for retention (Figure 4);
- Crop trees should be free of insect attack on the stem. Look for sawdust at the base of the tree & silk webbing at the junction of stem & branch.

Tree classes D = Dominant, CD = Co-dominant, SD = Sub-dominant, S = Suppressed

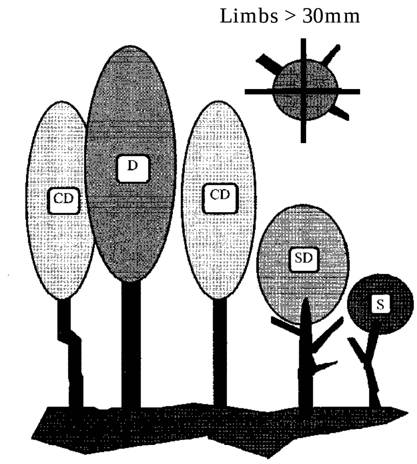



*Figure 4. Tree selection*

## B. Dominance

- Select trees from the **dominant** (D) and **co-dominant** (CD) classes (Figure 5.);
- Sub-dominant (SD) trees should only be selected if there are insufficient suitable dominant & co-dominant trees to reach prescribed stocking levels;
- Suppressed trees should never be selected for crop trees;
- All crop trees should have a conical crown indicative of vigorous growth;
- Any tree, either sawlog or pulp >30 cm dbh should be retained (bark thickness on this size tree can prove to be a troublesome barrier to penetrate).

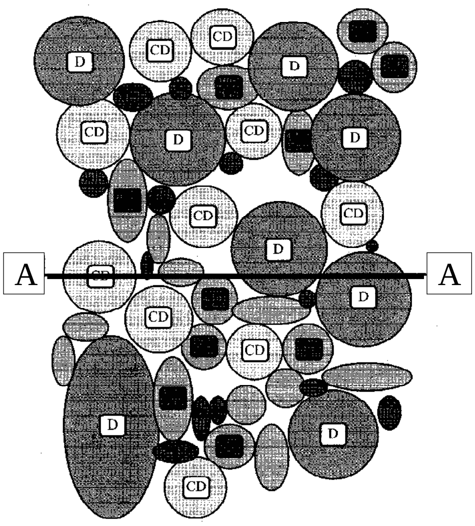



*Figure 5. Plan view: Unthinned stand*

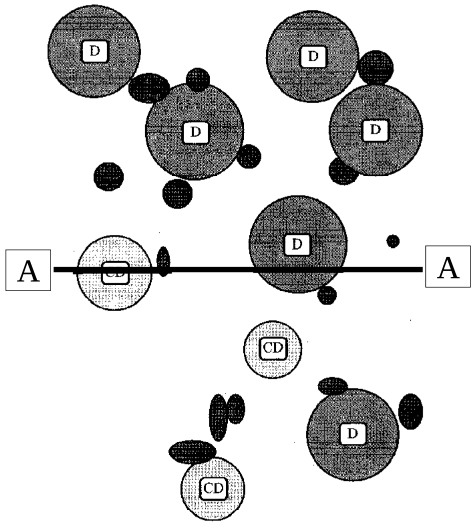



*Figure 6. Plan view: Thinned stand*

## C. Spacing

**Spacing is the third priority in *tree selection*, after *form* & *dominance*.**

- It may be necessary to retain poorer form trees in order not to enlarge any natural canopy gap;
- It is preferred to retain two trees of equal class at a closer spacing than retain a tree of poorer form at the prescribed spacing (Figure 5, 6, 7 & 8);
- Co-dominant & dominant wattles may be retained where the eucalypt stocking rate is insufficient to meet prescriptions;
- Retain all blackwoods in addition to prescription.

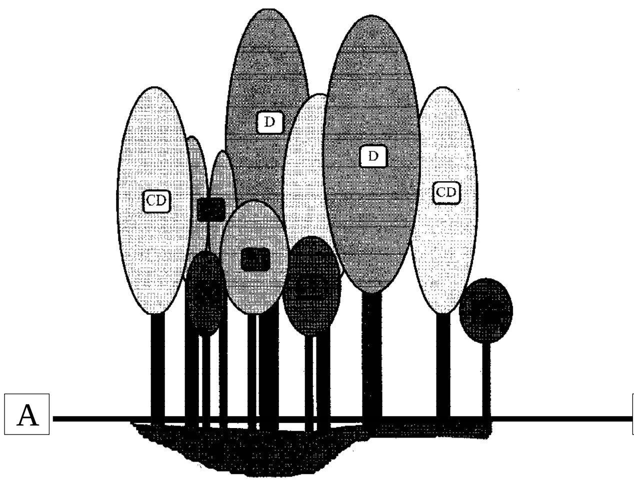



*Figure 7. Cross section: Unthinned stand*

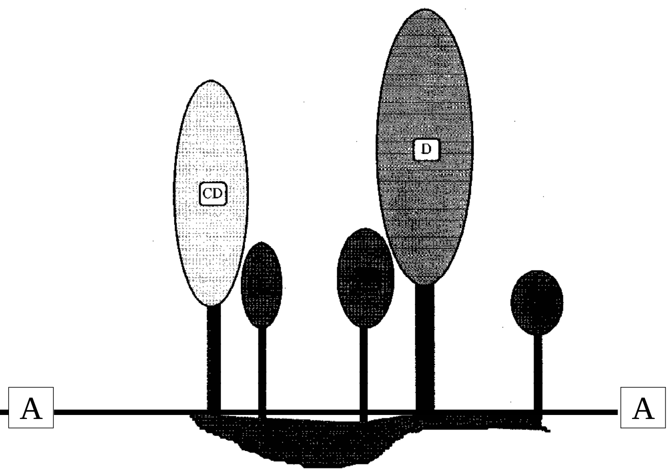



*Figure 8. Cross section: Thinned stand*

**Summary**

Due to varying site conditions (eg. poorly drained & rocky), across any coupe, trees will not necessarily grow evenly, therefore it maybe necessary to retain some trees which in other circumstances would be removed from the stand. The intention is to maintain an even canopy in this age class. The poorer form trees can be removed at the time of first commercial thinning.

**D. Stem injection**

***Maintenance***

- Sharpen the blade at regular intervals when used frequently;
- Flush the system regularly with clean water to maintain a clean and consistent fluid flow;
- Dispose of waste water as per FT pesticide manual;
- Valve components require periodic (weekly) inspection. Clean or replace worn items;
- Make sure the breather hole is free of obstruction at all times;
- Do not hit hammer into stumps under any circumstances. Wood fragments will block the outlet hole in the blade. Carry a twist drill to clear any blockages;
- Check delivery hose for any crimping which may reduce dosage applied;
- Secure carrypack in an upright position and guard against the blade damaging the hose & knapsack.

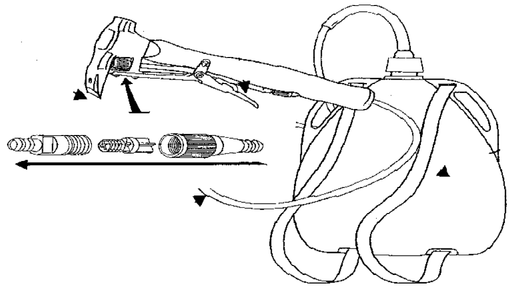
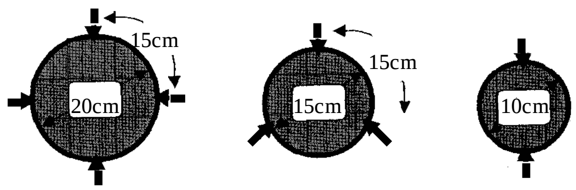


*Figure 9. Stem injector unit*

***Using the stem injector***

- Apply 1 ml per injection site;
- Injection sites should be spaced evenly around the tree. Remember the number of injection sites per tree will vary depending on the size of the tree, as is illustrated in Figure 10;
- Only inject the target species.

*Figure 10. Plan view of the stem injection sites for 20 cm, 15 cm and 10 cm diameter trees.*




## 4. Commercial Thinning

CT is generally used in stands between 25 and 45 years old. Both cable and ground-based harvesting systems are used and considerable volumes of wood are recovered, almost entirely pulpwood.

### 4.1 Selection of areas

Areas potentially suitable for commercial thinning are determined from PI typing, aerial photographs and local knowledge. Stand characteristics should match the criteria given below. Field assessment using the MARVL assessment and inventory system is then used to determine if the coupe is actually suitable for thinning.

**Screening Criteria for Potential CT Areas**

| | |
|---|---|
| **Age:** | • 25 to 40 years old |
| **PI types:** | • ER2 and ER3, density of ‘a’, ‘b’ or ‘c’ |
| **Density:** | • at least 500 stems per hectare larger than 17 cm dbhob |
| **Site Index:** | • 30 or greater |
| **Volume:** | • Average tree volume at least 0.2 $m^3$ |
| | • Removable eucalypt volume > 70 tonnes/ ha |
| **Min. area:** | • 10 ha, but two adjacent 5 ha patches are acceptable |

### 4.2 Prescriptions

Commercial thinning prescriptions aim to retain one-half the basal area (BA) and to never reduce the BA below 16 $m^2$/ ha. Therefore, the pre-thinning stand BA must always be at least 32 $m^2$/ ha for thinning to be viable. The number of crop trees retained will generally be between 150-250 stems per hectare (sph), depending on the standing volume prior to thinning and the sizes of potential crop trees. Thinning prescriptions are generated from assessment data collected and processed using the MARVL system.

### 4.3 Operational considerations

All dangerous overstorey trees must be felled prior to the thinning operation, especially standing dead trees (Figure 11). If other values apply to these trees (ie conservation, habitat or species diversity) the area influenced by them should be excluded from any thinning operation.

A uniform canopy must be maintained to reduce the chance of windthrow and epicormic growth. On wind-exposed sites, areas considered for thinning should be scheduled for the drier part of the year.

Given the logging slash present in recently-thinned stands, and the investment which has been made in the crop trees, fire risk must be managed in surrounding coupes. Wherever possible, thinning operations should be located at least 2 km from current clearfell coupes. Fuel reduction burns are not feasible in thinned regrowth.

*Figure 11. Standing dead trees are dangerous to operators working in thinning operations.*

## 5. Harvesting Systems for Commercial Thinning

The harvesting method chosen must satisfy silvicultural requirements as well as providing a commercial return for the operator. The decision to use ground-based or cable harvesting is based mainly on site characteristics; ground-based operations are more suited to relatively flat sites, whereas cable operations suit steep sites.

### 5.1 Felling technique

Manual felling is done using chainsaws. Mechanical felling is done using a machine, which allows the operator to fall trees from within the safety of an enclosed cab. Advantages over chainsaw felling include improvements in productivity, feller safety, tree control, and damage minimisation on the retained crop trees. Mechanical felling machines can be used in both ground-based and cable operations, on slopes up to 21$^{o}$ in the absence of large downers, dense understorey or rock (Figure 12).

*Figure 12. Obstacles such as downers can hinder the movement of machinery in ground based operations.*

For both manual or mechanical operations, directional felling is important for the prevention of damage to crop trees and the avoidance of costly and dangerous ‘hang ups’. Where possible trees should be felled to maximise the ease of extraction and reduce the possibility of damage to crop trees by machinery.

## 5.2 Ground-based harvesting

Ground-based thinning operations are appropriate on terrain with less than 14° slope and suitable soil conditions (refer to Forest Practices Code). If site conditions are otherwise, high levels of ground disturbance and retainer damage may occur. There should be less than 150 $m^3$/ ha of ground debris before thinning, as a high incidence of downers prior to thinning can impede movement of machinery and lead to clumps and gaps by the end of the operation. Ground based-operations where mechanical extraction is used can be a problem where trees are less than one metre apart, as the process of pulling or pushing a tree can damage the root system of a neighbouring retained tree. Ideally, roads and landings should be located on the lower side of the coupe to allow downhill skidding and forwarding. This will minimise any difficulties presented by working across the slope.

*Matting of snig tracks*

Ground-based harvesting is limited to dry weather only, unless "matting" of snig tracks is practiced. Matting consists of laying tree head waste and understorey material across tracks, to eliminate rutting by machinery in wet weather. At the completion of the operation, the matting can remain, but drainage lines must be restored as per the Forest Practices Code.

*Guidelines for ground-based operations*

Damage can be minimised by planning operations carefully, especially the location of drag or snig tracks, roads and processing sites. The precautions shown in Figure 13 are strongly recommended.

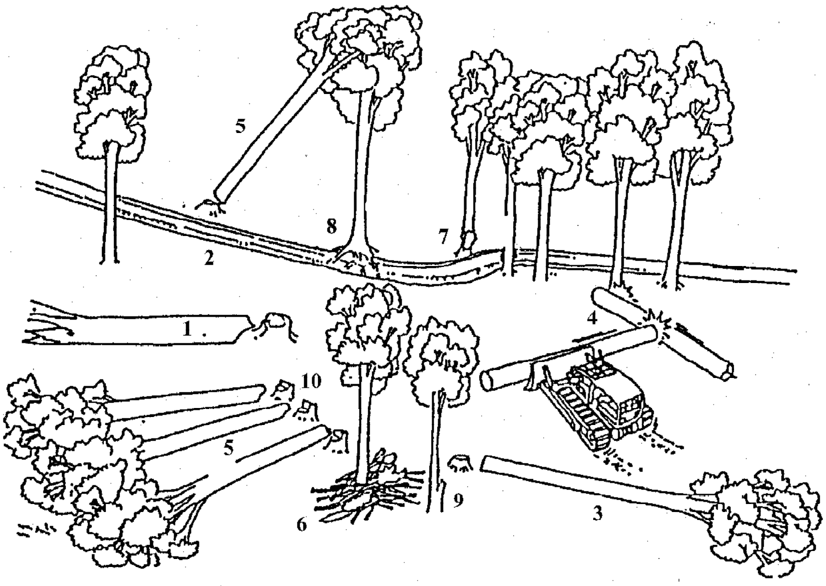



*Figure 13. The damage minimisation precautions for a ground-based thinning operation.*

1. Fell all dead trees first, unless specified as Habitat Clumps.
2. Keep drag tracks straight.
3. Cut truck length timber at stump, and cut short length butt logs if trees are longer than truck length.
4. When pushing downers watch their ends to avoid indirect damage to crop trees.
5. Use directional falling techniques to reduce falling damage to crop trees and make recovery of felled trees easier.
6. Avoid piling slash against crop trees.
7. Use 'corner' trees along snig track, outrow edges and landing bays and remove them at the end of the operation.
8. Avoid snigging or driving over the roots of crop trees.
9. Do not cut limbs or second stems from crop trees.
10. Stump height should not exceed half the diameter at stump height or 15 cm, whichever is greater.

### 5.3 Cable harvesting

Cable logging can be employed in a much wider range of weather and terrain and causes minimal damage to the stand and the soil profile.

*Requirements*

- Slope 14° - 21°
- Absence of large dead stags
- Presence of suitable tailhold trees
- Terrain which allows adequate deflection
- Roads structurally sound enough to be used for continuous landings

*Layout of cable thinning operations*

Cable thinning operations generally consist of a series of "outrows" (Figure 17) which run up and down the slope approximately every 30 m, through which the cable will run. Where possible, a road running along the contour at the top of the block, at right angles to the outrows, is used as a continuous landing. This facilitates uphill yarding, which in turn improves operator control and lessens damage to crop trees. To begin manual directional felling, the outrow position should be located and the tailhold tree identified. Felling is done within the outrows first, commencing from the tailhold tree, with trees being felled with the butt towards the pull direction and parallel to the outrow direction. These trees should be yarded first, creating the outrow. Trees in the bays between outrows are felled at 20° next to the outrow, increasing to 45°. This ensures the best recovery angle for easiest extraction with minimal crop tree damage.

*Guidelines for cable thinning operations*

Damage can be minimised by planning operations carefully, especially the location of drag or snig tracks, roads and processing sites. The precautions shown in Figure 14 are strongly recommended.

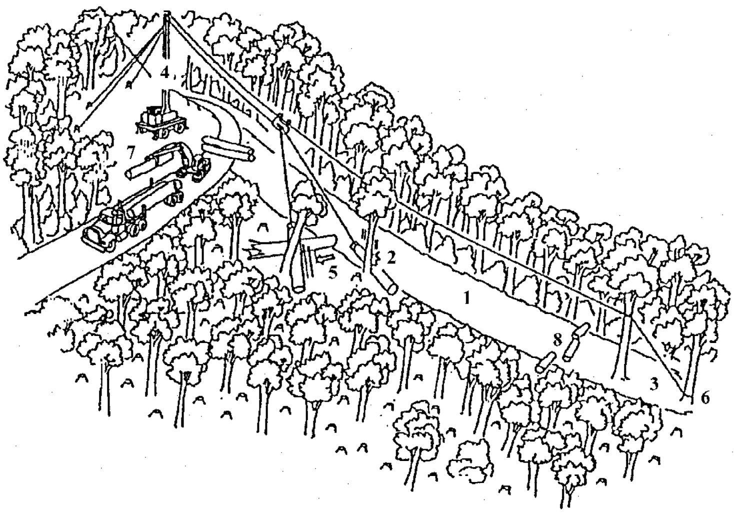



*Figure 14. The damage minimisation precautions for a cable thinning operation.*

1. In outrows greater than 200 m long, unsupported skylines can flex causing damage to retained trees during side pulling.
2. Outrows need to be placed accurately otherwise suspended logs can pass too closely to one side of the row causing damage to retained trees.
3. Outrows should be located at right angles to the contours. Cross slope yarding is undesirable as control of suspended logs is difficult.
4. Yarding speeds need to be matched to ground conditions and slowed when difficulties such as downers and scrub occur.
5. Care must be taken that suspended logs do not run along downers which lie across and at oblique angles to outrows. Cut out the section of the downer crossing the outrow.
6. The use of broad band strapping on tail hold trees reduces damage. If wounding does occur then the tree should be removed.
7. The use of natural gaps for processing areas and corner trees for stacking wood will reduce damage. Heel boom loaders allow roads to be used as continuous landings.

## 5.4 A Field Operators Guide to Commercial Thinning (CT)

***General aim***

To identify trees at the time of commercial thinning which have stem and crown characteristics likely to produce specification sawlogs at final harvest (Figure 15). Trees that do not meet these characteristics are harvested.

All retained trees must:

- have a good piece of tree stem, which will become a sawlog.
- be able to grow this sawlog quickly.

The following features are to be used when deciding if a tree should be retained or removed. If it comes down to a choice between two trees, always choose the tree with the greatest amount of potential sawlog. All trees should be large and healthy with their canopy above or at the same height as the rest of the stand. Surrounding trees must not overshadow retained trees. Suppressed trees should not be retained.

**A. Tree form**

Have a dense, vigorous, healthy crown, preferably with well developed branching. The crown should be at least a quarter of the total tree height.

Should not have kinks with a displacement of more than a quarter of stem diameter unless there is a 2.5 m potential sawlog above or below the kink.

Have no sign of epicormics (stem shoots). If epicormic growth is present, seek specialist advice.

Have a sweep of no more than one-third of stem diameter over 2.5 m unless there is a 2.5 m potential sawlog above or below the sweep.

Should have a minimum 2.5 m potential sawlog with three quadrants free of any branches and pegs more than 4 cm diameter or bumps that protrude more than 10 cm from the stem.

Have no signs of damage or decay such as bumps, open or rubbing wounds.

Crop trees should be single stemmed to at least 2.5 metres above stump height. If not, both stems should be retained. **Never remove only one stem.**

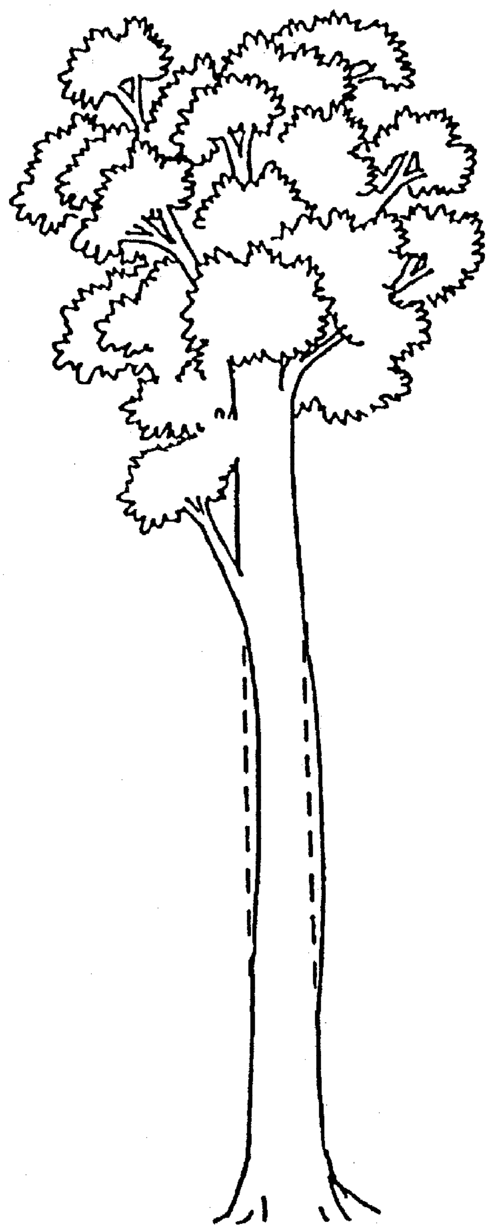


*Figure 15. A good example of a tree suitable for retention.*

## B. Spacing

Different final spacings are used depending on final stocking selected by the management planners: The spacing is intended to retain about half of the basal area on about one third of the stems.

For example:

| | |
|---|---|
| 250 stems per hectare | 6.5 metres between trees |
| 175 stems per hectare | 7.5 metres between trees |
| 130 stems per hectare | 8.5 metres between trees |

It is very important that an even canopy remains after the thinning.
To do this you must follow the guidelines in Figure 16:

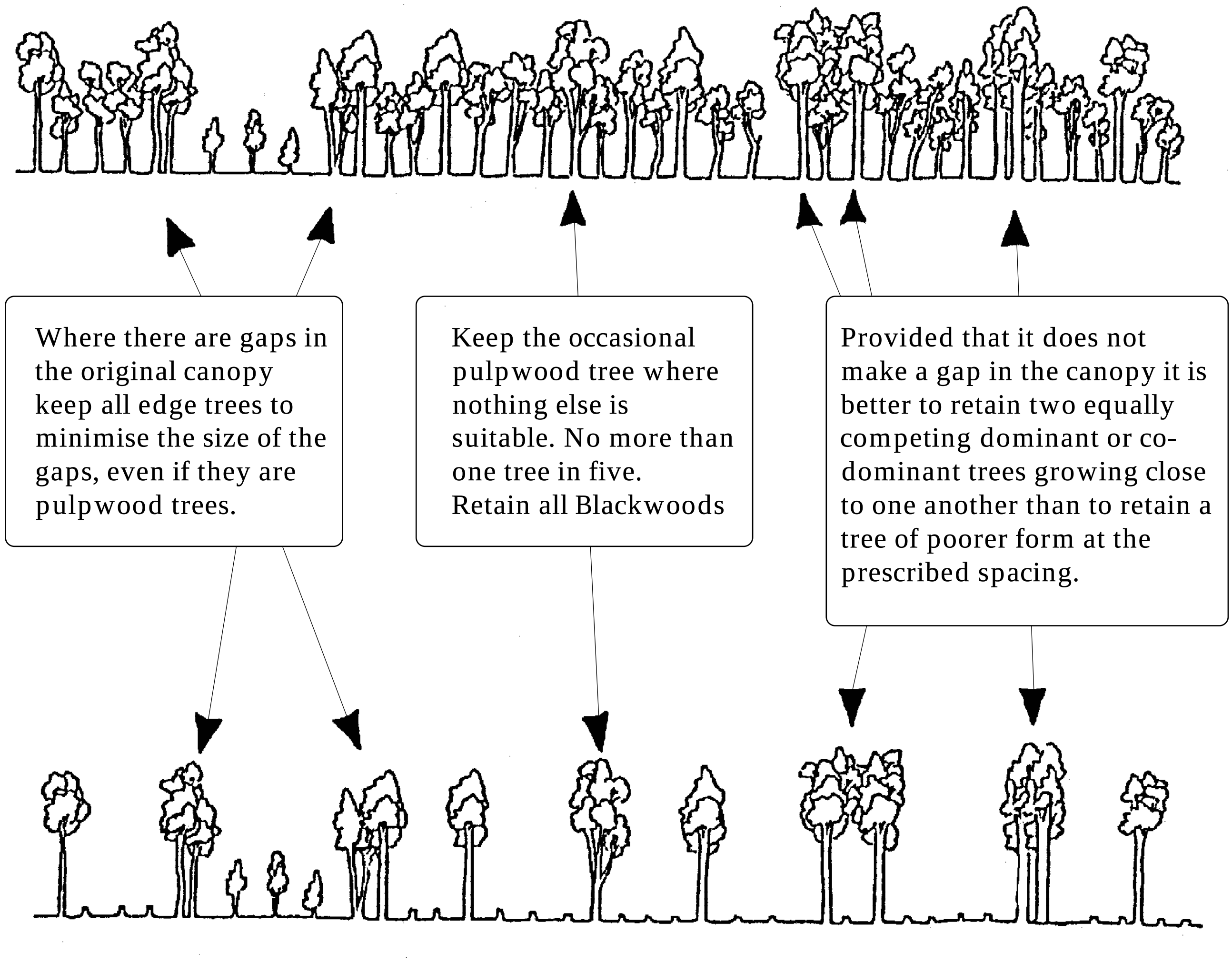



*Figure 16. Some spacing guidelines to achieve an even retained canopy.*

## 6. Damage in Commercial Thinning Operations

Damage to crop trees during a thinning operation will degrade the quality of the stand at final harvest. Damage may be caused by impacts of any type on the main stem or within the crown. It is recognised that some damage is likely in all operations, but the objective is to minimise damage. **The target for damage to crop trees is Nil, but levels up to 10% are tolerated.**

Stand damage is monitored throughout the operation to identify and rectify its causes. Damage is measured from a sample of crop trees. The most important information is the position and cause of the injury so preventive measures can be implemented. For example, in cable thinning, poor directional felling may position the tree so that yarding results in stem damage to a crop tree, but the wound is attributed to yarding rather than felling. Thus, observation and interpretation are necessary to correctly identify the cause of damage.

*Figure 17. An outrow in a cable thinning operation.*

## Part B: Silvicultural Principles Of Thinning

# Part B: Silvicultural Principles Of Thinning

## 1. Introduction

Without thinning, all trees in a growing stand compete for nutrients, water and light. As the stand ages, those least able to compete will begin to die, a process known as self-thinning. Silvicultural thinning is a more controlled process and allows selection on the basis of both size and form, rather than simply retaining the most vigorous trees. Silvicultural thinning will generally occur earlier and remove more trees at once than natural self-thinning. Thinning also provides for the utilisation of removed stems through their sale as pulplogs or the occasional small sawlog. The retained trees also benefit in terms of opportunities for accelerated growth.

### 1.1 Suitable stands

Stands suitable for thinning are typically heavily stocked, even-aged, and display vigorous growth. Ideally, they have a relatively even canopy layer, and have achieved canopy closure (Figure 18). Patchy, less vigorous sites are less suited to thinning, as their potential to produce large volumes of wood quickly are inherently limited. Site selection should take into account the presence of adequate numbers of trees of potential sawlog form prior to thinning, and the presence of healthy, vigorous crowns on potential crop trees.

*Figure 18. An overstocked young regrowth stand suitable for pre-commercial thinning.*

### 1.2 How thinning works

Thinning causes a forest stand to concentrate all the wood it is capable of producing onto fewer stems. Thinning in Tasmania is done “from below”. This means removing small, suppressed, and poorly-formed trees first, followed by enough subdominants and codominants to meet the correct spacing and retention rates.

The percentage of wood removed in a thinning operation is referred to as the **thinning intensity**. Generally speaking, the greater the thinning intensity, the more wood that is removed, and the greater the growth response on the retained trees.

Wood production is often measured in basal area (BA; $m^2$/ ha). Basal area is the sum of the cross-sectional areas of all the trees in the stand measured at breast height (1.3 m). Individual tree basal area is derived from diameter measurements. Sampling plots are used to build up the information needed to make an estimate of basal area for the stand.

*Basal area increment*
Increases in basal area are a better indicator of growth response to thinning than increases in diameter, because they reflect the cross-sectional area of wood produced. The **basal area increment** for an individual tree or an entire stand is the difference in basal area from one measurement to the next. A given increase in diameter on a large tree will represent more new wood than the same increase in diameter on a small tree; on a tree 20 cm in diameter, a 1 cm increase represents 32 $cm^2$ of new wood, whereas on a tree 40 cm in diameter the same 1 cm increase represents 64 $cm^2$ of new wood. Using basal area enables us to compare rates of growth on trees of different initial sizes, and in stands of different initial densities.

Webb and Incoll (1969) found that up to 50% of a stand's basal area can be removed without decreasing the overall basal area increment in subsequent years. Removing more wood than this will enhance individual crop tree growth, but at the expense of overall stand growth. This has been confirmed for Tasmania by Goodwin (1990), who estimated that the optimal basal area reduction for a 25-year-old vigorous stand was 56%. Over time, the rate of wood production in unthinned areas declines relative to that of thinned areas, allowing the thinned areas to eventually achieve standing volumes similar to those produced without thinning.

This concept is illustrated in Figure 19. A 24-year-old stand of *E. regnans* in the Plenty Valley was thinned to three intensities, equivalent to basal area reductions of 34%, 49%, and 67%, and unthinned control areas reserved. The change in mean stand BA for each treatment over time is shown throughout the thirty-one years following thinning. Initially, the rate of wood production in all treatments was similar. As the BA of the thinned plots approached that of the unthinned stand, all increment rates declined, although they were still greater in the thinned areas than in the control. After 31 years, the two relatively lightly thinned stands (34% and 49% BA removal) have both returned to similar BA levels as the unthinned plots. Mean stand BA for the heavily thinned plots (67% BA reduction) has not approached that of the control plots.

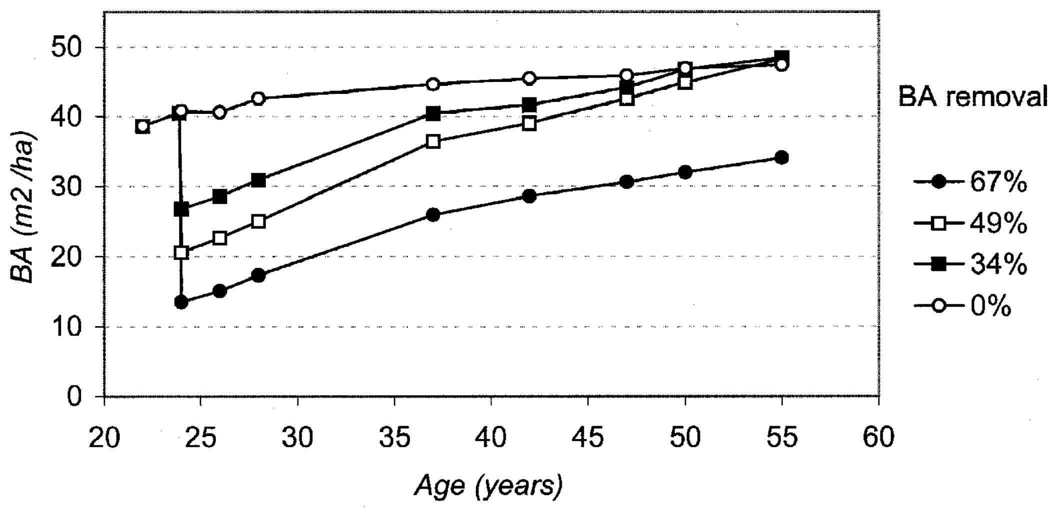



*Figure 19. Change in the mean nett BA of thinned and unthinned plots of* E. regnans *treated at age 24 years. Data have been weighted to account for slight pre-thinning differences in stand BA.*

## 2. Growth Response to Thinning

Regrowth eucalypts display a positive growth response to thinning. Trees with the most space around them are able to grow most quickly. The magnitude of this response is determined by the thinning intensity, stand age and quality, and the dominance class and crown development of retained trees. The relationship between thinning intensity and diameter increment is approximately linear (Figure 20).

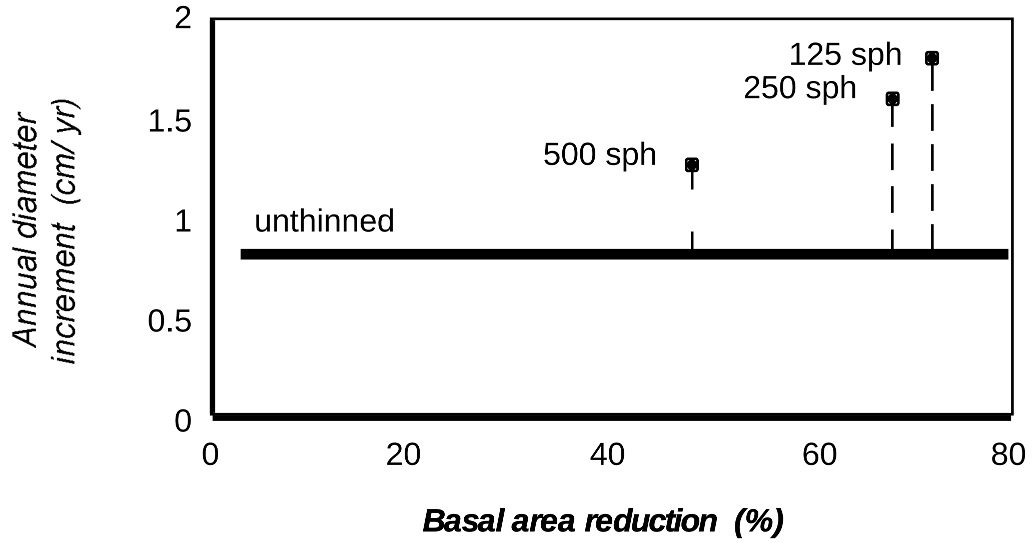



*Figure 20. Annual diameter increment in the 8 years following thinning for the largest 100 sph in a stand of regrowth* E. obliqua *thinned at age 24 years to three densities at SO022E. The dashed vertical lines represent the diameter increment advantage gained by thinning.*

**2.1 Pre-commercial thinning (PCT)**

The purpose of PCT is to prepare stands for a commercial thinning. To date, there has been no commercial-aged thinning done in Tasmania in stands which have been pre-commercially thinned. Results from mainland Australia indicate that PCT is capable of increasing the volume of both retained and harvested trees at the time of a subsequent commercial thinning. PCT can also increase access within the stand at the time of commercial thinning.

For example, Connell and Raison (1996) reported on a stand of *E. sieberi* and *E. baxteri* regeneration which was thinned at age 6 to approximately 2000 sph from an estimated 40,000 sph. After 22 years, thinning had not dramatically affected the total BA on the plot, but it had affected the species composition, individual tree size, and stand density. During an experimental first commercial thinning in this stand, operational costs were reduced by about 20%, pulpwood yields were increased by 30% and the size of trees retained after commercial thinning was increased by 60%.

The Young Regrowth Thinning Series (YRTS) was established by the Forestry Commission in the early 1980s, and consists of five thinning experiments in 15 to 25-year-old eucalypt regrowth around Tasmania. The YRTS trials are comparable in age and stand structure to three experimental trials in PCT established by Forestry Tasmania in 1998, although they were thinned to waste using chainsaws, as opposed to stem injection. In the initial three years following stem injection, growth response in the stem-injected trials has been comparable to that in the YRTS trials. Results from the YRTS trials provide an indication of the potential growth responses in current PCT experiments and operations (LaSala 2000).

In both sets of trials, stem retention rates of 500 and 250 sph equated to basal area reductions of approximately 50% and 75%, respectively. By 15 years after thinning, stand productivity in the YRTS trials had been maintained in the plots where 50% of the BA had been removed, and these stands were ready for a commercial thinning. The diameter increment of the largest 200 stems, or nominal “crop trees” had been enhanced by approximately 5 cm since thinning, or an extra 0.3 cm per year (Figure 21). There was no consistent advantage from thinning observed on the next largest 300 stems, ie the pulpwood crop which would be removed at the commercial thinning. In the plots where 75% of the BA had been removed, the diameter increment of the largest 200 stems had been enhanced by approximately 7.5 cm since thinning, or an extra 0.5 cm per year.

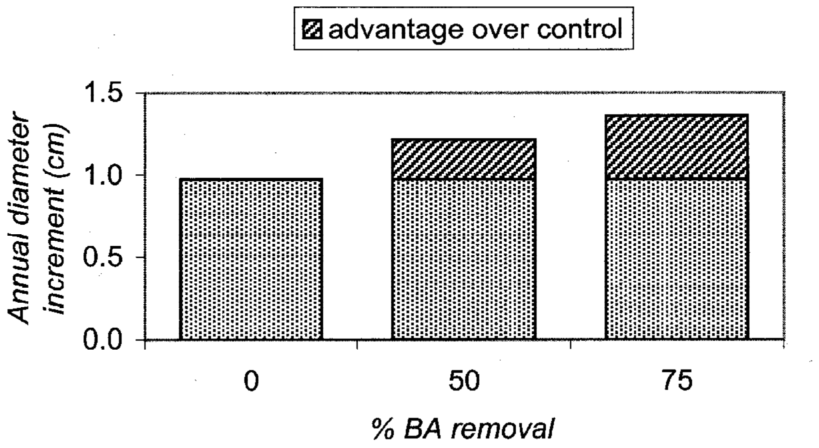



*Figure 21. Average annual diameter increment (cm) recorded on the largest 200 sph in three of the Young Regrowth Thinning Series (YRTS) trials in the 15 years following treatment.*

## 2.2 Commercial thinning (CT)

Four research trials were established in 1990 and 1991 by the Forestry Commission in regrowth generated in the late 1960s (Brown 1996). Two were located in *E. regnans* stands in the upper Florentine Valley (RP004F and RP003B), one in a lowland mixed stand of *E. obliqua* and *E. regnans* in the Southern Forests (SO022E), and one in relatively high-elevation *E. delegatensis* in the Southern Forests (AR008C). These trials investigated numerous aspects of response to thinning, and form the basis for many of the observations presented below.

Three of these research trials (RP004F, SO022E, and AR008C) were thinned at about age 24 years and included a 250 sph treatment. Measurements made in these stands in the eight years since thinning have been compared with results from a model which is used by Forestry Tasmania to predict stand growth (Goodwin 2000). Ten high-quality coupes from around Tasmania were "grown on" using this model to predict their response following a thinning to 250 sph at age 24 years.

Figure 22 shows how the three research trials compared with the group of ten modelled coupes prior to thinning, just after thinning at age 24, and eight years later. The three stands where measurements were taken appear to define the upper and lower bounds of the range of growth response in the ten coupes which were modelled. This was also true when the unthinned plots in the three measured stands were compared with results from the ten coupes "grown on" without thinning.

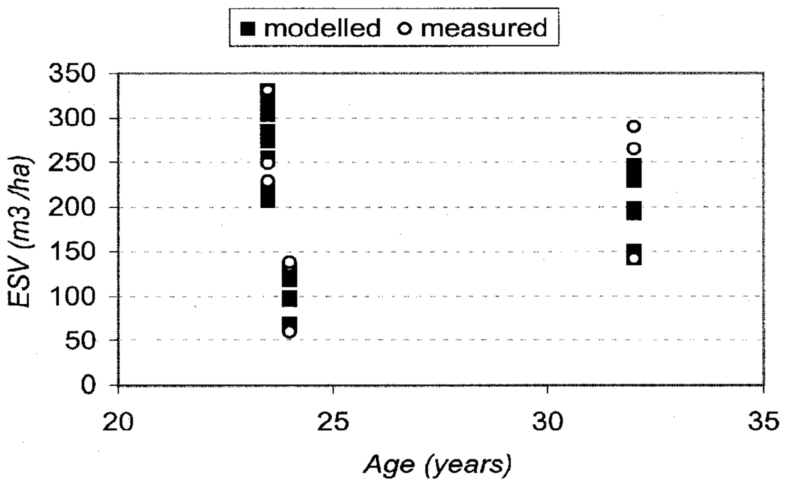



*Figure 22. Entire Stem Volume (ESV) for modelled and measured coupes before and after thinning at age 24 years, and at age 32 years. These volumes have not been discounted for stand patchiness, roading, or decay in any way. The ESV is approximately 10% greater than merchantable volume.*

Since the measured and modelled stands appeared to be growing in roughly the same manner, the model was used to predict volume at clearfell ages of 65, 80 and 90 years for both thinned and unthinned stands (Figure 23). These results indicate that thinned stands contained as much wood by the time they are approximately 80 years old as unthinned stands. In addition, the thinned stands produced a pulpwood crop at their earlier harvest.

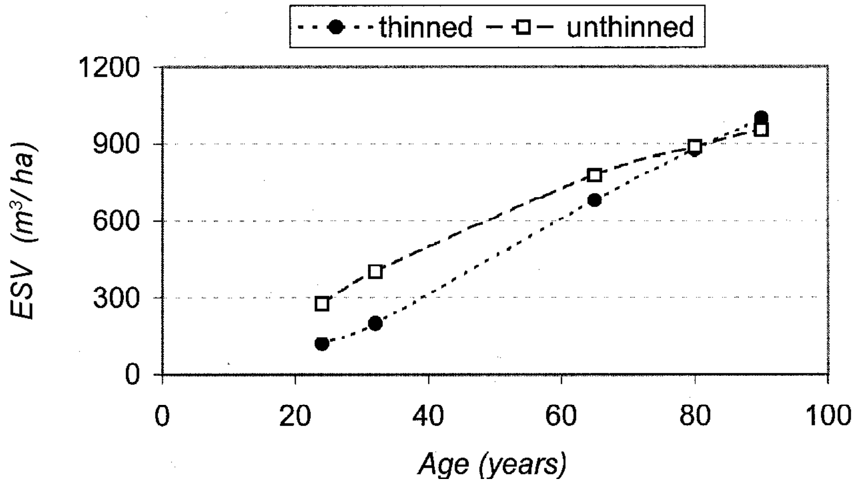



*Figure 23. Mean modelled Entire Stem Volume (ESV; $m^3$/ ha) for ten high-quality coupes from age 24 years until age 90 years, using both "thinned" and "unthinned" scenarios.*

### 2.3 Tree height

Thinning does not generally affect tree height (Smith *et al* 1997), so trees in thinned stands will generally be larger in diameter for a given height. For example, 8 years after thinning at SO022E, a tree 28 m in height in an unthinned plot was 35.8 cm in diameter, whereas a tree of the same height in one of the most heavily-thinned plots was 39.7 cm in diameter. This equates to a difference in merchantable volume of 0.2 $m^3$. Planning exercises which estimate the volumes of thinned coupes at their final clearfell must take this change in the height:diameter ratio into account.

### 2.4 Increases in sawlog yield

An increase in the sawlog:pulpwood ratio is often reported as a major benefit of thinning. Two mechanisms are at work: firstly, thinning changes the stand by preferentially retaining trees of potential sawlog form, and secondly, thinning increases growth on these retained stems, so they are able to grow more quickly to merchantable sawlog size. Both these mechanisms result in a greater volume of sawlog being produced, and therefore an increase in the sawlog:pulpwood ratio.

Results from the model described above indicated that a single commercial thinning would result in sawlog yields at a clearfell at age 65 years of approximately 20% more than without thinning, and that the inclusion of a pre-commercial thinning as well would increase this figure by an additional 5%. A typical unthinned stand would need to be grown on to a clearfell age of 80 years to produce the same sawlog yield as a typical thinned stand at age 65 years.

## 3. Factors Affecting Growth Response

### 3.1 Dominance class

Even though dominant trees by definition had the most access to light before the stand was thinned, they still seem to benefit most from thinning. This is generally true at all intensities of thinning. The magnitude of response is proportional to the dominance class of the tree (Figure 24).

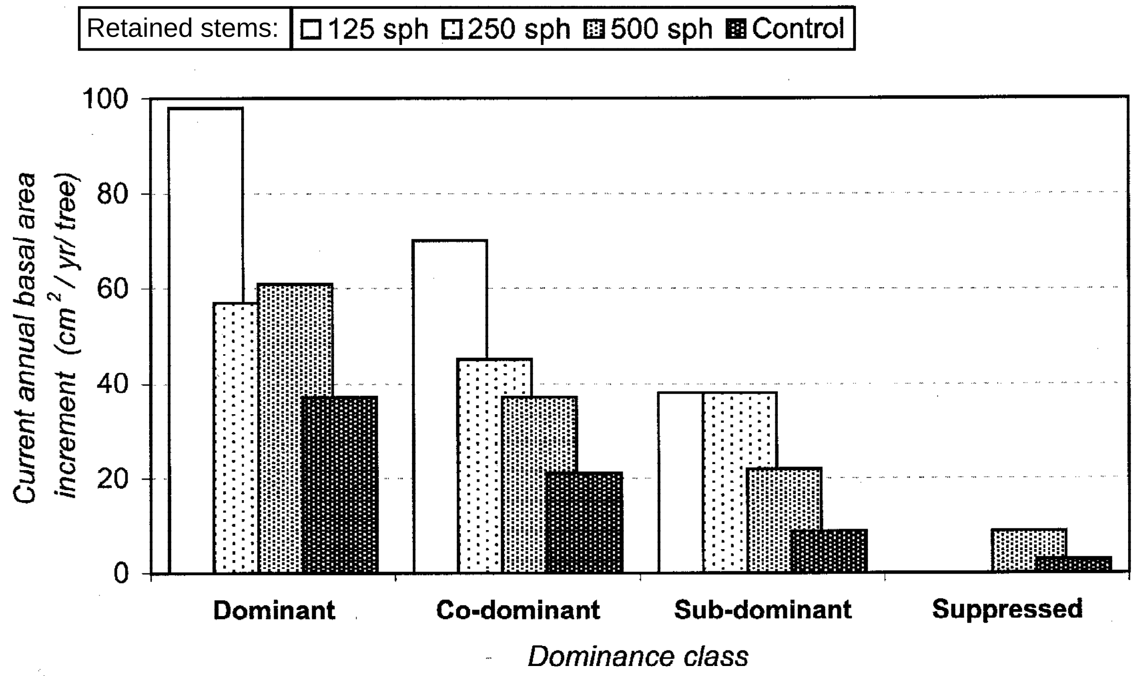



*Figure 24. The relationship between dominance class and current annual basal area increment. Data are for a 27-year-old stand of* E. delegatensis *(AR008) thinned at age 24 years to three final stockings, plus an unthinned control.*

### 3.2 Crown development

Crown development is also strongly related to growth response. The ability of a stand to re-colonise a site following thinning depends upon the capacity of the crowns to expand and fill the gaps left in the canopy. Trees with well-developed crowns can grow quickly to compensate for the wood removed in thinning. Trees with poorly developed crowns have less capacity to capture sunlight, produce extra carbohydrate, and convert it to extra wood. Growth responses at all levels of thinning intensity have been positively correlated with crown development (Figure 25).

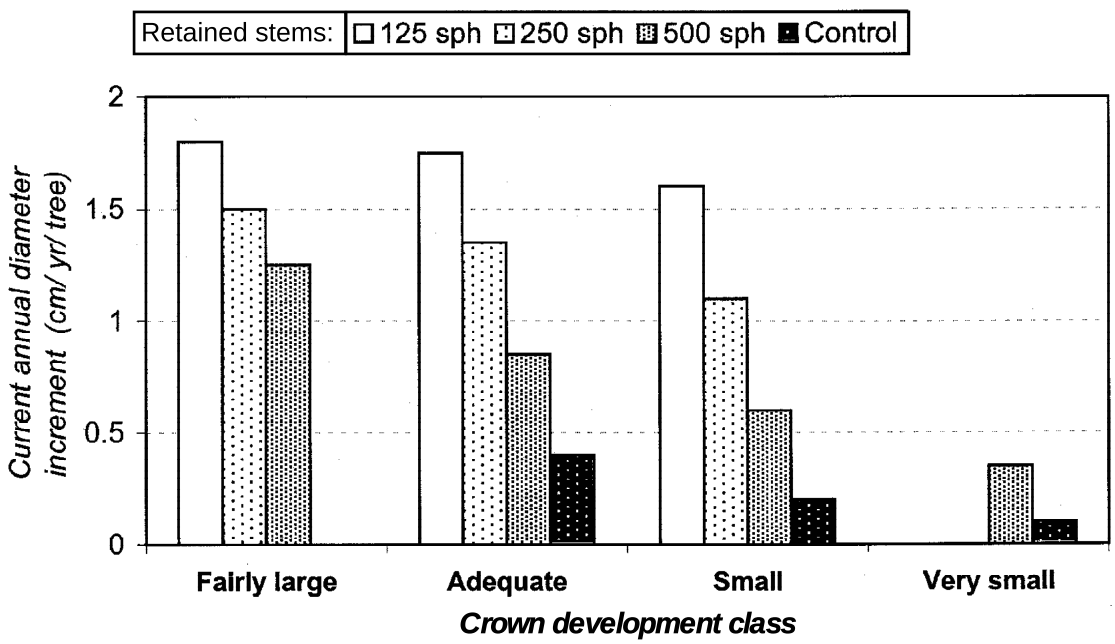



*Figure 25. The relationship between development class and annual diameter increment. Data are for a 27-year-old stand of* Eucalyptus delegatensis *(AR008) thinned at age 24 years to three final stockings, plus an unthinned control.*

### 3.3 Stand age

If two stands are different ages but have similar tree densities and stand basal areas, the older stand must be growing less quickly. This older stand will respond less dramatically if it receives the same thinning prescription as its younger, more vigorous counterpart. The younger stand is more suitable for thinning.

Trees in young stands are growing more quickly than those in old stands. Thinning should be done during this period of rapid growth to be most effective. If thinning is done later to the same level of retained stems, the gaps in the canopy will be smaller, and the crowns of the crop trees will not take long to expand and fill them. Therefore, the growth response will be relatively short-lived.

If thinned at all, older stands should have fewer numbers of crop trees retained, to give their established crowns adequate room to expand and re-occupy the site. This response is expected to be slower to begin in relatively older stands, but will probably be of longer duration (Goodwin 1990).

### 3.4 Duration of the response

The "thinning advantage" is the additional diameter increment that can be attributed to thinning, above and beyond the growth which would have occurred anyway. The thinning advantage at the SO022E experimental site throughout the eight years following thinning is shown in Figure 26, expressed as the additional annual diameter increment between successive measurements which has been conferred by thinning. Two years after thinning, these increment advantages over the unthinned plots were greatest for the 250 and 125 sph treatments, and gradually declined over the following six years. The advantage in the 500 sph plots was smaller in all years, and dropped slightly between the second and third year.

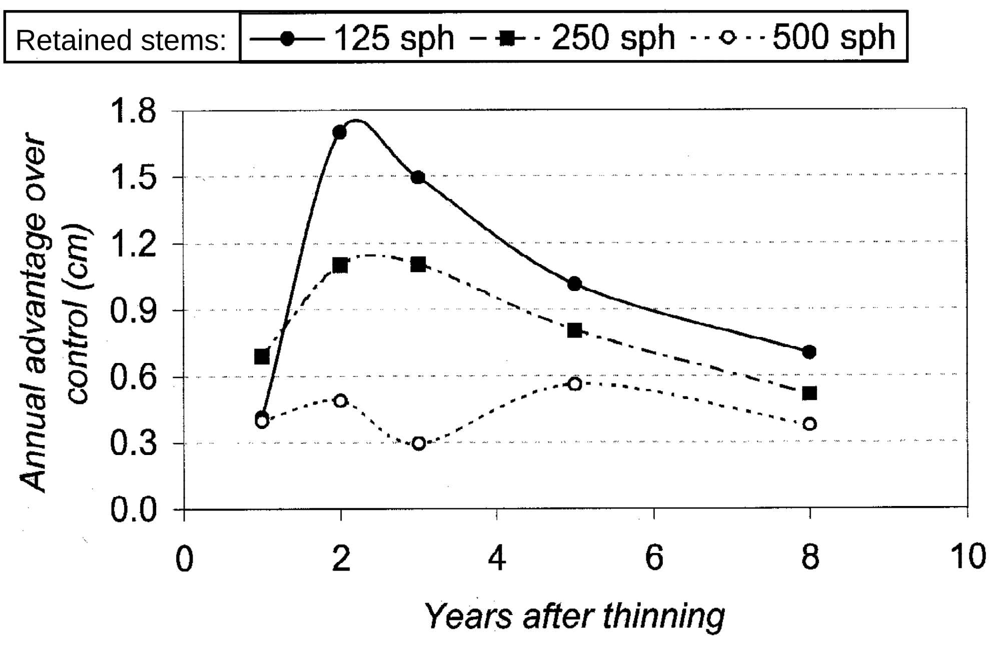



*Figure 26. Mean annual diameter increment advantage for the largest 100 sph in each of the eight years following thinning in a stand of regrowth* E. obliqua *thinned at age 24 years to three densities.*

Brown (1997) reported on a 50-year-old stand of *E. obliqua* in the Southern Forests which had been thinned to various intensities and monitored for 25 years. The growth response to thinning was still apparent throughout the period of measurement, although there had been a steady lessening of thinning advantage over this time.

## 4. Other Effects of Thinning

### 4.1 Epicormics

Epicormics are leafy branches which appear on the main stem of eucalypts in response to stresses such as defoliation or drought (Jacobs 1955). Their purpose is to restore the crown and give the tree more leaf area. Observations of thinned stands indicate an increase in epicormic production after thinning, which has been attributed to the increase in available light. Epicormics arise from dormant buds which have been contained beneath the bark, which are stimulated by the stress event to break through the bark and form a shoot. Persistent epicormics have the potential to devalue appearance-grade timbers such as veneer in the same way as persistent live branches.

Both before and after thinning, the more dominant a tree is in the stand structure, the less likely it is to have epicormics. Brown (1996) found that epicormic production was inversely related to crown volume, density, and vigour, all of which are closely related to tree dominance. In the Forestry Tasmania commercial thinning trials (Part B, Section 2.2), epicormics have been observed mostly in the unthinned control plots, and on subdominant and suppressed trees in all plots which are competing for resources. The practical implication is that when considering stands for thinning, crown size, vigour and health should be carefully considered. Stands with widespread epicormics prior to thinning should be examined to determine the reason for the epicormics and their likelihood of persisting.

### 4.2 Branch retention and clear bole length

Maximising the length of stem which is free of branches, or the “clear bole”, is extremely important for the production of sawn timber. Both live and dead branches cause knots.

When a stand is heavily stocked and has an even canopy, trees grow quickly and evenly in height. They also shed their lower branches, which die because they receive very little light. Scrub competition can also encourage the shedding of branches. Thinning tends to enable branches at the base of the crown to persist, by providing the crop trees with light on all sides, and encouraging the expansion of the crown. Webb (1966) noted no further rise in clear bole length after thinning in *E. regnans* stands older than 20 years.

Therefore, Goodwin (1990) and others have recommended that commercial thinning should not occur until a “satisfactory” length of clear bole has been achieved. Fortunately, stands suitable for thinning are dense and fast-growing by nature, and several sections of sawlog are generally free of branches by the time the stand is scheduled for thinning. For example, in the three Forestry Tasmania PCT trials (Part B, Section 2.1), the mean height of the lowest green branch of retained trees was 11 m by about age 16 years.

### 4.3 Effects on understorey

The felling of trees and movement of machinery during a commercial thinning operation will undoubtedly have an effect on the understorey through mechanical disturbance. The longevity of this effect is not completely known. Bauhus (1999) studied the effects on the understorey of thinning a 26-year-old stand of *E. sieberi* in East Gippsland, and concluded that the structure and composition of the understorey remained largely unchanged. They also noted that the understorey species occurring in these forests are well adapted to much more dramatic disturbances, such as clearfelling and burning. Appleby (1998) examined *E. regnans* coupes in Victoria for the invasion and persistence of exotic species after clearfelling. He concluded that although the establishment and growth of weeds were aided by clearfelling, weed lifespan was short, and their influence on the normal successional patterns of native species was negligible.

Peacock (1994) found that thinning damaged tall shrubs, covered the ground vegetation with slash and led to varying degrees of soil and litter disturbance regardless of the intensity or method employed. This was a short-term study, and was unable to determine if thinning fundamentally changed the pattern of understorey secondary succession. Peacock also commented that since ground-based thinning resulted in more soil disturbance than cable thinning, there was greater colonisation of the site by herbaceous pioneer species.

Changes in available light are another possible source of impact on understorey species, although Landsberg (1986) maintains that thinning from below will not dramatically increase light levels reaching the understorey, as these are established by the dominant trees. The removal of part of the canopy during PCT may also affect understorey growth and composition. Observations of thinned coupes point to an increase in cutting grass (*Gahnia grandis*) and bracken fern (*Pteridium esculentum*) cover following treatment. Rapid growth by these invasive understorey species may adversely affect the response of retained trees on thinned stands by competing for soil water (West *et al* 1995).

Floristic studies have been put in place by Forestry Tasmania to document the effects of PCT on understorey growth and composition over time.

## 5. Decay and Damage

The success of a thinning operation in accelerating sawlog production is strongly dependent upon minimising the amount of defect in the retained trees. Discolouration and decay is caused by fungi which can enter the tree through wounds which have occurred naturally or been inflicted during thinning operations. Decay is unacceptable in sawn timber and will result in the log being downgraded to pulpwood or unmerchantable timber.

### 5.1 Background decay

The majority of background decay (decay already present prior to thinning) arises during the process of branch shedding (Wardlaw 1996)(Figure 27). Although neither the abundance nor the size of dead branches, branch stubs and bumps are reliable indicators of internal decay, efforts can be made to reduce the likelihood of decay occurring in crop trees by avoiding retaining trees with these features.

Consistent application of clearly defined selection criteria based on form, dominance and spacing does cull many severely decayed trees during thinning. However on sites with high levels of decay many trees containing severe decay could still be retained after thinning. Pure stands of *E. obliqua* in lowland areas have significantly higher levels of background decay than stands with *E. regnans* or *E. delegatensis* (Wardlaw 2000). There is also some evidence that lower pre-thinning stand densities can lead to higher levels of background decay, due to a greater tendency to retain dead branches. Crop tree retention rates must take into account factors such as stand density and species so that adequate numbers of trees are free of decay at final harvest.

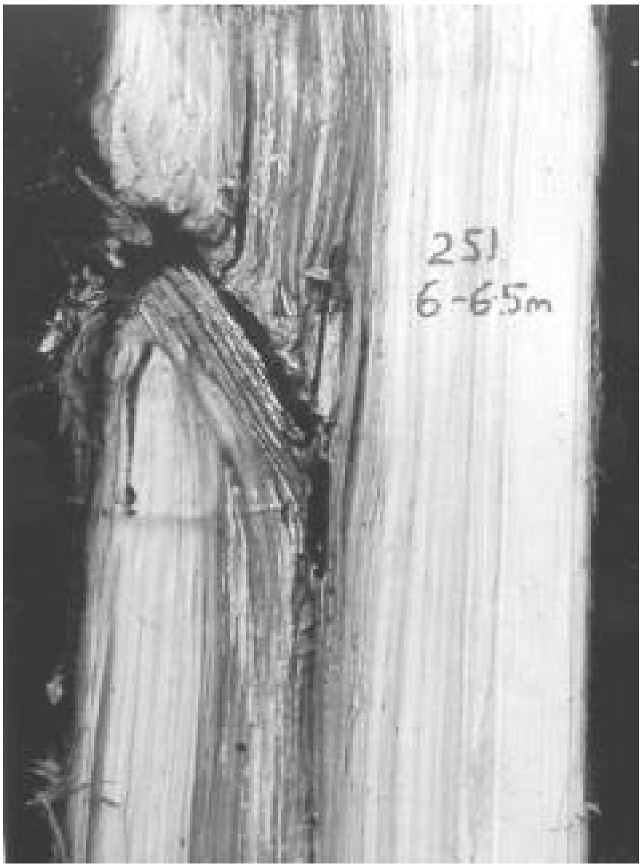


*Figure 27. Decay arising from naturally shed branches.*

### 5.2 Damage arising from thinning operations

Wounds inflicted on retained trees during thinning operations (Figure 28) will almost invariably lead to the establishment of discolouration and decay if the cambium is exposed (open wound)(Figure 29) or the bark-cambium bond is broken (closed wound). Wound size appears to have little effect on the amount of discolouration and decay in the long term (White and Kile 1991). A disturbing finding arising from examining older stem wounds (up to 25 years after wounding) is the high incidence of wounds in which barrier zones (as kino veins) are breached by wood decay fungi, allowing the outward spread of decay into wood formed after wounding. This corresponds with a rapid increase in the rate of spread of the decay (White and Kile 1991). The failure of the barrier zone could result in substantial losses of sawlog volume in damaged trees if they are retained for a long time following thinning.

Wounding can occur at all stages of the thinning operation and the position of wounds on the retained trees can give useful clues for identifying the particular stage(s) of the operation causing damage. By promptly monitoring thinning damage throughout the operation it is possible to identify and address those problems in a timely manner to reduce future damage.

*Figure 28. Wounding resulting from thinning damage.*

## 6. Planning Considerations

Thinning requires the consideration of certain unique planning issues.

### 6.1 Fire risk

One of the major planning constraints associated with thinning is the higher level of fuel present after the operation. It is not considered feasible in Tasmania to carry out fuel reduction burns in thinned coupes because of the high fuel loads and the sensitivity of the retained trees to fire. The location of thinned coupes amongst conventionally logged coupes is problematic, as it is not recommended that any regeneration burn take place within two kilometres of areas with high levels of flash fuel within two years of harvest (Cheney 1988).

Tree crowns (heads), bark, and other harvest residue make up the fuel load. The climate on the floor of the forest is altered by thinning, with higher wind speeds and air temperatures, lower humidity, and lower moisture content in the fuel itself. Understorey vegetation characteristics change because of these changes to the microclimate, especially increased light. Bracken ferns and cutting grass may grow vigorously, each having a far higher flammability than the replaced woody species (Cheney and Gould 1991).

*Figure 29. Discolouration and decay resulting from an open wound.*

One of the major advantages of stem injection as a means of pre-commercial thinning is that the foliage is released to the ground gradually and slash levels do not build up rapidly. Decomposition prevents an excessive build-up of fine combustible material and the larger stem portions are held vertically until substantially broken down.

A Western Australian study (O'Connell 1997) found that half the volume of leaves in thinning slash had decomposed within eighteen months, although woody components of the slash were much slower to break down. The rate of breakdown of this slash in Tasmania and the rate of its loss of flammability are currently being investigated.

### 6.2 Intensive native forestry

Thinning should be considered as part of an integrated, long-term management strategy (Figure 30). A large proportion of areas assessed as being otherwise suitable for thinning in Tasmania must be discounted because of site conditions, principally access for machinery. The presence of stags, downers, open-grown trees on old snig tracks, or patchy stand density will all cause areas to be classified as unsuitable for thinning. These conditions are often a result of previous harvesting and silvicultural practices.

Areas which are about to be harvested which have appropriate terrain and forest types for thinning in future should be identified prior to clearfelling. Harvesting operations can then aim to produce a site suitable for thinning operations in the next rotation, increasing the cost-effectiveness of the next operation. When the coupe is regenerated, sowing rates should be high enough to produce stand densities which encourage trees of good form. The road system used at harvest should be designed to enable later expansion, in particular for use as continuous landings for cable operations if appropriate.

*Figure 30. A suitable stand for pre-commercial thinning.*

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## Appendix 1. Glossary

| | |
|---|---|
| Basal area: | The cross-sectional area of a tree stem taken at 1.3 m above ground. Stand basal area is expressed in square meters per hectare ($m^2$/ ha ). |
| Basal area increment: | The difference in basal area between one measurement and the next. |
| Bole height: | Height above ground where the lowest branch carrying green foliage meets the stem. |
| Cambium: | Tissue in a tree stem situated between the bark and the sapwood, and from which new bark and sapwood are formed. |
| Clear bole: | Tree stem above stump height and lower than bole height. |
| Crop tree: | Tree that is selected for retention during a thinning operation. |
| dbhob: | Diameter at breast height over bark. Measured at 1.3 m above mineral soil on the high side of the tree. |
| Downer: | A dead tree trunk lying on the forest floor. |
| Epicormics: | Small, leafy branches which appear on the main stem of eucalypts in response to stresses such as defoliation or drought. |
| Key tree: | The tree that is selected in a thinning operation, as the basis for selecting which of the surrounding trees are to be either removed or retained. |
| Matting: | Tree head waste and understorey material laid across snig tracks, to eliminate rutting by machinery in wet weather. |
| Outrows: | Parallel, clearfelled corridors in a stand along which logging machinery transports timber to the landing from the thinned “bays” between the outrows. |
| Piece size: | The size, in volume or weight, of individual pieces of timber being handled in a logging operation. |
| Potential sawlog: | Trees of satisfactory form to eventually produce sawn timber (see Part A), but not yet of sufficient size. |
| Prescription: | Document which details the characteristics of the stand to be retained in a thinning operation, specifying stem retention rate, retained tree spacing, basal area retention rate, and any special instructions for the coupe. |
| Retainer: | Retained tree, also known as “crop tree”. |
| Snig track: | Track along which felled logs are dragged in a ground-based logging operation, and along which machinery can move around the coupe. |
| Thinning intensity: | The proportion of the stand which is removed in a thinning operation, usually expressed as a percentage reduction of basal area. |

## Native Forest Silviculture Technical Bulletin Series

| No | Title | Date of Release |
|---|---|---|
| 1 | Eucalypt Seed and Sowing | 1991 |
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Produced on an Apple Power MacIntosh 7300/200® computer, in 11pt 'Palatino'