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Lowland dry eucalypt forests

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Prepared by Mark Neyland
First edition (1991) prepared by Neil McCormick
Layout and design by Leigh Edwards
Division of Forest Research and Development
Forestry Tasmania.

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Contents

Part A: Silvicultural Prescriptions for the Management of Lowland Dry Eucalypt Forests

1. Introduction

Lowland dry eucalypt forests occur throughout northern and eastern Tasmania (Map 1), typically in areas with an average annual rainfall below 1000 mm. Characteristically, they comprise a short to moderately tall open cover of eucalypts over a multi-layered shrub understorey. The ground layer composition is highly variable but bracken, shrubs, grasses and sedges are often common. Throughout the range of lowland dry eucalypt forest, the floristics change constantly. At any given site, the plant composition is influenced by the landform (topographic position), geology, climate, fire history and land use. For management purposes the understorey can often be allocated to one of four widespread understorey types i.e. grassy, shrubby, sedgy, or heathy.

Lowland dry eucalypt forests typically have a multi-aged stand structure resulting from gap-phase recruitment to the canopy. Seedlings may establish continuously in canopy gaps, with additional pulses of regeneration arising from major disturbances such as wildfire. The eucalypt canopy usually comprises a mix of species.

Lowland dry eucalypt forests have been heavily exploited since the European settlement of Tasmania. They have provided land for agriculture following vegetation clearance on the richest soils, rough grazing for stock on poorer soils, fence posts, firewood, sawn timber and pulpwood. Land clearance for agriculture has severely depleted the extent of some lowland dry eucalypt communities and some have always had limited distributions. These communities are now managed for protection on State forest (Table 1).

Traditionally, lowland dry eucalypt forests were harvested using a variety of techniques including clearfelling. In recent years realisation of the many benefits of partial harvesting techniques has led to most harvesting being by partial methods. Well-managed partial harvesting is aesthetically pleasing, conserves existing potential sawlogs and advance growth, ensures an ongoing supply of on-site seed, minimises the risk of grass invasion, protects regeneration from climatic extremes and often reduces the need for browsing control.

Forest practices officers who prepare Forest Practices Plans are required to be familiar with the vegetation communities which are protected under the Regional Forest Agreement (RFA). Understanding and managing RFA protected communities is covered in detail in the Forest Practices Authority forest botany course and the forest botany manuals. The manuals are available through the Forest Practices Authority website at www.fpa.tas.gov.au

2. Silvicultural Considerations

The optimum silvicultural prescription for any lowland dry eucalypt forest will be dependent on the stand structure and site conditions. The following guidelines will assist in determining the appropriate silvicultural prescription for any given coupe. The focus of all good silviculture is on the trees that are retained.

1. Retain a forested environment during harvesting to minimise the rate of grass invasion, reduce climatic extremes and minimise browsing damage to eucalypt seedlings.

2. Retain existing regeneration wherever possible as it is already established and is the product of many years of growth.

3. Potential sawlogs should be retained wherever possible to maximise future sawlog yields.

4. The use of fire to create receptive seedbed is not essential, providing that adequate exposure of mineral soil has been obtained by logging disturbance and/or additional scarification. When fuel levels after logging are unacceptably high, burning may be undertaken as a slash management option. Where valuable advance growth

is present the use of high intensity or broadcast fire is undesirable, particularly on sites which may be difficult to regenerate.

5. Mechanical disturbance should aim to expose mineral soil by removal of vegetation and litter layers. Care must be taken to minimise soil movement, compaction or displacement, particularly on infertile soils and sites susceptible to erosion.

6. Retained mature trees and older regrowth which carry good seed crops provide an ongoing source of on-site seed which assists the successful establishment of regeneration and provides a form of insurance against wildfires. If a wildfire destroys the regeneration, the retained trees can provide further seed.

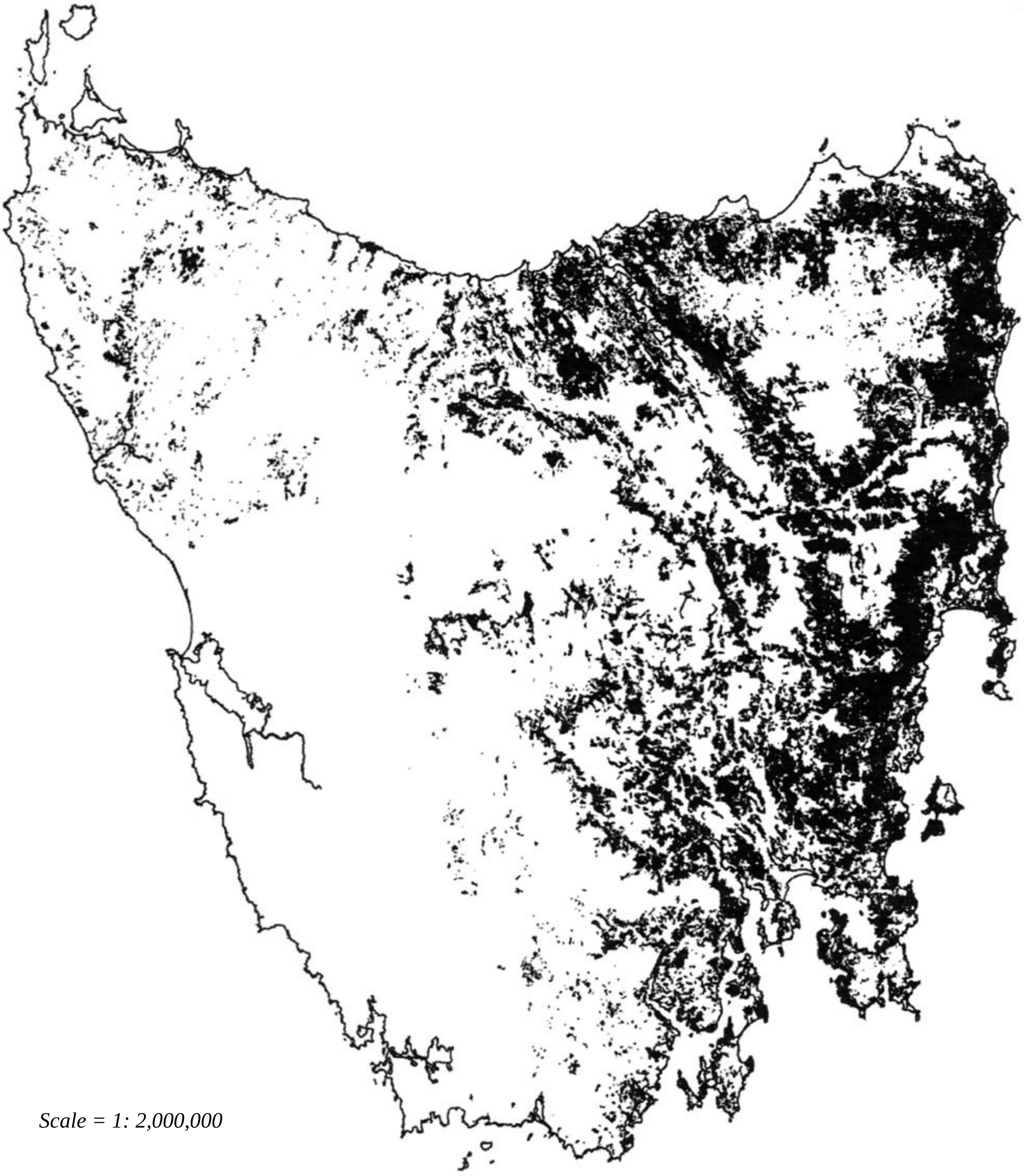
7. During the regeneration phase, monitoring of browsing animals, and control where required, is essential to ensure successful regeneration.

Table 1. Area of lowland dry eucalypt forest by tenure and RFA vegetation community (after Tasmanian and Australian Governments 2007).

RFA Code	*RFA Community*	*Total reserved¹*	*State forest and other public land*	*Private land*	*Total*
O	Dry *E. obliqua* forest	40 000	69 000	50 000	159 000
AC	Coastal *E. amygdalina* dry sclerophyll forest	60 000	59 000	65 000	185 000
SO #	*E. sieberi* on other substrates	8 000	31 000	7 000	46 000
AD	*E. amygdalina* forest on dolerite	21 000	25 000	129 000	175 000
P	*E. pulchella - E. globulus - E. viminalis* grassy shrubby dry sclerophyll forest	26 000	25 000	98 000	150 000
N	Dry *E. nitida* forest	135 000	19 000	6 000	159 000
DSC #	*E. viminalis/E. ovata/E. amygdalina/E. obliqua* damp sclerophyll forest	10 000	14 000	14 000	38 000
SG #	*E. sieberi* on granite	4 000	11 000	2 000	18 000
AS	*E. amygdalina* forest on sandstone	4 000	8 000	17 000	30 000
NF	Furneaux *E. nitida* forest	19 000	5 000	7 000	30 000
PJ #	*E. pauciflora* on Jurassic dolerite	1 000	4 000	14 000	19 000
PS	*E. pauciflora* on sediments	4 000	3 300	9 000	16 000
TD	*E. tenuiramis* on dolerite	5 000	2 000	700	8 000
V *	*E. viminalis* grassy forest	3 000	1 400	107 000	112 000
TI *	Inland *E. tenuiramis* forest	7 000	1 700	45 000	54 000
AI *	Inland *E. amygdalina* forest	3 000	1 800	20 000	25 000
GG *	Grassy *E. globulus* forest	6 000	800	7 000	14 000
RO *	*E. rodwayi* forest	200	400	8 000	9 000
OV *	Shrubby *E. ovata* forest	300	400	6 000	7 000
G *	*E. viminalis* and/*or E. globulus* coastal shrubby forest	300	30	900	1 000
V *	Furneaux *E. viminalis* forest	100	0	20	100
T	*E. tenuiramis* on granite	3 000	40	200	300
RI *	*E. risdonii* forest	200	10	200	400
MO	*E. morrisbyi* forest	20	0	0	20
Total		**360 000**	**282 000**	**613 000**	**1 256 000**

* Communities which on State forest, are protected wherever prudent and feasible.
# Communities which on State forest, are protected wherever prudent and feasible, wherever they occur as oldgrowth.
¹. Total reserved area includes both formal and informal reserves.

Map 1. Distribution of lowland dry eucalypt forests in Tasmania (after PLUC 1996).



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3. Selection of the Silvicultural System

A silvicultural system normally comprises a harvesting treatment in conjunction with a regeneration treatment.

Guidelines for the selection of the appropriate silvicultural system are detailed in the following figures and flow charts.

Figure 2. Selection of the harvesting treatment

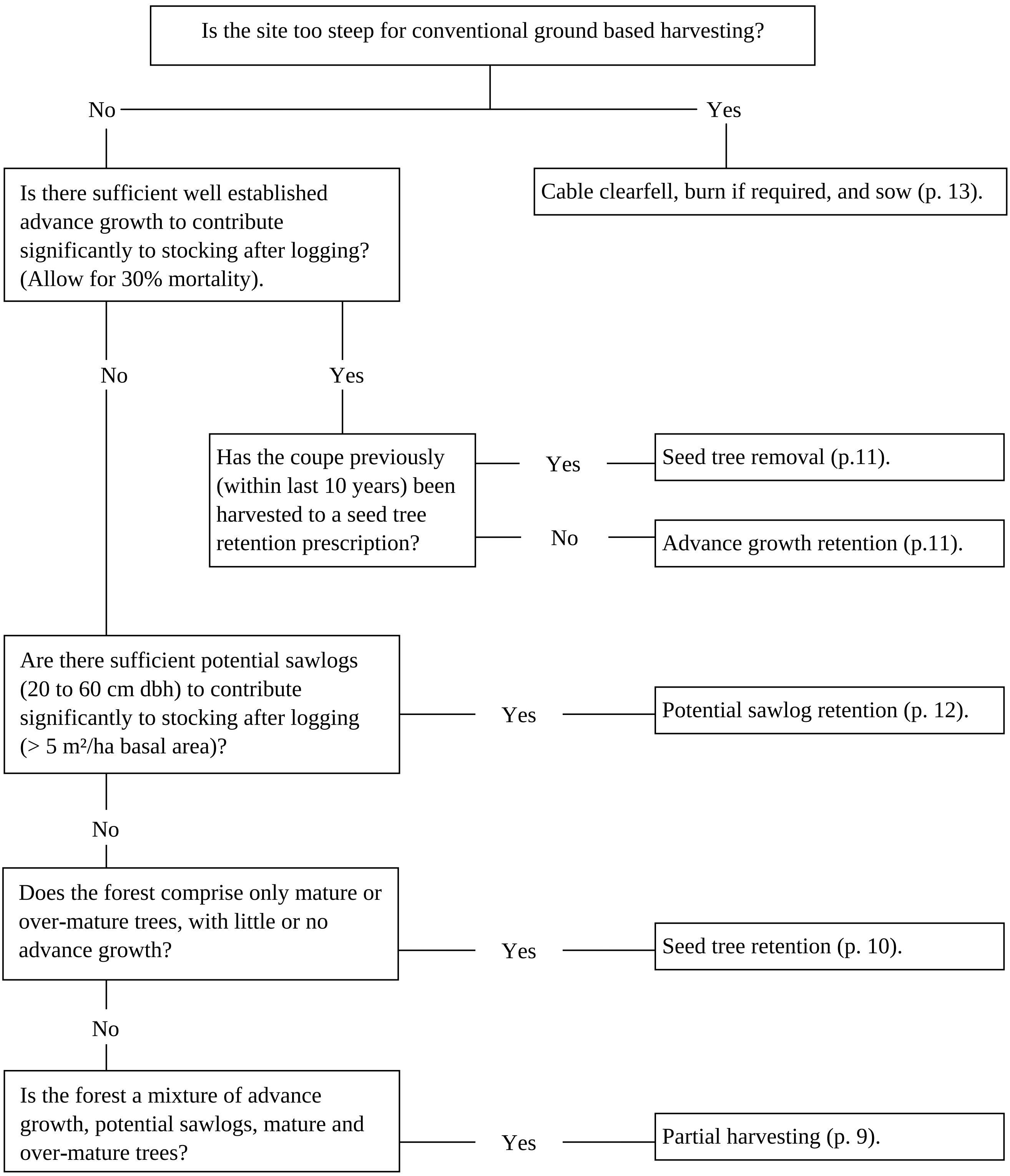


Figure 3. Selection of the regeneration treatment.

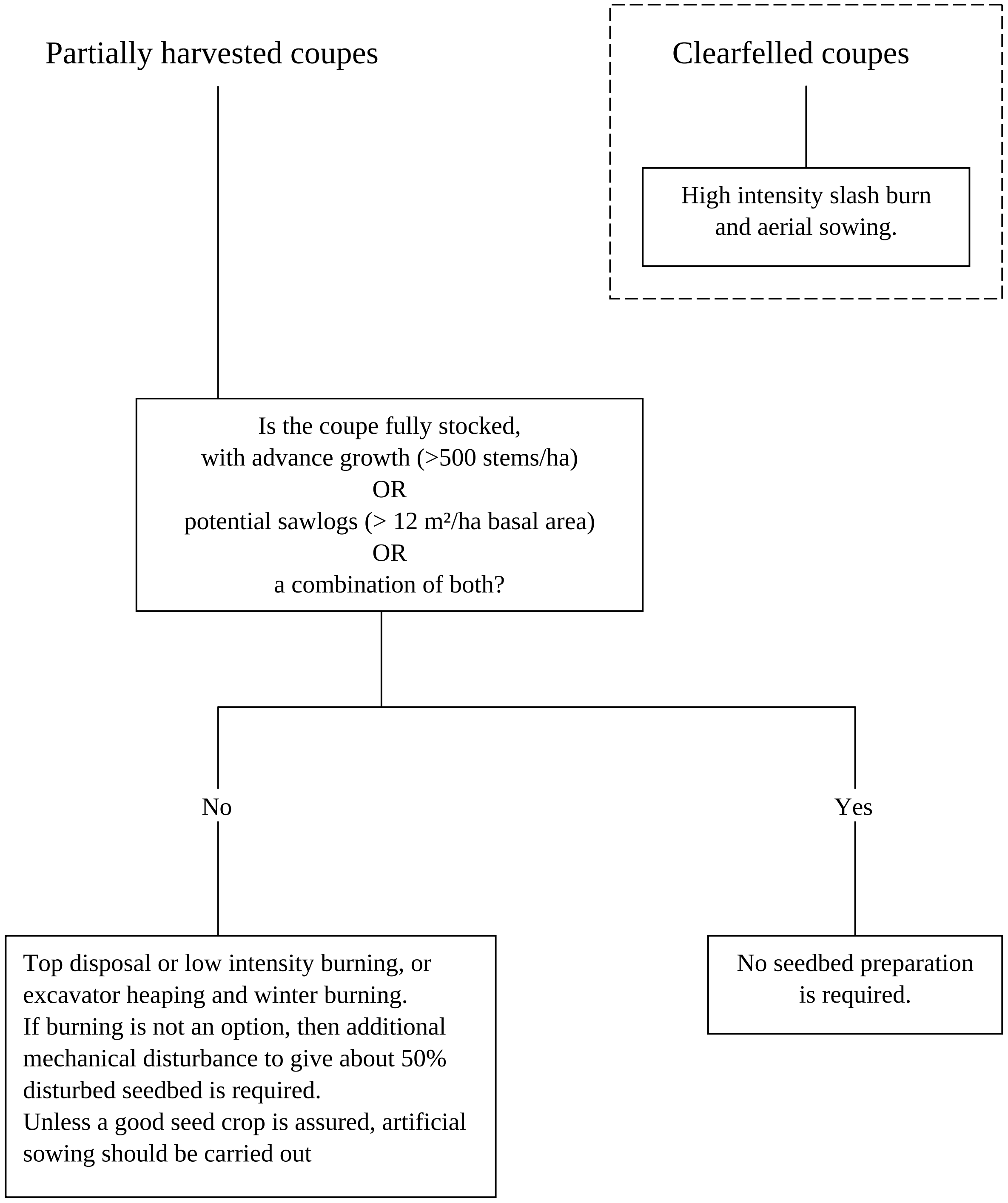
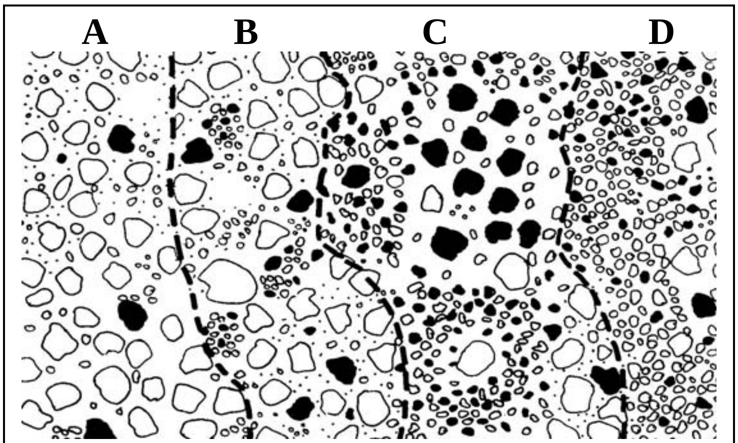


Figure 4. Stand structure and selection of silvicultural system

Legend

Trees — *Potential sawlogs* — *Advance growth* — *Seedlings*

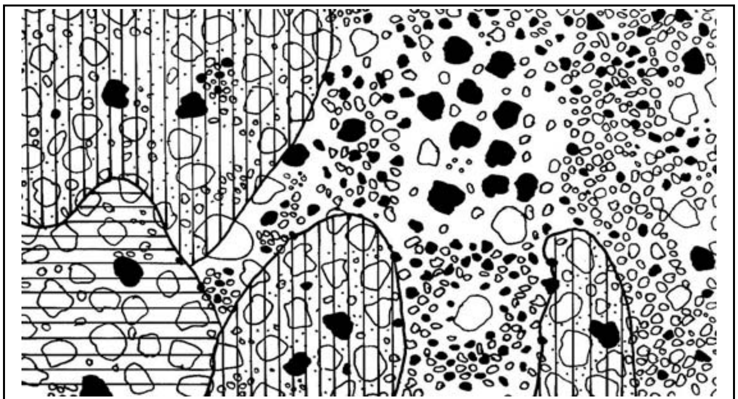
A : Virgin forests have a variety of structures but a preponderance of large sizes is common
B : Small clumps (arising from past single tree harvesting or low intensity fire)
C : Patchy (arising from past intensive harvesting or fire)
D : Even-aged (arising from past clearfelling or severe fire)



Planning

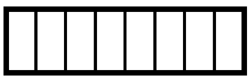
Lowland dry eucalypt forests have a variety of structures and tend to be a mosaic of age classes.

The identification of potential sawlogs and advance growth is the first step in selecting the most appropriate silvicultural treatment.

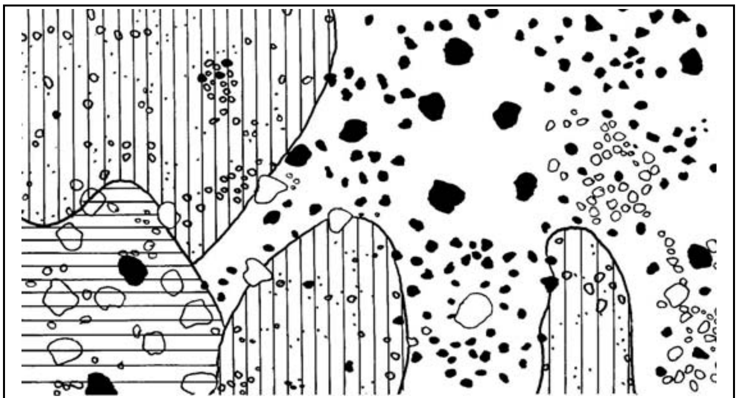


Pre-harvest

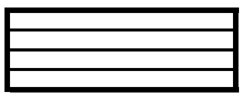
Patches wh`ich contain sufficient potential sawlogs may be spaced. Other vigorous stems should be released by removing poorer quality trees.



Patches which contain an adequate stocking of advance growth should have all marketable stems removed to release the advance growth. Cull trees should be removed.



Post-harvest



Patches which contain few or no potential sawlogs or advance growth should have healthy vigorous mature trees retained to provide seed and shelter.

4. Silvicultural Systems and Harvesting Criteria

Lowland dry eucalypt forests are often comprised of cohorts of trees in a range of size classes – advance growth, potential sawlogs, mature and over-mature trees which occur in a complex mosaic. For coupes in such forests, prescription of a single silvicultural system, for example, advance growth retention, will not adequately describe the operation nor provide sufficient information to ensure the best outcomes. In these cases, a patchwork approach using the silvicultural systems described below is required. So, for example, where a patch is comprised of mature trees with little advance growth present, a seed tree system must be applied. In other parts of the coupe, where there are clumps of advance growth, the advance growth is retained and any overwood should be removed. This approach is illustrated and explained further in Figure 4.

The principles below apply to the net harvestable area and assume that all special values such as habitat clumps have been identified for protection in the preparation of the Forest Practices Plan.

The key principles of partial harvesting which must be considered in determining the appropriate prescription for any given coupe include:

- Regeneration must be established before all the overstorey is removed.

- Most advance growth should be retained. Some damage to the advance growth is to be expected where overstoreys are removed but should be minimised. The critical outcome in advance growth retention operations is that a minimum of 500 well-formed and evenly-distributed stems be retained per hectare.

- Potential sawlogs should be retained at an even spacing. The table on page 12 shows the appropriate spacing for potential sawlogs of different sizes.

- A seed crop assessment should be undertaken and a satisfactory seed crop recorded (as prescribed in Technical Bulletin 1) before partial harvesting commences. Where the seed crop assessment identifies a lack of seed and scheduling dictates that harvesting must go ahead, then on-site or in-zone seed must be collected during the harvesting for later sowing unless the seed centre is known to hold appropriate seed in store.

- All mature and over-mature trees should be removed except where required as seed trees. Removal of trees > 100 cm dbh is a priority.

- Seed trees should be of reasonable form and quality with healthy, balanced crowns and good seed crops. Seed trees also provide young regeneration with shelter from the worst extremes of wind and sun. Once the regeneration is established, the seed trees may be removed.

- Most cull trees should be removed from harvested areas. Cull trees with large spreading crowns are a priority for removal. Culls with small crowns may be retained as habitat trees.

- Sites which are known to be particularly difficult to regenerate, such as exposed rocky knobs, frost hollows and the poorest quality grassy peppermint forests, should not be harvested.

4.1 Seed tree retention

Appropriate forest stands: Lowland dry eucalypt forests that lack sufficient advance growth or potential sawlogs suitable for retention. An adequate seed crop should be present in the retained trees. If the seed crop is inadequate it is acceptable to sow; however it is preferable when possible to reschedule harvesting until an adequate seed crop is available.

Harvesting method: All trees are harvested other than 7 to 12 well-spaced trees per hectare. Seed trees should be of reasonable form and quality with healthy, balanced crowns and good seed crops. The proportion of species present on the site prior to harvesting should be reflected in the retained trees. Any advance growth should be retained undisturbed.

A higher retention rate should be used in grassy forests and sites prone to windthrow, e.g. granite soils on ridges in north-east Tasmania.

Regeneration treatment:

Site preparation: Receptive seedbed must be created by low intensity broadcast burning, top disposal burning, excavator heaping, harvesting disturbance or additional mechanical disturbance. On grassy sites, deliberate additional mechanical disturbance may be required to create sufficient seedbed.

Source of regeneration: New seedlings may arise from seed shed from felled crowns (if the slash is retained unburnt), from the retained seed trees and from the release of advance growth (where present). If no seed is present the site must be sown.

Monitoring and protection: Indicator plots must be established, as soon as site preparation is completed, to monitor germination and problems due to inadequate seedfall, lack of receptive seedbed or browsing damage.

As the plots are a measure of the success of the seedfall on the coupe, they should not be artificially sown.

Because they are relying on natural seedfall, the plots can be larger than standard, up to 4 m by 4 m.

Browsing damage: Browsing transects should be established and monitored, and control of browsing undertaken if required, as prescribed in Technical Bulletin 12.

Regeneration survey: A seedling survey must be carried out about two years after the regeneration treatment. A multi-aged survey is the appropriate method where seed tree retention occurs as a mosaic within patches treated by the advance growth or potential sawlog retention methods.

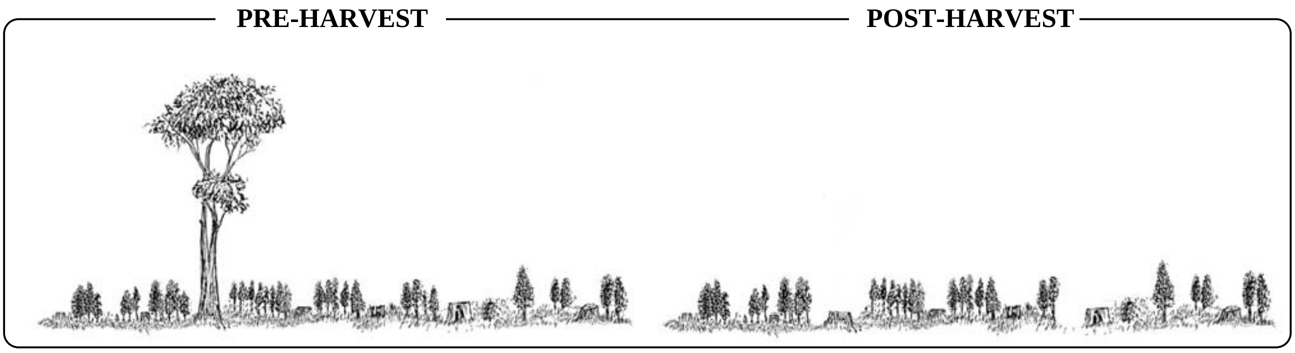
4.2 Seed tree removal

Appropriate forest stands: Lowland dry eucalypt forests that have previously been harvested to a seed tree retention prescription.

Harvesting method: The retained seed trees should be removed when the coupe is stocked with regeneration taller than the competing understorey. This may require 3 to 7 years, depending on site quality.

Regeneration treatment:

Seed tree removal is only undertaken when the stand is stocked with advance growth. No additional regeneration should be required.



4.3 Advance growth retention

Appropriate forest types: Uneven-aged forests containing advance growth that has good potential for further growth. The cohorts of advance growth are often of different ages as they arise from different disturbances.

Harvesting method: Most mature and over-mature stems should be harvested. Regardless of the understorey type (grassy, sedgy, heathy or shrubby), the advance growth should be clearly taller than the competing understorey before the overstorey trees are removed.

Regeneration treatment:

Advance growth retention is only undertaken when the stand is stocked with advance growth. No additional regeneration should be required.

Regeneration survey: A multi-aged survey must be carried out within one year of the regeneration treatment.

4.4 Potential sawlog retention

Appropriate forest types: Two-aged high quality forests comprising potential sawlogs (20 to 60 cm dbh) and a mature overstorey.

Harvesting method: All mature trees should be harvested and the potential sawlogs evenly retained at 9 to 12 m^2 of basal area per hectare.

Regeneration treatment:

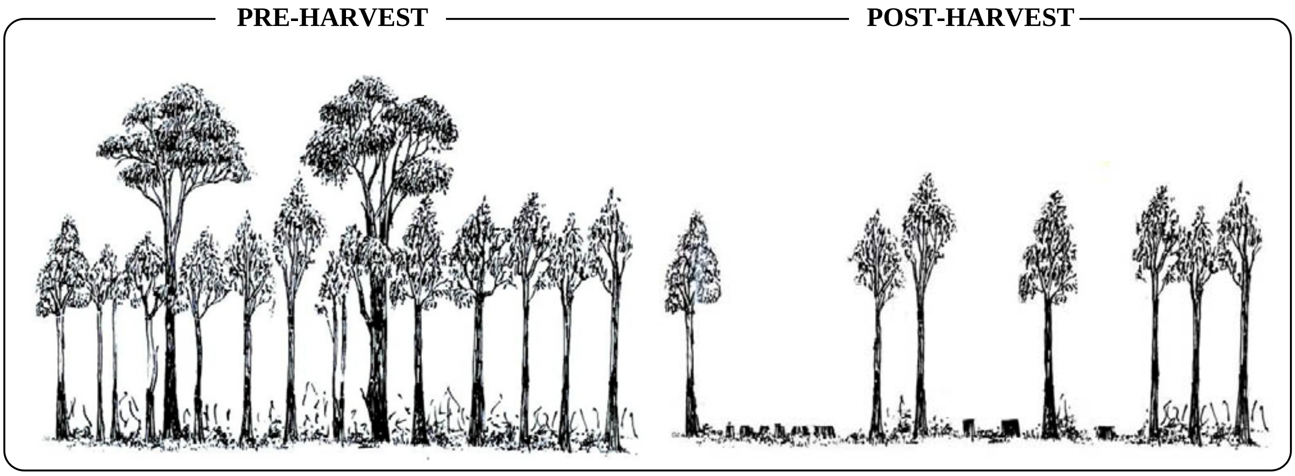
Potential sawlog retention is only undertaken when the stand is adequately stocked. No additional regeneration should be required.

Regeneration survey: A multi-aged survey must be carried out within one year of the regeneration treatment.

Potential sawlog retention spacings

For a retained basal area of 9 or 12 m²/ha (for stem densities and spacing at other basal areas see Technical Bulletin No. 5.)

9 m²/ha			12 m²/ha		
Mean dbh (cm)	Stems per ha	Spacing (m)	Mean dbh (cm)	Stems per ha	Spacing (m)
20	286	6	20	382	5
25	183	7	25	244	6
30	127	9	30	170	8
35	94	10	35	125	9
40	72	12	40	95	10
45	57	13	45	75	12
50	46	15	50	61	13
55	38	16	55	51	14



4.5 Clearfelling

Appropriate forest stands: Lowland wet eucalypt forests (i.e. both mixed forests and wet sclerophyll forests) typically dominated by *E. obliqua* or *E. regnans*.

High altitude *E. delegatensis* forests on moderate to steep slopes with a rainforest or wet sclerophyll understorey.

Lowland dry eucalypt forests on steep slopes, which are to be harvested using cable machines.

Harvesting method: All stems are harvested, including non-merchantable trees (culls). Scrub felling or pushing is often used to improve the fuel preparation prior to the regeneration burn.

Regeneration treatment:

Site preparation: High intensity burn to remove fuels and create receptive seedbed.

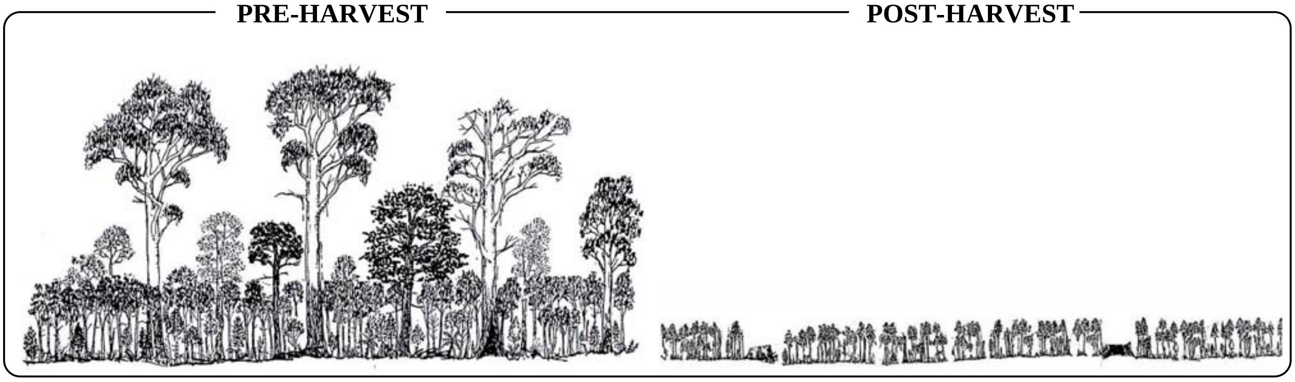
Source of regeneration: Aerial sowing. Seed should be sown onto the receptive seedbed as soon as possible after the regeneration burn. Further details on sowing are contained in Technical Bulletin No. 1.

Monitoring and protection: Indicator plots must be established to monitor germination and problems due to frost, drought, insects and browsing damage.

Browsing damage: Browsing transects should be established and monitored, and control of browsing undertaken if required, as prescribed in Technical Bulletin No. 12.

Regeneration survey: A seedling regeneration survey should be carried out in late summer/early autumn in the year following the regeneration burn, as described in Technical Bulletin No. 6.

Further details: See Technical Bulletins No. 2, *Eucalyptus delegatensis* forests and No. 8, Lowland wet eucalypt forests.



Part B: Silvicultural Description of Lowland Dry Eucalypt Forests

1. Introduction

Part B of this Technical Bulletin has been prepared to provide field staff with some background information relevant to the silviculture of lowland dry eucalypt forests. Section 2 of Part B of this Technical Bulletin has been revised from Duncan (1999).

2. Forest Ecology

2.1 The characteristics of dry eucalypt forests

Dry eucalypt forests mainly occur as Specht's (1970) woodland and open forest structural formations. These are dominated by trees with a height of 10 to 30 m, and a canopy cover of 10-30% (woodland) or 30-70% (open forest). However, dry eucalypt forests can extend beyond these formations in response to the physical environment, successional phase or history of disturbance at a site. For example, tall open forests and woodlands, with a dominant tree height exceeding 30 m, can occur on relatively moist or fertile sites. Such forests often contain both xeromorphic (plants adapted to very dry conditions) and mesomorphic (plants suited to moister conditions) understorey species, and are described as damp sclerophyll in some classifications, e.g.

Forbes *et al.* (1982). At the other extreme, very dry or infertile sites and some disclimax communities may have a tree cover of less than 10% (open woodland communities), or trees shorter than 10 m (low open forest, low woodland or low open-woodland communities). In such situations, dry sclerophyll vegetation grades into shrubland (or scrub), heath, sedgeland or grassland, depending on the nature of the understorey. These understorey characteristics have also been used to classify dry sclerophyll communities in Tasmania (Duncan and Brown 1985) and for Australia as a whole (Johnston and Lacey 1984).

2.2 Drought tolerance

Dry eucalypt forests and woodlands typically occupy sites which are prone to drought, as a result of topographic attributes (e.g. exposure to solar radiation and winds; depth and permanence of the water table) or edaphic factors (e.g. soil texture, structure and depth). In Tasmania, dry eucalypt forests occupy sites where the mean annual rainfall is generally below 900 mm. Summer maximum temperatures average 20 to 22°C with winter minimums around 3 to 5°C. Species occupying dry or exposed sites utilise several adaptations or strategies to survive or avoid physiological drought.

Xeromorphic attributes enable perennials and many annuals to reduce transpiration in periods of water stress, and survive extremes of temperature and radiation (Gillison and Walker 1981). Most trees and shrubs (e.g. *Banksia* spp., *Acacia* spp.) and many perennial monocots (e.g. *Xanthorrhoea* spp.) are sclerophyllous. Other xeromorphic features, utilised by both sclerophyllous (hard leaves with thick cuticles) and non-sclerophyllous species (softer leaves), include pendulous leaves (e.g. *Eucalyptus* spp.), glaucousness (a waxy coating, e.g. *E. tenuiramis*, silver peppermint), rolled leaf margins (e.g. *Hakea* spp., *Poa* spp.), a dense indumentum (coating of fine hairs), (e.g. *Lasiopetalum* spp.) and reduced leaves (e.g. *Allocasuarina* spp., *Exocarpos* spp., *Callitris* spp.). Many annual forbs, geophytes, graminoids and grasses are drought avoiders which have short growing and flowering periods, which generally coincide with favourable climatic conditions in spring and early summer.

It has been suggested that xeromorphy is also an adaptive response to low phosphorus, nitrogen and trace elements in the soil (Beadle 1968, 1981; Specht 1972, 1981). Xeromorphy often acts in combination with other strategies to optimise absorption of nutrients from the soil or efficiency of use after they are absorbed (Bowen 1986). Some Australian plants form symbiotic relationships with micro-organisms, exchanging carbohydrates and other growth substances for nitrogenous compounds. Nitrogen fixation in root nodules is typical of species of families Mimosaceae (*Acacia* spp.), Fabaceae (e.g. *Pultenaea* spp., *Daviesia* spp., *Bossiaea* spp.), and Casuarinaceae (*Allocasuarina* spp.), and may also occur in many other families (Bowen 1986). Efficiency of nutrient uptake can be enhanced by development of complex root systems, such as the proteoid root system of family Proteaceae. Many xeromorphic plants benefit from associations with mycorrhizal fungi, which aid in nutrient uptake and balance (Warcup 1986).

2.3 Nutrient status and nutrient cycling

The nutrient status of a site depends primarily on the chemical and physical properties of its substrate. At a broad scale, this can be inferred from the rock type occurring in an area, but on a local scale factors such as climate, landform, fire history and land use will influence rates of soil and litter accumulation or removal.

Nutrient cycling in sclerophyll forests can vary in response to substrate fertility. Evergreen perennial plants with slow growth rates are favoured on infertile sites. Maintenance of nutrients within the plant is enhanced by resorption of nutrients, particularly nitrogen and phosphorus, prior to leaf abscission (Attiwill *et al.* 1978; Adams and Attiwill 1988). Rapid movement of nutrients from the plant canopy to the soil may take place through insect frass and the excreta of vertebrates (Springett 1978), with dry sclerophyll forests and woodlands typically supporting high diversities and numbers of phytophagous (plant-eating) fauna (Recher 1985).

Nutrients stored in rhizomes, lignotubers and other subsurface vegetative organs enable regeneration of plants after fire, browsing or unfavourable seasons.

The impact of fire on nutrient cycling in dry sclerophyll vegetation is extremely complex, and depends on factors such as intensity, frequency and season of occurrence and the characteristics of the vegetation itself (Gill 1981). The breakdown of litter in dry sclerophyll communities is slow, and the litter itself is combustible. Less mobile minerals, such as calcium and magnesium, are released from the litter to the soil by fire, but volatile elements, such as nitrogen, can be lost to the atmosphere. Elements can also be removed from the system in smoke or by redistribution of ash by wind or water (Gill 1981).

2.4 Fire and regeneration

Specht (1981) suggested that much of the xeromorphic flora was pre-adapted to a fire-prone environment by adaptations to aridity and nutrient deficiency. Paradoxically, some of these adaptations not only facilitate the survival or post-fire recovery of species, but are themselves fire-promoting (Gill 1975; Recher and Christensen f1980; Ashton 1981; Dickinson and Kirkpatrick 1985). Features enhancing flammability include the concentration of respiratory wastes and oils in leaves, and the withdrawal of nutrients prior to abscission. The resulting inhibition of decompositional activity, due to the poor nutritional status of the litter, leads to a build up of leaves, bark and woody material on the forest or woodland floor. It takes only a minor shift in weather conditions for a ground fire trickling through the litter to be converted to a crown fire, with the understorey igniting and the hanging ribbons (e.g. *E. viminalis*) or fibrous bark (e.g. *E. obliqua*) of the eucalypts forming a wick to a canopy saturated with volatile oils. Wind-blown embers allow wildfires to spread by spotting, often many kilometres ahead of a fire-front (Mount 1979).

2.5 Fire frequency

The flammable nature of the litter, and under appropriate conditions the living vegetation itself, encourages a natural fire frequency of about four to 20 years in dry sclerophyll vegetation (Mount 1979). This frequency varies according to the characteristics of the understorey. Forests and woodlands with a grassy or sedgy understorey have a higher natural fire frequency (i.e. shorter period between fires) than those with a heathy or shrub understorey, dominated by woody species. The natural fire frequency will be lowest in damp sclerophyll forests, where broad-leaved species are also present in the understorey. The vegetation itself may be maintained as a disclimax or seral stage by a particular fire regime; for example maintenance of grassy woodlands by Aboriginal use of frequent fires of low intensity, and their subsequent change to grassy and shrubby forests following the cessation of Aboriginal burning (Jones 1969; Kirkpatrick *et al.* 1988; Duncan 1990). Changes in fire regimes can lead to change in structure and composition of dry sclerophyll communities in a manner akin to the ‘ecological drift’ described for vegetation types occurring in perhumid areas of Tasmania (Jackson 1968; Brown and Podger 1982; Ellis 1985a). This is because of differences in the modes of survival or regeneration of overstorey and understorey species, which will depend in part on the season, intensity and frequency of fires.

2.6 Vegetation response to fire

Purdie (1977a; 1977b) identifies two modes of vegetative regeneration, both of which will be favoured by frequent cool fires. Vegetative increasers (e.g. *Pteridium esculentum, Acacia dealbata*, *Leptocarpus tenax*) regenerate from buds on lateral shoots and rhizomes. Vegetative decreasers (e.g. *Poa* spp., *Gahnia* spp., coppice sprouting shrubs) regenerate from dormant buds at the base of tussocks or vertical stems. Vegetative decreasers fare unable to increase their abundance by vegetative growth, but are capable of surviving most fires, and can recolonise bare areas if the interval and land use between fires allow establishment of seedlings. Vegetative reproducers, such as bracken (*Pteridium esculentum*) which is both robust and unpalatable to browsing animals, is capable of forming near-monocultures on sites where very high fire frequencies have exhausted the regenerative resources (vegetative or seed) of other species.

Woody scleromorphic species which regenerate primarily from seed tend to be favoured by infrequent fires, which typically will be locally intense in some of the burnt area. Such species are reduced in cover and abundance if successive frequent and cool fires exhaust or fail to stimulate their regenerative reserves, and prevent immature individuals from attaining maturity (Gill 1975). Broad-scale regeneration of legumes and *Acacia* species may require high intensity fires (Shea *et al.* 1979). Intense fires also favour slower growing species, because competition from many vegetative reproducers is reduced or eliminated by lethal soil temperatures. Serotinous and fire-sensitive trees, notably *Callitris* spp. and to a lesser extent *Allocasuarina* spp., although morphologically adapted to drought-prone environments, are largely restricted to sites protected from frequent fires by topography (e.g. coastal land forms) or substrate characteristics (e.g. very rocky sites) (Harris and Kirkpatrick 1991).

2.7 Eucalypt response to fire

Some species utilise both vegetative and seed regeneration to recover from fire, with the relative importance of the different strategies depending on the severity of the fire. Trees of *Eucalyptus* occurring in dry sclerophyll environments will survive mild fires because of their thick or reflective bark. Vegetative regeneration is achieved by basal sprouting from lignotubers, or stem sprouting from epicormic buds, the verdant hues of the new growth often providing a bizarre contrast to an otherwise blackened landscape. Seed is released from protective woody capsules which have dried out and opened in the aftermath of the fire. The bare, burnt ground favours the establishment of shade-intolerant eucalypt seedlings, particularly where sterilisation of the soil under heavy fuels (e.g. logs) has provided an impetus to seedling growth by reducing populations of unfavourable micro-organisms (Renbuss *et al.* 1973) or reducing competition from other vascular species, notably robust vegetative reproducers. However, some soils can become baked and hydrophobic, leading to inhibition of seedling establishment (Dickinson and Kirkpatrick 1987).

2.8 Eucalypt regeneration and fire

Eucalypt-dominated dry sclerophyll forests and woodlands typically have a multi-aged structure. Age classes of seedlings, saplings and trees may have some correlation with past fire years. However, the mosaic pattern of most fires, coupled with the armoury of adaptations available to eucalypts, allows some trees, saplings and lignotubers to survive even hot fires. Gaps in the canopy often result from fire, either directly by killing individuals in the overstorey, or indirectly by continued erosion of the butts of trees by locally intense fires, leading to eventual collapse of the tree. Thus recruitment to the canopy is a sporadic but continuous process, but is less obvious in vegetation subjected to frequent firing, coupled with browsing by native or introduced herbivores, such as the fire-deflected disclimax grassy woodlands. The variety of strata and local habitats (e.g. tree hollows) in relatively undisturbed dry sclerophyll vegetation, as well as the generally high diversity of vascular species, supports abundant and diverse fauna (Gowland 1977; Pattemore 1980; Dickinson *et al.* 1986).

2.9 Dominant eucalypt species

Peppermints

Eucalypt species dominate dry sclerophyll vegetation throughout most of its range in Tasmania. Of the 29 eucalypt species native to Tasmania, 26 have been recorded from dry sclerophyll sites, though some are only marginal occupiers and others have a very restricted distribution in the State. Members of the peppermint group (subgenus Monocalyptus series Piperitae) are the most widespread dry sclerophyll dominants and tend to occupy sites which are well-drained and infertile or drought-prone. *Eucalyptus amygdalina* is the most widespread dominant in lowland and upland environments in eastern and northern Tasmania, while *E. nitida* dominates similar but more local sites in western Tasmania and islands of the Furneaux Group. Peppermint species exhibit a degree of site fidelity in south-eastern Tasmania, with *E. pulchella* occupying dry sites on Jurassic dolerite, *E. amygdalina* being associated with Triassic sediments, *E. tenuiramis* mainly occurring on Permian and Triassic sediments, and *E. risdonii* being restricted to highly insolated (very sunny) sites on Permian mudstone in the Meehan Range near Hobart. A glacial treeline may have ormed a barrier which prevented some of the south-eastern endemic eucalypts from spreading to apparently suitable sites in the north (Kirkpatrick *et al.* 1995). *Eucalyptus coccifera* is the most widespread dominant on relatively dry, well-drained subalpine sites on the Central Plateau, and has a sporadic distribution on exposed peaks in eastern Tasmania (Williams and Potts 1996). Transfer of genes is common between Tasmanian species of peppermints, and several hybrids, hybrid swarms and clines have been documented (Duncan 1989). They include a cline involving *E. amygdalina* and *E. pulchella*, which is primarily related to site exposure in the eastern dolerite uplands (Kirkpatrick and Potts 1987), an altitudinal cline involving *E. nitida* and *E. coccifera* (Shaw *et al.* 1984), and a geographic cline involving *E. amygdalina* and *E. nitida*.

Ashes

Members of the ash group (subgenus Monocalyptus, series Obliquae) co-occur with peppermint species as sites become more fertile or less drought-prone. On a local scale, this can result from an increase in effective precipitation from orographic trapping of clouds and subsequent stripping of moisture by the vegetation, from reduction in site insulation or exposure to drying winds, or from the presence of water retentive soils or a more reliable or accessible water table. The ash species assume dominance as site moisture availability further increases; the trees become taller and more even-aged, and mesomorphic shrubs become more abundant in the understorey. The above scenario is typical of relatively moist and well-drained sites both in lowland areas, where *E. obliqua* is the major ash species in dry sclerophyll forest, and upland areas, where *E. obliqua* is replaced by *E. delegatensis*. In north-eastern Tasmania, *E. sieberi* dominates large tracts of frost-free sites of moderate fertility. *Eucalyptus pauciflora* is widespread but often local in relatively fertile but frost-susceptible environments in northern and eastern Tasmania and the Central Plateau.

Gums

Members of the gum group (subgenus Symphyomyrtus) are often present as minor or subdominant species in Monocalyptus-dominated forests and woodlands. Symphyomyrtus species also occur locally as dominants or co-dominants, generally in woodlands on dry fertile sites (e.g. *E. globulus, E. viminalis, E. rubida*), or drainage basins or flats (e.g. E. *ovata*, *E. rodwayi*). Other Symphyomyrtus species (e.g. *E. perriniana*, *E. morrisbyi*) are very restricted in their distribution. Hybridisation is common in co-occurring Symphyomyrtus species, particularly in ecotonal environments and on sites subject to disturbance or other environmental stress (Pryor 1976; Williams and Potts 1996).

2.10 Understorey floristics

Dominant species

At least half of the approximately 1530 native vascular species that have been recognised for Tasmania have been recorded from dry sclerophyll forests and woodlands. All of Tasmania's dry sclerophyll vascular genera, and about 80% of its species, are shared with south-eastern mainland Australia, but there is a degree of local and regional variation in the dry sclerophyll flora. Dominant or conspicuous dicotyledonous families include Asteraceae, Casuarinaceae, Dilleniaceae, Epacridaceae, Fabaceae, Lauraceae, Myrtaceae, Pittosporaceae, Proteaceae, Rhamnaceae, Rutaceae, Santalaceae, Thymelaeaceae and Tremandraceae. Prominent monocotyledonous families include Cyperaceae, Iridaceae, Juncaceae, Liliaceae, Orchidaceae, Poaceae, Restionaceae and Xanthorrhoeaceae. *Callitris* (family Cupressaceae) is the only gymnosperm genus extending into dry sclerophyll environments. *Pteridium esculentum* (family Dennstaedtiaceae) is by far the most widespread fern.

Endemism

Some families and genera are characterised by relatively high numbers of Tasmanian endemics. Endemism increases with distance from the submerged Bass Strait landbridge, with altitude, and with geological uniqueness (Brown *et al.* 1983; Kirkpatrick and Brown 1984a). Many of the dry sclerophyll endemics are found on dolerite, a substrate which is widespread in Tasmania but rare on south-eastern mainland Australia. Dry sclerophyll endemics are often associated with environments which are particularly drought-prone or subject to other forms of environmental stress. The dry dolerite foothills and tiers of the central east coast are a major centre of local endemism (Kirkpatrick *et al.* 1980; Kirkpatrick and Brown 1984a, 1984b), with some genera, such as *Epacris*, appearing to be actively speciating in this area (Crowden 1986; Williams and Duncan 1991).

Serpentinite outcrops in the north and west of the State form other centres of local endemism (Brown *et al.* 1986), in this case the soils being effectively infertile because high levels of manganese inhibit nutrient uptake by plants. Dry sclerophyll genera with disproportionately high numbers of Tasmanian endemics include *Bedfordia, Odixia, Olearia* (Asteraceae), *Cyathodes, Epacris, Richea* (Epacridaceae), *Westringia* (Lamiaceae), *Eucalyptus, Leptospermum* (Myrtaceae), *Lomatia, Orites* (Proteaceae), *Spyridium* (Rhamnaceae), and *Danthonia, Deyeuxia* and *Poa* (Poaceae).

Non-vascular plants

The non-vascular flora of dry sclerophyll forests and woodlands remains largely unstudied. Abundance and diversity of bryophytes and lichens appear to be less than in wetter forest types, although high altitude doleritebased forests can support a rich crustose lichen flora. Ratkowsky *et al.* (1989) recorded 35 species of macrolichens from dry sclerophyll forests on the Wellington Range, which was similar to the numbers recorded for other forest and non-forest vegetation types. The dry sclerophyll bryoflora of the Wellington Range, and its recovery from the 1967 wildfire, are described by Ratkowsky *et al.* (1989).

The composition and structure of dry sclerophyll understoreys at any site are strongly related to environmental variables, particularly susceptibility to drought and water logging, nutrient status and fire history. Herbaceous species attain their greatest diversities on dry but fertile sites. The understorey of poorly drained sites contains a high proportion of graminoids, though epacridaceous and myrtaceous species can also be conspicuous, depending on the successional stage. The highest diversity of shrub species occurs on relatively infertile or rocky sites. An increase in site moisture availability and fertility is paralleled by a decrease in understorey xeromorphy, with mesomorphic shrubs becoming more prominent in the understorey.

2.11 Dry sclerophyll communities

Duncan and Brown (1985) identified seven main dry sclerophyll groups, which were further subdivided into 36 communities, on the basis of their understorey characteristics and overstorey dominants. The composition and structure of the groups and communities primarily reflect variations in the major variables (drought susceptibility, nutrient status and fire history) which have encouraged the development of a sclerophyllous flora.

Subalpine dry eucalypt forests, *Callitris* dominated communities and *Allocasuarina* dominated communities are not considered any further here. Characteristics, typical species and distributions of the four major dry sclerophyll groups are detailed in Table 2.

Table 2. Structure, floristics and distribution of Tasmanian dry sclerophyll groups (after Duncan and Brown 1985).

Forest group	*Characteristics*	*Distribution*	*Level*	*Typical species*
Grassy	Trees 12-25 m, cover <10-30%. Shrubs sparse -moderate. Ground layer dense and, dominated by grasses, diversity high.	Lowland plains and hills in drier regions. Substrate mainly dolerite, basalt or mudstone.	Dominants	*E. delegatensis, E. pulchella, E. amygdalina, E. tenuiramis, E. pauciflora, E. globulus, E. dalrympleana, E. viminalis, E. rubida, E. ovata*
			Shrubs	*Acacia dealbata, A. mearnsii, Bursaria, Astroloma humifusum, Epacris impressa*
			Ground Layer	*Grasses, herbs, Lomandra, Lepidosperma, Diplarrena moraea*
Sedgy	Trees <10-20 m, cover <10-30%. Shrub density variable, diversity low-moderate. Ground layer dense and dominated by sedges, diversity high.	Widespread but generally local on poorly drained sites. Substrate various, soils often deep.	Dominants	*E. ovata, E. rodwayi, E. nitida, E. perriniana*
			Shrubs	*Leptospermum, Melaleuca, Callistemon, Acacia verticillata, Epacris lanuginosa, Sprengelia incarnata, Bauera*
			Ground Layer	*Gahnia grandis, Restio australis, Leptocarpus, Lepidosperma filiforme, Empodisma, Isolepis, Gymnoschoenus, Patersonia,* herbs
Heathy	Tree <10-20 m, cover <10-40%. Shrubs <2 m dense, diversity high. Ground layer sparse, except on frequently fired sites, diversity low.	Infertile and/or siliceous substrates in lowland areas. Mainly on coastal plains, but extending to undulating sandstone terrain on the south east.	Dominants	*E. amygdalina, E. nitida, E. tenuiramis, E. obliqua, E. viminalis*
			Shrubs	*Banksia, Leptospermum, Allocasuarina, Xanthorrhoea, Acacia, Aotus, Dillwynia, Amperea, Pimelea linifolia, Tetratheca*
			Ground Layer	*Pteridium, Lepidosperma*
Shrubby	Trees 20-30+ m (Lower on exposed sites), cover 20-50%. Shrubs dense, multi-layered to 6 m, diversity moderate-high. Ground layer sparse - moderate, diversity low.	Upland and moist lowland substrates in lowland areas, or argillaceous substrate. Ground surface often rocky.	Dominants	*E. obliqua, E. delegatensis, E. amygdalina, E. sieberi, E. viminalis, E. dalrympleana*
			Shrubs	*Acacia dealbata, Bedfordia, Banksia, Exocarpos cupressiformis, Lomatia tinctoria, Pultenaea, Daviesia, Cyathodes, Epacris, Olearia*
			Ground Layer	*Pteridium, Blechnum nudum, Polystichum, Dianella tasmanica*

Grassy forests

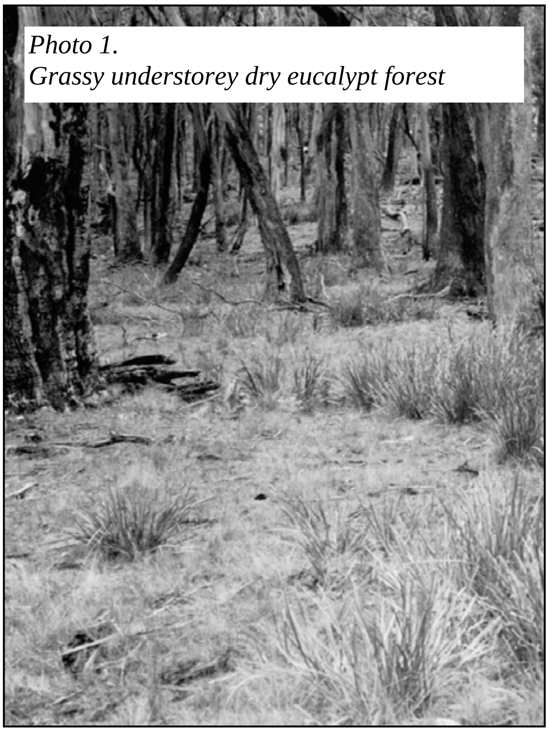


Photo 1.
Grassy understorey dry eucalypt forest

Eucalypt forests and woodlands with grass-dominated understoreys occupy sites which are relatively fertile but dry or frost susceptible. They reached their greatest extent in the broad valleys of subhumid climatic zones (e.g. Midlands and Fingal Valley), but now largely comprise remnant stands, or paddock trees succumbing to rural tree decline. This lost landscape of vast woodlands extending over hills and plains is depicted in John Glover's evocative painting of Mills Plains.

The dominant species of the grassy forests and woodlands are gums (*E. globulus, E. viminalis*), peppermints (*E. amygdalina, E. pulchella*) and ashes (*E. pauciflora, E. delegatensis*). The understorey typically comprises sparse shrub strata and a dense and diverse ground layer dominated by grasses, graminoids and dicotyledonous herbs. Understorey diversity appears to be maintained by a high frequency of cool fires or light browsing, both of which reduce the biomass of robust graminoids and enable intertussock species to persist (Fensham and Kirkpatrick 1989). The replacement of 'fire-stick farming' (Jones 1969) practised by the Aborigines with less frequent but more intense settlers' fires resulted in a restructuring of the vegetation from woodland to forest, in those areas not converted to crops or pasture. Narrow crowned, forest-form saplings and trees gradually exploited gaps between the spreading woodland-form trees (Kirkpatrick *et al.* 1988; Duncan 1990), and the understorey became increasingly shrubby. A similar process is described for cool uplands in northeastern Tasmania (Ellis 1985a).

Sedgy forests

Photo 2.
Sedgy understorey dry eucalypt

Eucalypt forests and woodlands with sedge-dominated understoreys are wide-spread but local on poorly drained sites on a variety of geological substrates. Sites with strongly impeded drainage have an open-woodland structure, and are dominated by *E. ovata* (lowlands) or *E. rodwayi* (upland or frost susceptible sites). Trees become taller and denser as drainage improves, and peppermints (*E. amygdalina, E. nitida*) and ashes *(E. pauciflora*) can also dominate or co-dominate sedgy communities. The predominance of either graminoids or shrubs in the understorey is a result of the fire regime and drainage characteristics of a site. Higher fire frequencies favour the development of graminoids (e.g. *Gahnia grandis*, *Lepidosperma* spp., *Leptocarpus tenax*, *Xyris* spp., *Gymnoschoenus sphaerocephalus*) because of their capacity for rapid vegetative regeneration. Many species of sedges are intolerant of low light levels, and are eliminated or much reduced in cover by canopy closure of taller growing shrubs (e.g. *Leptospermum* spp., *Melaleuca* spp., *Callistemon viridiflorus*, *Sprengelia incarnata*) if there are longer intervals between fires. Sedgy communities grade into shrubby, heathy or grassy communities as drainage improves, for example around the edges of marshes. As drainage becomes progressively more impeded, sedgy woodlands grade into scrub (shrubland), moorland or sedgeland.

Heathy forests

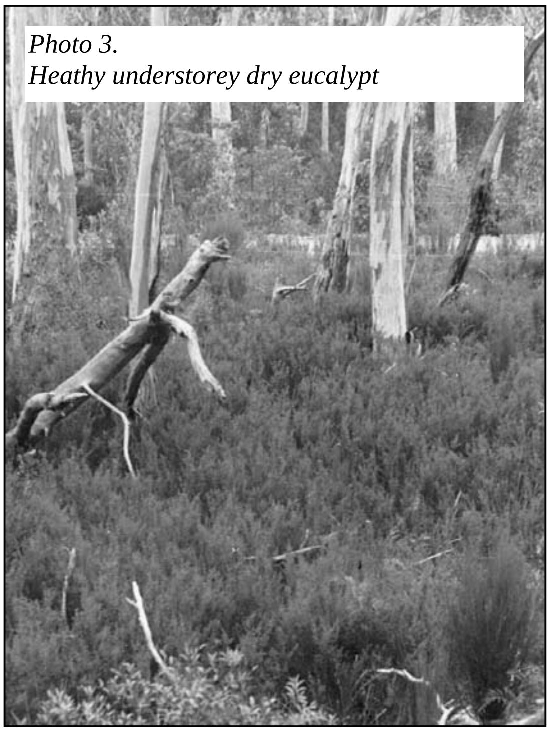


Photo 3.
Heathy understorey dry eucalypt

Eucalypt forests and woodlands with heath-dominated understoreys occur on well drained but relatively infertile siliceous substrates, in lowland areas throughout Tasmania, including the Bass Strait islands, and the successional forests and woodlands occurring in oligotrophic environments in the west and south-west. Peppermints (notably *E. amygdalina*, *E. nitida* and *E. tenuiramis*) are the main dominants, but *E. sieberi*, *E. obliqua* and occasionally *E. pauciflora* can dominate heathy communities in eastern Tasmania. The understorey in relatively undisturbed vegetation has a dense and diverse low (<2 m) shrub stratum, dominated by species of families Myrtaceae, Epacridaceae and Proteaceae. Orchids are seasonally conspicuous in a relatively sparse ground stratum. Bracken (*Pteridium esculentum*) is present as a minor species on infrequently burnt sites, but is competitively advantaged by frequent burning, which also leads to a depauperate shrub flora. Several shrub species are also susceptible to *Phytophthora cinnamomi* (Podger *et al.* 1990a, 1990b), which is wide-spread in lowland siliceous sites in all areas of the state. Heathy dry sclerophyll forests and woodlands grade into scrub and heath as sites become more exposed or infertile, into sedgy communities as drainage becomes impeded and into shrubby communities as fertility improves.

Shrubby forests

Eucalypt forests and woodlands with a multi-layered, shrub dominated understorey are widespread on comparatively fertile and well drained sites, which often have a high surface rock cover. They are the major dry sclerophyll type in dolerite uplands such as the Eastern Tiers and Western Tiers. Shrubby communities also occur on less fertile sites with relatively high moisture availabilities. Structure varies from tall open forest to woodland. Ash species (*E. obliqua* on lowland sites, *E. delegatensis* in uplands and *E. sieberi* in north-eastern Tasmania) tend to dominate on moist or shaded sites.

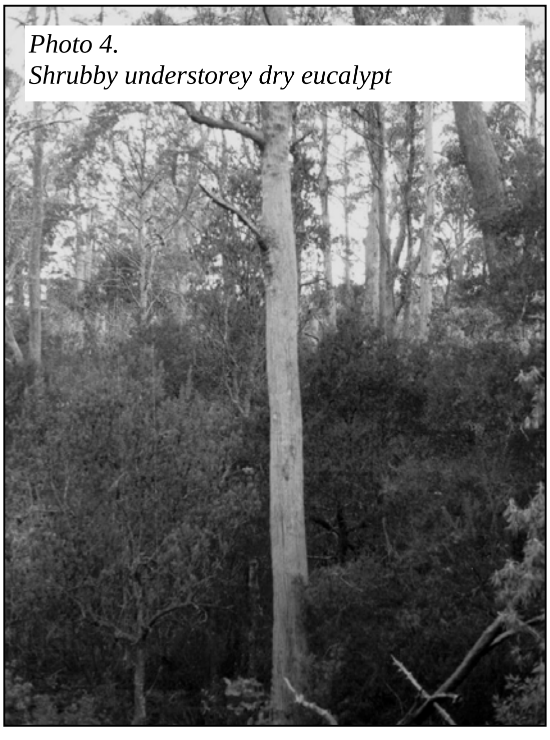


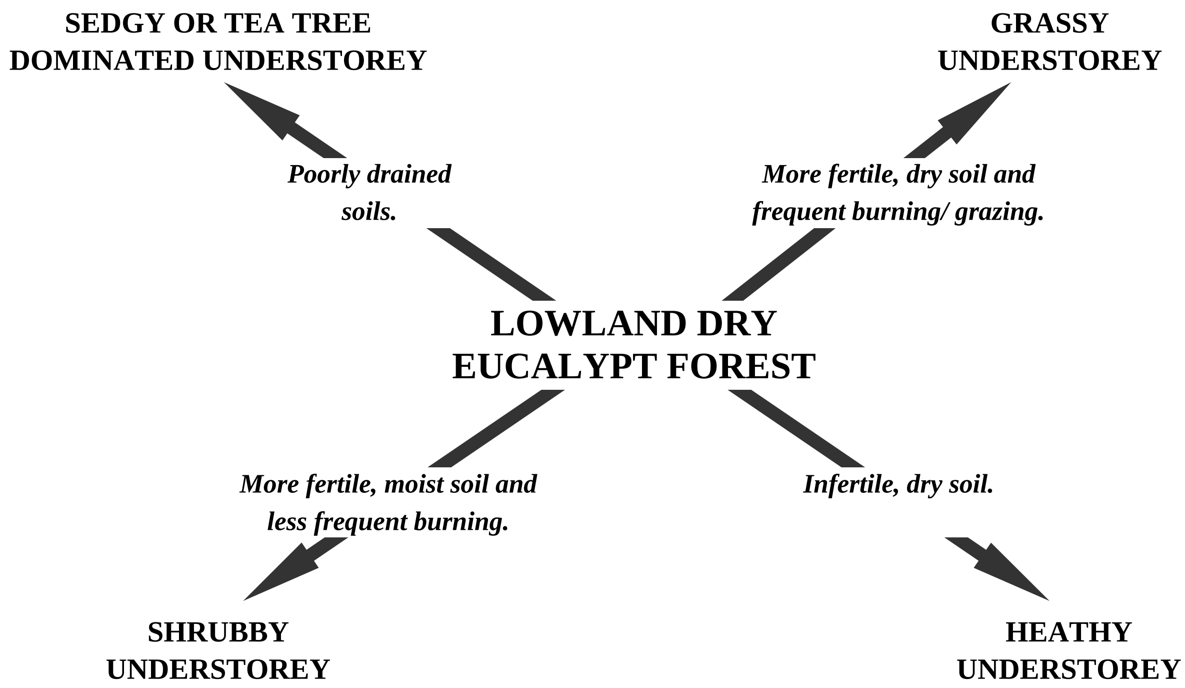
Photo 4.
Shrubby understorey dry eucalypt

Peppermints (*E. amygdalina, E. pulchella, E. tenuiramis*) co-occur on more exposed sites, often in broad ecotones between forests dominated by ashes and those dominated by peppermints. The tall shrub to small tree layer is generally sparse, with eucalypt saplings often a major component. The medium shrub layer is dense and diverse.

Density of the low shrub and ground layers is variable.

Shrubby communities on dry upland sites typically have a strong endemic component. On sites with relatively high moisture availability, mesomorphic shrubs (e.g. *Bedfordia salicina, Beyeria viscosa, Zieria arborescens, Olearia* spp.) may co-occur with xeromorphic species, the mix being defined as damp sclerophyll forests. The vegetation grades into wet sclerophyll forests as moisture availability increases and mesomorphic shrubs assume dominance in the understorey.

Figure 5. Understorey types in dry forests.



3. Regeneration from Seed

3.1 Seeding habits

Flowering in the major dry forest eucalypts is often highly variable and may differ from year to year and from one site to another (Florence 1996). The main flowering period is usually spring to early summer. Mature seed is generally produced 9-12 months after flowering. Natural seedfall occurs throughout the year but often shows a peak during autumn and spring (Todd 1991; Bassett 2001). Commercial seed collection is usually carried out during summer-autumn.

Further information on the seeding habits of eucalypts is available in Native Forest Silviculture Technical Bulletin No. 1, 'Eucalypt Seed and Sowing'.

3.2 Seedling initiation

Seedling initiation requires the coincidence of viable seed, a suitable seedbed and environmental conditions suitable for early growth.

Seed pre-treatment

Viable mature seed of most eucalypt species germinates under favourable conditions without pre-conditioning.

A few species, particularly sub-alpine species such as *E. delegatensis* and *E. pauciflora*, require cold, moist pre-treatment to break dormancy. Good timing of sowing will allow stratification to be achieved on the ground naturally. Most lowland dry forest eucalypt species do not need seed pre-treatment.

Seedbed

Germination may occur among dense plants and litter but due to inadequate supplies of light, water and nutrients the germinants rarely become established. Receptive seedbed is mineral soil which has had the litter layer removed either mechanically or by fire, exposing mineral soil, and from which the competing understorey vegetation has been removed, allowing sufficient light to reach the forest floor. In managed forests, a receptive seedbed can be created either by disturbance from logging machinery, deliberate scarification or from burning.

The area of receptive seedbed, and the length of time for which seedbed remains receptive, varies with the type of disturbance and the understorey. Lockett and Candy (1984) found that growth rates of regeneration established on both unburnt and burnt seedbed on two dry sites (approximately 850 mm and 800 mm mean annual rainfall) did not differ significantly. The unburnt treatment allowed vigorous coppice shoots to establish an initial height advantage which appeared to be maintained. The early results suggested that, on productivity grounds, the case for slash burning was not as strong in Tasmanian drier, more open, lower quality forests as in the wetter, higher quality forests.

Pennington and Ellis (1997) compared post-harvesting regeneration in a series of seed tree coupes on the East coast near Nugent. They applied regeneration treatments of burning and mechanical disturbance to different coupes both before and after harvesting. The most responsive treatment in terms of subsequent stocking was pre-harvest cultivation, which is presumably related to the fact that the site was disturbed whilst still carrying a full overstorey and hence high levels of seed. Seed in harvested heads would also be falling onto mechanically disturbed ground. They also found that burning did not contribute significantly to recruitment of new seedlings.

The trial was monitored over a five year period and by the final measurements the stocking on undisturbed seedbed was similar to that on burnt ground which supports Lockett and Candy's (1984) findings. Lack of competition appears to be more critical to seedling survival than the nature of the seedbed.

Grassy understorey dry eucalypt forest

Experience with logging and regeneration trials on the Eastern Tiers indicates that the grass sward present in the unlogged forest may quickly increase its cover following the removal of the overstorey. Grass does not readily re-invade where there has been a high intensity burn and ash bed is produced. However, areas of low intensity burn and ground disturbance are quickly invaded by grass. Eucalypt germination and establishment is good on these sites, but survival is sometimes poor and growth rates are slower than those achieved on ashbed. Grass prevents regeneration establishment by physical occupation of the seedbed and by competition for soil, water and nutrients (Ellis 1985b; Ellis *et al.* 1985).

Photo 5. A logged grassy understorey forest showing grass re-invasion and failed regeneration.

Burning just prior to logging has been trialed in an attempt to overcome regeneration establishment problems by reducing grass competition (Pennington *et al.* 2001). Grass re-invasion is slower under a forest canopy.

The trial showed that there was little advantage in terms of post-harvest stocking of the coupe and the amount of charcoal on the trees can increase the difficulty of de-barking the logs and may make them unsaleable as pulpwood (Orr and Todd 1992). Operational trials on a range of grassy peppermint forests on the east coast clearly demonstrated that regeneration after clearfelling and sowing is unreliable. When dry seasons follow harvesting there will be little in the way of regeneration (McCormick 1987). Partially harvested coupes which retain a component of mature trees in the canopy can continue to regenerate for years after the harvesting (Orr and Todd 1992) and are able to take advantage of good seasons when they occur.

Heathy and sedgy understorey dry eucalypt forest
These vegetation types are often characterised by a sparse understorey in the unlogged stand and consequently an exposed seedbed is readily obtained after logging. Sedges are often a result of a high fire frequency because of their capacity for rapid vegetative recolonisation (Duncan and Brown 1985) and often appear after logging and occupy seedbed.

If it is expected that a logged coupe will be rapidly recolonised by heaths or sedges, additional site preparation may be required to ensure seedbed remains sufficiently receptive to support regeneration. This may be achieved by hot burns or additional scarification. Poorly drained sedgy sites should be excluded from logging.

Shrubby understorey dry eucalypt forest
Shrubby understorey indicates increased moisture availability and improved site quality. Seedbed in these forests must be exposed by removal of the shrub layer. Often this can be satisfactorily achieved by disturbance associated with logging activity. Where this is not adequate, additional scarification can be undertaken.

Alternatively, broadcast or top-disposal burning can be used.

3.3 Factors affecting regeneration establishment

'Establishment' is the period from germination to when the seedling is sufficiently developed to survive and grow on to become a sapling. In better quality forests this establishment period is generally about twelve months. In drier, lower quality forests the period can be much longer as the climatic and environmental factors present can inhibit seedling growth. Establishment may take as long as four or five years on some sites, such as grassy understorey dry eucalypt forest.

Photo 6. Pre-logging burn in dry eucalypt forest showing the reduction in ground cover and creation of burnt seedbed.

Light
Dry forests are typically open with sparse understoreys, so light is usually not a limiting factor in seedling establishment. Shading of regrowth by mature trees is not thought to cause significant growth loss (Rotheram 1983). Bowman (1986a) estimated that a typical dry *E. delegatensis* forests allowed 40 to 60% of available sunlight through the canopy.

Water stress
Dry forests occur in areas subject to periodic severe drought. Droughts at seedling establishment can lead to substantial losses and severe understocking. This is both unpredictable and unavoidable. Saplings die occasionally after a prolonged drought, especially where they are on shallow soils.

Unburnt slash piles are likely to be accompanied by increased soil moisture as a result of the mulching effect of dead leaves and reduced evaporation resulting from decreased wind velocities and increased shading. Retained trees are more likely to compete with regeneration for moisture rather than light in the more open dry eucalypt forests (See 3.3).

Temperature
Dry forests are typically subjected to hot dry winds during the summer and severe frosts and exposure during the winter. Abnormally high or low temperatures out of season are likely causes of significant damage and seedling losses.

Eucalypt seedlings may initially have difficulty establishing on very exposed ashbed in these drier forests. This has been attributed to “ashbed death” (Fagg 1981) which is possibly caused by high soil temperatures (Cunningham 1960) or desiccation (Dexter 1967; De Bano and Rice 1973). Observations indicate that seedlings that do establish on or alongside exposed ashbed often have growth rates superior to those achieved on other seedbeds.

Frost can heave small seedlings from loose friable soils. The seedlings roots are lifted by the formation of icicles in the ground and later soil subsidence leaves the roots exposed, which usually results in death. Frost can also damage the leaves and kill new shoots. Growth will be inhibited and small seedlings may be killed.

The weather records in Appendix 1 show that frosts are most likely to occur in July, with that month recording between 12 and 16 frosts. Frosts in the middle of winter do not cause as much damage as those during autumn and spring. Seedlings are most susceptible during periods of rapid growth when unseasonal frosts can severely damage the soft growing tips and split stems causing death by ringbarking.

Unburnt slash which forms natural cages and a degree of canopy retention provides some environmental protection against frost.

Photo 7. A fallen head with accompanying seed source that has protected establishing seedlings from harsh climatic conditions and browsing.

Soil factors
Many dry forests are characterised by soils of low fertility with rock or impeding layers which restrict root growth. The forests on granites and sandstones establish and grow very slowly, probably as a result of moisture and nutrient limitations. A heathy understorey indicates poor nutrient availability whereas the other understorey types occur on more fertile soils. There is some evidence to indicate that a grassy understorey may cause microbial changes within the soil which have an inhibiting effect on seedling establishment and growth (Ellis 1985b; Ellis *et al.* 1985).

Overwood competition
The suppressive effects of overwood on regrowth have been demonstrated for a number of eucalypt species (e.g. Ellis and Graley 1987; Bauhus *et al.* 2000 and see recent review by Bassett 2001). Possible causes are competition for moisture or nutrients and allelopathy. In dry forests, competition for moisture appears to be a major factor (Rotheram 1983; Bowman and Kirkpatrick 1986b).

The growth of regeneration is strongly affected by both the proximity of individual seedlings to retained trees, and by the total stocking of retained overwood. Rotheram (1983) found that in karri (*E. diversicolor*) forests, growth of regeneration was suppressed within an area of up to two crown radii around the bole of veteran trees.

For *E. sieberi* stands in Victoria, Incoll (1979) found that the zone of suppression was closer to four to six times the radius of the overwood crown. The total effect of retained trees on regeneration is very pronounced at high retention rates. Rotheram (1983) estimated that each 5% in overwood crown cover was associated with a 10% reduction in regrowth stem volume. For example, in karri, a 15% crown cover of veterans would reduce regrowth volume by 30%. (A 15% crown cover equates to 5 trees/ha with crown radii of 10 m or 19 trees/ha with crown radii of 5 m).

Retention of 12, 60 cm dbhob seed trees per hectare is equivalent to a retained basal area of less than $4m^2$/ha.

At this level of retention, (which is the maximum recommended for seed tree retention harvests, see Part A), there is very little suppression of the regeneration. In order to ameliorate climatic effects, to prevent grass invasion and to provide an ongoing supply of seed, some overwood must be retained. This is considered to be more important than the potential loss of productivity which arises from suppression of the regeneration by the retained trees.

Browsing
The browsing of native forest regeneration by native mammals can cause significant damage to individual seedlings and reductions to stocking and growth in many coupes in the first two years after sowing (Cremer 1969; Edwards and Wilkinson 1992; Forestry Commission 1992).

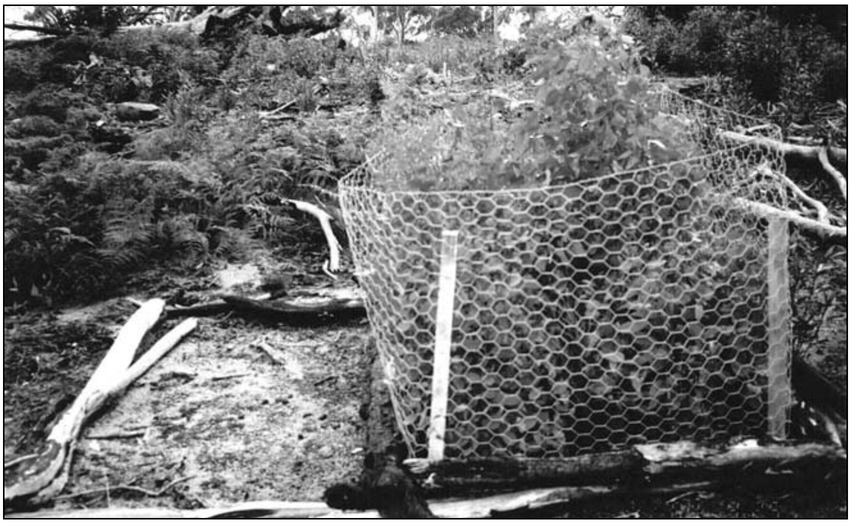


Photo 8. Unbrowsed seedlings in a fenced indicator plot on the right.

Other causes of understocking include inadequate seed supply, frost, drought and insect damage, disease, and, in wet eucalypt forests, poor burns. For more information on browsing damage and control see Technical Bulletin 12 (Forestry Tasmania 1999).

Insects
Damage by leaf eating insects is common throughout dry forests and severe defoliation can lead to death of seedlings. During a prolonged dry spell on the East Coast, cotyledon browsing by cut worms (*Agrotis* spp.) caused significant losses (H. Elliott pers. comm.). Other insects likely to damage regeneration include chrysomelid beetles, sawflies, weevils, psyllids, scales and leaf skeletonisers (Elliott and de Little 1985).

Wood and bark feeding insects such as weevils, longicorn beetles and swift moths can cause damage by boring in living plant tissue. Seed eating insects may attack eucalypt seed in the capsule or after it falls on the ground.

Ants are a major predator of eucalypt seed on the ground (Ashton 1979).

For more information on insect damage and control see the “Pests and Diseases Management Plan” (Forestry Commission 1991).

3.4 Early growth patterns

Observations indicate the following problems may be encountered:

- Dry forests on harsh sites often have good seedling germination but this is often followed by high mortality.

- The early high mortality necessitates an abundant seed supply to ensure that all the favourable niches receive seed. If the seed for a dry forest coupe is to be entirely artificially sown, a higher sowing rate than for moister sites will be required (refer to Technical Bulletin No. 1. 'Eucalypt Seed and Sowing').

- Growth rates are very slow during the establishment period. A grassy understorey trial in the Eastern Tiers had mean seedling heights of only 20 cm at age four years (McCormick 1987).

- Seedlings in dry forests often have a 'flattened-top' appearance, caused by insect and mammal browsing and/or climatic factors. Most seedlings eventually grow out of this shape although sapling form is sometimes multi-leadered.

4. Regeneration from Advance Growth and Coppice Shoots

4.1 Advance growth

Advance growth in dry forests may persist for decades as semi-dormant lignotuberous seedlings or as suppressed saplings. A lignotuber is the woody swelling at the base of a seedling stem, originating from axils of cotyledons and first formed leaves and containing much bud-producing tissue capable of forming coppice shoots when the old shoot is destroyed (Hillis and Brown 1978).

The development of a lignotuber endows a seedling with outstanding capabilities to persist for many years in the presence of substantial competition, to recover promptly from frequently repeated destruction of its shoots by fire or insects, and, after the lignotuber and roots are sufficiently developed, to grow rapidly into a sapling as soon as competition is sufficiently reduced (Hillis and Brown 1978).

Most advance growth responds rapidly following the removal of the overstorey and multi-stemmed seedlings develop a well-formed dominant shoot. Kellas *et al.* (1987) showed that regrowth stems of *E. obliqua* which had been suppressed for at least 25 years were able to respond appreciably in basal area and height growth following release from competition. The magnitude of growth response increased with increasing crown dominance and degree of release. Wherever possible, advance growth should be retained as a future crop.

4.2 Coppice

Coppice shoots arise from strands of bud-producing tissue that originate from leaf axils and persist within the phloem. At least some of the inner bark on the stump must remain intact after felling if coppice is to be produced. The capacity of stumps to coppice varies with species, age and, in some cases also with the season of cutting and the environment (Hillis and Brown 1978). Victorian studies on low elevation *E. sieberi/ E. globoidea* forests (Hoare and Holtzapffel 1991) showed: • coppicing capacity diminished with age;

- the effect of stump height was significant only for sapling size trees (there were twice as many coppice clusters on 60 cm high stumps compared to 10 cm high stumps);

- season of felling had no affect on coppicing capacity, although the timing of bud emergence was more rapid after summer cutting (6 weeks) than after winter cutting (26 weeks);

- season of felling did affect growth rates, with three times greater growth after winter felling than summer felling for an equivalent period of growth.

Tasmanian experience has indicated that approximately 50% of stumps produced coppice shoots still intact 10 years after logging in *E. amygdalina, E. viminalis* and *E. obliqua* forest (S. Orr, pers. comm.). In *E. delegatensis* forest rapid early growth of coppice is often lost through windthrow of the poorly anchored shoots (L. Wilson, pers. comm.).

Within dry eucalypt forests coppice may often form a substantial component of the regrowth stand, although it is not always a reliable source of regeneration.

5. Growth and Yield

A minimum age of at least 80 years is required to produce a category 3 (regrowth) sawlog of 40 cm dbh on dominant stems in E3-E4 dry eucalypt forest (McCormick 1988). This may be an optimistic figure as the development of a single stem to the minimum measurement point may take 10-20 years on adverse sites. The growth of many trees will be much less than that of the dominant stems, so a minimum sawlog rotation of 120 years may be more appropriate for poor sites.

A typical rotation of E3- to E4b lowland dry eucalypt forest could be expected to have an approximate total stand volume MAI of 1 to 3 m^3 per ha per annum.

5.1 Volume production

Unlogged dry eucalypt forests have merchantable volumes in the range 35 to 200 t per ha, although some wetter stands may carry higher volumes. Forests having less than 50 t per ha are currently regarded as noncommercial.

The proportion of sawlogs to pulpwood harvested from many dry forests is low. Poor tree form, fire scars, insect damage (termites) and a high incidence of centre rot prevents many trees from becoming sawlogs. Dry forests generally have a high proportion of the “gum” and peppermint species eucalypts, which are less preferred for sawmilling.

Typical yields from clearfelled stands are from 0-15 m^3 per ha of sawlog and 50-200 tonnes per ha of pulpwood (Forestry Commission 1987). Many operations are carried out on previously cut over stands in which lower sawlog yields can be expected.

5.2 Thinning

Thinning for silvicultural reasons is rarely economical in dry forests because of relatively low stand volume and slow growth rates. The use of uneven-aged management regimes (partial harvesting) provides a better opportunity for maximising increment on selected growing stock (McCormick and Cunningham 1989).

6. Damage to Older Stands

6.1 Fire

The evolutionary process in dry forests has adapted them to tolerate frequent light fires. They have a thick and/or fibrous stocking of bark at the base of the trunk that protects the living tissue from fire. The leaves in the crown may be burnt or scorched, but the trees recover by growing epicormic shoots and they quickly re-establish a crown. The non-ash species appear to develop lignotubers more readily than ash species and recovery of advance growth from lignotuberous shoots after fires is common.

Frequent burning may eventually change shrubby and heathy understorey forest into a grassy understorey type.

These frequent light burns are also responsible for the virtual absence of advance growth in grassy understorey forests. Damage to older trees from fire in these stands may result in centre rot (pipe) and kino-vein formation, degrading the quality of the timber. Frequent fires may cause large burn holes in the butt which may ultimately lead to windthrow.

6.2 Drought

These forests are frequently exposed to prolonged droughts which can occasionally cause tree death where soils are shallow.

6.3 Insects

Insect defoliation of older stands can be quite severe and may lead to growth losses and death of even mature trees. Heavy defoliation of dry forests by the peppermint looper (*Paralaea beggaria*) has resulted in widespread deaths in established stands. Chrysomelids and other leaf eating insects can cause significant reduction in crown leaf area resulting in growth increment losses. The dampwood termite (*Porotermes adamsoni*) attacks trees damaged by fire and will create hollow core or pipe (Elliott and Bashford 1984) resulting in substantial volume and log quality losses.

6.4 Windthrow

Many dry forests occur on very shallow soils, often with an impeding layer which restricts root growth to the upper horizons. The trees tend to form large shallow plates, rather than tap roots. They are often unstable and windthrow is likely if the stand is opened up following a wet period. Trees on soils derived from granites and sandstones appear to be the most susceptible to windthrow.

6.5 Phytophthora

Phytophthora cinnamomi is widespread throughout many dry forests which have sedgy, heathy and shrubby understoreys. Damage is greatest in the shrub layers although overstorey eucalypts have been killed on some poorly drained coastal sites.

E. sieberi, E. obliqua and *E. amygdalina* are most susceptible, while *E. globulus*, *E. viminalis* and *E. ovata*

display significant tolerance. *Phytophthora cinnamomi* may have a significant role in determining species distribution of eucalypts and understorey plants in certain areas. Information on *Phytophthora cinnamomi* is available in the 'Pests and Diseases Management Plan' (Forestry Commission 1991).

6.6 Tree decline

Dieback of dry eucalypt forests is common in the Midlands and the north-east of Tasmania (Neyland 1996) where large areas of dead and dying trees are the remnants of once-extensive woodlands (Orr and Todd 1992).

Tree decline is caused by a combination of many factors. The opening up of these forests and woodlands to agriculture and grazing, heavy use of chemical fertilisers, root disturbance from ploughing, root trampling and compaction by domestic stock and little or no recruitment of seedlings have led to significant areas of dead and dying forest. Droughts, exposure and possum and insect damage also have a detrimental effect on these remnant stands. These stands have trees with poor, thin crowns and many dead limbs and few, if any, younger trees in the understorey. Where these symptoms are identified, the stands should not be logged until more information on possible ameliorative treatments is available.

7. Silvicultural Management

Tasmanian dry forests almost invariably comprise a range of size and age classes of trees. Partial harvesting techniques which take stand structure into account and which recognise the value of retaining useful advance growth and potential sawlogs to grow on are preferred to clearfelling options which often waste much useful stock. Partially harvested coupes require less new regeneration to bring them up to a fully stocked condition and generally do not require the application of aerially sown seed. Yields from a single harvest may be lower than those achieved through clearfelling but the return time to a second harvest will be much less following partial harvesting than after clearfelling.

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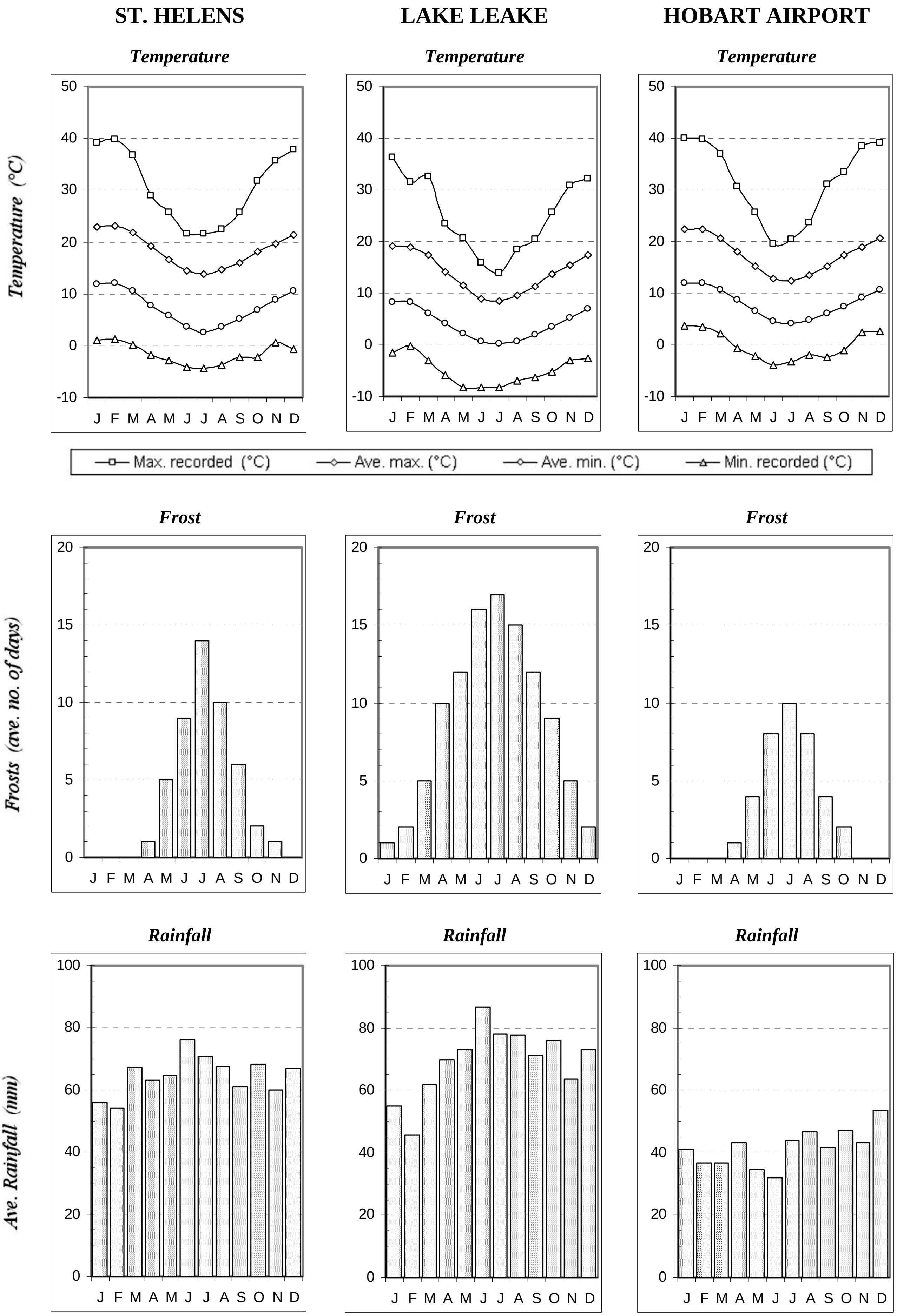
Appendix 1. Weather records



Tasmanian Native Forest Silviculture Technical Bulletin Series

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