Species Composition, Stocking and Growth of Dry Eucalypt Forest before and after Logging in Eastern Tasmania

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Abstract

Low site quality, uneven-aged, dry eucalypt forests growing on a range of sites were assessed for species composition, stocking and basal area prior to clearfelling, slash burning and aerial sowing. Similar assessments were made of the regenerated forest at age 9-10 on the same sites.

Species composition of the regeneration at age 9-10 was generally closer to that of the unlogged forests than the sowing mix used to regenerate the stand. Sowing mixes were often biased towards ash species eucalypts for both ash and peppermint/gum sites but this bias was generally not reflected in the new forests, particularly on peppermint/gum sites.

Stocking and basal area of the forests prior to harvesting ranged from 109 to 339 stems ha^{-1} and 21.9 to 42.9 m^{2}ha^{-1} respectively. At age 9-10, the stocking of the regenerated forests ranged from 984 to 5579 stems ha^{-1} (55-96% 16 m^2 stocking) with basal areas of 0.61-5.4 m^{2}ha^{-1}.

Mean diameter of stems > 5 cm dbhob in the regenerated forest varied little both between plots (7.0-8.4 cm), and between species within and between plots (6.0-8.9 cm). The bulk of the total regeneration present was of seedling origin although some coppice stems were present on all plots. The mean coppice per cent of total regeneration was 4.3 although for stems > 5 cm dbhob, coppice per cent averaged 16.9. Six of the 11 eucalypt species recorded on the plots coppiced, and growth of individual coppice stems was significantly greater than seedlings on nine of the 11 plots.

The use of alternative silvicultural systems to clearfelling and sowing in these forests is discussed in relation to the species composition of the regeneration and genetic conservation.

Introduction

Until the late 1960s, dry eucalypt forest in Tasmania was mainly selectively logged for sawlogs and for minor local products such as poles, fence posts and firewood. With the advent of a large export woodchip industry, clearfelling of all merchantable stems followed by slash burning and aerial sowing with eucalypt seed was used as the main logging and regeneration method over very large areas of dry eucalypt forest.

During the 1970s, some public concern was expressed over the effects of this practice on flora, fauna and other forest values. In 1977, a Senate Inquiry (Senate Standing Committee on Science and the Environment 1977) recommended increased research to provide more quantitative data to assist rational debate on the issue.

In 1978, the Forestry Commission established a series of plots in a range of mature dry eucalypt forests in eastern Tasmania to study the effects of clearfelling and regeneration practice on the insect fauna associated with eucalypt and non-eucalypt vegetation.

As part of this study, forests were assessed for eucalypt species composition, stocking and basal area before logging. Following logging, the plots were re-established to study these same parameters in the eucalypt regeneration for a substantial proportion of the rotation, that is, for at least 20 years.

This paper provides data on the eucalypt regeneration at age 9-10 and compares some major characteristics of this regeneration with the original unlogged forest.

Methods

Three plots were established in each of four logging coupes in uneven-aged, dry eucalypt forest in eastern Tasmania. The location and basic descriptors of these coupes are summarised in Table 1.

Each plot was rectangular, measuring 75 m x 50 m (0.375 ha), and the corners were marked with wooden pegs and wire stakes before logging commenced. Within each coupe, the three plots were located to sample the range of eucalypt species associations which were usually related to aspect.

Before logging, all eucalypts > 5 cm dbhob (diameter at breast height over bark) on each plot were tagged with aluminium markers, and their diameters measured. The numbers of stems < 5 cm were also recorded for each plot. Species composition, stocking and basal area were determined from these data.

Following logging, the plot corners were located and marked with steel pickets. The dates of logging, burning and sowing, and the eucalypt species composition (by weight) of the sowing mix were recorded for each coupe. The percentage by weight of the sowing mix was converted to number of germinants by using data on long-term averages of germinants per kilogram of seed for each species (E. Lockett, unpublished data). One plot (TO 54/1) was not logged for operational reasons, and plot EL 7/3 was left unburnt following logging.

In 1989-90 when the regeneration was aged 9-10 years, each plot was assessed (using total counts) for stock type (coppice or seedling), number of stems, species composition, and height and diameter (stems > 5 cm dbhob) of the eucalypt species. A taped 16 m^2 grid was used to locate all individual eucalypts on each plot.

Dominance of individual eucalypt species in the regenerated stand was arbitrarily assessed by comparing the number of individuals in the tallest 20 per cent of trees on the plot with their representation in the total tree count (A. Goodwin, unpublished data). This relationship was expressed as:

$$\text{'dominance value'} = 5 \times \frac{(\text{no. in tallest } 20\%)}{(\text{total no. on plot})}$$

Values > 2.0 are arbitrarily considered to indicate dominance, while those < 0.5 indicate declining dominance status.

Comparison of the species composition in the unlogged forest, sowing mix and the regenerated stand was aided by the use of a 'similarity index' (A. Goodwin, unpublished data) calculated as shown below:

$$\text{'similarity index'} = \frac{\sum_i (A_i - B_i)^2}{100}$$

where A and B are the percentages of the same species in the forests/sowing mix/ regeneration being compared.

Values of the similarity index of < 3 are arbitrarily considered to indicate very similar species composition; 3-10 indicates similar composition; and values > 10 indicate dissimilar composition.

Results

Stocking and basal area of the unlogged forest

Stocking and basal area of unlogged forest at the 12 sites are shown in Table 2. Stocking and basal area ranged from 109 to 339 stems ha^{-1} and 21.9-42.9 m^2ha^{-1} respectively. The uneven-aged nature of these dry sclerophyll

Table 1. Coupe descriptors.

Coupe	Location (1:100 000) Tasmap	Altitude (m a.s.l.)	Parent material	Photo interpretation type
SW 48	Nugent 543 940	320	Woodsdale sandstone	f'dE3&4c
MC 33	Little Swanport EP 668 392	580	Dolerite	f'dE3&4c
TO 54	Little Swanport EP 762 473	460	Dolerite	E4b.ER
EL 7	Break O'Day FQ 030 837	300	Dolerite	E4b.ER

forests makes age determination, and therefore estimates of growth rate, difficult. Estimates of age obtained by ring counts over a range of diameter classes indicated that trees on the plots ranged in age from approximately 50 to 200 years old at the time of clearfelling.

One of the 12 plots (TO 54/1), and three further plots used for insect studies in SW 51 (a coupe adjacent to SW 48) were not logged for operational reasons. These unlogged plots were also remeasured at the time of assessment of the regeneration. Growth of the trees on these plots over ten years was very slow, with mean basal area growth of only 0.17 ± 0.05 $m^2ha^{-1}yr^{-1}$. Seven per cent of the trees on TO 54/1 died in the ten-year period.

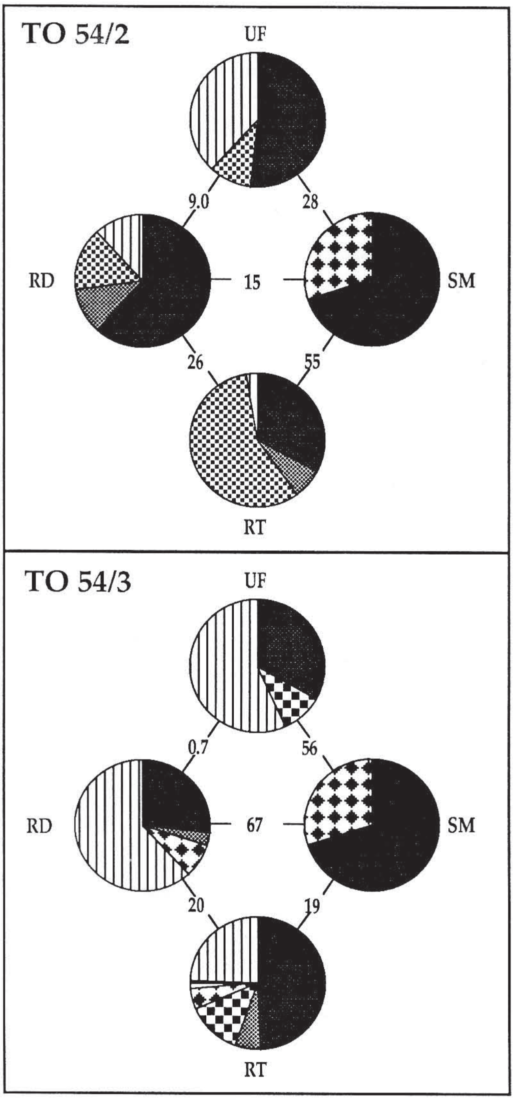
Species composition

Figure 1 shows the species composition of the mature forest, sowing mix, total regeneration and regeneration > 5 cm dbhob; similarity indices are also given. Species composition of the larger regeneration (presumably the best indicator at age 10 of the eventual species composition of the stand) is generally closer to the species composition of the forest prior to logging than to the sowing mix used to regenerate the stand. This is particularly true for the peppermint/gum sites, for example SW 48/2, SW 48/3 and TO 54/3, even though the sowing mix on these sites was biased towards the ash species.

Only on one site (MC 33/2) was there evidence that the sowing mix had significantly altered the species composition of the stand. The sowing mix for the coupe MC 33 contained 70 per cent *E. delegatensis*

Table 2. Basal area and stocking of the unlogged forests.

Plot	Stocking (stems ha^{-1})	Basal area (m^2ha^{-1})
SW 48/1	109	33.1
SW 48/2	125	25.8
SW 48/3	238	32.9
TO 54/1	296	24.3
TO 54/2	139	30.1
TO 54/3	160	23.3
MC 33/1	339	34.7
MC 33/2	291	37.4
MC 33/3	115	21.9
EL 7/1	254	32.7
EL 7/2	222	39.6
EL 7/3	178	42.9



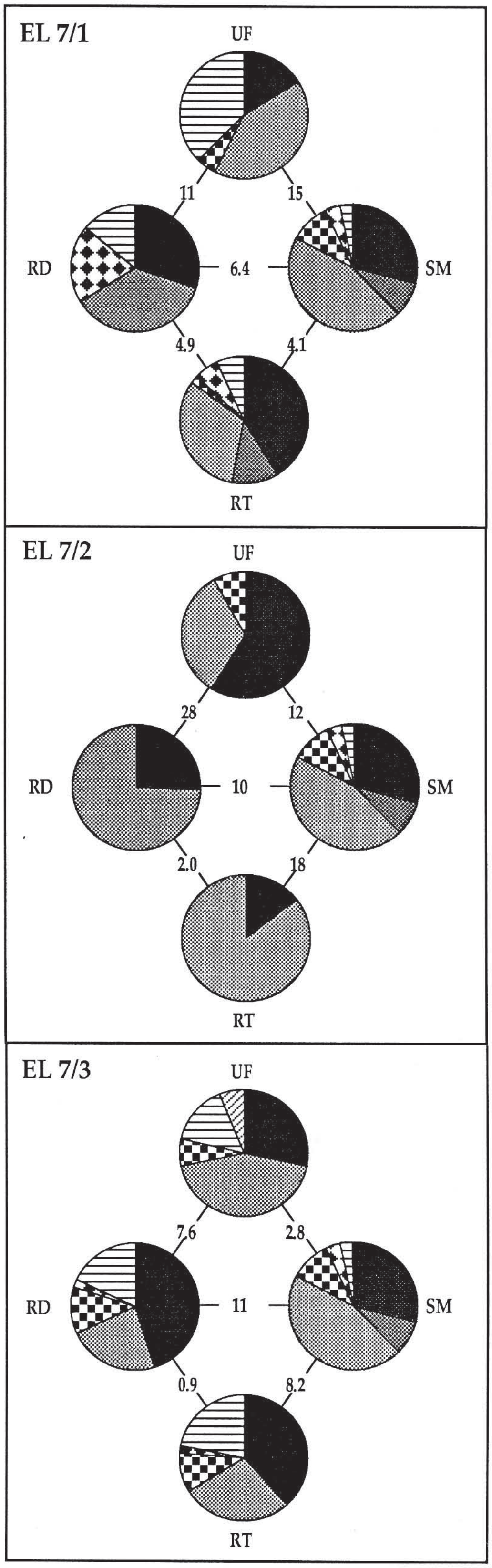
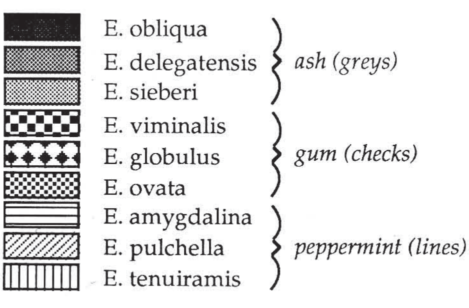


Figure 1. Species composition of Unlogged Forest (UF); Sowing Mix (SM); Regeneration - all stems (RT); and Regeneration - larger than 5 cm dbhob (RD). Similarity of species composition is indicated by the 'similarity' index. Values < 3 indicate great similarity, 3 - 10 indicate reasonable similarity, and values > 10 indicate dissimilarity.



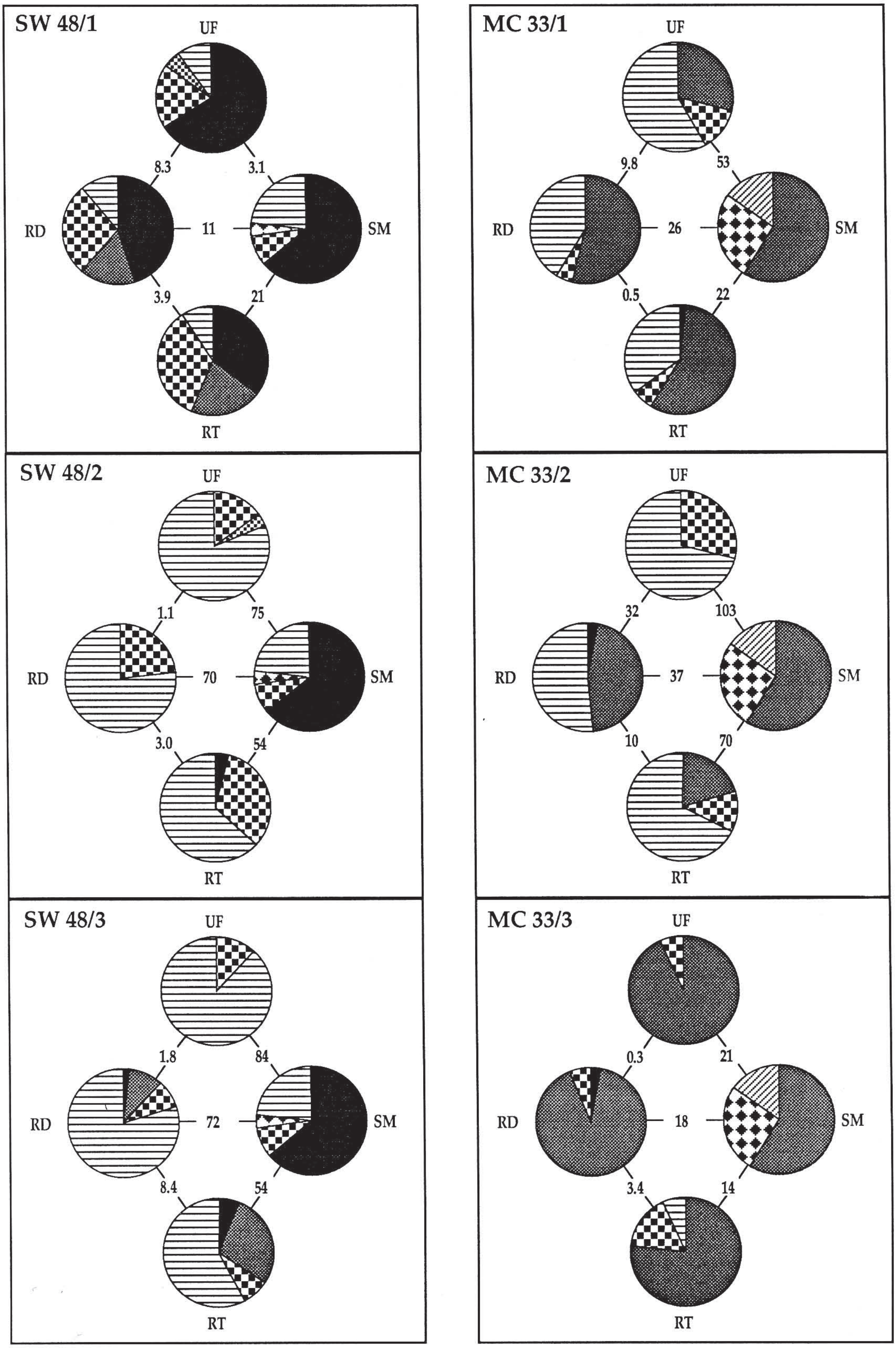

SW 48/1
UF
8.3
3.1
RD
11
SM
3.9
21
RT
MC 33/1
UF
9.8
53
RD
26
SM
0.5
22
RT
SW 48/2
UF
1.1
75
RD
70
SM
3.0
54
RT
MC 33/2
UF
32
103
RD
37
SM
10
70
RT
SW 48/3
UF
1.8
84
RD
72
SM
8.4
54
RT
MC 33/3
UF
0.3
21
RD
18
SM
3.4
14
RT

Table 3. Stocking and growth of regeneration.

Plot	Age	Stems/ha	Per cent of 16 m^2 plots stocked	Dbhob of stems > 5 cm (mean $\pm$ s.e.)	Basal area/ (m^2ha^{-1})	Mean dominant height (m)
SW 48/1	10	1 213	58	7.1 $\pm$ 0.3	1.05	6.5
SW 48/2	10	1 419	68	7.2 $\pm$ 0.2	1.42	6.4
SW 48/3	10	1 224	62	8.4 $\pm$ 0.3	2.04	7.4
MC 33/1	10	2 547	83	7.0 $\pm$ 0.3	1.65	7.1
MC 33/2	10	4 544	96	7.4 $\pm$ 0.2	3.60	7.7
MC 33/3	10	1 147	75	7.4 $\pm$ 0.2	1.62	8.3
TO 54/2	10	5 579	95	7.0 $\pm$ 0.2	3.01	7.3
TO 54/3	10	984	63	7.0 $\pm$ 0.5	0.61	5.0
EL 7/1	9	989	55	7.3 $\pm$ 0.4	0.78	6.8
EL 7/2	9	5 437	85	7.2 $\pm$ 0.3	2.83	7.7
EL 7/3	9	3 509	80	8.3 $\pm$ 0.2	5.44	11.0

and although this species was not present in the original forest on plot MC 33/2, 45 per cent of the regeneration > 5 cm dbhob at age 10 was *E. delegatensis*. *E. globulus* was included in the sowing mix for several coupes (up to 20% by weight) but, except for one site, was either absent or represented at a very low level in the regeneration.

Unmerchantable trees (culls) were left on some sites and these contributed to the regeneration; the most obvious example being at TO 54/2 where no *E. ovata* was sown but 56 per cent of the total regeneration was *E. ovata* presumably resulting from seed fall from several *E. ovata* culls left after harvesting.

At SW 48/1 and SW 48/3, *E. delegatensis*, which was neither present in the mature forest nor included in the sowing mix (according to coupe records), was strongly represented in the regeneration (21% and 28% respectively). This anomaly probably resulted from incorrect labelling of seed used to make up the sowing mix or an error in recording the composition of the mix (i.e. *E. delegatensis* was probably included in the mix).

Stocking and growth of regeneration

All logged plots were satisfactorily stocked with regeneration at age 9-10 (984-5579 stems ha^{-1}; 55-96% of 16 m^2 plots stocked). The mean diameter of stems > 5 cm dbhob was similar across all plots, ranging from 7.0 to 8.4 cm. Mean dominant height (MDH) ranged from 5.0 to 11.0 m at age 9-10, with the largest MDH occurring on the unburnt plot EL 7/3 (Table 3).

There was a reasonably narrow range of diameters between species and within individual species across plots. Species which had not occurred previously on plots also grew at a similar rate to naturally occurring species, for example *E. delegatensis* SW 48/3 (Table 4). Calculation of 'dominance values' (dv) showed that *E. globulus* (EL 7/1), *E. delegatensis* (MC 33/2) and *E. tenuiramis* (TO 54/2, TO 54/3) were assuming reasonable dominance (i.e. dv > 2.0) while *E. delegatensis* (EL 7/1), *E. viminalis* (MC 33/2, MC 33/3) and *E. ovata* (TO 54/2) appeared to be declining in dominance (dv < 0.5).

Performance of coppice

Six of the nine eucalypt species present in the regeneration had some individuals of coppice origin. Ash, gum and peppermint species all coppiced, with *E. amygdalina* being the most frequent. The coppice per cent ranged from 0.2 to 22.5 for total stems, but increased to 1.7 to 62.7 for stems > 5 cm dbhob. Coppice stems had significantly larger diameters than seedlings on nine of the 11 regenerated plots (Table 5).

Discussion

The Forestry Commission's stocking standards are based on a regeneration survey at age one or two years (Lockett 1986) and regenerated areas would typically require at least 50 per cent 16 m^2 stocking to qualify as satisfactorily stocked. The stocking achieved in the regenerated plots is indicative of the generally satisfactory stocking levels in coupes harvested and regenerated on State forest since the advent of the export woodchip industry (Tasmanian Woodchip Export Study Group 1985). In Victoria, a later age (sapling) assessment is conducted. This assessment, conducted at age four to five in fast-growing forests and at 10-15 years in slow-growing forests, requires a minimum of 492 saplings (> 2 m high and of good form) per hectare to be classed as satisfactorily stocked (Squire *et al.* 1991). Although the form of the regeneration in the present study was not assessed, it is likely that all the regenerated plots would have been satisfactorily stocked by the Victorian standards.

Although stocking has usually been satisfactory, growth of the regeneration in several low quality (E4) dry sclerophyll forests in eastern Tasmania has been slow (McCormick and Cunningham 1989). The range of diameters (dbhob) and mean dominant heights (MDH) for the regenerated plots (7.0-8.4 cm, and 5.0-11.0 m respectively) indicates a site index (expected MDH at age 50 years) range of 21.9 to 25.3 from site index curves developed for *E. obliqua* (A. Goodwin, unpublished data). The difficulties of comparing an even-aged, ten-year old stand with the uneven-aged forest prior to logging preclude an assessment of the relative growth rates of the old and the new forests. However, measurements of these plots at a later age (e.g. age 20) may enable an assessment to be made.

Table 4. Growth of regeneration of individual eucalypt species (species with more than ten individuals > 5.0 cm dbhob per plot).

Species	Plot	No. of stems in original stand (%)	Diameter* (cm)
E. amygdalina	SW 48/2	81	7.5 ± 0.3
	SW 48/3	88	8.9 ± 0.3
	MC 33/1	58	6.9 ± 0.4
	MC 33/2	71	6.9 ± 0.2
	EL 7/3	15	7.7 ± 0.4
E. delegatensis	SW 48/1	a [†]	6.5 ± 0.4
	SW 48/3	a	6.5 ± 0.4
	MC 33/1	29	7.1 ± 0.4
	MC 33/2	a	8.1 ± 0.3
	MC 33/3	93	7.4 ± 0.2
	TO 54/2	a	6.4 ± 0.4
E. globulus	EL 7/1	1	7.1 ± 1.2
E. obliqua	SW 48/1	66	7.5 ± 0.5
	TO 54/2	52	7.1 ± 0.2
	EL 7/1	16	7.5 ± 0.7
	EL 7/2	59	7.7 ± 0.7
	EL 7/3	28	8.7 ± 0.3
E. ovata	TO 54/2	10	6.8 ± 0.6
E. sieberi	EL 7/1	41	7.0 ± 0.4
	EL 7/2	33	7.1 ± 0.4
	EL 7/3	43	8.3 ± 0.6
E. tenuiramis	TO 54/2	38	7.1 ± 0.6
	TO 54/3	57	6.9 ± 0.7
E. viminalis	SW 48/1	19	7.0 ± 0.5
	SW 48/2	15	6.4 ± 0.5
	SW 48/3	12	6.0 ± 0.3

* mean ± standard error
[†] a = absent

In the early 1970s, there was optimism expressed by some people that sites could be made 'more productive' by sowing back a much higher proportion of favoured ash species on both ash and non-ash sites, and sowing mixes of the day often reflected this philosophy. In the late 1970s, the Forestry Commission's regeneration policy included a formula for calculation of a sowing mix which, although biased towards ash species,

Table 5. Incidence and growth of coppice.

Plot	Coppicing species	Coppice per cent of: Total stems	Coppice per cent of: Stems > 5 cm dbhob	Diameter (cm)* Coppice	Diameter (cm)* Seedlings
SW 48/1	*E. obliqua*	1.5	11.2	9.6 ± 0.7	6.9 ± 0.3
SW 48/2	*E. amygdalina* } *E. viminalis* }	4.7	25.4	8.6 ± 0.5	6.8 ± 0.2
SW 48/3	*E. amygdalina*	22.5	62.7	9.5 ± 0.4	6.5 ± 0.2
MC 33/1	*E. amygdalina* } *E. delegatensis* }	2.9	6.3	9.5 ± 1.9	6.4 ± 0.3
MC 33/2	*E. amygdalina* } *E. delegatensis* }	2.1	11.6	8.2 ± 0.5	7.3 ± 0.2
MC 33/3	*E. delegatensis*	1.9	4.3	8.7 ± 0.2	7.3 ± 0.2
TO 54/2	*E. obliqua*	0.2	1.7	7.1 ± 0.6	7.0 ± 0.2
TO 54/3	*E. tenuiramis*	2.4	19.2	9.2 ± 0.8	6.4 ± 0.5
EL 7/1	*E. amygdalina* } *E. sieberi* }	3.8	16.0	8.1 ± 0.9	7.1 ± 0.4
EL 7/2	*E. obliqua* } *E. sieberi* }	0.5	11.1	11.1 ± 1.3	6.7 ± 0.3
EL 7/3	*E. amygdalina* } *E. obliqua* } *E. sieberi* } *E. viminalis* }	4.6	17.6	12.1 + 0.6	7.5 ± 0.2

* mean ± standard error

more reasonably represented the species composition of the original stand (Forestry Commission, Tasmania 1978).

On the basis of the original species composition of the plots, the sowing mixes used in the study areas were often biased towards ash species on both ash and peppermint/gum sites (although, of course, the mixes were based on the species composition of the whole coupe). The results of this study are only applicable to the assessed plots rather than the whole coupe, but they indicate that sowing mixes have had little influence on regeneration composition on the plots in terms of producing higher proportions of commercially favoured species. Goodwin (1982) also found in similar forests that the species composition of regeneration tended to mimic the composition of the previous forest rather than the ash-rich sowing mix, and that ash regeneration was no more productive than the predominant peppermint or gum.

There is obviously high variability in the success of 'ash introductions' over the vast range of sites in these forests and as Goodwin (1982) states 'the long term future of such introductions is still unclear and it is imperative that non-ash species continue to be well represented'. This is assured under the current sowing prescriptions (Lockett 1991) which more accurately reflect the species composition of the stand prior to logging. The introduction of new sowing technology (use of helicopters and improved delivery mechanisms) will increase the precision of sowing to allow species to be placed on appropriate sites within coupes (e.g. *E. amygdalina* on some dry north-facing slopes) where these specific sowings are appropriate.

On most sites, cull trees of several species remained after logging and in some plots these have no doubt been major contributors to the species composition of regeneration. Although the main reason for a bias of ash species in past sowing mixes was the notion of increased productivity, another reason was that ash species tend to have fewer cull trees (i.e. future seed sources) than non-ash species (Goodwin 1982). Site specificity is an important consideration in any regeneration policy, and highly site specific species such as *E. ovata* are usually not adequately substituted for by other species (Goodwin 1982). The substantial representation of *E. ovata* in the regeneration in TO 54/2, where no *E. ovata* was sown but culls were present, supports this opinion. Most plots had low numbers of advance growth (stems < 5 cm dbhob) present after logging but these were killed by the slash burn except in EL 7/3 (no burning) where two stems remained.

A move away from clearfelling to alternative silvicultural regimes such as regrowth retention, potential sawlog retention and seed tree systems in dry eucalypt forests has occurred in recent years (McCormick and Cunningham 1989). These regimes can result in improved genetic conservation by using seedfall from retained trees rather than sowing with seed from other areas, and lower regeneration costs through less demand for expensive seed. The results from the present study provide further justification for these regimes (where stand structures and conditions are appropriate) in that species composition of the regenerated stand has generally not been influenced by manipulating sowing mixes (i.e. no commercial advantage, in terms of establishing 'more productive' species, has been gained from the sowing). However, selective logging regimes can, of course, significantly change the proportions of species which occur naturally on the site.

These results are based on measurements early in the rotation, and further assessment of the plots later in the rotation will determine whether the current species composition is maintained. However, the message from the results so far is that manipulating the sowing mixtures in order to improve productivity by favouring particular species is likely to be ineffective, particularly for ash introductions on peppermint/gum sites.

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