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Seedling regeneration, growth and density of *Eucalyptus obliqua* following partial harvesting in the Warra silvicultural systems trial. 6. The first “single tree/small group selection” coupe, Warra 5D, age 3 years

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6. The first “single tree/small group selection” coupe,
Warra 5D, age 3 years.**

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SUMMARY

Three years after the completion of harvesting, the regeneration in WR5D doesn't meet current Forestry Tasmania stocking standards (42% against 65% of 16 m² plots stocked). There are approximately 600 eucalypt seedlings to the hectare, unevenly distributed across the coupe. The mean height of the seedlings at age 3 is 0.45 m, compared to a mean age 3 height on similar seedbed across the rest of the Warra silvicultural systems trial of 1.95 m and a mean height on burnt-to-mineral soil seedbeds across the rest of the trial of 2.88 m. Both the restricted light and the nature of the seedbed are having a demonstrable effect on growth of the seedlings in WR5D. Rainforest species are establishing slowly despite persistent lyrebird scratching.

1. Introduction

Tall *Eucalyptus obliqua* forests are the most widespread and abundant commercial native forests in Tasmania, occupying some 425 700 ha (Public Land Use Commission 1996). The Warra long-term ecological research (LTER) site was established in 1995 in order, amongst other things, to focus research on this forest type (Brown 1998). Neyland *et al.* (2000) demonstrated that the tall *E. obliqua* forests at Warra are representative of many of the *E. obliqua* tall forests in Tasmania, particularly of those in southern and south-eastern Tasmania but also, with some qualification, of forests elsewhere in the State.

The Warra silvicultural systems trial (SST) was established in 1998 to explore alternatives to the ‘clearfell, burn and aerially sow’ method of wet eucalypt forest silviculture (Hickey *et al.* 2001). The first single tree/small group selection (SGS) coupe to be opened in the SST was Warra 5D (WR5D), a 10 ha coupe which was harvested to a single tree/small group selection prescription developed by a design group and described further below; the full prescription is attached as appendix 1.

This report examines the post-harvesting seedbed, seedfall and seedling establishment and growth for the first three years following the harvesting and regeneration treatment.

The null hypothesis being tested here is:

- that seedlings will establish and grow in the gaps created during the single tree/small group selection harvesting as successfully as seedlings in a clearfelled, burnt and sown coupe.

2. Methods

2.1. Study site

The Warra SST is located within the Warra LTER site (latitude: 43° 04' S; longitude: 146° 40' E) which is situated at the junction of the Weld and Huon Rivers in the southern forests of Tasmania. The SST occupies south-east facing slopes above the Huon River and ranges in altitude from 50 to 250 m asl. Slopes are gentle to moderate (<20°) and rainfall is about 1450 mm per annum. Soils are variable throughout the SST, but are largely derived from Jurassic dolerite (Laffan 2001).

The pre-harvest vegetation in WR5D was tall oldgrowth *E. obliqua* mixed forest, with small pockets of regrowth eucalypt arising from a fire which burnt through the study area in 1898 (Hickey *et al.* 1999, Alcorn *et al.* 2001). The understorey throughout the harvested area (which did not extend significantly into any of the regrowth areas) was dominated by species typical of thamnian rainforest, notably horizontal scrub (*Anodopetalum biglandulosum*), celery-top pine (*Phyllocladus aspleniifolius*), myrtle (*Nothofagus cunninghamii*), leatherwood (*Eucryphia lucida*), sassafras (*Atherosperma moschatum*) and occasional blackwoods (*Acacia melanoxylon*) together with smaller shrubs (e.g. *Orites diversifolia*, *Tasmannia lanceolata*, *Trochocarpa cunninghamii*, *Cenarrhenes nitida*, *Anopterus glandulosus* and *Aristotelia peduncularis*) and ferns (Neyland 2001).

2.2. Harvesting

The aim of harvesting was to maintain a forested environment at all times, whilst harvesting timber from small gaps using semi-permanent snig tracks. The harvesting rate of 40 m³/ha every 20 years was based on a notional mean annual increment of 2 m³/ha/year. Tree selection was determined on the basis of safety, removal of unwanted stems and the retention of any tree with the potential to produce a larger sawlog in the future. The harvesting slash was not to be burnt but piled alongside the semi-permanent snig tracks or heaped into windrows in the gaps. Regeneration would rely on natural seedfall.

Harvesting of the coupe was undertaken by a small crew working on an hourly rate rather than a piece rate, so as to not compromise the safety factors of a difficult operation. At the completion

of harvesting, the total area disturbed was approximately 1.6 ha. Harvesting commenced on the 1st May 2001 and was completed by the 21st.

2.3. Seedfall

Six 1 m² seed traps were established in the coupe on the 22nd August 2001, ie following the completion of harvesting but prior to the expected commencement of seedfall in the spring. The six traps were established subjectively in four of the gaps created during harvesting – three were located one each in three of the smaller (15 m diameter) gaps, and three in a line across the largest (45 m) gap. The contents of each trap were collected monthly from December 2001 to April 2004, taken back to the laboratory, air dried and the contents sorted. The sorted seed was placed onto damp filter paper on a germination tray, cold stratified for a week at 0° C, then moved to a constant 20° C, 24 hour light environment to germinate. Germinating seed was counted over three weeks.

2.4. Seedbed assessment

At the completion of harvesting, the entire harvested area of WR5D was surveyed using chain and compass. The coupe was mapped into three seedbed classes; disturbed mineral soil, partially corded tracks and landings with some exposed mineral soil, and deep slash, arising from the piling up of the harvesting debris at the completion of harvesting. Areas of compacted subsoil were rare, and all the exposed soil had been disturbed. As there was no burning in WR5D, the seedbed classes which applied in the other coupes within the SST were not relevant (or in other words, all the exposed seedbed in WR5D would be classified ‘unburnt/disturbed’ under the system used in the other coupes).

2.5. Regeneration

Seedling regeneration was assessed in March each year for three years after the regeneration burn, following the methods of Forestry Tasmania (1996) except that the randomly located grid was placed over the coupe with lines 10 m apart and plots located every 10 m along the lines. At each sample point a circular 16 m² plot centred on the sample point was searched for eucalypt and rainforest species seedlings (myrtle, blackwood, leatherwood, celery-top pine and sassafras). This provided a 16% sample, a much higher intensity of sampling than is usual, but the small area harvested and the broken nature of the available seedbed meant that a higher intensity sample was

required. The height of the tallest seedling on the 16 m² plot was recorded, if present, as was the mean height of the competing understorey vegetation. A schematic plan of the coupe was prepared to show where the stocked plots occurred.

2.6. Browsing

A cotyledon browsing transect was established on the 18th April 2002. Fifty eucalypt cotyledons, located in a rough line extending from the landing up through the largest gap, were marked with a wire peg.

A browsing transect of 51 seedlings was established on the 16th April 2002 to monitor browsing of eucalypt seedlings by native mammals, following prescribed operational procedures for monitoring mammal browsing of regeneration (Forestry Tasmania 1999). The transect followed an irregular line from the landing to the northern edge of the coupe. Where possible, seedlings were selected at approximately two metre intervals. In some places, due to lack of seedlings, distances between seedlings were much larger. The browsing transect was monitored monthly. The height of each seedling was measured and any browsing damage to the seedling noted.

2.7. Seedling establishment and growth – the single-tree plots

A set of single-tree plots was established to assess the influence on seedling establishment and growth of the seedbed, competing vegetation and the adjacent unharvested forest around the coupe. The plots were established in the second summer following burning (February 2003) and have been remeasured at age three years (June 2004). At establishment, there were two ages of eucalypt seedlings present, those arising from the 2001/02 season and those from the 2002/03 season. All the tagged seedlings were assigned a putative age ('Year' in results).

In the other coupes within the SST the single tree plots were located using the seedbed assessment grid. Such a grid was not established in WR5D, as explained above. Instead, a rough grid of 10 m by 10 m was randomly located over the coupe. The nearest dominant seedling to each grid point was identified, tagged with a numbered aluminium tag, and measured. Dominant seedlings were defined as seedlings that were healthy and at least as tall and preferably taller than the surrounding regenerating vegetation. As the plots were 10 m apart, the 'nearest' seedling was limited to a distance of 5 m. If no dominant seedling could be located within 5 m, nothing was

recorded for that plot. The location of each seedling was sketched onto a plan of the coupe and yellow flagging tape attached to the nearest convenient branch.

The height of each tree was measured to the nearest centimetre, the diameter of the root collar immediately above any basal swelling was measured to the nearest millimetre, the diameter of the stem either at one third of the height of the tree or 1.3 m, whichever was the least, was measured to the nearest millimetre (stem diameter), the spread of the crown in both the north-south and east-west direction was measured to the nearest centimetre. Measurements pertaining to the tree are hereafter referred to as stem variables.

The cover-abundance of the surrounding vegetation on a plot of 16 m² centred on the seedling was recorded using the Braun-Blanquet scale (1 = <1% cover, 2 = 2 to 5% , 3 = 6 to 25%, 4 = 26 to 50%, 5 = 51 to 75%, 6 = 76 to 100%) (Mueller-Dombois and Ellenberg 1974) for each vegetation guild. The mean height of each guild was measured to the nearest centimetre. The guilds used were trees, shrubs, ferns, sedges and herbs. Only eucalypts were defined as trees. The shrub layer includes tall shrubs such as dogwood, (*Pomaderris apetala*), tea tree (*Leptospermum* spp), lancewood (*Nematolepis squamea*), paperbark (*Melaleuca squarrosa*) but also includes low shrubs such as *Bauera rubioides*. In most instances plots were dominated by either tall or low shrubs. Measurements pertaining to the vegetation are hereafter referred to as vegetation variables.

The basal area of the retained trees in the adjacent unharvested forest around each seedling was assessed at age 2 years using a prismatic wedge with a basal area factor of 2. Fifty-five single-tree plots were established. Six seedlings died between establishment and the June 2004 measurement, resulting in the age three year data set comprising 49 seedlings.

2.8. Analysis of the single tree plots

All analyses of the single tree plot data were conducted using Statgraphics Plus 2.1 (Statistical Graphics Corporation 1994-1996). A Pearsons product moment correlation matrix was prepared to examine the relationships between the stem variables, the vegetation variables and the retained basal area. The mean height of the seedlings was calculated.

3. Results

3.1. Seedfall

Table 1. Total seedfall (viable seeds) in the six seedtraps (each 1 m²) by year and species.

Year	Eucalypt	Myrtle	Blackwood	Leatherwood	Celery-top	Sassafras
2001/02	16	19	96 ^{#1}	99	0	0
2002/03	85	3	1	73	0	0
2003/04	80	858	1	341	0	0

#1. Recorded in a single trap.

Table 2. Seedfall per hectare per year and total equivalent seedfall.

Year	Eucalypt	Myrtle	Blackwood	Leatherwood	Celery-top	Sassafras
2001/02	26 500	31 500	160 000	165 000	0	0
2002/03	141 500	5 000	1 500	121 500	0	0
2003/04	133 000	1 430 000	1 500	568 000	0	0
Total	301 000	1 466 500	163 000	854 500	0	0

The seedfalls above are taken from only six traps and therefore the figures for the coupe seedfall are indicative only.

3.2. Seedbed assessment

Of the harvested area of approximately 1.6 ha, about 0.8 ha was disturbed mineral soil and considered highly receptive to seed, 0.5 ha was partially covered by cording material and considered partly receptive to seed, and 0.3 ha was covered by the heaped up harvesting debris and was considered unreceptive to seed. The harvesting created a series of snig tracks generally six to ten metres wide, and a number of small clearings or gaps ranging from about 15 m diameter (small gaps) up to about 45 m diameter (large gaps). The receptive seedbed was concentrated in the gaps, notably the largest central gap, and was also found as small pieces in and alongside the cording on the snig tracks.

3.3. Regeneration

Table 3. Regeneration survey results age 1 to 3 years.

Date of survey	Stocked plots	Total receptive plots	16m ² stocking, whole coupe (%)	Seedling density (stems/ha)	Mean height of eucalypt regeneration
16/4/02	40	93	43	618	0.04 m
3/4/03	45	127	35	635	0.15 m
70/6/04	41	98	42	625	0.45 m

The seedling density is based on the mean count of seedlings on the 16 m² plots.

Table 4. Rainforest species regeneration age 2 and 3 years.

	% 16 m ² plot stocking 2003	Mean height 2003	% 16 m ² plot stocking 2004	Mean height 2004	Stems per hectare
Myrtle	17	5	17	13	670
Blackwood	54	9	56	13	1470
Leatherwood	37	6	62	12	2550
Celery-top pine	3	4	25	7	220
Sassafras	0	0	3	5	20

Rainforest species, especially leatherwood which has had the most consistent seedfall year to year, are establishing successfully, if slowly, despite the lyrebird and pademelon activity.

Typically the seedlings are located within natural caging provided by the smaller branches of felled stems. The mast seedfall of myrtle seed in autumn 2004 should improve the stocking of myrtle over the next year or so.

3.4. Seedling heights

Table 5. Mean seedling height at age 3 years in Warra 5D compared to the other coupes within the silvicultural systems trial (all results based on single tree plot data).

Mean height	WR5D	WR8C	WR1B	WR1AL	WR1AN	WR1AF	WR8B	WR8H
Coupe	62	152	138	370	366	300	295	187
Unburnt disturbed seedbed	62	92	104	290	303	224	209	145
Burnt to mineral soil	-	176	163	433	440	317	293	193

Seedling growth in Warra 5D is clearly slower than that in all the other coupes. In all the other coupes, seedlings on burnt to mineral soil seedbed are growing significantly faster than seedlings on unburnt and disturbed seedbed.

3.5. Browsing

Of the fifty seedlings tagged on the cotyledon browsing transect established in April 2002, one became an established seedling, about 15 cm high at the final measurement, two seedlings were still at the two leaf pair stage, and three were still cotyledons. The remaining 44 cotyledons had disappeared.

Of the 51 seedlings sampled in the seedling browsing transect, eleven had died by July 2004 (monitoring is ongoing as the seedlings have yet to reach 1 metre in height). Browsing in WR5D has continued at a low level (generally less than 10% of the seedlings have been browsed at any given measurement) since November 2001. The chart (Figure1) shows that seedling growth slowed over each winter and improved in each summer. The coupe has not been poisoned.

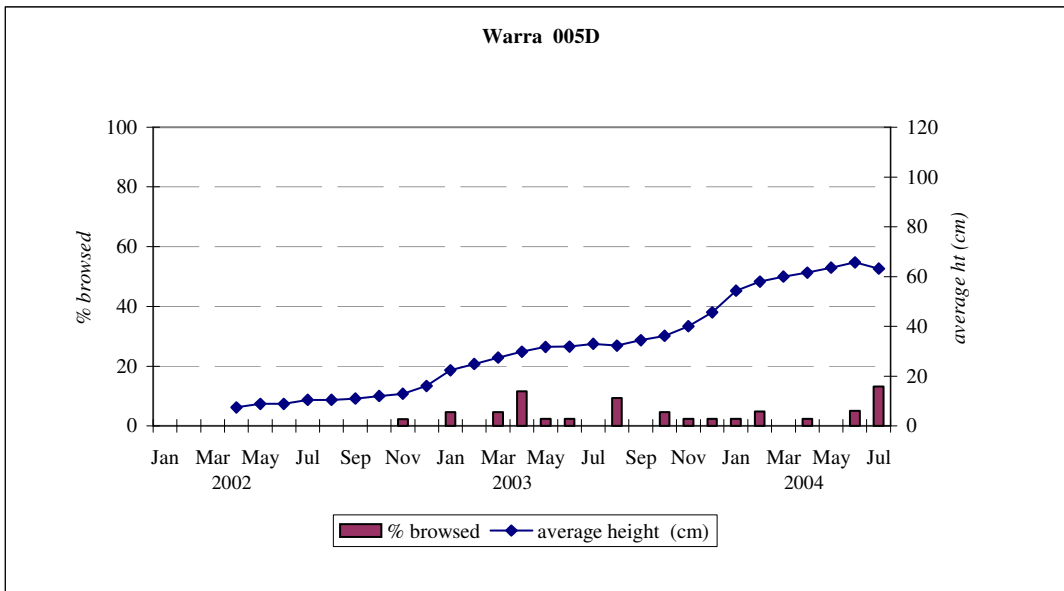


Figure 1. Average seedling height and incidence of browsing over time, Warra 5D

3.6. Seedling establishment and growth – the single tree plots

Table 4. Pearsons product moment correlation matrix. Only the most statistically significant correlations are shown ($P \leq 0.05$) (age 3 data).

	Ht	RC diam	Diam 1/3	N'th S'th	East West	Shrb cover	Shr ht	Sed cov	Sed ht	Fern covr	Ferht	Tree cover	Tree ht	BA
Height	----- -													
Root collar diameter	0.91 44	----- -												
Diam 1/3 ht	0.93 71	0.95 89	----- -											
North-south	0.86 52	0.94 19	0.92 12	----- -										
East west	0.88 70	0.93 91	0.91 07	0.94 82	----- -									
Shrub cover						----- -								
Shrub height						0.70 58	----- -							
Sedge cover								----- -						
Sedge height								0.73 42	-----					
Fern cover						0.31 66				-----				
Fern height										0.81 46	-----			
Tree cover				0.33 87	0.29 75	0.40 19						-----		
Tree height	0.30 29	0.37 47	0.40 47	0.42 38	0.38 96	0.36 16						0.85 99	----- -	
BA rtd trees			-0.28 22	-0.32 41						-0.3 099	-0.3 850			-----
Year	0.41 61	0.42 45	0.44 94	0.38 59	0.42 04							0.30 45	0.33 16	

Herbs were only present on three plots, so correlations between herb cover or height and any other factor were considered coincidences, and they have not been included in the above table.

As in all the other coupes within the SST the height of the subject seedling is closely correlated with the other stem variables –root collar diameter, diameter at one-third height and width and breadth of the crown. Tree height, defined as the height of any surrounding eucalypts only, is

also strongly correlated with all the stem variables – all the trees present in WR5D are of similar (low) stature. For shrubs, sedges, ferns, herbs and trees there is a correlation between height and cover; ie as the height increases the cover increases. The relationship between fern cover and shrub cover may be real – both are rare but on occasional plots both have been able to establish.

The basal area of the surrounding trees shows weak relationships with stem diameter, north-south spread of the crown, fern cover and fern height. These are all considered likely to be coincidences.

Year, which is the assumed age of the seedlings at the time of establishment of the single tree plots, shows a correlation with all the stem variables and tree cover and height. This indicates that the three-year-old seedlings (mean height 0.71 m) are significantly larger than the two-year-old seedlings (mean height 0.31 m).

4. Discussion

At age 3, Warra 5D has a moderate stocking of 620 stems per hectare, of slowly growing seedlings which are unevenly distributed across the coupe. Only in the largest gap (45 m diameter) ++does it appear likely that seedlings will establish and grow to maturity. Seedlings where present in the smaller gaps are etiolated, pale, insect damaged, prone to mammal browsing damage and non-vigorous. Alcorn (2002) indicated that the smallest gap in which *E. obliqua* seedlings could successfully establish was a gap of 30 m diameter, and that observation is supported by the present study.

Seedfall in WR5D has not been a limiting factor. The seed trap data clearly shows that the seedfall, particularly of *E. obliqua*, myrtle and leatherwood has been more than sufficient. In clearfelled, burnt and aerially sown *E. obliqua* coupes in the southern forests of Tasmania, the standard sowing rate of 0.875kg/ha (Forestry Commission 1991) is equivalent to 44 000 viable seeds per hectare. The eucalypt seedfall in WR5D has been at least 6 times this amount over the first three years. Myrtle and leatherwood seedfall has been more than twice as heavy as that for *E. obliqua* and autumn 2004 is clearly a mast seedfall year for myrtle. There has also been significant falls of blackwood seed, but blackwood typically regenerates from ground stored seed. There have been many blackwood seedlings observed in the coupe, but many of these have been lost to browsing by pademelons. No celery-top pine seed was recorded in the traps. Celery-top pine regenerates from ground stored seed (and 25% of the plots in the year 3 regeneration survey

were carrying small celery-top pine seedlings) so seedfall of celery-top pine is not a limiting factor to establishment. Only a single sassafras seed was recorded in the traps. Sassafras seeds regularly and the light seed is well dispersed by wind. Sassafras seedlings are very rare in the coupe, but ongoing recruitment can be expected.

The browsing transect indicates that mammal browsing has continued at low levels, particularly in winter of each year. No seedlings have died as a direct result of mammal browsing but there has been some loss of height growth. A greater impact on the coupe has been the level of lyrebird activity. At almost every visit to the coupe over the first three years, there has been fresh evidence of lyrebird scratching. Of the fifty seedlings tagged on the cotyledon browsing transect established in April 2002, only one became an established seedling. Many of the others were scratched out or buried by the lyrebirds. At age 3, much of the seedbed in the coupe still looks like it did the day that harvesting ceased – freshly exposed soil and organic matter lightly fluffed up. There is no doubt that large numbers of seedlings that may have established in the harvested area failed to do so not because of limiting light but because of the lyrebirds. There has been a mast myrtle seedfall in autumn 2004 and it will be interesting to watch the coupe over the next few years to see whether the huge myrtle seedfall can result in enough seedlings such that some establish despite the lyrebirds.

5. Conclusion

Seedling establishment and growth in WR5D is patchier and slower than in any of the other coupes within the trial. Monitoring of the coupe is ongoing as the seedlings are not yet out of the reach of the browsing mammals. A subsequent report at age 6 will further assess progress.

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Appendix 1. Revised Treatment Specifications for Single tree/ small group selection trial, Warra 5D, 8/5/2001

The 10 ha site is oldgrowth mixed forest up to 60 m tall with some 100-year-old regrowth. Safety is of primary importance. A harvesting contractor will be employed on an hourly rate to encourage safe practices rather than high production rates. The treatment specifications are:

1. Establish a safe landing with hazardous trees removed within two tree lengths of the landing.
2. Create two primary snig tracks that will be permanent, matted and extend from the landing to the back of the coupe. Temporary secondary snig tracks will extend from the primary network.
3. Remove other hazards. Trees that are a danger to any work on the site must be removed, preferably by directional felling but by blowing them down if necessary. Hazardous trees should be felled first to maximise time before personnel are required to work in the area.
4. Harvest commercial size trees (of any species) which are mature now and unlikely to produce any additional useful wood if retained. Trees that would otherwise be damaged by removal of the hazardous trees should also be harvested (depending on markets). About 40 m³/ ha will be harvested from the 10 ha site (ie recovered volume to be about 400 m³).
5. Any tree with the potential to add additional useful wood should be retained.
6. Retain at least 2-3 oldgrowth trees per 5 ha as habitat trees.
7. Damaged eucalypt trees with open wounds should be removed as long as their removal will not cause excessive damage to neighbouring trees. Any damaged myrtle trees should be removed. Moderately damaged celery-top pine trees may be decay resistant and should be retained.
8. Solid wood (including firewood) will be extracted. Any unsaleable material brought to the landing should be taken back to the forest and used as matting/cording on primary snig tracks.

9. Gaps created by harvesting should receive light disturbance of some of the soil by an excavator to create suitable seedbed (small, even tiny patches of disturbed seedbed are acceptable). Regeneration will be by natural seedfall. Burning will be excluded except for roadside landing debris which must be heaped and burnt in autumn to reduce the hazard.
10. Slash in gaps created by harvesting should be piled onto permanent snig tracks at the completion of the harvesting. Any remaining material should be flattened using an excavator so that as much of the fuel as possible is in contact with the ground where it will remain moist and eventually rot away.
11. The notional harvest volume is about 40 m³/ha every 20 years.
12. Aim to maintain 250 to 400 m³/ha of useful growing stock, and at least 75% of the forest cover at all times.
13. Priority for marketing will be 1. Veneer, 2. Sawlog, 3. Other fibre products 4. Firewood. Sawlogs should be made available to the highest tenderer.