Response of understorey floristics to pre-commercial thinning and fertilising in even-aged eucalypt regeneration

M.G. Neyland* and A.V. LaSala
Forestry Tasmania, GPO Box 207, Hobart 7001
*e-mail: mark.neyland@forestrytas.com.au (corresponding author)

Abstract

Floristic change in the understorey following thinning of the overstorey eucalypts and fertilising was monitored at three sites in southern Tasmania. The sites all carried even-aged eucalypt regeneration established following clearfell, burn and sow operations. The stands were 16–21 years old at the time of treatment. The treatments applied were thinning by direct stem injection of glyphosate, which removed 50% (at one site) and 75% (at the other two sites) of the original basal area, and fertilising, in a replicated and blocked experiment that included controls.

The floristics of the understorey were surveyed at the time of treatment and then four or five years later. The three sites carried very different understoreys, ranging from a closed layer of broad-leaved shrubs to a sparse herb-rich ground cover. Four to five years after treatment, there was no detectable change in the understorey floristics at any of the sites, with respect to either abundance or species composition, that could be attributed to the treatment. At one site, the cover of ground ferns and cutting grass increased, but this increase was independent of treatment.

The results of this experiment indicate that neither thinning by direct stem injection nor fertilising will have a major impact on the floristic structure or composition of the understorey on similar sites in the four to five years immediately following the treatments.

Introduction

Pre-commercial thinning (PCT) of dense young eucalypt regrowth by stem injection with glyphosate has recently been undertaken on an operational level throughout Tasmania, with 2500 ha treated since 1998. Pre-commercial thinning is employed to concentrate wood production onto fewer, larger stems (Connell and Raison 1996; LaSala 2000). In Tasmania, stands considered suitable for PCT are typically eucalypt regrowth aged 10–25 years, in wet sclerophyll forests dominated by *Eucalyptus obliqua* or *E. regnans* (Forestry Tasmania 2001). Injection of glyphosate directly into the unwanted stems is employed, retaining about 500 stems per hectare. Pre-commercial thinning aims to prepare the stand for a subsequent commercial thinning within 10–15 years.

Previous studies in Australia have shown that silvicultural practices such as thinning and fertilising can significantly increase the growth of the retained trees (Stoneman *et al.* 1996; Brown 1997; Connell *et al.* 1997; LaSala 2000) but there has been little work done on the response of the understorey. Bauhus *et al.* (2001) found only a minor understorey response in thinned and fertilised *E. sieberi* forests in East Gippsland, Victoria, following thinning and fertilising treatments. There were no significant effects from the treatments on understorey cover, understorey species diversity or guild

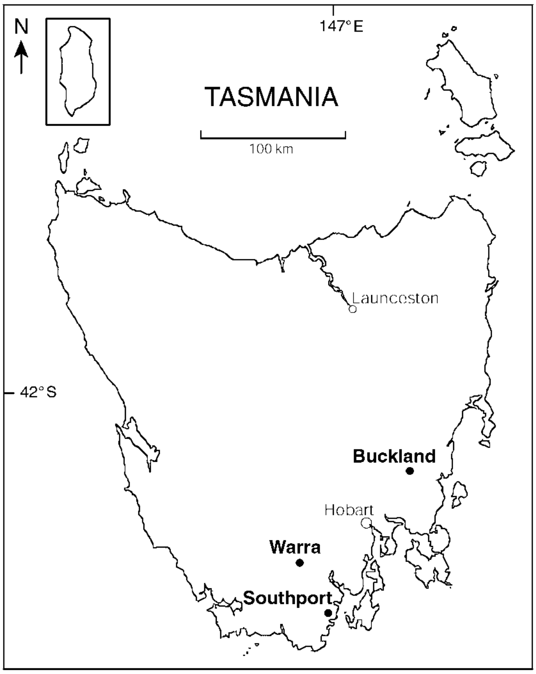

Figure 1. Location of the study sites.

diversity. The cover of bracken (*Pteridium esculentum*) was higher in the thinned and fertilised plots than in the control or the thinned plots, and the cover and relative importance of the herb *Gonocarpus teucrioides* were higher in the thinned plots compared to the control. Liangmin *et al.* (1996) found that the addition of fertilisers had no significant effect on the species composition and density of the understorey in regenerating mountain ash (*E. regnans*) forests of Victoria. In the karri forests of Western Australia, Grove (1988), studying the effects of fertilising alone, found that the low background levels of N and P can be limiting to growth of the understorey. In the same study, the density of regrowth eucalypts was shown to have a pronounced effect on the cover and abundance of understorey plants, with high eucalypt densities significantly restricting understorey development.

A research trial designed to examine the growth response of eucalypts to PCT and/or fertiliser addition was established at three sites in Tasmania in 1998 and 1999 (LaSala, in press). The stands at the three sites were all even-aged, having regenerated following clearfell, burn and sow operations (Hickey and Wilkinson 1999). The objective of the present study was to characterise the understorey vegetation at each of these sites and to monitor any changes in the understorey following stem injection and fertiliser addition. This was done in response to two concerns. The first was that the understorey may take up much of the increased water and nutrients available as a result of the treatment, thus restricting the growth response of the eucalypts. The second was that the treatments may reduce the vascular plant diversity at the sites, through competitive (e.g. by encouraging the growth of one species at the expense of another) or toxic effects.

A range of potential responses from the understorey vegetation was thus anticipated. Ground-layer species such as *Gahnia grandis* (cutting grass) and *Pteridium esculentum* (bracken) were expected to flourish with the increase in available light and nutrients that followed thinning and fertilising. The abundance and diversity of the herb-rich understorey at one site was thought likely to respond similarly, although it was also considered possible that the fertiliser could have toxic effects and therefore reduce the herb diversity. The closed, tall shrub layer at another site was expected to show little response. The null hypothesis being posed here is that the understorey vegetation, regardless of site and forest type, shows no response in terms of either cover-abundance or species richness to the thinning and/or fertilising treatments.

Methods

The present study analyses a subset of plots of a PCT and fertiliser addition experiment that was established in young *E. obliqua* stands in southern Tasmania at three sites: Southport, Buckland and Warra (LaSala, in press) (see Figure 1).

Site descriptions and vegetation

Nomenclature of plant species follows Buchanan (2005).

Southport.—Altitude of the Southport site is approximately 240 m a.s.l. The site is on a north-facing slope and receives approximately 1000 mm of rain per year (Bureau of Meteorology 2005). Based on photo-interpretation (PI) data of the previous stand (Stone 1998), the *E. obliqua* and *E. regnans* regrowth has a mature-age height potential of 41–76 m. The soils are derived from dolerite parent material.

The experiment at Southport was established in 16-year-old *E. obliqua* and *E. regnans* regeneration, with a dense wet sclerophyll understorey. The dominant understorey species were all small trees or tall shrubs: *Pomaderris apetala, Acacia dealbata, Beyeria viscosa, Bedfordia salicina, Nematolepis squamea, Acacia verticillata, Correa lawrenceana* and *Cassinia aculeata*. Others also present but less common were *Prostanthera lasianthos, Zieria arborescens* and *Olearia argophylla*. Generally, these species formed a very dense secondary stratum beneath the open eucalypt canopy. Dominant species in the sparse ground layer included *Coprosma quadrifida, Gahnia grandis, Pteridium esculentum, Senecio biserratus* and *Clematis aristata*. The last two species were both commonly present as young plants which appeared not to persist. Several other herbs, shrubs and ferns were rare in the ground layer, which was sparse throughout.

Buckland.—Altitude of the Buckland site is approximately 400 m a.s.l. The site faces north, with a slight slope, and receives about 800 mm of rain per year (Bureau of Meteorology 2005). Based on PI data of the previous stand (Stone 1998), the *E. obliqua* regrowth has a mature-age height potential of 27–41 m. The soils are derived from dolerite parent material.

The experiment at Buckland was established in 21-year-old *E. obliqua* regeneration, with an open understorey. The small shrub layer (to about 3 m high) of *Acacia terminalis* was sparse. The ground layer of *Pteridium esculentum* and *Lomatia tinctoria* was also sparse, although localised thickets of *Pteridium* were sporadic throughout the study area. Herbs, grasses and orchids were also sparse but provided some botanical diversity in an otherwise dry and open forest.

Warra.—Altitude of the Warra site is approximately 80 m a.s.l. The site faces north-east and slopes towards the Huon River. It receives approximately 1200 mm of rain per year (Bureau of Meteorology 2005). Based on PI data of the previous stand (Stone 1998), the *E. obliqua* regrowth has a mature-age height potential of 55–76 m. The reddish-brown soils are well-drained and derived from dolerite parent material.

The experiment at Warra was established in 16-year-old *E. obliqua* regeneration, with an open understorey. The dominant understorey species were ground ferns, smaller shrubs, cutting grass and herbs: *Pteridium esculentum, Histiopteris incisa, Gahnia grandis, Clematis aristata, Pimelea drupacea, Hydrocotyle hirta, Hypolepis rugosula, Dicksonia antarctica* and *Blechnum wattsii*. Taller shrubs were present, but sparse; dominants included *Acacia verticillata, Cyathodes glauca, Acacia melanoxylon* and *Leptecophylla juniperina*. Rainforest species (*Nothofagus cunninghamii, Atherosperma moschatum, Eucryphia lucida* and *Phyllocladus aspleniifolius*) were present in the understorey as widely dispersed small trees and shrubs.

Experimental design

The experimental design comprised a replicated, fully randomised, factorial experiment undertaken at three sites. The factors were thinning and fertilising. Floristic analysis occurred across plots in which thinning was applied at two levels, 0% and 50% (at Buckland) or 75%

Table 1. Basal area (m²/ha) for stems greater than 10 cm DBHOB by site, before and immediately after pre-commercial thinning (PCT).

	Southport		Buckland		Warra	
	Pre-PCT	Post-PCT	Pre-PCT	Post-PCT	Pre-PCT	Post-PCT
Control	24.6	24.6	23.1	23.1	26.1	26.1
Thinned	22.8	8.0	24.9	12.7	26.6	8.6

Table 2. Dates at which floristic assessments occurred. Figures in brackets refer to the number of months since the experimental treatment was applied.

	Warra	Southport	Buckland
Year 0	November 1998 (0.5)	August 1999 (1)	October 1999 (1)
Year 4/5	October 2003 (60)	October 2003 (51)	November 2003 (50)

Table 3. ANOVA tables comparing Euclidean distance in the NMS ordination space between plots at age 0 and at age 4/5 years with the factors block, thinning and fertilising for the three sites.

		Southport		Buckland		Warra	
Source	Df	*F*-ratio	*P*-value	*F*-ratio	*P*-value	*F*-ratio	*P*-value
Main effects							
Block	2	0.26	0.7753	0.14	0.8681	1.68	0.2538
Thinning	1	3.57	0.1009	0.21	0.6581	1.82	0.2188
Fertilising	1	4.17	0.0804	2.27	0.1752	1.14	0.3206
Residual	7						
Total (corrected)	11						

(at Southport and Warra) basal area removal, and fertilising at two levels, 375 kg/ha of N:P 4:1 and none. Thinning was done using stem injection of glyphosate to kill unwanted stems greater than 10 cm DBHOB, selected on the basis of form, size and spacing. The Buckland site had a comparatively low initial stand density so the basal area at that site was only reduced by 50%. Fertiliser was broadcast by hand. Three replicates of each treatment were established at each site and blocked across its topography (LaSala, in press).

Measured plots at Southport and Warra were 30 m x 30 m (0.09 ha) and 25 m x 25 m (0.0625 ha) at Buckland, with a 10 m treated buffer on all sides. The plots at Buckland were smaller in order to fit the experiment into the available area of relatively homogenous forest. Felling of remnant overstorey stags at the Warra experiment removed a small and randomly selected part of the standing eucalypt regrowth cover in all treatments, prior to establishment of the plots. The standing basal area at the three sites before and immediately after thinning is shown in Table 1.

Twelve plots (three replicates by two levels of basal area removal by two levels of fertilising) were established at each site.

In each plot, five 5 m x 5 m subplots were established in the four corners and the centre, and marked with wire pegs. Initial floristic surveys were conducted within one month of the experimental treatment, before the overstorey foliage had been affected by the treatment, and then four or five years later (Table 2).

At each assessment, the cover-abundance of each vascular plant species present within each 25 m^2 subplot was visually estimated using the modified Braun-Blanquet Scale (Mueller-Dombois and Ellenberg 1974): 1 = < 1%, 2 = 1–5%, 3 = 6–25%, 4 = 26–50%, 5 = 51–75%, 6 = 76–100%. All vascular plants present were identified to species level with the exception of some orchids and grasses which were identified to genus. The average cover for each species present in the plot was calculated from the values for that species from each of the five subplots.

Analysis

To compare the three sites, the data from the three study sites at year zero were combined and analysed using non-metric multi-dimensional scaling (NMS). Then, for each site, an NMS ordination was used to compare the floristics of each plot at year zero with the floristics of each plot at year four/five. All the NMS ordinations were conducted using the slow and thorough option within PC-ORD (McCune and Mefford 1999). This option runs up to 400 iterations, with an instability criterion of 0.00001. In most instances, the NMS was then repeated several times, to ensure that the final result was consistent.

The Euclidean distance between the year zero and year four/five locations in the NMS ordination space was calculated for each site. The Euclidean distance is the two-dimensional distance between the year zero and year four/five location of each replicate point in the two-dimensional NMS ordination space. As the ordination is a representation of a multi-dimensional space, some distortion is inherent (Westphalen 2003). However, NMS ordinations are the most robust of the various available ordination methods (Minchin 1987). Multi-factor ANOVA was then used to test for relationships between the Euclidean distance for the site replicates and the factors block, thinning and fertilising.

To allow closer examination of the cover-abundance data from the three sites, the mean Braun-Blanquet scores for the most common species (all the species which occurred on more than 50% of the plots) were compared for each treatment from age zero to age four/five.

Results

The NMS ordination of the combined data from all three sites at age 0 and at age 4/5 years showed that the sites were floristically distinct, both at age 0 (Figure 2a) and at age 4/5 years (Figure 2b). Therefore, straight-forward comparisons between the three sites could not be made and all subsequent analyses were conducted site-by-site.

The multi-factor ANOVAs of the relationships between the Euclidean distances between the plots and the factors, block, thinning and fertilising, found that there were no significant effects of any of the three factors on the floristics at Southport, Buckland or Warra (Table 3).

Southport.—At Southport, the broad-leaved shrub layer was dense at establishment of the trial and remained dense at the final measurement. Little change was expected in this vegetation type and little change was found (Figure 3, Table 4). There was almost no change in the cover-abundance of the most common species (Table 4). However, there was some variation in the cover-abundance of the less common species. *Clematis aristata*, which has wind-dispersed seed, was more common at age four than at age zero, although most of the individuals observed were very small plants and, from observations at the Warra site and

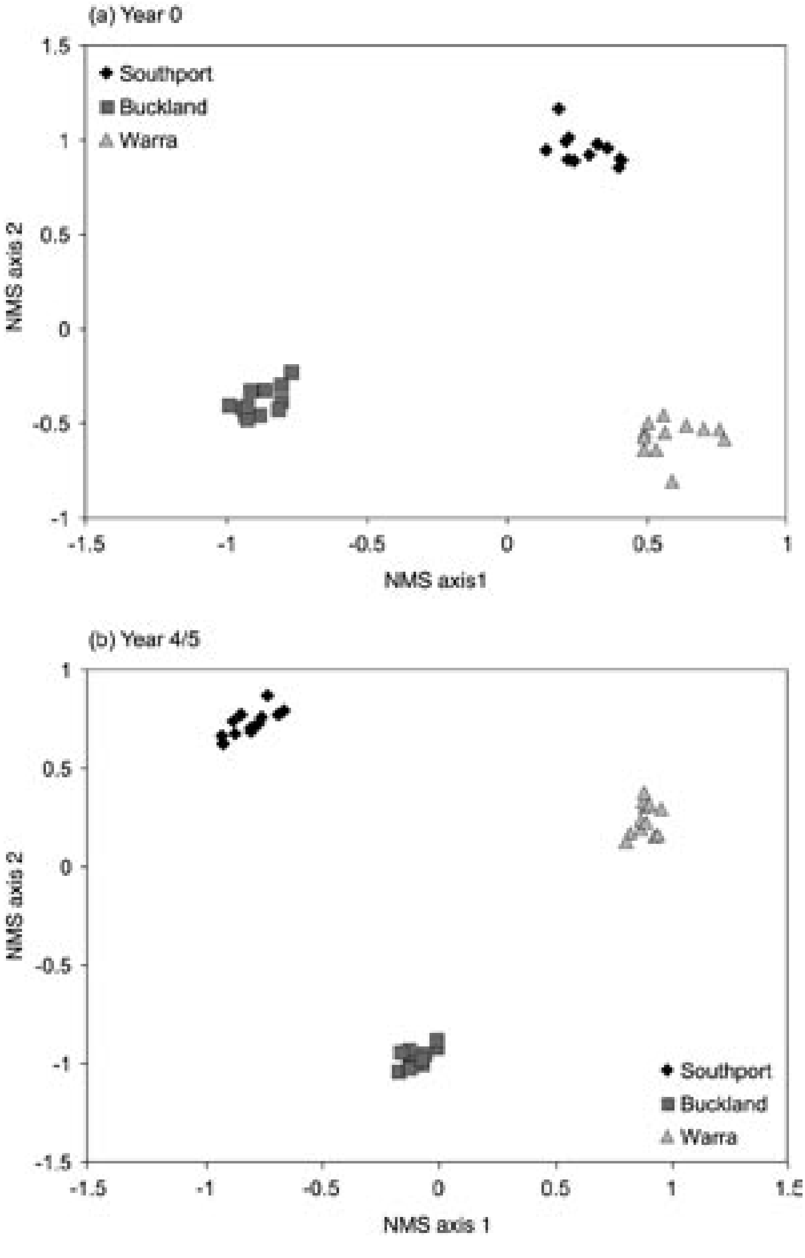

Figure 2. NMS ordination of the plots from each of three sites at year 0 and year 4/5.

elsewhere, these may not persist as they are susceptible to being buried beneath the leaf litter. *Microsorum pustulatum* (kangaroo fern), *Polystichum proliferum* (mother shield fern) and *Rumohra adiantiformis* were also more common at age four than at age zero and all were observed as small plants with immature fronds. Their presence is attributed to natural successional processes—colonisation by ferns at about this age (stand age was 20 years at final measurement) is typical of wet eucalypt forest regrowth (Peacock and Duncan 1994). There was no consistent change in the understorey vegetation in response to the thinning and/or fertilising treatments.

Table 4. Mean Braun-Blanquet scores, with standard error in brackets, by year, species and treatment for the 10 most common species at the Southport experiment: (a) thinned/unthinned plots; (b) fertilised/unfertilised plots; and (c) at year 1 and year 5.

		Acacia dealbata	*Acacia verticillata*	*Bedfordia salicina*	*Beyeria viscosa*	*Cassinia aculeata*	*Coprosma quadrifida*	*Correa lawrenceana*	*Gahnia grandis*	*Nematolepis squamea*	*Pomaderris apetala*
(a) Thinned (T) vs unthinned (Ut)											
Year 1	Ut	2.20 (0.18)	0.40 (0.16)	1.07 (0.23)	1.67 (0.27)	0.47 (0.15)	1.43 (0.14)	0.63 (0.20)	1.60 (0.23)	1.13 (0.28)	3.13 (0.13)
Year 5	Ut	2.17 (0.19)	0.57 (0.21)	1.27 (0.28)	1.80 (0.30)	0.10 (0.07)	1.53 (0.16)	0.73 (0.23)	0.77 (0.20)	1.07 (0.26)	3.53 (0.13)
Year 1	T	2.30 (0.17)	1.00 (0.24)	1.10 (0.22)	2.27 (0.24)	0.70 (0.18)	1.27 (0.14)	0.60 (0.20)	1.47 (0.23)	0.83 (0.28)	2.70 (0.22)
Year 5	T	2.17 (0.19)	1.20 (0.26)	1.33 (0.26)	2.50 (0.26)	0.63 (0.16)	1.60 (0.18)	0.77 (0.23)	1.23 (0.24)	0.80 (0.24)	2.80 (0.15)
(b) Fertilised (F) vs unfertilised (Uf)											
Year 1	Uf	2.23 (0.16)	0.37 (0.18)	1.37 (0.23)	1.63 (0.27)	0.50 (0.15)	1.43 (0.14)	0.40 (0.17)	1.30 (0.23)	0.77 (0.27)	2.97 (0.19)
Year 5	Uf	2.27 (0.19)	1.03 (0.22)	0.80 (0.20)	2.30 (0.24)	0.67 (0.18)	1.27 (0.14)	0.83 (0.21)	1.77 (0.23)	1.20 (0.29)	2.87 (0.18)
Year 1	F	2.07 (0.17)	0.43 (0.18)	1.57 (0.28)	1.77 (0.30)	0.37 (0.13)	1.83 (0.18)	0.60 (0.23)	1.27 (0.23)	0.67 (0.23)	3.20 (0.16)
Year 5	F	2.27 (0.20)	1.33 (0.27)	1.03 (0.25)	2.53 (0.27)	0.37 (0.14)	1.30 (0.15)	0.90 (0.23)	0.73 (0.21)	1.20 (0.27)	3.13 (0.16)
(c) Year 1 vs year 5											
Year 1		2.25 (0.12)	0.70 (0.15)	1.08 (0.16)	1.97 (0.19)	0.58 (0.12)	1.35 (0.10)	0.62 (0.14)	1.53 (0.16)	0.98 (0.20)	2.92 (0.13)
Year 5		2.17 (0.13)	0.88 (0.17)	1.30 (0.19)	2.15 (0.20)	0.37 (0.09)	1.57 (0.12)	0.75 (0.16)	1.00 (0.16)	0.93 (0.18)	3.17 (0.11)

Table 5. Mean Braun-Blanquet scores, with standard error in brackets, by year, species and treatment for the 10 most common species at the Buckland experiment: (a) thinned/unthinned plots; (b) fertilised/unfertilised plots; and (c) at year 1 and year 5.

		Caladenia spp.	*Ehrharta* spp.	*Gahnia grandis*	*Gonocarpus teucrioides*	*Hydrocotyle hirta*	*Lagenophora stipitata*	*Lomatia tinctoria*	*Pteridium esculentum*	*Viola hederacea*	*Wahlenbergia* spp.
(a) Thinned (T) vs unthinned (Ut)											
Year 1	Ut	0.40 (0.09)	0.90 (0.06)	0.20 (0.10)	0.87 (0.08)	0.63 (0.09)	0.67 (0.09)	1.70 (0.17)	2.50 (0.13)	0.93 (0.05)	0.33 (0.09)
Year 5	Ut	0.57 (0.09)	1.00 (0.00)	0.23 (0.12)	0.37 (0.09)	0.87 (0.06)	0.67 (0.09)	1.93 (0.20)	3.13 (0.20)	0.83 (0.07)	0.57 (0.09)
Year 1	T	0.30 (0.09)	0.83 (0.07)	0.87 (0.17)	0.93 (0.08)	0.30 (0.09)	0.70 (0.09)	1.83 (0.13)	1.90 (0.18)	0.70 (0.09)	0.23 (0.08)
Year 5	T	0.70 (0.09)	0.93 (0.05)	0.90 (0.18)	0.63 (0.09)	1.03 (0.08)	0.57 (0.09)	1.77 (0.17)	3.50 (0.20)	0.90 (0.06)	0.53 (0.09)
(b) Fertilised (F) vs unfertilised (Uf)											
Year 1	Uf	0.43 (0.09)	0.83 (0.07)	0.43 (0.13)	0.87 (0.08)	0.50 (0.09)	0.63 (0.09)	1.83 (0.15)	1.97 (0.18)	0.77 (0.08)	0.27 (0.08)
Year 5	Uf	0.73 (0.08)	0.97 (0.03)	0.53 (0.15)	0.67 (0.09)	0.87 (0.06)	0.57 (0.09)	1.73 (0.19)	2.97 (0.19)	0.90 (0.06)	0.70 (0.09)
Year 1	F	0.27 (0.08)	0.90 (0.06)	0.63 (0.17)	0.93 (0.08)	0.43 (0.09)	0.73 (0.08)	1.70 (0.15)	2.43 (0.15)	0.87 (0.06)	0.30 (0.09)
Year 5	F	0.53 (0.09)	0.97 (0.03)	0.60 (0.18)	0.33 (0.09)	1.03 (0.08)	0.67 (0.09)	1.97 (0.19)	3.67 (0.18)	0.83 (0.07)	0.40 (0.09)
(c) Year 1 vs year 5											
Year 1		0.35 (0.06)	0.87 (0.04)	0.53 (0.11)	0.90 (0.06)	0.47 (0.06)	0.68 (0.06)	1.77 (0.10)	2.20 (0.12)	0.82 (0.05)	0.28 (0.06)
Year 5		0.63 (0.06)	0.97 (0.02)	0.57 (0.12)	0.50 (0.07)	0.95 (0.05)	0.62 (0.06)	1.85 (0.13)	3.32 (0.14)	0.87 (0.04)	0.55 (0.06)

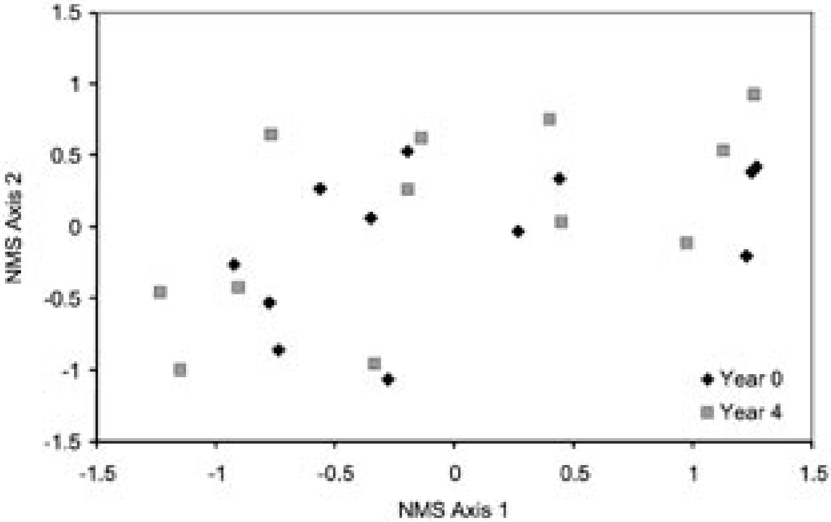

Figure 3. NMS ordination of the Southport plots from year 0 and year 4.

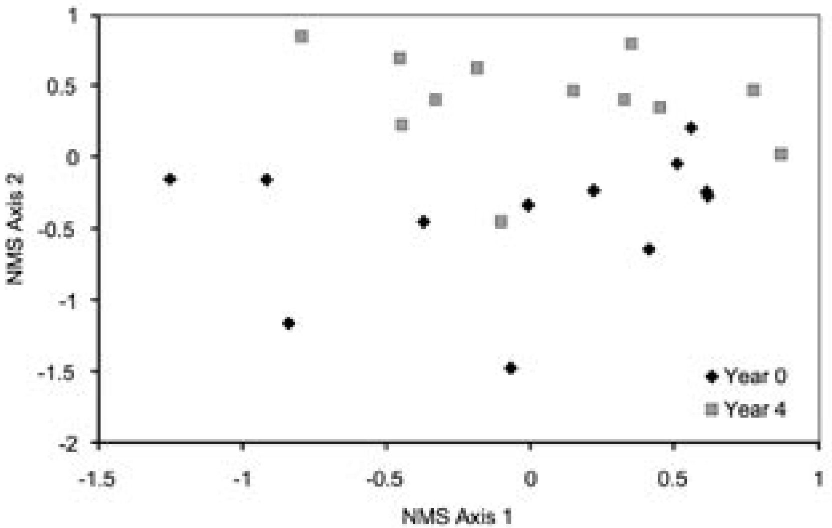

Figure 4. NMS ordination of the Buckland plots from year 0 and year 4.

Buckland.—At Buckland, the ground layer was more species-rich than at the other two sites and about half of the species recorded were grasses, herbs or orchids. Whilst some change was detected from establishment to the final measurement (Figure 4), examination of the data showed that on most plots this was restricted to the presence or absence of only a few species with generally low cover-abundance and that there was neither consistent recruitment nor loss of any species. The common species showed little change with either treatment or time (Table 5). However, the smaller herbs and grasses can be buried very easily beneath the litter layer in this forest type, and small plants are more easily missed. There was no consistent change in the understorey vegetation in response to the thinning and/or fertilising treatments.

Warra.—As at the other two sites, at Warra there was no consistent change in the

Table 6. Mean Braun-Blanquet scores, with standard error in brackets, by year, species and treatment for the 12 most common species at the Warra experiment: (a) thinned/unthinned plots; (b) fertilised/unfertilised plots; and (c) at year 1 and year 5.

		Acacia melanoxylon	*Acacia verticillata*	*Blechnum wattsii*	*Clematis aristata*	*Cyathodes glauca*	*Dicksonia antarctica*	*Gahnia grandis*	*Histiopteris incisa*	*Hydrocotyle hirta*	*Hypolepis rugosula*	*Pimelea drupacea*	*Pteridium esculentum*
(a) Thinned (T) vs unthinned (Ut)													
Year 1	Ut	0.10 (0.07)	0.60 (0.18)	0.17 (0.07)	0.80 (0.10)	0.43 (0.14)	0.40 (0.14)	1.40 (0.22)	1.00 (0.15)	0.37 (0.09)	0.27 (0.08)	0.57 (0.09)	0.87 (0.11)
Year 5	Ut	0.17 (0.08)	1.07 (0.26)	0.03 (0.03)	0.80 (0.11)	0.67 (0.20)	0.50 (0.19)	1.93 (0.24)	2.03 (0.24)	0.37 (0.09)	0.47 (0.15)	0.47 (0.09)	2.37 (0.19)
Year 1	T	0.20 (0.07)	0.50 (0.15)	0.17 (0.07)	0.50 (0.09)	0.60 (0.16)	0.13 (0.06)	0.90 (0.17)	0.70 (0.09)	0.40 (0.09)	0.37 (0.11)	0.63 (0.09)	1.07 (0.12)
Year 5	T	0.43 (0.15)	1.13 (0.27)	0.17 (0.07)	0.57 (0.11)	0.90 (0.23)	0.10 (0.06)	1.57 (0.26)	1.90 (0.29)	0.53 (0.09)	0.90 (0.21)	0.33 (0.09)	3.23 (0.20)
(b) Fertilised (F) vs unfertilised (Uf)													
Year 1	Uf	0.20 (0.09)	0.47 (0.16)	0.13 (0.06)	0.63 (0.10)	0.70 (0.17)	0.33 (0.13)	1.17 (0.21)	0.90 (0.11)	0.27 (0.08)	0.27 (0.08)	0.53 (0.09)	0.90 (0.13)
Year 5	Uf	0.37 (0.11)	0.97 (0.29)	0.10 (0.06)	0.73 (0.11)	1.00 (0.23)	0.40 (0.19)	1.70 (0.25)	1.20 (0.26)	0.33 (0.09)	0.17 (0.09)	0.40 (0.09)	2.57 (0.21)
Year 1	F	0.10 (0.06)	0.63 (0.17)	0.20 (0.07)	0.67 (0.10)	0.33 (0.11)	0.20 (0.09)	1.13 (0.19)	0.80 (0.14)	0.50 (0.09)	0.37 (0.11)	0.67 (0.09)	1.03 (0.10)
Year 5	F	0.23 (0.14)	1.23 (0.23)	0.10 (0.06)	0.63 (0.11)	0.57 (0.18)	0.20 (0.06)	1.80 (0.26)	2.73 (0.25)	0.57 (0.09)	1.20 (0.20)	0.40 (0.09)	3.03 (0.20)
(c) Year 1 vs year 5													
Year 1		0.15 (0.05)	0.55 (0.12)	0.17 (0.05)	0.65 (0.07)	0.52 (0.10)	0.27 (0.08)	1.15 (0.14)	0.85 (0.09)	0.38 (0.06)	0.32 (0.07)	0.60 (0.06)	0.97 (0.08)
Year 5		0.30 (0.09)	1.10 (0.19)	0.10 (0.04)	0.68 (0.08)	0.78 (0.15)	0.30 (0.10)	1.75 (0.18)	1.97 (0.19)	0.45 (0.06)	0.68 (0.13)	0.40 (0.06)	2.80 (0.15)

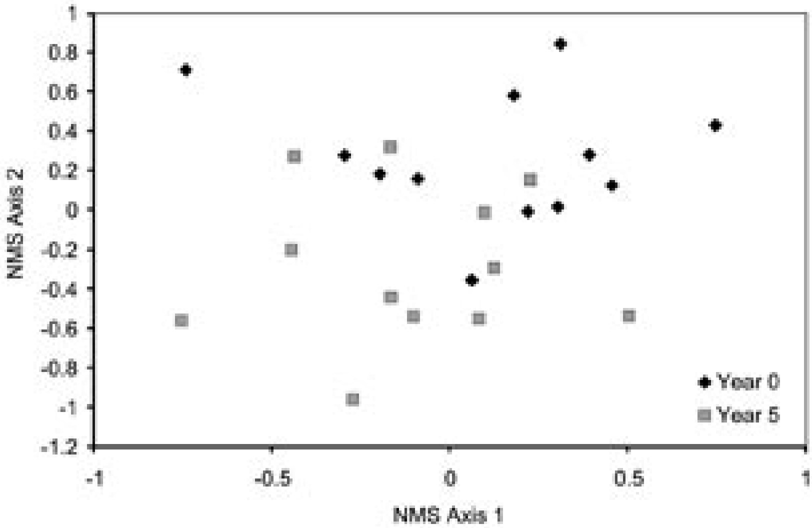

Figure 5. NMS ordination of the Warra plots from year 0 and year 5.

understorey vegetation in response to the thinning and/or fertilising treatments (Figure 5). The cover-abundance of the ground ferns (*Pteridium esculentum, Histiopteris incisa, Hypolepis rugosula*) and cutting grass (*Gahnia grandis*) increased significantly from year zero to year five but this increase occurred across all treatments (Table 6). Felling of remnant overstorey stags at the Warra experiment removed a small and randomly selected part of the standing eucalypt regrowth cover in all treatments prior to establishment. The responses observed may be related to this cull felling, or to annual variations in growing conditions.

Conclusions

Four years after thinning and fertilising at three sites with different understoreys, there had been no consistent change in the understorey vegetation attributable to the treatments. At two sites (Southport and Buckland), there was no significant change in the understorey vegetation at all. At Warra, the ground ferns and cutting grass showed a general increase in cover, independent of treatment. Bauhus *et al.* (2001) also found that bracken was one of the more responsive species. West and Osler (1995) found that understoreys dominated by cutting grass had a significant negative impact on the response to thinning of *Eucalyptus regnans* regrowth at one site. As there was no difference between the response of the understorey on the fertilised compared to the unfertilised plots at Warra, and as the retained eucalypts have shown a positive growth response to both the pre-commercial thinning and fertilising treatments (LaSala, in press), competitive effects by the understorey at Warra appear minor. There was no suggestion at any of the sites that the different treatments had resulted in a loss of any species.

At Warra and Southport, the floristics study was conducted in plots thinned 25% more heavily than is the operational norm (LaSala, in press). The lack of response by the understorey to any of the treatments imposed in this study therefore suggests that pre-commercial thinning and/or fertilising treatments as currently applied in Tasmania will have little impact on the understorey floristics on similar sites for the first four or five years after treatment.

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