Selection, harvesting damage, burning damage and persistence of retained trees following dispersed retention harvesting in the Warra silvicultural systems trial in Tasmania

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Abstract

Trees retained in two coupes after dispersed retention harvesting of wet Eucalyptus obliqua *forests were monitored for health and persistence for three years following completion of harvesting and regeneration burning. In one coupe, windthrow was the major cause of death following harvesting, although overall losses were small, at less than 10% of the retained basal area. In the other, an overly hot regeneration burn killed many trees, resulting in a net loss of 36% of the retained basal area. More than two-thirds of the loss was caused by the fire and less than one-third was caused by windthrow. More regrowth trees than oldgrowth trees were windthrown in both coupes, indicating that oldgrowth trees are relatively more windfirm than regrowth. There were no extreme windthrow events in either coupe. Most of the windthrown trees fell in the first 18 months after harvesting. Presenting slash fuels in a manner which facilitates burning, for example by using excavators to heap the slash, and lighting fires under milder weather conditions than those experienced during the burn in WR008C, will assist in improving outcomes in future dispersed retention coupes.*

Harvesting damage across the two coupes averaged 46%. The normal target for damage to retained trees in partially harvested State forest coupes is 0%, with a tolerated maximum of 10%. As damage to the cambial layer almost inevitably leads to decay columns within the stem, damage to 46% of the retained trees is clearly excessive. Future harvests of this type need to minimise damage to the retained trees, especially where they are required for long-term sawlog production.

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Introduction

The Warra silvicultural systems trial (SST) was established in 1997 (Hickey *et al.* 1999a) to test alternatives to clearfelling in the wet *Eucalyptus obliqua* forests of Tasmania. The alternatives being trialled include patchfells and stripfells, dispersed retention, aggregated retention, single tree/small group selection and clearfelling with retained understorey islands. Full details of the rationale behind the trial and the perceived advantages and disadvantages of the treatments being trialled are provided in Hickey *et al.* (2001).

In the dispersed retention harvesting treatment, about 10% of the pre-harvest standing basal area was retained, comprising both oldgrowth and regrowth trees, evenly dispersed through the coupe. The retained oldgrowth trees supply habitat, nest sites including hollows, and a future supply of coarse woody debris, whilst the regrowth trees will supply all these attributes in the future and may also provide a source of larger diameter sawlogs (Hickey *et al.* 2001).

Freshly exposed forest edges are susceptible to windthrow (e.g. Gardiner *et al.* 1997; Quine *et al.* 1995; Ruel *et al.* 2001). In the dispersed retention coupes it was anticipated that the retained trees, being isolated from their former neighbours by the harvesting, would also be susceptible to windthrow. As broadcast, low intensity burns were planned for the dispersed retention coupes, it was also anticipated that the burning would impact on the retained trees.

This paper discusses the selection, damage and long-term persistence of the retained trees in the two dispersed retention coupes within the Warra SST (WR001B and 008C) (Figure 1). WR001B (Photos 1, 2) and WR008C (Photo 3) were both harvested to a dispersed retention prescription which called for retention of 10% of the original standing basal area as a mixture of evenly dispersed oldgrowth and regrowth trees.

The area of WR001B is 14.5 ha. The original eucalypt basal area was 72.5 m^2/ha, of which 8.7 m^2/ha (12%) was retained at the completion of harvesting. WR008C is 9.5 ha. The original eucalypt basal area was 74 m^2/ha, of which 4.5 m^2/ha (6%) was retained at the completion of harvesting.

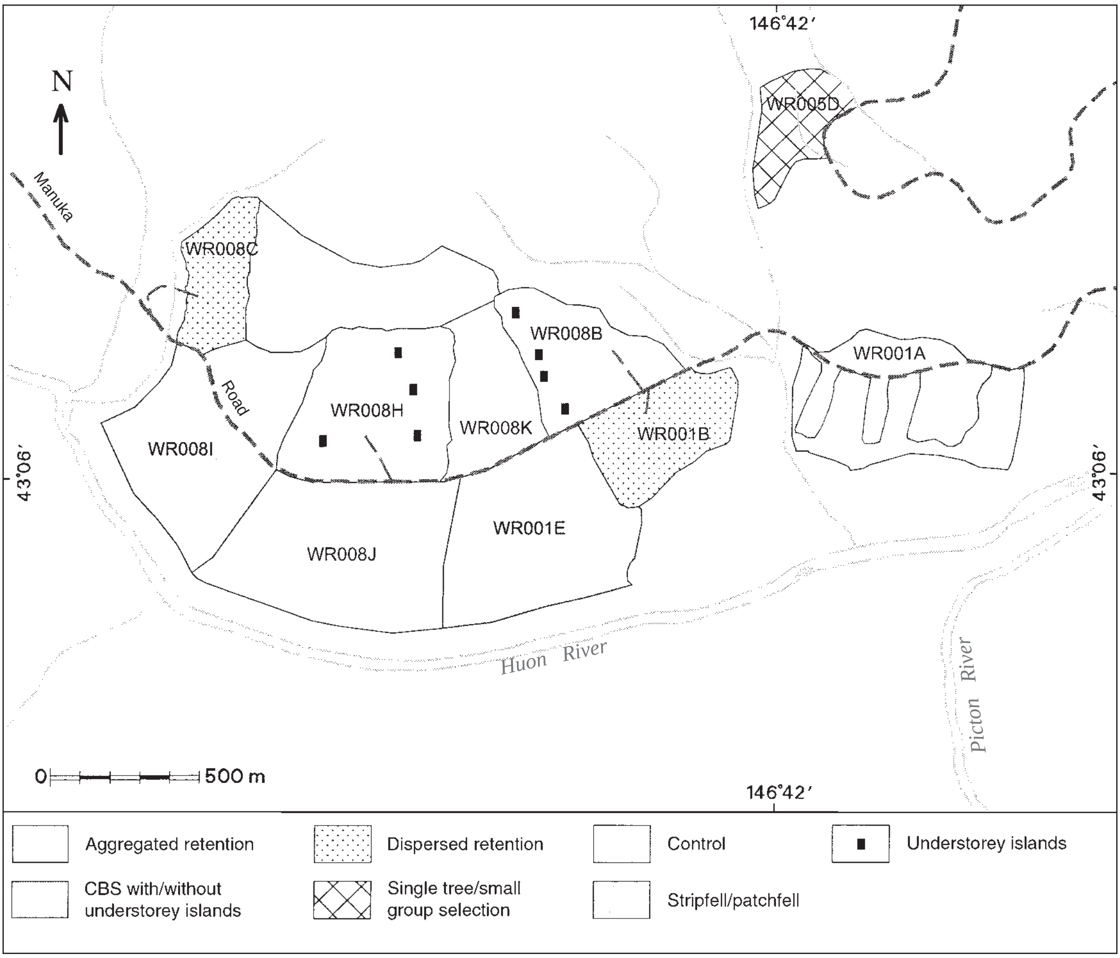

Figure 1. Map of treatments at the Warra silvicultural systems trial (from Hickey et al. *2001).*

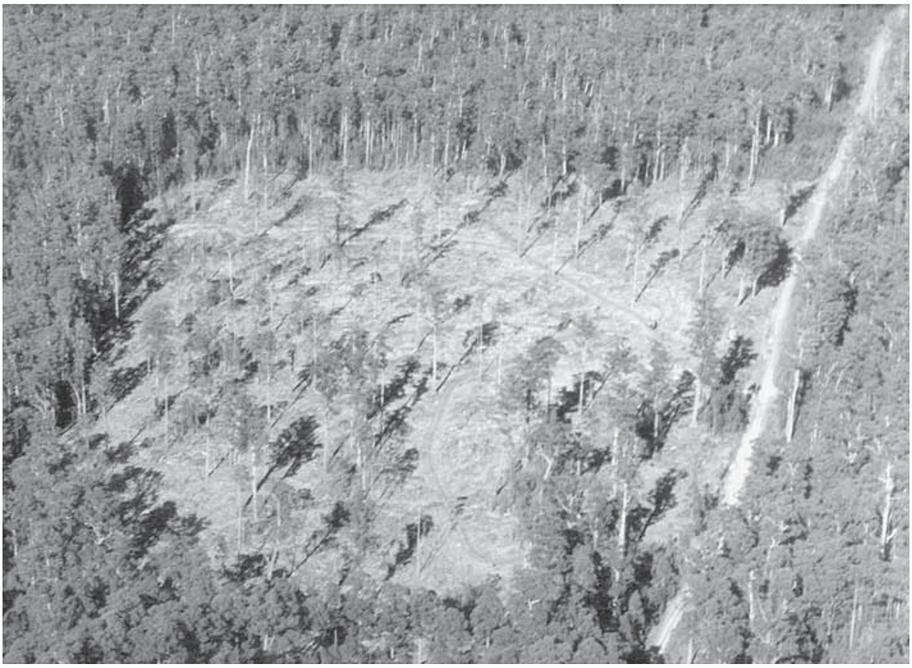

Photo 1. Aerial view of WR001B after harvesting and burning.

Photo 2. WR001B after harvesting and burning.

Photo 3. Aerial view of WR008C after harvesting and burning.

Methods

Study site

The study area is located within the Warra Long-Term Ecological Research (LTER) Site (Brown *et al.* 2001), approximately 60 km south-west of Hobart, Tasmania (43º04'S, 146º41'E). Altitude of the study area ranges from 60 to 160 m above sea level. The soils are moderately well drained to poorly drained and are mostly derived from Jurassic dolerite. The area has a temperate maritime climate, with a mean summer maximum of 16.2ºC and a mean winter minimum of 7.6ºC; the prevailing wind direction is from the north-west and mean annual windspeed is 13.6 km/h (climate information courtesy of Bureau of Meteorology, Hobart). Winter storms are characterised by strong south-westerly winds. Wet *Eucalyptus obliqua* forest extends throughout the study site (Neyland 2001).

The Warra LTER area has had a diverse fire history (Hickey *et al.* 1999b). Major fires occurred in 1898, 1906, 1914 and 1934 (*op. cit.*). The fires in 1898 and 1934 initiated regeneration throughout the study area and the 1914 fire initiated regeneration in parts (Alcorn *et al.* 2001). None of the fires was hot enough to destroy all the standing oldgrowth stems (Hickey *et al.* 1999b). The forests now comprise oldgrowth trees, characterised by their large trunks and crowns, abundant fire scars and fire-killed branches, and regrowth trees which have arisen following the various fires. Some of the regrowth trees have charcoal present on their lower stem, indicating that they are of the earlier cohorts.

At the completion of harvesting in wet eucalypt forests in Tasmania, it is routine procedure to use an excavator to clear a firebreak around the harvested area. This creates a mineral earth swathe about 4–6 m wide around the entire coupe. It also creates a line of heaped fuels, a windrow effectively, which can result in locally higher fire intensities during the regeneration burn. In all the assessments described here, both the firebreak and the windrow are treated as part of the coupe.

Table 1. Burn and disturbance classes for seedbed assessments.

B0	Unburnt (or burnt so lightly as to not affect the seedbed)	D0	Undisturbed
BL	Burnt but litter still present (minor soil heating but soil often not exposed)	D1	Revealed (litter removed from mineral soil or disturbed and aerated)
BM	Burnt to mineral soil (charcoal present over exposed and heated mineral soil)	D2	Compacted (litter removed and soil compacted, generally from machinery movement)
B2	Oxidised (intense soil heating, soil oxidation)		

WR001B

Tree selection

The harvesting prescription for WR001B called for retention of 10% of the original standing basal area as evenly dispersed trees, comprising both oldgrowth and regrowth. Trees to be retained were all marked for retention at a nominal 30 m spacing prior to the contractor commencing harvesting. Wherever the faller had concerns about the safety of retaining a particular tree, he was permitted to fell that tree as long as a nearby tree was retained instead. All trees within one tree length of the landing or major snig tracks were felled for safety reasons.

Harvesting and burning

WR001B was harvested conventionally in a ground-based operation using two excavators and a small bulldozer. The coupe was burnt at low intensity, very late in the burning season. It was hand-lit by a nine-person team walking through the coupe with drip torches. In order to minimise the impact of the regeneration burn on the retained trees, an excavator was used to rake any logging slash present away from the bases of the retained trees, prior to burning.

Assessing the burn

The intensity of the regeneration burn was determined after the burn by randomly locating a 50 m by 10 m grid over the coupe and assessing the seedbed at each grid point. The intensity of the burn and impact of the harvesting on the soil at each point was classified using the classes shown in Table 1. The presence of any intact vegetation was noted.

The burning and disturbance impacts on the soil have a combined effect in terms of the receptivity of the seedbed to eucalypt seed. However, where the soil was fully oxidised by the fire, it was not considered possible to allocate the point to a disturbance class, the oxidation having altered the soil beyond the point at which disturbance effects could be recognised.

The assessment determined the proportion of the coupe which had burnt and the intensity of the burn (where burnt), the extent of soil disturbance arising from the harvesting, and the area of live vegetation remaining after the burn.

Tree monitoring

All retained trees on the coupe were located by GPS and assessed after logging but prior to burning. Each tree was given an individual code in relation to its position on the coupe. The trees were assessed for burn damage from previous fires (in order to be able to identify damage arising from the subsequent regeneration burn), age class (oldgrowth or regrowth), merchantability class (sawlog, pulplog or cull), crown damage, stem damage (deep scrape or light scrape and cause if identifiable) and health (alive, dead or windthrown). When assigning trees to either oldgrowth or regrowth classes, both form and size were taken into account; the regrowth is generally less than 100 cm DBHOB. All the retained trees were assessed again using the criteria above, immediately after the regeneration burn, then quarterly for two years, then annually. As part of the post-burn assessment, a visual assessment of the degree of crown scorch (%) arising from the regeneration burn was also undertaken.

WR008C

Tree selection

The original harvesting prescription for WR008C was identical to that for WR001B. However, safety concerns arising at WR001B led to a number of changes in the prescription for WR008C. Due to concerns about working under the retained trees, trees marked for retention were regarded as 'preferred trees'. If they were considered unsafe for retention, they were to be felled and replaced with an alternative tree (that met the criteria), if available, within a 10 m radius. The coupe was logged using a major central north-south snig track—any oldgrowth trees within one tree height of the snig track (or landing) were to be felled and nearby regrowth trees retained instead of the oldgrowth.

In all other respects, the harvesting, retention, burning and post-harvesting and post-burning assessments of WR008C followed the methods for WR001B.

Results

WR001B

Actual retention versus planned retention

The plan for the harvest in WR001B was to retain ten trees per hectare with a retained basal area of 7 m^2/ha (about 10% of the original). At the completion of harvesting, five regrowth and four oldgrowth trees had been retained per hectare, with a mean basal area across the coupe of 8.7 m^2/ha (12% of the original) (Table 2). The trees themselves were not evenly distributed across the coupe. One hundred and forty-four trees were retained on the coupe, comprising 83 oldgrowth and 61 regrowth trees. That the retained basal area is slightly higher than planned is largely the consequence of retaining oldgrowth trees which were deemed to be too dangerous to fell.

Impacts of harvesting

Harvesting damage was recorded from 44% of the retained trees (Table 3). Sixty-two per cent of the regrowth trees and 31% of the oldgrowth were damaged in some way by the harvesting. The major problem was deep scrapes into the bark of the retained trees, caused either by machinery or felled trees striking the stem of the retained tree and knocking a section of the bark away from the cambium. Two trees suffered crown damage as a result of felled trees breaking out large branches.

Impacts of burning

The post-burn seedbed assessment of WR001B showed that about three-quarters of the coupe remained unburnt (Table 4). About one-quarter of the coupe was burnt to mineral soil or burnt to litter and only three per cent was oxidised. However, it was noted during the assessment that the burnt patches were widely distributed across the coupe, with the exception of the extreme western edge which was heavily shaded by the adjacent unharvested forest and which remained effectively unburnt at the completion of the operation.

The post-burn assessment of the retained trees found that whilst the fire had 'run up' about half the retained trees, only four trees (3%) had been severely scorched by the fire. Nine oldgrowth trees were recorded as having had hot fires in or around their bases.

Longer term impacts

The assessment of the retained trees in WR001B three years after the completion of harvesting found that five trees had died standing and 17 had been windthrown (Table 5). Three of the four oldgrowth trees

Table 2. Number of retained trees lost at WR001B, from completion of harvesting to three years later. (BA = basal area)

	Oldgrowth	Regrowth	Total	BA (m^2/ha)
Post-harvesting	83	61	144	8.7
Age 3 years	77	45	122	8.0
Loss (*n*)	6	16	22	0.7
Loss (%)	**7**	**26**	**15**	**8.0**

Table 3. Number of retained trees with harvesting damage prior to burning at WR001B.

	Oldgrowth	Regrowth	Total
Logging damage to stem	25	37	62
Crown damage	1	1	2
Total damaged trees	26	38	64
Total retained trees	83	61	144
Damage (%)	**31**	**62**	**44**

Table 4. Seedbed assessment for WR001B (%, n *= 146). (Abbreviations for burn and disturbance classes are given in Table 1; na = not applicable)*

	D0	D1	D2	**Total for each burn class**
B0	51	17	5	**73**
BL	7	6	0	**13**
BM	3	8	0	**11**
B2	na	3	na	**3**
Total for each disturbance class	**60**	**35**	**5**	**100**

Table 5. Number of dead retained trees by cause of loss at WR001B after three years (% in brackets).

	Oldgrowth	Regrowth	Total
Fire-killed	3 (14)	1 (5)	4 (18)
Windthrown	2 (9)	15 (68)	17 (77)
Died standing (unknown cause)	1 (5)	0 (0)	1 (5)
Total	**6 (27)**	**16 (73)**	**22 (100)**

which died standing had been recorded in the post-burning assessment as having had hot fires in their bases; the fourth died from unknown causes. A regrowth tree which had been severely scorched during the regeneration burn was the only regrowth tree to die standing.

The windthrown trees were predominantly regrowth, none of which had been severely burnt but about half of which had been partly burnt during the regeneration burn. It is noteworthy that the windthrown trees were not lost during a single storm event but fell one at a time during different wind events.

By age three, 22 trees (15%) had died or been windthrown, equating to a basal area loss of 0.7 m^2 / ha or 8% of the original retention of 8.7 m^2 / ha.

WR008C

Actual retention versus planned retention

Eight regrowth and two oldgrowth trees per hectare were marked for retention, equivalent to a retained basal area of 6 m^2 / ha (95 trees on a 9.5 ha coupe).

At the completion of harvesting, 85 trees (59 regrowth and 26 oldgrowth) remained on the coupe (9 trees / ha) with a basal area of 4.5 m^2 / ha, or 6% of the original standing basal area of 74 m^2 / ha (Table 6). The 85 trees were made up of 69 of the originally marked trees, and 16 unmarked trees (10 culls, four pulpwood and two sawlog) left by the harvesting crew. The unmarked retained trees were 11 oldgrowth and five regrowth. Five of the oldgrowth trees were in a close group but the rest were scattered throughout the coupe. The composition of all retained trees was 19 culls (22%), 31 sawlog (37%) and 35 pulpwood only (41%).

Impacts of harvesting

Harvesting damage to the boles of the retained trees was evident on 32 of the regrowth and six of the oldgrowth trees (Table 7). Most of the damage was to the bark on the lower portion of the stem; nine of the regrowth trees damaged by harvesting had severe bark damage, 12 had deep scrapes into live bark and nine had light scrapes into live bark. Two of the trees had root damage. Crown damage was of minor concern, with only three trees damaged as falling trees knocked branches out of a neighbouring crown. Overall, 48% of the retained trees were damaged by the harvesting.

Impacts of burning

The regeneration burn in WR008C was hotter than planned and decidedly hotter than that in WR001B. The day was warmer and the relative humidity lower than for the burn in WR001B. A light westerly breeze fanned the fire and, about 30 minutes after first lighting, the fire escaped into about 2 ha of the unharvested forest on the eastern side of the coupe (Photo 3). Many of the retained trees were set alight by the burn.

The post-burn seedbed assessment showed that 88% of the coupe had been burnt (Table 8) (cf. 27% in WR001B). Fifteen per cent of the coupe was oxidised soil, 33% burnt to mineral soil and 40% burnt to litter. The unburnt portions of the coupe were, as in previous coupes, along the more heavily shaded western side of the coupe.

Post-burn assessment of the retained trees found that 96% of the retained trees were damaged by the fire in some way. Fifty-five of 56 regrowth trees and 24 of 26 oldgrowth trees were moderately to severely scorched by the fire (average scorch across all burnt stems in the coupe was 86%). The unburnt trees were all on the western side of the coupe.

Longer term impacts

Three years after the regeneration burn, windthrow and related causes of damage

Table 6. Number of retained trees lost at WR800C, from completion of harvesting to three years later. (BA = basal area)

	Oldgrowth	Regrowth	Total	BA (m^2/ha)
Post-harvesting	26	59	85	4.5
Age 3 years	16	35	51	2.9
Loss (*n*)	10	24	34	1.6
Loss (%)	**38**	**41**	**40**	**36.0**

Table 7. Number of retained trees with harvesting damage prior to burning at WR008C.

	Oldgrowth	Regrowth	Total
Logging damage to stem	6	32	38
Crown damage	1	2	3
Total damaged trees	7	34	41
Total retained trees	26	59	85
Damage (%)	**27**	**58**	**48**

Table 8. Seedbed assessment for WR008C (%, n *= 131). (Abbreviations for burn and disturbance classes are given in Table 1; na = not applicable)*

	D0	D1	D2	**Total for each burn class**
B0	5	7	1	**12**
BL	24	17	0	**40**
BM	24	8	2	**33**
B2	na	15	na	**15**
Total for each disturbance class	**52**	**46**	**2**	**100**

Table 9. Number of dead retained trees by cause of loss at WR008C after three years (% in brackets).

	Oldgrowth	Regrowth	Total
Fire-killed	6 (18)	16 (47)	22 (65)
Windthrown	4 (12)	8 (24)	12 (35)
Total	**10 (29)**	**24 (71)**	**34 (100)**

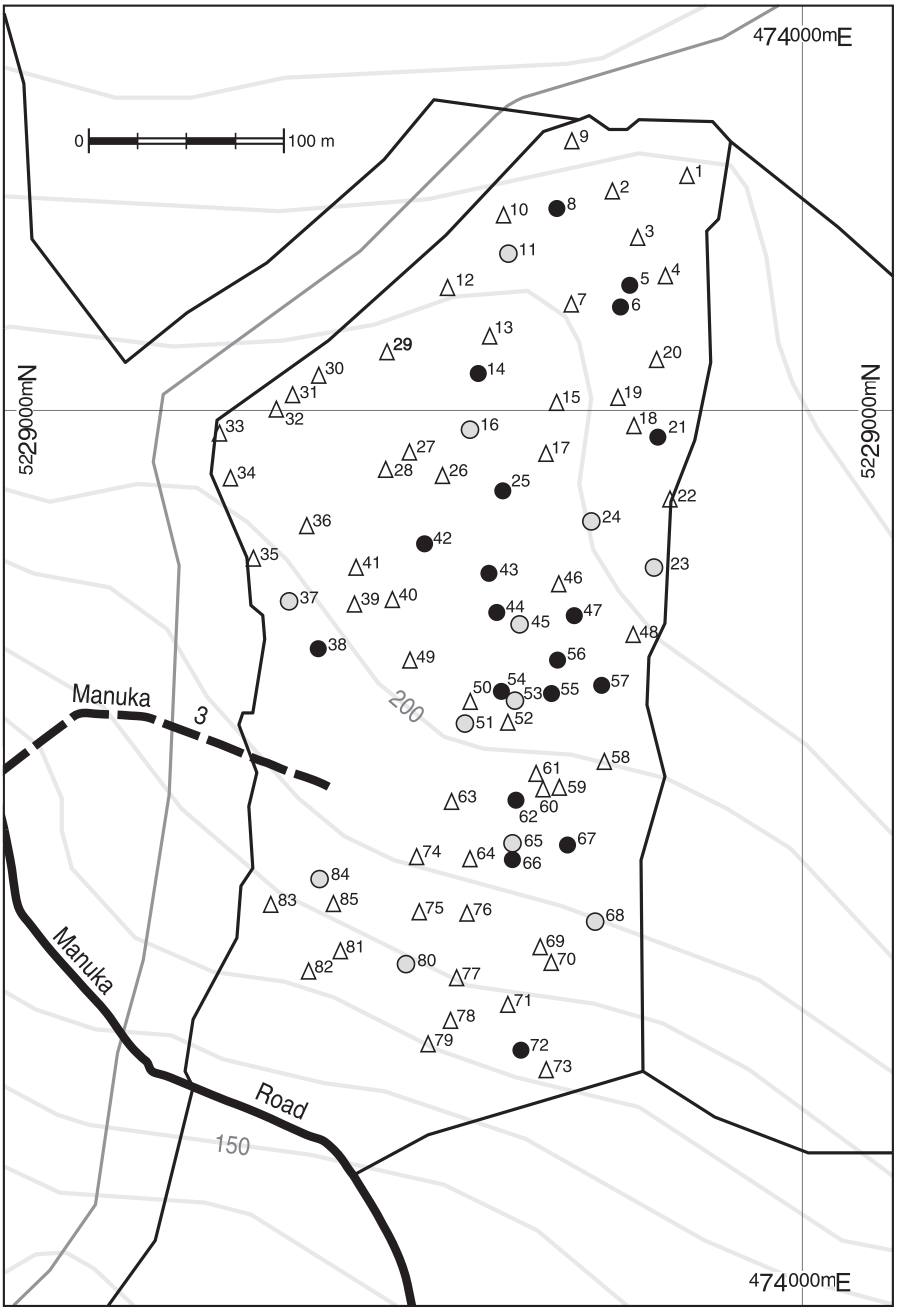

Figure 2. Location of retained trees in WR008C: retained trees (△), windthrown trees (◯) and dead trees (fire killed) (●).

had only a minor impact on the coupe, with 12 trees (14%) lost (Table 9). The trees had fallen one by one—as for WR001B there was not a single windstorm event which toppled the trees but rather there was a gradual loss. Four oldgrowth trees were amongst the trees lost and all had been severely affected by the regeneration burn. One tree collapsed during the burn. One was felled during the mop-up operations after the burn because it was still burning, was located close to the edge of the coupe and was deemed dangerous. Two more trees fell in the first three months after the burn—both broke off at mid stem at a point which had been severely burnt during the fire. None of the oldgrowth trees was windthrown in the classical sense; that is, with an intact but uplifted root plate. Figure 2 shows the location of all the windthrown trees within the coupe and it is apparent that they are dispersed throughout the coupe.

The eight regrowth trees which had been windthrown had all fallen with intact root plates. Three fell prior to the regeneration burn and four in the first quarter after the burn. Only one more tree has fallen since, in the subsequent 12 months.

Twenty-two trees (six oldgrowth and 16 regrowth) died in the first two years after the regeneration burn. All were badly scorched during the burn. All the trees produced epicormic shoots in the first spring following the fire, but the shoots were neither vigorous nor abundant and by the following winter the trees had all died. All the dead trees were in the centre or on the eastern side of the coupe, where the fire was the hottest (Figure 2). There have been no subsequent deaths.

In total, ten oldgrowth (38% of the original 26) and 24 regrowth (41% of 59) trees have been lost since the completion of harvesting. At the completion of harvesting, a basal area of 4.5 m^2/ha had been retained on the coupe. Three years later, the standing basal area is 2.9 m^2/ha, a reduction of 36%.

Discussion and conclusions

In both dispersed retention coupes, the level of harvesting damage to the retained trees was greater than 40%. Harvesting damage, particularly bark damage resulting from machinery or log impacts to the base of the stem, which was the major problem in both coupes (Tables 3, 7), allows decay organisms to attack the wood (Wardlaw 2003). Where the grower is anticipating a return from these trees in the future, their value will be significantly downgraded if they have decay present. In this trial, harvesting damage was not closely controlled but would need to be if dispersed retention were to be used more routinely. In current partial-harvesting operations in dry forest types, the level of acceptable damage to the retained trees is set at less than 10% and this is regularly achieved (unpublished data), so similar levels of damage may be achievable in this forest type. The trees in wet eucalypt forests are taller and the understoreys are denser than in dry forests, contributing to the difficulty of minimising damage to the retained trees.

There have been no extreme windthrow events in either of the coupes. All the windthrows have been single tree-fall events, widely distributed over time, although most of the trees fell in the first 18 months after harvesting and there have been few recent falls. All but one of the oldgrowth trees which fell had been burnt during the regeneration burns. Most of these had hollow bases from past fires. Once fire established inside these trees, the usual consequence was that the trees collapsed. Similar results for oldgrowth trees have been reported from Western Australia (Whitford and Williams 2001).

The hotter-than-planned fire in WR008C also had a major impact on the regrowth trees. Many of the trees were completely scorched and the subsequent death rate suggests that the cambium of many of these trees was killed. The thick bark on *E. obliqua* is known to offer some protection from the heat of a fire (Gill and Ashton 1968) but the bark on regrowth trees is not as thick as that on oldgrowth trees and so offers less protection. The fibrous, stringy bark on *E. obliqua* also means that the fire readily carries up the stem. However, many of the trees in WR001B were black following the burn but their crowns remained unscorched; this reflects the differing conditions under which the two coupes were burned (see Marsden-Smedley and Slijepcevic 2001).

It is likely that there will always be some windthrow following partial harvesting. Losses due to windthrow in this study were small but notable. In WR008C, the loss due to windthrow alone was about 4% of the retained standing basal area whereas the losses following the regeneration burn and consequent windthrow and stem collapse amounted to 36% of the retained standing basal area. A loss of 4% can probably be sustained by the forest grower; losses of 36% certainly cannot be sustained.

Fire is an essential tool in managing harvesting and regeneration in wet eucalypt forests. The large slash loads which arise during harvesting must be removed to create receptive seedbed and mechanical methods have proved prohibitively expensive in most instances. WR001B has satisfactorily regenerated by age three (unpublished data) which demonstrates that low intensity burning following harvesting in wet eucalypt forests, as applied in WR001B, can produce satisfactory regeneration. WR008C has also regenerated satisfactorily (unpublished data) following the overly hot burn and subsequent escape, but at significant cost in terms of loss of standing volume. Learning to manage low intensity fires and developing methods for arranging fuels in a manner which facilitates burning is a key challenge for those that advocate dispersed retention harvesting in wet eucalypt forests.

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