Vegetation of the Warra silvicultural systems trial

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Abstract

Vegetation types were classified within a trial testing alternative silvicultural systems to clearfell, burn and sow at the Warra Long-Term Ecological Research Site. Three vegetation types were recognised within the silvicultural systems trial: Eucalyptus obliqua *wet forest with a wet sclerophyll understorey dominated by tea-tree, cutting grass and bauera (G-type),* E. obliqua *mixed forest with an understorey of rainforest species typical of thamnic rainforest, particularly horizontal scrub (T-type) and* E. obliqua *mixed forest with an understorey of rainforest species typical of callidendrous rainforest (C-type). The three types were floristically distinct and were readily recognisable in the field. The ordination of internal and remote (external) control plots established recently agrees with the ordination of the vegetation prior to the establishment of the silvicultural systems trial. Therefore, these plots will be useful for future monitoring. Fire history was shown to have a major influence on the vegetation.*

Introduction

The silvicultural systems trial (SST) occupies approximately 200 ha within the Warra Long-Term Ecological Research (LTER) Site. The SST was established to develop alternatives to the traditional clearfell, burn and sow harvesting method for tall wet eucalypt forests. The harvesting systems used in the SST and the layout of the trial are described in Hickey *et al.* (2001).

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Monitoring the impact of the range of harvesting systems on the vegetation was a major part of the SST. This paper reports on the vegetation of the trial area prior to the commencement of harvesting. A major aim of this study was to compare a preliminary analysis of the vegetation which classified the vegetation of the SST into three broad groups, with the results of this more detailed analysis. Future papers will analyse the short- and long-term impacts of the harvesting systems on the vegetation.

Methods

Geology and soils

The SST was deliberately located at Warra on an area of relatively uniform slope, aspect and soil type. Quaternary dolerite talus overlies Permian sediments in all the coupes except WR001A (Figure 1), in which the Permian sediments are much more exposed. Aerial photo interpretation of the vegetation (Stone 1998) indicated that before the SST was established the vegetation of the site was relatively homogeneous, except along major drainage lines where rainforest elements were more obvious beneath the ubiquitous eucalypt canopy.

Vegetation types and controls

Analysis of vegetation data from previous studies at Warra, such as pre-logging surveys by Walsh (1994), F. Duncan (unpublished data) and D. Ziegeler (unpublished data), classified

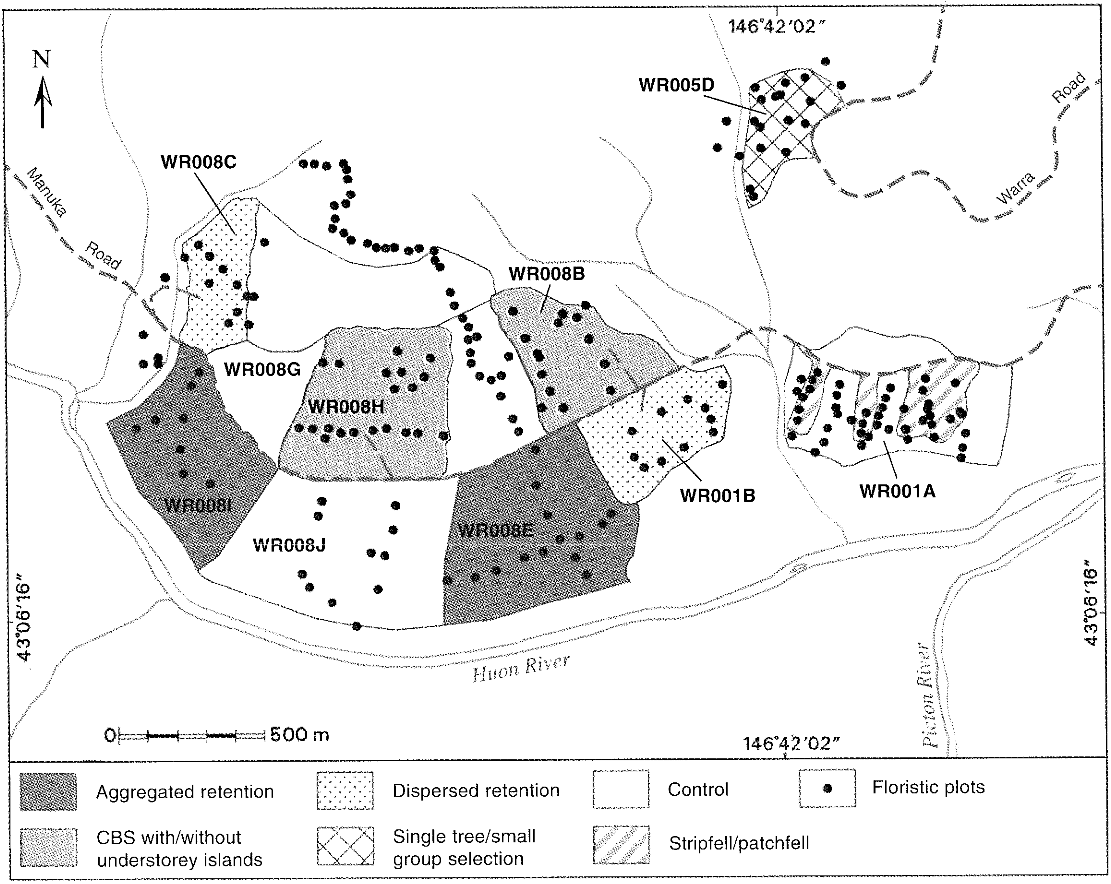

Figure 1. The Warra silvicultural systems trial showing the layout of the coupes and the vegetation quadrats.

the vegetation within the SST into three communities:

1. *Eucalyptus obliqua* wet sclerophyll forest with an understorey dominated by *Leptospermum lanigerum, Melaleuca squarrosa, Nematolepis squamea*, Bauera rubioides* and *Gahnia grandis* (similar to OB3 *sensu* Duncan and Johnson 1995).
2. *Eucalyptus obliqua* mixed forest with an understorey of rainforest species typical of thamnic rainforest (*sensu* Jarman *et al.* 1984).
3. *Eucalyptus obliqua* mixed forest with an understorey of rainforest species typical of callidendrous rainforest (*sensu* Jarman *et al.* 1984).

* Formerly known as *Phebalium squameum* (Wilson 1998).

The three communities were designated G-type (for *Gahnia grandis*-dominated understoreys), T-type for thamnic rainforest understoreys and C-type for callidendrous rainforest understoreys. For long-term monitoring, control plots were established internally (i.e. within the SST) for G and T understorey types and remotely (i.e. outside the SST) for T and C understorey types. Additional control plots (for internal C and remote G) will be added to the SST as soon as suitable locations are identified.

Plot establishment

Quadrats (10 m x 10 m) were established at an approximate density of one quadrat per hectare in each coupe within the SST (Figure 1). Plots of 50 m x 20 m were also established in each coupe and divided into ten, 10 m x 10 m quadrats. The same design was used for control plots established in each of the three major vegetation types found in and around the trial area. Access tracks have been cut throughout the SST, between and around the coupes, and quadrats were established along these tracks, also at an approximate density of one plot per hectare. A total of 302 quadrats was established.

Plot measurements

In each quadrat, data were collected on the cover-abundance of each higher plant species present using the Braun-Blanquet scale (Mueller-Dombois and Ellenberg 1974) and the projected foliage cover (%) of each layer of the vegetation. The relative abundance and preferred substrate of a group of distinctive bryophytes were recorded. Environmental data were collected on the slope, aspect, landform and rockiness.

Fire history and drainage were determined indirectly. Hickey *et al.* (1999) have documented the fire history of the site from ring counts of understorey species and determined that major fires occurred within the Warra SST in 1898, 1906, 1914 and 1934. Alcorn *et al.* (2001) investigated the ages of each of the eucalypt regrowth cohorts present on each CFI plot (continuous forest inventory, Lawrence 1978) within the SST area and determined that regrowth arose from fires in 1898, 1914 and 1934. From the diameters of regrowth stems present on each plot, and data from Alcorn *et al.* (2001) and Hickey *et al.* (1999), an estimate was made of the likely number of the known fires (post-1897) to have occurred on that plot.

Soil drainage was assessed by Pennington *et al.* (2001) and a soil drainage value was assigned to a vegetation quadrat where survey points used in the study by Pennington *et al.* (2001) were within 20 m of that quadrat. As soil drainage data were only available for a subset of the quadrats, a separate analysis was undertaken for that subset.

Data analysis

Analysis of the vegetation data was undertaken using PC-ORD (McCune and Mefford 1999). The data were ordinated using detrended correspondence analysis (DCA) and non-metric multi-dimensional scaling (NMS) and classified using two-way indicator species analysis (TWINSPAN). Problems identified in TWINSPAN and DCA (Oksanen and Minchin 1997; Tausch *et al.* 1995) have been corrected in the versions of these programs used in PC-ORD (McCune and Mefford 1999). NMS can use random configurations as a starting point or it can take the output from another ordination program as the starting point. In this case, both approaches were used. The configuration provided by DCA was used for one analysis and a full series of random starts was used in another.

The ordination provided by NMS was analysed by regression of the sample variables (slope, aspect, altitude, fire history and for the subset analysis only, drainage) against the ordination scores of the quadrats.

The results of the TWINSPAN analysis were overlain on the results of the NMS in order to determine the spread of the quadrats through the environmental space and to examine the clustering of the quadrats in order to determine the point at which it was reasonable to stop the TWINSPAN division. Uncontrolled, TWINSPAN will keep dividing each group until there are less than a pre-determined and arbitrary number of plots in each group. In this study, the division was stopped at the four-group level, and the relationship between the groups was examined using multi-response permutation procedure (MRPP), which tests the hypothesis of no difference between the groups.

As an additional test of the groups produced through TWINSPAN and NMS, cluster analysis was used to produce a hierarchical, agglomerative and polythetic dendrogram of the quadrats.

The location of each of the quadrats from the control plots was identified on the scatterplot of the quadrats (Figure 2) to examine whether the control plots were representative of the vegetation of the SST.

The results of the analysis described above were compared visually with the preliminary classification of the quadrats.

Results

Ordination

The DCA ordination and the two NMS ordinations were very similar in their final result and only one is shown (the second NMS, Figure 2). The only difference between the DCA ordination and the random start NMS ordination lay in the orientation of the output—the relationships between the points was the same (the NMS (1) ordination was the same as the DCA ordination except that it was rotated about 60 degrees). The NMS (2) ordination, which used the DCA output as a starting configuration, was almost identical to that produced by DCA. There was a significant reduction in stress between the one dimensional (0.24) and two-dimensional (0.16) results but little additional reduction in stress in three dimensions (0.12), which suggests that the data are two-dimensional. The two-dimensional ordination is shown.

The dendrogram produced by the cluster analysis clustered the quadrats into three groups which are overlain on the NMS ordination (Figure 2).

Fire history was the only sample variable found to be significantly related to the ordination ($R^2 = 0.693$). The subset analysis (not shown) which included the drainage sample variable also found fire history to be the only significantly related variable.

TWINSPAN

The first division of the TWINSPAN classification separated rainforest understorey types, characterised by the presence of *Eucryphia lucida*, from wet sclerophyll understorey types, characterised by the presence of *Gahnia grandis* and *Bauera rubioides*. A second division separated the rainforest plots into thamnic and callidendrous understorey types. The thamnic types were characterised by the presence of *Anodopetalum biglandulosum*, *Cenarrhenes nitida* and *Eucryphia lucida*, whilst the callidendrous types were characterised by the presence of *Dicksonia antarctica* and *Hymenophyllum cupressiforme*. A second division of the wet sclerophyll understorey types separated plots which contained rainforest elements from those without rainforest elements.

Multi-response permutation procedure

The multi-response permutation procedure tests the hypothesis that there was no difference between the groups identified by the TWINSPAN analysis. The test rejected the hypothesis and showed that the difference between the groups was highly significant ($P < 0.0001$).

Comparison of classifications

Quadrats shaded in Figure 2 are those which were classified differently by the cluster analysis and ordination described above, as compared to the preliminary classification. It is evident from the figure that all the plots which were misclassified were those which lay close to the boundaries of the three groups.

Discussion

The ordination and classification procedures, in combination with the multi-response permutation procedure and the cluster analysis, show strong support for the preliminary qualitative classification of the vegetation. The three groups were clearly separated by the ordination, albeit with a zone of overlap. Control plot quadrats encompass the full environmental space

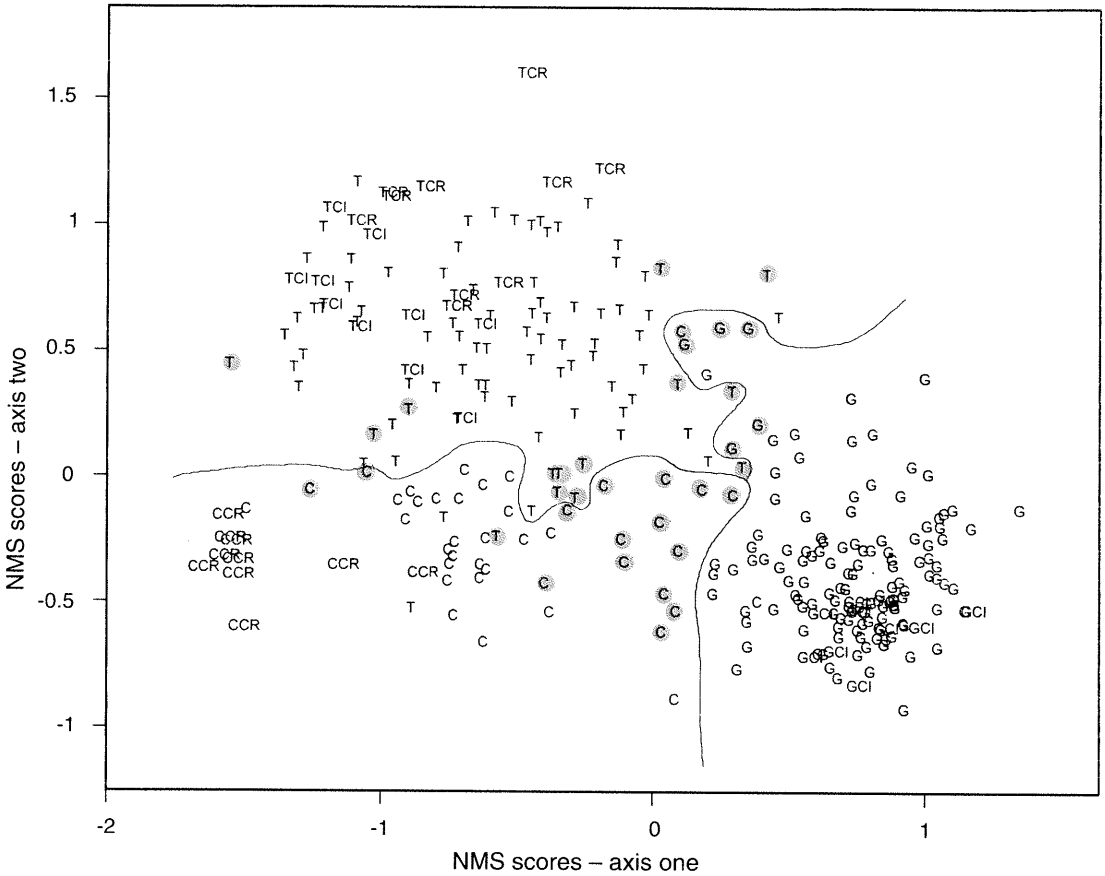

Figure 2. NMS ordination of the quadrats. Codes G, C and T as described in the text. Codes TCR = T control remote, TCI = T control internal, CCR = C control remote, GCI = G control internal. The points are labelled G, C or T according to their classification by the cluster analysis. The points TCR, TCI, CCR, GCI are labelled according to their respective control plots. Points that are shaded are those classified differently by the NMS ordination as compared to the preliminary classification.

covered by the vegetation of the SST (Figure 2). Any change that results from external influences such as climate change will be reflected by changes in the location of control plots in the ordination space. Changes in the vegetation that are brought about by the harvesting operations will be discernible as changes in location of treatment plots in the ordination space relative to the controls.

Vector fitting indicates that the vegetation within the Warra SST is most strongly influenced by the local fire history of each site. Fire behaviour in turn is influenced by local topography and this is reflected in the vegetation (Hickey *et al.* 1999). Below Manuka Road (Figure 1), wet sclerophyll understoreys dominate the vegetation except along the major drainage lines where rainforest elements predominate. Above Manuka Road, wet sclerophyll understoreys dominate the flatter areas and rainforest understoreys are restricted to the major drainage lines and to the steeper south-facing slopes that run across the middle of WR008H and WR008B. In WR001A, rainforest understoreys are restricted to the steeper slopes and the lower gentler slopes are again dominated by wet sclerophyll understoreys.

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G-type forest

Eucalyptus obliqua wet sclerophyll forests over tall *Melaleuca squarrosa* swamp forest (*sensu* Corbett and Balmer 2001). This community is closely related to OB3, *Eucalyptus obliqua – Phebalium squameum – Bauera rubioides* wet sclerophyll forest (*sensu* Duncan and Johnson 1995).

Trees: *Eucalyptus obliqua*
Shrubs: *Leptospermum lanigerum, Melaleuca squarrosa, Nematolepis squamea, Acacia verticillata, Bauera rubioides*
Ferns: *Blechnum wattsii, Gleichenia microphylla*
Graminoids: *Gahnia grandis*

This community is the most homogeneous of the forest types within the SST and is widespread. It occupies most of the lower gentle slopes and flats. Four of the eight coupes (WR008C, 8I, 1E and 1B) within the SST comprise only this forest type. The *E. obliqua* overstorey is a mixture of oldgrowth and regrowth arising from past fires, with a mean top height of about 45 m. The understorey is about 10 m tall and varies from an open shrub layer to closed thickets. It is dominated by *Leptospermum lanigerum* and *Melaleuca squarrosa*, with *Nematolepis squamea* and *Acacia verticillata* widespread but less common. *Gahnia grandis* and *Bauera rubioides* are ubiquitous, forming a closed ground layer except where the tea-tree and paperbark understorey forms a closed secondary canopy and light levels beneath this are low enough to control the spread of *Gahnia* and *Bauera*. *Blechnum wattsii* (hard water fern) is found throughout the community as small clumps and does not form the dense thickets characteristic of some rainforests.

T-type forest

Eucalyptus obliqua over thamnic rainforest (*sensu* Jarman *et al.* 1984). (This community is closely related to OB1001, Kirkpatrick *et al.* 1988.)

Trees: *Eucalyptus obliqua, Eucryphia lucida, Phyllocladus aspleniifolius, Nothofagus cunninghamii, Atherosperma moschatum, Acacia melanoxylon*
Shrubs: *Cenarrhenes nitida, Anodopetalum biglandulosum, Anopterus glandulosus*
Ferns: *Blechnum wattsii, Grammitis billardierei, Hymenophyllum rarum, Grammitis magellanica* subsp. *nothofageti*
Graminoids: *Gahnia grandis*

This is the dominant mixed forest community within the SST. The structure is highly variable, ranging from dense thickets of horizontal with few other species present to more broken forest with a high species diversity and a variable structure.

C-type forest

Eucalyptus obliqua over callidendrous rainforest (*sensu* Jarman *et al.* 1984). (This community is closely related to OB1000, Kirkpatrick *et al.* 1988.)

Trees: *Eucalyptus obliqua, Nothofagus cunninghamii, Phyllocladus aspleniifolius, Eucryphia lucida, Acacia melanoxylon, Atherosperma moschatum*
Shrubs: *Acacia verticillata*
Ferns: *Polystichum proliferum, Hymenophyllum flabellatum, Blechnum wattsii, Histiopteris incisa, Dicksonia antarctica, Grammitis billardierei, Hymenophyllum cupressiforme, Hymenophyllum rarum*
Graminoids: *Gahnia grandis*

Mixed forest with a callidendrous rainforest understorey occurs only in local patches within the Warra SST. It is most common in WR001A, on the better drained soils which have developed on the Permian sediments. The eucalypts in WR001A are also consistently taller and of better form than those in the rest of the SST. Rainforest species trees which probably arose following the last wildfire in 1934 (J. Hickey, pers. comm.) form a small (15–20 m tall) tree layer over an understorey dominated by ferns.

Appendix 2. Vegetation of the Warra SST, showing species abundance by vegetation type. (C-, T- and G-type forest are described in Appendix 1.)

		Forest type		
		C	T	G
FERNS AND FERN ALLIES				
Aspleniaceae	*Asplenium appendiculatum*	r	r	–
Blechnaceae	*Blechnum nudum*	r	r	r
	Blechnum wattsii	c	c	c
Dennstaedtiaceae	*Histiopteris incisa*	c	o	o
	Hypolepis rugosula	r	r	–
	Pteridium esculentum	r	r	o
Dicksoniaceae	*Dicksonia antarctica*	c	o	o
Dryopteridaceae	*Polystichum proliferum*	o	–	r
	Rumohra adiantiformis	o	o	r
Gleicheniaceae	*Gleichenia microphylla*	–	r	c
	Sticherus tener form B	–	r	r
Grammitidaceae	*Ctenopteris heterophylla*	o	o	r
	Grammitis billardierei	c	c	o
	Grammitis magellanica subsp. *nothofageti*	o	c	r
	Grammitis pseudociliata	o	o	–
Hymenophyllaceae	*Crepidomanes venosum*	o	–	–
	Hymenophyllum australe	o	o	r
	Hymenophyllum cupressiforme	c	o	o
	Hymenophyllum flabellatum	c	o	o
	Hymenophyllum marginatum	r	o	r
	Hymenophyllum peltatum	o	o	o
	Hymenophyllum rarum	c	c	o
Polypodiaceae	*Microsorum pustulatum*	o	o	r
Psilotaceae	*Tmesipteris elongata*	r	–	–
	Tmesipteris obliqua	o	o	r
CONIFERS				
Podocarpaceae	*Phyllocladus aspleniifolius*	c	c	o
FLOWERING PLANTS — Dicotyledons				
Asteraceae	*Olearia argophylla*	r	–	r
	Olearia persoonioides	–	r	–
Cunoniaceae	*Anodopetalum biglandulosum*	o	c	r
	Bauera rubioides	–	o	c
Dilleniaceae	*Hibbertia empetrifolia*	r	–	o
Elaeocarpaceae	*Aristotelia peduncularis*	r	o	o

		Forest type		
		C	T	G
Epacridaceae	*Cyathodes glauca*	o	o	o
	Cyathodes juniperina	–	r	r
	Epacris impressa	–	–	r
	Monotoca glauca	o	o	o
	Prionotes cerinthoides	o	–	o
	Trochocarpa cunninghamii	–	o	r
	Trochocarpa gunnii	–	r	–
Escalloniaceae	*Anopterus glandulosus*	r	o	r
Eucryphiaceae	*Eucryphia lucida*	c	c	o
Fabaceae	*Pultenaea juniperina*	–	–	r
Fagaceae	*Nothofagus cunninghamii*	c	c	o
Haloragaceae	*Gonocarpus teucrioides*	–	–	o
Mimosaceae	*Acacia melanoxylon*	c	c	r
	Acacia mucronata	–	–	r
	Acacia verniciflua	–	–	r
	Acacia verticillata	c	o	c
Monimiaceae	*Atherosperma moschatum*	c	c	r
Myrtaceae	*Eucalyptus delegatensis*	–	r	r
	Eucalyptus obliqua	c	c	c
	Leptospermum glaucescens	–	–	r
	Leptospermum lanigerum	r	r	c
	Leptospermum scoparium	–	–	o
	Melaleuca squamea	–	–	r
	Melaleuca squarrosa	o	r	c
Oleaceae	*Notelaea ligustrina*	–	–	r
Pittosporaceae	*Billardiera longiflora*	–	–	r
	Pittosporum bicolor	o	o	r
Proteaceae	*Banksia marginata*	–	–	o
	Cenarrhenes nitida	o	c	o
	Lomatia polymorpha	–	–	r
	Orites diversifolia	–	r	–
	Telopea truncata	–	–	r
Ranunculaceae	*Clematis aristata*	o	o	o
Rhamnaceae	*Pomaderris apetala*	o	o	o
	Pomaderris elliptica	–	–	r
Rubiaceae	*Coprosma nitida*	–	r	r
	Coprosma quadrifida	o	o	o
	Galium australe	r	r	o

		Vegetation type		
		C	T	G
Rutaceae	*Correa lawrenceana*	–	r	o
	Nematolepis squamea	o	o	c
Thymelaeaceae	*Pimelea cinerea*	–	r	–
	Pimelea drupacea	o	o	o
	Pimelea sericea	–	–	r
Violaceae	*Viola hederacea*	–	–	r
Winteraceae	*Tasmannia lanceolata*	o	o	o
FLOWERING PLANTS — Monocotyledons				
Cyperaceae	*Baumea tetragona*	–	–	r
	Gahnia grandis	c	c	c
	Isolepis wakefieldiana	–	–	r
	Lepidosperma ensiforme	–	–	o
	Schoenus apogon	–	–	r
Liliaceae	*Drymophila cyanocarpa*	r	o	o
Restionaceae	*Baloskion tetraphyllum*	–	–	r
	Calorophus elongatus	–	–	o

– = not recorded from that vegetation type
r = rare: found in less than 5% of plots in that vegetation type
o = occasional: found in 5 to 50% of plots in that vegetation type
c = common: found in more than 50% of plots in that vegetation type