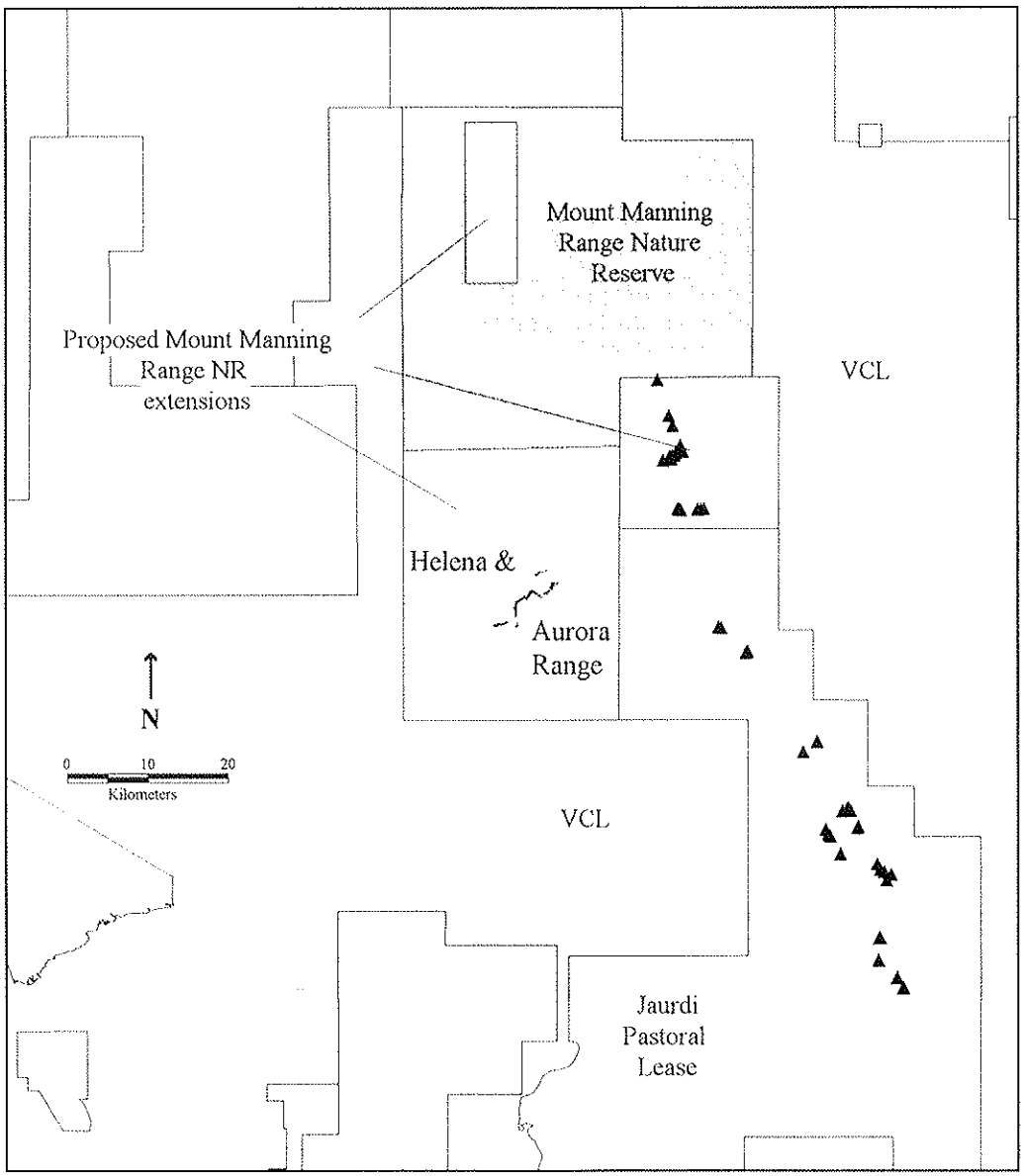
Floristic Survey of the Hunt Range, Yendilberin and Watt Hills of the Eastern Goldfields of Western Australia.

Neil Gibson and Michael N. Lyons



This project was funded under the National Estate Program, a Commonwealth - financed grants scheme administered by the Australian Heritage Commission (Federal Government) and the Heritage Council of W.A. (State Government).

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Neil Gibson and M.N. Lyons

Science and Information Division, Department of Conservation and Land Management, PO Box 51 Wanneroo, Western Australia 6065

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ABSTRACT

A study was undertaken of the flora and plant communities of the Jaurdi greenstones, the Watt and Yendilberin Hills and the Hunt Range. The area has a complex geology which includes Archaean mafic, ultramafics and banded ironstones, and Tertiary laterites. Fifty three quadrats were established along the range system and data from these sites were used to define eight community types that were correlated with topographic position, slope and substrate type. A total flora of 285 taxa was recorded from the range, of which 271 were native and 14 were weeds. One species of Declared Rare flora and five taxa listed on CALM's priority flora list were found in the study area. A further three taxa are recommended for listing on the priority flora list.

None of the Bungalbin vegetation system is presently in any National Park or Nature Reserve, although the northern section of the Hunt Range has been recommended for inclusion into the Mt Manning Range Nature Reserve.

Mining on Jaurdi station has the potential to severely impact on the restricted breakaway community type and any further expansion into this type will need to be carefully assessed. Impacts of wood harvesting for mining operations and for the water pipeline boilers are still evident on Jaurdi; revegetation in these vegetation types clearly takes many decades.

INTRODUCTION

Jaurdi homestead is located some 60 km east of Koolyanobbing and 135 km west of Kalgoorlie. Running north north west from the homestead is a series of uplands of contrasting geologies which include mafic and ultramafic ridges (these formations are commonly termed greenstones), banded ironstones and extensive Tertiary laterites.

Greenstone and banded ironstone ranges are common landforms of the Eastern Goldfields and extend from the Highclere Hills in the west to the Roe Hills some 300 km further east and stretch north - south over 800 km. The uplands of Jaurdi station form part of the western most greenstone belts (Figure 1). Despite the greenstone and banded ironstone ranges being heavily exploited for minerals for over a hundred years a detailed knowledge of the vegetation and flora of the region is still lacking.

Jaurdi station was purchased by CALM in 1989 using Sandalwood Conservation and Regeneration Project funding. The station is not used for grazing. In the Goldfields region management plan (CALM 1994) it is proposed that the northern section of Jaurdi station (covering the Hunt Range) be incorporated into the Mt Manning Range Nature Reserve, while the southern section (including the Yendilberin and Watt Hills and the Jaurdi greenstones) be vested as State Forest for sandalwood and flora and fauna conservation (Figure 2). Much of the southern section of Jaurdi has been cut over for timber to feed the pumping stations supplying water to the goldfields earlier this century.

CLIMATE

The climate of the region is semi arid mediterranean with warm winters and hot summers. Mean annual rainfall at Southern Cross (100 km south west) is 288 mm although seasonal variation is high. The driest year on record was 1940 with 117 mm and the wettest was 1943 with 542 mm. Most rain falls in winter generally associated with frontal activity from May through August. Summer falls (to 100 mm) are highly erratic and result from thunderstorms.

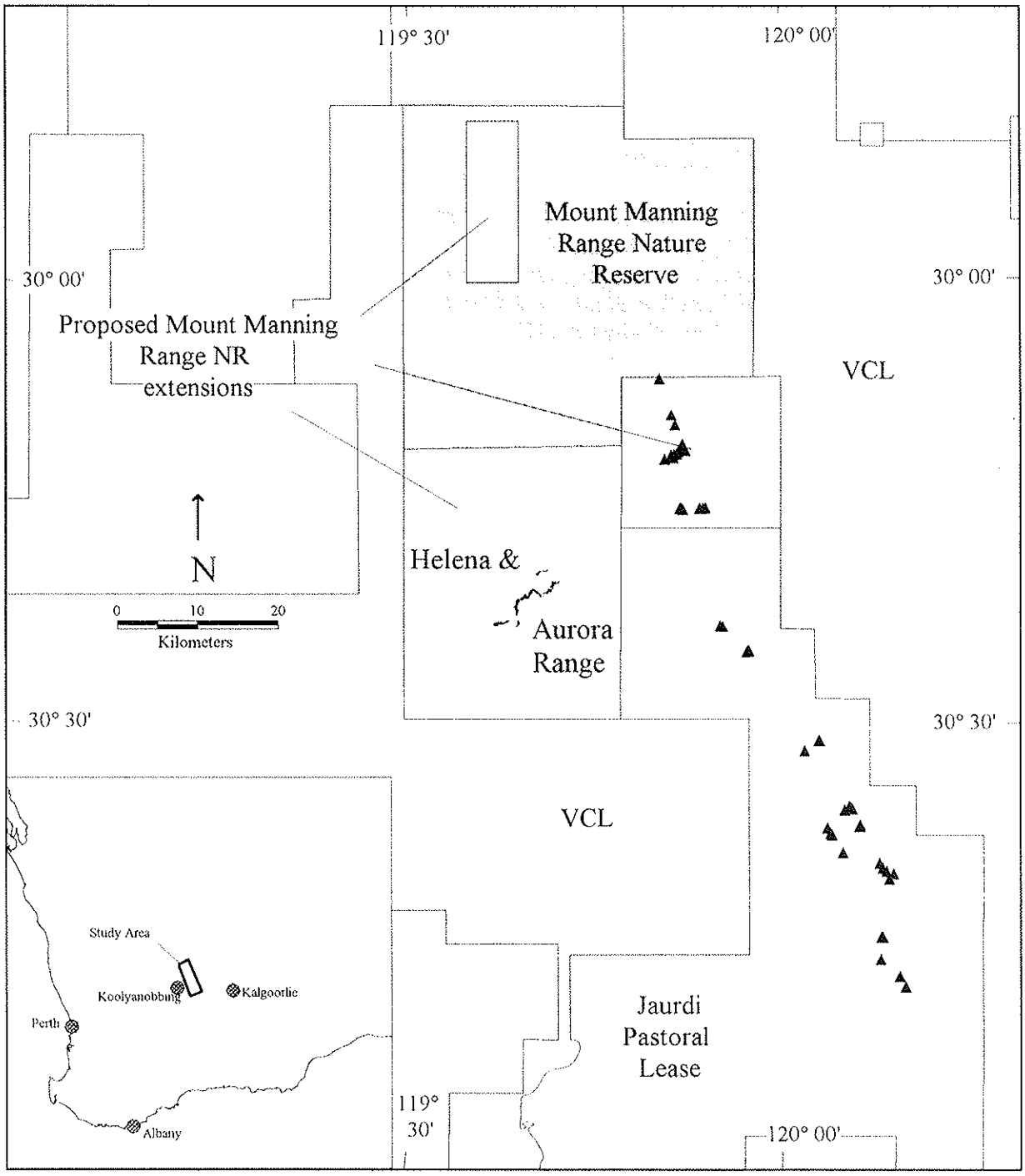


Figure 1. Location of the study area.

Heaviest falls are associated with rain bearing depressions forming from tropical cyclones (Newbey 1985, Bureau of Meteorology 1988).

The temperature data from Southern Cross shows mean maximum temperatures are highest in January (34.5°C) with December through March all recording mean annual temperatures above 30°C with the highest daily temperature on record of 45.6°C. Lowest mean minimum temperatures of below 5°C are recorded in July and August. Lowest daily minimum temperature on record was –3.8°C.

GEOLOGY AND LANDFORMS

The geology of the study area has been mapped and described in detail in Jackson and Kalgoorlie 1: 250000 sheets (Chin & Smith 1983, Wyche 1993) and the geology and landforms have been summarised by Newbey (1985). The study area has been tectonically stable since the Proterozoic (600 - 2500 million years (My) ago). The major landscape features are controlled by the Archaean (2500 - 3700 My old) granites which underlie most of the study area and have weathered into gently undulating plains and broad valleys covered by Tertiary soils (< 65 My old). Immediately north of the Jaurdi homestead are a series of Archaean mafic and ultramafic ridges. These give way to the Watt and Yendilberin Hills which are have a core of resistant Archaean banded ironstones (formed from lacustrine deposits of iron oxides and quartz sand) and chert surrounded by Tertiary laterites. Further to the north the Hunt Range is largely greenstone and a narrow band of banded ironstone. The upland areas and around the base of the range have been extensively laterised. The net result is a subdued landscape set in extensive outwash plains of Tertiary colluvium.

VEGETATION

Jaurdi station lies in the Coolgardie interzone which is generally dominated by eucalypt woodlands and shrublands on yellow sandplains The interzone marks the transition in vegetation from the species rich south west to the more arid communities of the desert regions (Beard 1990).

Beard (1972, 1978) first described the major structural formations of this area which he grouped into vegetation systems. He defined the vegetation of the Watt and Yendilberin Hills and the Hunt Range as forming part of the Bungalbin System. This system also encompasses the ironstone and greenstone areas of the Helena and Aurora Range, the Koolyanobbing Range and Mt Jackson area. The undulating greenstone plain north of Jaurdi homestead is described as part of the very widespread Jackson system.

The Bungalbin system is most well developed on the massive banded ironstone ranges (Helena and Aurora, Mt Jackson and Koolyanobbing Range). The system is a low thicket composed of *Acacia quadrimarginea, A. tetragonophylla, Allocasuarina acutivalvis* with trees of *Brachychiton gregorii* and on massive outcrop *Dryandra arborea*. This system typically has an understorey of *Dodonaea* spp., *Eremophila clarkei, Eriostemon brucei, Grevillea paradoxa* and a range of annual species (Beard 1972). On Mt Finnerty *Allocasuarina acutivalvis* dominated rather than *Acacia quadrimarginea.* On the lower slopes *Eucalyptus corrugata and Brachychiton gregorii* were present merging below with woodlands of *E. corrugata, E. longicornis, E. loxophleba* and *Casuarina pauper (=C. cristata)* (Beard 1978).

The Jackson system around Jaurdi homestead is described as woodlands principally composed of *E. sheathiana, E. salubris, E. transcontinentalis* and *Casuarina pauper* with an understorey of either broombush (*Eremophila*) or saltbush (*Atriplex*) (Beard 1978). Elsewhere

on the Jackson sheet Beard describes *Acacia* shrublands and breakaways in this vegetation system (Beard 1972).

Beard's pioneering work was followed up some years later with a major regional survey of the biota of the Eastern Goldfields, produced in a series of cell reports. The Jackson-Kalgoorlie report (Dell *et al.* 1985, Newbey & Hnatiuk 1985) covered Jaurdi station but adds little to Beards previous descriptions. Both Beard's survey and the later biological survey of the eastern goldfields were undertaken to provide regional overviews. Consequently the individual ranges were not sampled extensively.

The only other report on the vegetation of the study area is that of Henry-Hall (1990) who provides a general description of the vegetation of the Hunt Range and the vegetation of the granitic soils around Pittosporum Rock Hole.

The aim of the present work was to undertake a detailed floristic survey of the undulating greenstone plain north of Jaurdi homestead and the Watt and Yendilberin Hills and the Hunt Range (Figure 1). This involved the compilation of a detailed flora list for the range and the associated outwash areas, and to describe the vegetation patterning of this area based on a series of permanently located quadrats.

METHODS

Fifty three 20 m x 20 m quadrats were established from Jaurdi homestead north along the greenstone belt, and continuing along the Watt Hills, the Yendilberin Hills and the Hunt Range and their associated outwash plains (Figure 2). These sites attempted to cover the major geographical, geomorphological and floristic variation found in the study area. Care was taken to locate sites in the least disturbed vegetation available in the area being sampled. No attempt was made to undertake detailed sampling of the extensive colluvial flats of the area between the ranges which were largely dominated by *Eucalyptus salmonophloia* and *E. salubris* (Chin & Smith 1983, Wyche 1993). Some opportunistic sampling was undertaken on the granite substrates around Pittosporum and Kurrajong Rock Holes

Within each site all vascular plants were recorded. Most of the quadrats in the Hunt Range were sampled in mid July 1995 with the rest of the sites being sampled in mid September 1995. Data on topographical position, slope, aspect, percentage litter, percentage bare ground, percentage exposed rock, vegetation structure and condition were collected from each site. Topographical position was scored on a subjective seven point scale. (Ridge tops (1); upper slopes (2); midslopes (3); lower slopes (4); valley flats (5); small rise in valley (6); washlines (7)). Slope was scored on a one to three scale from flat to steep. Aspect was recorded as one of 16 cardinal directions. Vegetation structure was recorded using Muir's (1977) classification.

All sites were permanently marked with four steel fence droppers and their positions fixed using a GPS unit. Twenty four soil samples from the A horizon were collected and bulked from each site. These soil samples are presently being analysed.

Sites were classified according to similarities in species composition. In these analyses only perennial species were used to facilitate comparisons with classifications from other ranges in the area (Gibson & Lyons 1995, Gibson *et al.* 1997).

The site and species classifications undertaken used the Czekanowski coefficient and "unweighted pair-group mean average" fusion method (UPGMA, Sneath and Sokal 1973). Semi-strong hybrid (SSH) ordination of the sites data was undertaken to show spatial

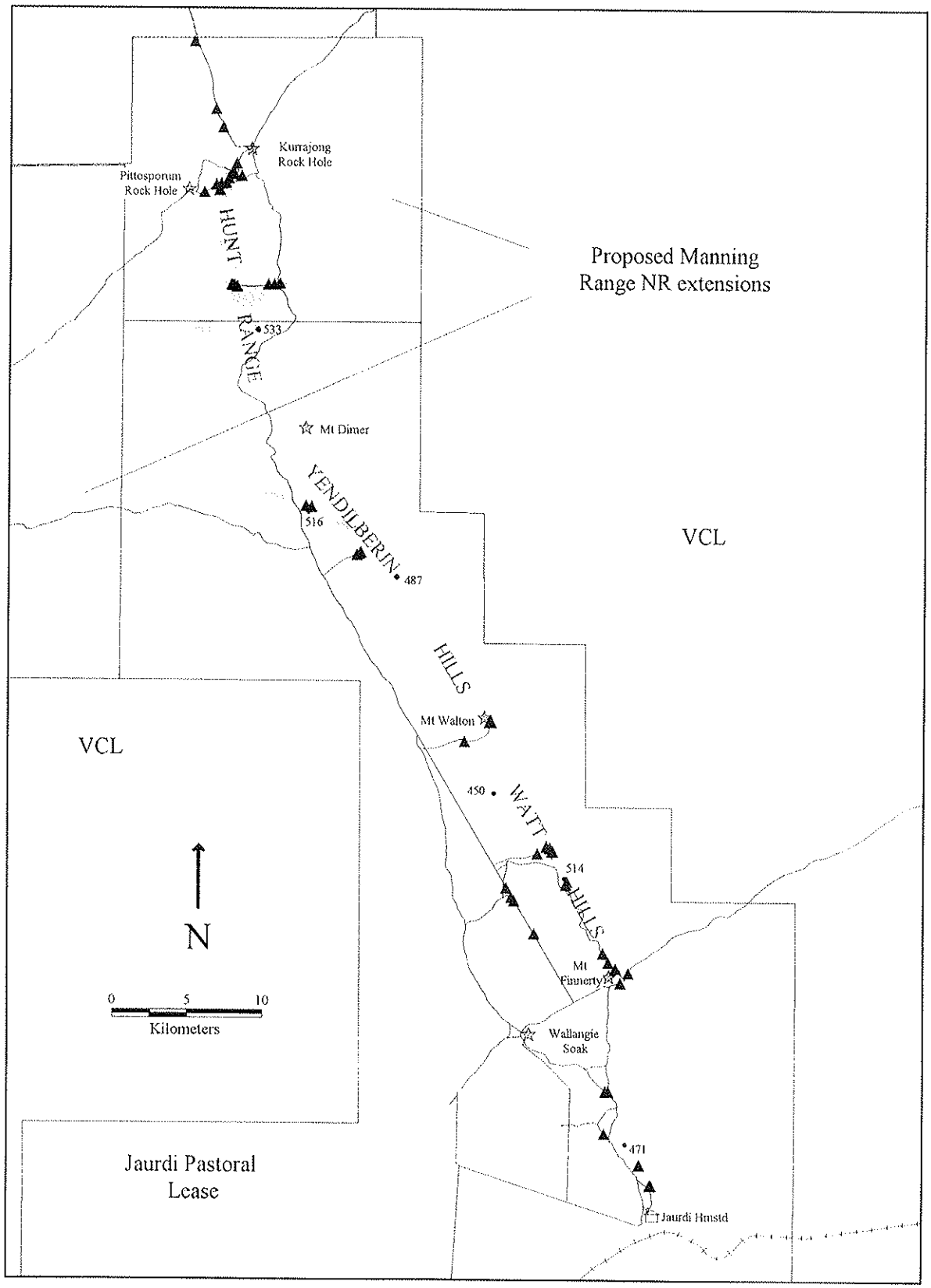


Figure 2. Location of survey sites within the study area.

relationships between groups and to elucidate possible environmental correlates with the classification (Belbin 1991).

Nomenclature follows Green (1985) and current usage at the Western Australian Herbarium (PERTH). Manuscript names are indicated by "ms" after the name. Selected voucher specimens will be lodged in the Western Australian Herbarium.

RESULTS

FLORA

A total of 285 taxa (species, subspecies and varieties) were recorded from the Jaurdi greenstone, Watt Hills, the Yendilberin Hills and the Hunt Range. The flora list was compiled from taxa found in the 53 plots or the adjacent area and from other opportunistic collections (Appendix 1). Of these 285 taxa, 271 are native and 14 are weeds.

The best represented families were the Asteraceae (40 native taxa and 2 weeds), Myrtaceae (32 taxa), Poaceae (12 native taxa and 6 weeds), Chenopodiaceae (16 taxa), Myoporaceae (16 taxa), Mimosaceae (15 taxa), and Proteaceae (13 taxa). This pattern is typical of the flora of the South Western Interzone (Newbey & Hnatiuk 1985). Good rains were experienced in the winter and early spring of 1995, reflected by the large numbers of annuals and geophytes on the flora list (Appendix 1). The most common genera were *Eucalyptus* (20 taxa), *Eremophila* (16 taxa) and *Acacia* (15 taxa).

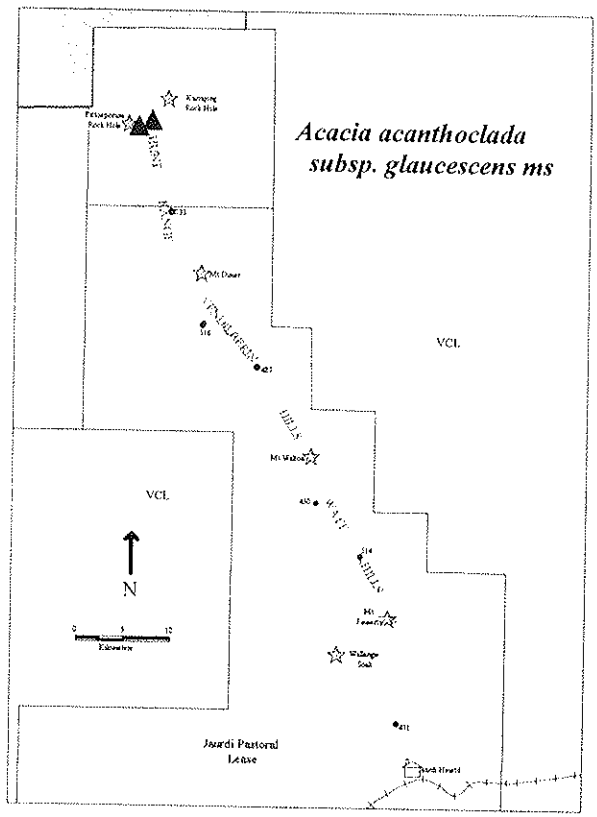
During the survey one Declared Rare taxon and six taxa listed on CALM's priority flora list (CALM 1996) were encountered (Table 1, Figure 3).

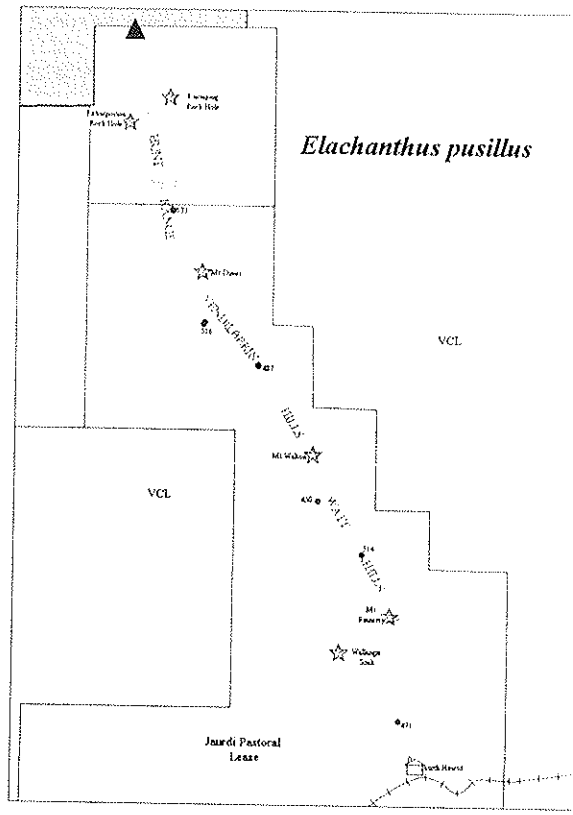
Table 1. Priority Flora encountered during the survey (CALM 1996).

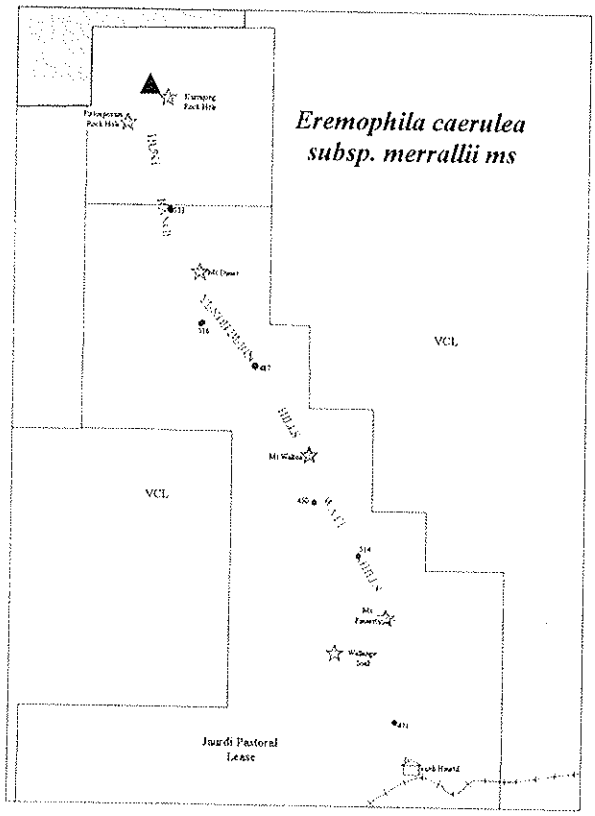
Taxon	***Current priority listing***
Acacia acanthoclada subsp. *glaucescens* ms	3
Elachanthus pusillus	2
Eremophila caerulea subsp. *merrallii* ms	DRF
Grevillea erectiloba	4
Grevillea georgeana	3
Leucopogon breviflorus	2
Trymalium urceolare	2

Grevillea georgeana and *Leucopogon breviflorus* were widespread along the entire range from near Jaurdi homestead to close to the Mt Manning Range Nature Reserve boundary (Figure 3). *Grevillea georgeana* was restricted to the banded ironstones while the *Leucopogon* occurred on a variety of substrates, including banded ironstone, sand over laterite and greenstone.

Acacia acanthoclada subsp. *glaucescens* ms, *Elachanthus pusillus, Eremophila caerulea* subsp. *merrallii* ms, *Grevillea erectiloba* and *Trymalium urceolare* were all located near the northern end of the Hunt Range (Figure 3). The *Acacia* and *Elachanthus* were growing on greenstone soils near the base of the range.







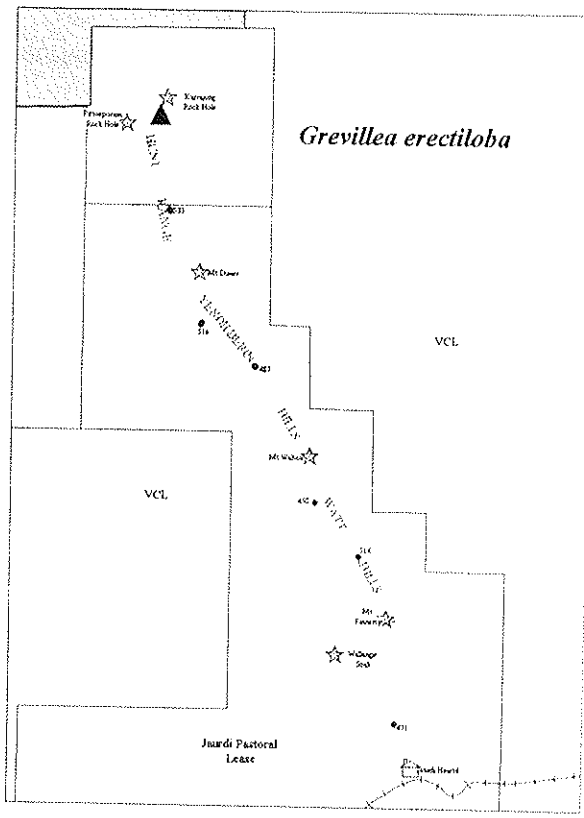


Figure 3. Populations of Priority Flora (triangles- new populations, diamonds - known populations) recorded during the current survey.

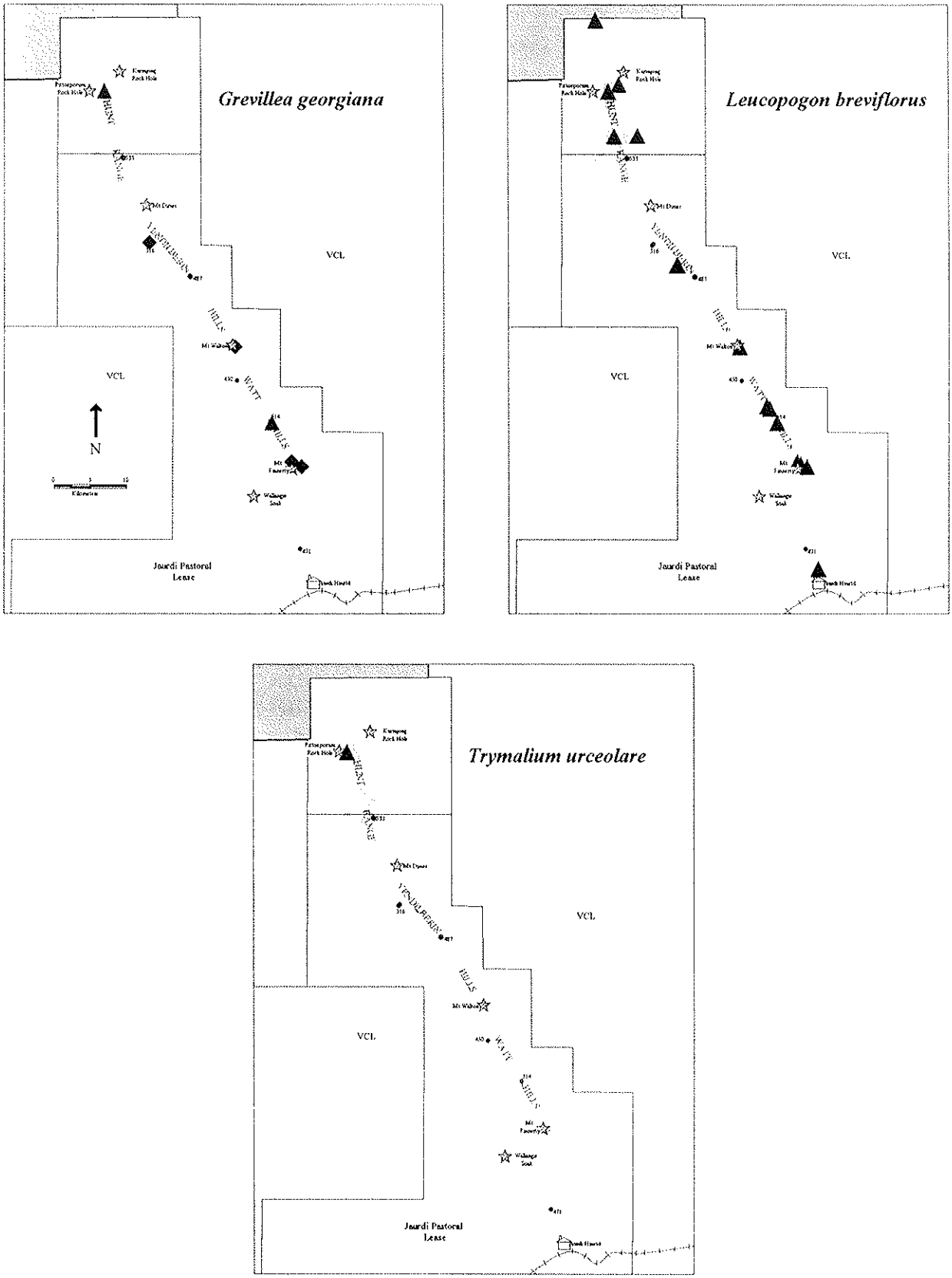


Figure 3. (cont'd.) Populations of Priority Flora (triangles- new populations, diamonds - known populations) recorded during the current survey.

The *Elachanthus* is a small annual daisy which has been poorly collected. Only four collections are lodged in PERTH, one collected by S. Moore in the WA goldfields in 1895, another by W.V. Fitzgerald from Kalgoorlie in 1898, and a third by G.J. Keighery 16 km east of Cocklebiddy in 1981. The fourth collections lacks collection details. Further work is required to determine this species extent north of the Hunt Range.

Grevillea erectiloba was found on yellow sands over laterite a similar habitat to where it has been located at the Helena and Aurora Range and the Mt Manning Range (Gibson *et al.* 1997, Gibson & Lyons 1997). The *Trymalium* was located on a yellow sand sheet in the saddle of the Hunt Range between Pittosporum and Kurrajong Rock Holes. This represents a range extension of some 350 km from the Bindoon – Calinigiri area.

On red clay flats over decomposing granite at the base of the Hunt Range a large population of the Declared Rare taxon *Eremophila caerulea* subsp. *merrallii* ms was located. This taxon is known from a number of populations from the Hunt Range and south to Southern Cross area and west to the Bruce Rock.

Three other taxa were recorded that have been very poorly collected. *Leucopogon* aff. *rubicundus* was collected on the top of a breakaway. This matches a single collection in PERTH (RJC & PJS 7790) collected from a breakaway apparently 3km SE Weowanie Rock (c. 50 km SSW of the study area).

A *Gnephosis* sp. related to *G. brevifolia* was collected from a *E. salmonophloia* woodland near Jaurdi homestead. This collection matches *Gnephosis* sp. Norseman (KRN 8096) which was collected 12 km north east of Norseman.

Austrostipa blackii was collected twice, once near Green Dam and again below the Hunt Range. This taxon is widespread in South Australia, New South Wales and Victoria, but has only been collected three times previously in Western Australia, most recently in 1959 (Vickery *et al.* 1986).

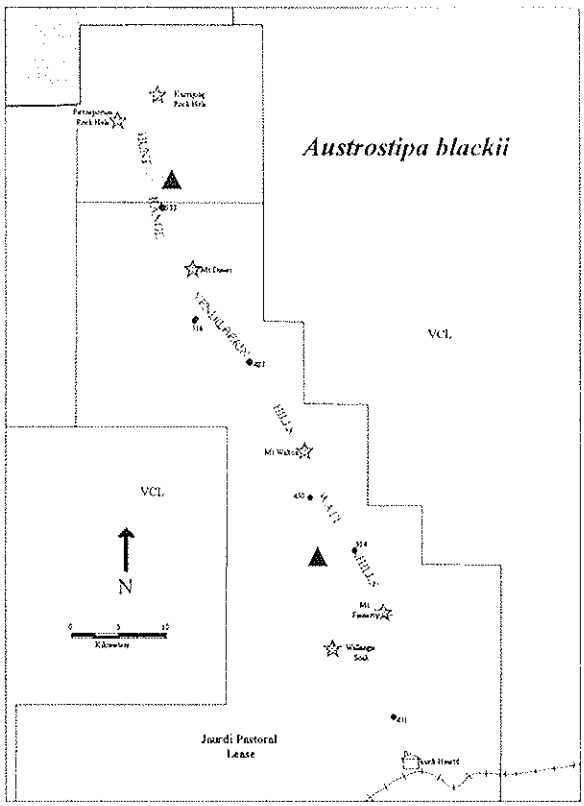
All three taxa should be listed on CALM's priority flora list as priority 2 taxa.

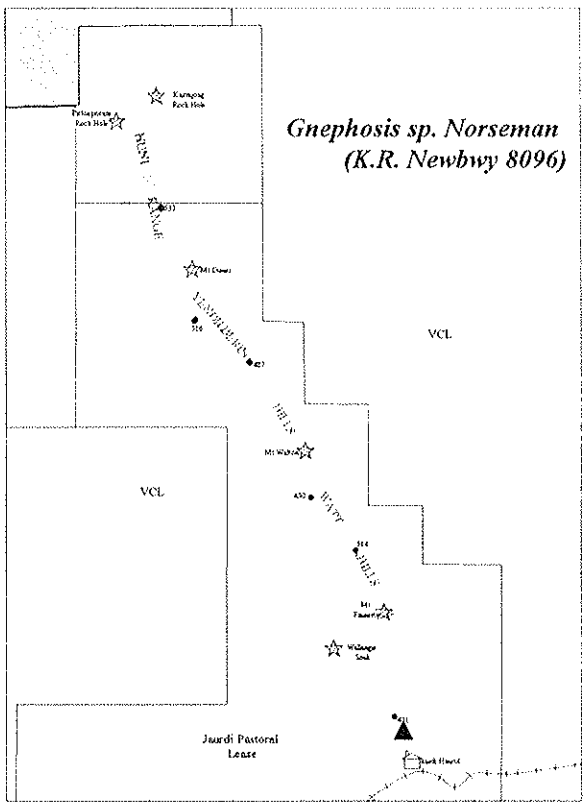
(Priority 2 taxa are defined as:- Taxa which are known from one or a few (generally < 5) populations, at least some of which are not believed to be under immediate threat (ie not currently endangered). Such taxa are under consideration for declaration as 'rare flora', but are in urgent need of further survey.)

In the Yendilberin Hills and on the Hunt Range *Acacia ?sibina* was collected. The specimens had longer peduncles than is typical of the species. Fruiting material needs to be collected to confirm the identification, but if it proves to be *A. sibina* it will be the most southern occurrence of this taxon.

VEGETATION

Only material that could be identified down to species level was included in the analysis (c.99% of records). In the 53 quadrats established on the Jaurdi greenstones, Watt and Yendilberin Hills and Hunt Range 236 taxa were recorded of which 148 were perennial (Appendix 2 & 3). Forty three perennials occurred at only one site. Preliminary analyses showed these singletons had little effect on the community classification and therefore were excluded. As a result the





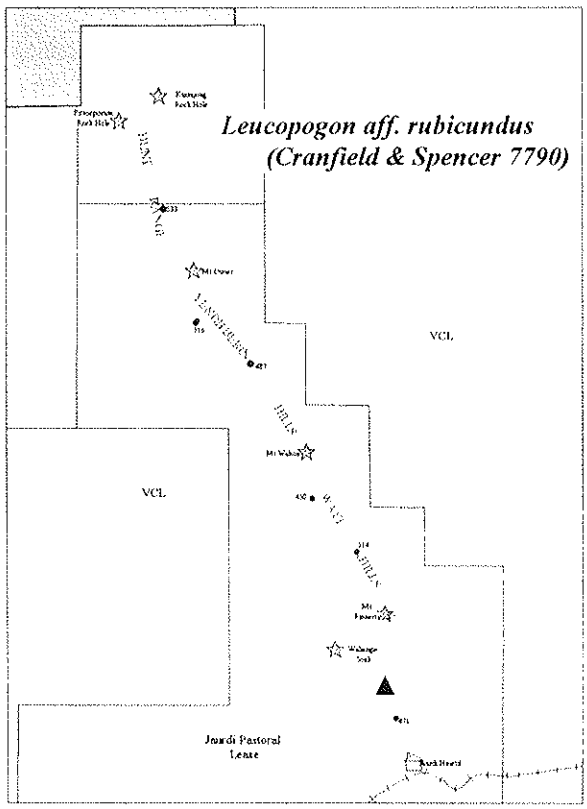


Figure 4. Populations of taxa proposed as Priority Flora recorded during the current survey.

Figure 5. Dendrogram of the sites from the Hunt Range, Yendilberin and Watt Hills showing the seven group level classification.

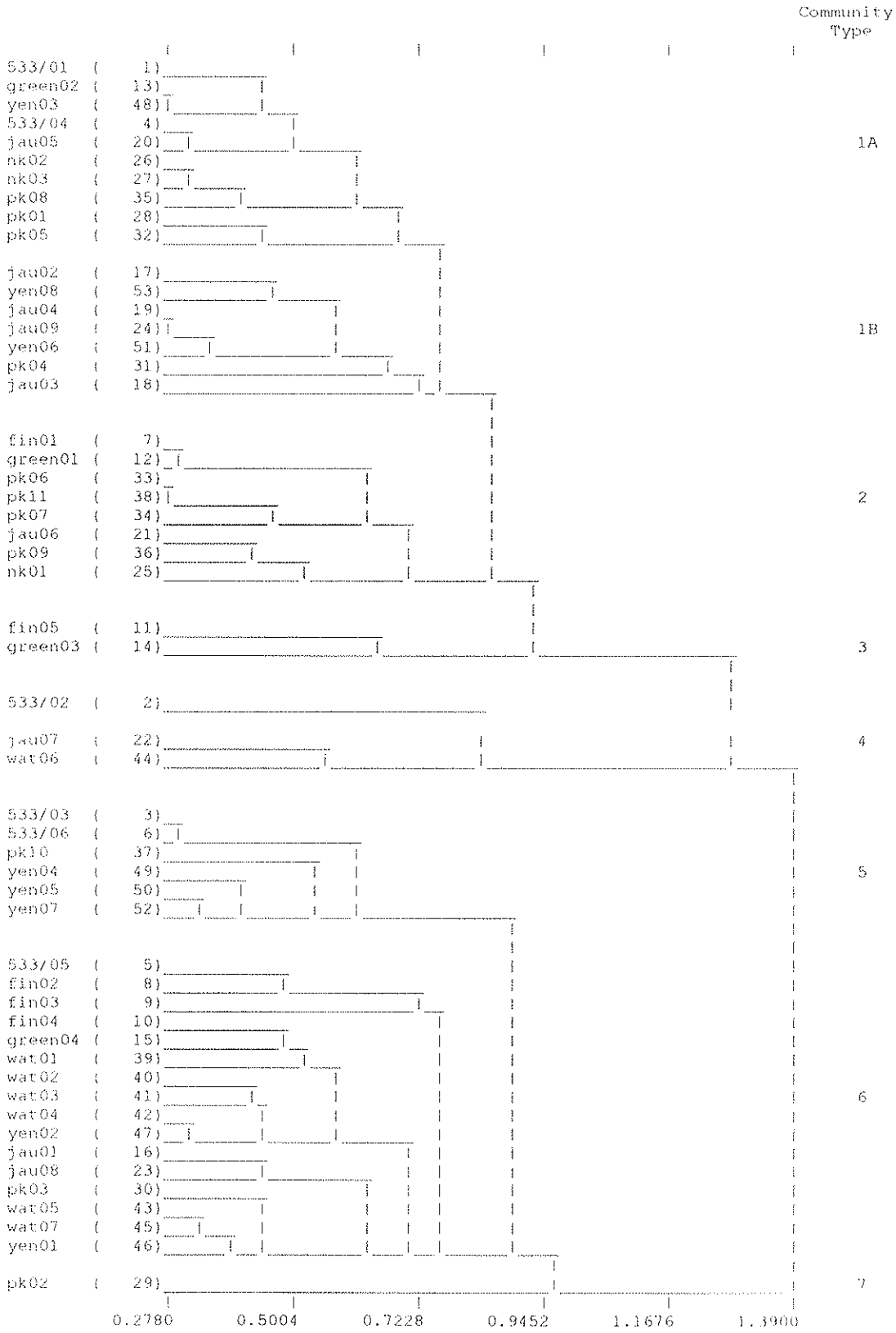
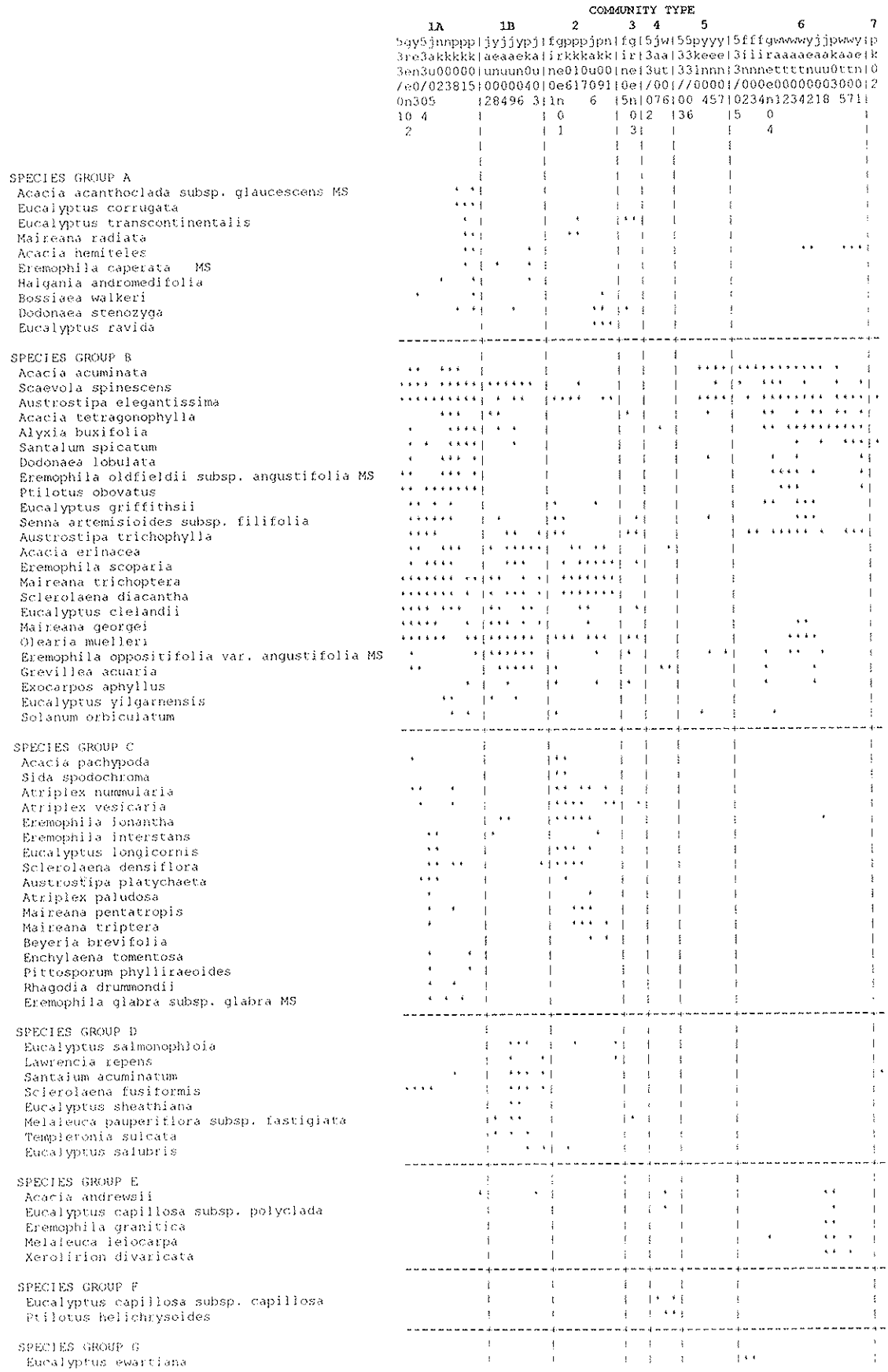
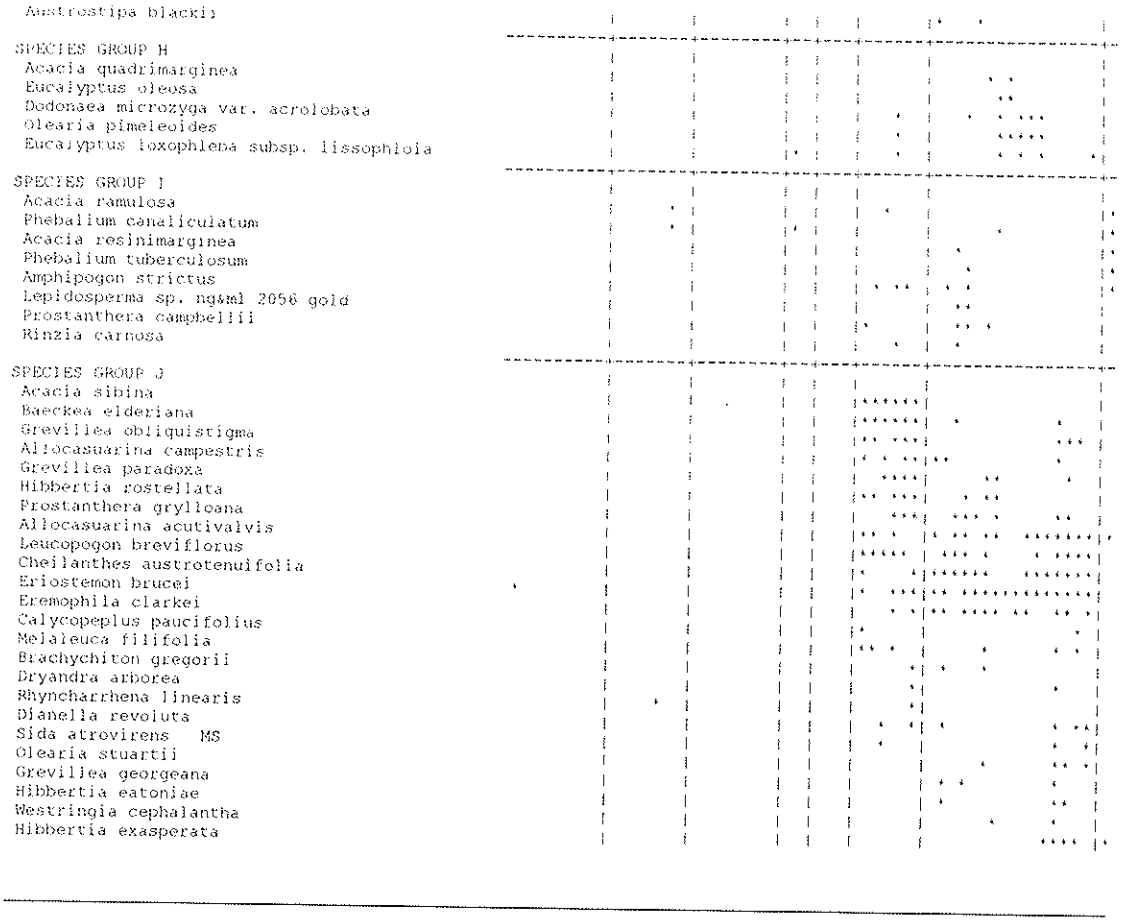


Table 2. Sorted two way table of the Hunt Range, Yendilberin and Watt Hills sites showing species occurrence by community type. Site codes appears as columns, species code as rows.





final data set consisted of 105 perennial taxa in 53 sites. Species richness ranged from one to 24 taxa per site, with individual taxa occurring in between two and 37 of the 53 sites.

Multivariate analysis can assist in sorting both sites and species data such that patterns in species composition are more easily seen. The decision as to the number of site and species groups defined is subjective and related to the scale of pattern of interest (Kent and Coker 1992). In this analysis site groups are discussed at the seven group level which best reflects the scale of patterning seen in the field (Figure 5, Table 2).

The dendrogram shows the 53 sites divide into two primary groups, based on soil type with the eucalypt woodlands (community type 1, 2 & 3) of the deeper more fertile soils separating from the *Acacia* and *Allocasuarina* shrublands (community types 5, 6 & 7) of the less fertile sites. Within the first group, sites from community type 1 are typically dominated by *Eucalyptus clelandii* , *E. griffithsii* or *E. longicornis*. Species in species group B are typical of this type as is the lack of species in species group J. Common species in the understorey include *Olearia muelleri*, *Acacia erinacea* and *Maireana georgei*. Community type 1 can be split into two subgroups, type 1a typically includes taxa such as *Acacia acuminata, Ptilotus obovatus, Dodonaea lobulata, Eremophila oldfieldii*, *Sclerolaena densiflora* and other taxa in species group C. While type 1b is well represented by species in species group D including *E salmonophloia, E. salubris* and *Melaleuca pauperiflora* subsp. *fastigiata.* Community type1b representing deeper and or more fertile soils lower in the landscape. Average species richness was similar (18.3 cf 14.4 perennial taxa / plot) between subgroups.

Community type 2 shared many species in species group B but also had high representation of species in the chenopod rich species group C. Sites in this type were typically low in the

landscape and dominated by *Eucalyptus ravida* or *E. longicornis*. Average species richness was 13.0 taxa / plot.

Community type 4 was dominated or co-dominated by *Eucalyptus transcontinentalis* and *E. clelandii*. Both sites in this group were species poor (average richness of 8.5 taxa / plot) and both sites had been extensively cut over for timber. Community type 5 was also species poor with an average species richness of only 3.3 taxa / plot. This community type occurred on breakaways and was dominated by *Eucalyptus capillosa* subsp. *capillosa* or *E. capillosa* subsp. *polyclada*. The difference between the subspecies was that the first was a tree and the second a mallee. The understorey was typically *Ptilotus helichrysoides* (species group F) but on one site on the Hunt Range was totally lacking. It is not clear if the growth form of the eucalypt is genetically fixed or if the tree habit develops with old age.

Community type 5 is the typical community occurring on sandy soils on laterites or banded ironstone. This community type is characterised by species in species group J, some of which are shared with community type 6. Those largely restricted to and generally co-dominant in community type 5 include *Allocasuarina campestris, Baeckea elderiana, Grevillea obliquistigma, Acacia ?sibina,* and *Grevillea paradoxa.* This community was found in the north of the study area on Hunt Range and on the Yendilberin Hills. On the Hunt Range it occurred as a dense thicket on the top of the range on sands developed on a laterite sheet and on laterites on change in slope at the base of the range. On the Yendilberin Hills the community was more open and occurred on north and north north west facing slopes. Average species richness was 13.8 taxa / plot.

Community type 6 was more widespread occurring from the Hunt Range to near Jaurdi homestead. It was most widespread in the Watt Hills. This community generally occurred on shallow soils. Species groups J and B were typical of this community type, but as noted above some taxa in species group J were absent or occurred at low frequency. This community type was generally dominated or co-dominated by *Acacia acuminata,* with or without a variable eucalypt component. On massive banded ironstone the *Acacia acuminata* was replaced by *Acacia hemiteles.* The two way table indicates that three subgroups might be defined in community type 6 (Table 2). The first characterised by species group I, then a *Eucalyptus oleosa – E. loxophleba* subgroup (characterised by species in species group H) and an *Acacia hemiteles* subgroup on the massive banded ironstones (characterised by species in species group E, and by such taxa as *Dianella revoluta* and *Hibbertia exasperata* from species group J). All three subgroups usually share species such as *Eriostemon brucei, Leucopogon breviflorus, Allocasuarina acutivalvis* and *Eremophila clarkei.* Average species richness in community type 6 is high at 16.5 taxa /plot.

The last community type (type 7) occurred on deep yellow sands in the saddle on the Hunt Range between Pittosporum and Kurrajong Rock Holes. These sands are presumed colluvial deposits derived from weathered laterites higher in the landscape. This community type was considerably different from all other sites sampled with 10 shared taxa and a further nine recorded only from this one site.

Physical Correlates

From the preceeding descriptions it can be seen that the community types are strongly correlated with substrate and topography. Community type 1a tended to occur on clays and loams on small ridges and side slopes on flat to gentle slope (Tables 3 & 4), while community type 1b occurred lower in the landscape.

Table 3. Community type by position in landscape

Community type	Upland	Upper slope	Mid slope	Lower slope	Valley	Small riser in valley	Washline
1a	2	4	2		1	1	
1b	1	1		3	1		1
2	1	1		2	4		
3			1		1		
4		3					
5	1	2	1	1	1		
6	6	3	3	3		1	
7	1						

Table 4. Community type by slope category.

Community type	< 5° slope	5° – 20° slope	> 20° slope
1a	4	6	
1b	1	6	
2	3	5	
3	1	1	
4		1	2
5		5	1
6		14	2
7		1	

Community type 2 occurred on deeper clay loams mostly in the valleys on flat to gentle slopes, while community type 4 occurred in similar position to community type 1 but were generally species poor. The breakaways community (type 4) generally occurred on upper slopes and steeper slopes, surface rock cover in this community type was high (Table 5).

Table 5. Community type by surface rock cover.

Community type	< 30% rock cover	30%- 70% rock cover	> 70% rock cover
1a	2	7	1
1b	3	2	2
2	4	3	1
3	1	1	
4			3
5			4
6	1	2	11
7	1	4	

Cover of surface rock was also typically high in community types 5 and 6, with community type 5 occurring at any position in the landscape where the lateritic sheet remained while community type 6 was concentrated in the uplands or upper slopes. Both these communities

occurred on gentle slopes. Community type 7 was restricted to on patch of deep yellow sand on the saddle of the Hunt Range.

Ordination Results

Ordination of the site data was undertaken to show spatial relationships between groups and to better elucidate possible environmental correlates with the classification. The results of a three dimensional ordination (stress level 0.18) shows reasonable separation of most of the classificatory groups. The plot of the first two axes appears to show a soil fertility gradient from left to right with the deep loam soils of the community type 3 (*E. longicornis – E. ravida* over chenopods) occurring on the left and the skeletal and / or sandy soils of communities 5 and 6 on the right (Figure 6). On the second axis the breakaway community (type 4) segregates from the rest. The ordination shows the continuum nature of the vegetation sampled. More detailed interpretation of the major gradients will be possible when the soil mechanical and soil chemical data become available.

DISCUSSION

The Jaurdi greenstones, the Watt and Yendilberin Hills and the Hunt Range have a rich flora with 285 taxa having been recorded, including one Declared Rare Flora species and six species on CALM's priority flora list. In addition three further taxa were identified which should be listed as priority flora.

The flora is comparable with that of the Helena and Aurora Range (Gibson *et al.* 1997) and Bremer and Parker Ranges (Gibson & Lyons 1995). Jaurdi station is located 50 km to the east of the Helena and Aurora Range and well to the north of the Bremer and Parker Ranges. The uplands of Jaurdi station (which include the Jaurdi greenstones, the Watt Hills, the Yendilberin Hills and the Hunt Range) are less extensive in area than the Helena and Aurora Range and this is likely to contribute to the lower number of taxa recorded. The flora of the Bremer and Parker Ranges are likely to be significantly underestimated since they were sampled in a year poor for annuals and geophytes.

There are significant biogeographic differences between the northern and southern range systems, with eucalypts and *Melaleuca* spp. being more diverse in the south and *Eremophila* spp. more diverse in the north. All areas are poorly known floristically as indicated by the significant number of priority flora, the recommendation for further listings and the number of new populations recorded for each range (Table 6).

The primary split between community types 1, 2, 3, and 4 from community types 5, 6 and 7 largely conform with the division between Beard's Jackson and Bungalbin systems (Beard 1972, 1978). Species typical of the Bungalbin system are found in species groups E, G, H, I and J. Our data show that the Bungalbin system can be subdivided into three community types and community type 6 may be further subdivisible into three subtypes. Beard (1972, 1978) although recognising variation within the Bungalbin system did not describe the patterns reported here.

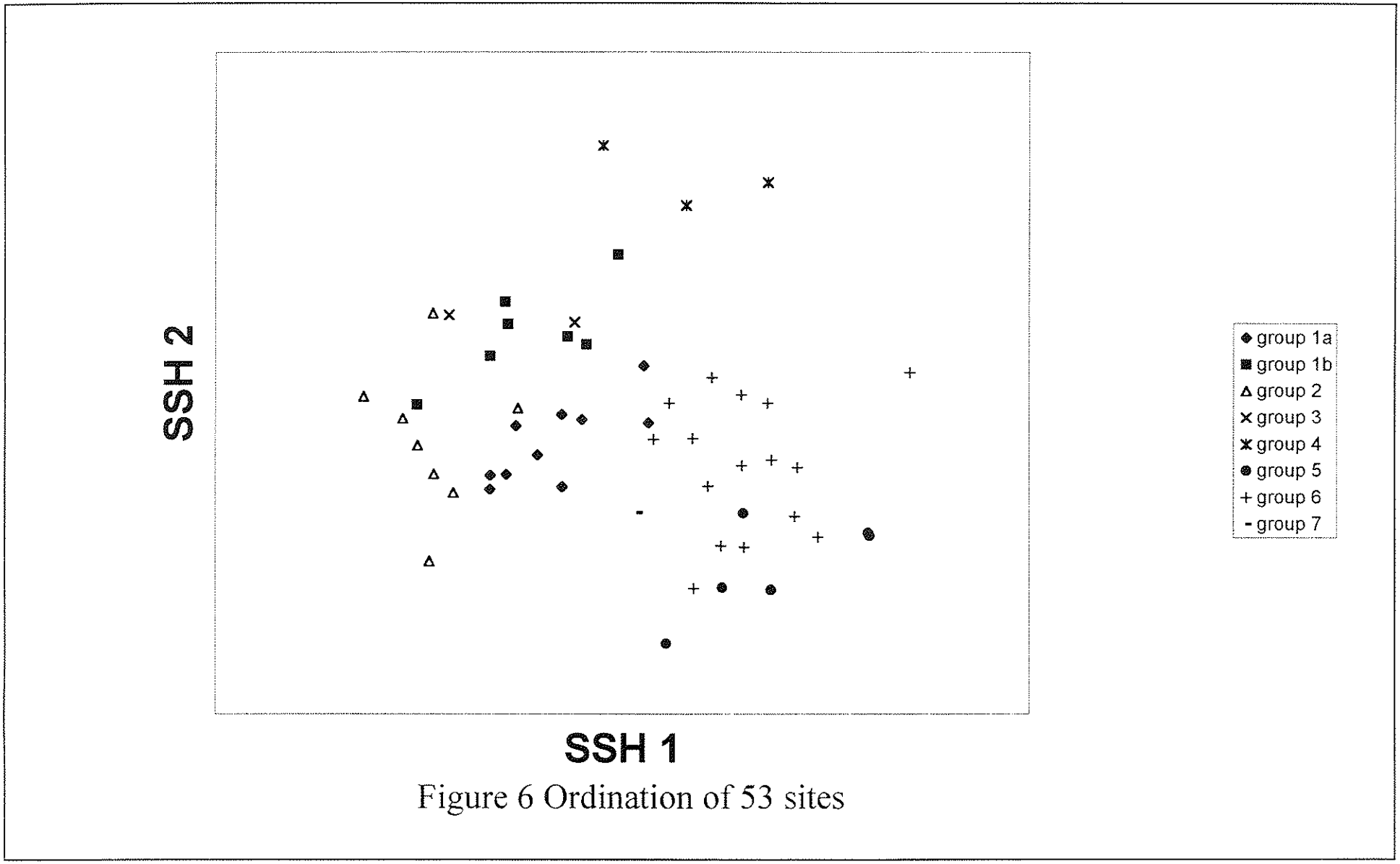


Figure 6 Ordination of 53 sites

Table 6. Comparison of the floras of the uplands of Jaurdi station with the Helena and Aurora Range, the Bremer Range and the Parker Range.

	Upland of Jaurdi Station	Helena and Aurora Range	Bremer Range	Parker Range
Total taxa	285	325	269	256
Declared Rare Flora	1	1	1	-
Priority taxa	6	10	6	8
Recommended listing	3	3	2	3
Eucalyptus spp.	20	19	30	29
Melaleuca spp.	4	5	19	14
Acacia spp.	15	17	17	20
Eremophila spp.	16	14	11	7

The Bungalbin system is typical of the outcrops of banded ironstone (Beard 1972,1978). What is clear from the present survey is that this system also encompasses vegetation of decomposing laterites and that these laterites occur both on the tops of ranges and also at the change in slope at the base of the ranges. What is not clear is if these laterites are solely derived from banded ironstones or were derived from a several different geologies.

The banded ironstones on Jaurdi station are much smaller and less extensive outcrops than on the Helena and Aurora Range or the Koolyanobbing Range to the west. Consequently somewhat different plant associations are recorded. Gibson *et al.* (1997) record three floristic communities on the banded ironstones of the Helena and Aurora Range. One was an upland community on massive ironstone variously dominated or co-dominated by *Dryandra arborea, Calycopeplus paucifolius, Acacia quadrimarginea, Grevillea zygoloba, Melaleuca nematophylla (=M. filifolia)* and *Allocasuarina acutivalvis*. The second community that occurred on the upper slopes and breakaways was dominated by *Eucalyptus ebbanoensis* or *E. capillosa* subsp. *capillosa*. The third community occurred on the mid slopes and was generally dominated by *Eucalyptus ebbanoensis* over *Neurachne* sp. Helena & Aurora (KRN 8972). With the possible exception of the breakaway community type, direct analogues of these three communities do not occur on Jaurdi station. *Dryandra arborea* and *Calycopeplus paucifolius* (common and widespread on the Helena and Aurora Range) were rarely recorded on Jaurdi and *Eucalyptus ebbanoensis* and *Neurachne* sp. Helena & Aurora (KRN 8972) were entirely lacking.

There are however strong similarities in species composition between the ironstone floras of the two range systems. Species group J from the Jaurdi analysis shares many taxa in common with species group H from the Helena and Aurora analysis. The smaller size of the outcrops and the more extensive development of laterite on the Jaurdi uplands are the most likely explanations of the shift in floristic composition although a climatic gradient may also be involved.

These data imply that while broad agreement exists between Beards vegetation systems (based on structural mapping, dominant species and geology) and the floristic classification presented here (based on perennial species presence / absence) significant variation does occur within a vegetation system and not all components of this variation are present on all ranges.

None of the Bungalbin vegetation system is presently in any National Park or Nature Reserve, although the northern section of the Hunt Range and the Helena and Aurora Range have been

recommended for inclusion into the Mt Manning Range Nature Reserve (CALM 1994). Our results support these recommendations.

Small scale mining has and continues to occur on Jaurdi station. While the greenstone community types appear to be widespread, mining activity is also impacting on the much more restricted breakaway community (type 4). Any future expansion into this community type will need to be very carefully assessed.

Jaurdi was also extensively cut over to supply wood for mines and the boilers of the pumping stations for the goldfields water pipeline. The most severely impacted areas were avoided in the present study although community type 3 may be a result of this cutting. What is clear is that these communities take exceptionally long periods (many decades) to recover from such perturbations due to their very slow growth rates and the episodic nature of recruitment events in this arid and highly variable climate.

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APPENDIX 1

Flora List for the Hunt Range, Yendilberin and Watt Hills.

This list includes all taxa from both the sampling quadrats and the opportunistic collections. Nomenclature follows Green (1975) and current usage at PERTH (ms denotes a manuscript name, * indicates a weed).

Family: Adiantaceae
- Cheilanthes austrotenuifolia
- Cheilanthes lasiophylla
- Cheilanthes sieberi subsp. sieberi

Family: Aizoaceae
- * Mesembryanthemum nodiflorum

Family: Amaranthaceae
- Ptilotus aervoides
- Ptilotus carlsonii
- Ptilotus exaltatus
- Ptilotus gaudichaudii
- Ptilotus helichrysoides
- Ptilotus holosericeus
- Ptilotus obovatus

Family: Anthericaceae
- Thysanotus manglesianus
- Thysanotus patersonii

Family: Apiaceae
- Daucus glochidiatus
- Hydrocotyle rugulosa
- Trachymene cyanopetala
- Trachymene ornata
- Uldinia ceratocarpa

Family: Apocynaceae
- Alyxia buxifolia

Family: Asclepiadaceae
- Rhyncharrhena linearis

Family: Asteraceae
- Actinobole uliginosum
- Angianthus tomentosus
- * Arctotheca calendula
- Asteridea athrixioides
- Blennospora drummondii
- Brachyscome ciliaris
- Calotis hispidula
- Cephalipterum drummondii
- Ceratogyne obionoides
- Chthonocephalus pseudevax
- Elachanthus pusillus
- Erymophyllum ramosum subsp. ramosum
- Gilruthia osbornei
- Gnephosis sp. Norseman (KRN 8096)
- Gnephosis tenuissima
- Hyalosperma demissum
- Hyalosperma zacchaeus
- * Hypochaeris glabra
- Isoetopsis graminifolia
- Lawrencella rosea
- Leucochrysum fitzgibbonii
- Millotia myosotidifolia
- Millotia tenuifolia
- Olearia exiguifolia
- Olearia muelleri
- Olearia pimeleoides
- Olearia stuartii
- Podolepis canescens
- Podolepis capillaris
- Podolepis lessonii
- Podotheca angustifolia
- Pogonolepis stricta
- Rhodanthe laevis
- Rhodanthe oppositifolia
- Rhodanthe rubella
- Rhodanthe stricta
- Schoenia cassiniana
- Senecio glossanthus
- Streptoglossa liatroides
- Trichanthodium skirrophorum
- Triptilodiscus pygmaeus
- Waitzia acuminata

Family: Boraginaceae
- * Echium plantagineum
- Halgania andromedifolia

Family: Brassicaceae
- * Brassica tournefortii
- Harmsiodoxa brevipes
- Lepidium muelleri-ferdinandii
- Lepidium rotundum
- Stenopetalum filifolium

Family: Caesalpiniaceae
- Senna artemisioides subsp. filifolia
- Senna cardiosperma subsp. cardiosperma

Family: Campanulaceae
- Wahlenbergia tumidifructa

Family: Casuarinaceae
Allocasuarina acutivalvis
Allocasuarina campestris
Allocasuarina corniculata
Casuarina pauper

Family: Centrolepidaceae
Centrolepis pilosa

Family: Chenopodiaceae
Atriplex nummularia
Atriplex paludosa
Atriplex vesicaria
Enchylaena tomentosa
Maireana carnosa
Maireana georgei
Maireana pentatropis
Maireana radiata
Maireana trichoptera
Maireana triptera
Rhagodia drummondii
Sclerolaena densiflora
Sclerolaena diacantha
Sclerolaena fusiformis
Sclerolaena parviflora
Threlkeldia diffusa

Family: Chloanthaceae
Lachnostachys coolgardiensis

Family: Colchicaceae
Wurmbea tenella

Family: Crassulaceae
Crassula colorata

Family: Cupressaceae
Callitris glaucophylla
Callitris preissii subsp. verrucosa

Family: Cyperaceae
Isolepis cernua
Lepidosperma aff. angustatum
Lepidosperma sp. (NG & ML 2056)
Schoenus nanus

Family: Dasypogonaceae
Lomandra effusa
Xerolirion divaricata

Family: Dilleniaceae
Hibbertia eatoniae
Hibbertia exasperata
Hibbertia rostellata group

Family: Droseraceae
Drosera macrantha subsp. macrantha

Family: Epacridaceae
Leucopogon aff. rubicundus (RJC & PJS 7790)
Leucopogon breviflorus

Family: Euphorbiaceae
Beyeria brevifolia
Calycopeplus paucifolius
Euphorbia drummondii
Monotaxis occidentalis
Poranthera microphylla

Family: Frankeniaceae
Frankenia sp.

Family: Geraniaceae
* Erodium cicutarium
Erodium cygnorum

Family: Goodeniaceae
Brunonia australis
Dampiera eriocephala
Dampiera stenostachya
Goodenia berardiana
Goodenia krauseana
Goodenia mimuloides
Goodenia occidentalis
Scaevola spinescens
Velleia rosea

Family: Haloragaceae
Gonocarpus nodulosus
Haloragis gossei

Family: Juncaceae
Juncus aridicola

Family: Juncaginaceae
Triglochin calcitrapum

Family: Lamiaceae
Prostanthera althoferi subsp. althoferi
Prostanthera campbellii
Prostanthera grylloana
Prostanthera incurva
Westringia cephalantha
Westringia rigida

Family: Lobeliaceae
Isotoma petraea

Family: Loganiaceae
Mitrasacme paradoxa

Family: Loranthaceae
Amyema benthamii
Amyema preissii
Lysiana casuarinae

Family: Malvaceae
Lawrencia repens
Sida atrovirens ms
Sida spodochroma

Family: Mimosaceae
Acacia acanthoclada subsp. glaucescens ms
Acacia acuminata
Acacia andrewsii
Acacia assimilis subsp. assimilis
Acacia colletioides
Acacia daviesioides
Acacia erinacea
Acacia hemiteles
Acacia merrallii
Acacia pachypoda
Acacia quadrimarginea
Acacia ramulosa
Acacia resinimarginea
Acacia ? sibina
Acacia tetragonophylla

Family: Myoporaceae
Eremophila caerulea subsp. merrallii ms
Eremophila ? caperata ms
Eremophila clarkei
Eremophila decipiens subsp. decipiens ms
Eremophila drummondii
Eremophila glabra subsp. glabra ms
Eremophila granitica
Eremophila interstans
Eremophila ionantha
Eremophila latrobei subsp. latrobei ms
Eremophila maculata
Eremophila oldfieldii subsp. angustifolia ms
Eremophila oppositifolia var. angustifolia ms
Eremophila rugosa ms
Eremophila scoparia
Eremophila serrulata

Family: Myrtaceae
Baeckea elderiana
Eucalyptus brachycorys
Eucalyptus capillosa subsp. capillosa
Eucalyptus capillosa subsp. polyclada
Eucalyptus celastroides
Eucalyptus clelandii
Eucalyptus corrugata
Eucalyptus cylindrocarpa
Eucalyptus ewartiana
Eucalyptus griffithsii
Eucalyptus hypochlamydea subsp. hypochlamydea ms
Eucalyptus leptopoda subsp. leptopoda
Eucalyptus longicornis
Eucalyptus loxophleba subsp. lissophloia
Eucalyptus oleosa
Eucalyptus ravida
Eucalyptus salmonophloia
Eucalyptus salubris
Eucalyptus sheathiana
Eucalyptus transcontinentalis
Eucalyptus yilgarnensis
Euryomyrtus maidenii ms
Leptospermum roei
Malleostemon roseus
Malleostemon tuberculatus
Melaleuca filifolia
Melaleuca leiocarpa
Melaleuca pauperiflora subsp. fastigiata
Melaleuca uncinata
Micromyrtus imbricata
Rinzia carnosa
Thryptomene urceolaris

Family: Ophioglossaceae
Ophioglossum lusitanicum

Family: Orchidaceae
Pterostylis aff nana
Pterostylis picta
Thelymitra aff. macrophyllum

Family: Orobanchaceae
* Orobanche minor

Family: Papilionaceae
Bossiaea walkeri
Mirbelia aff. densiflora
Mirbelia sp. (NG & ML 2055)
Templetonia sulcata

Family: Phormiaceae
Dianella revoluta

Family: Pittosporaceae
Pittosporum phylliraeoides

Family: Plantaginaceae
Plantago aff. hispidula (NG & ML 1732)
Plantago drummondii

Family: Poaceae
* Aira caryophyllea
Amphipogon strictus
Aristida holathera
Austrostipa blackii
Austrostipa elegantissima
Austrostipa platychaeta
Austrostipa trichophylla
* Bromus rubens
Danthonia caespitosa

Elymus scaber
Eragrostis dielsii
Eragrostis eriopoda
Eriachne flaccida
* Hordeum leporinum
Monachather paradoxus
* Pentaschistis airoides
* Rostraria pumila
* Vulpia myuros

Family: Polygalaceae
Comesperma volubile

Family: Portulacaceae
Calandrinia corrigioloides
Calandrinia eremaea
Calandrinia ptychosperma

Family: Primulaceae
* Anagallis arvensis

Family: Proteaceae
Dryandra arborea
Grevillea acuaria
Grevillea erectiloba
Grevillea georgeana
Grevillea haplantha subsp. haplantha
Grevillea huegelii
Grevillea obliquistigma subsp. obliquistigma
Grevillea paradoxa
Grevillea zygoloba
Hakea minyma
Hakea preissii
Hakea recurva
Persoonia sp.

Family: Rhamnaceae
Stenanthemum stipulosum
Trymalium myrtillus subsp. myrtillus
Trymalium urceolare

Family: Rutaceae
Eriostemon brucei subsp. brucei
Phebalium canaliculatum
Phebalium canaliculatum x megaphyllum intergrade
Phebalium megaphyllum ms
Phebalium tuberculosum

Family: Santalaceae
Exocarpos aphyllus
Leptomeria preissiana
Santalum acuminatum
Santalum spicatum

Family: Sapindaceae
Dodonaea lobulata
Dodonaea microzyga var. acrolobata
Dodonaea stenozyga
Dodonaea viscosa subsp. angustissima

Family: Solanaceae
Nicotiana occidentalis
Solanum lasiophyllum
Solanum orbiculatum

Family: Stackhousiaceae
Tripterococcus brunonis

Family: Sterculiaceae
Brachychiton gregorii

Family: Stylidiaceae
Levenhookia leptantha
Stylidium induratum

Family: Zygophyllaceae
Zygophyllum aff. tesquorum
Zygophyllum apiculatum
Zygophyllum eremaeum
Zygophyllum glaucum
Zygophyllum ovatum

APPENDIX 2

Floristic data set for the Hunt Range, Yendilberin and Watt Hills.

The full data set (263 taxa x 53 quadrats) is provided in Cornell University Condensed Format. The species code is derived from the first three letters of the genus and species names with a further two letters from intraspecific rank where applicable except where otherwise listed below.

Non standard species codes.

Eucalyptus salmonophloia	EUCSALm
Eucalyptus salubris	EUCSALu
Maireana trichoptera	MAITRIc
Maireana triptera	MAITRIp

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jaurdi full dataset 31-7-97
(13I6)                                                          5
     1     15     38     41     72     79     85    122    135    137    140    158    179
   180    183    194    198    199    208    210    226    228    234
     2     82
     3     13     17     18     29     35     39     43     54     77    107    112    120
   127    134    144    174    185    196    216    221    226    228
     4     27     47     58     66     68     75     85     90    137    138    140    141
   158    165    182    183    184    193    194    197    198    199    201    208    210
   211    212    236
     5      2     16     17     18     24     35     43     63     77     79     87    105
   107    116    121    127    168    170    180    186    194    196    208    209    218
   221    227    228
     6     13     17     19     21     29     31     35     42    112    120    121    127
   134    144    185    196    221    228
     7      9     26     28     47     69     88     90    100    108    116    135    158
   170    197    201    205    207    210    212    230    236
     8      2     18     21     31     34     35     42     43     49     54     63     77
    87    104    110    118    121    134    153    154    176    185    186    196    210
   212    220    221    222    228
     9      2     12     17     29     35     43     54    104    127    132    134    143
   147    155    167    174    175    177    190    212    216    219    221    228
    10      2     14     17     20     21     35     43     46     51     54     63     73
    77     88    100    107    108    110    116    120    121    127    132    134    135
   145    153    164    174    175    185    194    196    210    221    228    234
    11     14     52     73     91     97    100    146    158    162    212    235    236
    12      4      9     26     28     69     75     90     95    140    158    195    197
   198    201    205    210    211    212    234    236
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    80     85     88    107    108    116    135    137    140    158    179    180    183
   186    193    194    198    199    201    208    210    212    234    236
    14     28     53     75     85     97    135    158    201    212    224
    15      2     14     20     24     43     50     54     63     72     77     88    107
   116    127    135    170    175    180    185    186    194    196    207    208    209
   210    212    221    228    233    234    236
    16      2      3     14     17     20     31     43     46     47     48     51     54
    67     69     73     77     91    101    114    121    134    145    152    159    161
   166    170    185    186    193    195    210    212    220    221    226    227
    16    232
    17      6      8     14     68     73     85     98    137    140    146    158    182
   194    198    215
    18      6     37     38     46     47     48     74     78     80     95    102    116
   117    123    125    126    137    140    148    171    182    192    197    198    199
   202    203    212    213    223
    19      6     37     69     73     75     80     94     96    100    108    126    137
   146    158    192    194    198    199    208    212    215    223    236
    20     37     47     68     75     88     90    135    137    140    158    179    183
   197    198    201    210    211    212    228    236
    21      6     52     68     73     75     88     93    100    140    158    179    198
   236
    22      3     20     57     83    108    181
    23      3     17     20     31     43     54     67     77     83    119    133    145
   155    161    185    196    221    232
    24      6     15     20     37     46     52     73     75     94     96     98    108
   116    135    146    158    180    182    192    193    194    198    199    210    212
   236
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194
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36 6 26 28 30 32 52 75 79 84 93 140 141
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204 207 210 219 221 226 228
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116 130 138 139 140 141 178 179 194 196 197 198 206
210 236
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39 212 219 221 227 228
40 2 15 17 20 47 51 63 72 73 77 91 92
113 120 121 127 155 158 159 162 175 183 185 210 212
221 228 229
41 2 10 14 15 20 24 35 37 47 50 72 73
77 88 92 101 107 127 135 137 158 159 170 180 183
185 193 201 210 212 218 226 228
42 2 7 20 47 51 63 77 88 91 121 135 137
158 159 169 172 185 194 201 208 210 212 224 228
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103 112 113 118 119 121 127 131 134 145 150 155 160
161 170 175 193 196 210 212 221 226 227 228 232
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57 76 77 104 112 119 127 134 144 150 156 177 180
186 193 208 210 212 216 221 227 228
46 7 14 17 20 35 36 38 43 47 48 49 50
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170 180 183 185 188 193 194 204 208 210 212 221
46 228
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63 72 77 79 88 100 108 116 121 127 158 159 161
170 180 185 196 201 210 221 226 228
48 2 6 24 26 28 32 47 85 88 107 108 116
135 137 140 158 170 180 194 198 199 201 210 211 212
234 236
49 2 13 14 17 21 29 47 50 51 54 63 73
77 91 112 113 120 134 135 144 159 163 172 175 185
190 201 210 228
50 2 13 18 21 29 54 77 112 113 120 134 172
175 185 194 210 218 228
51 6 73 75 80 85 94 95 108 137 140 158 189
192 194 198 199 210 215
52 2 13 18 29 34 35 43 49 55 63 73 77
112 113 120 155 173 175 185 189 195 210 218 221 226
228
53 14 20 36 62 69 73 85 104 108 135 137 140
158 169 180 194 201 208 210 228
0

ACAACAGLACAACU ACAAND ACAASSASACACOL ACAERI ACAHEM ACAMER ACAPAC ACAQUA
ACARAM ACARES ACASIB ACATET ACTULI AIRCAR ALLACU ALLCAM ALLCOR ALYBUX
AMPSTR AMYBEN AMYPRE ARIHOL ASTATH ATRNUM ATRPAL ATRVES BAEELD BEYBRE
BLEDRU BOSWAL BRACIL BRAGRE BRUAUS CALCOR CALERE CALHIS CALPAU CALPREVE

CEPDRU CEROBI CHEAUS CHELAS COMVOL CRACOL DANCAE DAUGLO DIAREV DODLOB
DODMICACDODSTE DODVISANDROMAC DRYARB ELAPUS ELYSCA ENCTOM ERADIE ERAERI
ERECAEMEERECAP ERECLA EREDECDEEREDRU EREGLAGLEREGRA EREINT EREION ERELATLA
EREMAC EREOLDANEREOPPANERERUG ERESCO ERESER ERIBRU EROCIC EROCYG ERYRAMRA
EUCBRA EUCCAPCAEUCCAPPOEUCCEL EUCCLE EUCCOR EUCEWA EUCGRI EUCLEPLEEUCLON
EUCLOXLIEUCOLE EUCRAV EUCSALm EUCSALu EUCSHE EUCTRA EUCYIL EUPDRU EXOAPH
GILOSB GNESP GONNOD GOOBER GOOKRA GOOMIM GOOOCC GREACU GREERE GREGEO
GREHUE GREOBL GREPAR HAKPRE HALAND HALGOS HARBRE HIBEAT HIBEXA HIBROS
HYADEM HYAZAC HYDRUG HYPGLA ISOGRA LAWREP LAWROS LEPMUE LEPROE LEPROT
LEP_ANG LEP_JI LEUAFFRULEUBRE LEUFIT MAICAR MAIGEO MAIPEN MAIRAD MAITRIc
MAITRIp MALROS MALTUB MELFIL MELLEI MELPAUFAMELUNC MESNOD MICIMB MILMYO
MILTEN MIRDEN MITPAR MONOCC MONPAR NICOCC OLEEXI OLEMUE OLEPIM OLESTU
PENAIR PHECAN PHECXM PHETUB PITPHY PLAAFFRIPODANG PODCAN PODCAP PODLES
POGSTR PORMIC PROALTALPROCAM PROGRY PROINC PTEPIC PTICAR PTIEXA PTIGAU
PTIHEL PTIHOL PTIOBO RHADRU RHOLAE RHOOPP RHORUB RHOSTR RHYLIN RINCAR
ROSPUM SANACU SANSPI SCASPl SCHCAS SCHNAN SCLDEN SCLDIA SCLFUS SCLPAR
SENARTFISENCARCASENGLO SIDATR SIDSPO SOLLAS SOLORB STEFIL AUSBLA AUSELE
AUSPLA AUSTRI STRLIA STYIND TEMSUL THEAFFMATHRURC THYMAN THYPAT TRACYA
TRAORN TRIBRU TRICAL TRISKI TRYMYRMYVELROS VULMYU WAIACU WESCEP WESRIG
WURTEN XERDIV ZYGAFFTEZYGERE ZYGGLA ZYGOVA
533/01 533/02 533/03 533/04 533/05 533/06 fin01 fin02 fin03 fin04
fin05 green01 green02 green03 green04 jau01 jau02 jau03 jau04 jau05
jau06 jau07 jau08 jau09 nk01 nk02 nk03 pk01 pk02 pk03
pk04 pk05 pk06 pk07 pk08 pk09 pk10 pk11 wat01 wat02
wat03 wat04 wat05 wat06 wat07 yen01 yen02 yen03 yen04 yen05
yen06 yen07 yen08

APPENDIX 3

Geographical location for the sites from the Hunt Range, Yendilberin and Watt Hills.

Plot	Latitude	Longitude
533/01	30.2631	119.8737
533/02	30.2622	119.8716
533/03	30.2617	119.8698
533/04	30.2618	119.8949
533/05	30.2618	119.8991
533/06	30.2612	119.9030
fin01	30.6790	120.1400
fin02	30.6731	120.1455
fin03	30.6704	120.1363
fin04	30.6670	120.1315
fin05	30.6612	120.1277
green01	30.6497	120.0803
green02	30.6299	120.0665
green03	30.6277	120.0645
green04	30.6220	120.0608
jau01	30.8003	120.1617
jau02	30.8003	120.1608
jau03	30.7885	120.1538
jau04	30.7885	120.1530
jau05	30.7693	120.1292
jau06	30.7693	120.1292
jau07	30.7441	120.1318
jau08	30.7441	120.1318
jau09	30.7441	120.1297
nk01	30.1680	119.8632
nk02	30.1570	119.8582
nk03	30.1165	119.8435
pk01	30.2070	119.8505
pk02	30.2025	119.8585
pk03	30.2055	119.8612
pk04	30.2018	119.8622
pk05	30.2013	119.8655
pk06	30.1986	119.8672
pk07	30.1954	119.8710
pk09	30.1961	119.8690
pk10	30.1971	119.8762
pk11	30.1896	119.8728
wat01	30.6186	120.1030
wat02	30.6204	120.1023
wat03	30.6017	120.0825
wat04	30.6005	120.0930
wat05	30.6005	120.0925
wat06	30.5986	120.0910
wat07	30.5976	120.0887
yen01	30.5237	120.0493
yen02	30.5236	120.0507

yen03	30.5350	120.0317
yen04	30.4226	119.9583
yen05	30.4218	119.9593
yen06	30.4232	119.9567
yen07	30.3947	119.9255
yen08	30.3941	119.9218