Flora and vegetation of the Eastern Goldfields Ranges: Part 6. Mt Manning Range

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Abstract

This study of the flora and plant communities of the Mt Manning greenstone belt (some 100 km N of Koolyanobbing) recorded a total flora of 238 taxa, of which 234 were native and four were introduced. The species list is poorer than reported for previously studied ranges and shows a compositional shift consistent with the more semi-arid nature of the climate. The most common life-forms were shrubs 50% and annual herbs 23.5%. No taxa were found to be endemic to the greenstone belt. Seven community types were defined from 54 quadrats established along the range system. These communities types were strongly correlated with edaphic factors, and are compositionally distinct from those of nearby ranges to the south. The vegetation of the Mt Manning Range, like that of the Helena & Aurora Range to the south and Die Hardy Range to the west, is very poorly conserved. The results of the current survey support previous recommendations for the inclusion of the Mt Manning greenstone belt into the Nature Reserve.

Keywords: flora, vegetation, Goldfields, Mt Manning Range, Western Australia, greenstone

Introduction

The Mt Manning greenstone belt extends some 30 km from the Mt Manning Range north to the Evanston-Menzies Road, about 100 km north of Koolyanobbing. It consists of ca a 1 km-thick sequence of variously metamorphosed basalt overlain by chert and banded ironstone, which in turn is overlain by high-Mg basalt and minor gabbro separated by banded ironstone (Greenfield 2001). These belts are a common landform of the Eastern Goldfields and incorporate most of the mineralization. As a consequence, they have been heavily exploited for mineral exploration and mining for over 100 years. Despite this, a detailed knowledge of the flora and vegetation of individual ranges is still lacking, although broad scale structural vegetation mapping (Beard 1972) and regional surveys (Keighery *et al.*1995) are available.

This paper continues a this series of papers that report on detailed floristic studies on some of these ranges, to address this deficiency (Gibson *et al.* 1997; Gibson & Lyons 1998a,b; Gibson & Lyons 2001a,b). The Mt Manning greenstone belt is the most arid system yet studied, and provides contrast to the biogeographic patterns reported from other range systems.

Study Locality

The study area lies ca 100 km north of Koolyanobbing and covers all of the Mt Manning greenstone belt (Fig 1; Greenfield 2001). The belt runs north-south and is ca 6 km wide but quickly narrows to less than 2 km. The geology of the study area has been mapped and described in detail in the Lake Giles and Bungalbin 1: 100000 sheets (Greenfield 2001, Chen & Wyche 2001) following earlier regional studies of Walker & Blight (1983). The lenticular greenstone belts of this region are believed to be 3000 My old and to have subsequently undergone multi-staged metamorphism that peaked with the major granitiod intrusion between 2710 and 2670 My ago. These ancient rocks have weathered into gently undulating plains and broad valleys covered by Tertiary soils (< 65 My old). These soils may develop in situ from the weathering of laterite duricrusts, or represent depositional soils derived from the ancient rocks or the Tertiary laterization (Greenfield 2001). The net result is a very subdued landscape except for the highly resistant banded ironstones which form a series of abrupt rocky outcrops.

The climate of the region is warm dry mediterranean with warm winters and hot summers. Mean annual rainfall at Diemals Station (ca 45 km NW of the range) is 275 mm, with moderate seasonal variation over the 23 years of record (1970-1994; decile 1, 157 mm; decile 9, 436 mm) Most rain falls in winter generally associated with frontal activity from April through August. Summer falls are highly erratic and result from thunderstorms. Heaviest falls (to 127 mm) are associated with rain bearing depressions forming from tropical depressions (Milewski & Hall 1995; Bureau of Meteorology 2004). The temperature data from Diemals show mean maximum temperatures is highest in January (36 °C) with November through March all recording mean annual temperatures above 30 °C. Lowest mean minimum temperatures of 4 °C are recorded in July. The highest daily maximum temperature recorded was 46.5 °C with the lowest being –4.6 °C. On average there are 15.9 days a year over 40 °C and 67.2 days above 35 °C, with 11.1 days per year with the minimum below freezing (Bureau of Meteorology 2004).

The Mt Manning Range lies in the South Western

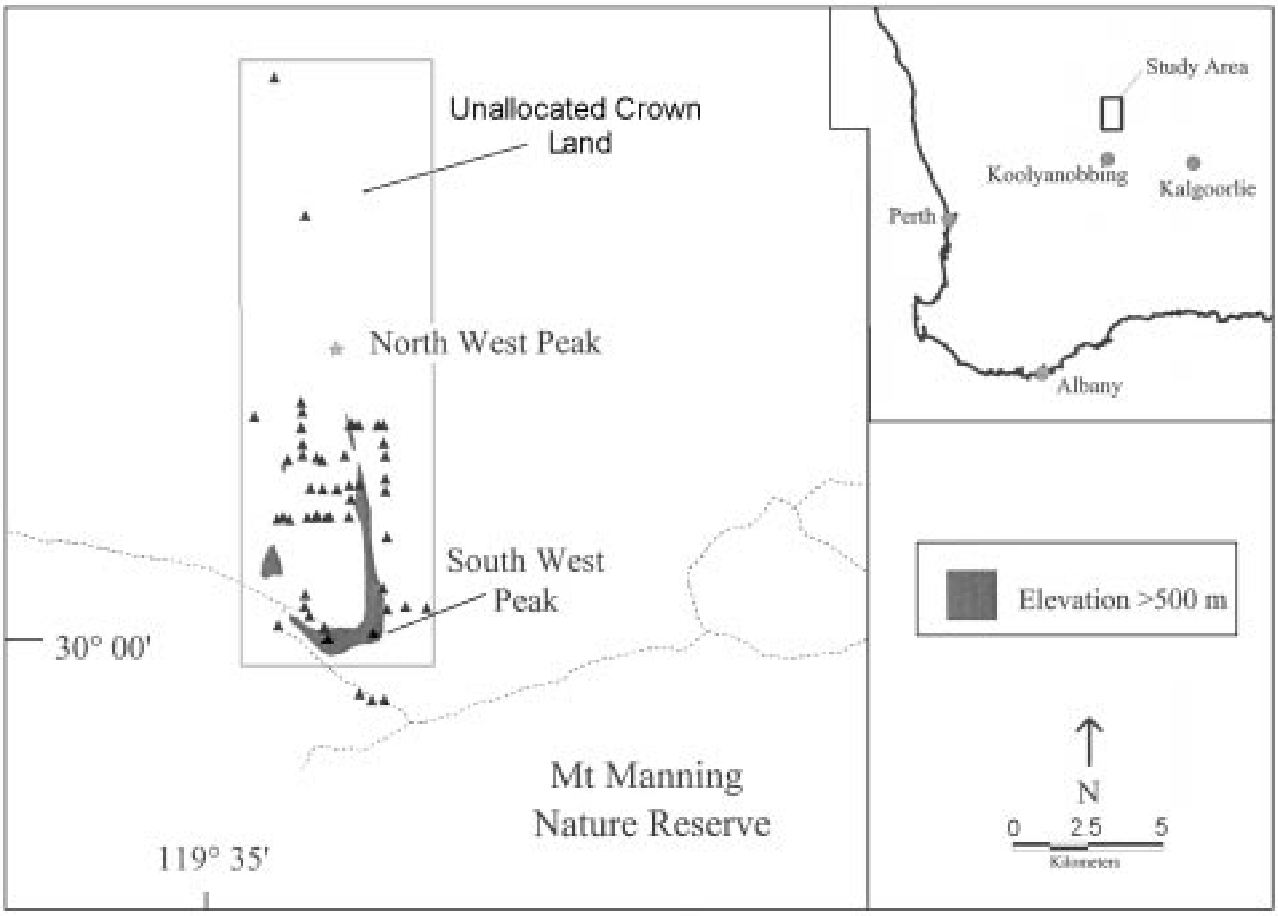

Figure 1. Location of the study area and distribution the 54 quadrats along the Mt Manning Range (solid triangles). Most of the uplands (and the quadrats sampled) fall in an enclave of Unallocated Crown Land within the Mt Manning Nature Reserve.

Interzone close to the border with the Murchison botanical region (Beard 1990). The Interzone is generally dominated by eucalypt woodlands and shrublands on yellow sandplains and it marks the transition in vegetation from the species-rich south west to the more arid communities of the desert regions. The Murchison region is dominated by mulga (*Acacia aneura)* low woodlands.

Beard (1972) described the major structural formations of the Jackson 1:250 000 sheet which lies immediately south of the Mt Manning Range. He consideres the Die Hardy vegetation system on the northern edge of that map sheet to be similar to that occurring on the banded ironstones of Mt Jackson and Koolyanobbing Range, but slightly different due to its lower rainfall. *Brachychiton gregorii* and *Dryandra arborea* are occasional trees on the range crest, with the northern slopes dominated by open scrubs of *Acacia aneura, A. linophylla, A. acuminata, A. tetragonophylla* and *Dodonaea* sp. The southern slopes support dense thickets of *Allocasuarina acutivalvis* and *A. campestris* with some acacias and eucalypts.

Keighery *et al.* (1995) ascribe the vegetation of the Mt Manning Range to this vegetation system. They identify 30 major structural vegetation units as occurring along the range. The ridges of the range support five structural units; *Acacia aneura* tall shrubland, *Eucalyptus ebbanoensis* mallee, *Acacia quadrimarginea* tall shrubland, *Dryandra arborea* tall shrubland, and *Allocasuarina acutivalvis* tall shrubland. The *E. ebbanoensis* mallee is a stunted version of the vegetation of the lower slopes. The two *Acacia* shrublands have similar composition but differing dominance and the *Dryandra* shrubland occupies lateritic patches on the ridge crests. Pure *Acacia aneura* low woodlands occur on lower slopes on deep colluvial soils while the valleys are dominated by *Eucalyptus salubris* and / or *E. salmonophloia* woodland or by *Casuarina pauper* (syn *C. cristata*) low woodland around the base of the Mt Manning Range and on small rises of greenstone on the plain. The surrounding sandplain is dominated by *Eucalyptus formanii* over *Plectrachne rigidissima.*

The aim of the present work was to undertake a detailed floristic survey of the Mt Manning greenstone belt. This involved the compilation of a detailed flora list, and the description of the vegetation patterning of the area based on a series of permanently located quadrats.

Methods

Fifty-four 20 m x 20 m quadrats were established on Mt Manning Range, side slopes and outwash plains surrounding the range (Fig 1). These quadrats attempted to cover the major geographical, geomorphological and floristic variation found in the study area. Care was taken to locate quadrats in the least disturbed vegetation available in the area being sampled. All vascular plants were recorded within each quadrat. Quadrats were permanently marked with four steel fence droppers and their positions determined using a GPS unit. Twenty-four soil samples from the upper 10 cm were collected from each quadrat. These were bulked and analyzed for electrical conductivity, pH, total N, total P, available K (McArthur 1991).

Quadrats were sampled in early November 1995. Data on topographical position, slope, aspect, percentage litter, percentage bare ground, percentage surface rock (bedrock and surficial deposits) and vegetation structure were collected from each quadrat. Topographical position was scored on a subjective six point scale; ridge tops = 1, upper slopes = 2, midslopes = 3, lower slopes = 4, valley flats =5, small rise in valley =6. Slope was scored on a one to three scale from flat to medium, to steep. Aspect was recorded as one of 16 cardinal directions. Altitude was taken from 1:100000 series topographical map to nearest 10 m. Vegetation structure was recorded using Muir's (1977) classification.

Quadrats were classified according to similarities in species composition. In these analyses only perennial species were used to facilitate comparisons with classifications from other ranges (Gibson *et al.* 1997; Gibson & Lyons 1998a,b; Gibson & Lyons 2001a,b). The quadrat and species classifications undertaken used the Czekanowski similarity coefficient and "unweighted pair-group mean average" fusion method (UPGMA module in PATN, Belbin 1995, beta value -0.1, Sneath & Sokal, 1973). Semi-strong hybrid (SSH in PATN) ordination of the quadrat data was undertaken to show spatial relationships between quadrat groups (here referred to as community types) and to elucidate possible environmental correlates with the classification (Belbin 1991). Methods of Dufrene & Legendre (1997) were used to determine best indicator taxa for each group (from PC-ORD v 4.24, McCune & Mefford 1999).

Climate estimates (mean annual temperature, annual temperature range, mean annual rainfall, rainfall coefficient of variation) were obtained from BIOCLIM (Busby 1986), a prediction system that uses mathematical surfaces fitted to long term climate data. Relationships among and between physical site parameters and climate estimates were examined using Spearman rank correlation coefficient. To reduce the probability of type I errors given the number of intercorrelations, significance differences were reported at a level of $P<0.01$. Vectors for the physical site parameters, latitude, altitude and climatic estimates were fitted to the ordination along axes of highest correlation using the principal axis correlation routine (also known as rotational correlation analysis) in the PATN package (Belbin 1995). Statistical significance of these vectors was determined using random permutations of the values of the variable among sites (Faith & Norris 1989). Statistical relationships between quadrat groups for physical site parameters and climate estimates were tested using Kruskal-Wallis non-parametric analysis of variance (Siegel 1956).

Nomenclature generally follows Paczkowska & Chapman (2000). Voucher specimens have been be lodged in the Western Australian Herbarium. Introduced taxa are indicated by a "*".

Results

Flora

A total of 238 taxa (species, subspecies, varieties) were recorded from the Mt Manning greenstone belt (Appendix 1). The flora list was compiled from taxa found in the 54 quadrats or the adjacent area and from collections of the Western Australian Herbarium. Of these 238 taxa, 234 are native and four are weeds. Sampling was undertaken in the first week of November 1995 and although good rains had fallen in winter and spring of 1995, the annuals and geophytes were largely finished and further additions could be expected to the flora list. The best represented families were the Asteraceae (37 native taxa and 2 introduced taxa), Myrtaceae (32 taxa), Chenopodiaceae (13 taxa), Poaceae (12 native taxa and 2 introduced taxa) Myoporaceae (11 taxa), and Mimosaceae (10 taxa). This pattern is typical of the flora in changeover zone between the of the South Western Botanical Province and the Eremaean (Gibson *et al.* 2000). The most common genera were *Eucalyptus* (17 taxa), *Eremophila* (11 taxa) and *Acacia* (10 taxa). Most common life-forms were shrubs 50%, annual herb 23.5%, perennial herbs 5.5%, mallee 5.0%, trees 4.6% and perennial grasses 4.2%. These six life-forms accounted for over 92% of taxa recorded.

Six taxa of conservation significance (Atkins 2001) were recorded (*Calytrix creswellii, Daviesia purpurascens, Eremophila* sp (GJ Keighery 4372), *Eucalyptus formanii, Grevillea erectiloba,* and *Grevillea georgeana*). Of these *Eremophila* sp (GJ Keighery 4372) and *Calytrix creswellii* are the most poorly known, being represented by only 5 and 15 collections respectively in the Western Australian Herbarium. All six taxa with the exception of *Daviesia purpurascens* have a geographic range of ca 200 km and can be considered regional endemics of the greenstone and banded ironstone ranges (*Eremophila* sp (GJ Keighery 4372), *Grevillea erectiloba, Grevillea georgeana*) or the surrounding sandplain (*Calytrix creswellii, Eucalyptus formanii*), although the latter two taxa do also occur on the lower slopes or outwash plains of the Mt Manning Range.

Vegetation

Only plant material that could be identified to species or subspecies level was included in the analysis (ca 95% of records). In the 54 quadrats established on the Mt Manning Range, 197 taxa were recorded of which 142 were perennial. Fifty-five perennials occurred at only one quadrat. Preliminary analyses showed these singletons had no effect on the community classification and were therefore not considered further. As a result the final data set consisted of 87 perennial taxa in 54 quadrats. Species richness ranged from five to 23 taxa per quadrat, with individual taxa occurring in between two and 38 of the 54 quadrats.

The 54 quadrats were divided into two primary groups, the first group (types 1-5) containing quadrats with skeletal soils over banded ironstone or weathered yellow sand on banded ironstone or laterite, the second group (types 6 & 7) containing quadrats on greenstone or colluvial soils (Fig 2).

- Community type 1 were species poor quadrats that

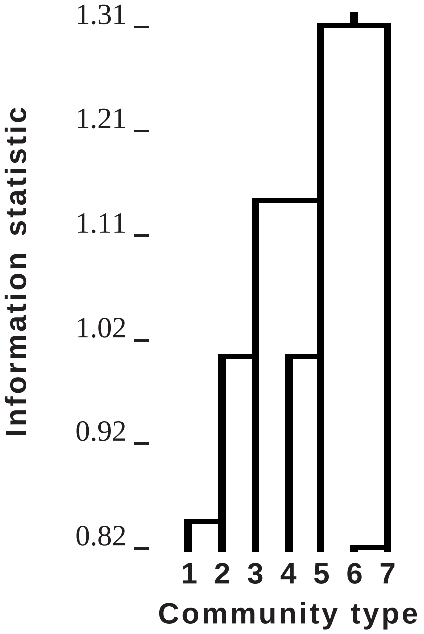

Figure 2. Dendrogram of 7 group level classification of 54 quadrats established along the Mt Manning greenstone belt.

generally occurred on massive banded ironstone near the crest of the range. Species richness was low (mean 10.5 taxa plot^{-1}) with only some taxa in species groups A and F (Appendix 2) being consistently represented. Best indicator species for this group were the rock fern (*Cheilanthes austrotenuifolia*), *Calycopeplus paucifolius, Austrostipa trichophylla,* and *Eremophila clarkei.* Other constant species to this group included the perennial grass *Amphipogon strictus.* One quadrat in this group occurred on massive greenstone on a small rise near the base of the range.

- Community type 2 occurs on the lower flanks of the ranges on somewhat deeper soils. This community type is generally dominated or co-dominated by *Eucalyptus ebbanoensis*, *Acacia ramulosa, A. aneura, A. quadrimarginea* and / or at the foot of the range by *Callitris glaucophylla.* Indicator taxa include *Callitris glaucophylla, Prostanthera althoferi* subsp *althoferi.* Species groups G and H are largely restricted to this community type but at low constancy levels (Appendix 2). Species group A is also well represented, as is *Eremophila latrobei* subsp *latrobei.* Average species richness was 12.7 taxa plot^{-1}.
- Around the base of the range and on some upland units, a characteristic yellow sand unit develops over laterite. Community type 3 occurs on this unit and is characterized by high constancy of taxa in species group F, half of which are indicator species. Typical co-dominant indicators include, *Allocasuarina acutivalvis, Melaleuca nematophylla* and *Acacia quadrimarginea.* Typical shrub indicators include *Baeckea elderiana, Hibbertia rostellata, Grevillea obliquistigma, Phebalium canaliculatum, Grevillea paradoxa* and *G. georgeana* (Appendix 2). Average species richness is high at 14.5 taxa plot^{-1}. This community is most common around the base of the range but does occur where ever the laterite sheet remains.
- Community type 4 occurs on eroding breakaways which are dominated by *Eucalyptus capillosa* subsp *capillosa.* This landform is very restricted at the Mt Manning Range; it is more common on the banded ironstones of the Helena and Aurora Range and the Yendilberin Hills to the south (Gibson *et al.* 1997; Gibson & Lyons 2001b).
- Community type 5 occurred at a single quadrat on sandy alluvial soils in a narrow drainage line at the base of the range. Species richness was low with only eight perennial species being recorded, three of which were only recorded at this quadrat. This quadrat was dominated by *Eucalyptus formanii*; it may represent either a depauperate example of community type 2 or be more representative of the surrounding sandplain that were not sampled in this study (Keighery *et al.* 1995).
- Community types 6 and 7 appear to represent community types on the more fertile soils lower in the landscape. Taxa in species group A are most faithful to these two communities.
- Community type 6 are eucalypt mallees and woodlands which are found on the lower slopes, valley and small rises in the valleys. These quadrats are generally dominated by *Eucalyptus griffithsii* and / or *E. ebbanoensis* or occasionally by *Casuarina pauper.* This community differs from community type 7 by the general lack of chenopods (Appendix 2). Best indicator taxa of this community included *Eucalyptus griffithsii, Olearia muelleri, Acacia tetragonophylla, Ptilotus obovatus* and *Acacia erinacea.* Average species richness was high at 16.9 taxa plot^{-1}.
- The final community type (type 7) is the chenopod rich eucalypt woodlands of the valleys and small rises. Common dominants include *Eucalyptus salubris* and occasionally *Casuarina pauper*. Indicator taxa were largely chenopods (Appendix 2). Average species richness was again high at 14.5 taxa plot^{-1}.

Physical Correlates

Soil parameters showed high levels of intercorrelation, as did the site parameters and the climate parameters. Total P was not correlated with any other soil parameter except for total N, while total N was not correlated with pH (Table 1). All other soil parameters were intercorrelated. Of the site parameters only topographic position showed no intercorrelation while slope, aspect, percentage rock, percentage litter and percentage bare ground were all highly intercorrelated. Altitude, latitude and the four climate parameters also showed a significant degree of intercorrelation. A much lower degree of intercorrelation was evident between these three different types (soil, site and climate) of parameters (Table 1).

Table 1

Matrix of Spearman rank correlation coefficients between site physical parameters and climate estimates. Only correlation significant at P < 0.01 shown. (Climate parameter codes: Tann, mean annual temperature; Tar, annual temperature range; Rann, mean annual rainfall; Rcv, rainfall coefficient of variation.)

	EC	**pH**	**N**	**P**	**K**	**Position**	**Slope**	**Aspect**	**% rock**	**% litter**	**% bare**	**altitude**	**latitude**	**Tann**	**Tar**	**Rann**	**Rcv**
EC	1.000																
pH	0.558	1.000															
N	0.689		1.000														
P			0.612	1.000													
K	0.706	0.765	0.576	0.441	1.000												
Position	0.364	0.620			0.485	1.000											
Slope							1.000										
Aspect							0.604	1.000									
% rock			0.449				0.473	0.451	1.000								
% litter							-0.477	-0.433	-0.532	1.000							
% bare			-0.428				-0.532	-0.452	-0.800	0.353	1.000						
Altitude		-0.535				-0.445						1.000					
Latitude													1.000				
Tann		0.465										-0.659	0.455	1.000			
Tar				-0.404									0.875		1.000		
Rann												0.738		-0.828		1.000	
Rcv																-0.362	1.000

Table 2

Plant community mean values for soil, site and climate parameters. Differences between means of groups 1, 2, 3, 6,and 7 tested using Kruskal-Wallis non-parametric analysis of variance. Mean species richness and number of quadrats given for comparison. (* indicates P<0.05, ** indicates P<0.01, *** indicates P<0.001.) Climate parameter codes: Tann, mean annual temperature; Tar, annual temperature range; Rann, mean annual rainfall; Rcv, rainfall coefficient of variation.

	Community type						
	1	2	3	4	5	6	7
EC**	6.3	2.7	2.8	58.0	2.0	6.0	9.4
pH***	5.1	4.7	4.6	4.4	5.5	6.1	6.8
N*	0.125	0.054	0.057	0.090	0.034	0.070	0.082
P	230.8	145.1	98.5	180.0	88.0	131.5	165.7
K***	155.0	149.6	83.8	160.0	91.0	220.5	368.6
Position	2.5	4.7	3.1	4.0	5.0	5.2	5.1
Slope	2.3	1.5	1.4	2.0	2.0	1.7	1.4
Aspect	5.5	2.1	3.3	4.0	4.0	3.1	2.1
% rock**	85.0	22.0	53.6	90.0	10.0	59.5	30.7
% litter*	10.0	31.5	27.7	10.0	10.0	26.0	42.9
% bare**	0.0	33.0	19.1	0.0	10.0	13.0	25.7
Altitude**	560	484	485	480	450	475	471
Latitude	-29.9700	-29.9673	-29.9250	-29.9851	-29.9961	-29.9551	-29.9693
Tann**	18.8	19.1	19.2	19.1	19.2	19.2	19.2
Tar	30.2	30.1	30.2	30.1	30.1	30.2	30.1
Rann*	254.5	247.1	246.6	247.0	244.0	246.2	246.3
Rcv	33.0	33.0	33.1	32.9	33.2	33.0	33.0
Richness	10.5	12.7	14.5	7.0	5.0	16.9	15.4
No quadrats	4	10	11	1	1	20	7

As community types 4 and 5 were only represented by single quadrats, they were excluded from the statistical analysis of environmental differences. Significant differences were found between mean values for three of the four soil parameters, three of the six site parameters and three of the six climate parameters for community types 1, 2, 3, 6 and 7 (Table 2). Community type 1 showed a high percentage of exposed rock and occurred at higher altitudes with a higher estimated rainfall than other community types. The soils of this community were high in total N and had a higher pH and EC than community types 2 and 3 which occurred on deeper more acid sands. Community types 2 and 3 were differentiated primarily on available K, percentage surface rock and percentage bare ground. The single quadrat that sampled a breakaway (type 4) showed very high values of EC probably related to erosion of the freshly exposed clays beneath the duricrust. The soils of community types 6 and 7 were close to neutral, showed high levels of available K and intermediate levels of total N and occurred at lower altitude than types 1 to 3. The chenopod rich community type 7 had the highest pH, and highest levels of available K recorded as well as the best developed litter layer (Table 2).

The edaphic differences between community types are also reflected in the ordination (stress 0.18 for the three dimensional solution) on which the highest correlated environmental vectors have been plotted (Fig 3). Community types 6 and 7 typical of the lower slopes and outwash flats occur in the lower left quadrant. The skeletal higher nutrient soils of the top of the range (type 1) occur in the middle right of the figure while the nutrient poor sandy soils (of types 2 and 3) in the upper right of the figure. The outlying nature of community type 5 can be seen while community type 4 is very different from the others in the third dimension (not shown). In addition to edaphic factors, altitude and rainfall, topographic position and percentage litter cover were significantly correlated with the quadrats in ordination space (Fig 3).

Discussion

The total of 238 taxa that we recorded on the Mt Manning Range compares with 293 taxa recorded by Keighery *et al.* (1995) for the sandplains of Mt Manning Range Nature Reserve, in addition to the range. The total for the range is low compared with the list for the Helena and Aurora Range (324 taxa), and this probably reflects in part the sampling of the Mt Manning Range later in the season when many of the annuals and geophytes were not as apparent (Gibson *et al.* 1997). However the flora list for the range is also lower than those for the Bremer Range (267 taxa) and the Parker Range (254 taxa), which were also sampled in a very poor year for annuals and geophytes (Gibson & Lyons 1998a,b). This low total species richness is also consistent with a decline in species richness along an increasing aridity gradient (Beard 1972). The Mt Manning Range lies just south of the boundary between the South Western Interzone and the Murchison botanical region. The Interzone is the change over zone between the species-rich South West and the more arid Eremaean zone.

Beard (1972) mapped the southern extreme of the Mt Manning Range as part of the Jackson vegetation system but later stated (Beard 1976) that the Mt Manning Range was probably similar to the vegetation of the Die Hardy system covering the banded ironstone formations of the

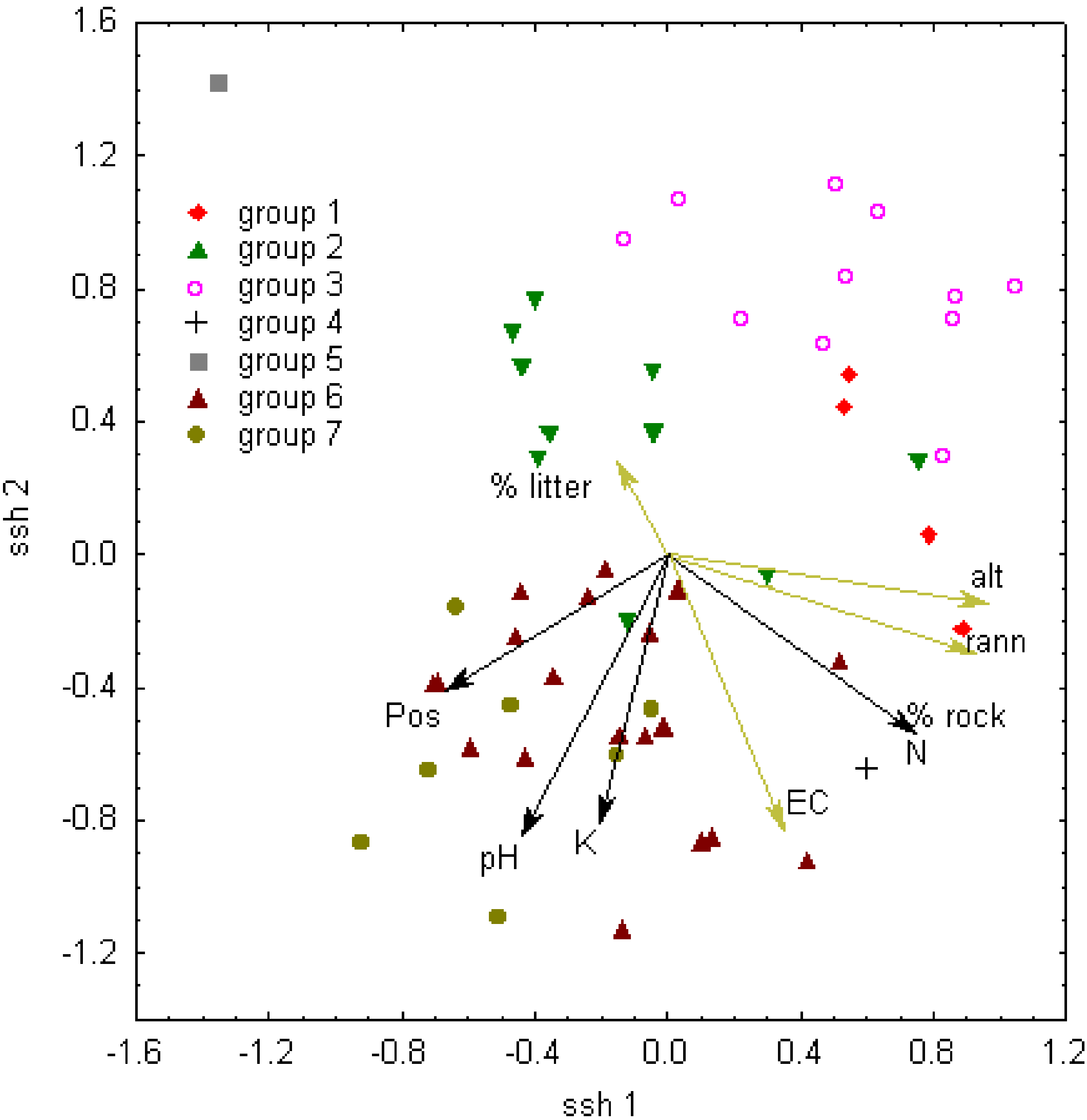

Figure 3. Ordination of the 54 quadrats coded by community type. Arrows show the direction of the best fit linear correlation environmental parameters; open arrows P<0.05, solid arrows P<0.001.

Die Hardy Range. Keighery *et al.* (1995) concurred that the vegetation of the Mt Manning Range area should be considered part of Beard's Die Hardy vegetation system. Further detailed survey work of the Die Hardy Range is needed to assess this.

The data suggest that floristic variation across the range is considerably less than structural variation described by Keighery *et al.* (1995). The present classifications allow the placement of the structural units described earlier to be set in a topography-soil context.

We were not able to relocate the *Dryandra arborea* shrubland on the top of Mt Manning Range described by Keighery *et al.* (1995) despite extensive searches in the region of South East Peak, the ridge to the west, and the more extensive ridge to the north. This community type, which is common on the massive ironstone tops of the Helena & Aurora Range (70 km to the south), must be localized in small patches on the Mt Manning Range. This decrease in the occurrence of this community type is likely to be associated with the decreasing rainfall (Beard 1972). *Dryandra arborea* was encountered twice off the range, on skeletal soils over decomposing granites and on deep yellow sands. Both populations occur on the gridline between North West Peak and the Evanston-Menzies road. These populations represent the northern limits of this species.

Keighery *et al.* (1995) listed *Neurachne* sp (GJK & JA 1951) as a common perennial grass of the *Eucalyptus ebbanoensis* woodlands of the lower slopes. This taxon was not recorded during the current survey. Common perennial grasses recorded included *Amphipogon strictus, Austrostipa trichophylla,* and *Austrostipa elegantissima.* The *Neurachne* may have been missed due to lateness of the survey. The distribution of this species on the range needs clarification.

A significant number of new populations of *Grevillea erectiloba* and *Grevillea georgeana* were located during the present survey. These species are of conservation concern (Atkins 2001). *Grevillea georgeana* generally occurs on massive banded ironstone while *G. erectiloba* generally occurs on yellow sands over laterites around the base of the range. Of the five regional endemics of the banded ironstones and associated soils of the Helena and Aurora 70 km to the south (Gibson *et al.*1997), *Grevillea erectiloba, Grevillea georgeana* and *Mirbelia* sp Helena & Aurora (BJL 2003) occur as far north as the Mt Manning Range.

The main section of the Mt Manning Range is in an enclave of Unallocated Crown Land within the Mt Manning Nature Reserve ("the doughnut reserve" Fig 1). So despite being surrounded by a Nature Reserve only a few hundred hectares of the vegetation of the Mt Manning greenstone belt is presently reserved (Greenfield 2001).

The present survey clearly shows that the ridge and slope communities are fundamentally different in composition from those reported for the Helena and Aurora Range (Gibson *et al.* 1997). The Helena and Aurora Range is also composed of massive banded ironstones of the same age (Chin & Smith 1983). The differences in vegetation and flora most likely reflect differences in present day climate, or past history during the arid periods of the Tertiary (Hopper 1979), or both. Previous studies have suggested that the vegetation of the range is most similar to that on the Die Hardy Range (Beard's Die Hardy vegetation system), this remains to be tested.

The vegetation of the Mt Manning Range like the vegetation of the Helena & Aurora and Die Hardy Ranges is very poorly conserved. Our work supports the recommendations of CALM (1994) and Keighery *et al.* (1995) that the Mt Manning Range should become part of the Mt Manning Nature Reserve.

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APPENDIX 1

Flora list for Mt Manning Range, includes all taxa from the sampling quadrats and adjacent areas and collections lodged in the Western Australian Herbarium from the range. Nomenclature generally follows Paczkowska and Chapman (2000), * indicates an introduced taxon.

Adiantaceae
- *Cheilanthes austrotenuifolia*
- *Cheilanthes lasiophylla*

Amaranthaceae
- *Ptilotus aervoides*
- *Ptilotus divaricatus*
- *Ptilotus drummondii*
- *Ptilotus exaltatus*
- *Ptilotus gaudichaudii*
- *Ptilotus holosericeus*
- *Ptilotus leucocoma*
- *Ptilotus obovatus*

Anthericaceae
- *Thysanotus patersonii*
- *Thysanotus speckii*

Apiaceae
- *Daucus glochidiatus*
- *Trachymene ornata*

Apocynaceae
- *Alyxia buxifolia*

Asclepiadaceae
- *Marsdenia australis*
- *Rhyncharrhena linearis*

Asteraceae
- *Actinobole uliginosum*
- *Asteridea athrixioides*
- *Blennospora drummondii*
- *Calotis hispidula*
- *Calotis multicaulis*
- *Cephalipterum drummondii*
- *Chthonocephalus pseudevax*
- *Erymophyllum ramosum* subsp *ramosum*
- *Gilberta tenuifolia*
- *Gilruthia osbornei*
- *Gnephosis tenuissima*
- **Hypochaeris glabra*
- *Lawrencella rosea*
- *Leucochrysum fitzgibbonii*
- *Millotia* sp
- *Olearia exiguifolia*
- *Olearia humilis*
- *Olearia muelleri*
- *Olearia pimeleoides*
- *Olearia stuartii*
- *Olearia subspicata*
- *Podolepis canescens*
- *Podolepis capillaris*
- *Podolepis lessonii*
- *Podotheca angustifolia*
- *Rhodanthe citrina*
- *Rhodanthe laevis*
- *Rhodanthe manglesii*
- *Rhodanthe oppositifolia*
- *Rhodanthe rubella*
- *Rhodanthe stricta*
- *Schoenia cassiniana*
- *Senecio glossanthus*
- **Sonchus oleraceus*
- *Streptoglossa cylindriceps*
- *Streptoglossa liatroides*
- *Trichanthodium skirrophorum*
- *Vittadinia humerata*
- *Waitzia acuminata*

Boraginaceae
- *Halgania integerrima*

Brassicaceae
- *Stenopetalum filifolium*
- *Stenopetalum pedicellare*

Caesalpiniaceae
- *Senna artemisioides* subsp *filifolia*
- *Senna pleurocarpa* var *pleurocarpa*

Campanulaceae
- *Wahlenbergia tumidifructa*

Casuarinaceae
- *Allocasuarina acutivalvis*
- *Allocasuarina campestris*
- *Allocasuarina corniculata*
- *Allocasuarina eriochlamys* subsp *eriochlamys*
- *Allocasuarina helmsii*
- *Casuarina pauper*

Chenopodiaceae
- *Atriplex nummularia*
- *Atriplex vesicaria*
- *Enchylaena tomentosa*
- *Maireana georgei*
- *Maireana pentatropis*
- *Maireana radiata*
- *Maireana trichoptera*
- *Maireana triptera*
- *Rhagodia drummondii*
- *Sclerolaena densiflora*
- *Sclerolaena diacantha*
- *Sclerolaena fusiformis*
- *Threlkeldia diffusa*

Crassulaceae
- *Crassula colorata*

Cupressaceae
- *Callitris glaucophylla*

Cyperaceae
- *Lepidosperma* sp

Dasypogonaceae
- *Xerolirion divaricata*

Dilleniaceae
- *Hibbertia rostellata*
- *Hibbertia spicata*

Droseraceae
- *Drosera menziesii*

Epacridaceae
- *Leucopogon* sp Clyde Hill (MA Burgman 1207)

Euphorbiaceae
- *Calycopeplus paucifolius*
- *Poranthera microphylla*

Frankeniaceae
- *Frankenia desertorum*

Geraniaceae
- *Erodium cygnorum*

Goodeniaceae
- *Brunonia australis*
- *Dampiera juncea*
- *Dampiera roycei*
- *Goodenia berardiana*
- *Goodenia occidentalis*
- *Scaevola spinescens*
- *Velleia hispida*
- *Velleia rosea*

Haloragaceae
- *Glischrocaryon flavescens*
- *Gonocarpus nodulosus*
- *Haloragis gossei*

Lamiaceae
- *Lachnostachys coolgardiensis*
- *Physopsis viscida*
- *Prostanthera althoferi* subsp *althoferi*
- *Prostanthera grylloana*
- *Westringia cephalantha*

Lauraceae
- *Cassytha nodiflora*

Lobeliaceae
- *Lobelia heterophylla*

Loganiaceae
- *Phyllangium paradoxum*

Loranthaceae
- *Amyema gibberula*
- *Amyema miquelii*

Malvaceae
- *Abutilon otocarpum*
- *Abutilon oxycarpum*
- *Lawrencia* sp
- *Sida atrovirens*
- *Sida calyxhymenia*
- *Sida chrysocalyx*

Mimosaceae
- *Acacia acuminata*
- *Acacia andrewsii*
- *Acacia aneura*
- *Acacia coolgardiensis* subsp *effusa*
- *Acacia erinacea*
- *Acacia kempeana*
- *Acacia neurophylla*
- *Acacia quadrimarginea*
- *Acacia ramulosa*
- *Acacia tetragonophylla*

Myoporaceae
- *Eremophila alternifolia*
- *Eremophila clarkei*
- *Eremophila decipiens*
- *Eremophila glabra* subsp *glabra*
- *Eremophila interstans*
- *Eremophila ionantha*
- *Eremophila latrobei* subsp *latrobei*
- *Eremophila oldfieldii* subsp *angustifolia*
- *Eremophila oppositifolia* subsp *oppositifolia*
- *Eremophila scoparia*
- *Eremophila* sp Mt Jackson (GJ Keighery 4372)

Myrtaceae
- *Aluta aspera* subsp *aspera*
- *Baeckea elderiana*
- *Calytrix creswellii*
- *Calytrix divergens*
- *Eucalyptus brachycorys*
- *Eucalyptus capillosa* subsp *capillosa*
- *Eucalyptus ebbanoensis* subsp *ebbanoensis*
- *Eucalyptus ebbanoensis* subsp *glauciramula*
- *Eucalyptus formanii*
- *Eucalyptus grasbyi*
- *Eucalyptus griffithsii*
- *Eucalyptus kochii* subsp *amaryssia*
- *Eucalyptus leptopoda* subsp *subluta*
- *Eucalyptus longicornis*
- *Eucalyptus loxophleba* subsp *lissophloia*
- *Eucalyptus moderata*
- *Eucalyptus oldfieldii*
- *Eucalyptus oleosa* subsp *repleta*
- *Eucalyptus salubris*
- *Eucalyptus subangusta* subsp *subangusta*
- *Eucalyptus yilgarnensis*
- *Euryomyrtus maidenii*
- *Homalocalyx thryptomenoides*
- *Malleostemon roseus*
- *Melaleuca acuminata*
- *Melaleuca fulgens*
- *Melaleuca leiocarpa*
- *Melaleuca nematophylla*
- *Melaleuca uncinata*
- *Thryptomene kochii*
- *Thryptomene urceolaris*
- *Verticordia helmsii*

Orchidaceae
- *Oligochaetochilus pictus*
- *Thelymitra* aff *macrophyllum*

Papilionaceae
- *Daviesia purpurascens*
- *Mirbelia depressa*
- *Mirbelia ramulosa*
- *Mirbelia* sp Helena & Aurora (BJ Lepschi 2003)

Phormiaceae
- *Dianella revoluta*

Pittosporaceae
- *Bursaria occidentalis*
- *Cheiranthera filifolia* var *filifolia*

Plantaginaceae
- *Plantago* aff *hispidula* (NG & KB 3179)

Poaceae
- *Amphipogon strictus*
- *Aristida holathera*
- *Austrodanthonia caespitosa*
- *Austrostipa elegantissima*
- *Austrostipa platychaeta*
- *Austrostipa trichophylla*
- *Bromus arenarius*
- *Eragrostis dielsii*
- *Monachather paradoxus*
- *Neurachne* sp (GJK & JA 1951)
- **Pentaschistis airoides*
- *Triodia rigidissima*
- *Triodia scariosa*
- **Vulpia myuros*

Portulacaceae
- *Calandrinia eremaea*
- *Calandrinia* sp Bungalbin (GJK& NG 1656)

Proteaceae
- *Dryandra arborea*
- *Grevillea acuaria*
- *Grevillea erectiloba*
- *Grevillea georgeana*
- *Grevillea nematophylla* subsp *nematophylla*
- *Grevillea obliquistigma*
- *Grevillea paradoxa*
- *Hakea minyma*

Rhamnaceae
- *Stenanthemum stipulosum*

Rubiaceae
- *Psydrax suaveolens*

Rutaceae
- *Boronia coerulescens*
- *Phebalium canaliculatum*
- *Phebalium filifolium*
- *Phebalium tuberculosum*
- *Philotheca brucei* subsp *brucei*
- *Philotheca tomentella*

Santalaceae
- *Exocarpos aphyllus*
- *Santalum acuminatum*
- *Santalum spicatum*

Sapindaceae
- *Dodonaea divaricata*
- *Dodonaea lobulata*
- *Dodonaea rigida*
- *Dodonaea stenozyga*
- *Dodonaea viscosa*

Solanaceae
- *Nicotiana occidentalis*
- *Solanum cleistogamum*
- *Solanum lasiophyllum*
- *Solanum orbiculatum*
- *Solanum plicatile*

Stackhousiaceae
- *Stackhousia intermedia*

Sterculiaceae
- *Brachychiton gregorii*
- *Keraudrenia velutina* subsp *elliptica*

Stylidiaceae
- *Stylidium induratum*
- *Stylidium limbatum*
- *Stylidium repens*
- *Stylidium yilgarnense*

Zygophyllaceae
- *Zygophyllum apiculatum*
- *Zygophyllum eremaeum*
- *Zygophyllum ovatum*

Appendix 2

Sorted two-way table of quadrats established on the Mt Manning greenstone belt showing species occurrence by community type. Quadrats appear as columns and species as rows. Taxa in bold are indicator species identified by INDVAL (Dufrene & Legendre 1997) at four group level ($P < 0.05$). Single quadrat groups (types 4 and 5) not considered. Statistical significance tested by randomization procedure.

	Community type						
	1	2	3	4	5	6	7
SPECIES GROUP A							
Acacia acuminata	**	* *	**			***** * * *	
Acacia ramulosa	*	********	*** ******			** **** *	*
Amphipogon strictus	****	**********	****** ****			***** **** *** **	
Thysanotus patersonii	**	**** *	***** *			*** *** *	*
Acacia erinacea				*		*** ** *******	***
Maireana trichoptera						* * ** *	***
Austrodanthonia caespitosa			*			* **** * *** * * **	* * *
Olearia muelleri						*************** **	* * *
Senna artemisioides subsp *filifolia*		* **** *				* ****** *** **	**
Austrostipa elegantissima	* *	* *** **	* *			********** * * **	*******
Austrostipa trichophylla	****	* *****				* ********* *******	* ****
Ptilotus obovatus	**	****				** *********** *****	** *
Scaevola spinescens		** * * *	* * *			** **** * * *** *	** *
Eucalyptus griffithsii		* *				* **** ******	
Maireana georgei		*				** * **** ** **	*****
Ptilotus gaudichaudii	*	* *	*			**** ** * * **	
Eremophila oppositifolia subsp *oppositifolia*		*		*		*** * ***	**
Eucalyptus ebbanoensis		**** *	*			* * ****	
Atriplex nummularia						****** *	* * **
Rhagodia drummondii						****** *	* *****
Sclerolaena diacantha						** *** *	* *****
Atriplex vesicaria						* * * *	*****
Eremophila scoparia						** ** **	** ***
Ptilotus exaltatus		**				** * **** *	* *****
Sclerolaena fusiformis		*				* *	******
SPECIES GROUP B							
Acacia tetragonophylla		* *				*** **** * ** **	*
Casuarina pauper						* * ** **	*
Exocarpos aphyllus						** * * ** *	*
Eremophila decipiens						* * * ***	*
Dodonaea lobulata		*				* *****	
Eremophila oldfieldii subsp *angustifolia*		*				* ** * ****	*
Alyxia buxifolia		*	* *	*		* ** * * ** *	
Eremophila interstans						** *	*
Eremophila sp Mt Jackson (GJ Keighery 4372)						* *	
Eucalyptus longicornis						**	*
Dodonaea rigida		*	*			*	
Santalum spicatum		*	* *			** * * **	
SPECIES GROUP C							
Allocasuarina campestris	*					*	
Dodonaea stenozyga						* *	
Eremophila glabra subsp *glabra*						* *	*
Ptilotus aervoides						***	* * *
SPECIES GROUP D							
Enchylaena tomentosa		*					*
Ptilotus divaricatus		*			*	*	*
Eucalyptus grasbyi		*					**
Eucalyptus salubris							****
Rhyncharrhena linearis	*		*			*	**
SPECIES GROUP E							
Austrostipa platychaeta						** **	
Threlkeldia diffusa				*		*	*
Eremophila ionantha						**	**
Maireana pentatropis						*	*

	Community type						
	1	**2**	**3**	**4**	**5**	**6**	**7**
Maireana radiata						*	** *
Eucalyptus oleosa subsp *repleta*						*	*
SPECIES GROUP F							
Acacia aneura	*	*** *	*				
Acacia quadrimarginea	*	*** ** *	** ******			*	
Eremophila latrobei* subsp *latrobei		*** *	*** *				
Allocasuarina acutivalvis	* *		** *******	*			
Baeckea elderiana			**********				
Melaleuca nematophylla	*		******				
Calycopeplus paucifolius	** *		** ****				
Grevillea paradoxa	*		* ******				
***Leucopogon* sp Clyde Hill (MA Burgman 1207)**	*	*	******				
Hibbertia spicata	*		* *** *				
Prostanthera grylloana	*		* * ** *				
Grevillea obliquistigma			** ****		*		
Hibbertia rostellata			**** ** *				
Phebalium canaliculatum		**	***** * **				
Cheilanthes austrotenuifolia	****		****			*	
Philotheca brucei subsp brucei	**		* ****	*			
Grevillea georgeana			* * *				
Stylidium yilgarnense			**				
SPECIES GROUP G							
Acacia coolgardiensis subsp *effusa*		*	*				
Westringia cephalantha		* *				* * *	
Aluta aspera subsp *aspera*		**					
Callitris glaucophylla		***					
Ptilotus leucocoma		**					
Olearia pimeleoides	*	** ***	*				
Prostanthera althoferi* subsp *althoferi		* ****	*				
Monachather paradoxus		* ***	** *			*	
SPECIES GROUP H							
Mirbelia depressa		**					
Oligochaetochilus pictus		*		*			
Sida atrovirens		* *					
Sida calyxhymenia	*	*				**	
SPECIES GROUP I							
Eremophila clarkei	**	*	* *				
Eucalyptus formanii		*	* **		*		
Euryomyrtus maidenii		*	* **				
Phebalium tuberculosum		*	*		*		
Triodia rigidissima			*		*		