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Flora and vegetation of banded iron formations of the Yilgarn Craton: Mount Gibson and surrounding area

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ABSTRACT

A total of 243 taxa, 233 native and 10 weeds, were recorded from study of the flora and plant communities of the Mount Gibson Range and surrounding ironstone ranges on the Ninghan pastoral lease, 60 km southeast of Paynes Find. Seven priority flora, one declared rare flora and one new species were identified during the study. Fifty quadrats were established to cover the geomorphology, floristic variation and geographical variation across the ranges. Data from these quadrats were used to define seven community types. Geography and landscape morphology separated the communities, with four communities found only on the Mount Gibson Range. Of these four, two had restricted distributions within the range. None of the ranges are currently reserved in the conservation estate.

INTRODUCTION

Banded Iron Formation (BIF) ranges within the Yilgarn Craton are highly prospective for iron ore exploration and mining. Previous studies on ironstone and greenstone ranges in the Goldfields have found high plant endemicity and restricted plant communities and it is thought that these patterns may also be found on the ranges in the Yilgarn (Gibson et al. 1997; Gibson & Lyons 1998a,b; Gibson & Lyons 2001a,b; Gibson 2004a,b). The current knowledge of the vegetation and flora that occur on these ranges is poor and based primarily on the structural description of the dominant vegetation rather than the community composition (Beard 1976).

The study area is located approximately 60 km southwest of Paynes Find and covers the extent of Mount Gibson, Yandhanoo Hills and several smaller hills on the Ninghan pastoral lease.

The climate of the area surrounding Mount Gibson is semi-desert mediterranean, with 9 to 11 months of dry weather, mild wet winters and hot dry summers (Beard 1990). Mean annual rainfall recorded at Paynes Find is 282.5 mm, and rainfall is highly variable in the region (180.5 mm 1st decile; 398 mm 9th decile; recorded 1919 to 2004). Rain primarily falls in winter, although some summer rainfall does occur. The highest maximum temperatures occur during summer, with the January as hottest month (mean maximum temperature 37.1 °C and mean 8.9 days above 40 °C). Winters are mild with lowest mean maximum temperatures recorded for July of 18.4 °C. Temperatures occasionally fall below 0 °C in winter (a mean 3.1 days below 0 °C), with a mean minimum of 5.4°C in July.

In terms of geology, the Mount Gibson Range lies within the Murchison Province of the Yilgarn Craton. The geology of the Mount Gibson area is complex and composed of several fold belts. The Retaliation Belt is represented mainly by the Mount Gibson Range and is comprised of banded iron formations and cherts in the lower sedimentary association, bounded by volcanic flows with marker bands of banded ironstone formation. The Yandhanoo Hills and small hills near Warro Well (Figure 1) are part of the Yandhanoo Belt. This belt is composed mainly of metasedimentary rocks of thoroughly recrystallised cherts and banded ironstone (Lipple et al. 1983).

The Mount Gibson Range occurs in the southern part of the Yalgoo IBRA region. This region is an interzone, between southwest bioregions and the Murchison IBRA region (Environment Australia 2000). Broadscale mapping by Beard (1976) shows several vegetation associations. The Mount Gibson Range was mapped as shrublands of *Acacia acuminata* (jam) and *Allocasuarina acutivalvis* on ironstone. Colluvial slopes were mapped as medium woodland of York gum (*Eucalyptus loxophleba*), Salmon gum (*Eucalyptus salmonophloia*) and gimlet (*Eucalyptus salubris*). Surrounding Mount Gibson, the vegetation was mapped as shrubland of bowgada (*Acacia ramulosa*) and *Acacia quadrimarginea* on stony ridges and shrublands of bowgada and jam scrub.

Payne et al. (1998) describe Mount Gibson as part of the Tallering Land System. This broad classification includes banded ironstone ranges from Mount Karara running northwards to Yalgoo. These included several plant communities occurring on the landforms; 20% of the system is composed of ridges and hills, some banded ironstone, with shallow stony red earths with *A. ramulosa* and other acacias over *Thryptomene* and *Philotheca* species. Fifty eight percent of the land system consisted of hillslopes covered in scattered to moderately dense shrublands of

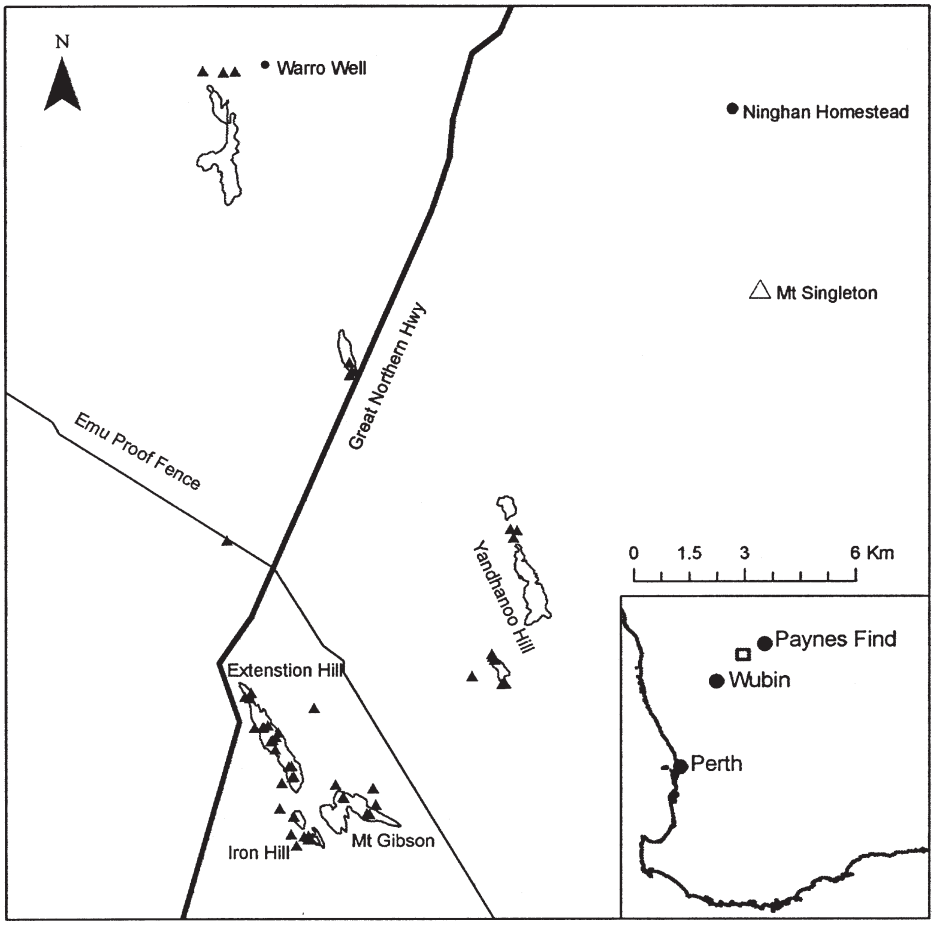

Figure 1. Location of survey and distribution of quadrats (▲) on Mount Gibson and surrounding banded iron formation ranges on Ninghan Station. Contours at 340 m are shown.

A. ramulosa and other *Acacia* spp. over *Eremophila* spp., *Ptilotus obovatus*, *Thryptomene* spp. and *Philotheca* spp. The remaining part of the system covered the stony plains, drainage tracts and stripped surfaces.

The aim of the survey is to identify the plant communities that occur on the ironstone range of Mount Gibson and surrounding areas. This was done through detailed flora lists and community descriptions based upon 50 permanently established quadrats on the range and surrounding area. This survey will be part of a larger regional study of flora and plant communities of banded ironstone formations of Yilgarn Craton.

METHODS

Fifty 20 x 20 m quadrats were established on Mount Gibson and several banded ironstone ranges in the surrounding area. In this report, Mount Gibson Range refers to several smaller hills, Extension Hill, Iron Hill and Mount Gibson (Figure 1). All quadrats were established between September and October 2005. The location of quadrats attempted to cover the major geographical, geomorphologic and floristic variation found on the hills and valleys in the study area. Each quadrat was permanently marked with four steel fence droppers and their positions determined using a GPS unit. All vascular plants within the quadrat were recorded and collected for later identification at the Western Australian Herbarium. Data on topographical position, disturbance, abundance, size and shape of coarse fragments on the surface, the amount of exposed bedrock, cover of leaf litter and bare ground were recorded following McDonald et al. (1990). Additionally, growth form, height and cover were recorded for dominant taxa in each stratum (tallest, mid- and lower).

Twenty soil samples were collected from the upper 10 cm of the soil profile within each quadrat. The soil was bulked and the 2 mm fraction was analysed for B, Ca, Cd, Co, Cu, Fe, K, Mg, Mn, Mo, Na, Ni, P, Pb, S and Zn using the Mehlich No. 3 procedure (Mehlich 1984). The extracted samples were then analysed using an Inductively Coupled Plasma - Atomic Emission Spectrometer (ICP-AES). This procedure is an effective and cost efficient alternative to traditional methods for evaluating soil fertility and has been calibrated for Western Australian soils (Walton & Allen 2004). pH was measured in 0.01M $CaCl_2$ at soil to solution ratio of 1:5. Effective cation

exchange capacity (eCEC) was calculated from the sum of exchangeable Ca, Mg, Na and K (Rengasamy & Churchman 1999). Exchangeable Ca, Mg, Na and K were obtained by multiplying the values of Ca, Mg, Na and K obtained from ICP-AES by a standard constant.

Quadrats were classified on the basis of similarity in species composition on perennial species only, to be consistent with other analyses of banded ironstone ranges. Life form followed Paczknowska and Chapman (2000), where perennial is defined as a plant whose life span extends over 2 or more growing seasons. The quadrat and species classifications were undertaken using the Bray and Curtis coefficient and Flexible UPGMA (Unweighted pair-group mean average, Belbin 1989). Indicator species and species assemblages characterising each community were determined following Dufrene and Legendre (1997). Quadrats were ordinated using SSH (semi-strong hybrid multidimensional scaling), correlations of environmental variables were determined using the PCC routine in PATN (Belbin 1989) and significance determined by MCAO (monte- carlo attributes in ordination) permutation tests in PATN. PCC is a routine that runs multiple linear regressions on the variables and the ordination coordinates, resulting in a vector for each variable within the ordination plot. The MCAO is a monte-carlo test determining the robustness of the PCC results by randomly assigning values of variables to objects and then running the PCC routine (Belbin 1989).

Statistical relationships between quadrat groups were tested using Kruskall-Wallis non parametric analysis of variance (Siegel 1956), followed by non-parametric post-hoc comparison (Zar 1999). Correlations between soil and physical site parameters were analysed using the Spearman's rank correlation.

Nomenclature generally followed Paczkowska and Chapman (2000).

RESULTS

Flora

A total of 243 taxa, 233 native and 10 weeds, were recorded from the 50 established quadrats and adjacent areas. A total of 56 families as recorded, and dominated by Asteraceae (51 taxa, 4 weeds), Myrtaceae (19), Mimosaceae (18) and Poaceae (16 taxa, 3 weeds).

Rare and Priority Flora

Seven priority species (designated P1, P2, P3) and one declared rare flora (DCF) were found during the survey. All species are poorly collected, with less than 20 collections for each species present in the Western Australian Herbarium.

- *Acacia cerastes* (P1) is a small shrub to 1 m with intricate wiry branches and reduced phyllodes and is known only from Mount Gibson Range and several granite outcrops near Mount Gibson. This was an opportunistic collection from the range. The species is a disturbance opportunist and was recorded growing on an old exploration track.
- *Austrostipa blackii* (P3) is a perennial tufted grass found mainly in the eastern states of Australia. It was recorded from only one site on Yandhanoo Hills growing on a rocky hillcrest under *Acacia umbraculiformis* and *Melaleuca nematophylla* shrubland.
- *Darwinia masonii*, one of two declared rare flora recorded in the survey, is restricted to the Mount Gibson Range. It is a myrtaceous shrub to 2 m with bright red flowers and long styles indicating bird pollination. This species occurred across the entire range, growing on the rocky crests and upper slopes.
- *Dodonaea amplisemina* (P3) is poorly collected shrub to 2 m. It is closely related to *Dododaea pinifolia* but differs with larger fruit and two different leaf forms. This shrub was highly palatable and was severely grazed by feral goats. It was collected only from two sites on Yandhanoo Hills, growing in *A. ramulosa* and *A. umbraculiformis* shrublands.
- *Micromyrtus* sp. Warriedar (S. Patrick 1879A) (P1) is a spindly myrtaceous shrub growing to 2 m with small pale yellow flowers. It is known from only 10 records in the Western Australian Herbarium and collected only from banded ironstone ranges in the Yalgoo IBRA region. This is the first record of this taxon for the Mount Gibson Range. *Micromyrtus* sp. Warriedar (S. Patrick 1879A) was collected mainly from the crests of Mount Gibson only.
- *Persoonia pentasticha* (P2) is a proteaceous shrub to 2 m with pungent 5 ribbed leaves. It has previously been recorded from Mount Gibson Station and has been recorded from other areas of banded ironstone formations.
- *Podotheca uniseta* (P3) is a small annual daisy, closely related to *Podotheca gnaphaloides*, differing by the presence of a single pappus on each achene. It was collected from a single site on Mount Gibson. This is the first record of the species for the range.
- *Rhodanthe collina* (P1) is an annual daisy with small delicate flowers. It has been poorly collected with only 13 records in the WA Herbarium. In this survey, it was found growing on crests and slopes of Yandhanoo Hills and the Great Northern highway, and on the Emu Proof Fence.

New Species

- *Lepidosperma gibsonii* DRF is a new species endemic to Mount Gibson. It was initially collected from Extension Hill, within a proposed mining footprint. The species is found growing across the range, mainly in gullies and sheltered positions (Barrett 2007). This species is closely related to *Lepidosperma ferricola*, which is also an endemic to the Koolyanobbing Range, in the eastern goldfields (Barrett 2007).

Range Extensions

Five species found during the survey, including the priority species *A. blackii*, had significant range extensions (>100 km from previously known collections).

- *Austrostipa hemipogon* is commonly found across the southwest of the State. It is a tufted perennial grass. It was recorded from a single site on Mount Gibson.
- *Crassula tetramera* and *Crassula closiana* are small annual succulent herbs, both less than 5 cm. *Crassula tetramera* is poorly represented in the herbarium, with only 11 collections. It can be easily distinguished from other species in the genera due to the 4-merous flowers and follicles opening by an apical pore. *Crassula closiana* is also distinctive with a long flowering pedicel and follicles. The survey extended their northwest and northeast distribution respectively. Due to their small size, they may have been overlooked.
- *Hemigenia macphersonii* has been poorly collected, with only six specimens in the Western Australian State Herbarium. In this survey, it was collected from a single site on the Mount Gibson Range. It has previously been recorded from other banded ironstone ranges. The survey extended it's southern extent by approximately 100 km.

Taxonomic interest

- *Hibbertia* aff. *rostellata* belongs to an unresolved species complex with *Hibbertia exasperata*, *Hibbertia nutans* and *Hibbertia uncinata*, and referred to as the *Hibbertia exasperata* group (Wheeler 2004). *Hibbertia rostellata* is found mainly in the Avon Wheatlbelt and parts of the Mallee IBRA regions, growing on yellow sands, sand over gravel, and lateritic gravel, although a few specimens have been collected from greenstone ranges in the Goldfields. In contrast, *H.* aff. *rostellata* was collected only from the Mount Gibson Range and mainly from *Allocasuarina acutivalvis* subsp. *prinsepiana* woodlands on rocky crests and midslopes. The Mount Gibson populations are approximately 100 km from the nearest population of *H. rostellata*. The taxonomy of this group needs to be resolved.
- *Hibbertia hypericoides* is a shrub to 1.5 m with bright yellow flowers. It is distributed from the Swan Coastal Plain, north to the Geraldton Sandplains. The population collected at Mount Gibson are nearly 200 km to the east of the nearest collection, which is a significant range extension for the species. In this survey it was collected from Yandhanoo Hills and Mount Gibson Range from rocky outcrops on crests and midslopes. It has previously been collected from Yandhanoo Hills.

Plant communities

A total of 239 taxa were recorded for the 50 established quadrats, with 120 species of perennial taxa. Ninety three taxa occurred in more than one quadrat. Final analysis was conducted using perennial species only. Preliminary analysis showed little difference on community classification when annual species and singletons were removed. Two species, *Rhodanthe polycephala* and *Rhodanthe laevis*, were combined to a species complex for the analysis, due to the difficulty in differentiating between the two species in the field.

Community groups were separated into 7 plant communities, based upon clear patterning in the final dendrogram (Figure 2). The first split in the dendrogram separated Communities 6 and 7 found mainly on Extension Hill, a part of the Mount Gibson Range. The second division separated the remainder of sites on Mount Gibson (Communities 4 and 5) and the colluvial outwashes (Community 3) from sites on Yandhanoo Hills and other hills more distant to Mount Gibson (Communities 1 and 2). These divisions can also be seen in the sorted two-way table of the sites and species classification (Table 1).

Community 1 – Woodlands, shrublands and open shrublands of *A. umbraculiformis*, *A. ramulosa* var. *ramulosa* and *Calycopeplus paucifolius* over shrublands of *Eremophila latrobei, Philotheca sericea, Mirbelia bursarioides* and *Aluta aspera* subsp. *hesperia*. This

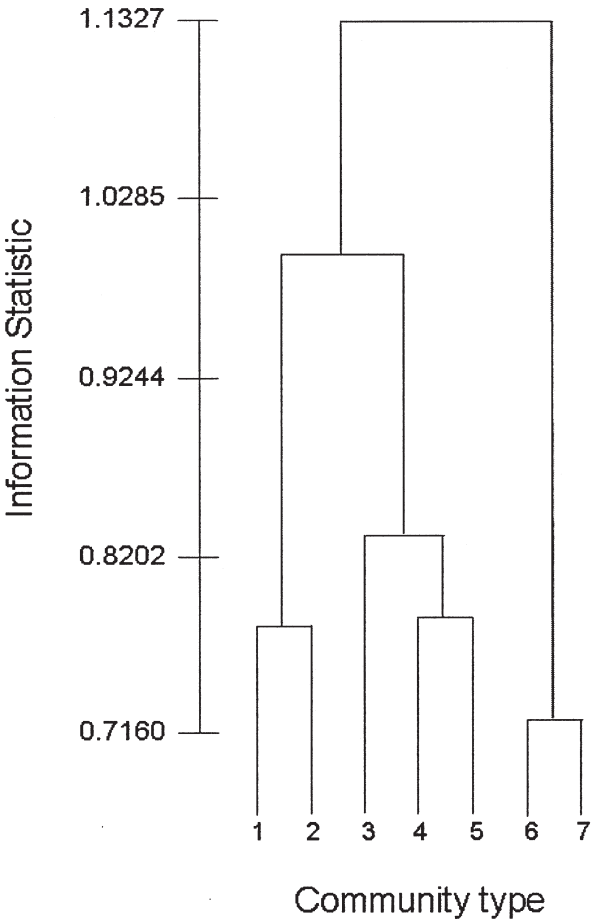

Figure 2. Dendrogram of 7 group level classification of the 50 quadrats established on Mount Gibson and surrounding ranges.

community was found on Yandhanoo Hills and sites adjacent to the Great Northern Highway from crests to lower slopes. The mean species richness was 34.2 ± 0.8 species per quadrat. It was characterised by species from Group E and indicator species *A. umbraculiformis*, *Acacia ramulosa* subsp. *ramulosa*, *E. latrobei* subsp. *latrobei* and *Monachather paradoxus* (Table 1).

Community 2 – Woodlands and shrublands of *Acacia assimilis* subsp. *assimilis* and *A. umbraculiformis* over shrublands of *Eremophila* spp., *Hemigenia* sp. Yalgoo and *M. bursarioides*. This community consisted of all sites near Warro Well, a single site from adjacent to the Emu Proof Fence and a site from Yandhanoo Hills (Figure 1). This community contained the most species poor sites (mean 23.3 ± 0.8 taxa per quadrat) and is characterised by species from Group D and E (Table 1). Indicator species were *A. ramulosa* var. *ramulosa*, *A. aspera* subsp. *hesperia*, *Cheiranthera filifolia* var. *simplicifolia*, *Eremophila forrestii* subsp. *forrestii*, *E. latrobei* subsp. *latrobei*, *H.* sp. Yalgoo (A.M. Ashby 2624), *Micromyrtus clavata* and *M. bursarioides*.

Community 3 – Open *Eucalyptus* woodlands over *Acacia* spp. This community is represented by only 3 quadrats located near Mount Gibson, Yandhanoo Hills and the Great Northern Highway on the colluvial plains. The dominant *Eucalyptus* species was either *Eucalyptus kochii* subsp. *amaryissa* and/or *Eucalyptus loxophleba* subsp. *supralaevis*. This community is characterised by species from Group B and mean species richness of 35.3 ± 0.7 species per quadrat (Table 1). Indicator species were *Acacia obtecta, Acacia tetragonophylla*, *M. paradoxus, Olearia muelleri*, *Ptilotus obovatus* subsp. *obovatus*, *Rhagodia* sp. Watheroo (R.J. Cranfield & P.J. Spencer 8183) and *Senna artemisioides* subsp. *filifolia*.

Community 4 – Mallee woodland and woodlands of *Eucalyptus* spp. (*Eucalyptus horistes*, *E. loxophleba* subsp. *supralaevis* or *E. kochii* subsp. *amaryissia*) over shrublands of *A. acuminata*. This community was only found on the lower slopes of the Mount Gibson Range. The community is characterised by species from Group A and B with a mean species richness of 32.4 ± 0.7 species per quadrat (Table 1). Indicator species were *A. acuminata*, *Acacia anthochaera*, *Acacia andrewsii*, *Acacia colletioides*, *Allocasuarina acutivalvis* subsp. *prinsepiana*, *Amphipogon caricinus*, *Maireana georgei, Melaleuca hamata, Philotheca brucei* subsp. *brucei* and *Scaevola spinescens*.

Community 5 – Open shrublands and shrublands of *Allocasuarina acutivalvis* subsp. *prinsepiana*, *C. paucifolius*, and *A. tetragonophylla* over shrublands of *P. brucei* subsp. *brucei* and *Ptilotus obovatus*. This community consisted primarily of sites on rocky outcrops on upper slopes and hill crests on Mount Gibson Range. It was not found on Extension Hill. This was the most species rich community (mean 38.5 ± 1.2 species per quadrat) and was characterised by taxa from groups E and H (Table 1). Indicator species were *Acacia exocarpoides*, *A. tetragonophylla*, *Cheilanthes adiantoides*, D*arwinia masonii*, *Hakea recurva*, *P. brucei* subsp. *brucei*, *Prostanthera magnifica*, *Prostanthera patens* and *P. obovatus* var. *obovatus*.

Community 6 – Open woodlands, shrublands and sparse shrublands of *A. acutivalvis* subsp. *prinsepiana*, *M. nematophylla*, *A. assimilis* subsp. *assimilis* and *Grevillea obliquistigma* subsp. *obliquistigma* over shrublands of *Hemigenia* sp. Paynes Find and *Leucopogon* sp. Clyde Hill. This community is found mainly on the crests and upper slopes of Extension Hill (Figure 1) with mean species richness of 35.1 ± 0.8 species per quadrat. It was characterised by taxa from species group G with indicator species *A. acutivalvis* subsp. *prinsepiana*, *Cassytha nodiflora, Grevillea obliquistigma* subsp. *obliquistigma, Hemigenia* sp. Paynes Find, *Leucopogon* sp. Clyde Hill, *M. nematophylla and Melaleuca radula* (Table 1).

Community 7 – Open woodlands, woodlands and shrublands of *Allocasuarina acutivalvis* subsp. *prinsepiana*, *Acacia coolgardiensis* subsp. *effusa* over *Aluta apera* subsp. *hesperia*. This community was found only on the lower slopes of Extension Hill and was characterised by taxa from Species Group G and I (Table 1). The sites had a mean species richness of 31.6 ± 1.2 species per quadrat. Indicator species were *A. coolgardiensis* subsp. *effusa*, *A. acutivalvis* subsp. *prinsepiana*, *A. aspera* subsp. *hesperia*, *A. caricinus* var. *caricinus*, *Baeckea* sp., *Enekbatus stowardii*, *Eucalyptus oldfieldii*, *Melaleuca fabri*, and *Stylidium confluens*.

Physical Correlates

The soil parameters showed significant intercorrelations but there were few significant correlations with site characters (Table 2). Maximum rock size showed significant correlations with all the other physical site characters. Iron showed significant correlations with most of the physical site characters apart from aspect, surface coarse fragment abundance and litter cover (Table 2).

Community 1 showed several significant differences in soil composition to the other communities (Table 3). It had a lower pH than Community 5 and was higher in copper and potassium than Communities 4 and 6. Community 7 was also lower than Community 1 in copper levels but had similar levels of potassium (Table 3). Zinc was different in several communities, with Community 1 having a higher level than Communities 4, 5 and 7.

Community 1, on Yandhanoo Hills and Great Northern Highway, recorded more grazing (caused by feral goats) than the Communities 6 and 7 found on Extension Hill (Table 4), and had a higher percentage cover of leaf litter than Community 7. Community 4 occurred on more gentle slopes than Community 1, which was found on the slopes and crests of Yandhanoo Hills and Great Northern Highway (Table 4).

Community 4 had smaller amount of coarse surface fragments than Community 5 and 7 and little or no rock outcrops compared to Community 5 and 6, the latter found on sites with rock outcrops (Table 4).

The three dimensional ordination (stress = 0.17) clearly separated Communities 6 and 7, found mainly on Extension Hill. These communities are characterised by lower levels of grazing, copper and zinc (Figure 3). The communities more distant from the Mount Gibson Range

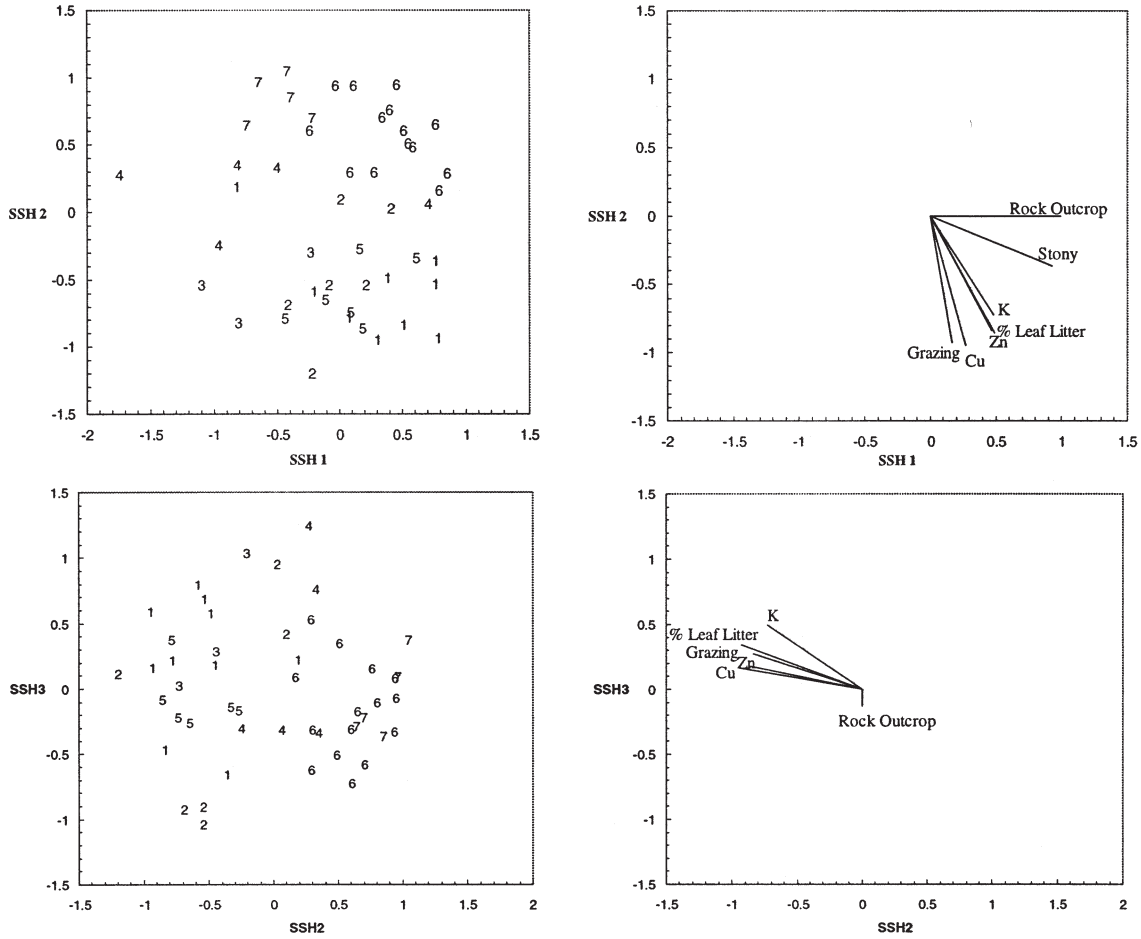

Figure 3. Three dimensional ordination showing Axis 1, 2 and 3 of the 50 quadrats established on Mount Gibson and surrounding ranges showing community type. Lines represent the strength and direction of the best fit linear correlated variables (P<0.05).

(1 and 2) are located in the lower right quadrant and were correlated with higher zinc, copper and grazing. Community 4 (Eucalypt woodlands on lower slopes) was more variable generally lower in surficial rock and coarse fragment cover. Community 5 is located in the lower half of the ordination, with the sites clustered together and correlated with higher surficial rock and coarse fragments. It is found on the upper slopes and crests of Iron Hill and Mount Gibson, high grazing, percentage leaf litter, copper and zinc.

DISCUSSION

Flora

Two hundred and forty three taxa were recorded for Mount Gibson. Two declared rare flora (DRF), seven priority flora and one new species were identified during the survey. The two DRF taxa, *D. masonii* and *L. gibsonii*, are endemic to the Mount Gibson Range. Similar numbers of taxa and priority flora have been recorded for other banded ironstone and green stone ranges on the Yilgarn Craton (see Gibson 2004b). The closest ironstone ranges to this survey are situated to the north and are contained within the Central Tallering landsystem (including Mt. Karara). A concurrent survey of these ranges found 414 taxa, while covering twice the area and number of quadrats (Markey & Dillon, 2008). More comparable is the survey of banded iron ranges of Koolanooka and Perenjori Hills to the west, which found 237 taxa, with six endemic species (Meissner & Caruso, 2008).

L. gibsonii is known only from the Mount Gibson Ranges, growing in gullies and on slopes in shallow soils over ironstone (ATA Environmental 2006a, Barrett 2007). Recent taxonomic work has recognised many new species of *Lepidosperma*, including *L. gibsonii*, which are endemic to banded ironstone ranges on the Yilgran Craton (Barrett 2007).

Mount Gibson occurs within the interzonal Yalgoo bioregion (Thackway & Cresswll 1995), an area with affinities to both Eremaean and Southwest botanical Provinces (Beard 1976). The ranges of several Southwest taxa, *A. hemipogon* and *H. hypericoides*, are at the eastern extent of their range. In contrast, a characteristic Eremaean species complex, *A. aneura*, is at the western most extent of its distribution.

Communities

Geographical location was a strong influence on the classification of the communities. Community 1 is found primarily at Warro Well, Community 2 from Yandhanoo and the Great Northern Highway and Communities 4, 5, 6 and 7 all occur on the Mount Gibson Range. Community 3 is the only shared community, occurring on the colluvial soils between Yandhanoo Hills and Extension Hill and near the hills on Great Northern Highway.

Within Mount Gibson Range, geographical location also influences the community types, with several communities restricted to specific parts of the range. Community 5 is found on Iron Hill and Mount Gibson but not Extension Hill, while Community 7 is only found on the lower slopes of Extension Hill. Community 6 occurs predominantly on Extension Hill, but has several quadrats located on Mount Gibson (Figure 1). There are similarities between the hills on the lower slopes of Mount Gibson Range, with Community 4 found across the range on the lower slopes and colluvial sites.

The geographic patterns are largely consistent with those described in a floristic survey conducted concurrently with this project (ATA Environmental 2006b). That survey provided more detailed classification with twice the number of permanent quadrats established on the crest and upper slopes of the Mount Gibson Range and surrounding area.

Within the Mount Gibson Range, topography separated some of the communities. Community 4 occurred on the lower slopes of Mount Gibson Range, Community 6 was found mainly on the crests and midslopes of Extension Hill, Community 5 occurred on the rocky outcrops of Iron Hill and Mount Gibson, and Community 7 was found only on the lower slopes of Extension Hill. However, Communities 1 and 2 occurred on all positions on the hills ie. crest, midslopes and lower slopes.

Soil fertility was not a strong variable in separating community type, with only a gradient of high to low potassium within the ordination. Community 1 was higher in potassium than Communities 4 and 6. However, total nitrogen was not measured in this survey, and this may reveal an additional relationship.

The Mount Gibson Range has been mapped as the Tallering landsystem (Payne et al. 1998) which include the Blue Hills, Mt. Karara and Windanning ironstone ranges to the north. However, when comparing the communities found on the Central Tallering landsystem (Markey & Dillon, in press), there were no communities in common with Mount Gibson. In particular, many of the dominant taxa on the Central Tallering ranges, such as *Acacia sibina*, were not recorded on Mount Gibson (Markey & Dillon, in press).

This study found several communities restricted to the Mount Gibson Range and no communities found elsewhere on any ironstone ranges outside of this area. The high species turnover within the ranges ie. markedly different plant communities occurring on relatively close ridges within Mount Gibson, has implications for future conservation of the range, especially communities 6 and 7 which are restricted to specific parts of the Mount Gibson Range. None of the ranges is currently in a conservation reserve.

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Table 1

Sorted two-way table of quadrats established on Mount Gibson and surrounding ranges showing species by community type. Taxa shaded grey within a community are indicator species identified by INDVAL >17 (Dufrene & Legendre 1997) at the 7 group level (* indicates p< 0.05; ** p<0.01; statistical significance tested by randomisation procedures).

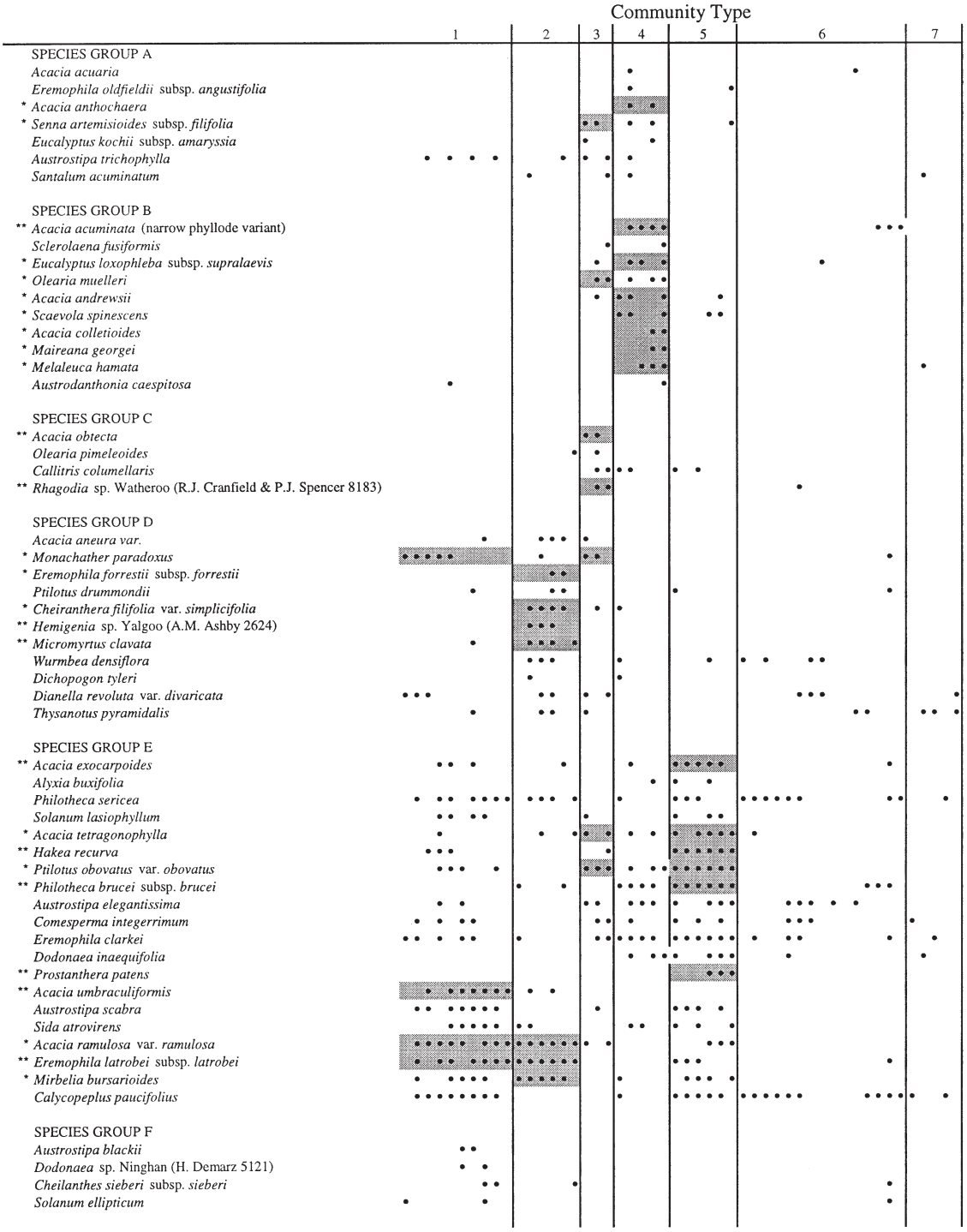

Table 1 (cont.)

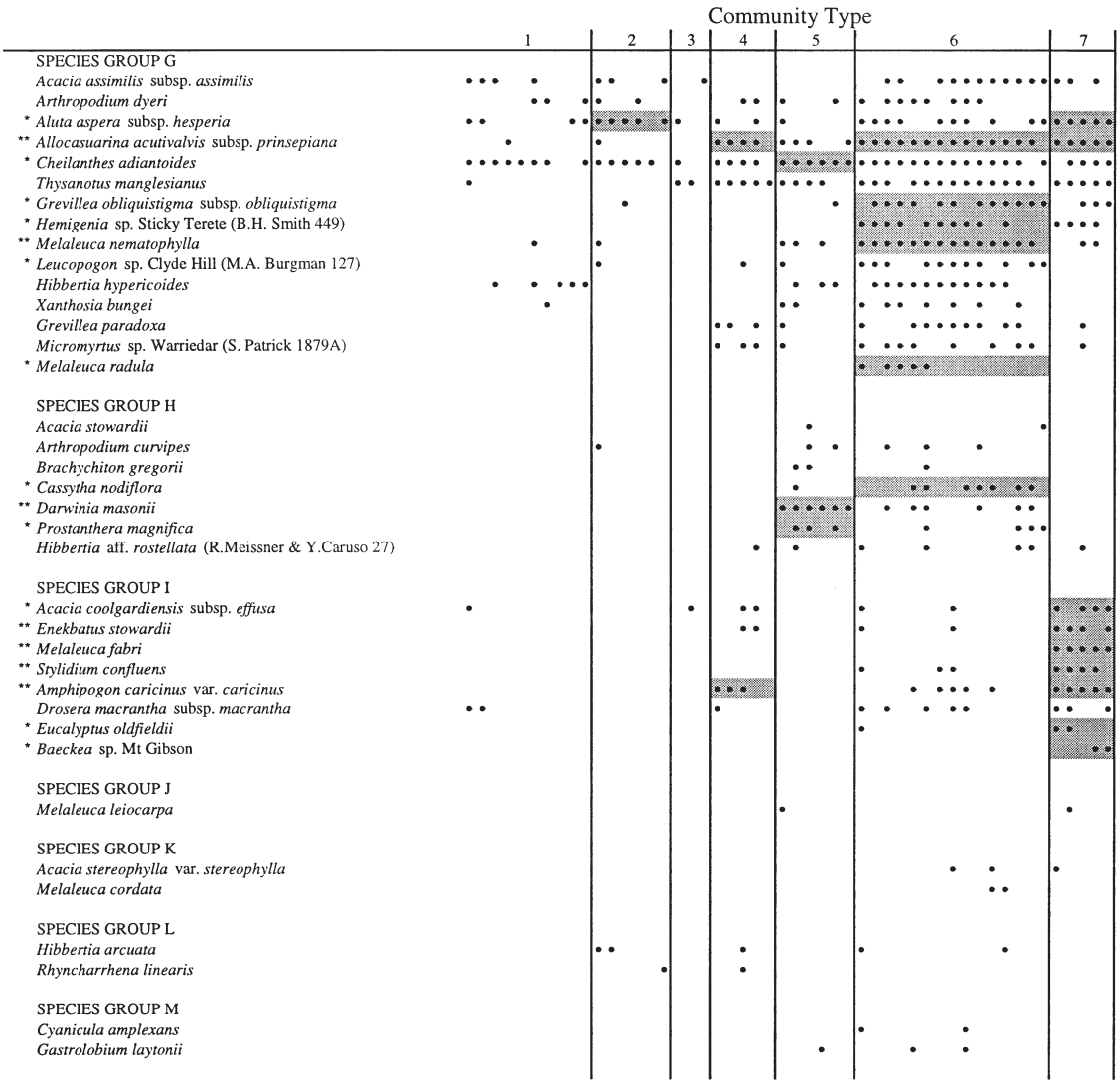
Community Type
1
2
3
4
5
6
7
SPECIES GROUP G
Acacia assimilis subsp. assimilis
Arthropodium dyeri
* Aluta aspera subsp. hesperia
** Allocasuarina acutivalvis subsp. prinsepiana
* Cheilanthes adiantoides
Thysanotus manglesianus
* Grevillea obliquistigma subsp. obliquistigma
* Hemigenia sp. Sticky Terete (B.H. Smith 449)
** Melaleuca nematophylla
* Leucopogon sp. Clyde Hill (M.A. Burgman 127)
Hibbertia hypericoides
Xanthosia bungei
Grevillea paradoxa
Micromyrtus sp. Warriedar (S. Patrick 1879A)
* Melaleuca radula
SPECIES GROUP H
Acacia stowardii
Arthropodium curvipes
Brachychiton gregorii
* Cassytha nodiflora
** Darwinia masonii
* Prostanthera magnifica
Hibbertia aff. rostellata (R.Meissner & Y.Caruso 27)
SPECIES GROUP I
* Acacia coolgardiensis subsp. effusa
** Enekbatus stowardii
** Melaleuca fabri
** Stylidium confluens
** Amphipogon caricinus var. caricinus
Drosera macrantha subsp. macrantha
* Eucalyptus oldfieldii
* Baeckea sp. Mt Gibson
SPECIES GROUP J
Melaleuca leiocarpa
SPECIES GROUP K
Acacia stereophylla var. stereophylla
Melaleuca cordata
SPECIES GROUP L
Hibbertia arcuata
Rhyncharrhena linearis
SPECIES GROUP M
Cyanicula amplexans
Gastrolobium laytonii

Table 2

Spearman's rank correlation of soil chemistry parameter and physical site characters. Cells with numbers present represent significant correlation at $P < 0.05$.

	eCEC	pH	B	Ca	Cd	Co	Cu	Fe	K	Mg	Mn	Mo	Na	Ni	P	Pb	S	Zn	Aspect	Slope	Surface Rock Abundance	Surface Rock Size	Rock Outcrop Abundance
eCEC																							
pH	0.55																						
B	0.44																						
Ca	0.98	0.60	0.41																				
Cd																							
Co	0.43	0.43	0.46	0.35	0.29																		
Cu	0.29		0.43			0.55																	
Fe	0.47			0.53																			
K	0.41		0.42	0.29		0.53	0.72																
Mg	0.94	0.55	0.40	0.89		0.45		0.41	0.39														
Mn	0.50	0.71	0.35	0.49		0.75	0.44			0.54													
Mo					0.46	0.31	0.33		0.32		0.33												
Na	0.52		0.37	0.40		0.35		0.28	0.70	0.58		0.30											
Ni	0.54		0.44	0.47		0.67	0.45		0.56	0.46	0.36		0.47										
P	0.01	-0.41							0.36				0.38										
Pb							-0.31																
S		-0.78		-0.33		-0.44					-0.58		0.33		0.46								
Zn			0.28			0.41	0.61		0.60				0.37	0.42	0.40								
Aspect							-0.29								-0.31								
Slope								0.32															
Surface Rock Abundance					-0.40																		
Surface Rock Size	0.35			0.37	-0.27			0.41		0.33										0.40			
Rock Outcrop Abundance								0.55					0.31				0.29			0.50		0.67	
Runoff								0.29												0.75		0.31	0.38
%Litter					-0.30		0.34														0.38	0.34	
%Bare								0.36														0.30	

Table 3

Plant community mean values for soil chemistry parameters (measured in mg/kg except eCEC and pH). Differences between ranked values tested using Kruskall –Wallis non-parametric analysis of variance. Standard error in parentheses. a and b represent significant differences between community types at P < 0.05 (n = number of quadrats, P = probability, ns = not significant). Community 3 was excluded from analysis due to low quadrat number.

	Community Type							
	1	**2**	**3**	**4**	**5**	**6**	**7**	**P**
eCEC	3.3 (0.5)	3.5 (0.3)	3.3 (0.6)	3.9 (1.4)	4.8 (0.7)	3.6 (0.5)	2.5 (0.3)	ns
pH	4.7 (0.1)[a]	5.2 (0.1)[ab]	5.1 (0.2)	5.2 (0.4)[ab]	5.2 (0.0)[b]	4.9 (0.1) [ab]	4.9 (0.1) [ab]	0.02
Ca	393.0 (57.8)	476.736.1	411.779.8	578.0253.3	651.777.7	472.069.5	294.037.2	ns
Mg	89.2 (14.9)	84.8 (8.5)	88.7 (22.2)	81.2 (20.0)	140.8 (32.5)	99.9 (14.3)	76.4 (11.6)	ns
P	9.1 (2.0)	4.7 (0.5)	13.7 (6.2)	5.8 (0.6)	6.3 (1.4)	7.6 (0.9)	5.0 (0.5)	ns
K	198.0 (16.1)[a]	125.7 (8.4)[ab]	163.3 (28.5)	97.0 (10.2)[b]	116.8 (13.0)[ab]	113.8 (8.5)[b]	112.0 (22.5)[ab]	<0.01
B	0.7 (0.1)	0.8 (0.1)	0.7 (0.2)	0.6 (0.1)	0.5 (0.0)	0.6 (0.1)	0.5 (0.0)	ns
Cd	0.01 (0.00)	0.01 (0.00)	0.01 (0.00)	0.01 (0.00)	0.01 (0.00)	0.01 (0.00)	0.01 (0.00)	ns
Co	0.5 (0.2))	0.5 (0.1)	0.9 (0.5)	0.4 (0.2)	0.3 (0.1)	0.2(0.0)	0.3 (0.1)	ns
Cu	2.4 (0.1)[a]	2.2 (0.4)[ab]	2.0 (0.5)	1.2 (0.2)[b]	1.4 (0.1)[ab]	1.2 (0.1)[b]	1.3 (0.1)[b]	<0.01
Fe	51.7 (4.0)	45.2 (3.5)	44.7 (4.8)	48.6 (7.6)	69.8 (5.8)	73.2 (12.4)	43.0 (2.3)	0.02
Mn	92.5 (17.2)	100.2 (10.9)	135.7 (38.2)	68.8 (17.7)	106.7 (14.4)	71.7 (10.9)	81.2 (20.7)	ns
Mo	0.01 (0.00)	0.01 (0.00)	0.01 (0.00)	0.01 (0.00)	0.01 (0.00)	0.01 (0.00)	0.01 (0.00)	ns
Na	35.1 (8.2)	14.8 (1.3)	19.7 (4.8)	12.8 (3.2)	21.3 (5.3)	21.1 (4.7)	23.8 (9.6)	ns
Ni	0.3 (0.1)	0.4 (0.1)	0.3 (0.1)	0.3 (0.1)	0.3 (0.1)	0.2 (0.0)	0.2 (0.1)	ns
Pb	0.7 (0.1)	0.8 (0.1)	0.9 (0.2)	0.8 (0.1)	0.9 (0.1)	0.9 (0.1)	0.8 (0.1)	ns
S	17.6 (3.7)[a]	6.3 (0.7)[b]	10.0 (4.0)	10.6 (1.5)[ab]	8.2 (0.8)[ab]	14.3 (2.5)[a]	12.2 (2.2)[ab]	0.01
Zn	3.3 (0.4)[a]	2.4 (0.4)[ab]	2.8 (0.7)	1.4 (0.2)[b]	1.3 (0.2)[b]	1.7 (0.1)[ab]	1.3 (0.2)[b]	<0.01
n	10	9	3	5	6	15	5	

Table 4

Plant community mean values for physical site parameters; aspect (16 cardinal directions), slope (degrees), coarse fragment (CF) abundance (0 – no coarse fragments to 6 very abundant coarse fragments), grazing (0 –no evidence of grazing and 1 grazed), maximum size of coarse fragments (1 – fine gravely to 7 large boulders), rock outcrop (RO) abundance (0 – no bedrock exposed to 5 – rockland), runoff (0 – no runoff to 5 – very rapid), % leaf litter and bare ground (1 – >70% to 4 – <10%). Differences between ranks tested using Kruskall-Wallis non-parametric analysis of variance. Standard error in parentheses. a, b and c represent significant differences between community types at P < 0.05 (n = number of quadrats, P = probability, ns = not significant).

	Community Type							
	1	**2**	**3**	**4**	**5**	**6**	**7**	**P**
Aspect	6.9 (1.5)	7.7 (1.9)	3.7 (3.7)	8.4 (2.0)	8.3 (2.7)	7.3 (1.5)	9.8 (2.8)	ns
Slope	10.7 (1.6)[a]	4.2 (0.8)[ab]	1.0 (1.0)	2.8 (0.6)[b]	10.7 (2.0)[ab]	9.3 (1.4)[ab]	12.6 (7.1)[ab]	0.01
Grazing	1.0 (0.0)[a]	1.0 (0.0)[a]	1.0 (0.0)	0.4 (0.2)[ab]	0.7 (0.3)[ab]	0.2 (0.1)[b]	0.0 (0.0)[b]	<0.01
CF Abundance	3.9 (0.2)	4.3 (0.3)	2.0 (0.6)	3.4 (0.4)	3.7 (0.3)	3.7 (0.2)	3.0 (0.5)	ns
Max. Size	4.5 (0.3)[ab]	4.2 (0.3)[ab]	2.7 (0.3)	3.4 (0.4)[b]	5.3 (0.3)[a]	4.1 (0.2)[ab]	2.4 (0.6)[b]	<0.01
RO Abundance	1.6 (0.4)[ab]	0.3(0.2)[ab]	0.0 (0.0)	0.0 (0.0)[b]	2.8 (0.7)[a]	2.3 (0.4)[a]	0.4 (0.4)[ab]	<0.01
Runoff	1.8 (0.2)	1.8 (0.3)	0.0 (0.0)	1.4 (0.2)	2.5 (0.3)	2.4 (0.2)	2.0 (0.3)	ns
%Leaf Litter	3.8 (0.1)[a]	3.5 (0.2)[ab]	2.7 (0.3)	2.4 (0.2)[ab]	3.3 (0.3)[ab]	2.6 (0.3)[ab]	2.0 (0.5)[b]	<0.01
% Bare Ground	1.2 (0.1)	1.2 (0.1)	1.0 (0.0)	1.0 (0.0)	1.3 (0.2)	1.2 (0.1)	1.0 (0.0)	ns
n =	10	9	3	5	6	15	5	

APPENDIX 1

Flora list for Mount Gibson, including all taxa from the sampling quadrats and adjacent areas. Nomenclature follows Paczkowska and Chapman (2000), * indicates introduced taxon.

Adiantaceae

Cheilanthes adiantoides
Cheilanthes sieberi subsp. *sieberi*

Aizoaceae

* *Cleretum papulosum*

Amaranthaceae

Ptilotus drummondii
Ptilotus exaltatus
Ptilotus gaudichaudii var. *parviflorus*
Ptilotus helipteroides
Ptilotus obovatus var. *obovatus*

Anthericaceae

Arthropodium curvipes
Arthropodium dyeri
Caesia sp. Wongan (K.F. Kenneally 8820)
Dichopogon tyleri
Thysanotus manglesianus
Thysanotus pyramidalis
Tricoryne elatior

Apiaceae

Daucus glochidiatus
Hydrocotyle rugulosa
Trachymene cyanopetala
Trachymene ornata
Trachymene pilosa
Xanthosia bungei

Apocynaceae

Alyxia buxifolia

Asclepiadaceae

Rhyncharrhena linearis

Asphodelaceae

Bulbine semibarbata

Asteraceae

Bellida graminea
Blennospora drummondii
Brachyscome cheilocarpa
Brachyscome ciliocarpa
Brachyscome perpusilla
Brachyscome pusilla
Calocephalus multiflorus
Calotis hispidula
Calotis multicaulis
Cephalipterum drummondii
Ceratogyne obionoides
Chthonocephalus pseudevax
Feldstonia nitens
Gilberta tenuifolia
Gilruthia osbornei
Gnephosis tenuissima
Hyalosperma demissum
Hyalosperma glutinosum subsp. *glutinosum*
Hyalosperma glutinosum subsp. *venustum*
* *Hypochaeris glabra*
Isoetopsis graminifolia
Lawrencella davenportii
Lawrencella rosea
Millotia myosotidifolia
Myriocephalus guerinae
Myriocephalus pygmaeus
Olearia humilis
Olearia muelleri
Olearia pimeleoides
Podolepis canescens
Podolepis lessonii
Podotheca gnaphalioides
Podotheca uniseta
Rhodanthe battii
Rhodanthe chlorocephala subsp. *rosea*
Rhodanthe chlorocephala subsp. *splendida*
Rhodanthe citrina
Rhodanthe collina
Rhodanthe laevis
Rhodanthe manglesii
Rhodanthe maryonii
Rhodanthe polycephala
Rhodanthe pygmaea
Rhodanthe spicata
Rhodanthe stricta
Schoenia cassiniana
Schoenia filifolia subsp. *filifolia*
* *Sonchus oleraceus*
Waitzia acuminata var. *acuminata*
* *Urospermum picroides*
* *Ursinia anthemoides*

Brassicaceae

Lepidium oxytrichum
Stenopetalum anfractum
Stenopetalum filifolium

Caesalpiniaceae

Senna artemisioides subsp. *filifolia*
Senna glutinosa subsp. *chatelainiana*
Senna sp. Austin (A. Strid 20210)

Campanulaceae

Wahlenbergia gracilenta
Wahlenbergia tumidifructa

Casuarinaceae

Allocasuarina acutivalvis subsp. *prinsepiana*

Celastraceae

Psammomoya grandiflora

Chenopodiaceae

Chenopodium melanocarpum
Maireana georgei
Maireana marginata
Maireana trichoptera
Rhagodia sp. Watheroo (R.J. Cranfield & P.J. Spencer 8183)
Sclerolaena fusiformis
Sclerolaena gardneri

Colchicaceae

Wurmbea densiflora

Crassulaceae

Crassula closiana
Crassula colorata var. *acuminata*
Crassula colorata var. *colorata*
Crassula extrorsa
Crassula tetramera

Cupressaceae

Callitris columellaris

Cuscutaceae

* *Cuscuta epithymum*

Cyperaceae

Schoenus nanus
Lepidosperma gibsonii

Dasypogonaceae

Chamaexeros macranthera

Dilleniaceae

Hibbertia arcuata
Hibbertia glomerosa var. *glomerosa*
Hibbertia hypericoides
Hibbertia aff. *rostellata* (R.Meissner & Y.Caruso 27)

Droseraceae

Drosera macrantha subsp. *macrantha*

Epacridaceae

Leucopogon sp. Clyde Hill (M.A. Burgman 1207)

Euphorbiaceae

Calycopeplus paucifolius
Euphorbia boophthona
Euphorbia tannensis subsp. *eremophila*
Poranthera microphylla

Geraniaceae

* *Erodium cicutarium*
Erodium cygnorum

Goodeniaceae

Brunonia australis
Goodenia berardiana
Goodenia havilandii
Goodenia mimuloides
Goodenia occidentalis
Goodenia pinifolia
Goodenia pinnatifida
Scaevola spinescens
Velleia cycnopotamica
Velleia hispida
Velleia rosea

Haloragaceae

Gonocarpus nodulosus
Haloragis odontocarpa forma rugosa
Haloragis trigonocarpa

Juncaginaceae

Triglochin sp. B Flora of Australia (P.G. Wilson 4294)

Lamiaceae

Hemigenia macphersonii
Hemigenia sp. Sticky Terete (B.H. Smith 449)
Hemigenia sp. Yalgoo (A.M. Ashby 2624)
Prostanthera magnifica
Prostanthera patens
Prostanthera althoferi subsp. *althoferi*

Lauraceae

Cassytha nodiflora

Lobeliaceae

Lobelia winfridae

Loganiaceae

Phyllangium sulcatum

Loranthaceae

Amyema gibberula var. *tatei*

Malvaceae

Sida atrovirens
Sida chrysocalyx

Mimosaceae

Acacia acuaria
Acacia acuminata (narrow phyllode variant)
Acacia andrewsii
Acacia aneura
Acacia anthochaera
Acacia assimilis subsp. *assimilis*
Acacia cerastes
Acacia colletioides
Acacia coolgardiensis subsp. *effusa*
Acacia exocarpoides
Acacia neurophylla subsp. *erugata*

Acacia obtecta
Acacia ramulosa var. *ramulosa*
Acacia stereophylla var. *sterophylla*
Acacia sibirica
Acacia tetragonophylla
Acacia umbraculiformis

Myoporaceae

Eremophila clarkei
Eremophila forrestii subsp. *forrestii*
Eremophila glutinosa
Eremophila latrobei subsp. *latrobei*
Eremophila oldfieldii subsp. *angustifolia*

Myrtaceae

Aluta aspera subsp. *hesperia*
Baeckea sp.
Darwinia masonii
Enekbatus stowardii
Eucalyptus horistes
Eucalyptus kochii subsp. *amaryssia*
Eucalyptus kochii subsp. *plenissima*
Eucalyptus loxophleba subsp. *supralaevis*
Eucalyptus oldfieldii
Melaleuca atroviridis
Melaleuca cordata
Melaleuca eleuterostachya
Melaleuca fabri
Melaleuca hamata
Melaleuca leiocarpa
Melaleuca nematophylla
Melaleuca radula
Micromyrtus clavata
Micromyrtus sp. Warriedar (S. Patrick 1879A)

Orchidaceae

Cyanicula amplexans
Cyanicula sp.

Papilionaceae

Gastrolobium laytonii
Mirbelia bursarioides

Phormiaceae

Dianella revoluta var. *divaricata*

Pittosporaceae

Cheiranthera filifolia var. *simplicifolia*

Plantaginaceae

Plantago aff. *hispida* (R.Meissner & Y.Caruso 121)

Poaceae

Amphipogon caricinus var. *caricinus*
Aristida contorta
Austrodanthonia caespitosa
Austrostipa blackii
Austrostipa elegantissima
Austrostipa eremophila
Austrostipa hemipogon
Austrostipa nitida
Austrostipa scabra
Austrostipa trichophylla
Bromus arenarius
Lachnagrostis plebeia
Monachather paradoxus
* *Pentaschistis airoides* subsp. *airoides*
* *Elymus* sp.
* *Vulpia muralis*

Polygalaceae

Comesperma integerrimum

Portulacaceae

Calandrinia eremaea complex
Calandrinia sp. Blackberry (D.M. Porter 171)
Calandrinia sp. Bungalbin (G.J. Keighery & N. Gibson 1656)
Calandrinia sp. Truncate capsules (A. Markey & S. Dillon 3474)
Calandrinia translucens

Proteaceae

Grevillea obliquistigma subsp. *obliquistigma*
Grevillea paradoxa
Grevillea pityophylla
Grevillea sp.
Hakea recurva
Persoonia pentasticha
Persoonia sp.
Persoonia sp. Paynes Find (D. Edinger et al. 313)

Rutaceae

Phebalium tuberculosum
Philotheca brucei subsp. *brucei*
Philotheca sericea
Philotheca tomentella

Santalaceae

Santalum acuminatum
Santalum spicatum

Sapindaceae

Dodonaea inaequifolia
Dodonaea sp. Ninghan (H. Demarz 5121)

Solanaceae

Nicotiana rosulata
Solanum ellipticum
Solanum lasiophyllum
Solanum orbiculatum subsp. *orbiculatum*

Sterculiaceae

Brachychiton gregorii
Rulingia luteiflora

Stylidiaceae

Stylidium confluens

Thymelaeaceae

Pimelea avonensis

Urticaceae

Parietaria cardiostegia

Zygophyllaceae

Zygophyllum eremaeum
Zygophyllum ovatum
Zygophyllum tesquorum