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Flora and vegetation of the banded iron formations of the Yilgarn Craton: the northern Yerilgee Hills, Menzies

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ABSTRACT

A survey was undertaken on the flora and plant communities associated with the northern Yerilgee Hills, located some 110 km west of Menzies and in the Yilgarn region of Western Australia. The hills are the formed by the exposure of the northern Yerilgee greenstone belt, and consist of seams of banded iron formation and mafic volcanics. A total of 183 taxa (182 native) were recorded from 51 quadrats and opportunistic collections. Four taxa were of conservation significance, two of these being new records for the survey area. At least three potentially new taxa, two regional endemics and one near-endemic taxon were also located. No range-restricted endemic taxa were reported. Six floristic community types were derived from numerical classification analysis of a presence/absence dataset of perennial species. Nonparametric ANOVA found significant differences between community types in site physical and soil chemical parameters. Ordination (nonmetric multidimensional scaling) analyses indicated generally highly significant ($p \leq 0.001$) correlations between floristic composition and topographic position, substrate and edaphic factors. These outcropping landforms are currently unreserved and occur on unallocated crown land and mining tenements cover the entire area. Exploration activities are the most immediate threat to the Yerilgee communities, while mining is a future potential threat.

Keywords: banded iron formation, conservation, flora, vegetation communities, Yerilgee greenstone belt, Yilgarn.

INTRODUCTION

The Yilgarn Craton is the basement rock underlying much of southern Western Australia, much of which has been weathered into gently undulating plains that are overlain by deeply weathered regolith (Cornelius et al. 2007). Greenstone belts of mafic volcanics and banded iron formation (BIF) are common in the northern and eastern parts of the Yilgarn Craton (Chen & Wyche 2003; Greenfield 2001), and outcrop as discrete, prominent hills and elongate ridges in an otherwise flat landscape. These are isolated landforms in a semi-arid–arid landscape, which have been identified as being of high conservation value since they harbour both endemic and rare flora and fauna. The ranges also support geographically restricted vegetation communities and exhibit high between-range β-diversity (Department of Environment and Conservation 2007; Environmental Protection Authority 2007; Gibson et al. 2007; Mattiske 2001a, 2001b). Greenstone belts are also rich in mineral deposits, hence they are currently subject to considerable exploration and mining interests. Therefore, conservation management and planning decisions require detailed information on the biota of these ironstone formations.

This paper is part of a series of surveys that describe the flora and communities on approximately 25 individual ranges in the northern Yilgarn region, and aim to place these ranges within a regional context (Gibson et al. 1997, 2007; Gibson & Lyons 1998, 2001a, 2001b; Gibson 2004; Markey & Dillon 2008a, 2008b, 2009, 2010a, 2011; Meissner & Caruso 2008a, 2008b, 2008c; Meissner et al. 2010a, 2010b). The northern Yerilgee Hills have been identified as an area requiring detailed survey (Department of Environment and Conservation 2007), and this survey aims to provide a detailed description of the flora and communities for this landform and highlight the significance of the range within the Eastern Goldfields and wider Yilgarn region.

STUDY SITE

This survey targeted vegetation on the upland areas of banded iron formation on the northern Yerilgee Greenstone Belt, which is referred to in this study as the northern Yerilgee Hills. The survey area is located in the Eastern Goldfields, c. 460 km north-east of Perth, and in

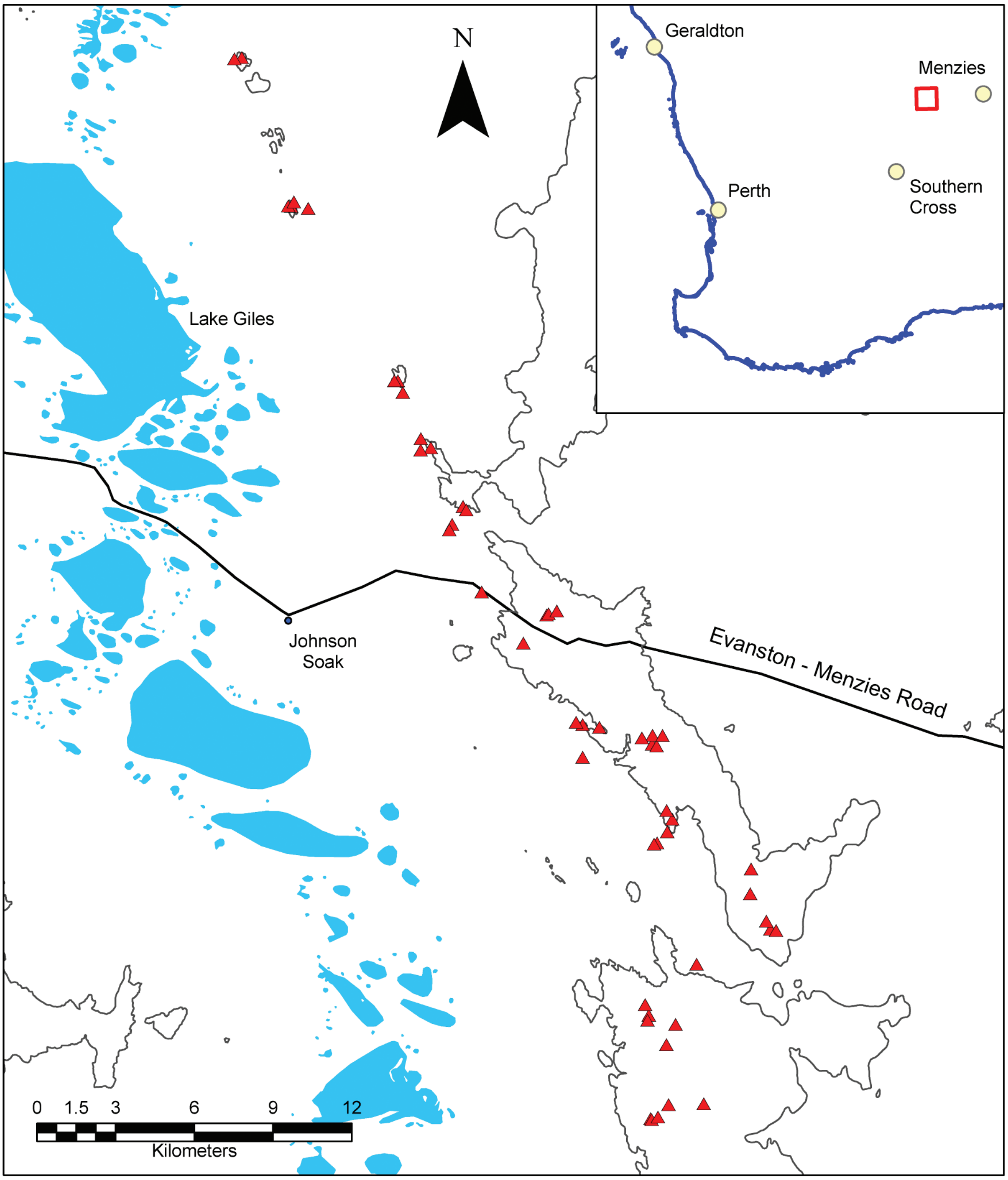

Figure 1. Map showing the location of the survey region relative to major towns in the Yilgarn region of Western Australia (insert), and the landforms and landmarks within the northern Yerilgee Hills survey area. Locations of the 51 quadrats on the Yerilgee Hills are marked (▲). The uplands of the survey area (> c. 410 m) are outlined by contour lines and playa lakes are indicated by filled areas.

an area of ironstone ranges that has been referred to as the Greater Mount Manning Region (Environmental Protection Authority 2007). The study area is located in the Shire of Menzies, 110 km west of Menzies township and c. 170 km northeast of Southern Cross (Fig. 1). The nearest homesteads are Diemals (61 km west of the survey area) and Mt Elvire (58 km north-west). The survey area is located over a latitudinal range of 29° 36' 20' to 29° 58' 31', and longitudinal extent from 119° 47' 50" to 120° 1' 21", and covers a rectangular area, 40 km north–south and 21 km east–west. The length of the range associated with the Yerilgee greenstone belt is c. 94 km and c.10 km wide, and the surveyed extent is c. 44 km long (north–south) by c. 8 km wide at its widest point (east–west).

Land Use History

Pastoralism and mining have been the main industries in the wider Mount Manning Region since the late 19th century, and very little vegetation has been cleared for agriculture (Beard 1972; Faithfull 1994). The northern Yerilgee Hills study area occurs primarily on unallocated crown land (UCL), with some sites located in the northern part of the Mt Manning Nature Reserve and others on Mt Elvire Station, a former pastoral lease acquired as a sandalwood reserve in 1991 by the Department of Conservation and Land Management (Department of Conservation and Land Management 1994). The station was de-stocked after purchase and reserved as a nature reserve and state forest in 2001, and has been proposed as a conservation reserve (Environmental Protection Agency 2007). Sandalwood harvesting continues over the study area, particularly north of the Evanston–Diemals road (Fig. 1). There is no evidence of historical livestock grazing in the northern Yerilgee Hills, but there are several active or retired pastoral leases adjoining the survey area (including Credo, Walling Rock and Mt Elvire stations.)

The survey area is located in far north-west corner of the Ularring District of the North Coolgardie Mineral Field, and abuts the south-eastern edge of the Yilgarn Mineral Field (Greenfield 2001; Walker & Blight 1983). Extensive gold mining and settlement throughout these mineral fields commenced in the late 19th century (Beard 1972; Faithfull 1994; Matheson & Miles 1947). Mining of iron ore deposits in the wider Mount Manning Region commenced in the 1960s (Beard 1972; Greenfield 2001), and extensive exploration for gold, iron ore and, to a lesser extent, nickel has been carried since the 1970s (Chen & Wyche 2003; Greenfield 2001). Renewed global interest has caused a resurgence of mining interest in the region (Greenfield 2001), and high prices and demand for steel has made the small deposits of iron ore in Yilgarn BIF ranges economically viable. Although the northern Yerilgee Hills have not been mined, a new round of iron ore exploration commenced in 2007.

Climate

The survey area is described as semi-desert Mediterranean, with cool, wet winters and hot, dry summers (Beard 1976, 1990; Milewski & Hall 1995; Newbey 1985). Rainfall is variable, with marginally more rain falling during winter months, but irregular summer rainfall also occurs (Milewski & Hall 1995). The two closest meteorological centres to the study area are Diemals Homestead and Menzies (Bureau of Meteorology 1908–). The annual rainfall for these centres is 276 mm and 251 mm respectively, with the wettest months between April and August. The average summer daily maximum (Dec–Feb) is 34.3 °C at Menzies and 35.3 °C at Diemals, with average temperatures over 40 °C occurring between December and March. The coolest period is between June and August, when average minima fall below 7 °C (Bureau of Meteorology 1908–).

Geology

The Yerilgee greenstone belt lies within the Southern Cross Domain of the Yilgarn Craton (Cassidy et al. 2006). The geology of the study region has been described and mapped on the 1:100,000 Lake Giles geological sheet (SH 50-8, 2838; Greenfield 2001), and 1:250,000 Barlee geological sheets (SH 50-8; Walker & Blight 1983). The Yilgarn Craton is composed primarily (c. 70%) of Archaean granitoids and gneisses (c. 3.6–2.63 Ga). Much of the remaining supracrustal rocks are assemblages of metamorphosed intrusive volcanics and sedimentary rocks, which are locally referred to as greenstones (Cassidy et al. 2006; Champion & Smithies 2001, 2003). These greenstone belts in the Southern Cross Domain have been aged as c. 3–2.9 Ga (Groenewald & Riganti 2004). The Yerilgee greenstone belt sequence is high-Mg basalt, with gabbro intrusions and overlain by ultramafic rocks and BIF. These are overlain with an uppermost of sequence of high-Mg basalt and sedimentary rocks (Greenfield 2001). Much of the belt is mapped as mafics, ultramafics, amphibolite and metamorphosed high-Mg basalt, with gneissic granitoids along the eastern margin and substantial seams of BIF and metasedimentary rocks.

The numerous BIF ridges provide the greatest topographic relief in the Mount Manning Region (Greenfield 2001). These ridges generally trend north–south and are <30 m in height. On the plains surrounding the ranges, a lateritic duricrust overlies granites, and this is covered by quartz sands and pisolite nodules (Greenfield 2001). Lateritic deposits also occur on the tops of the range, which have been formed by intensive weathering in the Tertiary (Greenfield 2001). The lowest elevations within the survey area are dominated by the extensive system of playa lakes associated with Lake Giles and Lake Barlee.

The lowest point within the northern Yerilgee hills survey area is c. 400 m above sea level (ASL), rising to altitudes of 500–510 m ASL at the highest points on the range (Greenfield 2001). A lateritic breakaway in the north-east of the survey area has a maximum altitude of 602 m ASL. The highest elevations and most conspicuous outcroppings of massive BIF occur immediately south of the Evanston–Menzies main road, and many of the taller ridges south of the road form a broad summit surface covered in lateritic deposits.

Vegetation

The survey area lies on the boundary of the southern edge of the Murchison and the Coolgardie IBRA bioregions, and is c. 60 km to the southeast margin of the Yalgoo Interim Biogeographic Regionalisation for Australia (IBRA) bioregion (Department of Environment and Water Resources 2007). These IBRA bioregions are derived from the Murchison and South Western Interzone botanical regions as defined by Beard (1972, 1976, 1990), and the boundary roughly coincides with the Evanston–Menzies road (Fig. 1). The southern boundary of the Murchison region is set where there is an abrupt transition from mulga (*Acacia aneura*) dominated shrublands to *Eucalyptus* woodland on lowlands, and the vegetation of this wider region is intermediate in character between the South West flora and more arid Eremaean flora (Beard 1976, 1990; Keighery et al. 1995).

The vegetation of the Yerilgee Hills has not been specifically addressed, but has been broadly covered by regional surveys. The Yerilgee Hills lie immediately north of the Jackson Area that Beard (1972) mapped and described at a scale of 1:250,000, but fall within Beard's (1976) survey of the wider Murchison Region at a scale of 1:1,000,000. In these surveys, Beard (1972, 1976) described the Bungalbin and Die Hardy Systems (i.e. a series of vegetation communities along a catenary sequence) for ironstone ranges in the Mount Manning Region. While the Die Hardy System was mapped on the Die Hardy Range and assumed to occur on the Mt Manning Range, Beard (1976) did not state if this system covered ranges north of Mt Manning (including the Yerilgee Hills).

The Yerilgee Hills were included in the Barlee–Menzies regional vegetation survey of Keighery et al. (1995), where communities were defined by structure and species composition of the upper stratum. Nearly 30 communities were described for the greenstone ranges within this region, including six communities on banded ironstone hillslopes and summits, two communities on greenstone hills slopes and summits, 11 communities on surrounding undulating plains, low ridges and colluvial flats and nine woodland communities in the broad valleys. In general, ironstone upper-slope and summit communities consisted of *Acacia aneura*, *Allocasuarina acutivalvis* or *Banksia arborea* shrublands, while *Acacia quadrimarginea* shrublands or *Eucalyptus ebbanoensis* woodlands/mallee-covered hill-slopes. Lowland communities consisted of *Eucalyptus*, *Acacia aneura* or *Casuarina pauper* woodlands, while *Eucalyptus* or *Callitris columellaris* woodlands dominated broad valleys.

More recent surveys in the Mount Manning Region have addressed several ranges on an individual basis and have used quadrat-based floristic data to describe communities (Gibson 2004; Gibson et al. 1997; Gibson & Lyons 2001a, 2001b; Mattiske 2001b). These studies have found significant differences among ranges in floristic composition and that they harbour endemic and highly restricted floristic communities (Mattiske 2001b).

METHODS

Fifty-one permanent quadrats were established on the northern half of the Yerilgee greenstone belt (Fig. 1), during the final two weeks of September 2007. Quadrats were placed strategically over the range in order to sample the topographic catena, different geologies and the greatest variation in floristic communities. This strategic placement of sites has been used to survey other ranges in the Yilgarn Craton (e.g. Gibson 2004). An effort was made to place quadrats within the least disturbed vegetation, although some disturbed sites were still sampled (i.e. sites that had been cut over for sandalwood). Quadrats were permanently marked with a steel fence picket at each corner and their location and altitude recorded by GPS (Garmin 76, Garmin Ltd, Kansas). The presence and cover class estimate of all vascular plant species (spermatophytes and pteridophytes) were recorded in each quadrat. Additional records were made adjacent to quadrats or opportunistically on the range. Vouchers were collected for species identification at the Western Australian Herbarium, where representative specimens of all taxa have been lodged. Vegetation structure and cover was described according to McDonald et al. (1998). The geographical distributions of taxa were obtained from online records at the Western Australian Herbarium (1998–). The *Acacia aneura* species complex was resolved to morphotypes that approximated the varieties described by Pedley (2001).

For each quadrat, a number of soil and site environmental parameters were determined. Topographical position, aspect, slope, litter and bare ground cover, exposed bedrock and surficial rock cover, surficial rock size, soil colour and soil texture were noted using the methods of McDonald et al. (1998). Percentage surface rock fragment cover class, maximum surface rock fragment size and exposed bedrock outcrop cover were all coded on a semi-quantitative scale (Table 3), and percentage ground and litter cover were estimated visually. Twenty soil samples from the top 10 cm were collected regularly over the quadrat, bulked and sieved. The 2 mm fraction was analysed at the Chemistry Centre of Western Australia. The concentrations of 16 elements (Al, B, Ca, Cd, Co, Cu, Fe, K, Mg, Mn, Mo, Na, Ni, P, S and Zn) were determined using inductively coupled plasma atomic emission spectrometry (ICP AES; Mehlich 1984; Walton & Allen 2004). Soil organic carbon (%) was determined using Metson's colorimetric modification of the Walkley and Black wet oxidation method S09 (Metson 1956, method 6A1 of Rayment & Higginson 1992). Total soil nitrogen (%) was measured calorimetrically following a modified Kjeldahl digest (method S10; Rayment & Higginson 1992). Soil pH was measured in 0.01M $CaCl_2$ (method S3, Rayment & Higginson 1992), and electrical conductivity ($EC_{1:5}$) measured in a 1:5 solution of soil extract:deionised water at 25 ºC (method S2; Rayment & Higginson 1992). Effective cation exchange capacity (eCEC) was estimated from the sum of individual charge equivalents per kilogram of Ca, Mg, Na and K, following the conversion of each element from their respective cation concentrations (from ICP AES) by dividing with 200.4, 121.6, 230, and 390 respectively (Soil and Plant Council 1999; Rayment & Higginson 1992).

Quadrats were classified according to similarities in species composition of perennial, non-singleton taxa, which is consistent with previous surveys (e.g. Gibson 2004; Markey & Dillon 2008a, 2008b; Meissner & Caruso 2008a, 2008b, 2008c). Only taxa resolved to at least species level were used in the analysis. After compiling the floristic data into quadrat by species matrices of presence/absence data, annual taxa were omitted since these desert ephemerals are seasonal in their distribution and abundance (Mott 1972, 1973). Singleton perennial taxa (appearing only in a single quadrat) were also excluded since these carry little information. The effect of these omissions was tested by comparing the results from classification analyses and from a pair-wise comparison of the matrices. Resemblance (association) matrices were generated from the site by species data matrices using the Bray–Curtis coefficient (measure of distance), and these were then compared using the '2 Stage' algorithm in Primer (Clark & Gorley 2006) to determine the degree of correlation between datasets following the exclusion of taxa.

Classification and ordination analyses on resemblance matrices were carried out using the statistical software package, PATN (V3.03; Belbin 1989). Flexible UPGMA (β = –0.1) was used to generate a species and site classification (Belbin et al. 1992). Indicator species analysis (INDVAL) was used to identify characteristic taxa for each community. INDVAL analysis was done in PC-Ord (McCune & Mefford 1999), using the methods of Dufrêne & Legendre (1997). A Monte Carlo permutation test, using 10,000 simulations, was used to test for the significance of these INDVAL values for each species ($p > 0.05$). Semi-strong hybrid (SSH) multidimensional scaling was used in the ordination of quadrats, based on floristic data, using 1000 random starts and 50 iterations in PATN (Belbin 1991). Principal Component Correlation (PCC) was used to correlate the environmental variables with the site ordination coordinates, with 10 000 iterations of a Monte Carlo procedure (MCAO) used as a bootstrap analysis to evaluate the significance of these correlation coefficients (Belbin 1989; Faith & Norris 1989). The Kruskal–Wallis nonparametric analysis of variance and Dunns post-hoc multiple comparisons were used to determine differences in community averages for individual environmental variables (Zar 1984). Univariate analyses were only conducted on groups with at least a minimum sample size ($n \geq 5$).

RESULTS

Flora

A total of 183 taxa (species, subspecies, varieties and forms) and two putative hybrids were recorded from within and adjacent to the 51 quadrats or from opportunities collections (Appendix 1). The small annual grass, *Pentaschistis airoides*, was the only naturalised species collected. Approximately 9% of taxa were annuals (ephemeral) or short-lived perennials. Taxa were from 40 families (as defined by the APG II system (Angiosperm Phylogeny Group 2003), with most from Mimosaceae (*Acacia*, 20 taxa), Chenopodiaceae (19 taxa), Myrtaceae (16 taxa), Myoporaceae (*Eremophila*, 15 taxa and one putative hybrid), Poaceae (14 native and one introduced taxon), Asteraceae (ten taxa), Proteaceae (nine taxa) and Lamiaceae (eight taxa and one hybrid). In addition to *Acacia* and *Eremophila*, the most common genera were *Eucalyptus* (12), *Maireana* (five), *Sclerolaena* (five), *Ptilotus* (five), *Sida* (five) and *Solanum* (five; Appendix 1).

The majority of taxa were perennial shrubs or trees, with less than 10% of taxa being annual or short-term perennial herbs (17 taxa). Of the remaining perennials, 39% were sub-shrubs/shrubs (71 taxa), 16% were tall shrubs/small trees (29 taxa), 10% were mallees or trees (19 taxa), 10% were chenopod sub-shrubs/shrubs (18 taxa), 7% were perennial grasses (12 taxa), 3% were perennial herbs (five taxa), 3% were geophytes (five taxa), 2% were mistletoes (four taxa) and 2% were perennial climbers (three taxa).

Priority taxa

Four taxa of conservation significance (Flora Conservation Codes as compiled by the Western Australian Department of Conservation and listed under the Western Australian Wildlife Conservation Act) were collected on the northern Yerilgee Hills, with all species regarded as data deficient or uncommon (Smith 2010).

- *Spartothamnella* sp. Helena & Aurora Range (PG Armstrong 155–109; Lamiaceae) has Priority 3 conservation status (Smith 2010). Although this species is known from several locations within the Yalgoo, Avon Wheatbelt and Coolgardie IBRA regions, this is a new record for this species from within the survey area. It was observed to be in scattered locations on the pediments and valley hillslopes of the Yerilgee Hills, and these findings are c. 60 km east of previously known collections in the Western Australian Herbarium (1998–), and c. 80 km east of new populations located on the Johnston Range (Markey & Dillon 2011). This species is considered to be a taxon with its distribution centred on BIF (Gibson et al. 2007).
- *Grevillea erectiloba* (Proteaceae) has Priority 4 conservation status (Smith 2010), and has been recorded from the area prior to this survey. It is distributed in the Coolgardie and Murchison IBRA bioregions, mostly within a range of 200 km centred around Mt Manning, but with one outlying population c. 200 km east of its main distribution (Western Australian Herbarium 1998–). Given its distribution, this species is considered to be a regional near-endemic. Within the survey area, this species was restricted to the upland laterites of the northern Yerilgee Hills. It has been recorded from a number of habitats, including lowland plains, but many collections are from upland BIF sites on ranges south of the Yerilgee Hills.
- *Austrostipa blackii* has Priority 3 conservation status, and occurs in scattered localities throughout the Avon Wheatbelt, Yalgoo and Coolgardie IBRA Bioregions. This was a new record for this species from within the survey area, although it is known from the Hunt Range 46 km to the south. Although the range of this species has been extended by previous surveys of Yilgarn ranges (Gibson & Lyons 2001a; Markey & Dillon 2008a), herbarium records indicate that this species is not restricted to BIF landforms (Western Australian Herbarium 1998–).

- *Banksia arborea* (P4) was found as a dominant tall shrub or tree growing on crests of rocky massive BIF and associated laterite. Given its distribution within a region of 200 km diameter, and restriction to crests of BIF (Western Australian Herbarium 1998–), this species is considered to be an endemic species of the Mount Manning Region (Environmental Protection Authority 2007).

Notable taxa

An entity tentatively identified as *Sida petrophila* s.l. (R Barker,[1], pers. comm.) was collected from a few locations at this study site and on the adjacent Johnston Range (c. 80 km east; collection numbers: A Markey & S Dillon 5815 and A Markey & S Dillon 5816; Markey & Dillon 2011). *Sida petrophila* s.s. is considered to be restricted to eastern Australia (Barker 2007), and the few collections from Western Australia require further examination since these populations are greatly disjunct from the eastern states. It is possible that this western variant could be a new taxon. Collections from the Diemals – Lake Giles area suggests that this species grows on colluvium overlying metabasalts, which occur in association with banded iron formation (this study; Markey & Dillon 2011).

Acacia aff. *balsamea* (collection number: A Markey & S Dillon 5212, sheet number PERTH07838611) was identified as putative new entity allied to *Acacia balsamea*, based on phyllode and seed characters being inconsistent with those of *Acacia balsamea* (B Maslin[2], pers. comm.) This entity is a putative new taxon which has a distribution greatly disjunct from the range of *Acacia balsamea* s.s. The closest population of *Acacia balsamea* s.s. is c. 200 km north of the Yerilgee Hills. According to herbarium records, *Acacia balsamea* is located in the Murchison IBRA, northwards into the Pilbara, Gibson Desert, Little Sandy Desert and Great Sandy Desert IBRA bioregions. A second novel entity of *Acacia* had affinities to *Acacia sibirica*. *Acacia* aff. *sibirica* (collection number A Markey & S Dillon 6092, sheet number PERTH07838654) has phyllodes and inflorescence very similar to those of *Acacia sibirica*, but is distinguished from the latter taxon by having wider pods.

Two other variants of known taxa that were considered as morphologically distinct were collected: *Grevillea* aff. *paradoxa* (collection number: A Markey & S Dillon 6097) and an atypical variant within the circumscription of *Austrostipa scabra s.l.* (collection number: A Markey & S Dillon 6114). The *A. scabra* is a complex currently under review (Alex Williams[3], pers. comm.), and further studies and collections are required to confirm the status of these collections.

Although the priority status of *Eremophila* sp. Mt Jackson (GJ Keighery 4372) had been removed in 2008, this species is still considered to be a regional endemic with a geographic range of just over 200 km and a distribution primarily centred on the foothills and flats around greenstone ranges.

Floristic Communities

The initial data matrix consisted of 153 taxa from 51 quadrats. Four pairs of taxa were amalgamated into three species complexes. These were *Austrostipa scabra* (atypical variant)/*Austrostipa nitida*, *Grevillea* aff. *paradoxa*/*Grevillea paradoxa*, *Enchylaena lanata*/*E. tomentosa* subsp. *tomentosa*. Intergrades of *Eremophila forrestii* x *latrobei* were amalgamated with the morphologically closest parental taxon. After these amalgamations and the omission of annual (14) and singleton perennial taxa (25), 114 taxa were included in the final data matrix (74% of total taxa). The correlation between original and final matrices was 98.6%. For the final dataset, species richness (taxa per quadrat) ranged from 16 to 32, and the average species richness was 22.7 ± 0.5 taxa per quadrat (mean ± SE).

Six floristic communities were identified from the classification of quadrat floristic data (Fig. 2). Floristic communities were based on the dendrogram topology, the sorted two-way table (Table 1), and from observations made during the fieldwork. The same analysis simultaneously classified the 114 taxa into nine species groups (Table 1).

The primary division separated community type 1 from the other sites (Fig. 2). This community was associated with upland summit surfaces of ridge tops. This division was evident in the two-way table (Table 1), where community type 1 was distinguished by high representation of taxa from species groups D and comparatively few taxa from species groups G, H and I. The second major division was between communities on rocky crests and mid to upper hillslopes (community types 2 and 3) and those lower in the landscape—from hill slopes, valley flats, pediments and outwashes and low plains around the BIF ridges (community types 4, 5 and 6). Taxa from species groups G and H were typically absent in these latter two upland communities, while these species groups were well represented in most of the lowland communities.

Community type 1: Mixed shrubland/mallee shrubland mosaic on upland summit surfaces

Substrate and location: Community type 1 was located on upland summit surfaces of BIF ridges, where parallel ridges and gently tilted BIF strata underlie relatively deep deposits of weathered, lateritic duricrusts. These are overlain with sandy soils and lateritic gravels. This community was located in the central to southern parts of the survey area, and was found at high elevations, on areas with low gradients and with low cover of exposed

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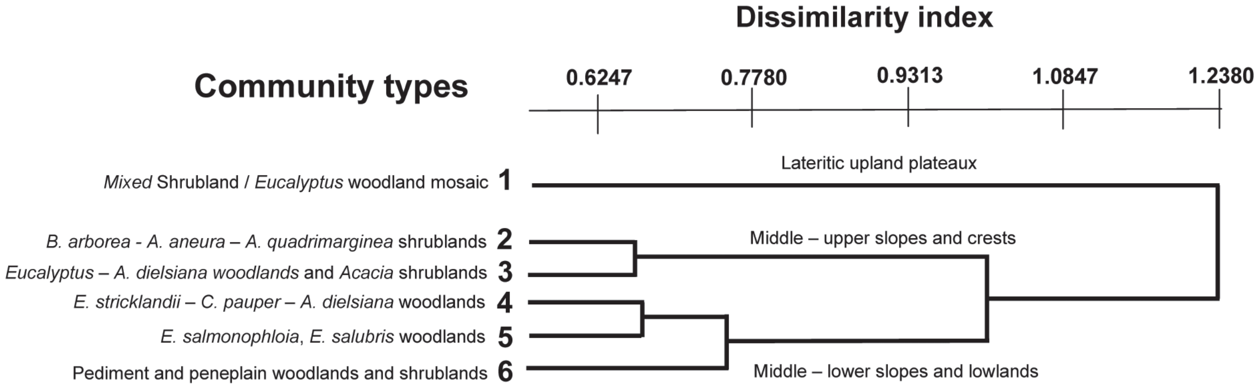

Figure 2. Summary dendrogram of the floristic community types of the northern Yerilgee Hills, resolved from classification analysis of a presence/absence data matrix of 114 perennial taxa from 51 quadrats. The classification method was flexible UPGMA (dilated using β = –0.1) using the Bray–Curtis measure of dissimilarity.

bedrock (<2%), with medium sized surface rocks and moderately shallow to deep soil depth categories (Table 3). Soils were strongly acidic (pH <4.8), and had relatively high concentrations of organic C, N and Fe (Table 4), relatively low concentrations of the most trace elements (particularly Ca, Co, K, Mg and Ni), and relatively lower average values for Na, $EC_{1:5}$ and eCEC.
Structural description: Typically a mosaic of shrublands co-dominated varyingly by *Acacia aneura*, *Allocasuarina eriochlamys* subsp. *eriochlamys*, *Banksia arborea*, *Acacia effusifolia*, or open mallee shrublands or isolated mallees of *Eucalyptus* (*E. ebbannoensis*, *E. ewartiana* and *E. horistes*). Many of the common and characteristic species come from the Proteaceae, Myrtaceae and Lamiaceae, and include *Prostanthera grylloana*, *Leucopogon* sp. Clyde Hill (MA Burgman 1207), *Olearia humilis*, *Grevillea paradoxa*, *Baeckea elderiana*, *Mirbelia microphylla*, *Prostanthera magnifica*, *Wrixonia prostantheroides*, *Grevillea oligomera*, *Baeckea elderiana* and *Aluta aspera* subsp. *aspera*. Many of these were significant indicator species (Table 2).
Species groups: Common and consistent taxa were from species group D (Table 1), and there was a moderate representation of taxa from species group F, a notable lack or complete absence of species from species groups G and H, and low representation from species group I. There were some floristic affinities to community type 2, particularly with taxa from species group E (Table 1).
Comments: Although community type 1 was a relatively heterogeneous unit, there was not enough sampling to distinguish sub-groupings among the mallee, mallee shrublands and shrublands. Perennial hummock grasses were uncommon within the survey area, however dense patches of *Triodia* cf. *scariosa* were observed in a mosaic shrubland of this community in southern parts of the survey area.
Mean perennial species richness: 20.9 ± 1.2 SE taxa per quadrat.

Community type 2: Banksia arborea – Acacia aneura – Acacia quadrimarginea *shrublands on massive BIF*

Substrate and location: Found on massive BIF outcrops on steep, rocky uplands. Located at notably high elevations and topographic locations, on steep slopes with moderate to large surface rocks, high runoff scores, a relatively high cover of exposed bedrock and notably skeletal soil depths (Table 3). Soils were strongly acidic (pH <4.8), and values for many trace elements were relatively low (Table 4).
Structural description: This community consisted of tall shrublands varyingly co-dominated by *A. aneura*, *A. quadrimarginea*, *Allocasuarina acutivalvis* and *B. arborea*. Other shrub taxa included *Melaleuca leiocarpa*, *Philotheca brucei* subsp. *brucei*, *Dodonaea rigida*, *Eremophila georgei*, *Eremophila latrobei* subsp. *latrobei* and *Ptilotus obovatus*. Common ground stratum species included both species of rock fern (*Cheilanthes* spp.) and *Sida* sp. golden calyces (HN Foote 32). Many of these characteristic shrub and geophytic species were commonly found growing out of rock fissures.
Species groups: Many of the common taxa were significant indicator species (Table 2), and occurred in species group F (Table 1). This community type has limited representation of taxa from species groups D, G and H, but notable representation of taxa from species groups E, F and I (Table 1). Two quadrats, which were located at the southern extreme of the survey area, were relatively dissimilar to the central and northern occurrence of this community type. Unlike the other sites, this pair of quadrats had characteristic representation from species group E and few taxa from species group F (Table 1). Further sampling of the range south of the survey area may identify a southern variant of this community type.
Mean perennial species richness: 21.9 ± 0.8 SE taxa per quadrat.

Table 1

Two-way table of sites and perennial species of the northern Yerilgee Hills, sorted by the site and species floristic classification of 114 taxa from 51 quadrats. Quadrats appear as columns, and species as rows, and both are ordered by group/community type. Each rectangle represents a species presence within a quadrat.

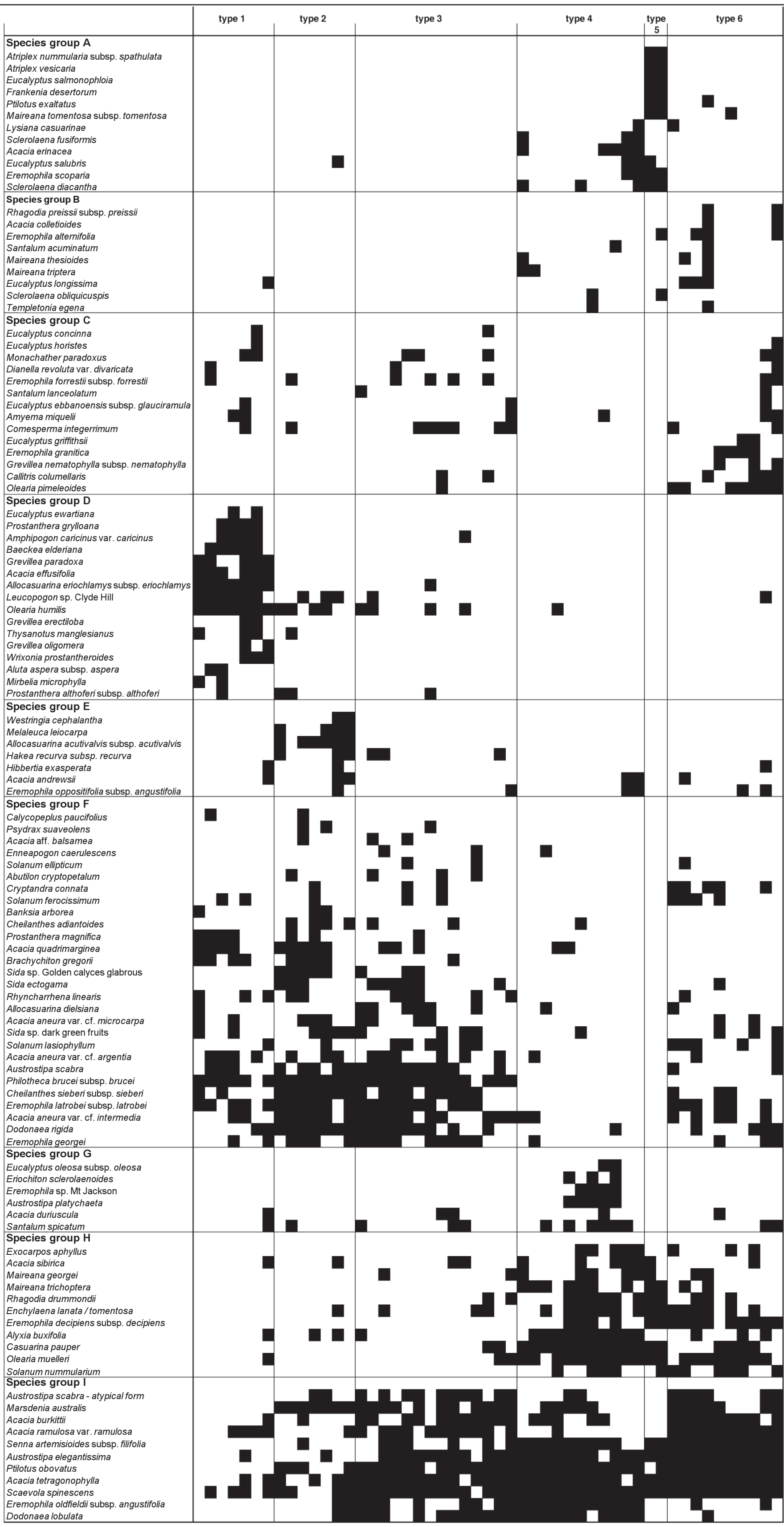

Table 2

Significant indicator species of floristic communities for the northern Yerilgee Hills. Indicator values (%) are shown only for taxa that were significant at p ≤ 0.05 (from Monte Carlo permutation test, * = p < 0.05, ** = p < 0.01, *** = p < 0.001). High indicator values (>25%) per taxon are indicated by shading.

Indicator species	Community type 1	2	3	4	5	6
*Acacia effusifolia****	86	0	0	0	0	0
Allocasuarina eriochlamys subsp. *eriochlamys****	93	0	0	0	0	0
Amphipogon caricinus var. *caricinus***	51	0	1	0	0	0
*Baeckea elderiana***	71	0	0	0	0	0
*Grevillea paradoxa***	71	0	0	0	0	0
Leucopogon sp. Clyde Hill*	50	13	0	0	0	1
*Olearia humilis****	51	17	4	0	0	0
*Prostanthera grylloana***	57	0	0	0	0	0
*Prostanthera magnifica**	35	9	1	0	0	0
*Wrixonia prostantheroides***	43	0	0	0	0	0
Allocasuarina acutivalvis subsp. *acutivalvis****	0	86	0	0	0	0
*Cheilanthes adiantoides**	0	41	3	1	0	0
Cheilanthes sieberi subsp. *sieberi****	4	45	19	0	0	4
*Dodonaea rigida****	3	41	17	0	0	7
Hakea recurva subsp. *recurva**	0	29	7	0	0	0
*Marsdenia australis****	0	34	21	7	0	17
*Melaleuca leiocarpa***	0	57	0	0	0	0
Philotheca brucei subsp. *brucei***	26	36	31	0	0	0
Sida sp. golden calyces glabrous*	0	55	5	0	0	0
*Acacia erinacea**	0	0	0	45	0	0
*Alyxia buxifolia****	1	5	0	48	0	5
*Austrostipa platychaeta***	0	0	0	45	0	0
*Casuarina pauper***	0	0	1	39	39	6
*Dodonaea lobulata****	0	4	30	40	0	0
Eremophila oldfieldii subsp. *angustifolia****	0	4	16	49	0	2
Eremophila sp. Mt Jackson*	0	0	0	36	0	0
*Exocarpos aphyllus**	0	0	0	27	0	12
*Ptilotus obovatus**	0	8	22	25	6	25
Atriplex nummularia subsp. *spathulata****	0	0	0	0	100	0
*Atriplex vesicaria****	0	0	0	0	100	0
*Enchylaena lanata/tomentosa**	0	1	2	16	39	14
*Eremophila decipiens subsp. decipiens**	0	0	0	6	44	36
*Eremophila scoparia***	0	0	0	3	85	0
*Eucalyptus salmonophloia****	0	0	0	0	100	0
*Frankenia desertorum****	0	0	0	0	100	0
Maireana tomentosa subsp. *tomentosa***	0	0	0	0	91	1
*Maireana trichoptera***	0	0	0	22	54	2
*Olearia muelleri**	1	0	1	28	33	21
*Ptilotus exaltatus***	0	0	0	0	91	1
*Rhagodia drummondii***	0	0	1	15	50	5
*Sclerolaena diacantha***	0	0	0	6	79	0
*Sclerolaena obliquicuspis**	0	0	0	1	42	0
*Acacia burkittii***	1	1	25	9	0	33
Acacia ramulosa var. *ramulosa****	13	1	24	0	0	39
*Austrostipa elegantissima**	1	1	16	21	25	25
*Callitris columellaris**	0	0	4	0	0	29
*Cryptandra connata**	0	3	3	0	0	32
*Eremophila granitica***	0	0	0	0	0	40
*Olearia pimeleoides***	0	0	1	0	0	64
Senna artemisioides subsp. *filifolia**	0	1	5	20	30	30

Community type 3: **Eucalyptus – Allocasuarina dielsiana** *woodlands and* **Acacia** *shrublands on mid- to upper hillslopes.*

Substrate and location: Sites were generally located on middle to upper hillslopes at moderate elevations and with moderate gradients, among ridges of interbedded BIF and mafic lithologies. Sites had deposits of BIF and mafic scree, little bedrock outcrop cover, shallow soils and moderate runoff scores (Table 3). Soils were weakly acidic, had moderately low in $EC_{1:5}$ and Na values, and concentrations of trace elements in the middle range of values (Table 4).
Structural description: Tall *Acacia* shrublands usually co-dominated by *A. aneura (A. aneura* var. cf. *intermedia* or var *cf. argentia*), *Acacia ramulosa* var. *ramulosa* and/or *Acacia burkittii*, and often overtopped by isolated trees of *Allocasuarina dielsiana*. Also open woodlands dominated by *Eucalyptus* (*E. concinna* or *E. ebbanoensis* subsp. *glauciramula*) or *Allocasuarina dielsiana* (sometimes also *Casuarina pauper). Acacia* aff. *balsamea, Acacia duriuscula* or *A. quadrimarginea* were occasionally co-dominants in the upper stratum. The middle stratum of sparse shrublands often included *Scaevola spinescens*, *E. latrobei* subsp. *latrobei*, *D. rigida*, *Solanum ferocissimum*, *P. brucei* subsp. *brucei*, *E. georgei*, *Eremophila oldfieldii, Dodonaea lobulata* and *P. obovatus.* Very few indicator species characterized this community (Table 2).
Species groups: While consistent, none of the common and dominant taxa were restricted to this community (Table 2). There was a notable absence of chenopods and other taxa from species groups G and H, and there was a limited representation of taxa from species groups C, D and E. A moderately high number of taxa from across species group F were common in this community. Taxa from species group I occurred with notable constancy, and both this and a lack of taxa from group E distinguished this community from community type 2 (Table 1).
Comments: Community type 3 was most floristically allied to community type 2.
Mean perennial species richness: 21.9 ± 0.6 SE taxa per quadrat.

Community type 4: **Eucalyptus stricklandii – Casuarina pauper – Allocasuarina dielsiana** *woodlands*

Substrate and location: Distributed on middle to lower slopes of ridges, low hills, hillocks and pediments. Found on colluvial deposits of BIF and mafic rocks, often with some deposits of calcrete. Sites were located at moderate elevations, on low gradients with little bedrock outcrop, shallow soils and moderate runoff scores (Table 3). Soils were weakly acidic to neutral and average trace element concentrations and soil eCEC were relatively high, with comparatively higher salinity values (Na and $EC_{1:5}$; Table 4).
Structural description: Woodlands dominated varying by *Eucalyptus stricklandii*, *C. pauper* and/or *A. dielsiana*, over tall shrubs or *Acacia* (*A. ramulosa* subsp. *ramulosa*, *A. burkittii*, *Acacia sibirica, A. quadrimargina*). Common species included *Santalum spicatum*, *Acacia erinacea*, *Eremophila* sp. Mt Jackson (GJ Keighery 4372), *Eremophila oldfieldii*, *D. lobulata*, *Alyxia buxifolia*, *S.spinescens, Olearia muelleri* and *P. obovatus,* over isolated chenopod subshrubs (*Maireana* and *Sclerolaena*) and the perennial speargrass, *Austrostipa platychaeta*.
Species groups: Many of the common and dominant taxa were significant indicator species (Table 2), as were taxa from species group G (Table 1). Taxa from species groups G, H and I were highly represented in this community, while there was a limited but notable occurrence of taxa from species group A. Species from the remaining species groups were either severely lacking or absent.
Mean perennial species richness: 20.5 ± 0.9 SE taxa per quadrat.

Community type 5: Tall, open **Eucalyptus salmonophloia – E. salubris** *woodlands over halophytes and chenopods*

Substrate and location: Environmental information from the two quadrats and additional field observations suggested that this community was located at relatively low altitudes and among the lowest topographic positions. It was restricted to the deep, sandy-clay soils in the flat, wide, lowland valleys between ridges, which were associated with both colluvial and alluvial deposits (Table 3). The soil pH was relatively high and approaching neutral, with relatively little organic C and concentrations of most elements (especially Ca, Co, Cu, K, Mg, Na, Ni and P) were at the higher range of values (Table 4).
Structural description: Tall, open woodlands of *Eucalyptus salmonophloia*, *E. salubris* over very sparse halophyte and chenopod-rich shrublands. Best indicator taxa included *Eremophila decipiens* subsp. *decipiens*, *Atriplex nummularia* subsp. *spathulata*, *Rhagodia drummondii*, *Frankenia desertorum* and species of *Enchylaena, Maireana* and *Sclerolaena* (Table 2).
Species groups: There was distinctive representation of a set of taxa from species group A, many of which had high fidelity to the community type. There was high representation from species group H and part of group I. Taxa from most other species groups were absent (Table 1). Despite some floristic similarities, this community was distinguished from community type 4 by a lack of taxa from species group G.
Comments: Although under-sampled in this survey, these woodlands cover a reasonably large area of lowland valleys between ridges in the southern half of the survey area. This low sampling has resulted in a large number of significant indicator species because of inflated constancy values (Table 2).
Mean perennial species richness: relatively high, at 24.5 ± 1.5 SE taxa per quadrat.

Community type 6: Pediment and peneplain woodlands and shrublands

Substrate and location: Woodlands and shrublands on the pediments and peneplains flanking BIF ridges, on colluvial deposits of BIF, calcrete, quartz and mafic

Table 3

Summary statistics (average ± SE) of site physical variables for floristic community types of the northern Yerilgee Hills, differences were determined using Kruskal–Wallis nonparametric analysis of variance. (* indicates $p < 0.05$, ** indicates $p < 0.01$, *** indicates $p < 0.001$), with Dunn's post-hoc test (LSD $p < 0.05$). [1]: no significant group differences detected in post-hoc test.

	Type 1	Type 2	Type 3	Type 4	Type 5	Type 6
Slope ***	1.4 ± 0.2 [ab]	9.7 ± 1.5 [c]	4.0 ± 1.0 [bc]	2.5 ± 0.7 [ab]	0.0 ± 0.0	0.5 ± 0.2 [a]
Topographic position* **	4.3 ± 0.2 [b]	4.8 ± 0.1 [b]	3.4 ± 0.2 [b]	3.0 ± 0.4 [ab]	1.0 ± 0.0	1.3 ± 0.1 [a]
Surface fragment cover** [1]	5.1 ± 0.3	4.3 ± 0.3	4.4 ± 0.3	5.3 ± 0.2	4.5 ± 0.5	4.0 ± 0.4
Maximum rock size* **	3.3 ± 0.3 [a]	5.3 ± 0.2 [b]	3.8 ± 0.4 [ab]	3.7 ± 0.1 [ab]	2.5 ± 0.5	2.5 ± 0.2 [a]
Bedrock cover* **	0.9 ± 0.6 [ab]	4.7 ± 0.2 [c]	1.1 ± 0.5 [bc]	1.1 ± 0.3 [ab]	0.0 ± 0.0	0.0 ± 0.0 [a]
Runoff ***	2.6 ± 0.4 [ab]	4.0 ± 0.2 [b]	2.9 ± 0.2 [b]	2.5 ± 0.3 [ab]	0.0 ± 0.0	1.1 ± 0.2 [a]
Soil depth* **	2.4 ± 0.2 [b]	1.0 ± 0.0 [a]	2.3 ± 0.2 [b]	2.0 ± 0.1 [ab]	3.0 ± 0.0	2.8 ± 0.1 [b]
% Litter cover [NS]	49.3 ± 4.9	32.1 ± 7.9	33.9 ± 4.1	31.4 ± 5.2	12.5 ± 2.5	32.5 ± 4.7
% Bare ground [NS]	75.7 ± 2.5	80 ± 3.5	84.6 ± 1.9	80.9 ± 1.9	87.5 ± 2.5	79 ± 3.1
Latitude [NS]	29.8869 ± 0.020	29.8657 ± 0.030	29.7818 ± 0.026	29.8076 ± 0.037	29.8975 ± 0.020	29.8303 ± 0.030
Longitude [NS]	119.9788 ± 0.000	119.9551 ± 0.017	119.909 ± 0.019	119.9163 ± 0.021	119.98 ± 0.009	119.9296 ± 0.017
Altitude* [1]	487.9 ± 6.2	489.1 ± 5.4	465.6 ± 6.5	467.8 ± 6.9	447.0 ± 6.0	458.3 ± 8.0
Total species	21.4 ± 1.0	23.4 ± 0.8	22.6 ± 0.7	21.1 ± 1.0	24.5 ± 1.5	25.1 ± 1.6
No. quadrats	7	6	14	11	2	10

Classes for site physical variables (from McDonald *et al.* 1998)

Topographic position: 1 = outwash; 2 = lower slope; 3 = mid slope; 4 = upper slope or low, isolated ridge/hillock; 5 = crest.
Surface rock fragment and exposed bedrock cover: 0 = 0%; 1 = <2%; 2 = 2–10%, 3 = 10–20%; 4 = 20–50%; 5 = 50–90; 6 = >90%.
Maximum rock fragment size: 1 = 2–6 mm; 2 = 6–20 mm; 3 = 20–60 mm; 4 = 60–200 mm; 5 = 200–600 mm; 6 = 600 mm–2 m.
Runoff: 0 = no runoff; 1 = very slow; 2 = slow; 3 = moderately rapid; 4 = rapid; 5 = very rapid.
Soil depth: 1 = 0–5 cm; 2 = 5–50 cm; 3 = >50 cm

Table 4

Summary statistics (average ± SE) of soil variables for floristic community types of the northern Yerilgee Hills, differences were determined using Kruskal–Wallis nonparametric analysis of variance (* indicates $p < 0.05$, ** indicates $p < 0.01$, *** indicates $p < 0.001$), with Dunn's post-hoc test (LSD $p < 0.05$). Units for parameters: eCEC = cmol(+)/kg, minerals = mg/kg, $EC_{1.5}$ = mS/m, organic C and N = %. pH values from $CaCl_2$ solution. Community type 5 was omitted from univariate analyses.

	Type 1	Type 2	Type 3	Type 4	Type 5	Type 6
$EC_{1:5}$**	3.6 ± 0.3 ^{a}	16.7 ± 11.6 ^{ab}	5.1 ± 1.0 ^{a}	12.5 ± 2.0 ^{b}	9.5 ± 5.5	4.1 ± 0.9 ^{a}
pH***	4.73 ± 0.1 ^{a}	4.76 ± 0.2 ^{a}	5.04 ± 0.2 ^{a}	6.56 ± 0.3 ^{b}	6.75 ± 0.8	5.56 ± 0.3 ^{ab}
OrgC**	1.084 ± 0.094 ^{ab}	2.241 ± 0.174 ^{b}	1.001 ± 0.129 ^{a}	1.329 ± 0.209 ^{ab}	1.02 ± 0.05	0.762 ± 0.079 ^{a}
N***	0.070 ± 0.005 ^{a}	0.130 ± 0.01 ^{b}	0.074 ± 0.006 ^{a}	0.098 ± 0.013 ^{ab}	0.083 ± 0.01	0.058 ± 0.006 ^{a}
B **	0.40 ± 0.07 ^{a}	0.47 ± 0.11 ^{a}	0.48 ± 0.06 ^{a}	1.32 ± 0.24 ^{b}	1.15 ± 0.25	0.53 ± 0.1 ^{a}
Ca***	364.3 ± 54.9 ^{a}	560.0 ± 61.0 ^{ab}	688.6 ± 219.0 ^{ab}	2322.7 ± 537.9 ^{b}	2945 ± 2055	804 ± 139.4 ^{b}
Co***	0.316 ± 0.095 ^{a}	0.303 ± 0.059 ^{a}	1.397 ± 0.187 ^{b}	2.11 ± 0.255 ^{b}	3.075 ± 0.025	1.869 ± 0.275 ^{b}
Cu***	0.90 ± 0.12 ^{a}	1.04 ± 0.08 ^{ab}	1.84 ± 0.18 ^{ab}	3.58 ± 0.3 ^{c}	3.05 ± 0.85	2.14 ± 0.27 ^{bc}
Fe***	51.4 ± 3.2 ^{ab}	74.6 ± 5.5 ^{b}	45.6 ± 2.4 ^{a}	47.0 ± 2.9 ^{a}	44.5 ± 0.5	39.6 ± 2.5 ^{a}
K **	104.0 ± 8.2 ^{a}	123.0 ± 9.1 ^{ab}	155.7 ± 10.7 ^{ab}	257.3 ± 47.9 ^{b}	390.0 ± 150.0	158.7 ± 16.9 ^{ab}
Mg***	54.7 ± 8.5 ^{a}	108.9 ± 29.3 ^{ab}	99.6 ± 14.6 ^{ab}	326.4 ± 31.0 ^{c}	670.0 ± 290.0	146.6 ± 26.8 ^{bc}
Mn***	49.6 ± 6.6 ^{ab}	33.3 ± 3.8 ^{a}	74.4 ± 7.2 ^{bc}	102.8 ± 12.6 ^{c}	118.5 ± 41.5	97.6 ± 13.7 ^{bc}
Na***	2.6 ± 0.7 ^{a}	43.9 ± 37.7 ^{ab}	5.4 ± 1.3 ^{a}	20.6 ± 3.0 ^{b}	25.5 ± 6.5	4.2 ± 0.7 ^{a}
Ni**	0.5 ± 0.1 ^{a}	0.8 ± 0.1 ^{ab}	1.2 ± 0.2 ^{ab}	2.0 ± 0.4 ^{b}	3.8 ± 1.9	1.4 ± 0.2 ^{b}
P***	3.0 ± 0.2 ^{a}	7.3 ± 0.9 ^{b}	6.0 ± 0.7 ^{b}	8.9 ± 1.7 ^{b}	10.0 ± 1.0	5.8 ± 0.6 ^{b}
S**	15.6 ± 1.4 ^{b}	45.6 ± 32.4 ^{b}	10.3 ± 1.0 ^{ab}	11.6 ± 2.9 ^{ab}	6.5 ± 2.5	6.2 ± 0.8 ^{a}
Zn **	0.77 ± 0.05 ^{a}	1.63 ± 0.19 ^{b}	1.18 ± 0.12 ^{ab}	1.53 ± 0.15 ^{b}	1.45 ± 0.05	1.17 ± 0.15 ^{ab}
eCEC ***	2.546 ± 0.357 ^{a}	4.196 ± 0.604 ^{ab}	4.678 ± 1.204 ^{a}	15.024 ± 2.944 ^{b}	21.316 ± 13.052	5.643 ± 0.912 ^{ab}
No. quadrats	7	6	14	11	2	10

fragments. Located at the lowest points in the landform, where the gradient was low, surface rocks were small and soils were deep (Table 3). Soils were weakly acidic, with relatively low values for both soil organic C and S, and moderate or high values for many soil trace elements (Table 4).

Structural description: Predominately open woodlands co-dominated by varying combinations of *A. dielsiana*, *Eucalyptus longissima*, *Eucalyptus griffithsii*, *Callitris columellaris* and *C. pauper*. Less frequently, quadrats within this community were described as tall shrublands of *Acacia* (including *A. ramulosa* var. *ramulosa* and *A. burkittii*). Dominant lower shrub stratum taxa were *Olearia pimelioides*, *Senna artemisioides* subsp. *filifolia*, *O. muelleri*, *P. obovatus* and species of *Maireana* and *Enchylaena*. Many of these common taxa were characteristic of the community (Table 2), as were *Eremophila granitica*, *Cryptandra connata* and *Austrostipa elegantissima* (Table 2).

Species groups: There were few taxa from both species groups A and G, and notable, albeit limited, representation from species groups B, C and F. Most taxa in this community occurred in species groups H and I, where taxa from the latter group were highly constant.

Average perennial species richness: relatively speciose at 24.4 ± 1.4 SE taxa per quadrat.

Environmental Correlates

The soils of the northern Yerilgee Hills were typically red-brown sandy clay loams and sandy loams. On average, these soils were acidic (pH 5.45 ± 0.14), shallow (5–50 cm depth), with over 50% cover of surface rock, mostly bare and lacking litter and plant cover (80 ± 1.1%; Tables 2 and 3). The altitude of quadrats ranged from 420 m to 509 m ASL.

Three elements (Al, Cd and Mo) were below the limits of detection in the soil chemical analyses. The remaining soil chemical and physical parameters were found to be generally moderately inter-correlated, with some strong (>0.7) or very strong correlations (>0.9) among soil variables (Table 5). A set of trace minerals was moderately to highly positively inter-correlated (B, Mg, Ca, Mn, Co, K and Cu), and moderately to strongly correlated with eCEC. Two variables associated with salinity, Na and $EC_{1:5}$, were strongly positively correlated. Organic C and N were very strongly positively correlated, and these were moderately correlated with Fe. Some soil variables (particularly Mg and Ca) were very strongly correlated with eCEC, and autocorrelation was expected as eCEC was partially calculated from these element concentrations.

Site physical variables were mostly moderately correlated, and only a small set of these was strongly positively inter-correlated (slope, runoff, topographic position, outcrop cover, maximum rock size; Table 5). These parameters were negatively correlated with soil depth and some were moderately positively correlated with soil N, organic C and Fe, and negatively correlated with Mn concentrations. Autocorrelation among closely related topographic variables (such as slope and runoff) was expected.

Univariate analyses

There were significant differences among the community types analysed for the majority of environmental

Table 5

Matrix of Spearman rank correlation coefficients for environmental variables collated from 51 quadrats established on northern Yerilgee hills. Only correlations significant at p < 0.01 are shown. Parameter codes are as follows: topographical position (Tp), litter ground cover (%litter), bare ground cover (%bare), maximum surface rock fragment size (MxR), and surface rock cover (%RF), exposed rock cover (outcrop). Full details of other environmental parameter codes are given in the methods section.

	EC	pH	OrgC	N	B	Ca	Co	Cu	Fe	K	Mg	Mn	Na	Ni	P	S	Zn	eCEC	Slope	Tp	%RF	MxR	Outcrop	Runoff	Soil	%litter	%bare	Lat	Long
Soil Chemical Parameters																													
EC																													
pH	0.579																												
OrgC	0.418	.																											
N	0.461	.	0.921																										
B	0.614	0.732	.	.																									
Ca	0.675	0.877	.	.	0.727																								
Co	.	0.624	-0.421	.	0.445	0.606																							
Cu	.	0.639	.	.	0.656	0.714	0.780																						
Fe	.	.	0.525	0.508	.	.	.	.																					
K	.	0.407	.	.	0.515	0.576	0.650	0.756	.																				
Mg	0.573	0.788	.	.	0.733	0.910	0.655	0.725	.	0.600																			
Mn	.	0.544	.	.	0.479	0.482	0.823	0.764	-0.362	0.554	0.497																		
Na	0.720	0.500	0.376	0.435	0.746	0.645	.	0.483	.	0.398	0.730	.																	
Ni	.	0.473	.	.	0.389	0.664	0.778	0.639	.	0.678	0.691	0.560	0.362																
P	0.375	0.439	.	0.456	0.421	0.590	0.431	0.547	.	0.635	0.603	0.378	0.441	0.489															
S	.	-0.416	0.590	0.503	.	.	-0.615	.	.	.	-0.406	-0.380	.	.	.														
Zn	0.474	.	0.434	0.500	0.387	0.425	.	0.468	.	0.465	.	.	0.525	.	0.637	.													
eCEC	0.648	0.853	.	.	0.744	0.988	0.626	0.735	.	0.616	0.953	0.490	0.681	0.684	0.624	.	0.419												
Physical Parameters																													
Slope	.	-0.412	0.430	0.379	.	.	-0.459	.	0.497	.	.	-0.458	.	.	.	.	.	.											
Tp	.	-0.398	.	.	.	.	-0.488	-0.480	0.656	-0.437	.	-0.552	.	.	.	.	.	.	0.537										
%RF	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.									
MxR	.	.	0.487	0.539	.	.	.	.	0.562	.	.	-0.408	.	.	.	.	.	.	0.658	0.649	.								
Outcrop	.	.	0.547	0.575	.	.	-0.368	.	0.576	.	.	-0.492	.	.	.	.	.	.	0.550	0.700	.	0.821							
Runoff	.	-0.387	0.386	0.395	.	.	-0.393	.	0.482	.	.	-0.435	.	.	.	.	.	.	0.763	0.740	.	0.783	0.677						
Soil	.	.	-0.460	-0.522	.	.	.	.	-0.492	.	.	0.436	.	.	.	.	.	.	-0.573	-0.562	.	-0.827	-0.817	-0.679					
%litter	.	.	.	.	.	.	-0.369	.	.	.	-0.406	.	.	.	.	0.499	.	.	.	.	.	.	.	.	.				
%bare	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	-0.548			
Lat	.	.	0.450	0.363	.	.	.	.	.	.	.	.	.	.	.	0.419	.	.	.	.	.	.	.	.	.	.	.		
Long	.	.	0.458	.	.	.	.	.	.	.	.	.	.	.	.	0.488	.	.	.	.	.	.	.	.	.	0.377	.	0.896	
Altitude	.	-0.459	0.518	0.419	.	.	-0.547	.	.	.	.	.	.	.	.	0.594	.	.	0.394	0.394	.	.	.	0.472	.	.	.	0.627	0.557

parameters (Tables 2 and 3). Community type 2 occupied sites that were significantly steeper and with a greater cover of exposed bedrock than community types 1, 4 and 6, and had significantly larger maximum rock sizes than community types 1 and 6 (Table 3). Soils for community type 2 were significantly shallower than for community types 1, 3 and 6. Community type 6 occupied significantly lower topographic positions than community types 1, 2 and 3, and had low values for runoff, slope and outcropping bedrock cover, all of which were significantly lower than for community types 2 and 3 (Table 3). Although differences in altitude and surface rock cover were found between the communities, post-hoc tests did not find significant pair-wise differences (Table 3).

Community type 4 had significantly higher $EC_{1:5}$ and Na values than community types 1, 3 and 6, which indicated relatively higher values for soil salinity. Trace element concentrations and eCEC values were also relatively high for community type 4. Concentrations of Cu and Mg were significantly higher than in community types 1, 2 and 3, Mn concentrations were significantly higher than in community types 1 and 2, and eCEC values were significantly higher than in community types 1 and 3 (Table 4). Both community types 4 and 6 had neutral or weakly acidic soils (pH > 5), and soil pH was significantly higher in community type 4 than in community types 1, 2 and 3. Community type 4 also had the significantly lowest levels of B among community types (Table 4).

Values for soil trace elements tended to be lowest in the community types 1 and 2. Co concentrations were significantly lower in these community types than those found in community types 3, 4 and 6 (Table 4). Community type 1 also had significantly lower Ca, Cu, Mg and Ni concentrations than community types 4 and 6, and significantly lower soil K concentrations than community type 4. Community type 2 had significantly lower Mn concentrations than community types 3, 4 and 6. Zn concentrations were notably low in community type 1, and were significantly lower than in community types 2 and 4 (Table 4).

The highest average organic C, N and Fe concentrations were found in the soils of community type 2 (Table 4). Soil organic C in community type 2 was significantly higher than in community types 3 and 6, and soil N concentrations were significantly higher than community types 1, 3 and 6. Fe concentrations in community type 2 were significantly higher than in community types 3, 4 and 6. Both community types 1 and 2 had relatively high concentrations of S, which were significantly higher than for community type 6, but not statistically different to community types 3 and 4. Community type 1 had significantly less P than all other community types (Table 4).

SSH MDS ordination

Semi-strong hybrid multidimensional scaling of the quadrat floristic data provided a three-dimensional solution to the floristic relationships between community types, of which two axes have been presented (Fig. 3a). The stress level (0.16) indicated moderate difficulty in reducing the data to three dimensions (Seber 1984). There was some segregation of sites according to community type, albeit with some overlap among some groups. Community type 4 formed a relatively close grouping of sites, while community type 1 was both the most heterogeneous group and most outlying community type. There was a notable separation of the extreme upland (community types 1 and 2) and lowland communities (community types 5 and 6), and communities were generally arranged in topographic sequence across the ordination.

There were significant correlations between a subset of the environmental variables and the site ordination (Fig. 3b). A number of other variables, such as Fe, organic C and N, were not significantly correlated with the ordination. Quadrats from community types 1 and 2 roughly coincided with high values along the fitted vectors for topographic position and runoff, with community type 2 being more closely associated with high scores of surface rock size. Community types 4, 5 and 6 correlated with the lowest extremes of the general topographic gradient (Fig. 3b).

There was an obvious gradient of soil microelement concentrations (B, Cu, Ca, Mg, Ni, Mn, Co, K), eCEC and soil pH (Fig. 3b). This gradient was roughly co-linear with the vector for topographical position, but was opposite in magnitude. The extreme high end of the gradient correlated with quadrats from community types 4 and 5, while community type 6 coincided with the gradient midpoint and both community types 2 and 1 aligned with the lower end (Fig. 3a and 3b). A vector for P was divergent to these other major gradients, and community types 1 and 4 were aligned at the lower and upper extremes of this gradient, respectively (Fig. 3a and 3b).

DISCUSSION

Flora and Vegetation

This is the first systematic survey of the flora on the northern Yerilgee Hills. Species counts from other quadrat-based surveys in the Mount Manning Region range from 131 to 303 native taxa, and from 96 to 148 perennial taxa within plots (Table 6). These broad comparisons have limitations, but numbers of shared perennial taxa between ranges decreases with distance, particularly in a north–south direction (Table 6). Decreasing floristic similarity with increasing spatial separation of ranges has been observed within the wider Mount Manning Region (Mattiske 2001b), and the wider northern Yilgarn (N Gibson[3], pers. comm.). Furthermore, the ranges that are less than c. 50 km apart may only share 30–55% of perennial taxa (Table 6; Mattiske 2001b). This spatial

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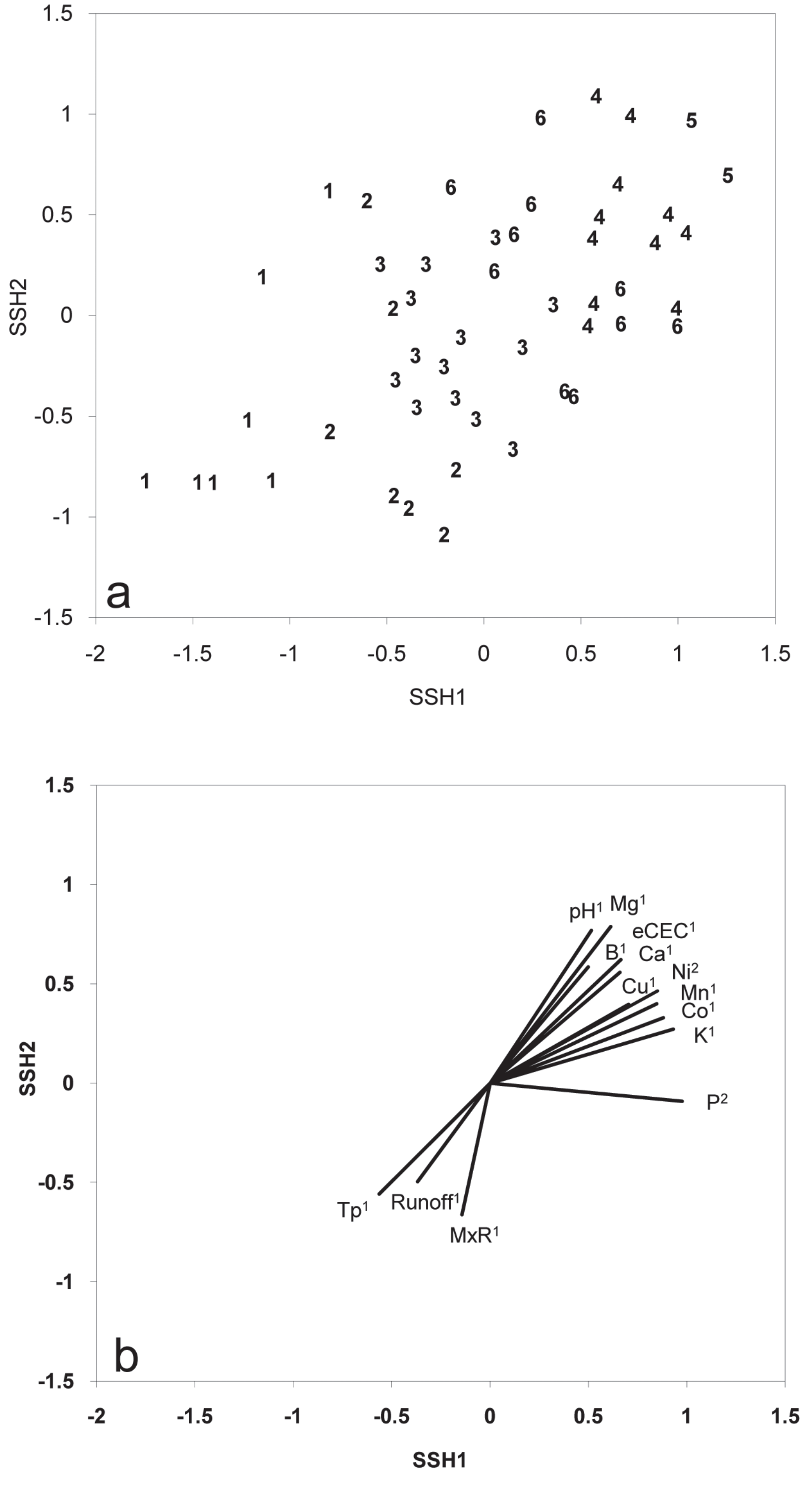

Figure 3. 3D SSH MDS site ordination for the northern Yerilgee Hills survey area, based on dissimilarities in floristic composition from Bray–Curtis dissimilarity matrix of presence/absence data of 114 perennial taxa from 51 quadrats. Sites are numbered by their respective floristic community types, and two axes (a: SSH axes 1 vs 2) of the three dimensional ordination are presented. Vectors of best fit linear correlations of site physical parameters and site ordination coordinates are illustrated in the adjacent panel (b). Vectors are illustrated in a positive direction only, and indicate strength and direction of correlation. Only significant vectors ($p < 0.05$) are displayed, as determined from Monte Carlo permutation tests. Level of significance is indicated by a superscript numeral: 1 = $p < 0.001$, 2 = $p < 0.01$; 3 = $p < 0.05$.

Table 6

Comparison of flora and shared perennial taxa on ranges adjacent to the northern Yerilgee Hills. Counts of perennial taxa or the combined total number of taxa between pairs of ranges are given in parentheses.

Range	No. native taxa (perennial)	No. taxa plots (perennial)/ no. plots	Distance from Yerilgee hills (km)	Shared perennial taxa (combined taxa)	No. taxa conservation significance	Reference
Northern Yerilgee Hills	182 (166)	156 (142) / 51	–	–	4 priority	This study
Mt Manning Range	234 (172)	197 (142) / 54	33 km SW	34% (249)	5 priority	Gibson (2004, 2007)
Johnston Range	176 (148)	157 (131) / 50	53 km E	54% (200)	1 DRF, 4 priority	Markey & Dillon (2011)
Die Hardy Range	142 (–)	–	55 km WSW	–	7 priority taxa	Gibson (2004); Mattiske (2001a)
Helena & Aurora Range	303 (209)	234 (117) / 55	68 km SSW	29% (291)	2 DRF and 12 priority taxa	Gibson et al. (1997, 2007)
Windarling Range	131 (–)	–	110 km WSW	–	2 DRF, 2 priority	Gibson (2007); Mattiske (2001a)
Hunt Range, Yendilberin and Watt hills	273 (190)	236 (148) / 53	46–88 km S	30% (269)	7 priority	Gibson & Lyons (2001a)
Highclere Hills	217 (135)	218 (96) / 45	138 km SW	23 % (240)	6 priority	Gibson & Lyons (2001b)

turnover of species could, in part, reflect increasing aridity in a north-easterly direction and a latitudinal turnover of climate and soils (Beard 1976, 1990; Keighery et al. 1995). High β-diversity among these isolated ranges could also be attributed to a number of factors, including range-specific differences in geomorphology, historical fluctuations in palaeoclimate and stochastic processes of colonisations and extinctions within and among ranges (Gibson et al. 2007; Hopper & Gioia 2004; Harrison 1997; Jacobi et al. 2007).

The northern Yerilgee Hills are on the boundary between the Coolgardie and Murchison IBRA bioregions. Both the representation of families and genera, and the vegetation communities in the survey area are typical for the Coolgardie IBRA and floras from other ironstone surveys in the Mount Manning Region (Beard 1976, 1990; Environmental Protection Authority 2007; Keighery et al. 1995; Newbey & Hnatiuk 1985; Gibson et al. 1997, Gibson & Lyons 2001a; Gibson 2004). Woodland communities on the lower slopes, valleys and plains of the northern Yerilgee Hills were still dominated by *Eucalyptus* spp., *Casuarina pauper, Callitris columellaris* and *Allocasuarina dielsiana*, while *Acacia aneura* shrublands were restricted to the hillslopes and uplands. Lowland mulga shrublands, which are indicative of the Murchison region (Beard 1976, 1990), were not observed on the pediments and peneplains of the survey area. However, the northern Yerilgee Hills have approximately half the number species of *Eucalyptus* and Myrtaceae reported for more southern ranges in the Mount Manning Region (Gibson & Lyons 2001a; Gibson et al. 1997), which reflects a transition to the Murchison bioregion.

Some of the floristic communities of the northern Yerilgee Hills have broad structural and floristic similarities to elements of the Die Hardy System of Beard (1972, 1976), formations described by Keighery et al. (1995), and communities described for individual ranges in the Mount Manning Region (Gibson 2004; Gibson et al. 1997; Gibson & Lyons 2001a; Mattiske 2001b). This includes broadly comparable lowland *Eucalyptus salmonophloia – Eucalyptus salubris* woodlands and/or *Acacia* shrublands and *Eucalyptus*/*Callitris*/*Allocasuarina* woodlands (Gibson & Lyons 2001a, Gibson 2004; Keighery et al. 1995; Mattiske 2001b, Newbey & Hnatiuk 1985). Broadly similar upland mosaic shrublands – mallee shrublands and rocky crest shrubland communities have also been described for the wider Mount Manning region (Gibson & Lyons 2001a; Gibson et al. 1997; Gibson 2004; Keighery et al 1995; Markey & Dillon 2011; Mattiske 2001b). However, many dominant or common taxa of these southern crest and lateritic upland communities are absent or restricted to southern sites on the northern Yerilgee Hills, including *Acacia cockertoniana*, *Grevillea georgeana*, *Hibbertia exasperata, Melaleuca nematophylla, Westringia cephalantha, Triodia* cf. *scariosa*, *Neurachne annularis, Grevillea arcuata* and *Hibbertia exasperata* (Gibson 2004; Gibson & Lyons 2001a; Keighery et al. 1995; MacFarlane 2007; Maslin 2007; Mattiske 2001a; Newbey & Hnatiuk 1985). There was even some suggestion of a latitudinal turnover within community type 2 over the northern Yerilgee Hills. Further survey of the southern Yerilgee Hills may find a southern variant of this community type.

Banksia arborea shrublands, in particular, are characteristic of the Die Hardy and Bungalbin Systems of Beard (1972, 1976), and are described for the Windarling, Jackson, Die Hardy Range and Helena and Aurora Ranges (Beard 1972, 1976; Keighery et al. 1995; Mattiske 2001b; Newbey & Hnatiuk 1985). Keighery et al. (1995) found *Banksia arborea* to be restricted to small patches on the Mt Manning Range, which Gibson (2004) could not relocate in a later survey. On the Yerilgee Hills, stands of *Banksia arborea* were only found on patches of narrow, rocky crests south of the Evanston–Menzies Road. Both these and small stands on the Johnston Range (Markey & Dillon 2011) represent the known northern limit of this species, as *Banksia arborea* shrublands are absent from the ironstones of Mt Elvire (25 km north-west of Johnson Soak; Keighery et al. 1995). Instead, *Acacia aneura* is a co-dominant with other species of *Acacia*) on the slopes on the northern Yerilgee hills, and on BIF ranges north of this area (Keighery et al. 1995).

Previous meta-analyses of quadrat-based floristic data from ranges in the Mount Manning Region have found range-specific differences in floristic composition (Mattiske 2001b). Groupings of lowland communities (supergroups of *Eucalyptus* and *Acacia* woodlands) are more widespread among ranges than the upland shrubland communities, which have considerably more restricted distributions among and within ranges (Mattiske 2001b). Changes in plant assemblages among ranges mirror trends in species turnover in the wider Coolgardie IBRA bioregion. A further meta-analysis of a larger dataset from the Mount Manning Ranges is required to determine the distinctiveness of floristic communities on the northern Yerilgee Hills. However, observations made in this study suggest that the northern Yerilgee Hills differ in floristic composition from adjacent ranges, and this may be most evident in the upland communities.

Geographical variation in floristic communities is also likely to be due to range-specific variation in soils and geomorphology, such as the relative extent and elevation of rocky crests and lateritic uplands (Gibson & Lyons 2001a). Complex BIF landforms in the Mount Manning Region support a high number of both rare and endemic taxa and unique crest communities (Environmental Protection Authority 2007). The northern Yerilgee hills are a relatively subdued landform that lack extensive massive outcroppings of BIF. The associated BIF crest communities do not appear to be as diverse as those described for the Die Hardy and Windarling Ranges by Mattiske (2001b). The northern Yerilgee Hills do support a highly distinctive community on the extensive laterities at the top of the range. This was more floristically distinct from adjacent communities than has been found within other ranges (Gibson 2004; Gibson & Lyons 2001a, 2001b).

Two regional endemics (*Banksia arborea*, *Eremophila* sp. Mt Jackson; GJ Keighery 4372) and one near endemic (*Grevillea erectiloba*) were reported for the northern Yerilgee Hills. Both *Eremophila* sp. Mt Jackson (GJ Keighery 4372) and *Grevillea erectiloba* are listed as regional or short-range endemics to the Mount Manning Region (Environmental Protection Authority 2007; Gibson 2004). Other taxa found on the Yerilgee Hills (*Banksia arborea*, *Spartothamnella* sp. Helena & Aurora Range; PG Armstrong 155–109) are recognised as having a distribution restricted to BIF (Gibson et al. 2007). Although there are fewer endemic species than reported for the other, more southern ranges in the Mount Manning Region (Environmental Protection Agency 2007; Mattiske 2001a; Gibson & Lyons 2001a; Gibson et al. 1997, 2007), other ranges can lack endemics altogether (Gibson & Lyons 2001b). Four priority taxa were located on the northern Yerilgee Hills, which is relatively low compared with some ranges in the region such as the Windarling and Die Hardy ranges, but comparable to others like the Mt Manning and Johnston Ranges (Table 6). While the number of rare or priority taxa appears to be correlated with the total number of species on BIF ranges, there is no simple association between the number of endemic taxa and overall species diversity (Gibson et al. 2007).

Many rare and endemic taxa of the Mount Manning Region tend to be BIF specialists associated with complex, elevated landforms that support a diversity of habitats, including extensive outcrops of massive BIF (Environmental Protection Authority 2007; Gibson et al. 2007; Mattiske 2001a). The northern Yerilgee Hills may not be of substantial elevation nor have the extensive BIF outcroppings to support BIF specialists like *Tetratheca paynterae* subsp. *paynterae* (Butcher et al. 2007), but they do harbour other notable BIF taxa, some of which are at their distributional limits.

Environmental Correlates

An association between floristic assemblages and topographic and/or edaphic factors have been documented for other arid ironstone ranges in the Yilgarn (for example, see Gibson 2004; Gibson & Lyons 2001a; Markey & Dillon 2008a, 2010a; Meissner & Caruso 2010a), as well as in the Pilbara (van Etten & Fox 2004), Queensland (Butler & Fensham 2008) and for Brazilian ironstones (Jacobi et al. 2007; Vincent & Meguro 2008). Distinct floristic associations were identified within the northern Yerilgee Hills that were partitioned by topographic position and substrate and correlated with environmental variables. Community differences in site physical and soil chemical parameters were most pronounced between topographic extremes, but also reflected geological substrate.

Soil attributes were typical for lithosols in the wider region (Hennig 1998), and these metalliferous, acidic, stony soils also reflected influence of parent bedrock (Gray & Murphy 2002; Vincent & Meguro 2008). Trends in soil composition and development were generally similar to those reported for other BIF ranges (Gibson 2004; Gibson et al. 1997; Gibson & Lyons 1998, 2001a; Markey & Dillon 2008a, 2008b, 2010).

Soils from the upland community types 1 and 2 were found to be strongly acidic (pH <4.8; Slattery et al. 1999), relatively infertile and lacking trace elements and heavy metals. Prolonged weathering has most likely leached the more mobile elements such as K, Ca and Mg (Britt et al. 2001; Cole 1973). The BIF crest community (community type 2) had significantly higher concentrations of Fe, presumably due to the in situ formation of soils and Fe enrichment from iron-rich bedrock (Britt et al. 2001; Cornelius et al. 2007; Foulds 1993). Relatively elevated concentrations of S in community types 1 and 2 soils could also be a results of in situ enrichment from sulfide-rich BIF bedrock, and these sulfides can lower soil pH (Britt et al. 2001; Cornelius et al. 2007; Foulds 1993). This contrasts with the lowland communities (particularly community types 5 and 6), where deep deposits of colluvium were relatively enriched with moderate to high levels of soil trace elements, heavy metals (Co, Cu and Ni), relatively lacking in S and weakly acidic to neutral (Slattery et al. 1999). Enrichment would come from leachates and colluvium (Ben-Shahar 1990; Britt et al. 2001; Cole 1973; Cornelius et al. 2007; Gray & Humphreys 2004; Gray & Murphy 2002), which contains cations (such as Ca, Mg) that can lower soil acidity and buffer soil pH (Gray & Murphy 2002).

Community types 3 and 4 were associated with moderately inclined hillslopes of mixed mafic and BIF geologies, although the latter community tended to occur on lower slopes, valleys and pediments, and with calcrete deposits. These communities were mostly separated on edaphic factors. The greater influence of mafic substrates probably accounted for relatively higher concentrations of soil microelements in community type 4, since soils from mafic substrates have comparatively higher levels of trace elements like P, Mn, K, Ca, Zn Cu and Mg (Britt et al. 2001; Cole 1973; Gray & Humphreys 2004; Gray & Murphy 2002, Jacobi et al. 2007). Calcrete deposits are often derived from mafic and ultramafic bedrock (Anand et al. 1997), and were observed to be common on the lower slopes, valleys and pediments on the northern Yerilgee Hills and in conjunction with community types 4, 5 and 6. Carbonates and mobile cations from mafics and calcrete can produce buffered, weakly acidic to neutral soils (Gray & Humphreys 2004; Gray & Murphy 2002). In addition to leachates, calcrete deposits probably also contributed to elevated soil trace element concentrations (particularly Ca) and pH values in these communities (Anand et al. 1997, Britt et al. 2001; Gray & Humphreys 2004; Gray & Murphy 2002).

The soils of community types 4 and 5 not only stand out with high concentrations of trace elements, but also for relatively high values for salinity. Community type 4 had a comparatively high Na concentration and $EC_{1:5}$, which suggested a deposition of salts derived from bedrock (Chartres 1993), although the salinity of these silty clay loam soils could be considered very low to low (Shaw 1999). The chenopod and halophyte-rich understorey of community type 5 also indicated greater relative salinity, although under-sampling of this community meant that Na, EC and Ca values were quite variable. Salinity values were also extremely variable for community type 2, and this community generally was not dominated by halophytes and chenopods. The weakly acidic to neutral soil pH values of this latter community was on a par with similar woodland communities on the Mt Manning range (Gibson 2004), but other chenopod-rich, lowland woodlands around greenstones have been reported to have more basic soils (Gibson & Lyons 2001a, 2001b)

Soils for the crest community (community type 2) were found to be significantly enriched with N and organic C, and this has been found in soils of other crest communities (Markey & Dillon 2009, 2011). Accumulations of leaf litter in crevices on rocky crests are a main source of these macronutrients in these small pockets of skeletal soil (Foulds 1993). The trend for some upland communities to have N- and C-enriched soils contradicts the generalisation that soil organic carbon is generally elevated in down-slope sites due to litter deposition and greater soil moisture (Baldock & Skjemstad 1999), and this general finding has been evident in other studies on greenstone ranges (Chalwell 2003; Gibson & Lyons 2001a, 2001b). Lower levels of organic C and N in the other communities (particularly community types 4, 5 and 6) could reflect a low overall ratio of leaf litter to soil on these deeper soils, while sampling on rocky crests was restricted to small pockets of highly enriched loamy soils.

We infer that there is a soil moisture gradient over the catena on the Yerilgee Hills, where skeletal or shallow soils, steep slopes and exposed bedrock on upland sites have a poor capacity to retain water, while lowland sites receive surface runoff and overlie groundwater sources (Cole 1973; Ben-Shahar 1990; Jacobi et al. 2007; Johnson 1998). This water deficit in upland areas can be compounded by the microclimate (high irradiance, extreme daily thermal variations and high evaporation; Jacobi et al. 2007). Ecophysiological studies have found that shallow-rooted shrubs on the rocky uplands of greenstone ranges are relatively more tolerant of xeric conditions and drought stress, while deep-rooted eucalypts avoid drought and maintain high rates of evapotranspiration by tapping into groundwater and soil moisture sources (Chalwell 2003). This would explain the limited establishment of tall woodlands and predominance of shrubs and mallee shrublands on upland summit surfaces (community type 1). Community type 2 had another suite of rock-rooted shrubs and geophytes (species group F such as *Cheilanthes*, *Cymbopogon*) that utilise the water and soil availability in rock fissures. Even with this relatively greater drought tolerance, dead shrubs were observed in the Yerilgee upland shrublands, most likely because of chronic drought.

Conservation

The vegetation of the northern Yerilgee Hills area is relatively free of exotic species and appears to be in good condition. We attributed this to relatively low levels of grazing, since livestock were absent and there was little evidence of feral goats. However, rabbits were causing some damage to the ground stratum in lowland woodlands. The main impact on the communities has been from sandalwood harvesting, which continues as a minor industry in the region. This harvesting has impacted the central and northern parts of the survey area, and old campsites, tracks and clearings remain decades after their establishment.

To date, almost none of the survey area is reserved on conservation estate and remains as unallocated crown land, with a small portion of the south-west area occurring within the Mt Manning Nature Reserve. Apart from this, none of the survey area is within any of the reserves proposed for the Mount Manning Region (Environmental Protection Authority 2007). Exploration or mining tenements cover the northern Yerilgee Hills, and exploration and drilling activities had commenced by August 2007. Given that mining has been proposed for all ranges within the Mount Manning Region, efforts should be made to minimise impacts on areas identified as having high conservation significance. Should mining proceed on the northern Yerilgee Hills, planning should minimise impacts on the restricted upland communities and priority taxa.

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REFERENCES

Anand RR, Phang C, Wildman JE, Lintern MJ (1997) Genesis of some calcrete in the southern Yilgarn Craton, Western Australia: Implications for mineral exploration. *Australian Journal of Earth Sciences* **44**, 87–103.

Angiosperm Phylogeny Group (2003) An update of the Angiosperm Phylogeny Group classification for the orders and families of flowering plants: APG II. *Botanical Journal of the Linnaean Society* **141**, 399–436.

Baldock JA, Skjemstad JO (1999) Soil organic carbon/soil organic matter. In *Soil Analysis: An Interpretation Manual* (eds KI Peverill, LA Sparrow, DJ Reuter), pp 159–170. CSIRO Publishing, Victoria.

Barker RM (2007) Two newly described species and a draft key to *Sida s. lat.* from Western Australia. *Nuytsia* **17**, 13–30.

Beard JS (1972) *Vegetation Survey of Western Australia: The Vegetation of the Jackson Area, Western Australia. Map and Explanatory Memoir. 1:250,000 Series.* Vegmap Publications, Sydney.

Beard JS (1976) *Murchison, 1:1,000,000 Vegetation Series: The Vegetation of the Murchison Region.* University of Western Australia Press, Perth.

Beard JS (1990) *Plant Life of Western Australia.* Kangaroo Press, Perth.

Belbin L (1989) *PATN Technical Reference.* CSIRO Division of Wildlife and Ecology, Lyneham, ACT.

Belbin L (1991) Semi-strong hybrid scaling, a new ordination algorithmn. *Journal of Vegetation Science* **2**, 491–496.

Belbin L, Faith D, Milligan GW (1992) A comparison of two approaches to beta-flexible clustering. *Multivariate Behavioural Research* **27**, 417–433.

Ben-Shahar R (1990) Soil nutrients distribution and moisture dynamics on upper catena in a semi-arid nature reserve. *Vegetatio* **89**, 69–77.

Britt AF, Smith RE, Gray DJ (2001) Element mobilities and the Australian regolith – a mineral exploration perspective. *Marine Freshwater Research* **52**, 25–39.

Bureau of Meteorology (1908–) *Climate Statistics for Australian Locations.* Available at http://www.bom.gov.au/climate/averages/. [Accessed May 2008]

Butcher R, Byrne M, Crayn D (2007) Evidence for convergent evolution among phylogenetically distant rare species of *Tetratheca* (Eleocarpaceae, formerly Tremandraceae) from Western Australia. *Australian Systematic Botany* **20**, 139–160.

Butler DW, Fensham RJ (2008) Lose the plot: cost-effective survey of the Peak Range, central Queensland. *Cunninghamia* **10,** 522–538.

Cassidy KF, Champion DC, Krapez B, Barley ME, Brown SJA, Blewett RS, Groenewald PB & Tyler IM (2006) A revised geological framework for the Yilgarn Craton, Western Australia. *Western Australian Geological Survey, Record 2006/8.* Perth, Western Australia.

Chalwell ST (2003) 'Plant communities of greenstone hills of the Eastern Goldfields of Western Australia as analogues for the rehabilitation of rocky waste dumps'. Unpublished PhD thesis, Murdoch University, Western Australia.

Champion DC, Smithies RH (2001) Archaean granites of the Yilgarn and Pilbara cratons, Western Australia. In *4th International Archaean Symposium 2002, extended abstracts.* (eds KF Casidy, JM Dunphy, MJ

Van Kranendonk), pp 134–136. Geoscience Australia, Records 2001/37, Canberra.

Champion DC, Smithies RH (2003) Archaean Granites. In *Magmas to Mineralisation: The Ishihara Symposium on Granites and Related Metallogenesis* (eds P Belvin, M Jones, B Chappell), pp 13–17. Geoscience Australia, Record 2003/14, Canberra.

Chartres CJ (1993) Sodic soils: an introduction to their formation and distribution in Australia. *Australian Journal of Soil Research* **31**, 751–760.

Chen SF, Wyche S (2003) *Geology of the Bungalbin 1:100,000 Sheet. 1:100,000 Geological Series Explanatory Notes.* Geological Survey Western Australia, Perth.

Clark KR, Gorley RN (2006) *Primer v6: User Manual/Tutorial.* PRIMER–E Ltd, Plymouth.

Cole MM (1973) Geobotanical and biogeochemical investigations in the sclerophyllous woodland and shrub associations of the Eastern Goldfields area of Western Australia, with particular reference to the role of *Hybanthus floribundus* (Lindl.) F. Muell. As a nickel indicator and accumulator plant. *The Journal of Applied Ecology* **10**, 269–320.

Cornelius M, Robertson IDM, Cornelius AJ, Morris PA (2007) *Laterite Geochemical Database for the Western Yilgarn Craton, Western Australia.* Geological Survey of Western Australia, Record 2007/9, Perth.

Department of Conservation and Land Management (CALM) (1994) 'Goldfields Regional Management Plan 1994–2004'. Management Plan No. 27. Department of Conservation and Land Management, Western Australia, unpublished report.

Department of Environment and Conservation (2007) Banded ironstone formation ranges of the Midwest and Goldfields. In *Strategic Review of the Conservation and Resource Values of the Banded Iron Formation of the Yilgarn Craton.* Government of Western Australia, Perth.

Department of Environment and Water Resources (2007) IBRA Version 6.1. Available from www.environment.gov.au/parks.nrs/ibra/version 6-1/. Updated 6th February [accessed June 2008].

Dufrêne M, Legendre P (1997) Species assemblages and indicator species: The need for a flexible asymmetrical approach. *Ecological Monographs* **67**, 345–366.

Environmental Protection Authority (2007) 'Advice on areas of the highest conservation value in the proposed extensions to Mount Manning Nature Reserve'. Unpublished report to the Minister for the Environment, Perth, Western Australia.

Faith DP, Norris RH (1989) Correlation of environmental variables and patterns of distribution and abundance of common and rare freshwater macroinvertebrates. *Biological Conservation* **50**, 77–98.

Faithful E (1994) Land use history. In *An Inventory and Condition Survey of the North-Eastern Goldfields, Western Australia.* Technical Bulletin No. 90 (eds AL Payne, AME Van Vreeswyk, HJR Pringle, KA Leighton, P Hennig), pp. 11–14. Department of Agriculture Western Australia, South Perth.

Foulds, W (1993) Nutrient concentrations of foliage and soil in south-western Australia. *New Phytologist* **125**, 529–546.

Gibson N (2004) Flora and vegetation of the Eastern Goldfields Ranges: Part 6. Mt Manning Range. *Journal of the Royal Society of Western Australia* **87**, 35–47.

Gibson N, Lyons MN, Lepschi BJ (1997) Flora and vegetation of the Eastern Goldfields Ranges, Part 1: Helena and Aurora Range. *CALMScience* **2**, 231–246.

Gibson N, Lyons MN (1998) Flora and vegetation of the Eastern Goldfields Ranges: Part 3. Parker Range. *Journal of the Royal Society of Western Australia* **81**, 119–129.

Gibson N, Lyons M (2001a) Flora and vegetation of the Eastern Goldfields Ranges: Part 5: Hunt Range, Yendilberin and Watt Hills. *Journal of the Royal Society of Western Australia,* **84**, 129–142.

Gibson N, Lyons MN (2001b) Flora and vegetation of the Eastern Goldfields ranges: Part 4: Highclere Hills. *Journal of the Royal Society of Western Australia* **84**, 71–81.

Gibson N, Coates DJ, Thiele KR (2007) Taxonomic research and the conservation status of flora in the Yilgarn Banded Iron Formation ranges. *Nuytsia* **17**, 1–12.

Gray JM, Humphreys GS (2004) Patterns of global soil distribution as revealed by two major soil databases. *Supersoil 2004. Proceedings of the 3rd Australian and New Zealand Soils Conference* (ed B Singh et al.), University of Sydney, 5–9 December 2004. The Regional Institute, Gosford, New South Wales. http://www.regional.org.au/au/asssi/supersoil2004/s8/oral/1697_grayjg.htm) [accessed November 2011].

Gray JM, Murphy BW (2002) Parent material and soil distribution. *The Journal of the Australian Association of Natural Resource Management.* **5,** 2–12.

Greenfield JE (2001) *Geology of the Lake Giles 1:100,000 Sheet: Western Australian Geological Survey, 1:100,000 Geological Series Explanatory Notes.* Geological Survey of Western Australia, Perth.

Groenewald PB, Riganti A (2004) *East Yilgarn 1:100,000 Geological Information Series – An Explanatory Note.* Report 95, Western Australian Geological Survey, Perth.

Harrison S (1997) How natural habitat patchiness affects the distribution of diversity in Californian serpentine chaparral. *Ecology* **78,** 1898–1906.

Hennig P (1998) Soils. In *An Inventory and Condition Survey of the Sandstone – Yalgoo – Paynes Find Area, Western Australia.* (eds AL Payne, AME Van Vreeswyk, HJR Pringle, KA Leighton, P Hennig), pp 95–118. Technical Bulletin No. 90, Agriculture Western Australia, South Perth.

Hopper SD, Gioia P (2004) The southwest Australian floristic region: evolution and conservation of a global hot spot of biodiversity. *Annual Review of Ecology, Evolution and Systematics* **35**, 623–650.

Jacobi CM, do Carmo FF, Vincent RC, Stehmann JR (2007) Plant communities on ironstone outcrops: a diverse and endangered Brazilian ecosystem. *Biodiversity and Conservation* **16,** 2185–2200.

Johnson SL (1998) Geology and hydrology. In *An Inventory and Condition Survey of the Sandstone – Yalgoo – Paynes Find Area, Western Australia.* (eds AL Payne, AME Van Vreeswyk, HJR Pringle, KA Leighton, P Hennig), pp 39–48. Technical Bulletin No. 90, Agriculture Western Australia, South Perth.

Keighery, GJ, Milewski AV, Hall NJ (1995) Vegetation and flora. In *The Biological Survey of the Eastern Goldfields of Western Australia: Part 12. Barlee–Menzies Study Area* (eds GJ Keighery, NL McKenzie, NJ Hall). *Records of the Western Australian Museum* **49**, 183–207.

McCune B, Mefford MJ (1999) *PC-ORD. Multivariate Analysis of Ecological Data, Version 4.* MjM Software Design, Glenden Beach, Oregon, USA.

McDonald RC, Isbell RF, Speight JG, Walker J, Hopkins MS (1998) *Australian Soil and Land Survey: Field Handbook,* 2nd ed. Australian Collaborative Land Evaluation Program, Canberra.

MacFarlane T (2007) A new species of *Neurachne* (Poaceae) from Western Australia. *Nuytsia* **17**, 215–222.

Markey AS, Dillon SJ (2008a) Flora and vegetation of the banded iron formations of the Yilgarn Craton: central Tallering Land System. *Conservation Science Western Australia* 7, 121–149.

Markey AS, Dillon SJ (2008b) Flora and vegetation of the banded iron formations of the Yilgarn Craton: the Weld Range. *Conservation Science Western Australia* 7, 153–178.

Markey AS, Dillon SJ (2009) Flora and Vegetation of the banded iron formations of the Yilgarn Craton: Herbert Lukin Ridge (Wiluna). *Conservation Science Western Australia* **7,** 391–412.

Markey AS, Dillon SJ (2010a) Flora and vegetation of the banded iron formations of the Yilgarn Craton: Gullewa. *Conservation Science Western Australia* 7, 531–556.

Markey AS, Dillon SJ (2011) Flora and vegetation of the banded iron formations of the Yilgarn Craton: the Johnston Range, Menzies. *Conservation Science Western Australia* **8**, 113–136.

Maslin BR (2007) *Acacia cockertoniana* (Leguminosae: Mimosoideae), a new species of Acacia from banded ironstone ranges of the south-west arid zone, Western Australia. *Nuytsia* **17**, 247–252.

Mattiske Consulting Pty Ltd (2001a) 'Review of the Flora on Portman Iron Ore Expansion Areas'. Unpublished report commission by Portman Iron Ore.

Mattiske Consulting Pty Ltd (2001b) 'Review of the Vegetation on Portman Iron Ore Expansion Areas'. Unpublished report commission by Portman Iron Ore.

Matheson RS, Miles KR (1947) *The Mining Groups of the Yilgarn Goldfield North of the Great Eastern Railway.* Western Australia Geological Survey, Bulletin 101, Perth.

Mehlich A (1984) Mehlich 3 soil test extractant: A modification of Mehlich 2. *Communications of Soil Science and Plant Analysis* **15**, 1409–1416.

Meissner RM, Caruso Y (2008a) Flora and vegetation of the banded iron formations of the Yilgarn Craton: Mt Gibson and surrounding area. *Conservation Science Western Australia* **7,** 105–120.

Meissner RM, Caruso Y (2008b) Flora and vegetation of the banded iron formations of the Yilgarn Craton: Koolanooka and Perenjori Hills. *Conservation Science Western Australia* 7, 73–88.

Meissner RM, Caruso Y (2008c) Flora and vegetation of the banded iron formations of the Yilgarn Craton: Jack Hills. *Conservation Science Western Australia* 7, 89–103.

Meissner RM, Bayliss B, Owen G (2010a) Flora and vegetation of the banded iron formations of the Yilgarn Craton: Mount Forrest – Mount Richardson Range. *Conservation Science Western Australia* **7,** 377–389.

Meissner RM, Bayliss B, Owen G (2010b) Flora and vegetation of the banded iron formations of the Yilgarn Craton: Cashmere Downs Range. *Conservation Science Western Australia* **7,** 349–361.

Milewski AV, Hall NJ (1995) Physical Environment. In *The Biological Survey of the Eastern Goldfields of Western Australia. Part 12: Barlee–Menzies Study Area* (eds GJ Keighery, NL McKenzie, NJ Hall). *Records of the Western Australian Museum Supplement*, **49**, 174–182.

Mott JJ (1972) Germination studies on some annual species from an arid region of Western Australia. *Journal of Ecology* **60,** 293–304.

Mott JJ (1973) Temporal and spatial distribution of an annual flora in an arid region of Western Australia. *Tropical Grasslands* 7, 89–97.

Newbey KR (1985) Physical Environment. In *The Biological Survey of the Eastern Goldfields of Western Australia. Part 3: Jackson–Kalgoorlie Study Area* (ed J Dell). *Records of the Western Australian Museum Supplement* **23**, 5–10.

Newbey KR, Hnatiuk RJ (1985) Vegetation and flora. In *The Biological Survey of the Eastern Goldfields of Western Australia. Part 3: Jackson–Kalgoorlie Study Area* (ed J Dell). *Records of the Western Australian Museum* Supplement **23**, 11–38.

Packowska G. Chapman AR (2000) *The Western*

Australian Flora: A Descriptive Catalogue. Wildflower Society of Western Australia, Western Australian Herbarium, CALM and Botanic Gardens and Parks Authority, Perth.

Pedley L (2001) *Acacia aneura* and relatives. In *Flora of Australia 11B, Mimosaceae, Acacia part 1.* (eds AE Orchard and AJG Wilson), pp. 309–328. Australian Biological Resources Study, Canberra, and CSIRO Publishing, Melbourne.

Rayment GE Higginson FR (1992) *Australian Laboratory Handbook of Soil and Water Chemical Methods.* Inkata Press, Melbourne.

Seber GAF (1984) *Multivariate Observations*. John Wiley and Sons, New York.

Shaw RJ (1999) Soil salinity – electrical conductivity and chloride. In *Soil Analysis: An Interpretation Manual* (eds KI Peverill, LA Sparrow, DJ Reuter), pp 129–145. CSIRO Publishing, Melbourne.

Slattery WJ, Conyer MK, Aitken RL (1999) Soil pH, aluminium, manganese and lime requirement. In *Soil Analysis: An Interpretation Manual* (eds KI Peverill, LA Sparrow, DJ Reuter), pp 103–128. CSIRO Publishing, Melbourne.

Smith MG (2010) 'Declared Rare and Priority Flora List for Western Australia, 16 September 2010'. Department of Environment and Conservation, Perth.

Sneath PHA Sokal RR (1973) *Numerical Taxonomy: The Principles and Practice of Numerical Classification*. Freeman, San Francisco.

Soil and Plant Council Inc. (1999) *Soil Analysis – Handbook of Reference Methods*. CRC Press, Boca Raton.

van Etten EJB, Fox JED (2004) Vegetation classification and ordination of the central Hamersley Ranges, Western Australia. *Journal of the Royal Society of Western Australia* **87,** 63–79.

Vincent RC, Meguro M (2008) Influence of soil properties on the abundance of plant species in ferruginous rocky soils vegetation, southeastern Brazil. *Revista Brasileira de Botânica*, **32**, 377–388.

Walker IW, Blight, DF (1983). *Barlee, Western Australia. Sheet SH/50-8.1:250,000 Geological Series Explanatory Notes.* Geological Survey of Western Australia, Perth.

Walton K Allen D (2004) Mehlich no. 3 soil test – the Western Australian experience. In *Supersoil 2004. Proceedings of the 3rd Australian and New Zealand Soils Conference* (ed. B Singh et al.), University of Sydney, 5–9 December 2004. The Regional Institute, Gosford, New South Wales http://www.regional.org.au/au/asssi/supersoil2004/s8/oral/1697_grayjg.htm) [accessed November 2011].

Western Australian Herbarium (1998–) *Florabase – The Western Australian Flora*. Department of Environment and Conservation, Available at http://florabase.dec.wa.gov.au/ [last accessed July 2007].

Zar J H (1984) *Biostatistical Analysis,* 2nd ed. Prentice-Hall International, New Jersey.

APPENDIX 1

Flora list for the northern Yerilgee Hills, compiled from collections within and adjacent to 51 quadrats. Nomenclature follows Packowska and Chapman (2000) and recent changes listed in the Census of Western Australia Flora (the Western Australian Herbarium (1998–). Family taxonomy follows the APG II system, which was current at time of compilation. Naturalised taxa are indicated by an asterisk. Reference collection numbers for informally (phrase) named taxa and for unnamed taxa are given in parentheses. Family taxonomy follows the APG II system (Angiosperm Phylogeny Group 2003), which was current at time of flora list compilation.

Adiantaceae
Cheilanthes adiantoides
Cheilanthes brownii
Cheilanthes lasiophylla
Cheilanthes sieberi subsp. *sieberi*

Amaranthaceae
Ptilotus aervoides
Ptilotus exaltatus
Ptilotus helipteroides
Ptilotus holosericeus
Ptilotus obovatus

Anthericaceae
Thysanotus manglesianus

Apiaceae
Trachymene ornata

Apocynaceae
Alyxia buxifolia

Asclepiadaceae
Marsdenia australis
Rhyncharrhena linearis

Asteraceae
Chrysocephalum puteale
Lawrencella rosea
Leiocarpa semicalva subsp. *semicalva*
Olearia humilis
Olearia muelleri
Olearia pimeleoides
Rhodanthe battii
Streptoglossa liatroides
Vittadinia humerata
Waitzia acuminata var. *acuminata*

Caesalpiniaceae
Senna artemisioides subsp. *filifolia*
Senna charlesiana

Casuarinaceae
Allocasuarina acutivalvis subsp. *acutivalvis*
Allocasuarina dielsiana
Allocasuarina eriochlamys subsp. *eriochlamys*
Casuarina pauper

Chenopodiaceae
Atriplex bunburyana
Atriplex nummularia subsp. *spathulata*
Atriplex vesicaria
Enchylaena lanata
Enchylaena tomentosa var. *tomentosa*
Eriochiton sclerolaenoides
Maireana georgei
Maireana thesioides
Maireana tomentosa subsp. *tomentosa*
Maireana trichoptera
Maireana triptera
Rhagodia drummondii
Rhagodia preissii subsp. *preissii*
Salsola tragus
Sclerolaena diacantha
Sclerolaena drummondii
Sclerolaena fusiformis
Sclerolaena gardneri
Sclerolaena obliquicuspis

Cupressaceae
Callitris columellaris

Dilleniaceae
Hibbertia exasperata

Epacridaceae
Leucopogon sp. Clyde Hill (MA Burgman 1207)

Euphorbiaceae
Calycopeplus paucifolius

Frankeniaceae
Frankenia desertorum

Goodeniaceae
Goodenia havilandii
Scaevola spinescens

Haloragaceae
Haloragis trigonocarpa

Lamiaceae
Physopsis viscida
Prostanthera althoferi subsp. *althoferi*
Prostanthera althoferi subsp. *althoferi x campbellii*
Prostanthera grylloana
Prostanthera magnifica
Spartothamnella sp. Helena & Aurora Range (PG Armstrong 155–109)
Spartothamnella teucriiflora
Westringia cephalantha
Wrixonia prostantheroides

Lobeliaceae
Isotoma petraea

Loganiaceae
Phyllangium sulcatum

Loranthaceae
Amyema gibberula var. *gibberula*
Amyema linophylla subsp. *linophylla*
Amyema miquelii
Lysiana casuarinae

Malvaceae
Abutilon cryptopetalum
Sida petrophila
Sida ectogama
Sida fibulifera
Sida sp. dark green fruits (S van Leeuwen 2260)
Sida sp. golden calyces glabrous (HN Foote 32)

Mimosaceae
Acacia andrewsii
Acacia aneura var. cf. *argentia*
Acacia aneura var. cf. *intermedia*
Acacia aneura var. cf. *microcarpa*

Appendix 1 (cont.)

Acacia aff. *sibirica* (A Markey & S Dillon 6092)
Acacia aff. *balsamea* (A Markey & S Dillon 5212)
Acacia assimilis subsp. *assimilis*
Acacia burkittii
Acacia colletioides
Acacia duriuscula
Acacia effusifolia
Acacia erinacea
Acacia jennerae
Acacia ligulata
Acacia murrayana
Acacia quadrimarginea
Acacia ramulosa var. *ramulosa*
Acacia sibina
Acacia sibirica
Acacia tetragonophylla

Myoporaceae
Eremophila alternifolia
Eremophila decipiens subsp. *decipiens*
Eremophila forrestii subsp. *forrestii*
Eremophila forrestii x *latrobei*
Eremophila georgei
Eremophila glabra subsp. *glabra*
Eremophila granitica
Eremophila latrobei subsp. *latrobei*
Eremophila longifolia
Eremophila oldfieldii subsp. *angustifolia*
Eremophila oppositifolia subsp. *angustifolia*
Eremophila pantonii
Eremophila pustulata
Eremophila serrulata
Eremophila sp. Mt Jackson (GJ Keighery 4372)
Eremophila subfloccosa subsp. *lanata*

Myrtaceae
Aluta aspera subsp. *aspera*
Baeckea elderiana
Eucalyptus concinna
Eucalyptus ebbanoensis subsp. *glauciramula*
Eucalyptus ewartiana
Eucalyptus griffithsii
Eucalyptus horistes
Eucalyptus leptopoda subsp. *subluta*
Eucalyptus longissima
Eucalyptus oleosa subsp. *oleosa*
Eucalyptus salmonophloia
Eucalyptus salubris
Eucalyptus stricklandii
Euryomyrtus maidenii
Melaleuca hamata
Melaleuca leiocarpa

Papilionaceae
Bossiaea walkeri
Mirbelia microphylla
Templetonia egena
Templetonia sulcata

Phormiaceae
Dianella revoluta var. *divaricata*

Pittosporaceae
Bursaria occidentalis
Pittosporum angustifolium

Poaceae
Amphipogon caricinus var. caricinus
Aristida contorta
Austrodanthonia caespitosa
Austrostipa elegantissima
Austrostipa blackii
Austrostipa platychaeta
Austrostipa scabra
Austrostipa scabra – atypical form
Austrostipa nitida
Enneapogon caerulescens
Eragrostis eriopoda
Eriachne pulchella subsp. *pulchella*
Monachather paradoxus
Paspalidium basicladum
* *Pentaschistis airoides*
Triodia cf. *scariosa*

Polygalaceae
Comesperma integerrimum

Proteaceae
Banksia arborea
Grevillea acuaria
Grevillea aff. *paradoxa*
Grevillea erectiloba
Grevillea nematophylla subsp. *nematophylla*
Grevillea obliquistigma subsp. *obliquistigma*
Grevillea oligomera
Grevillea paradoxa
Hakea recurva subsp. *recurva*

Rhamnaceae
Cryptandra connata
Stenanthemum stipulosum

Rubiaceae
Psydrax suaveolens

Rutaceae
Phebalium canaliculatum
Phebalium tuberculosum
Philotheca brucei subsp. *brucei*

Santalaceae
Exocarpos aphyllus
Santalum acuminatum
Santalum lanceolatum
Santalum spicatum

Sapindaceae
Dodonaea lobulata
Dodonaea microzyga var. *acrolobata*
Dodonaea rigida
Dodonaea viscosa subsp. *angustissima*

Solanaceae
Solanum ellipticum
Solanum ferocissimum
Solanum lasiophyllum
Solanum nummularium
Solanum plicatile

Sterculiaceae
Brachychiton gregorii

Violaceae
Hybanthus floribundus subsp. *curvifolius*

Zygophyllaceae
Zygophyllum eremaeum