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Flora and vegetation of the banded iron formations of the Yilgarn Craton: Herbert Lukin Ridge (Wiluna)

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ABSTRACT

A quadrat-based survey was undertaken on the flora and plant communities associated with the Herbert Lukin Ridge, which is a series of low hills of banded iron formation within the Joyners Find greenstone belt, in the Murchison region of Western Australia. The Herbert Lukin Ridge are is located on a pastoral lease, and mining and exploration tenements covering the entire extent. A total of 191 taxa (species, subspecies, varieties and forms) and 10 hybrids were recorded. Nine taxa of conservation significance were found, seven of these were new records for the area and three of these were notable (> 100 km) range extensions. Significant range extensions (> 200 km) are reported for four taxa not listed as being of conservation significance. One regional endemic was identified for the study area, and one putative new taxon was found. Two species are recommended for an upgrading of their conservation status. Six community types were resolved from classification analysis of floristic composition from 50 sites, covering much of the extent of this greenstone belt. Floristic communities are strongly associated with geomorphology and soil chemistry, with the greatest distinction being between upland and outwash communities. None of the described communities are represented on conservation estate. At present, mineral exploration and mining appear to pose the greatest potential threats to these particular communities.

INTRODUCTION

Greenstone belts are notable geological features in the Murchison region of Western Australia, as they form distinctive, isolated ranges in an otherwise subdued, low-lying landscape. These belts are composed variously of mafic, felsic rocks and banded iron formation (BIF), and have been distinguished as greenstone and ironstone ranges respectively. Together with the granitoids of the Yilgarn Craton, these greenstone belts are Archaean (2.7–3.0 Ga) in age, and have undergone deformation and faulting following their emplacement (Ferdinando 2002). These hills of ancient, exposed bedrock provide a unique substrate for plant communities in the semi-arid and arid zones of the Midwest of Western Australia.

Greenstone belts are highly prospective for deposits of iron-ore and precious and base metals. These areas have been heavily exploited over the past century and are currently undergoing extensive exploration for iron ore deposits. However, detailed descriptions of the flora and floristic communities of these vulnerable areas are lacking. To redress this deficiency, a series of approximately 20 vegetation surveys of ironstone ranges has commenced within the Northern Yilgarn region (Gibson *et al.* 2007; Markey & Dillon 2008a, 2008b; Meissner & Caruso 2008a, 2008b, 2008c). This current study is part of this survey effort, and aims to both describe floristic communities and document the flora of the Herbert Lukin Ridge (which is associated with the Joyners Find greenstone belt), and to correlate these communities with a number of environmental parameters.

Study Site

The Joyners Find greenstone belt outcrops as a series of low ridges and hills that are known as the Herbert Lukin Ridge. They are located *c.* 30 km south-west of the township of Wiluna, *c.* 940 km north-east of Perth (Figure 1). The study site is located within the shire of Wiluna, on the active pastoral lease of Lake Way Station and abutting the eastern margin of Ullala Station. There area is covered entirely by exploration tenements. The greenstone belt it is a north-south trending feature which is *c.* 40 km long, 6 km wide at its widest point and outcrops as three main segments from north to south (Ferdinando 2002). The study area was concerned with two of the three main segments of outcropping bedrock, which extends over a latitudinal range of 26.65–26.83 °S and longitudinal range of 119.93–119.97 °E.

Land Use History

Pastoral and mining activities have been the main economic industries within the Wiluna shire over the past century. Pastoralism was initiated in the general region in the 1890's, although gold mining was the main impetus

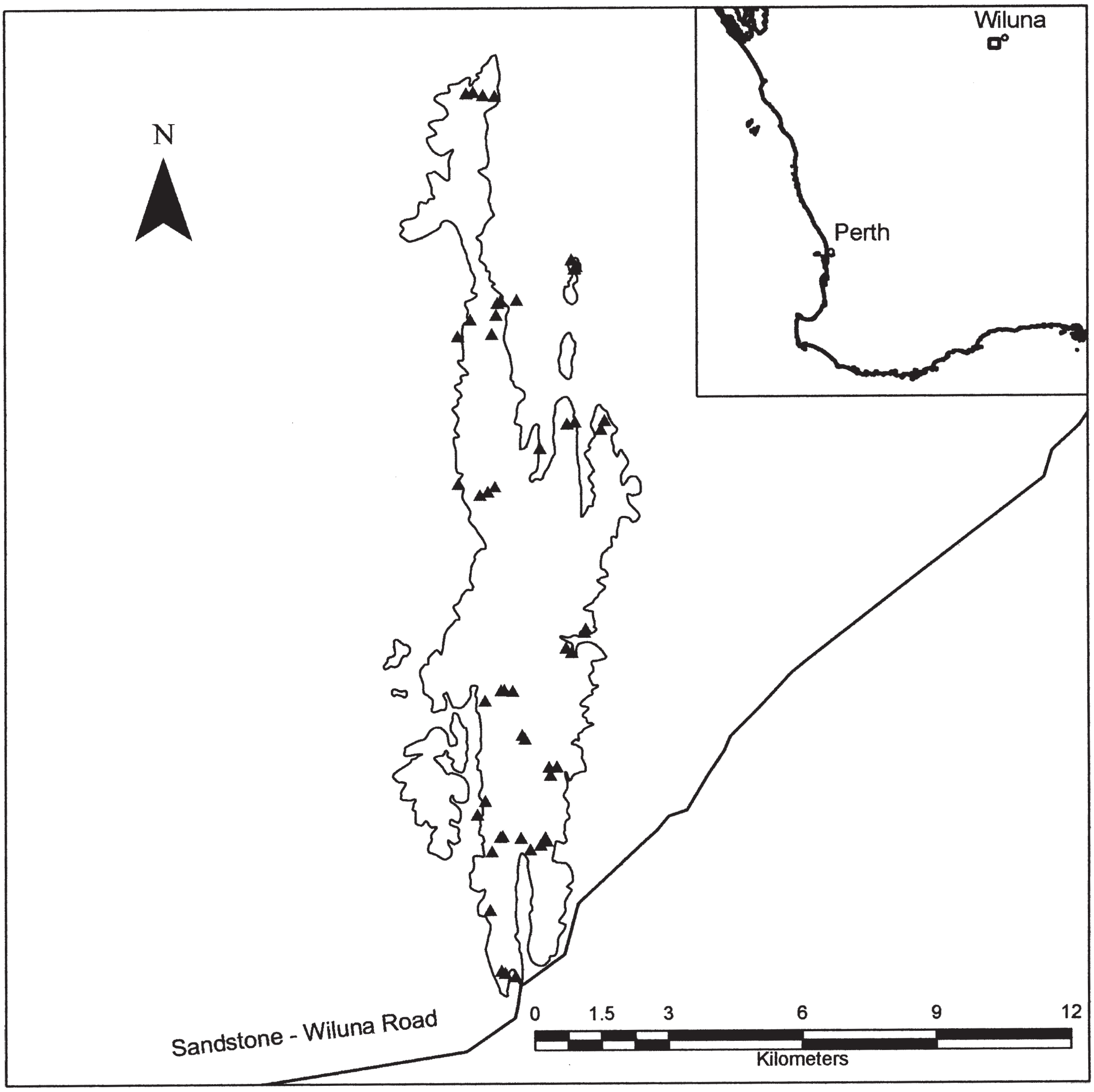

Figure 1. Location of the Herbert Lukin Ridge and associated reference landmarks. The distribution of the 50 permanent floristic quadrats over the survey area are marked by triangles (▲). The main outcropping ridges of the Joyner Find greenstone belt within the survey area are outlined.

for the establishment of the Wiluna township in 1892 (Faithfull 1994, Wilcox 1963). The Canning Stock route opened at Wiluna in 1906, and thereafter, cattle and sheep stations continued to develop in the Wiluna district (Wilcox 1963). After a century, pastoral leases are still active in the Wiluna area, including on Ullala and Lake Way stations

The Herbert Lukin Ridge is located in the Wiluna district of the East Murchison Goldfield (Elias *et al.* 1982). Gold discoveries were first made in the Meekatharra and Wiluna districts in the 1890's, and the greatest period of mining activity in the Wiluna region occured between 1931 and 1946 (Sofoulis & Mabbutt 1963). Two gold mines were established on the Herbert Lukin Ridge during this period; Joyner Find mine was established after gold was discovered there in 1935, and Channings Mine was established after gold discoveries in 1925. Several other gold mines and numerous workings were subsequently established in northern part of the belt (Ferdinando 2002; Wyche *et al.* 2004). As with much of the Meekatharra–Wiluna district (Sofoulis & Mabbutt 1963), operations had declined by the 1960s.

There has been a recent increase in mineral exploration and mining activities in Western Australia, and the Joyners Find greenstone belt has been recognised as highly prospective for iron ore and gold (Elias *et al.* 1982;

Ferdinando 2002). Secondary enrichment of BIF has lead to the development of haematite deposits (Elias *et al.* 1982), particularly in the north-east of the study area. Exploration activities have recently targeted these particular deposits, although the Herbert Lukin Ridge is covered entirely by exploration and mining tenements.

Climate

The study site falls within a climatic region described as arid (Gilligan 1994; Arnold 1963) or a desert climate with bimodal rainfall (Beard 1976, Beard 1990). The average annual precipitation ranges from 175 to 225 mm for the Wiluna subregion (Beard 1976), and 259 mm for Wiluna township (Australian Bureau of Meteorology 1908–). This is greatly exceeded by annual evaporation, which approaches 3800 mm (Gilligan 1994). Summer rainfall is sporadic and results from the south-eastern incursion of the remnants of tropical cyclones into the interior regions (Arnold 1963; Beard 1976; Gilligan 1994). Relative to summer rainfall, winter rainfall is more regular (albeit still unreliable), and arrives with south-westerly fronts during the autumn–winter months. The highest rainfall falls in March, while the driest months occur during spring (September–November).

The Wiluna region experiences cool winters and hot summers, the winter minima being markedly cooler than the more western areas (Arnold 1963). For Wiluna township, the average winter (June–August) maximum and minimum temperature are 20.2 °C and 6.2 °C, respectively. Average daily minima fall below 10 °C between May and September (Australian Bureau of Meteorology 1908–). Average daily maxima over 30 °C occur between October and March, and the average summer (December–February) daily maximum is 37.0 °C (Australian Bureau of Meteorology 1908–).

Geology

The geology of the study region has been described and mapped on the Merewether 1:100 000 geological sheet (SG 50-12, 2844) (Ferdinando & Tetlaw 2000). The Joyners Find greenstone belt (*cf.* Elias *et al.* 1982) is located within in the Southern Cross Domain of the Eastern Goldfields Superterrane of the Yilgarn Craton (Cassidy *et al.* 2006; Ferdinando 2002). It consists of a north-south trending syncline of Archaean metamorphosed ultramafic and mafic bedrock which is interbedded with metamorphosed banded iron formation (BIF) and associated metasediments. Along with low hills associated with the Yerrinda group of Proterozoic rocks over 10 km north of the study area, these outcroppings of Archaean bedrock are the main elevated landforms in the Wiluna area, which is otherwise dominated by gently undulating lowlands covered in Cainozoic sediments (Elias *et al.* 1982; Ferdinando 2002; Mabbutt *et al.* 1963).

The Herbert Lukin Ridge consists of five elongate, linear, north-south trending strike ridges of BIF, which are flanked by metamorphosed ultramafic, mafic and sedimentary rocks. This study focuses on three main ridges which outcrop for a distance of *c.* 21 km north-south, and are 1–2.5 km wide between the outermost ridges (Figure 1). These BIF ridges are subparallel, and diverge at the northern end of the belt (Elias *et al.* 1982; Ferdinando 2002). The altitude ranges from 550 to 630 m above sea level. The three most prominent ridges are 15–30 m high and up to 0.8–1 km wide, while minor outcroppings of ridges of BIF and chert are narrow (5 m wide) and less than 5 m in height (Ferdinando 2002; this study). The main ridgetops are flat-topped, and skelatal – shallow soils cover these flat areas between outcrops. Bedrock dips from moderate, west oriented angles to near vertical, and steep escarpments occur on both western and eastern slopes.

Soils of greenstone ranges are described as shallow or skeletal (< 50 cm), acidic (< pH 5.1) stony red earths with a clay loam texture (Litchfield 1963; van Vreeswyk 1994). As with most soils in this region, these are relatively infertile and low in phosphorus (Litchfield 1963). Deposits of colluvium and pavements of ferruginous gravels are features of the lower slopes (Litchfield 1963).

Vegetation

The Herbert Lukin Ridge is located in the Wiluna subregion of the Austin Botanical District, within the Eremaean Province (Beard 1976, 1990). This district has been adopted to form the Murchison IBRA region (Environment Australia 2000; Thackway & Creswell 1995) and, as such, is a region dominated by mulga (*Acacia aneura*) tall shrublands over an understory of *Eremophila* (Beard 1976, 1990; Speck 1963). To date, there have been no detailed surveys which specifically address the vegetation communities of the Herbert Lukin Ridge. Two broad-scale vegetation surveys have addressed the wider region in which the survey area occurs. Beard (1976) covered the region as part of a larger survey of the Murchison region, mapped on a scale of 1:1 000 000 and using physiognomic classification of vegetation formations. On this scale, the Herbert Lukin Ridge was mapped uniformly as *Acacia aneura* / A*cacia quadrimarginea* shrubland, and was not differentiated from other ranges in the area.

In their survey of rangelands in the Wiluna–Meekatharra region, Mabbutt *et al.* (1963) described and mapped land systems for the area, a land system being "an area or group of areas throughout which there is a recurring pattern of topography, soils and vegetation". Two main landsystems are associated with the Herbert Lukin Ridge: the Gabanintha land system covers much of the survey area while the Fisher land system occurs on low ridges of BIF and weathered schist on the margins. Both land systems are associated with greenstone ranges throughout the Wiluna-Meekatharra regional survey area. Speck (1963) described seven vegetation communities for the Gabanintha Land System (six of which are restricted to shallow, stony soils on crests and slopes); and four communities for the Fisher land system (three of which are restricted to shallow, stony soils on crests and slopes). These communities are not exclusive to any one land system but are spread among several other land systems within the Wiluna–Meekatharra area.

Recent surveys (Department of Environment and Conservation 2007; Markey & Dillon 2008a, 2008b; Meissner and Caruso 2008a, 2008b, 2008c) have found range-specific differences in vegetation communities that occur at a finer scale than described by Mabbutt *et al.* (1963) and Speck (1963). Meta-analysis of floristic data from several ranges within the Northern Yilgarn have identified range-specific communities, and a marked turnover of vegetation communities among ranges (N. Gibson, unpublished data). To date, there are no published descriptions of vegetation communities and the flora which specifically pertain to the Herbert Lukin Ridge.

METHODS

Fifty 20 x 20 m permanent quadrats were established within the survey area over a two week period in August, 2006 (Figure 1). Quadrats were established along a topographical sequence that spanned from ridge crests to the outwash plains. These quadrats were placed strategically within these landform elements, and repeated over the north-south extent of the survey area. This stratified sampling is an efficient method to capture floristic variation (Austin & Heyliger 1989; Gillison & Brewer 1985), and been used to survey other greenstone and BIF ranges on the Yilgarn Craton (e.g. Gibson 2004a, 2004b; Markey & Dillon 2008a, 2008b; Meissner & Caruoso 2008a, 2008b, 2008c). Quadrats were established in relatively intact vegetation, and both recently burnt (< 5 years) and heavily cleared areas (minesites, encampments, road clearings and tailings dumps) were avoided. This was to ensure that communities sampled were representative of the general vegetation comunities and were not influenced by severe disturbance regimes. Consequently, quadrats were not established on the southmost extent of the range (south of the Wiluna–Sandstone road) as this area had been recently burnt and access was limited (Figure 1).

Quadrats were permanently marked at each corner with four steel fence droppers and their position recorded by GPS. The presence and cover of all vascular plant species (spermatophytes and pteridiophytes) were recorded in each quadrat. Material was collected for identification at the Western Australian Herbarium, where representative specimens of all taxa have been lodged The geographical distributions and conservation status of taxa were obtained from online records (Western Australian Herbarium 1998–). Both vegetation structure and measures or visual estimates of environmental parameters (topographical position, aspect, slope, % litter, % bare ground, % rock cover class of both surface fragments and exposed bedrock) were made according to the standard definitions outlined in McDonald *et al.* (1998). Percentage surface rock fragment cover class (Rock Frag), maximum rock fragment size (MxR), runoff, soil depth, topographic position (Tp), exposed bedrock outcrop cover (% rock) were all coded on a semi-quantitative scale (*fide* McDonald *et al.* 1998, Table 2). Aspect was converted to radians and then transformed by sine and cosine functions in order to obtain a linear value for east-west and north-south respectively.

For each quadrat a bulked topsoil sample (10 cm) was collected regularly over the quadrat. Soil texture was estimated from bolus manipulation (McDonald *et al.* 1998). Soils were sieved (2 mm) prior to chemical analysis, and soil element, organic carbon and nitrogen contents were determined at the Chemistry Centre of Western Australia. Inductively coupled plasma atomic emission spectrometry, was used for the simultaneous determination of a suite of 16 elements (Al, B, Ca, Cd, Co, Cu, Fe , K, Mg, Mn, Mo, Na, Ni, P, S and Zn) (Mehlich 1984; Walton & Allen 2004). Soil organic carbon was determined using Metson's modification of the Walkley and Black wet oxidation method (method 6A1, Rayment & Higginson 1992). Total soil nitrogen was determined colorimetrically following a kjeldahl digest (method S10) and modified Berthelot indophenol reaction (Rayment & Higginson 1992). Soil pH was determined in 0.01 M CacCl2 in a soil:solution ratio of 1:5 (method S3, Rayment & Higginson 1992), and electrical conductivity (EC) was measured in a 1:5 solution of soil extract:deionised water at 25 °C (method S2, Rayment & Higginson 1992). The effective Cation Exchange Capacity (eCEC) was estimated from the sum total of individual charge equivalents per kilogram of Na, Ca, K and Mg, each of which had been converted from their respective concentrations that which had been determined by ICP AES from atomic emission spectrometry (Rayment & Higginson 1992; Soil and Plant Council 1999).

Classification and ordination analyses were conducted on a data matrix of shared perennial taxa from fifty quadrats, with both the singleton (species recorded from only one quadrat) and annual taxa (desert annuals and short lived perennials, *cf* Mott 1972, 1973) having been omitted from the data matrix prior to analysis. Singleton taxa were omitted since they give no information on between-site similarity (*fide* Legendre & Legendre 1983. The omission of annuals and singletons from analyses allows for comparison with other datasets collected in previous years, and is consistent with analysis methods from previous surveys on Western Australian ironstone and greenstone ranges (Gibson 2004a, 2004b; Markey & Dillon 2008a, 2008b; Meissner & Caruso 2008a, 2008b, 2008c). Following the exclusion of sets of taxa, resemblance matrixes (Bray-Curtis measure of dissimilarity) of these datasets were compared using the '2 Stage' algorithm in Primer using the Spearman rank correlation method (Clark & Gorley 2006). This was done to determine the degree of correlation between datasets following the exclusion of annuals and / or singleton taxa. Preliminary classification and ordination analyses found a high correlation and that singletons contained little additional information.

Pattern analysis was conducted using PATN (V3.03) (Belbin 1989). The Bray-Curtis coefficient was used to generate an association matrix for both the classification and ordination analyses. The flexible 'Unweighted Pair Group Method with Arithmetic mean' (UPGMA) clustering method (β = –0.1) was used to generate a species and site classification (Belbin 1992; Sneath & Sokal 1973). A two-way table or species by site occurrences was generated, ordered by both the site and species classifications. Significant indicator species at the six group level were identified by indicator species analysis (Dufrêne & Legendre 1997), using the INDVAL routine in PC-Ord (McCune & Mefford 1999), where measures are calculated from estimates of species fidelity and constancy to each community type. A Monte Carlo permutation test (10 000 simulations) was used to test for the significance of INDVAL measures.

Semi-strong hybrid (SSH) nonmetric multidimensional scaling (MDS) was used to produce a three dimensional ordination of the sites from the floristic data (Belbin 1991). The parameters of the ordination were set at 1000 random starts and 50 iterations of the procedure. Principal Component Correlation (PCC) was used to correlate site environmental parameters with the site ordination coordinates, and 1000 iterations a Monte-Carlo procedure (MCAO) was employed in PATN as a permutation test to evaluate the significance of these correlations (Belbin 1989; Faith & Norris 1989). The Kruskal-Wallis nonparametric analysis of variance was used to determine differences in environmental parameters among floristic community types, followed by nonparametric multiple comparisons (Dunn's posthoc) when required (Zar 1984).

RESULTS

Flora

A total of 191 taxa (species, subspecies and varieties) and 10 putative hybrids were recorded from the Herbert Lukin Ridge, based on collections within or adjacent to the fifty quadrats (Appendix 1). The predominant growth form of the flora consists shrubs / tall shrubs (55 %), followed by annual herbs (20.8 %), annual grasses (6 %), perennial grasses (5.9%), perennial herbs (4%), geophytes (2.5 %), parasites (2 %), climbers (1.5 %), mallee / trees (1.5 %) and annual sedges / rushes (1 %). This survey was recorded in a spring which followed good summer but poor winter rainfall. Consequently, the annual flora was dominated by annual grasses (e.g. *Aristida contorta*, *Eriachne pulchella* and *Eragrostis* spp.) and lacked an abundance and diversity of annual herbs (particularly in the Asteraceae). It is likely that numbers of annual and geophyte taxa are greatly underestimated, and poor flowering in perennials may have also potentially reduced the number of identified perennials.

Of these 191 taxa, only two were introduced species, although *Portulaca oleracea* may be considered indigenous in the Eremaean province (Hussey *et al.* 1997). Taxa were from 36 families, of which the most speciose were the Asteraceae (14 native taxa and 1 introduced taxon), Chenopodiaceae (23 taxa and 1 hybrid), Poaceae (23 native), Mimosaceae (*Acacia*) (15 taxa and 1 hybrid), Myoporaceae (*Eremophila*) (12 taxa), Amaranthaceae (11 taxa), Myrtaceae (8 taxa), Goodeniaceae (6 taxa), Malvaceae (11 taxa). In addition to the above mentioned genera (*Acacia*, *Eremophila*), the most numerous genera were *Ptilotus* (10 taxa), *Maireana* (9 taxa and 1 hybrid), *Senna* (7 taxa and 6 hybrids), *Sida* (6 taxa) and *Sclerolaena* (6 taxa) (Appendix 1). These families and genera are widespread in the Murchison region (Beard 1976, 1990) and have been reported for other ironstone surveys in the northern Murchison (Markey & Dillon 2008a; Meissner & Caruso 2008a).

Priority taxa

Nine taxa of conservation significance were collected in this survey, with seven of these being new records for the Herbert Lukin Ridge (Table 1). All taxa were associated with some part of the topographic profile of the ridges of banded iron formation. The ranges of three priority taxa (*Beyeria lapidicola*, *Prostanthera ferricola*, *Baeckea* sp. Melita Station (H. Pringle 2738) were extended by over 100 km.

- *Eremophila congesta* is the only regional endemic species for Herbert Lukin Ridge (a regional endemic being defined as being restricted to an area within a 100 km radius), and is known from four general locations in the Wiluna region. This Priority 1 species is found on rocky hills and outcrops. Prior to this survey, one collection had been made from the Herbert Lukin Ridge, and this species was observed to be uncommon within the survey area.
- *Ptilotus astrolasius* var. *luteolus* is a Priority 1 taxon known from seven other locations. This population is a new record for the Wiluna area, and is at the eastern edge of its known distribution. This taxon was located adjacent to an ephemeral creekline in an area that had been previously disturbed by grading.
- *Beyeria lapidicola* (formerly known as *Beyeria* sp. Murchison (B. Jeanes s.n. 7/7/2005) is listed as a Priority 2 species that has been recently formerly described by Halford and Henderson (2008). This taxon is currently known from three greatly disjunct locations (Western Australian Herbarium 1998–). Two other populations are on Bulga Downs Station and the Weld Range, 220km southeast and west of the Herbert Lukin Ridge, respectively. This collection extends the range of this taxon into the north east of the Murchison bioregion. All three populations occur on crests, hill slopes and steep escarpments of outcropping banded iron formation.
- *Olearia mucronata* is a Priority 3 species, which is known from six collections at The Western Australian Herbarium. This was a new record for the Herbert Lukin Ridge, which is *c.* 100 km north of the nearest known population. The five other known occurrences of this species are scattered through the Pilbara and Murchison IBRA bioregions. Specimens from this population were noted for their lack of ligulate ray florets, although these are present in other collections and are a included in the original species description

(Lander 1990). This species typically grows in shallow drainage depressions, and the Herbert Lukin Ridge population was located in a shallow gulley adjacent to a significant ridge of haematite.

- *Homalocalyx echinulatus* is a Priority 3 taxon previously known from 14 collections, including the Herbert Lukin Ridge. The distribution of this species is centred in the northern Murchison IBRA region. At least one new population was located during this survey, but this would be only 5 km south of the previously known locations for this species.
- *Baeckea* sp. Melita Station (H. Pringle 2738) is a Priority 4 taxon with a narrow distribution within the Murchison bioregion. This is a new record for this species at the Herbert Lukin Ridge, which is at the north-west limit of the species' distribution.
- *Calytrix uncinata* is listed as a Priority 3 species which is distributed through the Yalgoo and Murchison regions. The Herbert Lukin Ridge population is a new record for the survey area, and is within the northern limit of the range of this species.
- A new population of *Prostanthera ferricola* was located at Herbert Lukin Ridge, where it was only located on the main western ridge, where it growing on a rocky upper slope and crest of exposed massive BIF. This taxon has only been relatively recently described (Conn & Shepherd 2007), and is listed as a Priority 3 species (Atkins 20097). It is known from only six other locations, all within the northern Murchison region. This population is a range extension *c.* 130 km south-east from the nearest known population.
- *Acacia balsamea* is listed as a Priority 4 taxon, and is a new record for the Herbert Lukin Ridge. This new population is situated on the south-west limit of the species' range and is *c.* 180 km north of the nearest known population.

Putative new taxa

A morphologically distinct entity of *Sida* (*Sida* sp. (PERTH 07528140)) was collected from the Herbert Lukin Ridge which appears to be unlike other species in the genus. However, a search of the collections at the Western Australian Herbarium found a match with two collections (D.J. Edinger 5375 and A.A. Mitchell 4149) from locations 132 and 183 km west of Herbert Lukin Ridge, respectively. On the Herbert Lukin Ridge, this species this entitiy was restricted to a small area of massive haematite on the easternmost ridge. It has apparently unisexual flowers, and a robust, densely-branched, shrubby growth form which resembles that of *Sida calyxhymeniana* and *Sida ectogama*. Therefore, this *Sida* sp. (PERTH 07528140) could be confused with the latter two taxa based on similarities in growth form and leaf morphology. It differs from *Sida calyxhymeniana* by having very small calyx lobes which do not inflate to encompass the flower, and differs from *Sida ectogama* in that its flowers have a distinct androecial tube.

Hybrids

There were several new putative hybrid combinations recorded for the survey area, most of which were among taxa of *Senna* (Appendix 1). This has been commonly reported for the genus (Randall & Barlow 1998, but see Holman & Playford 2000). A continuum of variation was observed among intergrades of *Senna glaucifolia*, *Senna* sp. Meekatharra (E. Bailey 1–26) and *Senna artemisioides* subsp. *helmsii*.

A new hybrid combination was recorded for *Prostanthera althoferi* subsp. *althoferi* x *wilkeana*. Hybridisation is common among a closely related set of species within section *Prostanthera* (*fide* Conn 1988), particularly among *Prostanthera althoferi* subsp *althoferi*, *Prostanthera campbellii* and *Prostanthera sericea* (Western Australian Herbarium 1998–; B. Rye, pers. comm.[1]). This new hybrid combination was distinguished by the intermediate leaf characters and the relatively thick, hirsute and grey inflated calyx lobes on the fruit. These fruits match those of *Prostanthera wilkeana*, and are unlike the glabrous, chartaceous lobes in *Prostanthera campbellii* and *Prostanthera althoferi* subsp. *althoferi* (Conn 1988).

Range extensions

Significant range extensions (> 200 km) were recorded for four species without priority conservation listing, as was verified from records at the Western Australian Herbarium.

A collection of *Oxalis perennans* was a range extension of *c.* 383 km north from the nearest previous known location. This is a tuberous perennial which may be more widespread than herbarium records would suggest, as it is likely that material is being misidentified as *Oxalis corniculata* (G. Keighery, pers. comm.). G. Keighery is currently reviewing *Oxalis* in Western Australia, and suggests that this species is widely distributed through the Eremaean.

The Herbert Lukin Ridge collection of *Sida* sp. verrucose glands (F.H. Mollemans 2423) is an outlying population some 400 km south from previously known collections, all of which are otherwise concentrated in the Pilbara. Given that the genus is currently under revision and that this entity has not been formally described, the current range of the species could be more widespread than current records suggest.

The collection of *Hibiscus solanifolius* (*sensu lato*) is a considerable range extension, some 225 km north-west of previous collections near Lake Barlee. Recent surveys have also located this entity on other ironstone ranges in the northern Yilgarn (Markey & Dillon, in review; Meissner *et al.* in review). Prior to these surveys, most collections of this species have been made in the Central Ranges IBRA region, and it is suspected that the disjunct western populations could be a different entity. L. Craven (Australian National Herbarium) is currently reviewing

1 Barbara Rye: Research Associate, Department of Environment and Conservation, Western Australian Herbarium, Kensington.

the genus and this may verify the existence of several entities with affinities to *Hibiscus solanifolius* (G. Keighery, pers. comm.).

Recent surveys of ironstone ranges are continuing to expand southwards the range of *Cheilanthes brownii,* an often misidentified rock fern. The Herbert Lukin Ridge collection is a range extension of *c.* 200 km east from previously known populations at the Western Australian Herbarium, and *c.* 100 km north of a newly found population at Booylgoo Range (Markey & Dillon in review). These two collections extend the south-eastern limit of this species' range.

Floristic Communities

Because of difficulty in differentiating between closely related taxa due to a lack of flowering or fruiting material, some taxa had to be amalgamated into species complexes for floristic analyses (e.g. *Enchylaena tomentosa* and *Enchylaena lanata*). Similarly, closely related taxa (subspecies and varieties) were amalgamated when they were more informative when combined at a higher taxonomic level. Intergrading hybrids (e.g: *Senna glaucifolia* x sp. Meekatharra (E. Bailey 1–26)) were amalgamated with their morphologically closest parental taxon, but hybrids that were recognisable as distinct entities were retained as discrete taxa. The mulga complex (*Acacia aneura* and allied species) is a highly variable group (Miller *et al.* 2002), and could only be resolved to morphotypes which broadly approximated the varieties described by Pedley (2001).

A total of 174 taxa from 50 quadrats was assembled in a site by species data matrix, of which 50 were annual taxa and 21 taxa were perennial singletons. Preliminary analyses found that singletons and annuals had little overall effect on community classification, and perennial singletons were both relatively infrequent (average 0.4 ± 0.1 taxa / plot) and their occurrence evenly distributed across sites. After the omission of these annual and singleton perennial taxa, the final dataset consisted of 103 taxa (59 % of total taxa) from 50 quadrats. '2-Stage' comparison (Clark & Gorley 2006) of resemblance matrices of all datasets with / without annuals and/or singletons found that matrices were still highly correlated (*c.* 96%–99%), and there was a 95.7 % correlation between the data matrix with all taxa (singletons and annuals) and the perennial dataset used in final analyses. For the 50 quadrats, the average total species richness per quadrat was 26.1 ± 9.4 taxa per quadrat (x ± s.d.), and ranged from 11 to 59 taxa per quadrat. For the final dataset, there was an average of 18.8 ± 5.6 (s.d) shared perennial taxa per quadrat (range 8–31 taxa per quadrat).

From the floristic classification analyses of 50 quadrats, floristic communities were resolved at two levels in the classification: the two group and six group level (Figure 2). At the two group level, Community types 1 and 2 are separated from Community types 3–6. The analysis simultaneously resolved the 103 species into eight Species Groups (Appendix 2). The sorted two-way table ordered by the site and species classification also illustrates this separation, where Community types 1 and 2 have a relatively low representation of taxa from Species groups C and F–G and high representation from Species group D (Appendix 2). This classification at the two group level distinguishes floristic communities which are associated with uplands from rocky hill slopes, crests and upland

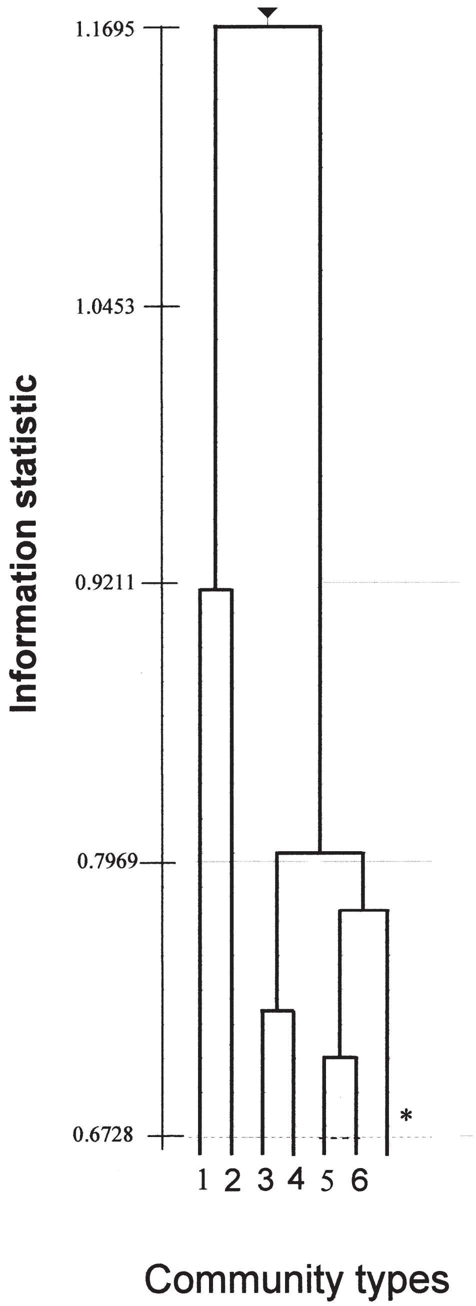

Figure 2. Summary dendrogram of floristic community types of the Herbert Lukin Ridge, resolved from classification analysis of a presence / absence data matrix of 103 perennial taxa from 50 quadrats. The dendrogram is resolved to the six group level. One quadrat (indicated by an asterisk) which was too dissimilar to any quadrats to fall into any of the floristic groups in the classification. Numbers of quadrats per community type are given under each community type number.

summit surfaces (Community types 1 and 2) from those on occurring on the lower slopes, shallow valleys, pediments and colluvial outwashes (Community types 3 to 6). Below this primary level of divergence, 49 quadrats were grouped into six main community types and one of these communities was further divided into distinctive subtypes (Figure 2). One quadrat was not assigned to any of these groups (Figure 2).

Community type 1 is found on crests and steeper upper slopes, and is a sparse – open tall shrubland of *Acacia aneura* var. cf. *macrocarpa*, *Grevillea berryana*, and (less commonly, *Acacia aneura* cf. var *argentea, Acacia quadrimarginea*) over mid storey shrub stratum of over *Eremophila latrobei* subsp. *latrobei*, *Prostanthera campbellii*, (occasionally *Dodonaea petiolaris* and *Baeckea* sp. Melita Station, *Eremophila punctata* and *Eremophila flabellata*), over common subshrubs *Ptilotus obovatus*, *Sida* sp. Golden calyces glabrous fruit (H.N. Foote 32), *Sida* sp. Excedentifolia (J.L. Egan 1925), the perennial herb *Ptilotus schwartzii,* the geophyte *Cheilanthes brownii*, and the perennial grasses *Eriachne helmsii*, *Eriachne mucronata* and *Monachather paradoxus.* Several of these taxa are significant indicator species (Table 2). Species groups D and part of Species group C are well represented in this community type, otherwise there are few or no species from the other Species groups. Poor representation of group E taxa, and greater representation in some group C taxa set it apart from Community type 2, the floristic group to which it is most closely allied (Appendix 2). Consequently, it is moderately species poor (17.8 ± 0.9 shared perennial taxa / quadrat).

Community type 2 is allied floristically to Community type 1. Sites belonging to this community type were located on flat summit surfaces on ridge tops, and on the undulating pediments and valley floors off the main ridges. Structurally, Community type 2 encompasses mosaics of *Acacia* over *Triodia* grasslands or low myrtaceous-*Eremophila* shrublands, with isolated mallees of *Eucalyptus kingsmillii* subsp. *kingsmillii.* This community is described as sparse – open shrublands of emergent tall shrubs of *Acacia aneura* var. cf. *microcarpa, Acacia aneura* var. cf. *aneura, Grevillea berryana* and *Acacia rhodophloia* (less frequently *Acacia quadrimarginea*), over mid shrub stratum of *Eremophila punctata*, *Eremophila latrobei* subsp. *latrobei*, *Eremophila jucunda* subsp. *jucunda* (less commonly, *Eremophila forrestii)*, subshrubs *Ptilotus obovatus*, *Sida* sp. Golden calyces glabrous fruit (H.N. Foote 32), (less commonly *Ptilotus schwartzii*) and *Monachather paradoxus.* Hummocks – open grasslands of *Triodia melvillei* are a distinctive layer in this community type. Where *Triodia melvillei* is absent or of low abundance, low shrubs such as *Homalocalyx echinulatus, Eremophila forrestii* and *Eremophila jucunda* are far more conspicuous, as are other perennial grasses, such as *Thyridolepis multiculmis.*

Community type 2 is distinguished by relatively both poor representation within Species group D and Group C, and differs from Community type 1 with and different subset of taxa from within these groups (Appendix 2). Community type 2 is very species poor (13.5 ± 0.9 shared perennial taxa quadrat). The significant indicator species are *Eremophila jucunda* subsp. *jucunda, Eremophila punctata* and *Triodia melvillei* (Table 2). Community type 2 shares similar suite of common taxa with Community type 1. However, the lower stratum of the former community type is dominated by *Triodia melvillei,* and there is a corresponding near-absence of *Ptilotus obovatus*, *Sida* sp. Excedentifolia (J.L. Egan 1925*)* and various perennial grasses.

Community type 3 is a relatively species rich community (23.7 ± 2.2 shared perennial taxa / quadrat) usually found on pediments, lower slopes and low outcrops of weathered BIF and other metasediments, quartz and ultramafic lithologies, usually obscured by colluvium. This community consisted of *Acacia aneura* (notably *Acacia aneura* var. cf. *tenuis*), and, less frequently, *Acacia balsamea* and *Acacia cuthbertsonii* subsp. *cuthbertsonii* tall open shrublands over shrubs such as *Scaevola spinescens, Senna artemisioides* subsp. *helmsii*, *Eremophila flabellata*, over sparse low shrubs such as *Maireana convexa*, *Maireana georgei*, *Ptilotus obovatus* and, less frequently, *Eremophila jucunda* subsp. *jucunda* and *Sida ectogama.* Significant indicator species are *Acacia balsamea, Acacia cuthbertsonii* subsp. *cuthbertsonii, Dodonaea microzyga* var. *acrolobata* and *Scaevola spinescens* (Table 2). Common ground level taxa with relatively high indicator vales for Community type 3 are *Enneapogon caerulescens, Ptilotus exaltatus* and *Sclerolaena eriacantha* (Table 2). This community type is distinguished by representation from Species group G and also has frequent representation from Species group *C.* There is low representation in species groups A, B, D, E and H. Two sites in this community type shared Species group F with the outlying site, which suggests some floristic similarities.

Community type 4 was only sampled twice, and represents a particular outwash plains community encountered only in the north of the study area. It is relatively species rich (28.0 ± 3.0 shared perennial taxa / quadrat). Community type 4 is characterised by representation from species group H, and has partial representation from Species groups G and C. Floristically, it is most similar to Community type 3 (Figure 2). and consists of tall, open shrubland of *Acacia aneura* and *Acacia tetragonophylla*, occasionally with isolated, emergent trees of *Acacia pruinocarpa*, over a mosaic of shrubland and chenopods, The shrubland is dominated by *Sida ectogama*, *Rhagodia eremaea*, *Eremophila flabellata*, *Eremophila galeata* and *Ptilotus obovatus*, which then grades into more open low chenopod shrubland and succulent geophytes, which is dominated by *Tecticornia*, *Maireana* and *Sclerolaeana.* There is a large number of significant indicator species owing to the small number of quadrats in this community type (Table 2). The majority of these indicator species are chenopods (*Atriplex codonocarpa, Rhagodia eremaea, Maireana convexa, Tecticornia* sp. Yoothapina Station (A.A. Mitchell 883), *Sclerolaena* spp. and *Sclerostegia disarticulata*) and perennial herbaceous geophytes (*Calandrinia schistorhiza, Ptilotus exaltatus* and *Ptilotus roei)*. There are also notable indicator species which are shrubs (*Eremophila galeata* and *Hakea leucoptera* subsp. *sericipes*).

Community type 5 was found on lower slopes, pediments and valley flats, and had relatively high species richness (22.6 ± 1.7 shared perennials / quadrat) and a relatively high number of annuals (Table 3). This community type is a tall shrubland or open tall shrubland of *Acacia aneura* (often *Acacia aneura* var. cf. *microcarpa* and occasionally *Acacia aneura* var. cf. *tenuis*), often with a canopy of *Acacia pruinocarpa*, over a typical mid-shrub stratum of *Eremophila forrestii*, *Eremophila latrobei* subsp *latrobei*, *Senna* spp., *Eremophila flabellata, Rhagodia eremaea, Sida ectogama* and *Ptilotus obovatus*, usually over *Ptilotus schwartzii*, *Sida* sp. Excedentifolia (J.L. Egan 1925) and the perennial grass, *Monachather paradoxa*. Significant indicator species are *Eremophila forrestii* subsp. *forrestii, Hibiscus solanifolius* and *Maireana planifolia* (Table 2). There is frequent representation from Species groups A and C and limited representation in Species group G, D and E (Appendix 2). Low representation in groups G and H distinguishes this community from Community types 3 and 4.

Community type 6 was represented by three midslope quadrats associated with a south-eastern ridge of massive, haematite-enriched outcrops, often with an underlying influence of mafic and ultramafic lithologies, and dipping into a mesic, shallow valley. This community is not markedly speciose (19.0 ± 1.7 shared perennial taxa / quadrat). This is a relatively loose assemblage of three quadrats. Community type 6 has poor representation in Species groups E–H, and most taxa in this community type fall in species groups C and D. The presence of Group D is shared with Community types 1 and 2, while Species group C allies this community to Community types 3, 4 and 5. This community type may be transitional between Community type 1 and type 5.

These three sites consisted of *Acacia aneura* cf. var *microcarpa* and occasional *Acacia pruinocarpa* over *Eremophila latrobei* subsp. *latrobei*, *Dodonaea petiolaris*, *Eremophila flabellata*, *Sida* sp. (PERTH 07528140) and, less frequently, *Eremophila jucunda* subsp. *jacunda*. Significant indicator species are *Dodonaea petiolaris, Harnieria kempeana* subsp. *muelleri*, *Ptilotus rotundifolius, Ptilotus schwartzii* and *Sida* sp. (PERTH 07528140).

SSH MDS Analysis

Semi strong hybrid multidimensional scaling (SSH MDS) was used to produce an ordination which represents floristic relationships among sites. The three dimensional solution had a stress value of 0.18, which was marginally adequate (Seber 1984). The ordination shows that sites are segregated into clusters of similar floristic composition, which correspond to their community type. The greatest differences in floristic composition is between Community types 1 and 2, and types 3, 4, 5 and 6. This supports the highest division in the classification which separates upland communities from those on the lower slope and outwashes. The clustering of sites into groups is moderate, as there is some degree of dispersion within groups and spatial overlap among groups. Community type 6 is not a close cluster, perhaps the least uniform group in the classification with affinities to other groups (2 and 5). The one quadrat which did not fall into any community types from the classification analysis was not an outlier in the ordination, but was close to sites from Community types 4 and 5.

Environmental Correlates

The soils for the survey area were found to be generally shallow (2–50 cm), acidic (average pH 4.3 ± 0.1) red-brown clay loams or silty clay loams. All sites were generally bare (80.7 ± 2.1 %), litter cover was low (14.6 ± 1.9%) and surface rock cover was high (> 50% cover). Four elements (B, Cd, Mo and Na) were undetectable in over half of the soil samples, and significant correlations were found among the remaining soil elements (Table 4). Similarly, a set of site physical parameters (topographical position, slope, rock fragment size outcrop cover and soil depth) were correlated. Rock outcrop cover, maximum surface rock fragment size, runoff and slope were positively correlated with organic C, N and Fe, and negatively correlated with soil pH. A suite of trace elements were negatively correlated with topography, Fe, N and organic C.

Two Community types (4 and 6) had too few sites to be included in univariate analyses. There were significant differences among the remaining six floristic community types in group means for most soil parameters and site geomorphological parameters (Kruskal-Wallis nonparametric ANOVA and Dunns post hoc pairwise comparisons, Table 3). Altitude, latitude and longitude were all nonsignificant parameters (Table 3) among the community types, because the survey area is relatively small (*c.* 20 km^2) and low in elevation (the maximum ridge height was 30 m), resulting in little variation in these parameters.

Soil concentrations of trace elements tended to be relatively high in the lower slope community types. Community types 5 and 3 were found to have the highest concentrations of Ca, Co, K, Cu, Mg, Mn, Ni, and the highest eCEC (Table 4). Conversely, levels of Fe, N and organic C were significantly lower in these communities, and the soils were less acidic. While sharing similar soil attributes, these community types occupied sites that were significantly different in terms of geomorphology. Community type 5 was located at the lowest ends of the topographic gradient, sites had significantly low slopes (2–3°), were confined to lower slopes and outwashes, where surface rock fragments were small (> 2cm), outcropping bedrock was absent, runoff was minimal and soils were among the deepest. Relative to type 5, Community type 3 occurred in higher topographic positions (middle slopes), on marginally steeper more inclined slopes with larger surface rock fragments (2–6 cm), some exposed bedrock (< 2% cover) and shallow soils. This community type was typically associated with colluvium overlying mafic, ultramafic, weathered BIF, laterite or other metasedimentary lithologies.

The soils from Community types 1 and 2 had significantly relatively low concentrations of trace elements, but were the most acidic and richer in organic C (Table 3). Levels of Fe and N were the highest in Community type 1 soils, but significantly lower in Community type 2. Values for Mg, Mn, Ni, P and Zn, and eCEC in Community type 2 soils were not only significantly lower than type 1, but were among the lowest of the groups tested. This suggests some leaching of these elements from the soils of type 2. Although both community types are located on the upper slopes and crests of the BIF ridges, they occupy different sites within these upland areas. Community type 1 is associated with the steepest slopes, with the largest surface rocks (> 60 cm), extensive rock outcrop cover (> 50%), high runoff and skeletal (< 5 cm) soils (Table 4). Rich loams were observed in these sites to accumulate in rock crevices that trapped organic material and moisture, which accounts for the high N and organic C levels. Community type 2 is located on the hill summits where the surface is gently inclined – flat and where shallow soils (> 5 cm) accumulate in over bedrock. Surface rock fragments are realively smaller, runoff is low and soils are relatively deeper than in Community type 1 (Table 4). There is some similarity between the three sites classified as Community type 6 and those for Community type 1. These sites were associated with steep, rocky slopes that were high in landscape and had acidic soils that had moderate values for organic C, N and trace minerals, and low values for soil P.

The soil values for Community type 4, especially in one site, were found to have exceptionally high values for soil EC, Mg, Mn, Co, S and eCEC. These sites occurred in characteristically flat areas with no runoff and deep, weakly acidic soils which are relatively enriched with minerals and salts (Table 4).

The findings of Principal Components Correlation analysis are essentially the same as from the previous univariate analyses (Figure 3). Aspect, latitude, longitude, rock fragment cover and leaf and bare ground cover were not significantly correlated with the site ordination. Three main environmental gradients are associated with the site ordination. One main soil chemical gradient of collinear trace elements (Ni, Co, Mg, eCEC, Cu, Mn, EC, pH) runs negative to an altitudinal gradient (topographical position and altitude) (Figure 3). These gradients are associated with the greatest separation between Community types 1, 2 and 6 (at the high altitude, low trace element, low pH and eCEC) from types 3, 4 and 5 (low altitude, high trace element, high pH and eCEC).

A third gradient consists of a set of broadly collinear vectors for rock outcrop cover and size fragment classes, slope, soil depth and runoff, and N, P, Fe and organic C (Figure 3). Community types 1 and 6 coincide with the high end of this gradient (high rock outcrop, large rock fragments, steeper slopes, skeletal soils, high N, org C and P), while community types 3, 4 and 5 align with the other extreme of low soil macronutients and deep soils on gently sloping terrain. Notably, the separation of Community 1 and 2 is also associated with this gradient, which corresponds to Community 2 being on flat terrain with relatively deeper soils, despite being located high in the landscape.

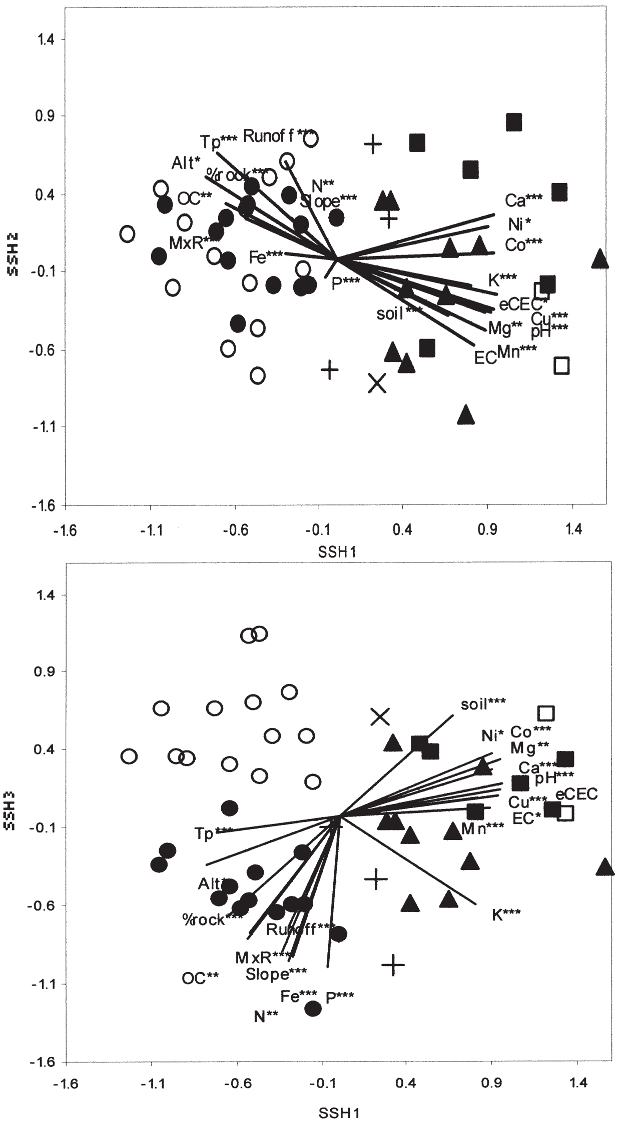

*Figure 3. 3D SSH MDS ordination of sites for the Herbert Lukin Ridge. Sites are coded by their respective floristic community types (1●, 2○, 3■, 4□, 5 ▲, 6 +, unplaced quadrat ×). Vectors of best fit linear correlations from Principle Components Correlation analysis are superimposed on the ordination. Only significant vectors (p < 0.05) are displayed, as determined from Monte Carlo permutation tests. *** p < 0.001, ** p < 0.01, 8* p < 0.05).*

DISCUSSION

Flora

Nine priority taxa were located by this survey, which significantly increased the total number of priority listed taxa known on the range (Western Australian Herbarium 1998–). One of these species is a regional endemic. These findings for the Herbert Lukin Ridge emphasise the value of ironstone ranges as habitats for priority flora (Gibson *et al.* 2007). An upgrading of the priority status of both *Beyeria lapidiocola* and *Prostanthera ferricola* is recommended(P1 or P2), given that they are poorly known, may number less than 10 populations, have a restricted distribution. *Beyeria sp. lapidicola* is only known from three known locations, two of which are currently threatened by mining. *Prostanthera ferricola* is known from six general locations within Western Australia, four of these locations are threatened by mining. There is some concern for three other taxa found at Herbert Lukin Ridge. Both *Olearia mucronata* and *Ptilotus astrolasius* var. *luteolus* are only known from six populations (Western Australian Herbarium 1998–). The putative new taxon, *Sida* sp. (PERTH 07528140), is only known from three, highly disjunct locations, and very little is known about this entity. It is evident that there is a paucity of detailed knowledge on BIF priority flora. Given the current threats to known populations, there remains a continued need for basic biological survey on other ranges in the arid regions of Western Australia.

Vegetation Communities:

Despite the low altitudinal separation (15–30 m) between the hills around the Herbert Lukin Ridge Joyners Find and the surrounding outwash plains, the floristic communities on rocky upland sites were significantly dissimilar to the lower slope and outwash communities. Community type 6 was the exception, and these three sites may have been placed in a transitional zone between upland to lower slope communities.

Speck (1963) reported a total of eleven vegetation communities for the Gabanintha and Fisher land systems, which are widespread land systems in the Wiluna region of Mabbutt *et al.* (1963). This current survey reports six floristic community types for the Herbert Lukin Ridge, which have been derived from classification analysis of all perennial taxa. There is only some broad agreement with the communities described by Speck (1963), for example, Community type 2 corresponds to the *Acacia grasbyi* (= *Acacia rhodophloia*) – *Triodia melvillei* community, while Community type 5 could be akin to the *Acacia aneura* – *A. ramulosa* var. *linophylla* community. The community descriptions of Speck (1963) are based on dominant taxa and apply to the wider Wiluna–Meekatharra region, and communities resolved in this fine scale study do not appear to be closely comparable to those of Speck (1963).

Surveys in wider northern Yilgarn region are finding that ranges which can be less than 100 km apart will harbour fundamentally different floristic communities (Gibson *et al.* 2007; Gibson & Lyons 1998a; Markey & Dillon 2008a, 2008b; Meissner and Caruso 2008a, 2008b, 2008c). This turnover of communities among ranges is associated, in part, with range-specific geology, a climatic gradient and the unique history of each individual range over the Quaternary (Hopper and Goia 2004; Gibson *et al.* 2007, Gibson & Lyons 1998b). The closest greenstone belt to the Joyners Find greenstone belt which has been adequately surveyed is the Booylgoo Range (125 km south). This is a range of mafic and BIF lithologies which has greater elevation and habitat heterogeneity (Markey & Dillon in review). These two areas have only 45% of native taxa in common (from a combined flora of 273 taxa), and do not appear to share any floristic communities with the Herbert Lukin Ridge (Markey & Dillon, in review). The distinctive *Acacia* – *Triodia melvillei* (Community type 2), saline outwash community (type 4) and ultramafic-weathered BIF *Acacia cuthbertsonii* shrublands (Community type 3) are absent from Booylgoo Range. Although the BIF communities may share similar elements (e.g. *Acacia aneura*, *Prostanthera campbellii, Eremophila forrestii* and *Eremophila jacunda*), there are notable differences in common or significant indicator species. For example, *Thryptomene decussata, Eremophila georgei, Philotheca brucei* subsp *brucei* and *Olearia humilis* are uncommon or absent from the Herbert Lukin Ridge, while *Sida* sp. (PERTH 07528140), *Stenanthemum petraeum*, *Triodia melvillei, Eremophila punctata* and *Acacia grasbyi* are uncommon or absent from the communities on the Booylgoo Range.

The Gum Creek and Poison Hills greenstone belts are closer to the Herbert Lukin Ridge (Wyche *et al.* 2004), but these areas have only recently been surveyed for their floristic communities. The Montague and Black Ranges are associated with the northern half of the Gum Creek greenstone belt (*c.* 75–90 km south-west of Joyners Find), and consist of predominately mafic lithologies of similar / comparable elevation (up to 560 m above sea level) (Elias *et al.* 1982, Tingey 1985). Given both the differences in geology and the distances between these ranges , it is likely that communities described for the Herbert Lukin Ridge (particularly upland communities) will not occur on the Montague and Black Ranges. Recent field observations suggest that this is the case (A. Markey, pers. obs).

Environmental correlates

There were significant differences in site soil chemical fertility, topographic position and geomorphology among the community types, and these environmental factors are all interrelated. Although causative relationships cannot be determined, floristic community types and environmental parameters are closely associated, and environmental factors are important predictors of community composition. For the Herbert Lukin Ridge, steep, rocky ridge tops with massive outcrops of bedrock and boulders have skeletal, acidic soils with relatively higher levels of organic C, Fe, N and P but are otherwise relatively deficient in soil trace elements. Although carbon and nitrogen levels are higher in these upland sites, the soils are skeletal, and the absolute values are low (< 1% organic C and < 0.08% total N) and on par with other ironstone ranges (*cf.* Gibson & Lyons 1998a). Acidic soils may result from weathered ironstone and low levels of exchangeable cations (*cf.* Gray & Murphy 2002). Higher levels of Fe and P are assumed to be derived from *in situ* soil development from weathering of the iron-rich parent rock (*cf.* Gray & Murphy 2002), and loam which accumulates in rock fissure enriches these silty clays with organic C and N from leaf litter.

Depositional areas on the lower slopes and outwash areas occupy the other end of this gradient, where deeper soils are enriched from leachates and therefore have higher levels of trace elements and a higher eCEC. These soils are also weakly acidic, tending to neutral, which is attributed to the buffering capacity of leachates, exchangeable cations and clays (Gray & Murphy 2002). These patterns of soil chemical fertility and geomorphology is generally consistent with those documented in other ironstone and greenstone ranges in the Eremaean of Western Australia (Gibson & Lyons 1998a, 1998b, 2001a, 2001b, Gibson 2004 a, 2004b, Markey & Dillon, 2008a, 2008b), although Gibson and Lyons (1998a) did find a trend for relatively higher carbon and nitrogen levels in lowland *Eucalyptus* woodland communities.

In addition to a general topographic gradient, bedrock type was inferred to have an influence on floristic communities. There was a distinctly different community (Community type 3) of *Acacia cuthbertsonii* subsp. *cuthbertsonii* shrublands which was associated with colluvium over weathered ultramafic, mafic, BIF and associated metasedimentary lithologies on the pediments and lower slopes of the landform. Soils were of similar chemistry to the colluvial lower slopes of BIF ridges, but the soils were more shallow, rocky and marginally steeper. In addition to receiving leachates, the underlying ultramafics or mafic substrates may be influencing soil chemical composition and enriching soils with trace elements (*cf.* Gray & Murphy 2002, Cornelius *et al.* 2007). Another interesting feature of the low BIF ridges of the Herbert Lukin Ridge is the flat summit surfaces and pediments which accumulate moderately shallow, nutrient-deficient soils. The relatively low levels of trace elements are presumed to result from leaching (*cf.* Gray & Murphy 2002). These sites were associated with the distinctive *Acacia* shrublands over hummocks of *Triodia melvillei* and low shrubs (Community type 2).

Conservation

The Herbert Lukin Ridge was observed to be relatively free of exotic species, and only two species were recorded in this survey. The vegetation on the hills was in relatively good condition, with no apparent signs of excessive damage from stock or feral herbivores. However, past mining and exploration activities have impacted on areas of vegetation in the Herbert Lukin Ridge. Considerable damage from numerous working and mines has occurred in parts of the central valley system between the historical mine sites, Joyner Find and Chandlers Mine. Little effort has been made over past decades to secure smaller excavations, or to clean up sites and rehabilitate these areas.

Distinct vegetation community types and endemic, priority and poorly known taxa occur on the Herbert Lukin Ridge, and these require a duty of best practice in the planning process to minimise environmental impacts None of the described communities are represented on conservation estate, and mineral exploration and mining activties pose a significant potential threat to these communities.

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Table 1

Taxa of conservation significance collected within the Joyners Find greenstone belt (Atkins 2008). Endemic taxa are defined as those restricted to hills within 100 km radius of Joyners Find Range. IBRA Regions are denoted as: Yal = Yalgoo, Mur = Murchison, Gas = Gascoyne, Pil = Pilbara, LSD = Little Sandy Desert, GS = Geraldton Sandplain, GD = Gibson Desert (Thackway and Cresswell 1995).

* = not restricted to an area within a 100 km radius of Joyners Find greenstone belt but scattered over wider area.

Family	Taxon	Status for Wiluna	Status	Distribution
Mimosaceae	*Acacia balsamea*	New record	P4	Mur, Gas, GD, LSD, Pil *
Myrtaceae	*Baeckea* sp. Melita Station	New record	P4	Mur, Yal*
Myrtaceae	*Calytrix uncinata*	New record	P3	Mur, Yal *
Myoporaceae	*Eremophila congesta*	–	P1	Mur, endemic
Myrtaceae	*Homalocalyx echinulatus*	New record	P3	Mur, GS, Gas *
Asteraceae	*Olearia mucronata*	New record	P3	Pil, Mur *
Euphorbiaceae	*Beyeria lapidicola*	New record	P2	Mur *
Amaranthaceae	*Ptilotus astrolasius* var. *luteolus*	New record	P1	Mur, Gas *
Lamiaceae	*Prostanthera ferricola*	New record	P3	Mur, Gas

Disjunct entails that the new population is > 100 km away from other known populations.
Endemic refers to taxa with their distributions restricted to within 100 km radius of the Herbert Lukin Ridge.

Table 2

Significant indicator taxa for the six floristic communities of the Herbert Lukin Ridge, as determined from Indicator Species Analysis (Dufrêne & Legendre 1997). Indicator values (%) are shown only for taxa which were significant at p < 0.05 (from Monte Carlo permutation test, * = p < 0.05, ** = p < 0.01, *** = p < 0.001). The highest indicator values per taxon are indicated by shading (maximum value = 100%). Explain indicator values (Legendre & Dufrene).

Indicator Species	**Community Type** 1	2	3	4	5	6
Baeckea sp. Melita Station *	36	0	0	0	0	0
Cheilanthes brownii ***	72	0	3	0	0	0
Eriachne helmsii ***	52	0	0	0	2	23
Prostanthera campbellii ***	65	0	0	0	0	8
Eremophila jucunda subsp. *jucunda* *	4	37	6	0	2	6
Eremophila punctata ***	27	38	0	0	2	5
Triodia melvillei *	0	51	3	0	0	0
Acacia balsamea *	2	1	50	0	0	0
Acacia cuthbertsonii subsp. *cuthbertsonii* **	0	0	67	0	0	0
Dodonaea microzyga var. *acrolobata* *	0	0	50	0	0	0
Scaevola spinescens ***	0	0	71	0	11	0
Atriplex codonocarpa ***	0	0	0	100	0	0
Calandrinia schistorhiza **	0	0	2	86	0	0
Enneapogon caerulescens *	0	0	31	44	0	5
Eremophila galeata **	0	0	8	70	1	0
Hakea leucoptera subsp. *sericipes* ***	0	0	0	100	0	0
Tecticornia sp. Yoothapina Station ***	0	0	0	100	0	0
Maireana convexa *	0	0	6	52	19	0
Porana commixta *	0	0	0	50	0	0
Ptilotus exaltatus *	0	0	24	54	2	0
Ptilotus roei **	0	0	8	75	0	0
Rhagodia eremaea *	0	0	2	54	20	0
Rhyncharrhena linearis **	0	5	0	67	3	0
Sclerolaena cuneata ***	0	0	0	100	0	0
Sclerolaena densiflora **	0	0	0	91	1	0
Sclerolaena eriacantha *	0	0	27	60	0	0
Sclerolaena fusiformis ***	0	0	0	100	0	0
Sclerostegia disarticulata ***	0	0	0	100	0	0
Eremophila forrestii subsp. *forrestii* ***	0	6	11	0	46	5
Hibiscus solanifolius *	1	0	0	0	54	0
Maireana planifolia *	0	0	0	0	60	0
Dodonaea petiolaris **	14	0	2	0	0	58
Harnieria kempeana subsp. *muelleri* *	1	0	0	0	1	53
Ptilotus rotundifolius **	0	0	0	0	0	67
Ptilotus schwartzii *	21	3	4	0	12	33
Sida sp. (PERTH 07528140) *	5	1	0	0	0	47
Number of quadrats	**14**	**14**	**6**	**2**	**10**	**3**

Table 3

Summary statistics (average ± s.e.) of environmental variables for floristic community types of the Herbert Lukin Ridge. Differences in averages between Community types (in bold) were determined using the Kruskal – Wallis nonparametric analysis of variance. (* indicates p < 0.05, ** indicates p < 0.01, *** indicates p < 0.001), with Dunn's posthoc test (LSD p < 0.05). Parameter codes are explained in the methods section. Units for parameters; eCEC = cmol(±)/kg, EC = mS/m, N = %, OrgC = organic carbon (%), minerals = mg/kg, altitude = m, latitude and longitude = decimal degrees. Abbreviations: Outcrop = bedrock outcrop cover, Rock Frag = surface rock fragment cover, Rock Max Size = maximum surface rock size category.

	Community Type					
	type 1	**type 2**	**type 3**	**type 4**	**type 5**	**type 6**
Soil parameters						
EC ^{NS}	**2.3 ± 0.1**	**2.0 ± 0.1**	**8.0 ± 5.3**	97.5 ± 82.5	**2.2 ± 0.2**	2.7 + 0.3
pH***	**4.08 ± 0.04^{a}**	**4.07 ± 0.03^{a}**	**4.48 ± 0.07^{b}**	6.0 ± 0.8	**4.42 ± 0.11^{b}**	4.33 + 0.19
OrgC (%) **	**0.97 ± 0.09^{b}**	**0.74 ± 0.09^{b}**	**0.55 ± 0.09^{a}**	0.65 ± 0.23	**0.61± 0.05^{a}**	0.67 + 0.08
N (%) ***	**0.07± 0.01^{a}**	**0.05 ± 0.00^{b}**	**0.05 ± 0.01^{b}**	0.07 ± 0.02	**0.05 ± 0.00^{ab}**	0.06 + 0.00
Al ^{NS}	447.9 ± 11.9	420.0 ± 10.6	436.7 ± 32.6	475.0 ± 75.0	417.0 ± 13.8	446.7 + 12
Ca ***	**111.1 ± 8.9^{a}**	**78.4 ± 9.0^{a}**	**285.0 ± 84.9^{b}**	315.0 ± 35	**151.2 ± 23.0^{b}**	150.0 + 55.7
Co***	**0.05 ± 0.01^{a}**	**0.04 ± 0.01^{a}**	**1.04 ± 0.45^{b}**	2.55 ± 0.93	**0.27 ± 0.11^{b}**	0.53 + 0.47
Cu*	**0.67 ± 0.03**	**0.65 ± 0.03**	**0.83 ± 0.08**	1.35 ± 0.25	**0.81 ± 0.07**	0.67 + 0.07
Fe***	**83.4 ± 17.9^{b}**	**40.1 ± 3.4^{a}**	**38.2 ± 4.1^{a}**	46.5 ± 5.5	**33.3 ± 2.4^{a}**	48.7 + 4.6
K***	**100.9 ± 7.9^{b}**	**68.6 ± 3.7^{a}**	**127.2 ± 7.1^{b}**	235.0 ± 65.0	**126.7 ± 13.0^{b}**	130.0 + 30.0
Mg***	**28.8 ± 2.4^{b}**	**16.4 ± 1.4^{a}**	**225.0 ± 101.9^{c}**	935.0 ± 765	**37.4 ± 6.6^{bc}**	50.0 + 25.1
Mn*	**17.2 ± 2.2^{ab}**	**10.1 ± 1.4^{a}**	**33.5 ± 10.1^{b}**	199.0 ± 131	**19.7 ± 5.5^{ab}**	31.7 + 16.2
Ni***	**0.15 ± 0.02^{ab}**	**0.09 ± 0.01^{a}**	**1.32 ± 0.64^{b}**	1.4 ± 1.1	**0.31 ± 0.08^{b}**	0.87 + 0.62
P***	**24.9 ± 12.1^{b}**	**5.1 ± 0.3^{a}**	**7.2 ± 0.9^{ab}**	16.5 ± 0.5	**8.4 ± 0.7^{b}**	7.0 + 0.6
S*	**11.1 ± 0.9^{ab}**	**11.1 ± 0.6^{b}**	**10.5 ± 2.8^{ab}**	130.0 ± 120	**7.5 ± 0.8^{a}**	13.0 + 1.5
Zn*	**2.06 ± 0.24^{b}**	**1.91 ± 0.86^{a}**	**1.95 ± 0.47^{ab}**	4.7 ± 0.8	**1.88 ± 0.21^{ab}**	2.23 + 0.84
eCEC***	**1.06 ± 0.07^{ab}**	**0.70 ± 0.06^{a}**	**3.70 ± 1.25^{b}**	11.73 ± 7.99	**1.39 ± 0.19^{b}**	1.50 + 0.56
Ca:Mg	**4.0 ± 0.3**	**4.8 ± 0.4**	**1.8 ± 0.3**	1.1 ± 0.9	**4.3 ± 0.3**	3.4 + 0.4
Physical Site Parameters						
Slope***	**15.4 ± 2.2^{b}**	**3.6 ± 0.7^{a}**	**4.3 ± 0.4^{ab}**	0.5 ± 0.5	**2.8 ± 0.6^{a}**	10.7 ± 2.2
Topography***	**4.2 ± 0.2^{b}**	**3.8 ± 0.4^{b}**	**3 ± 0.3^{ab}**	1 ± 0	**1.6 ± 0.1^{a}**	3.2 ± 0.2
Rock Frag ^{NS}	4.8 ± 0.2	4.9 ± 0.3	5.2 ± 0.4	5.5 ± 0.5	4.3 ± 0.3	5.3 ± 0.3
Rock Max Size***	**5.9 ± 0.2^{b}**	**4.1 ± 0.2^{a}**	**4 ± 0.3^{a}**	2.5 ± 0.5	**3.3 ± 0.2^{a}**	5 ± 0.6
Outcrop***	**4.2 ± 0.3^{b}**	**1.3 ± 0.4^{a}**	**0.8 ± 0.3^{a}**	0.0 ± 0.0	**0.0 ± 0.0^{a}**	3.0 ± 1.0
%Leaf_Litter^{NS}_	14.1 ± 2.7	13.5 ± 3.7	9.2 ± 2.4	6 ± 4	25 ± 6.4	6.7 ± 1.7
%Bare Ground^{NS}	83.9 ± 2	79.1 ± 3.9	88.3 ± 2.5	90 ± 5	71 ± 7.6	78.3 ± 1.7
Soil depth***	**1.2 ± 0.1^{a}**	**2.1 ± 0.2^{b}**	**2.1 ± 0.2^{ab}**	3.0 ± 0.0	**2.9 ± 0.1^{b}**	2.2 ± 0.2
Runoff**	**2.9 ± 0.2^{b}**	**1.9 ± 0.3^{a}**	**2.2 ± 0.2^{ab}**	0.0 ± 0.0	**1.9 ± 0.2^{a}**	2.7 ± 0.3
Aspect NS^{NS}	0.10 ± 0.13	-0.05 ± 0.16	0.02 ± 0.26	0.88 ± 0.00	0.20 ± 0.14	0.08 ± 0.04
Aspect EW^{NS}	0.32 ± 0.23	-0.18 ± 0.22	0.72 ± 0.17	-0.49 ± 0.00	0.16 ± 0.30	-0.33 ± 0.66
Altitude^{NS}	592 ± 5.4	589.9 ± 6.7	578.6 ± 4.7	557.7 ± 2	577.4 ± 5.0	610.9 ± 2.4
Latitude	-26.763 ± 0.015	-26.727 ± 0.014	-26.73 ± 0.015	-26.69 ± 0.004	-26.772 ± 0.016	-26.794 ± 0.005
Longitude	119.949 ± 0.002	119.946 ± 0.003	119.955 ± 0.005	119.955 ± 0.006	119.946 ± 0.002	119.955 ± 0.001
Number of species / quadrat						
All taxa [1]	23.3 ± 1.0	18.5 ± 1.2	32.2 ± 3.1	42.5 ± 6.5	32.5 ± 3.5	25.7 + 4.1
Annuals only	5.3 ± 0.7	4.7 ± 0.8	7.8 ± 1.3	13.0 ± 3.0	11.8 ± 2.5	6.7 ± 2.3
Perennials only[1]	17.8 ± 0.9	13.5 ± 0.9	23.7 ± 2.2	28 ± 3.0	22.6 ± 1.7	19 ± 1.7
Number of quadrats	14	14	6	2	10	3

[1]: including singleton taxa

Percentage cover classes: Rock Frag; 0 % cover (0); < 2 % cover (1); 2–10%, (2); 10–20% (3); 20–50% (4); 50–90% (5); > 90% (6).

Rock Max Size; 2–6 mm (1); 6–20 mm (2); 20–60 mm (3); 60–200 mm (4); 200–600 mm (5); 600 mm–2 m (6); > 2 m (7)

Outcrop cover; 0 % cover (0); < 2 % cover (1); 2–10%, (2); 10–20% (3); 20–50% (4); > 50% (6).

Soil depth: skeletal (< 2 cm) (1); shallow (2–50 cm), deep (> 50 cm)

Topographic position (Tp): outwash plain or flat (1); lower slope or pediment (2); mid slope (3), upper slope (4), crest (5)

Table 4: Matrix of Spearman rank correlation coefficients for environmental variables collated from 50 quadrats established on the Herbert Lukin Ridge. Only correlations significant at $p < 0.01$ are shown. Full details of environmental parameter codes are given in the methods section.

	EC	pH	OrgC(%)	N(%)	Al	Ca	Co	Cu	Fe	K	Mg	Mn	Ni	P	S	Zn	eCEC	NS	EW	Slope	Tp	%frag	MxR	%rock	Runoff	soil	%litter	%bare	altitude	latitude
Soil Parameters																														
EC	-																													
pH	.	-																												
Org C	.	.	-																											
N	.	.	0.901	-																										
Al	.	.	.		-																									
Ca	.	0.775	.	0.390		-																								
Co	.	0.851	.	.		0.811	-																							
Cu	.	0.426	.	.	0.408	0.443	0.470	-																						
Fe	.	.	0.776	0.751	.	.	.	.	-																					
K	0.468	0.692	.	.	.	0.765	0.771	0.424		-																				
Mg	.	0.704	.	.	.	0.861	0.804	0.419	.	0.825	-																			
Mn	.	0.643	.	0.458	.	0.779	0.703	.	.	0.634	0.703	-																		
Ni	.	0.717	.	.	.	0.794	0.868	.	.	0.741	0.823	0.743	-																	
P	.	.	.	0.486	.	.	.	.	.	0.419	.	.	.	-																
S	0.368	.	.	.	.	.	.	.	.	.	.	.	.	.	-															
Zn	.	.	.	0.491	.	0.514	0.371	.	.	0.535	0.496	0.479	0.487	0.384	.	-														
eCEC	0.397	0.773	.	.	.	0.960	0.848	0.463	.	0.876	0.945	0.758	0.829	.	.	0.537	-													
Physical Parameters																														
Aspect NS	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	-												
Aspect EW	.	.			.	.	.	.	.	.	.	.	.	.	.	.	.	.	-											
Slope	.	.	0.525	0.504	.	.	.	.	0.668	.	.	.	.	.	.	.	.	.	.	-										
Topography	.	-0.490	.	.	.	-0.367	-0.559	.	0.383	-0.481	-0.413		-0.399	.	.	.	-0.436	.	.	.	-									
%frag	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	-								
MxR	.	-0.474	0.453	0.364	.	.	-0.395	.	0.620	.	.	.	.	.	.	.	.	.	.	0.690	0.647	.	-							
%rock	.	-0.382	0.592	0.519	.	.	-0.399	.	0.774	.	.	.	.	.	.	.	.	.	.	0.682	0.724	.	0.766	-						
Runoff	.	.	0.500	0.412	.	.	.	-0.397	0.560	.	.	.	.	.	.	.	.	.	.	0.734	.	.	0.510	0.564	-					
soil	.	0.412	-0.495	-0.369	.	.	.	0.379	-0.696	.	.	.	.	.	.	.	.	.	.	-0.656	-0.647	.	-0.665	-0.805	-0.521	-				
%litter	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	-			
%bare	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	-0.387	-		
altitude	.	.	.	.	.	.	.	-0.447	0.370	.	.	.	.	.	.	.	.	.	.	0.503	.	.	.	0.448	0.434	-0.526	.	.	-	
latitude	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.		.	-0.436	.	.	.	-0.381	-
longitude	.	.	.	.	.	.	0.450	.	.	.	.	0.409	0.533	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

APPENDIX 1

Flora List for the Herbert Lukin Ridge. Taxonomic nomenclature follows Packowska and Chapman (2000) and recent records from the Census of Western Australian Plants database (the Western Australian Herbarium, DE 2008-C). Informal (phrase) names and entities of uncertain taxonomic status (i.e.: *confer*, *affinis* or *sp.*) are followed by a collection number. Introduced species are denoted by an asterisk.

Acanthaceae
Harnieria kempeana subsp. *muelleri*
Adiantaceae
Cheilanthes brownii
Cheilanthes sieberi subsp. *sieberi*
Amaranthaceae
Amaranthus mitchellii
Ptilotus aervoides
Ptilotus astrolasius var. *luteolus*
Ptilotus exaltatus
Ptilotus gaudichaudii var. *gaudichaudii*
Ptilotus helipteroides
Ptilotus obovatus
Ptilotus polystachyus var. *polystachyus*
Ptilotus roei
Ptilotus rotundifolius
Ptilotus schwartzii
Anthericaceae
Thysanotus manglesianus
Apiaceae
Trachymene ornata
Asclepiadaceae
Marsdenia australis
Rhyncharrhena linearis
Sarcostemma viminale subsp. *australe*
Asteraceae
Actinobole uligulosum
*Bidens bipinnata**
Brachyscome ciliocarpa
Calocephalus multiflorus
Calotis hispidula
Chrysocephalum puteale
Chthonocephalus viscosus
Erymophyllum ramosum subsp. *ramosum*
Olearia mucronata
Podolepis canescens
Rhodanthe charsleyae
Rhodanthe maryonii
Streptoglossa liatroides
Waitzia acuminata var. *acuminata*
Caesalpiniaceae
Senna artemisioides subsp. x *artemisioides* x subsp. x *sturtii*
Senna artemisioides subsp. *helmsii* x *glaucifolia*
Senna artemisioides subsp. *helmsii* x *glaucifolia* x *oligophylla*
Senna artemisioides subsp. aff. *helmsii*
Senna artemisioides subsp. *filifolia*
Senna artemisioides subsp. *helmsii*
Senna glaucifolia
Senna glaucifolia x sp. Meekatharra (E. Bailey 1–26) &
Senna glutinosa subsp *chatelainiana* x *charlesiana* A. S.
Senna glutinosa subsp. *chatelainiana*
Senna glutinosa subsp. x *luerssenii*
Senna sp. Austin (A. Strid 20210)
Senna sp. Meekatharra (E. Bailey 1–26)
Campanulaceae
Wahlenbergia tumidifructa
Casuarinaceae
Casuarina pauper
Chenopodiaceae
Atriplex codonocarpa
Chenopodium melanocarpum forma *melanocarpum*
Chenopodium saxatile
Dysphania glomulifera subsp. *eremaea*
Dysphania kalpari
Enchylaena tomentosa var. *tomentosa*
Maireana carnosa
Maireana convexa
Maireana georgei
Maireana melanocoma
Maireana planifolia
Maireana planifolia x *villosa*
Maireana thesioides
Maireana tomentosa subsp. *tomentosa*
Maireana triptera
Maireana villosa
Rhagodia eremaea
Sclerolaena cuneata
Sclerolaena densiflora
Sclerolaena eriacantha
Sclerolaena fusiformis
Sclerolaena microcarpa
Sclerostegia disarticulata
Tecticornia sp. Yoothapina Station (A.A. Mitchell 883)
Convolvulaceae
Porana commixta
Cyperaceae
Bulbostylis barbata
Cyperus squarrosus
Euphorbiaceae
Beyeria lapidicola
Euphorbia boophthona
Euphorbia drummondii subsp. *drummondii*
Euphorbia tannensis subsp. *eremophila*
Phyllanthus erwinii
Geraniaceae
Erodium cygnorum
Goodeniaceae
Brunonia australis
Goodenia havilandii
Goodenia macroplectra
Goodenia peacockiana
Goodenia triodiophila
Scaevola spinescens
Haloragaceae
Haloragis odontocarpa forma *pterocarpa*
Haloragis trigonocarpa
Lamiaceae
Prostanthera althoferi subsp. *althoferi x campbellii*
Prostanthera althoferi subsp. *althoferi* x *wilkeana*
Prostanthera campbellii
Prostanthera ferricola

Prostanthera wilkieana
Spartothamnella teucriiflora
Lobeliaceae
Isotoma petraea
Loranthaceae
Amyema gibberula var. *tatei*
Amyema hilliana
Lysiana murrayi
Malvaceae
Abutilon cryptopetalum
Abutilon oxycarpum subsp. *prostratum*
Hibiscus burtonii
Hibiscus gardneri
Hibiscus solanifolius
Sida sp. dark green fruits (S. van Leeuwen 2260)
Sida sp. Golden calyces glabrous fruit (H.N. Foote 32)
Sida sp. Excedentifolia (J.L. Egan 1925)
Sida sp. (PERTH 07528140)
Sida ectogama
Sida sp. verrucose glands (F.H. Mollemans 2423)
Mimosaceae
Acacia aneura var. cf. *aneura*
Acacia aneura var. cf. *argentea*
Acacia aneura var. cf. *microcarpa*
Acacia aneura var. cf. *tenuis*
Acacia aneura x *craspedocarpa*
Acacia balsamea
Acacia burkittii
Acacia craspedocarpa
Acacia cuthbertsonii subsp. *cuthbertsonii*
Acacia pruinocarpa
Acacia quadrimarginea
Acacia ramulosa var. *linophylla*
Acacia rhodophloia
Acacia sibirica
Acacia thoma
Acacia tetragonophylla
Myoporaceae
Eremophila clarkei
Eremophila congesta
Eremophila flabellata
Eremophila forrestii subsp. *forrestii*
Eremophila galeata
Eremophila jucunda subsp. *jucunda*
Eremophila latrobei subsp. *latrobei*
Eremophila hygrophana
Eremophila oppositifolia subsp. *angustifolia*
Eremophila pantonii
Eremophila punctata
Eremophila spectabilis subsp. *brevis*
Myrtaceae
Aluta maisonneuvei subsp. *auriculata*
Baeckea sp. Melita Station (H. Pringle 2738)
Calytrix desolata
Calytrix uncinata
Eucalyptus carnei
Eucalyptus kingsmillii subsp. *kingsmillii*
Homalocalyx echinulatus
Thryptomene decussata
Oxalidaceae
Oxalis perennans
Papilionaceae
Mirbelia rhagodioides
Swainsona canescens
Swainsona kingii
Poaceae
Aristida contorta
Aristida holathera var. *holathera*
Aristida obscura
Austrostipa elegantissima
Austrostipa trichophylla
Brachyachne prostrata
Digitaria brownii
Enneapogon caerulescens
Eragrostis dielsii
Eragrostis eriopoda
Eragrostis lacunaria
Eragrostis pergracilis
Eriachne helmsii
Eriachne mucronata
Eriachne pulchella subsp. *dominii*
Eriachne pulchella subsp. *pulchella*
Monachather paradoxus
Paspalidium basicladum
Thyridolepis mitchelliana
Thyridolepis multiculmis
Triodia concinna
Triodia melvillei
Tripogon loliiformis
Polygalaceae
Polygala isingii
Portulacaceae
Calandrinia creethae
Calandrinia monosperma
Calandrinia ptychosperma
Calandrinia schistorhiza
*Portulaca oleracea**
Proteaceae
Grevillea berryana
Hakea leucoptera subsp. *sericipes*
Hakea recurva subsp. *recurva*
Rhamnaceae
Stenanthemum petraeum
Rubiaceae
Psydrax latifolia
Psydrax rigidula
Psydrax suaveolens
Synaptantha tillaeacea var. *tillaeacea*
Santalaceae
Anthobolus leptomerioides
Santalum lanceolatum
Santalum spicatum
Sapindaceae
Dodonaea microzyga var. *acrolobata*
Dodonaea petiolaris
Dodonaea rigida
Solanaceae
Nicotiana rosulata subsp. *rosulata*
Solanum ellipticum
Solanum lasiophyllum
Solanum nummularium
Zygophyllaceae
Tribulus adelacanthus
Tribulus astrocarpus
Tribulus suberosus
Zygophyllum eichleri

APPENDIX 2

Two-way table of sites and perennial taxa of the Herbert Lukin Ridge, sorted by both the site and species classification. Quadrats appear as columns, and species as rows. Asterisk indicates a quadrat not assigned to any floristic community type.