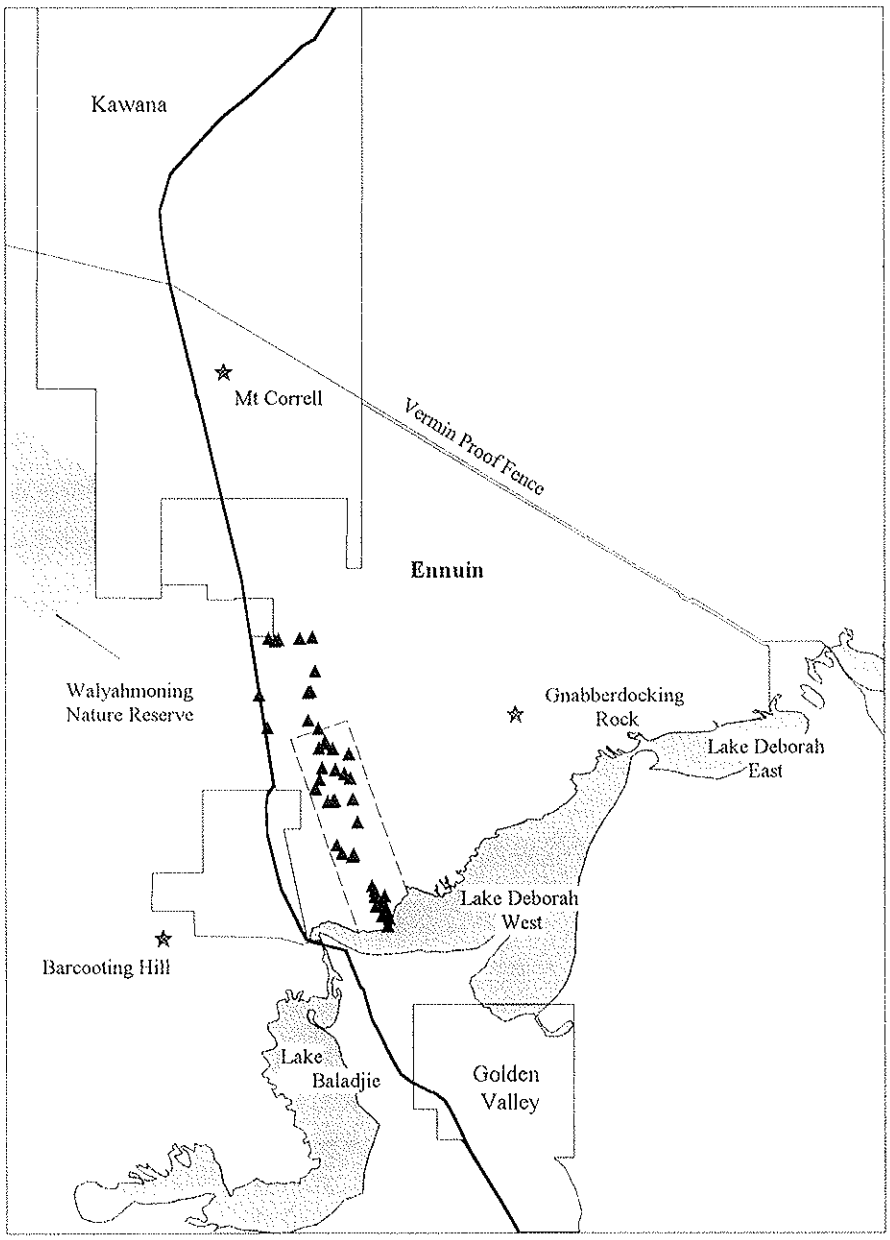
Floristic Survey of the Highclere Hills of the Eastern Goldfields of Western Australia

Neil Gibson and Michael N. Lyons



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

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July 1997

This report should be quoted in the following way:

Gibson, N. and Lyons, M.N. (1997) *Floristic Survey of the Highclere Hills of the Eastern Goldfields of Western Australia*
Unpublished Report for the Australian Heritage Commission
prepared by
Department of Conservation and Land Management.

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

ACKNOWLEDGEMENTS

We would like to thank Judy and Gerry Gauntlett for the invitation to work on Ennuin Station and their hospitality during our stay.

The following people are thanked for assistance with identifications in their particular field of expertise: Greg Keighery, Brendan Lepschi, Bruce Maslin, Barbara Rye, Malcolm Trudgen, and Paul Wilson.

ABSTRACT

A study was undertaken of the flora and plant communities of the Highclere Hills which lie some 25 km NNW of Bullfinch. The range is formed from greenstones and banded ironstones and is surrounded by an outwash plain derived from these units. Forty-five quadrats were established and data from these sites were used to define five community types that were correlated with substrate type. A total flora of 248 taxa was recorded from the range, of which 223 were native and 25 were weeds.

Three taxa listed on CALM's priority flora list were found on a sandplain adjacent to the range, another priority taxon was found on the range, and a further priority taxon was found on nearby granites. Only one of these taxa is currently reserved. *Tricoryne tuberosa* ms is recommended to be added to the priority flora list.

The floristic classification is in broad agreement with previous descriptions of the range but provides more detail than has previously been reported. None of the Highclere vegetation system is presently in any conservation reserve.

INTRODUCTION

The Highclere Hills are composed primarily of Archaean mafic and ultramafic rocks (these formations are commonly termed greenstones) and small outcrops of Archaean banded ironstones. Greenstone and banded ironstone ranges are one of the common landforms of the Eastern Goldfields and extend from the Highclere Hills in the west to the Roe Hills some 300 km further east and stretch north - south over 800 km. The Highclere Hills lie some 25 km NNW of Bullfinch, forming part of the western most greenstone belt in this region (Figure 1). Despite the greenstone ranges being heavily exploited for minerals for over a hundred years a detailed knowledge of the vegetation and flora of the region is still lacking.

CLIMATE

The climate of the region is semi arid mediterranean with warm winters and hot summers. Mean annual rainfall at Bullfinch (25 km south south east of Highclere Hills) is 296 mm although seasonal variation is high. The driest year on record was 1940 with 122 mm and the wettest was 1963 with 618 mm. Most rain falls in winter and is generally associated with frontal activity from May through August. Summer falls (to 100 mm) are highly erratic and result from thunderstorms. Heaviest falls are associated with rain bearing depressions forming from tropical depressions (Newbey 1985, Bureau of Meteorology 1988).

The closest meteorological station for which temperature data are available is Southern Cross (60 km to the south east). Mean maximum temperatures is highest in January (34.5°C) with December through March all recording mean annual temperatures above 30°C with the highest daily temperature on record of 45.6°C. Lowest mean minimum temperatures of below 5°C are recorded in July and August. Lowest daily minimum temperature on record was –3.8°C.

GEOLOGY AND LANDFORMS

The geology of the study area has been mapped and described in detail in Jackson 1: 250000 sheet (Chin & Smith 1983) and the geology and landforms have been summarised by Newbey (1985). The study area has been tectonically stable since the Proterozoic (600 - 2500 million years (My) ago). The major landscape features are controlled by the Archaean (2500 - 3700

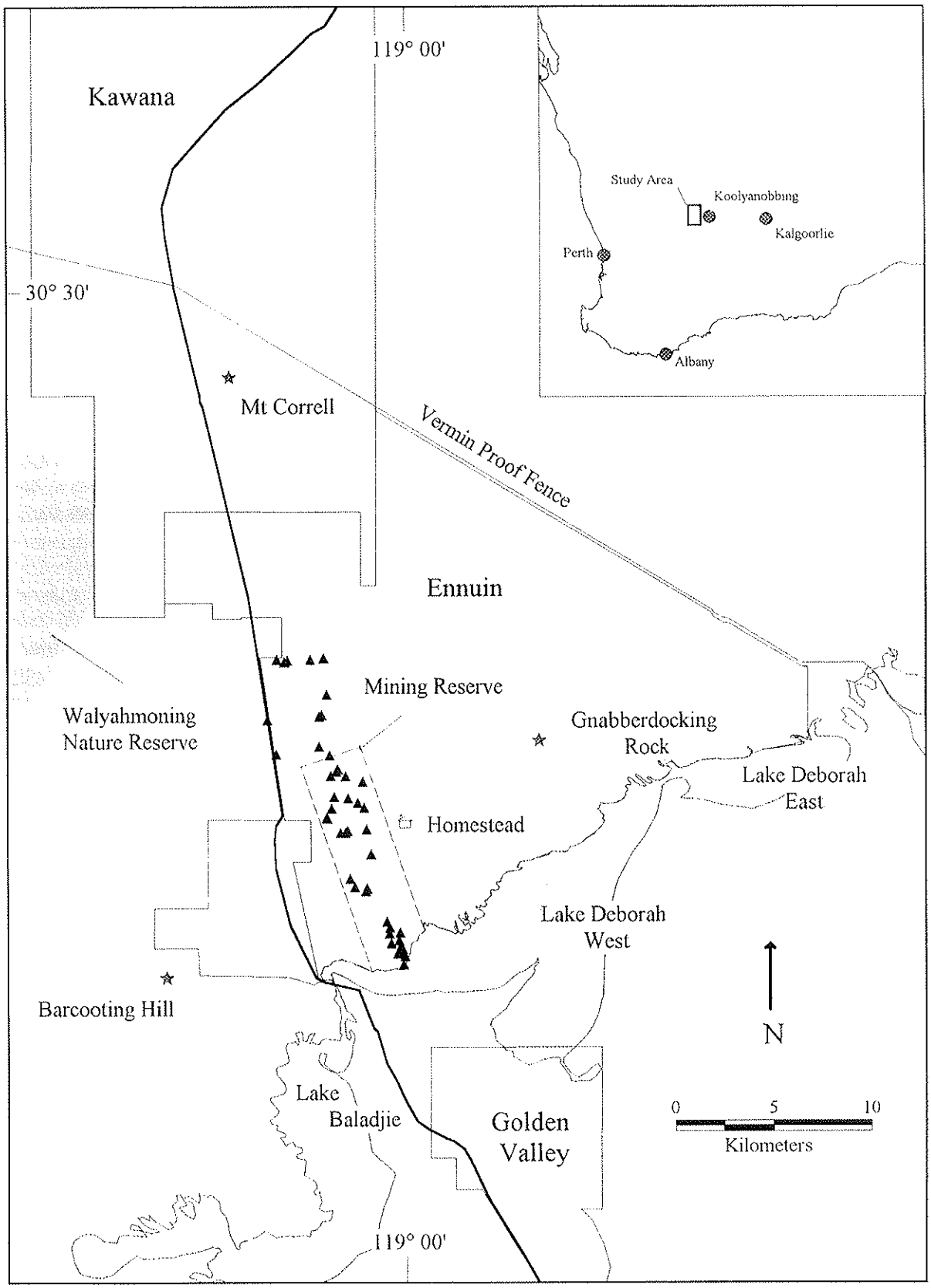


Figure 1. Location of study area.

My old) granites which underlie most of the study area and have weathered into gently undulating plains and broad valleys covered by Tertiary soils (< 65 My old). Trending NNW to SSE are linear bands of Archaean greenstone (mafic and ultramafic lithologies) and banded ironstone formations which were formed from lacustrine deposits of iron oxides and quartz sand. The Highclere Hills are part of the Bullfinch greenstone belt (Chin & Smith 1983). Widespread laterization of the granites and greenstones is believed to have occurred during the Cainozoic (the last 65 My). The net result is a very subdued landscape given the long period of erosion this area has undergone. The banded ironstone formation in the Bullfinch belt is relatively thin (< 10 m) unlike those of the Koolyanobbing belt (25 km to the east) which can reach thickness of up to 100 m (Chin & Smith 1983).

VEGETATION

The Highclere Hills lie in the Coolgardie interzone close to the border with the Avon botanical region (wheatbelt) (Beard 1990). The interzone is generally dominated by eucalypt woodlands and shrublands on yellow sandplains and it marks the transition in vegetation from the species rich south west to the more arid communities of the desert regions.

Beard (1972) first described the major structural formations of this area which he grouped into vegetation systems. He defined the vegetation of the greenstones and banded ironstones of the Highclere Hills as forming part of the Highclere System. This system also encompasses the greenstone and ironstone areas from near Mt Correll south to Bullfinch.

In this system he described the small ironstone outcrops as being covered by thickets of *Acacia quadrimarginea* with a few scattered trees of *Casuarina pauper (= C. cristata), Brachychiton gregorii* and *Pittosporum phylliraeoides* with *Dryandra arborea* (which is common on the banded ironstone of the Bungalbin system to the east) being entirely lacking. The hilly country of the greenstone areas are described as being covered by woodlands of *Eucalyptus longicornis* and *E. corrugata* with an understorey of saltbush *Atriplex hymenotheca* and *A. nummularia,* while on the flanks of the hills *Eucalyptus salmonophloia, E. salubris* and *E. loxophleba* woodlands are found.

Beard's pioneering work was followed up some years later with a major regional survey of the biota of the Eastern Goldfields, produced in a series of cell reports. The Jackson-Kalgoorlie report (Dell *et al.* 1985) covered the Highclere Hills. Dell *et al.* adopted a land system approach, somewhat broader than Beard's vegetation systems.

Newbey and Hnatiuk (1985) describe the vegetation of the Highclere Hills under the heading 'Undulating Plain (greenstone)'. They state that "the Highclere Hills support mainly *Eucalyptus corrugata* Low Woodland on low stony ridges, and *Eucalyptus salmonophloia* Woodland and *E. salubris* Low Woodland on the colluvial flats. Occurring rarely were shrublands of both *Acacia acuminata* and *A.* aff. *aneura* on stony rises, and *Eucalyptus longicornis* Low Woodland on the colluvial flats where the soil pH exceed 8.2." Newbey and Hnatiuk (1985) also note the occurrence of two taxa (*Hakea rigida* (KRN 9589) and *Leptosema aculeatum* (=*L. chambersii* subsp. nov.)) in the area which represented notable range extensions.

Both Beard's survey and the later biological survey of the eastern goldfields were undertaken to provide regional overviews. Consequently the individual ranges were not sampled extensively. The only other report on the vegetation of the study area is that of Henry-Hall (1990). This report details reserve recommendations for the southern goldfields. In the section on areas

requiring additional investigation, Henry-Hall recommends that the Department of Conservation and Land Management investigate the conservation values of the Highclere Hills.

The aim of the present work was to undertake a detailed floristic survey of that section of the Highclere Hills that occurs on Ennuin station and the associated mining reserve (Figure 1). This involved the compilation of a detailed flora list for the range and the associated outwash areas, and to describe the vegetation patterning of this area based on a series of permanently located quadrats.

Ennuin station was the first area taken up for grazing in the region with G. Lukin and D.B. Clarkson overlanding sheep from Toodyay in 1871 (Dell 1985) with the station being occupied more or less continuously ever since. Considerable mining and mineral exploration has occurred along the range since the discovery of gold in the Highclere Hills by Ed Payne on 20 October 1887 (Dell 1985). The grazing rights to the mining reserve that covers part of the Highclere Hills can only be taken up by Ennuin Station (J. Gaunlett, pers. comm.).

METHODS

Forty-five 20 m x 20 m quadrats were established on the range, its foot slopes and the outwash plain (Figure 2). These sites attempted to cover the major geographical, geomorphological and floristic variation found in the study area. Care was taken to locate sites in the least disturbed vegetation available in the area being sampled. No attempt was made to undertake detailed sampling of the Tertiary sand plain on the northern boundary of the station nor the adjacent granitic areas (Chin & Smith 1983) although some opportunistic sampling was undertaken.

Within each site all vascular plants were recorded. Quadrats were sampled in October 1996. Data on topographical position, slope, aspect, percentage litter, percentage bare ground, percentage exposed rock, vegetation structure and condition were collected from each site. Topographical position was scored on a subjective five point scale from ridge tops (1) and upper slopes (2), to midslopes (3), and to lower slopes (4) and valley flats (5). Slope was scored on a one to three scale from flat to steep. Aspect was recorded as one of 16 cardinal directions. Vegetation structure was recorded using Muir's (1977) classification.

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

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

The site and species classifications undertaken used the Czekanowski coefficient and "unweighted pair-group mean average" fusion method (UPGMA, Sneath and Sokal 1973). Semi-strong hybrid (SSH) ordination of the sites data was undertaken to show spatial relationships between groups and to elucidate possible environmental correlates with the classification (Belbin 1991).

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

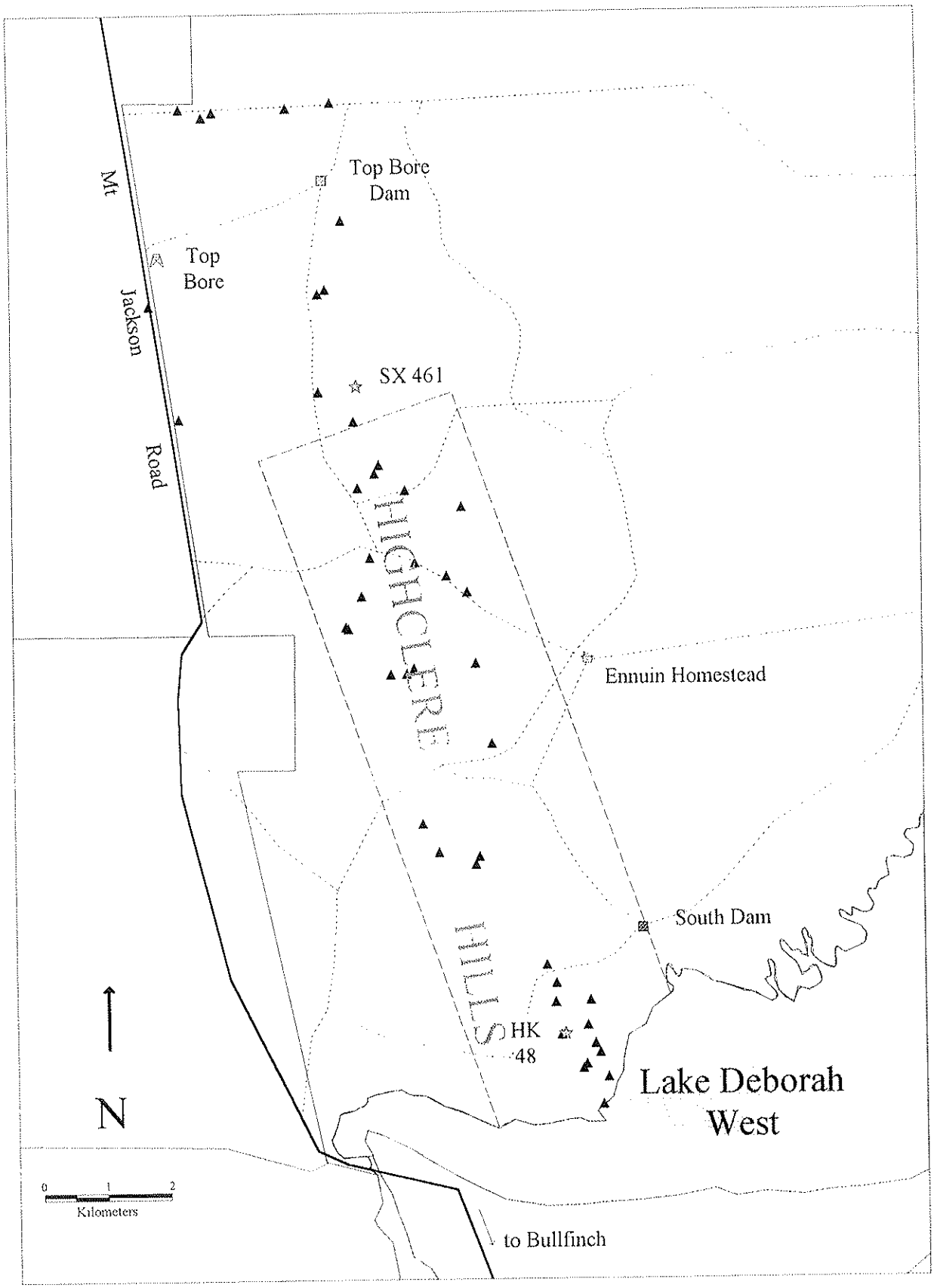


Figure 2. Location of survey sites on Ennuin Station.

RESULTS

FLORA

A total of 248 taxa (species, subspecies and varieties) were recorded from the Highclere Hills. The flora list was compiled from taxa found in the 45 plots or the adjacent area and from other opportunistic collections (Appendix 1). Of these 248 taxa, 223 are native and 25 are weeds.

The best represented families were the Asteraceae (48 native taxa and 4 weeds), Myrtaceae (21 taxa), Poaceae (20 native taxa and 8 weeds), Chenopodiaceae (13 taxa), Mimosaceae (9 taxa), Myoporaceae (9 taxa), and Brassicaceae (8 taxa and 5 weeds). This pattern is typical of the flora of the South Western Interzone (Newbey & Hnatiuk 1985). Good rains were experienced in the winter and early spring of 1996, reflected by the large numbers of annuals and geophytes on the flora list (Appendix 1).

The most common genera were *Eucalyptus* (14 taxa), *Acacia* (9 taxa), and *Eremophila* (9 taxa). Grassy weed species were encountered in almost all quadrats, reflecting a long history of grazing.

During the survey five taxa listed on CALM's priority flora list (CALM 1996) were encountered (Table 1, Figure 3). Three species were found on a small area of sandplain on the northern boundary of the station. This area was not surveyed in detail and further work may be rewarding. The new populations of *Stenanthemum newbeyi* occurred on small outcrops of banded ironstone and represent a significant extension of this species range. Previously it was believed to be an endemic of the Helena and Aurora Range some 80 km to the north east (Rye 1995).

The station owner drew our attention to the occurrence of *Grevillea tetrapleura* on the granitic soils east of the homestead. This species has previously been collected at Barracooting Rock to the west and the Lake Deborah causeway to the east of the station. No collections of this species from Ennuin station could be located in PERTH, however a number of collections were found from the granitic soils to the east of the homestead.

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

Taxon	***Current priority listing***
Daviesia purpurascens	4
Grevillea tetrapleura	4
Leucopogon breviflorus	2
Stenanthemum newbeyi	1
Stylidium choreanthum	2

Daviesia purpurascens has recently been delisted from DRF to Priority 4. Data from this survey and previous surveys (Gibson *et al.* 1997) supports this reassessment.

An unusual species of *Tricoryne* was collected from two populations, one on a banded ironstone ridge and the second on a greenstone ridge (Figure 4). This species is unusual in having a dense many flowered globular umbel, the only species in the genus to do so. A search at PERTH revealed that this taxon has been collected twice before, once near Billiburning Road in 1980 and a second time in the Karroun Hill Nature Reserve in 1983. This taxon will

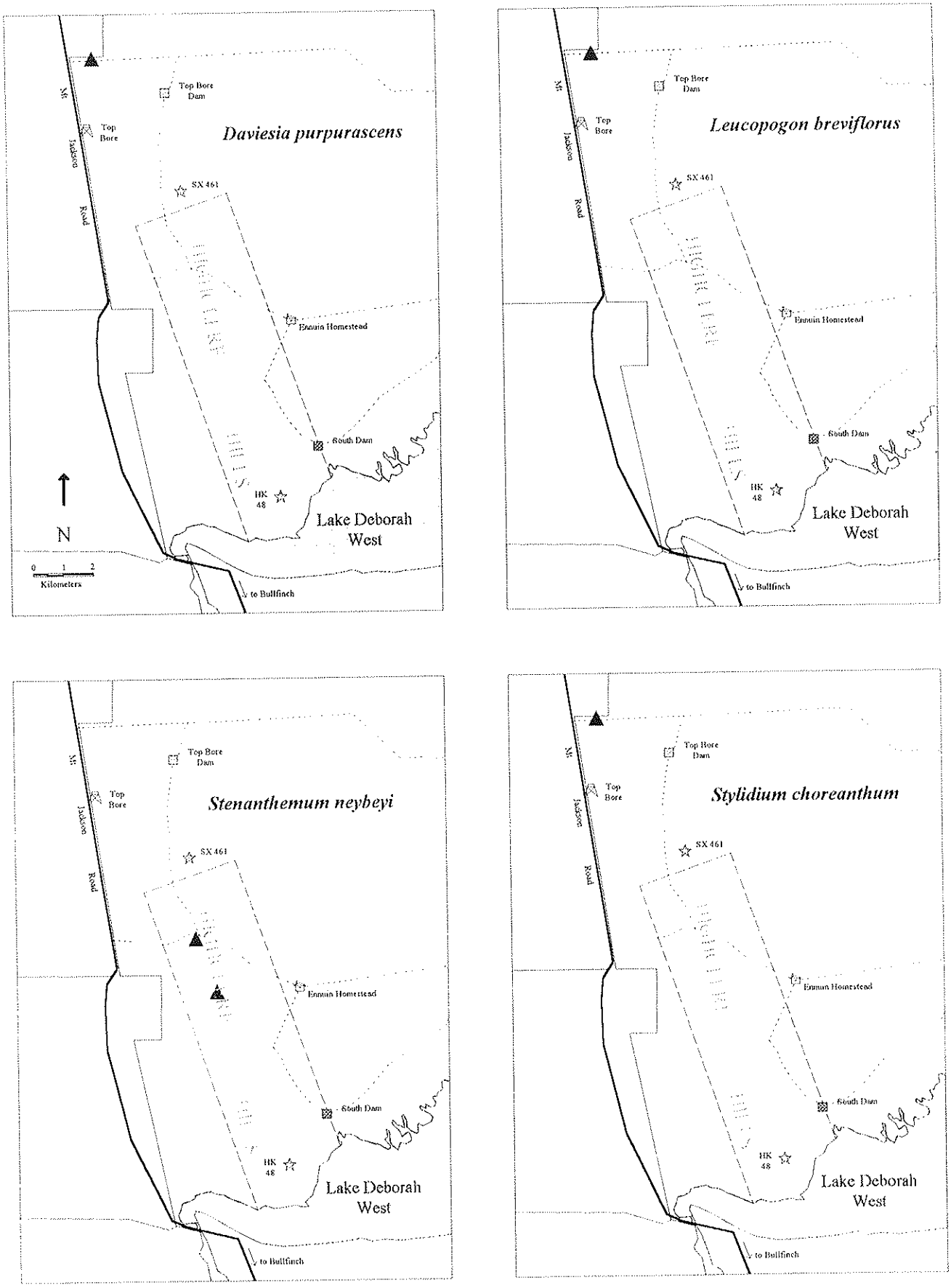


Figure 3. Populations of Priority Flora recorded during the current survey.

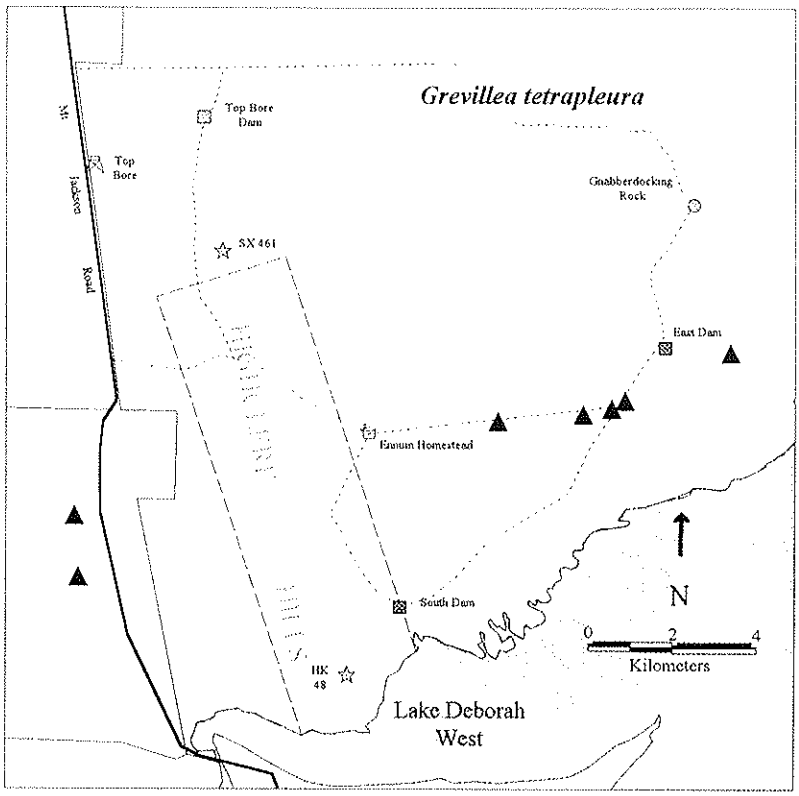


Figure 3. (cont'd.) Populations of Priority Flora recorded during the current survey.

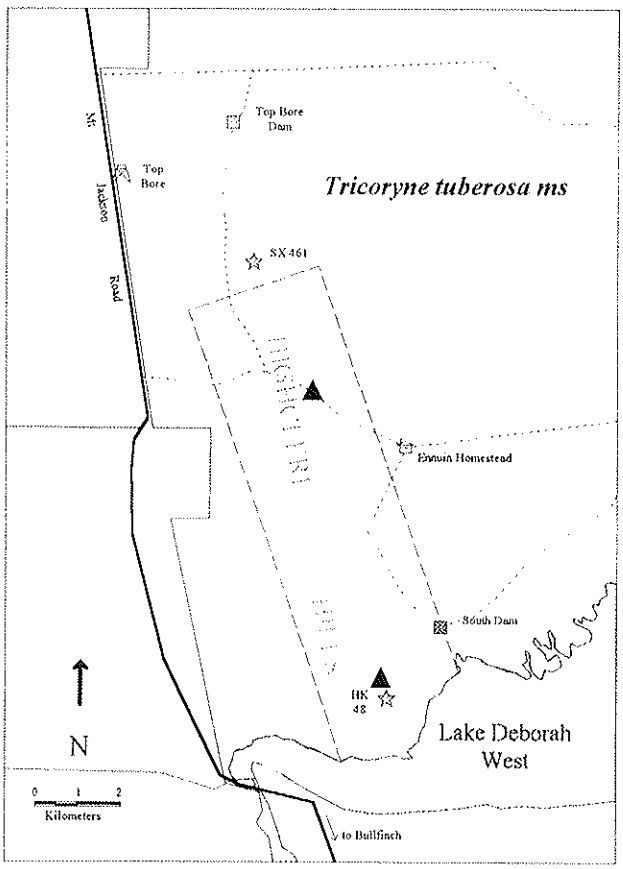


Figure 4. Populations of Tricoryne tuberosa ms recorded during the current survey.

be described as *Tricoryne tuberosa* ms (GJ Keighery, pers. comm.). It is recommended that this taxon be listed on CALM's priority flora list as Priority 2 (Figure 4).

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

One small area of sandplain and several areas of granites were visited during the survey, however no attempt was made to compile exhaustive flora lists from these areas. Twelve taxa that were not seen on the range were recorded from the granites (*Amphibromus nervosus, Chamaexeros fimbriata, Daviesia nematophylla, Dodonaea viscosa subsp. angustissima, Eucalyptus capillosa* subsp. *capillosa, Eucalyptus celastroides* subsp. *celastroides, Frankenia desertorum, Gunniopsis rubra, Melaleuca haplantha, Solanum hoplopetalum, Stylidium dielsianum, Wilsonia humilis)* and eight taxa were recorded from the sandplain that were not seen elsewhere on the range (*Billardiera coriacea, Daviesia purpurascens, Eremophila caperata ms, Eucalyptus hypochlamydea* subsp. *hypochlamydea ms, Eucalyptus leptopoda, Stylidium* aff. *leptophyllum* (NG & ML 2053*), Stylidium choreanthum, Thelymitra sargentii*).

VEGETATION

Only material that could be identified down to species level was included in the analysis (c.99% of records). In the 45 quadrats established on the Highclere Hills 218 taxa were recorded of which 96 were perennial (Appendix 2 & 3). Twenty nine perennials occurred at only one site. Preliminary analyses showed these singletons had little effect on the community classification and therefore were excluded. As a result the final data set consisted of 67 perennial taxa in 45 sites. Species richness ranged from four to 19 taxa per site, with individual taxa occurring in between two and 38 sites.

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

The dendrogram shows the forty five sites divide into two primary groups, the first group which has *Atriplex* spp. and *Sclerolaena* spp. as common components in the understorey, and the second which generally lacks these taxa (Figure 5, Table 2). Both of these groups can be further subdivided with a total of five communities being recognised. Within community types 1 and 4 two subgroups are recognised.

Community type 1 and 2 are eucalypt woodlands variously dominated by *Eucalyptus longicornis, E. salubris, E. salmonophloia* and /or *E. corrugata* with understoreys dominated by chenopods such as *Atriplex* spp., *Maireana* spp., *Sclerolaena* spp. as well as other species in species group F (Table 2). This species group is largely lacking from community types 3, 4 and 5 except for the perennial *Stipa* spp. and *Enchylaena tomentosa* which is also common occurs in community type 4. The single site that makes up community type 2 was very species poor (7 taxa) compared to community type 1 (mean c. 13 taxa / plot). It was noted that in these woodlands occasional large open areas occurred which were almost totally devoid of vegetation and consequently community type 2 is probably better considered an extreme form of community type 1.

Figure 5. Dendrogram of the sites from the Highclere Hills showing the five group level classification.

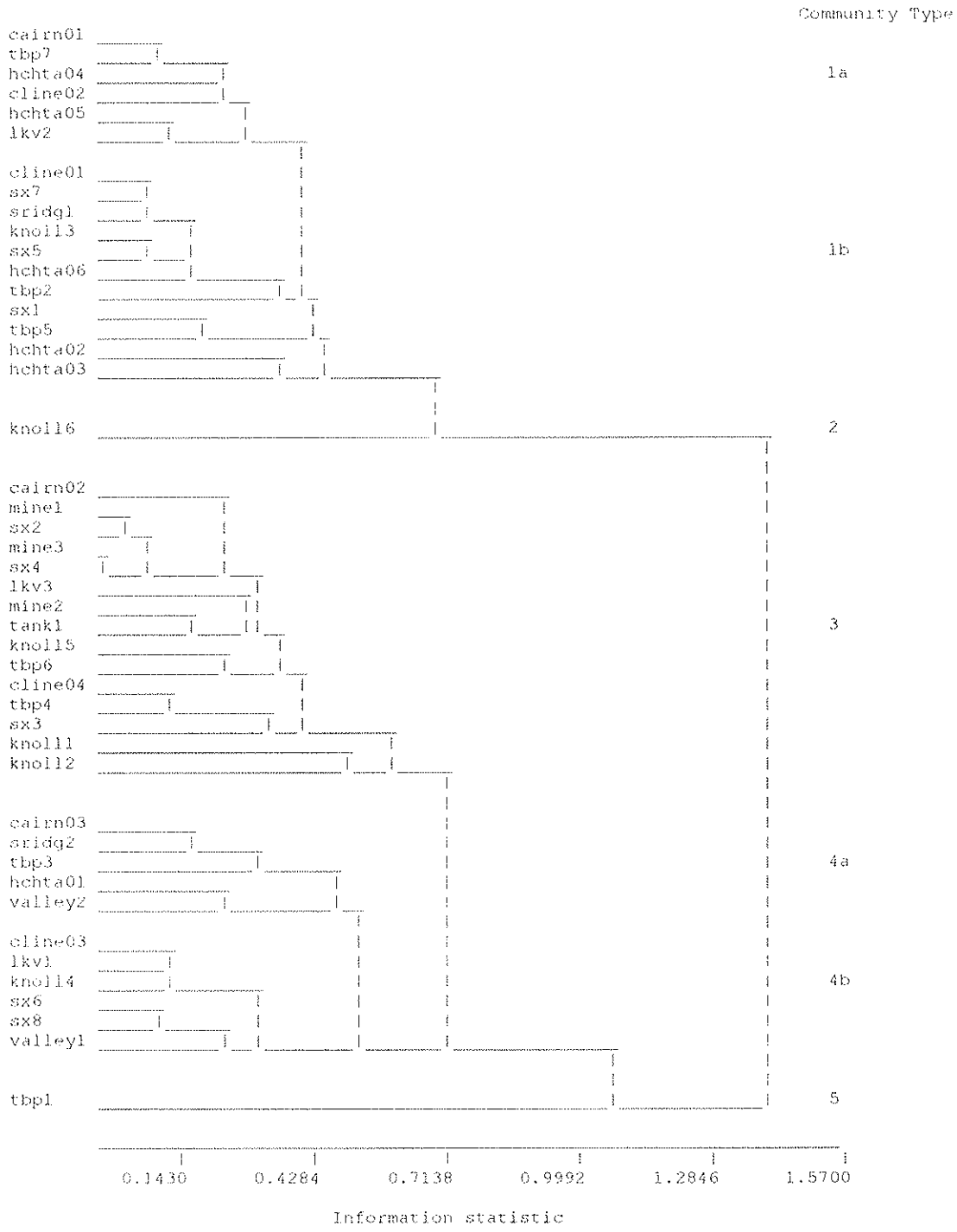
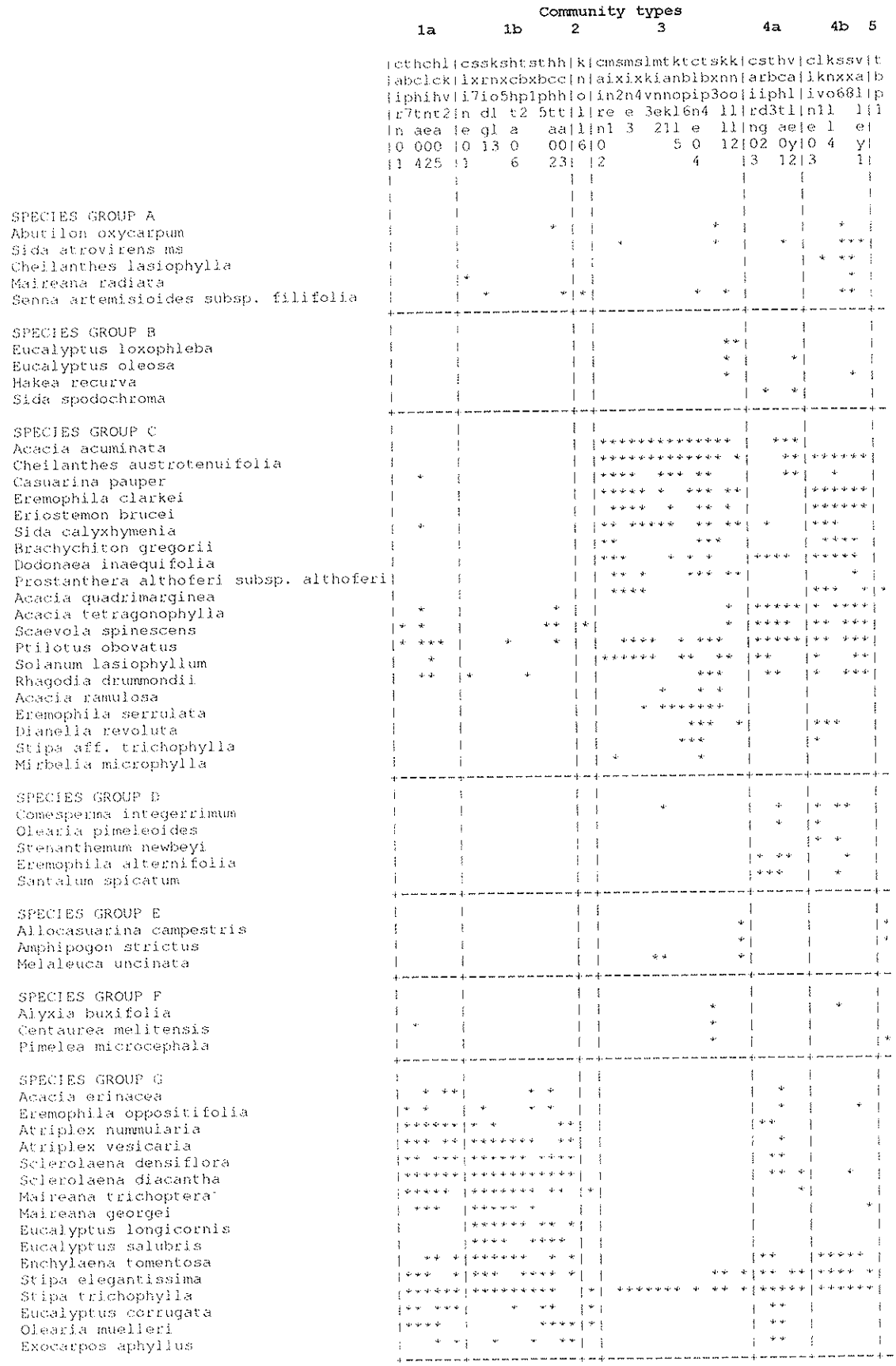


Table 2. Sorted two way table of the Highclere Hills sites showing species occurrence by community type. Site codes appears as columns, species code as rows.



SPECIES GROUP H						
Amyema miquelii		* *				
Eremophila interstans	**	* * *				
Stipa nitida		**				
Eucalyptus salmonophloia		** *				
Sclerolaena fusiformis	*	*				
Chenopodium curvispicatum		* * *			*	
Eremophila scoparia	**	* ***				*
Santalum acuminatum		* *			*	
Dodonaea stenozyga		* *				
Eucalyptus yilgarnensis		* **				
Eucalyptus sheathiana		** *	*			

Within community type 1 sites solely dominated by *Eucalyptus corrugata* can be separated (type 1a) from sites dominated by *Eucalyptus longicornis, E. salubris,* and/or *E. salmonophloia* (type 1b), although *E. corrugata* can co-occur with these species. This division is not correlated with any significant change in the understorey except that *Ptilotus obovatus* appears to be more faithful to type 1a (Table 2).

Acacia acuminata (jam) and *Casuarina pauper* are typical components of community type 3, while species such as *Acacia tetragonophylla* and *Scaevola spinescens* are more characteristic of community type 4. Species group C is generally both faithful and constant to types 3 and 4, however there are clearly different patterns in species occurrences between these types within this species group. There are also obvious differences in species dominance between these types, with almost all sites in community type 3 being dominated by an *Acacia acuminata* shrubland. Mean species richness is higher in community type 4 (15.7 taxa / plot cf. 11 taxa / plot). Both community types show low representation of species group F (except for the *Stipa* spp. and *Enchylaena tomentosa* as previously mentioned). Species group D is almost totally restricted to community type 4.

Community type 4 can be subdivided into two subgroups. Type 4b is entirely restricted to ridges of massive banded ironstone and can easily be separated from type 4a by the occurrence of such species as *Eremophila clarkei, Eriostemon brucei, Acacia quadrimarginea* and *Stenanthemum newbeyi,* while community type 4a generally occurs on deeper soils lower in the landscape.

Community type 5 is represented by a single site located on a eroding lateritic breakaway. This landform was rare in the study area. This site contained few shared perennial taxa (4 only) while a further 10 taxa were recorded only at this site. The site was dominated by *Allocasuarina campestris, Baeckea elderiana* and *Grevillea paradoxa.* A similar community type has previously been encountered on lateritic areas in the Hunt and Mt Manning Ranges some 70 – 100 km to the north east (Gibson, unpub data).

Physical Correlates

There was no significant difference between mean topographic position or slope class occupied by the different community types (Kruskal – Wallis one way analysis of variance, Table 3). While community type 4b generally occupied ridge tops or upper slopes, no obvious trend could be seen in the other spatial patterning of the other community types. It appeared geology, soil type and depth were more significant correlates with community occurrence (Tables 4, 5, & 6).

Table 3 Mean topographic position (1-upland to 5-valley flat) and slope (1-gentle to 3-steep) by community type

Community type	Mean position	Mean slope	No of quadrats
1a	3.17	2.17	6
1b	2.77	1.91	11
2	4.00	2.00	1
3	2.80	2.07	15
4a	2.80	2.20	5
4b	1.67	2.17	6
5	1.00	1.00	1

Table 4. Predominate surface rock type by community type.

Community type	Banded Ironstone	Greenstone	Iron nodules
1a	4	2	
1b	2	6	3
2		1	
3	2	11	2
4a	2	3	
4b	6		
5			1

Community type 4b was restricted to shallow soils on banded ironstone ridges high in the landscape. Community type 4a occurred on somewhat deeper soils on either banded ironstones or greenstones. Community type 3 was generally occurred to moderately deep red loam soils developed on greenstones, while the chenopod rich communities (types 1 & 2) tended to occur on deep red - brown loams (Tables 4, 5 & 6). When soil chemical data is available more detailed analysis of differences between community type will be possible.

Table 5. Soil depth by community type.

Community type	0-10 cm	0-30 cm	30-50 cm	>50 cm
1a			4	2
1b		1	3	7
2			1	
3	1	1	7	6
4a	2	1	1	1
4b	5	0	1	
5			1	

Table 6. Soil colour by community type

Community type	Brown loam	Red loam	Yellow sandy loam
1a	4	2	
1b	8	3	
2	1		
3		13	2
4a	2	3	
4b	1	5	
5			1

Ordination Results

Ordination of the site data was undertaken to show spatial relationships between groups and to better elucidate possible environmental correlates with the classification. The results of a two dimensional ordination (stress level 0.16) shows good separation of most of the classificatory groups. The first and second axes separated community type 5 from all other sites, further indicating the very different nature of this community type. The first and the third axes shows the gradation from community type 1 (bottom of figure) through community type 4 (centre) to community type 3 (top of figure) (Figure 6). The outlying nature of community type 5 is still apparent as is the relationship between the species poor community type 2 to community type 1.

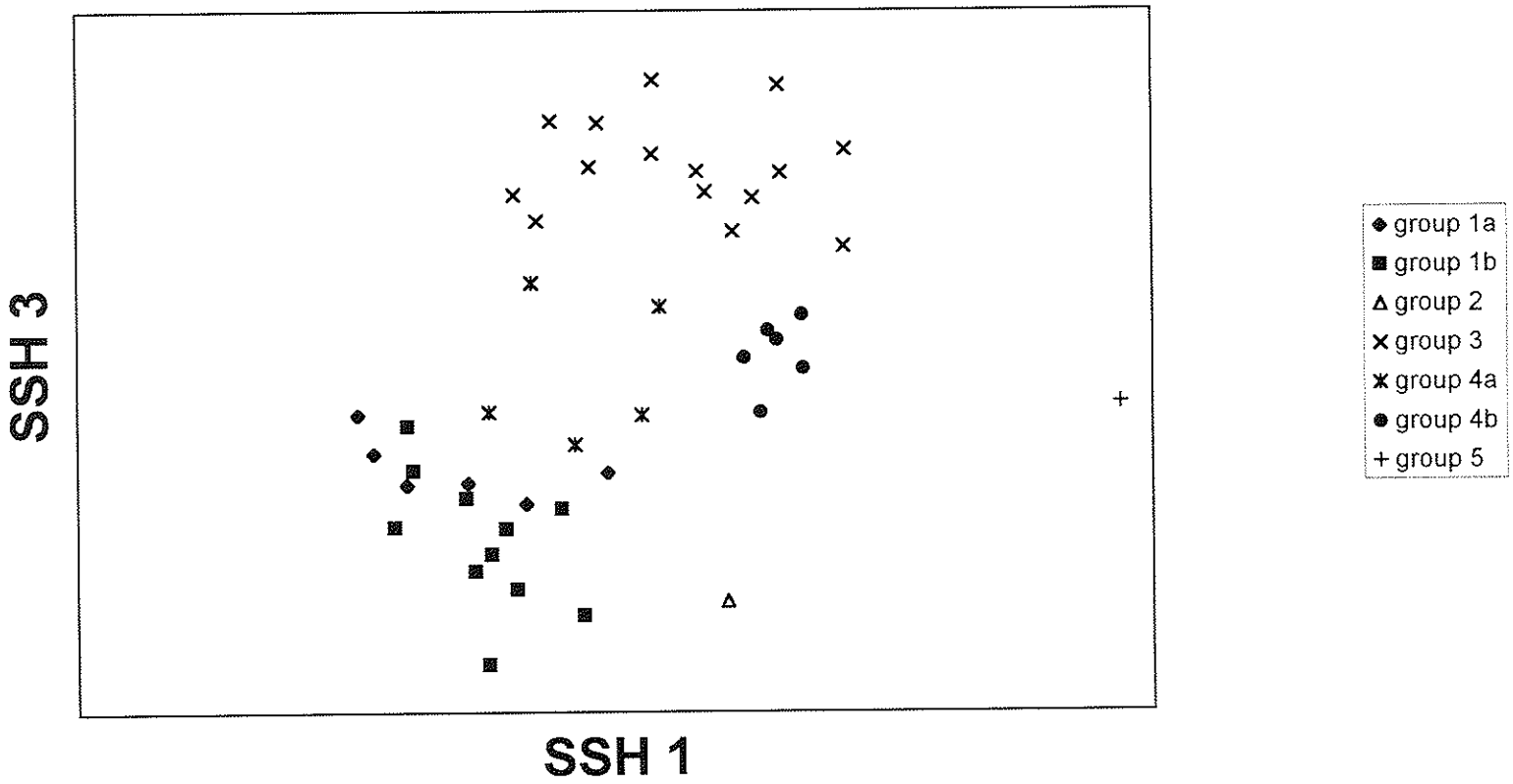
No clear segregation of community subtypes 1a and 1b is apparent; it was noted earlier that the differences between these subtypes is almost totally confined to the overstorey. Good segregation between the subtypes of community type 4 is apparent. Further inspection of the two way table (Table 2) shows that two quadrats in community type 4a share a number of species in species group F with community type 1. This relationship is also apparent in the ordination where two sites in community type 4a fall near sites from community type 1.

DISCUSSION

The section of the Highclere Hills on Ennuin station had a rich flora of some 248 taxa. The flora list for Ennuin station would be considerably extended if detailed surveys were undertaken of the granitic and sandplain areas. Only one species of priority flora (*Stenanthemum newbeyi)* was found on the range. This represents a significant range extension for the taxon from the Helena and Aurora Range some 80 km to the north east. This species was believed to be an endemic to the massive banded ironstones of that range system. *Stenanthemum newbeyi* occurred in the same habitat on the Highclere Hills but, as was noted above, this habitat is very much more restricted here. Three other priority taxa were recorded on the small area of sandplain in the north west corner of the station and another *Grevillea tetrapleura* is common on granitic soils to the east and west of the range.

Two populations of *Tricoryne tuberosa* ms were recorded from the range. These are the first recent records (two previous records date from the early 1980s) of this taxon which seems to be restricted in the small area between Karroun Hill Nature Reserve and Ennuin. Further survey is required to determine this species distribution, it is recommended that it be listed as a priority 2 taxon.

Figure 6. Ordination of 45 floristic plots by floristic group



The two species (*Hakea rigida* (KRN 9589) and *Leptosema aculeatum* (=*L. chambersii* subsp. nov.)) that Newbey and Hnatiuk (1985) highlighted as notable range extensions to the Highclere Hills were not located during the present survey. Herbarium records indicate they were originally collected north of Ennuin however they are both represented by only a single collection in PERTH. Further survey for these species is recommended.

The flora list for the Highclere Hill is somewhat poorer than that recorded for Helena and Aurora Range (324 taxa) and similar to that of the Bremer Range (268 taxa) and the Parker Range (256 taxa) (Gibson & Lyons 1995, Gibson *et al.* 1997). However the latter two ranges were sampled in a very poor year and numbers of annuals and geophytes will be significantly underestimated. The smaller than expected flora list for the Highclere Hills (given the abundance of annuals recorded) probably reflects the much more subdued topography of the Hills compared to the other ranges and hence lack of habitat heterogeneity.

The effects of this subdued habitat are also seen in the vegetation classification. Both Beard (1972) and Newbey and Hnatiuk (1985) considered that the low stony rises of the Highclere Hills were covered with *Eucalyptus corrugata* and / or *E. longicornis* woodlands with chenopod understoreys, with the associated colluvial flats being dominated by *Eucalyptus salmonophloia* and *E. salubris* woodlands. There is little evidence in our data of this topographic segregation on the Hills. Localised areas of deeper soils allow *E. salubris* and *E. salmonophloia* to develop over most of the landscape. While it is possible to split the woodlands into those dominated by *E. corrugata* (type 1a) and those dominated by *E. salubris* / *E. salmonophloia* (type 1b) there is little evidence of any significant change in the understorey species between these subtypes (Table 2). Analysis of soil chemistry data when it becomes available could be expected to show major differences between the chenopod rich communities (types 1 & 2) and shrublands of communities 3 and 4.

Newbey and Hnatiuk (1985) describe shrublands of both *Acacia acuminata* and *A.* aff. *aneura* rarely occurring on stony rises. In fact these *Acacia* shrublands (type 3) are one of the more widespread community types on the Ennuin section of the Highclere Hills. Indeed much of the eastern slopes are dominated by this community type.

The community of the massive ironstones (type 4) is fundamentally different from those recorded from the Helena and Aurora Range. The most obvious components of that community (*Dryandra arborea* and *Calycopeplus paucifolius*) appear to be totally absent from the Highclere Hills. The areas of massive banded ironstone habitat in this area are very small and fragmented. Two sites in the related community type 4a shows some intergradation with community type 1a further reflecting the mosaic nature of the plant communities on the Highclere Hills (Table 2, Figure 5).

The lateritic community (type 5) was very restricted on Ennuin but is very similar in species composition to similar landforms in the Hunt Range and Mt Manning Range (Gibson, unpublished data). Laterization was widespread during the Tertiary and similar laterite communities are widespread in the goldfields ranges.

Beard (1972) classifies all of the greenstone and banded ironstone areas of the Highclere Hills into the Highclere vegetation system, extending from north of Mt Correll to just south of Bullfinch. Ennuin station occupies the middle third of this band. None of this area is covered by any existing conservation reserve and most of the Hills are in a mining reserve. The floristic communities of the banded ironstones are obviously different from other ranges to the east. More detailed analysis is needed to determine the conservation status of the other communities identified on the Highclere Hills.

The Highclere Hills have had a long history of grazing. This is reflected in the vegetation by a high frequency of annual grasses in the 45 plots established. While the number of annual grasses is similar to that found on the Helena and Aurora Range they are much more widespread. As plots were established in the vegetation in the best condition no detailed analysis of grazing impacts is possible from our dataset. It was noted however that significant invasion of the introduced *Centaurea melitensis* (Malta thistle or Maltese cockspur) had occurred along some tracks and around old sheep camps and in areas disturbed by mining. This thistle is a native of the Mediterranean, Asia and Africa and is a widespread weed in southwest Western Australia. There is also a significant population of *Carrichtera annua* (Wards weed) around the homestead and yards.

Mineral exploration and mining have had significant local impacts along the Highclere Hills. As with most mining and exploration in the goldfields ranges there has been little effort to minimise impacts or rehabilitate areas once exploration or mining have ceased. Uncapped drill holes, open costines, abandoned drilling infrastructure, bagged drill hole material and piles of rock cores were common especially on the northern section of Ennuin. There is an urgent need for stricter environmental conditions to be placed on exploration and mining leases and for more detailed monitoring of these activities.

REFERENCES

Beard J.S. (1972) *The vegetation of the Jackson areas, Western Australia.* Vegmap, Perth.

Beard J.S. (1990) *Plant life of Western Australia.* Kangaroo Press, Kenthurst.

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

Bureau of Meteorology (1988). *Climatic averages Australia.* AGPS, Canberra

CALM (1996) *Declared Rare and Priority flora list* - 21/10/1996. Unpublished Report, CALM.

Chin, R.J. & Smith R.A. (1983) Jackson, Western Australia. 1: 250 000 geological series - explanatory notes. Geological Survey of Western Australia, Perth.

Dell J. (1985) Introduction. In: The biological survey of the Eastern Goldfields of Western Australia. Part 3 Jackson - Kalgoorlie study area. *Records of the Western Australian Museum Supplement* **23: 1-4.**

Dell J., How R.A., Newbey K.R., & Hnatiuk R.J. (1985) The biological survey of the Eastern Goldfields of Western Australia. Part 3 Jackson - Kalgoorlie study area. *Records of the Western Australian Museum Supplement* **23.**

Gibson N. & Lyons M.N. (1995) *Floristic survey of the Bremer and Parker Ranges of the Eastern Goldfields of Western Australia.* Unpublished report for the Australian Heritage Commission prepared by the Department of Conservation and Land Management.

Gibson N., Lyons M.N, & Lepschi B.J. (1997) Flora and vegetation of the eastern goldfields ranges, 1. Helena and Aurora Range. *CALMScience* **2: 231-246.**

Green J.W. (1985) *Census of the Vascular Plants of Western Australia.* Department of Agriculture, Perth.

Henry-Hall N.J. (1990) *Nature conservation reserves in the Eastern Goldfields, Western Australia. (Southern two thirds of CTRC System 11).* Unpublished Report to EPA Red Book Task Force.

Kent M. & Coker P. (1992) *Vegetation description and analysis: A practical approach.* Belhaven Press, London.

Muir B.G. (1977) Biological survey of the Western Australian wheatbelt. Part II. *Records of the Western Australian Museum Supplement* **3.**

Newbey K.R. (1985). Physical Environment. In: The biological survey of the Eastern Goldfields of Western Australia. Part 3 Jackson - Kalgoorlie study area. *Records of the Western Australian Museum Supplement* **23: 5-10.**

Newbey K.R. & Hnatiuk R.J. (1985). Vegetation and Flora In: The biological survey of the Eastern Goldfields of Western Australia. Part 3 Jackson - Kalgoorlie study area. *Records of the Western Australian Museum Supplement* **23: 11-38.**

Rye, B.L. (1995) New and priority taxa in the genera *Cryptandra* and *Stenanthemum* (Rhamnaceae) of Western Australia. *Nuytsia* **10: 255-305.**

Sneath P.H.A. & Sokal R.R. (1973) *Numerical taxonomy: The principles and practice of numerical classification.* Freeman, San Francisco.

APPENDIX 1

Flora List for the Highclere Hills.

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

Family: Adiantaceae
- Cheilanthes austrotenuifolia
- Cheilanthes lasiophylla

Family: Aizoaceae
- Gunniopsis rubra
- * Mesembryanthemum nodiflorum

Family: Amaranthaceae
- Ptilotus carlsonii
- Ptilotus divaricatus
- Ptilotus exaltatus
- Ptilotus gaudichaudii
- Ptilotus holosericeus
- Ptilotus obovatus
- Ptilotus spathulatus

Family: Anthericaceae
- Arthropodium dyeri
- Caesia occidentalis
- Thysanotus patersonii
- Thysanotus speckii
- Tricoryne tuberosa ms

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

Family: Apocynaceae
- Alyxia buxifolia

Family: Asclepiadaceae
- Rhyncharrhena linearis

Family: Asteraceae
- Actinobole uliginosum
- Angianthus milnei
- Asteridea athrixioides
- Blennospora drummondii
- Brachyscome ciliaris
- Brachyscome ciliocarpa
- Calotis hispidula
- * Centaurea melitensis
- Cephalipterum drummondii
- Chrysocephalum semicalvum
- Erymophyllum ramosum subsp. ramosum
- Gilberta tenuifolia
- Gilruthia osbornei
- Gnephosis drummondii
- Hyalosperma cotula
- Hyalosperma demissum
- Hyalosperma glutinosum subsp. glutinosum
- Hyalosperma zacchaeus
- * Hypochaeris glabra
- Isoetopsis graminifolia
- Lawrencella rosea
- Leucochrysum fitzgibbonii
- Millotia myosotidifolia
- Millotia tenuifolia
- Olearia muelleri
- Olearia pimeleoides
- Podolepis canescens
- Podolepis capillaris
- Podolepis lessonii
- Podotheca angustifolia
- Podotheca gnaphalioides
- Pogonolepis stricta
- Rhodanthe chlorocephala subsp. rosea
- Rhodanthe haigii
- Rhodanthe laevis
- Rhodanthe manglesii
- Rhodanthe oppositifolia
- Rhodanthe polycephala
- Rhodanthe rubella
- Schoenia cassiniana
- Senecio glossanthus
- * Sonchus oleraceus
- Streptoglossa liatroides
- Trichanthodium skirrophorum
- * Urospermum picroides
- Vittadinia humerata
- Waitzia acuminata

Waitzia citrina

Family: Brassicaceae
* Brassica tournefortii
* Carrichtera annua
* Heliophila pusilla
Lepidium rotundum
* Sisymbrium irio
* Sisymbrium runcinatum
Stenopetalum filifolium
Stenopetalum lineare

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

Family: Campanulaceae
Wahlenbergia preissii
Wahlenbergia tumidifructa

Family: Caryophyllaceae
* Cerastium glomeratum
* Silene gallica
Stellaria filiformis

Family: Casuarinaceae
Allocasuarina acutivalvis
Allocasuarina campestris
Casuarina pauper

Family: Chenopodiaceae
Atriplex nummularia
Atriplex vesicaria
Chenopodium curvispicatum
Enchylaena tomentosa
Maireana carnosa
Maireana georgei
Maireana radiata
Maireana trichoptera
Maireana triptera
Rhagodia drummondii
Sclerolaena densiflora
Sclerolaena diacantha
Sclerolaena fusiformis

Family: Convolvulaceae
Wilsonia humilis

Family: Crassulaceae
Crassula colorata

Family: Cuscutaceae
* Cuscuta epithymum

Family: Cyperaceae
Chrysitrix distigmatosa
Schoenus nanus

Family: Dasypogonaceae
Chamaexeros fimbriata

Family: Dilleniaceae
Hibbertia glomerosa

Family: Droseraceae
Drosera menziesii

Family: Epacridaceae
Leucopogon breviflorus

Family: Euphorbiaceae
Euphorbia drummondii
Poranthera microphylla

Family: Frankeniaceae
Frankenia desertorum

Family: Geraniaceae
* Erodium cicutarium
Erodium cygnorum

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

Family: Haloragaceae
Gonocarpus nodulosus
Haloragis gossei

Family: Lamiaceae
Hemigenia brachyphylla
Prostanthera althoferi subsp. althoferi
Prostanthera incurvata

Family: Lobeliaceae
Lobelia heterophylla
Lobelia winfridae

Family: Loganiaceae
Mitrasacme paradoxa

Family: Loranthaceae
Amyema benthamii
Amyema gibberula var. tatei
Amyema miquelii

Family: Malvaceae
Abutilon oxycarpum
Alyogyne hakeifolia
Lawrencia repens
Sida atrovirens ms
Sida calyxhymenia
Sida spodochroma

Family: Mimosaceae
Acacia acuminata
Acacia assimilis subsp. assimilis
Acacia coolgardiensis subsp. effusa
Acacia erinacea
Acacia nyssophylla
Acacia quadrimarginea
Acacia ramulosa
Acacia tetragonophylla
Acacia xerophila var. brevior ms

Family: Myoporaceae
Eremophila alternifolia
Eremophila caperata MS
Eremophila clarkei
Eremophila gibbosa
Eremophila interstans
Eremophila oppositifolia
Eremophila oppositifolia var. angustifolia ms
Eremophila scoparia
Eremophila serrulata

Family: Myrtaceae
Baeckea elderiana
Calothamnus gilesii
Chamelaucium pauciflorum subsp. thryptomenioides ms
Eucalyptus capillosa subsp. capillosa
Eucalyptus celastroides subsp. celastroides
Eucalyptus corrugata
Eucalyptus ewartiana
Eucalyptus hypochlamydea subsp. hypochlamydea ms
Eucalyptus leptopoda
Eucalyptus longicornis
Eucalyptus loxophleba
Eucalyptus oleosa
Eucalyptus salmonophloia
Eucalyptus salubris
Eucalyptus sheathiana
Eucalyptus transcontinentalis
Eucalyptus yilgarnensis
Euryomyrtus maidenii ms
Malleostemon tuberculatus
Melaleuca haplantha
Melaleuca uncinata

Family: Orchidaceae
Microtis media
Pterostylis picta
Thelymitra aff. macrophyllum
Thelymitra sargentii

Family: Papilionaceae
Daviesia nematophylla
Daviesia purpurascens
* Medicago laciniata
* Medicago minima
Mirbelia microphylla
Swainsona kingii

Family: Phormiaceae
Dianella revoluta

Family: Pittosporaceae
Billardiera coriacea

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

Family: Poaceae
* Aira caryophyllea
Amphibromus nervosus
Amphipogon strictus
Aristida holathera
Bromus arenarius
* Bromus diandrus
* Bromus rubens
Danthonia caespitosa
Elymus scaber
* Hordeum leporinum
Monachather paradoxus
* Pentaschistis airoides
* Rostraria pumila
* Schismus barbatus

Stipa elegantissima
Stipa nitida
Stipa sp. (NG & ML 2054)
Stipa trichophylla
Stipa aff. trichophylla
* Vulpia myuros

Family: Polygalaceae
Comesperma integerrimum

Family: Portulacaceae
Calandrinia corrigioloides
Calandrinia eremaea

Family: Primulaceae
* Anagallis arvensis

Family: Proteaceae
Grevillea obliquistigma
Grevillea paradoxa
Grevillea sarissa subsp. sarissa
Hakea preissii
Hakea recurva

Family: Rhamnaceae
Stenanthemum newbeyi
Stenanthemum stipulosum
Trymalium myrtillus

Family: Rutaceae
Eriostemon brucei

Family: Santalaceae
Exocarpos aphyllus
Santalum acuminatum
Santalum spicatum

Family: Sapindaceae
Dodonaea divaricata
Dodonaea inaequifolia
Dodonaea stenozyga
Dodonaea viscosa subsp. angustissima

Family: Solanaceae
Nicotiana occidentalis
Solanum cleistogamum
Solanum hoplopetalum
Solanum lasiophyllum
Solanum simile

Family: Sterculiaceae
Brachychiton gregorii

Family: Stylidiaceae
Stylidium aff. leptophyllum (NG & ML 2053)
Stylidium choreanthum
Stylidium dielsianum

Family: Surianaceae
Stylobasium spathulatum

Family: Thymelaeaceae
Pimelea microcephala

Family: Urticaceae
Parietaria debilis

Family: Violaceae
Hybanthus floribundus subsp. floribundus

Family: Zygophyllaceae
Zygophyllum eremaeum
Zygophyllum ovatum

APPENDIX 2

Floristic data set for the Highclere Hills.

The full data set (218 taxa x 45 quadrats) is provided in Cornell University Condensed Format. The species code is derived from the first three letters of the genus and species names with a further two letters from intraspecific rank where applicable except where otherwise listed below. *Aira caryophyllea* and *Pentaschistis airoides* proved difficult to consistently differentiate and have been treated as a species complex in full data set.

Non standard species codes.

Brachyscome ciliaris	BRACILs
Brachyscome ciliocarpa	BRACILa
Eucalyptus salmonophloia	EUCSALm
Eucalyptus salubris	EUCSALu
Maireana trichoptera	MAITRIc
Maireana triptera	MAITRIp
Stellaria filiformis	STEFILs
Stenopetalum filifolium	STEFILm

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ennuin dataset 218 species x 45 sites
(13I6)                                                                5
     1    21    22    23    27    30    38    53    66    73    85   111   118
   132   147   150   153   159   164   167   171   172   176   180   185   187
   191   195   205   211   218
     2     2    19    25    27    28    31    33    40    46    50    52    53
    56    58    63    71    89    92    96   103   107   110   126   131   134
   135   137   139   143   147   151   160   169   170   178   184   186   194
   203   205   212   214
     3     8    22    27    30    32    33    36    38    42    52    53    56
    60    61    89    92    96   101   129   135   137   138   139   147   151
   153   160   162   164   166   167   169   176   184   186   191   195   198
   202   205   211   218
     4    21    22    23    36    52    60    75    79   116   117   118   149
   150   152   155   164   168   171   172   176   186   191   195   218
     5    21    22    27    32    38    42    50    52    60    65    73    84
    89    97   103   111   116   118   122   132   135   137   143   147   151
   152   153   155   164   168   171   172   176   180   181   184   186   187
   195   211   212   218
     6     6     8    31    34    35    46    49    50    53    54    56    58
    60    63    69    71   107   110   113   114   129   131   133   134   139
   147   153   155   161   163   167   178   184   186   189   191   193   195
   203   212   213   214   215
     7     2     7    19    20    25    27    28    31    33    34    36    38
    40    42    46    50    51    53    54    63    68    69    71    89    92
    96   110   114   128   129   135   138   139   143   145   151   153   155
   159   160   161   162   169   174   178   186   187   193   203   210   212
   213
     8     2     8    21    27    32    40    42    46    51    52    53    56
    59    61    71    72    85    89    96   104   107   110   125   126   129
   135   137   138   139   147   151   153   154   158   160   161   162   165
   167   169   177   186   191   195   202   203   205   210   212   215
     9     1     8    21    22    23    32    38    47    52    53    67    71
    72    79    82    84    86    89    96   118   132   137   139   150   151
   152   153   157   160   164   167   171   172   176   185   192   205   211
   213   218
    10    16    22    23    29    36    60    65    71    75    78    84    86
   100   132   134   135   143   150   157   161   164   171   172   174   180
   186   191   192   205   212   218
    11     4     8    22    23    32    35    40    52    60    66    72    86
   112   115   116   118   132   135   138   139   151   153   155   167   172
   178   186   187   191   195   218
    12     4    21    22    23    35    50    52    65    66    67    73    92
   118   135   139   143   151   153   171   172   180   186   187   195   205
   218
    13     5    23    60    67    75    78   118   136   171   172   191   195
   218
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14 2 3 8 33 63 69 76 77 89 95 110 114
130 138 139 144 145 146 158 167 169 174 178 184 205
205 207 210 215
15 12 14 20 27 33 46 54 63 76 88 89 96
98 110 114 123 130 131 135 137 138 139 144 145 158
159 160 170 178 186 191 195 203 210 212 215 216
16 23 60 65 75 79 116 118 124 150 152 165 171
172 195 218
17 6 8 13 28 30 31 32 34 36 40 44 46
49 53 54 56 60 63 69 98 106 107 110 113 129
134 135 147 158 161 166 169 178 185 186 189 191 195
203 212 214 215
18 2 20 31 32 34 38 40 46 53 68 71 88
96 107 110 113 114 126 129 139 151 153 159 160 169
184 186 193 203 208 212 214 215 216
19 21 73 80 118 132 151 152 167 174 195 218
20 6 15 27 28 29 30 31 32 36 38 42 46
48 50 53 54 56 60 63 69 96 106 107 122 127
129 134 135 137 139 140 141 147 151 153 160 161 163
164 167 178 180 183 185 186 191 195 203 206 209 212
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21 4 21 22 23 27 29 36 50 59 60 67 72
73 84 86 111 150 157 164 171 172 176 180 186 191
195 205 218
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53 58 64 85 88 96 103 107 110 113 114 123 126
129 131 135 137 138 139 147 151 153 156 158 159 160
169 170 176 178 184 185 195 202 203 210 211 212 215
23 2 6 19 25 26 27 28 32 33 40 46 51
53 56 58 59 63 69 71 89 96 103 107 110 114
121 126 128 129 135 137 139 145 151 160 161 162 169
170 178 184 186 195 203 205 210 212 213 215
24 2 7 10 20 26 27 31 32 34 40 42 46
49 50 51 53 63 68 88 90 96 102 105 114 123
126 129 131 135 138 139 144 151 160 169 178 186 195
197 203 206 210 212 213 215 216
25 2 6 10 19 20 27 31 32 33 34 38 40
42 46 53 63 69 89 92 96 106 110 113 114 125
129 135 137 139 147 151 153 154 158 159 160 161 169
178 184 186 195 202 203 210 212 215
26 22 23 32 35 43 57 60 62 72 75 79 80
81 84 116 118 150 152 164 171 172 174 175 176 186
191 195 218
27 8 22 29 31 32 35 38 39 47 52 53 56
60 73 84 86 89 129 132 135 137 139 147 150 151
152 153 155 160 161 164 166 167 171 172 178 179 180
184 185 187 188 191 195 203 205 211 217 218
28 21 36 47 67 73 75 79 81 132 165 171 172
176 186 191 195 218
29 2 6 10 26 27 31 32 33 40 42 46 50
51 53 56 58 63 69 82 89 92 96 110 126 129
131 135 137 139 145 149 151 153 159 160 162 169 170
177 184 186 195 200 203 210 212
30 1 2 7 10 17 19 26 27 28 31 32 33
36 38 42 46 50 51 53 68 74 82 85 92 96
107 126 129 131 135 137 139 140 142 151 153 155 159
164 169 177 184 186 191 195 203 210 215
31 2 6 19 26 27 30 31 33 38 46 50 51
63 68 69 87 89 92 96 103 110 113 129 131 135
139 145 151 153 159 160 162 169 178 184 186 195 203
204 210 212 215
32 23 32 36 42 60 73 75 103 116 118 135 137
139 140 142 151 152 153 171 172 176 195 218
33 1 8 27 28 30 31 32 36 46 48 49 50
52 53 56 60 61 63 69 71 86 89 92 96 107
129 134 135 137 139 147 150 151 153 155 158 159 160
161 162 167 169 172 174 177 185 186 187 191 195 203
211 212 215
34 23 36 42 47 50 52 60 66 75 79 80 111
116 118 152 168 171 172 186 191 195 218
35 8 11 28 30 31 32 36 46 48 50 51 52
53 56 60 63 66 69 71 89 95 96 107 110 117
129 134 135 138 139 145 147 149 151 153 155 159 160
161 164 167 174 177 184 185 186 187 195 203 204 212
216
36 2 17 20 25 31 32 34 38 40 42 46 51
56 68 69 71 89 96 106 107 110 127 129 135 137
139 147 151 158 160 161 169 170 178 186 187 195 203
210 212 213 215
37 6 12 14 24 33 37 45 55 83 87 93 94

99 110 120 129 136 138 139 169 190 199 202 203 205
208 215
38 4 21 23 31 32 50 52 53 66 72 78 79
84 91 96 107 109 116 118 119 135 137 148 150 151
155 162 169 172 173 176 180 187 191 195 196 201 212
39 2 4 8 9 19 21 23 27 32 42 49 51
56 61 66 70 73 84 85 92 96 104 132 133 135
139 142 153 155 158 160 162 164 166 167 169 171 172
186 187 195 204 211 212 213 218
40 2 10 13 19 28 31 33 38 40 41 42 46
50 51 54 56 63 68 69 71 88 89 92 96 107
108 114 127 129 131 135 136 139 145 153 155 158 160
169 178 186 191 195 203 210 211 212 215
41 4 16 21 57 60 65 66 67 73 75 79 80
81 118 132 150 152 167 171 172 191 195 218
42 2 19 21 31 33 42 46 51 53 54 56 63
68 92 96 111 125 126 129 135 139 142 145 149 158
159 160 169 184 186 193 195 202 203 215
43 18 21 22 23 30 41 42 73 116 118 132 140
164 171 172 173 182 185 186 191 195 205 211
44 6 8 27 31 42 46 53 63 67 69 71 82
92 96 110 116 126 129 131 135 137 139 151 153 155
160 161 167 169 176 177 184 186 191 195 203 210 211
215
45 2 8 26 32 33 36 40 42 46 50 77 82
85 89 96 103 107 118 122 126 135 137 138 139 151
153 160 168 172 179 185 186 191 195 203 211 212 214
0

ABUOXY ACAACU ACACOOEFACAERI ACANYS ACAQUA ACARAM ACATET ACAXERBRACTULI
ALLACU ALLCAM ALYBUX AMPSTR AMYBEN AMYMIQ ANAARV ANGMIL ARIHOL ARTDYE
ASTATH ATRNUM ATRVES BAEELD BLEDRU BRACILa BRACILs BRAGRE BRATOU BROARE
BRODIA BRORUB BRUAUS CAEOCC CALCOR CALERE CALGIL CALHIS CARANN CASPAU
CENMEL CEPDRU CERGLO CHAFIM CHAPAUTHCHEAUS CHECUR CHELAS COMINT CRACOL
CUSEPI DANCAE DAUGLO DIAREV DODDIV DODINA DODSTE DROMEN ELYSCA ENCTOM
EREALT ERECAP ERECLA EREGIB EREINT EREOPP ERESCO ERESER ERIBRU EROCIC
EROCYG ERYRAMRAEUCCOR EUCEWA EUCLON EUCLOX EUCOLE EUCSALa EUCSALs EUCSHE
EUCYIL EUPDRU EURMAI EXOAPH GILOSB GILTEN GNEDRU GONNOD GOOBER GOOKRA
GOOMIM GOOOCC GREOBL GREPAR HAKREC HALGOS HELPUS HEMBRA HIBGLO HORLEP
HYACOT HYADEM HYAGLU HYAZAC HYBFLOFLHYDRUG HYPGLA ISOGRA LAWREP LAWROS
LEPROT LEUFIT LOBHET LOBWIN MAICAR MAIGEO MAIRAD MAITRIc MAITRIp MALTUB
MEDLAC MEDMIN MELUNC MESNOD MICMED MILMYO MILTEN MIRMIC MITPAR MONPAR
NICOCC OLEMUE OLEPIM PARDEB PENAIR PIMMIC PLAAFFHIPODANG PODCAN PODCAP
PODGNA PODLES POGSTR PORMIC PROALTALPROINC PTEPIC PTICAR PTIDIV PTIEXA
PTIGAU PTIHOL PTIOBO PTISPA RHADRU RHOCHLRORHOHAI RHOLAE RHOMAN RHOOPP
RHOPOL RHORUB RHYLIN ROSPUM SANACU SANSPI SCASPI SCHBAR SCHCAS SCHNAN
SCLDEN SCLDIA SCLFUS SENARTFISENCARCASENGLO SIDATR SIDCAL SIDSPO SILGAL
SISIRI SISRUN SOLCLE SOLLAS SONOLE STEFILm STEFILs STELIN STENEW STESTI
STIELE STINIT STIPSP STISP STITRI STRLIA STYSPA SWAKIN THEAFFMATHYPAT
THYSPE TRACYA TRAORN TRAPIL TRISKI TRITUB TRYMYR ULDCER UROPIC VELROS
VITHUM VULMYU WAHPRE WAHTUM WAIACU WAICIT ZYGERE ZYGOVA
cairn01 cairn02 cairn03 cline01 cline02 cline03 cline04 hchta01 hchta02 hchta03
hchta04 hchta05 hchta06 knoll1 knoll2 knoll3 knoll4 knoll5 knoll6 lkv1
lkv2 lkv3 mine1 mine2 mine3 sridg1 sridg2 sx1 sx2 sx3
sx4 sx5 sx6 sx7 sx8 tank1 tbp1 tbp2 tbp3 tbp4
tbp5 tbp6 tbp7 valley1 valley2

APPENDIX 3

Geographical location for the sites from the Highclere Hills.

Plot	Latitude	Longitude
cair01	30.8051	118.9950
cair02	30.8045	118.9956
cair03	30.8004	118.9915
cline01	30.7496	118.9644
cline02	30.7495	118.9670
cline03	30.7488	118.9682
cline04	30.7481	118.9783
hchta01	30.8110	118.9991
hchta02	30.8063	118.9991
hchta03	30.8029	118.9978
hchta04	30.8016	118.9970
hchta05	30.7990	118.9958
hchta06	30.7955	118.9963
knoll01	30.7431	118.9575
knoll02	30.7428	118.9571
knoll03	30.7385	118.9597
knoll04	30.7331	118.9611
knoll05	30.7236	118.9670
knoll06	30.7260	118.9762
lkv01	30.7958	118.9906
lkv02	30.7931	118.9908
lkv03	30.7905	118.9893
mine01	30.7338	118.9685
mine02	30.7357	118.9736
mine03	30.7380	118.977
sridg01	30.7706	118.9694
sridg02	30.7746	118.9720
sx01	30.7200	118.9628
sx02	30.7212	118.9621
sx03	30.7232	118.9592
sx04	30.7138	118.9587
sx05	30.7096	118.9530
sx06	30.6952	118.9543
sx07	30.6958	118.9531
sx08	30.6855	118.9570
tank01	30.7594	118.9808
tbp01	30.6695	118.9308
tbp02	30.6707	118.9346
tbp03	30.6700	118.9363
tbp04	30.6695	118.9483
tbp05	30.6688	118.9555
tbp06	30.6973	118.9266
tbp07	30.7133	118.9303
valley01	30.7763	118.9780
valley02	30.7752	118.9786