III Vegetation and Flora

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Background

A general outline of vegetation in the Kurnalpi-Kalgoorlie Study Area is as follows. Trees (5-10 m high) cover most of the Study Area. They are absent only on parts of Granite Exposures, Hills, Salt Lake Features and Sandplains in the northern half of the Study Area. Mallees (2-4 m high) and Hummock Grasslands occur on Sandplains and sandy situations on other landforms. Hills, and aprons of Granite Exposures, support tall shrubs (1.5-2.5 m high) and few low trees. Low shrubs (0.5 m high) without trees cover extensive areas only on Salt Lake Features. Although vegetation is generally low on the isolated rocky landforms and salty depressions in the Study Area, it is not necessarily more open here than elsewhere. The density of the tree cover is slightly greater in the south than in the north.

In the southern parts, some trees exceed 10 m in height and the main species are *Eucalyptus salmonophloia, E. lesouefii* and its allies, and *E. oleosa* and its allies. This changes with a slightly drier climate and the occurrence of a hardpan to low trees, including patches of mallees, of *Casuarina cristata, Eucalyptus* spp. and *Acacia aneura.* In the northeast of the Study Area only low trees of *Acacia aneura* remain. Soils containing lime near the surface have an understorey of *Maireana sedifolia*, especially in the north. In salty depressions succulent low shrubs of *Atriplex* occur, lightly wooded with low trees of *Casuarina cristata* in the south, grading to *Acacia aneura* in the north. Complex patches and mixtures of low shrubs, perennial grasses and other herbaceous plants occur in seasonally moist situations on Breakaways, Granite Exposures, and the sandy banks associated with salt lakes. Ephemeral plants (mainly Asteraceae in winter and Poaceae in summer) are thinly sprinkled over all landforms in the south of the Study Area and form tall, dense carpets in the north, given adequate rains.

Appendices I and II provide data on the detailed composition of vegetation types and the flora of the Kurnalpi-Kalgoorlie Study Area. The selection of quadrats and the parameters recorded are explained by Biological Surveys Committee of Western Australia (1984). Quadrats were broadly classified on the basis of the height, density and stratification of the vegetation, as well as the floristic composition of the tallest plants, into 45 types. The 26 sites listed in Appendix I give data on geomorphology and soils representative for each vegetation type. The occurrence of vegetation types, by landforms, is described below and summarised in Table 1.

Vegetation Descriptions

Breakaways (B): The vegetation on Breakaways in the Study Area is tall shrubland of *Acacia aneura* and *A. quadrimarginea* and is similar to that found on Granite Exposures. Associated shrubs include *Acacia craspedocarpa, Eremophila oldfieldii* ssp. *angustifolia, Eriostemon brucei, Sida calyxhymenia, Rhagodia drummondii* and *Ptilotus obovatus.* Ephemerals were generally uncommon even where soils were loamy. The herb *Nicotiana cavicola* was found in occasional shady overhangs. Otherwise,

variations in the floristic composition of Breakaways appeared to follow local patterns in landform, soil texture and chemical composition.

Drainage Lines (C): No Drainage Lines, as defined in this study, were recorded in the Study Area. Major creeklines, supporting stands of *Eucalyptus* spp., did not appear to penetrate this far south. Hills and relatively steep parts of other landforms included short, shallow creeklines in which water could be expected to flow after heavy rain. However, the vegetation of these features differed little from that adjacent, being slightly taller or denser and containing a few different species.

Dunefields (D): Dunefields closely associated with salt lakes were variable in their vegetation, bearing patches of low woodland of either *Callitris columellaris, Casuarina cristata* or *Acacia aneura. Eucalyptus* was generally uncommon but *E. oleosa* occurred in places on lower flanks of dunes as a tree mallee or low woodland. Associated low trees or tall shrubs included *Pittosporum phylliraeoides, Acacia tetragonophylla* and *Grevillea sarissa* and two species lacking in other landforms, *Dodonaea viscosa* ssp. *angustissima* and *Eremophila miniata*. The understorey varied widely, from stands of *Atriplex* spp. to stands of *Triodia scariosa*. In contrast to purely siliceous dunes associated with Sandplains, ephemerals were abundant and diverse after rain on Dunefields associated with Salt Lake Features. Characteristic species were *Gnephosis skirrophora, Erodium* spp. and *Helipterum* spp. *Casuarina cristata* formed extensive stands over mixed shrubs of various heights on rolling terrain of deep red sandy soil apart from actual Dunefields (see Salt Lake Features). In the northern parts of the Study Area these stands included some *Eucalyptus gracilis* and *Acacia aneura* among the trees or tallest shrubs, and *Eremophila scoparia* and *Maireana sedifolia* among the shrubs and low shrubs.

Granite Exposures (G): The vegetation of Granite Exposures in the Study Area was generally scrub of *Acacia* with no trees but a complex community of low herbaceous plants such as *Asteraceae*. However, within this category it was very variable according to fine differences in soil depth, moisture and chemical composition. The exposed rock surfaces bore sparse *Acacia quadrimarginea*. Where a little soil (neutral, gritty loamy sand) had accumulated on the inner apron immediately peripheral to rocks, there was an admixture of *Eremophila* spp. and *Dodonaea lobulata* and a sparse understorey of *Ptilotus obovatus*. A rich community of herbaceous plants included low grasses (e.g. *Aristida contorta*), annual legumes, resurection ferns (*Cheilanthes*), species of *Calandrinia* and *Goodenia*, and dwarf Asteraceae such as *Gnephosis tenuissima, Chthonocephalus pseudevax* and *Actinobole uliginosum*. Small areas waterlogged in winter bore annuals of *Isolepis, Schoenus* and *Triglochin*. Stunted trees of *Brachychiton gregorii* were a conspicuous feature of Granite Exposures. Outer aprons, as well as skeletal soils on granite of relatively basic composition, bore *Acacia acuminata* in the southern parts of the Study Area with scattered *Melaleuca uncinata, Pittosporum phylliraeoides, Acacia tetragonophylla, Eucalyptus loxophleba, Eremophila decipiens, Prostanthera* spp. and *Rhagodia drummondii*. Mallee of *Eucalyptus grossa* possibly

occurred locally in the southeast of the Study Area, as described for the adjacent Widgiemooltha-Zanthus Study Area by Newbey & Hnatiuk (1984). However, no stands were seen by the authors. Northwards from the south-central parts of the Study Area, the vegetation on aprons of Granite Exposures was generally a mixture of *Acacia aneura* and other *Acacia* species, over sparse *Scaevola spinescens, Cassia artemisioides* and most of the same low shrubs as listed above, and annuals including *Erodium* spp., *Podolepis* spp., *Waitzia* sp. and *Brunonia australis*. Where apron soils were alkaline, the local dominance of *Atriplex* recalled that of Salt Lake Features more than that described above. Here the herbaceous plants were *Helipterum battii, Lepidium* spp., *Senecio glossanthus, Eragrostis dielsii, Gnephosis foliata, G. burkittii, Stenopetalum robustum, Goodenia havilandii,* and scattered individuals of *Chthonocephalus pseudevax, Tetragonia* sp. and *Pogonolepis stricta*. A slight deepening of the otherwise skeletal soil allowed the entry of *Helipterum tenellum* even where lime was not present. However, *Helipterum strictum* was absent from Granite Exposures other than these alkaline aprons although the commonly associated species *Senecio glossanthus* was common there. Species excluded from the alkaline soils were *Waitzia acuminata, Helipterum pygmaeum* and *Trachymene* spp.

Where barely protruding granite was covered by a mantle of soil in parts of the Study Area, mallee of *Eucalyptus griffithsii* over hummock grass of *Triodia* was found. Mallee over hummock grass was characteristically associated with Sandplains further north, but was confined to Granite Exposures of this kind in the southernmost parts of the Study Area. Similar mantled Granite Exposures in the central parts of the Study Area bore mallee of *Eucalyptus gracilis* and *E. celastroides* over shrubs of *Acacia acuminata, A. hemiteles* and *Eremophila scoparia*, and dense ephemerals of *Helipterum battii, H. roseum* and other species.

Hills (H): Hills in the Study Area bore scrub of *Acacia* spp. On greenstone, *A. acuminata* and *A. aneura*, and on banded ironstone, *A. quadrimarginea*. Where colluvial stony soil was calcareous on Hills of basic rocks (including white quartz), the vegetation resembled that on Undulating Plains and Broad Valleys in the dominance of *Casuarina cristata* and the presence of a range of other species in common. However, *Maireana sedifolia* was more common on the lower slopes of Hills, as were *Atriplex* spp., *Pittosporum phylliraeoides* and *Cassia artemisioides*. A ground cover of ephemerals occurred in season on Hills despite the shallowness and stoniness of the soils. Their composition, particularly on basic rocks, was similar in some respects to that on a separate landform, Salt Lake Features, and had obvious links with the closely allied landform Undulating Plains.

Salt Lake Features (L): Salt Lake Features generally bore low shrubs of Chenopodiaceae with scattered patches of *Casuarina cristata*. Other low trees were *Myoporum platycarpum* in the south, and *Acacia aneura* in the north where trees tended to be confined to groves in the general cover of chenopodiaceous shrubs.

The salt lakes were virtually bare, featuring only low shrubs of *Halosarcia* growing

around the margin or extending patchily on to a few lake floors. The main species were *Halosarcia halocnemoides, H. doleiformis, H. indica* and *H. pruinosa*, and the only other perennials were *Frankenia* spp. and *Disphyma clavellatum*. Ephemerals grew well wherever the salinity was not extreme: *Brachycome* spp., *Cotula australis, Plantago* sp., *Stenopetalum robustum, Senecio* spp., *Daucus glochidiatus, Helipterum strictum* and *Swainsonia* spp. germinated in winter and several grasses (such as *Eragrostis dielsii*) and a few plants of *Dysphania simulans* in summer.

On slightly raised flats where soil had accumulated during past periods of aeolian activity, low shrubs of *Atriplex* (e.g. *A. hymenotheca*) occurred. Heavy, relatively nutrient-rich soils bore *Cratystylis subspinescens* and scattered *Sclerostegia disarticulata*, or *Muehlenbeckia cunninghamii* by discrete claypans in the north of the Study Area. Localities with slightly improved moisture relations immediately next to salt lakes supported scattered shrubs, up to 3 m high, of *Eremophila* spp. and *Lycium australe*. Low trees of *Eremophila miniata, Heterodendrum oleifolium, Pittosporum phylliraeoides* and *Casuarina cristata* entered where relatively deep substrates occurred on the broad plain surrounding salt lakes, with an understorey of *Maireana amoena* and other dwarf shrubs and perennial herbaceous plants characteristic of subsaline soils. The fine but loose sand or sandy loam piled into small dunes bore patches of low woodland of e.g. *Acacia aneura* or *Callitris columellaris* (see Dunefields). On the northwestern margins of salt lakes the shallow soils on eroded bedrock bore, in the south of the Study Area, low woodland of *Eucalyptus lesouefii* transitional to Undulating Plains, as described for the Widgiemooltha-Zanthus Study Area (Newbey & Hnatiuk 1984). Relatively well-grown *Casuarina cristata* with a variable and mixed understorey of *Eremophila, Olearia* and other species became dominant on plains of reddish sandy loam on the outer parts of Salt Lake Features. The soil texture graded with depth from sandy loam through to clay loam, with soft nodules of lime in the subsoil. There the most siliceous soils bore scattered *Eucalyptus oleosa* over hummock grass (*Triodia scariosa*) associated with ephemerals not found among hummock grass on Sandplains. Chenopodiaceae were rare in these local areas.

On dark red-brown alluvium with a hardpan, adjacent to salt lakes, in the northeastern parts of the Study Area, *Casuarina cristata* (and patches of *Eucalyptus gracilis*) over *Eremophila scoparia* was patchy, giving way extensively to *Acacia aneura*. On flats of sandy loam were open stands of *Hakea arida* over *Maireana pyramidata* and some *Cratystylis subspinescens* over ephemerals of e.g. *Helipterum roseum*. The slightly raised margins of bare lakes, and the hummocky surfaces nearby, featured dense low stands of *Atriplex* and scattered *Sclerostegia* which were treeless except on crests of low dunes or in saucers. All plants were lower than 5 m (*Casuarina cristata, Callitris columellaris, Pittosporum phylliraeoides, Acacia* spp., *Heterodendrum oleifolium, Hakea arida, Lycium australe*). The abundant ephemerals in season included *Helipterum roseum* (tending to salty and loamy soils), *H. craspedioides* (tending to the opposite), *H. charsleyae* (especially on open saucers), *H. maryonii*, **Erodium crinitum*, (asterisk suffix denotes a naturalized alien species) *Euphorbia drummondii, Velleia*

rosea and *Goodenia berardiana*. Where the substrate was kopi (solid gypsum), there were patches of *Maireana sedifolia* and *Grevillea sarissa*.

Calcareous Plains (P): Although extensive in the adjacent Widgiemooltha-Zanthus Study Area, Calcareous Plains were limited to the south eastern part within the Kurnalpi-Kalgoorlie Study Area. Some situations in Broad Valleys had similar calcareous subsoils and might be marginally categorised as Calcareous Plains. They supported similar woodland of *Eucalyptus salmonophloia* or *E. longicornis* with an understorey of *Maireana sedifolia*. Flat parts of Undulating Plains near Kalgoorlie bore woodland over *Atriplex* on a buffy or pinkish loam, with abundant annuals of *Stipa* spp. and ephemerals of *Plantago* sp. and *Gnephosis skirrophora*, a species restricted to lime-rich soil (although not necessarily with actual calcrete or limestone present). Other ephemerals included **Bromus diandrus*, **Sinapis arvensis*, **Hedypnois rhagadioloides*, *Zygophyllum* spp., *Cotula coronopifolia*, *Helipterum roseum*, *H. tenellum* (uncommon) and **Sonchus oleraceus* (on open ground as well as in the shelter of shrubs). The distinction between vegetation on Calcareous Plains and Broad Valleys or Undulating Plains was therefore arbitrarily drawn in the Study Area.

Tall shrubs of *Acacia hemiteles* and *Eremophila scoparia* formed a sparse mid-stratum throughout vegetation on Calcareous Plains in the Kurnalpi-Kalgoorlie Study Area. In places where *Maireana sedifolia* was absent they formed the understorey. In some other situations, *Casuarina cristata* was virtually the only tree present. The ephemerals on Calcareous Plains were sharply delimited from those on acidic to neutral soils, as seen for example in the absence of *Velleia rosea* from Calcareous Plains.

Sandplains (S): The typical vegetation on Sandplains in the Kurnalpi-Kalgoorlie Study Area was dense scrub of *Acacia* spp., *Allocasuarina* spp. and *Melaleuca* spp. On sand with lateritic gravel on remnants of the Tertiary peneplain, the composition was mainly *Acacia* aff. *coolgardiensis*, *A. ramulosa* and *Eucalyptus leptopoda* over soft perennial grasses (e.g. *Amphipogon*, *Eragrostis*) as well as dwarf shrubs of Myrtaceae (e.g. *Wehlia thryptomenoides*, *Baeckea* aff. *cryptandroides*, *Thryptomene urceolaris*). Hummock grass, *Triodia scariosa*, was represented by scattered plants. The few annuals or ephemerals seen included *Waitzia acuminata* and *Gnephosis pusilla*. While the widespread vegetation on Sandplains in the northern parts of the Eastern Goldfields (mallee over hummock grass) was also found in sandplains in the Kurnalpi-Kalgoorlie Study Area, it only occurred on small areas of particularly loose sand of colluvial origin. On deep sand on gentle slopes, Mallee of *Eucalyptus oldfieldii* and hummock grass of *Triodia scariosa* dominated the upper and lower stratum respectively, ephemerals were virtually absent and tall shrubs of Proteaceae were present in contrast to the widespread dense scrub described above. In addition, *Cassia artemisioides* and *Prostanthera* sp., not found on deep sand, were replaced by *Callitris*, *Westringia*, *Phebalium*, *Santalum* and *Leptomeria*. *Grevillea juncifolia*, *Grevillea didymobotrya*, *Melaleuca uncinata*, *Eremophila* sp., *Baeckea muricata*, *Keraudrenia integrifolia* and *Leptospermum roei* were present in both types in small and variable numbers, but *Acacia tetragonophylla*, *A. hemiteles*, *A. aneura*, *Cassia nemophila*, *Helipterum adpressum* and *Scaevola*

spinescens were minor components of dense scrub on gravelly Sandplains not penetrating the deep colluvial sand deposits. Some Sandplains in the Study Area were barely distinguishable from sandsheets on Granite Exposures. There the mallee were mainly *Eucalyptus gracilis*, with *Acacia merrallii* over *Triodia* and various low shrubs.

Near the transition to Broad Valleys, sheets of red sandy loam overlay lime subsoils on Sandplains. These bore tree mallee of *Eucalyptus transcontinentalis* over shrubs of *Scaevola spinescens, Westringia rigida* and *Olearia* spp. with scattered hummock grass of *Triodia scariosa*. Scattered broombush of *Eremophila paisleyi* was distinctive of such situations. Tree mallee of *Eucalyptus concinna* on flats of loam over lime hardpan adjacent to Sandplains was regarded as part of Broad Valleys. Comparison of the *Eucalyptus oldfieldii* and *Triodia scariosa* community on deep, pure sand with this type showed that perennials of the families Cupressaceae, Lamiaceae, Poaceae, Proteaceae, Rutaceae and Sterculiaceae were replaced by Amaranthaceae, Asteraceae, Caesalpiniaceae, Chenopodiaceae, Loranthaceae, Solanaceae and Zygophyllaceae, although sparse *Alyxia buxifolia, Acacia acuminata* and *A. colletioides* were present in both types and species-richness within the communities was similar (about 25 spp.). Within the genus *Acacia, A. heteroneura, A. inamabilis* and *A.* aff. *jutsonii* were replaced by *A. aneura, A. densiflora, A. hemiteles* and *A. ramulosa*. In vegetation of *Eucalyptus transcontinentalis* referred to above, Proteaceae were present (e.g. *Grevillea acuaria*) and *Acacia aneura* was absent.

Undulating Plains (U): Looking at Undulating Plains in the Study Area as a whole, the following generalised description can be given. Woodland was the general cover, with an understorey of tall shrubs on shallow soils and an understorey of low shrubs where soils were strongly calcareous. On the driest or most excessively drained sites the trees were stunted and scattered, and the understorey correspondingly more prominent. Throughout, herbaceous ground cover was fairly well-developed in season with a mixed composition reflecting minor variation in the soil.

Within this framework there was a definite change in both vegetation structure and floristic composition from south to north within the Study Area. Basically the vegetation graded from woodland of *Eucalyptus* in the south to open low woodland of *Casuarina cristata* over low shrubs of *Maireana* in the north. Shallow soils on rocky ridges bore relatively dense stands of tall shrubs of *Acacia* spp. such as *Acacia acuminata*.

Occurring over most areas of Undulating Plains in the Study Area was either *Eucalyptus lesouefii* or its closely related congener *E. clelandii*, although the plants were taller and more uniformly distributed in the south than in the north. The same was true of *Eucalyptus salmonophloia* although this species was confined to relatively deep, well-watered substrates. Tall trees of *Eucalyptus torquata* found on ultramafic soil in the south were replaced by *Casuarina cristata*, and at least by *Acacia aneura*, in the north.

In the southern parts of the Study Area, *Eucalyptus transcontinentalis, E. salubris* and several other species of trees occurred in patches. Stately, well-spaced trees of *Eucalyptus salmonophloia* grew with an understorey of *Maireana sedifolia* on flats, resembling Calcareous Plains. A possible distinction was that *Acacia hemiteles*, a species apparently

restricted to relatively deep soils in this sector, was absent from this type on Undulating Plains. However, this species is favoured by fire. Trees of *Eucalyptus lesouefii* over tall shrubs of *Eremophila oldfieldii* ssp. *angustifolia* gave way to patches of low trees of *Casuarina cristata* over low shrubs of *Maireana sedifolia* on shallow soils over greenstone. Low-lying areas locally bore low trees of *Eucalyptus salubris* over shrubs of *Atriplex*, with herbaceous species such as *Atriplex inflata* and *Tetragonia eremaea* on the ground after rain. *Eucalyptus oleosa* was not a common species on Undulating Plains in the south of the Study Area, but grew in a few creeklines with mallee of *Eucalyptus gracilis* and scattered *Pittosporum phylliraeoides*. A few creeklines bore alternative cover of *Maireana pyramidata* with only scattered emergent *Acacia murrayana* and occasional mallee of *Eucalyptus celastroides*. Flat wash zones bore an ephemeral community dominated by *Helipterum charsleyae* and *Cephalipterum drummondii*. On the deep calcareous soils of narrow colluvial flats between ridges of banded ironstone in the Kalgoorlie area, the understorey to *Eucalyptus* spp. comprised *Atriplex, Cratystylis, Maireana, Sclerostegia* and occasional *Frankenia* and *Halosarcia*. Scattered tall shrubs were *Eremophila oldfieldii* ssp. *angustifolia* and *E. oppositifolia*. Common annuals and ephemerals included *Sclerolaena* spp., *Zygophyllum* spp. *Lepidium* spp., *Calandrinia* spp., *Stenopetalum* spp., *Tetragonia* sp., *Crassula* sp. and *Senecio* sp. Finally, Cole (1973) reported certain localities in the southwest of the Study Area with a relatively stunted, open understorey including *Hybanthus floribundus* and *Dodonaea microzyga*, indicating rocks very rich in nickel. However, no areas of this kind were visited by the authors.

Eucalyptus torquata low woodland found in the extreme south of the Study Area was similar to that described for the Widgiemooltha-Zanthus Study Area by Newbey & Hnatiuk (1984). Trees of *Eucalyptus torquata* 6-7 m high were dominant, the only other tree species being *E. gracilis* (canopy cover 1%). Five separate strata of shrubs (canopy cover of each less than the 5%) could be distinguished from 0.5 m to 2.5 m high, although shrubs 0.5 - 1 m high were very sparse. Tall shrubs included *Acacia* spp., *Eremophila interstans* and *Santalum spicatum*, medium-high shrubs *Atriplex nummularia* and *Dodonaea lobulata*, and low shrubs mainly *Ptilotus obovatus* var. *obovatus* and *Sida calyxhymenia*. Annuals had a canopy cover of less than 1% and consisted of *Senecio glossanthus* and *Zygophyllum ovatum*.

From about the centre of the Study Area northwards, on virtually flat Undulating Plains, tall plants of *Eucalyptus* shrank to restricted groves (though not confined to low-lying areas). The tree stratum became dominated by *Acacia aneura* (showing a slight grove pattern in places), *Casuarina cristata* and some *Heterodendrum oleifolium*, with a general understorey of *Maireana sedifolia* as in the south of the Study Area. Patches of tall shrubland of *Acacia acuminata* entered. *Eucalyptus lesouefii* still occurred over *Casuarina cristata* and *Acacia* in places, while flats with gibber quartz bore *Acacia aneura* and *Maireana sedifolia* with some *Eucalyptus salmonophloia*. Creeklines bore *Heterodendrum, Acacia aneura* and *A. tetragonophylla* (with a patchy understorey of *Ptilotus obovatus*) over *Helipterum charsleyae, H. craspedioides, Goodenia berardiana,*

Velleia rosea, Cephalipterum drummondii and *Calotis multicaulis*. Broader drainages bore *Casuarina cristata* over *Maireana pyramidata* with the lime hardpan, at 10 cm depth, exposed by rain-scoured channels in places.

In the mixed, low open woodland extensive on lime hardpan soil in the central parts of the Study Area, patches of *Eucalyptus* spp. grew to 12 m, patches of *Casuarina cristata* to 9 m and patches of *Acacia aneura* to 7 m. The stands were poorly stratified with shrubs of various heights forming an understorey of patchy composition. *Eremophila scoparia* was characteristic and *Acacia hemiteles* appeared to grow even where hardpan was formed. Low shrubs of Chenopodiaceae, as usual, hugged shallow calcareous earths and in a few areas of this kind trees were sparse. *Cephalipterum drummondii, Gnephosis skirrophora, Helipterum* spp. and *Stipa trichophylla* were common. *Helipterum fitzgibbonii* was found under tall shrubs of *Acacia quadrimarginea* on banded ironstone.

In the northern parts of the Study Area, *Casuarina cristata* over *Maireana sedifolia* became the general cover on the higher-lying parts of Undulating Plains, interrupted by patches of *Acacia aneura* or individuals of *Brachychiton gregorii, Eucalyptus salmonophloia* and *Heterodendrum oleifolium*. Extensive rises, with a noticeably pale, pinkish soil, lacked trees other than scattered *Casuarina cristata, Acacia aneura, Pittosporum phylliraeoides, Eremophila oldfieldii* ssp. *angustifolia* and *Hakea arida*. Stands of *Atriplex vesicaria* and a few *A. nummularia* were scattered through the *Maireana sedifolia*, which gave way on relatively low-lying gibber plains to the first patches of *M. pyramidata*. A common species of ephemeral was *Helipterum charsleyae* wherever soil had accumulated. On the other hand, patches of *Acacia acuminata* lacked the *Maireana* understorey; the same was true of a few pure stands of *Acacia aneura* on some colluvial flats, or on certain ridges (bedrock type unknown) in the extreme north where the main ephemerals were *Helipterum craspedioides* with an admixture of *Velleia rosea* and *Cephalipterum drummondii*.

Broad Valleys (V): Vegetation patterns may be described separately for the northeastern, drier and mainly granite, and southwestern, moister and mainly greenstone, halves of the Study Area. Within both segments gradients in the vegetation can be traced from south to north.

In the northeastern half of the Study Area, woodland of *Eucalyptus salmonophloia* with shrubs of *Alyxia buxifolia, Scaevola spinescens* and *Cassia nemophila*, and the mistletoe *Amyema miquelii*, was similar to that found in the immediately adjacent Widgiemooltha-Zanthus Study Area (Newbey & Hnatiuk 1984). Patches of clay had lower, more stratified plants with an admixture of *Casuarina cristata, Eucalyptus salubris, E. campaspe* and *Maireana* species. Patches of sand associated with Granite Exposures had *Eucalyptus transcontinentalis* (and mallee of *E. gracilis*) over *Acacia hemiteles* and *A. acuminata* over ephemerals, e.g. *Velleia rosea*, with stands of *Acacia aneura, Eremophila granitica* and *Cratystylis subspinescens*. Farther north within the Study Area, the vegetation was low woodland of *Acacia aneura* with scattered low shrubs and a complete cover of herbaceous plants in season. In places, scattered *Casuarina cristata* and *Acacia aneura* and occasional *Brachychiton gregorii* grew in

scrub of *Acacia brachystachya* and other *Acacia* species. Understorey shrubs included *Solanum lasiophyllum* (especially where overgrazed), *Prostanthera wilkieana, Scaevola spinescens, Eremophila granitica* and sparse sheltered tufts of grasses such as *Monachather paradoxa.* The ephemerals consisted of *Waitzia acuminata, Actinobole uliginosum, Helipterum maryonii* (under shrubs), *Brunonia australis, Erodium* spp. *Isoetopsis graminifolia, Calandrinia* spp., *Goodenia* spp. and others, 1 cm to 1 m high.

Eucalyptus woodland occurred as outlying patches in the north of the Study Area on deep, calcareous soils while *Acacia aneura* occurred as outlying patches as far south as Kurnalpi townsite, associated in a general way with Granite Exposures. In the extreme north, soils lacked the dark pavement widespread elsewhere and the stands of *Acacia aneura* were virtually pure apart from *Bursaria occidentalis.* Here *Casuarina cristata, Eucalyptus* spp. and *Acacia hemiteles* hugged relatively deep, low-lying soils. The absence of *Maireana sedifolia* sharply distinguished Broad Valleys from Undulating Plains, and correlated with the change from a calcareous to a mainly siliceous hardpan in the soil.

In the southwestern half of the Kurnalpi-Kalgoorlie Study Area, Broad Valleys bore woodland of *Eucalyptus salmonophloia, E. salubris* and, in places, *E. lesouefii*, with stands in the extreme south of *E. transcontinentalis* and *E. flocktoniae.* This gave way northwards to open woodland of *Eucalyptus salmonophloia* over *Maireana sedifolia*, varied by extensive patches of mallee of *Eucalyptus oleosa* over hummock grass of *Triodia scariosa* on sandy Broad Valleys located southeast of Salt Lake Features. In the north of the Study Area, woodland of *Eucalyptus salmonophloia* formed only outlying stands. Here the vegetation was open woodland of *Eucalyptus oleosa* with low trees of *Casuarina cristata* and *Acacia aneura* and, in places, *Eucalyptus concinna.* Low open woodland of *Casuarina cristata* and *Acacia aneura* over *Maireana sedifolia* occupied situations transitional to Undulating Plains.

On Broad Valleys adjacent to Sandplains, *Eucalyptus concinna* was locally more common than co-existing *E. oleosa* and had a relatively dense layer of shrubs of various height. Taller than 2 m (cover 5%) was *Acacia ramulosa*; 1.5 - 2 m (cover 35%) were *A. acuminata* and some *Eremophila oldfieldii* ssp. *angustifolia*; and 1-1.5 m (cover 5%) were *Acacia tetragonophylla, A. colletioides, A. hemiteles, A. densiflora* and *Exocarpos aphyllus.* Shrubs of 0.5 - 1 m (very open) were the usual *Cassia nemophila, Dodonaea lobulata, Scaevola spinescens, Alyxia buxifolia* and *Eremophila* spp., and dwarf shrubs, similarly sparse, were *Maireana georgei, Olearia muelleri* and some *Ptilotus obovatus, Maireana triptera* and *Solanum oldfieldii* spp. *plicatile.* Herbaceous plants such as *Zygophyllum* spp. formed a very open ground cover. On shallow soils over calcrete hardpan, at similar transitions from Broad Valleys to Sandplains or Granite Exposures, the annuals and ephemerals were a mixture of elements: *Stipa* spp. *Helipterum fitzgibbonii, H. pygmaeum, Ptilotus gaudichaudii, Waitzia acuminata, Goodenia* spp., *Velleia* spp., *Calandrinia polyandra, Vittadinia* sp., *Aristida contorta, Brunonia australis,* and *Crassula exserta*, and to a lesser extent *Isoetopsis graminifolia, Lepidium* sp., *Menkea* spp., *Gnephosis tenuissima* and *Wahlenbergia* sp. This ephemeral

community showed strong affinities to that of similar soils on Undulating Plains but lacked characteristic elements of the local stands of *Acacia aneura* on Broad Valleys such as species of *Actinobole, Podolepis, Calotis hispidula, Helipterum maryonii, Plantago debilis, Trachymene ornata, Erodium* sp., *Brachycome* spp., *Daucus glochidiatus.*

Vegetation on parts of both Broad Valleys and Undulating Plains was similar to that on rocky shallow soil (vertebrate quadrat No. 6W-03 included both). The distinction was a largely arbitrary one in this Study Area where a lime hardpan masked a wide range of landforms. *Maireana sedifolia* and *Atriplex* were generally uncommon in both Broad Valleys and Undulating Plains of this sort. Widely occurring species shared, besides the common *Casuarina cristata*, were *Santalum spicatum, Dodonaea lobulata, Cassia nemophila, Olearia muelleri, Solanum nummularium, Solanum lasiophyllum, Stipa elegantissima, Ptilotus obovatus, Acacia aneura, A. tetragonophylla, Scaevola spinescens, Eremophila oldfieldii* ssp. *angustifolia* and *E. decipiens* — i.e. most of the species in each type. Differentiating the rocky shallow soils was the presence of *Cheilanthes, Brachychiton, Acacia quadrimarginea, Melaleuca uncinata* and *Thryptomene urceolaris*; and possibly *Acacia ramulosa, A. acuminata* and *Sida corrugata.* Differentiating the hardpan soils where *Casuarina cristata* dominated, was the presence of *Acacia colletioides, Eremophila parvifolia, E. latrobei* and possibly the commonness of *Cassia nemophila.* Other, more general species differentiating the rocky shallow soil were *Cassia artemisioides* and perhaps *Pittosporum phylliraeoides*, balanced by *Sclerolaena* spp. and possibly *Exocarpos aphyllus* and *Maireana* (spp. in general) on the hardpan soils.

Discussion

The Kurnalpi-Kalgoorlie Study Area contains most of the landforms found in the Eastern Goldfields. Breakaways and Sandplains are more common than in the Widgiemooltha-Zanthus Study Area to the south while the reverse is true for Calcareous Plains (Newbey 1984).

The flora of the Kurnalpi-Kalgoorlie Study Area had not previously been systematically recorded and documented. Consequently, gaps in the known range of many species of plants were filled. During our survey 3 ferns, 2 conifers and 486 species of flowering plants were recorded from the Study Area. Families with the largest numbers of species were Asteraceae (77 spp.), Leguminosae (broad sense) (50 spp.), Chenopodiaceae (44 spp.), Myrtaceae (42 spp.) and Poaceae (33 spp.). Genera with numerous species were *Acacia* (33 spp.), *Eucalyptus* (31 spp.), *Eremophila* (24 spp.), *Helipterum* (17 spp.) and *Maireana* (16 spp.). A comparison with the flora of the adjacent Widgiemooltha-Zanthus Study Area shows the disappearance of families typical of the South-Western Botanical Province, e.g. Droseraceae, Epacridaceae, Hypoxidaceae, Oxalidaceae and Rubiaceae as the Kurnalpi-Kalgoorlie Study Area is entered (Newbey & Hnatiuk 1984).

The Kurnalpi-Kalgoorlie Study Area is not known to contain extant populations of any Declared Rare Flora (Government Gazette 1989). Although no plant taxa are

apparently restricted to the Study Area, some have restricted distributions and several are endemic to the Eastern Goldfields or part thereof (e.g. *Eucalyptus woodwardii*). Other species have broad distributions but narrow habitats and might be threatened by degradation of specific environments, e.g. the perennial composite *Kippistia suaedifolia* which grows on small, localized pockets of kopi.

The soils of the Kurnalpi-Kalgoorlie Study Area, with their widespread subsoil lime hardpan, may be regarded as transitional from the floury, calcareous soils of southern parts of the Eastern Goldfields to the siliceous, red and brown hardpan soils of the dry country to the north (Teakle 1936). The soils on slightly elevated plains (Granite Exposures, Sandplains and parts of Undulating Plains) lack quartz pebbles, desert vanish or lime at the surface. The soils in those parts of the Study Area underlain by greenstone are dusky red or dark reddish brown loams, clay loams and clays, those parts underlain by granite dark reddish brown (in places approaching dark red) very sandy loams to clay loams. Lime accumulations occur widely in the subsoils in most landforms in the Study Area, to an extent not known in Study Areas immediately north or south. Surface porosity is greatest on the loosest soils of Dunefields and Sandplains, but elsewhere there is a soil crust. Shallow soils cover bedrock outcrops, e.g. skeletal granitic loamy sand. Elsewhere the two main subsoil features are ironstone gravel, a feature of ancient (Tertiary) Sandplains, kankar (lime nodules) in relatively heavy soils with a relatively moist climate, or lime hardpan at various depths (elsewhere). The lime hardpan is a form of calcrete (Carlisle 1978).

Little evidence of fire was found in the Kurnalpi-Kalgoorlie Study Area. Even under favourable climatic conditions, much of the woodland cover would hardly carry fire. The stands are generally very open with little accumulation of litter. The low plants are mainly non-flammable Chenopodiaceae, and annuals and grasses are generally sparse. Low woodlands in the adjacent Widgiemooltha-Zanthus Study Area have not burnt since pastoralists first acquired leases in the area (Newbey & Hnatiuk 1984). *Halosarcia* low shrubland is succulent and has not been known to burn. Mallee over hummock grass, followed by dense scrub of *Acacia* and *Allocasuarina* over a similar grassy understorey, are the vegetation types most likely to burn. The former use of fire by Aboriginal peoples in the Study Area is unknown although it is generally recognised that hummock grassland in central Australia was regularly burnt by these nomadic hunter-gatherers (Kimber 1983).

The plants in mallee over hummock grass are obviously adapted for survival of relatively frequent fires, judging from their floristic composition and regeneration methods of this community. What appears to be fire-prone vegetation is dominated by plants which not only have stout protective fruits retaining the seeds long after maturity, but also regenerate from lignotubers. Tightly sealed woody fruits characterize the main species, *Eucalyptus oldfieldii*, as well as *Melaleuca uncinata, Hakea francisiana* and *Callitris preissii*. On some of these plants the fruits on older branches or dead stems were dehisced at the time of detailed inspection of one sample stand. Trees are absent from this type of vegetation. The following percentages of plant cover in the upper stratum are

contributed by the tall shrubs of Myrtaceae, 80% (4 spp.), Proteaceae, 10% (2 spp.), Cupressaceae 5% (1 sp.). Mimosaceae contribute only 4% (4 spp.) and the rest is made up by small numbers of Santalaceae and Casuarinaceae. Similarly, perennial plants lower than 1.5 m in the mature vegetation consist of fire-adapted Poaceae (75%, 2 spp.), Myrtaceae (15%, 4 spp.) and Proteaceae (3%, 1 sp.) with only traces of 10 other families including Mimosaceae, Myoporaceae, Sterculiaceae, Rutaceae, Goodeniaceae, Apocynaceae, and Lamiaceae. However, the composition of the lower stratum changes dramatically for the first few years after fire, as there is a flush of short-lived semi-woody species such as Malvaceae and Solanaceae, as well as most of the few annuals ever found in this environment. These observations suggest that on the most excessively drained, nutrient-poor soils, fire is a natural feature of the vegetation calling for special adaptation for the protection of rootstocks and seeds.

The establishment of major towns in the Kurnalpi-Kalgoorlie Study Area brought with it disturbance of the vegetation. The main impact by Europeans has been cutting of timber over large areas of Undulating Plains and Broad Valleys and extensive grazing by stock on Salt Lake Features. The greatest modification has taken place immediately around Kalgoorlie-Boulder and Coolgardie in the southwest of the Study Area. Much of the vegetation was cleared, leading to the establishment of introduced weeds. This impact can be observed in lesser degree in local foci at various old mining centres and mineral exploration and mine sites on Undulating Plains scattered through the Study Area. Quantitative comparison of modified with natural areas was not possible for several reasons. Areas cut over were not clearly defined and cutting may have occurred more than once. Some of the area cut for timber has also been grazed at various intensities for decades. Broad impressions are that the cut-over stands today bear fewer plants of certain species per unit area, particularly tall shrubs of *Melaleuca* spp. upon which pastoralists may have relied for fence posts (K.R. Newbey, pers. comm.). These factors notwithstanding, the proclamation of a so-called "Green Belt" and the modification of mining practices in relatively recent times has resulted in a surprising recovery of the woodlands over wide areas.

The Kurnalpi-Kalgoorlie Study Area straddles the boundary between two major phytogeographic areas. The southern and southwestern third of the Study Area falls within the Eremaean Botanical Province, represented by the Austin Botanical District, and the remainder is in the South-western Interzone, represented by the Coolgardie Botanical District. This boundary, the so-called "mulga-eucalypt line", marks the transition from low woodland of *Acacia*, which covers the drier northern parts of the eastern Goldfields (Beard 1976) to woodland of *Eucalyptus*, which covers the moister southern parts of the Eastern Goldfields (Beard 1980). Owing to the gentle climatic gradient and generally level terrain, this boundary cannot be sharply defined. However soil changes resulting from climate reinforce purely climatic effects to produce a more abrupt discontinuity in the vegetation than might be predicted from climate alone.

The Study Area contains a considerable proportion of the woodland and low woodland of the South-western Interzone but is dominated by vegetation referable to

the Eremaean Botanical Province. Some floristic elements of the Southwestern Botanical Province occur in the Study Area. These are mainly associated with Granite Exposures and Sandplains and decrease in a northeasterly direction. This is seen as a response partly to climate but mainly to base-poor, iron-rich soils. Most soils in the Kurnalpi-Kalgoorlie Study Area are alkaline, although Broad Valleys in the Eremaean Botanical Province are neutral and siliceous. Vegetation dominated by *Maireana sedifolia* represents an outlier of vegetation systems of the Nullarbor Plain (Beard 1972, 1975).

Much of the Kurnalpi-Kalgoorlie Study Area supports woodland and low woodland typical of Undulating Plains and associated Broad Valleys. That of the northern parts continues, with minor changes, into the adjacent Edjudina-Menzies Study Area. The same is true of the southern parts which abut the Widgiemooltha-Zanthus Study Area. The western border of the Kurnalpi-Kalgoorlie Study Area roughly coincides with the edge of a major area of predominantly Southwestern Interzone thickets on sandy, lateritic and gravelly soils which penetrate from the Boorabbin-Southern Cross Study Area in minor tongues.

Acacia aneura is characteristic of Red Earths on Broad Valleys in the northern parts of the Eastern Goldfields. This species does not occur in pure stands on Broad Valleys in the Kurnalpi-Kalgoorlie Study Area, although it does occur widely on this landform in the northern parts of the Study Area in admixture with other tree species. In the southern half of the Study Area, *Acacia aneura* is characteristic of landforms with shallow soils and excessive drainage, rather than Broad Valleys.

Many plant species besides *Acacia* spp. and *Eucalyptus* spp. observe the mulga-eucalypt line. An obvious example is *Amyema maidenii*, a parasite on *Acacia aneura*. *Myoporum platycarpum* of the south of the Study Area is replaced on similar calcareous soils north of about Karonie by the ecologically similar *Eremophila longifolia*. Numerous ephemeral species of Asteraceae enter just north of the mulga-eucalypt line, forming a tall, continuous carpet of herbaceous plants absent from the Eastern Goldfields south of the Kurnalpi-Kalgoorlie Study Area.

Vegetation types as well as individual species undergo shifts in habitat from south to north in the Kurnalpi-Kalgoorlie Study Area. Tall shrubland of *Acacia acuminata* grows on Granite Exposures in the south. However, it generally avoids these in the north, where it is instead found on Undulating Plains (rises with relatively shallow soil) with a concomitant change in the form of the species from broad phyllodes to narrow phyllodes. The same is true of *Acacia aneura* although this species has a broader range of habitats and occupies mainly Broad Valleys in the north. *Acacia craspedocarpa* and *Acacia tetragonophylla*, while nowhere dominant, are similarly confined to Granite Exposures in the south but shift to Broad Valleys in the north, and *Brachychiton gregorii* follows the pattern but extends as an occasional component over several landforms. *Eremophila scoparia* occupies Undulating Plains in the south compared to Salt Lake Features in the north. *Maireana pyramidata* is confined to creeklines in the south but abandons these for the plains in the north. Mallee (*Eucalyptus gracilis*) over hummock

grass (*Triodia scariosa*) is characteristic of sandy situations in Salt Lake Features in the Widgiemooltha-Zanthus Study Area to the south (Newbey & Hnatiuk 1984) but is rare in the same situations in the Kurnalpi-Kalgoorlie Study Area.

The height and density of vegetation strongly reflect the moisture content of soils. In the Kurnalpi-Kalgoorlie Study Area, the vegetation on granitic landforms essentially consists of tall shrubland, mallee over hummock grass, and low woodland or tall mallee over broombush. The tall shrubland grows on the rockiest soils (rock outcrops or gravel plains) and the mallee on the sandiest soils. The low woodland over broombush occurs on loam to loamy sand over lime, and varies in height, density and stratification according to slight variations in soil, drainage and the depth of rock fragments or hardpan.

On and around Granite Exposures, vegetation types occur essentially in concentric rings. Skeletal soils on the otherwise base rock and at the immediate periphery support a variable cover of low to tall shrubs. These tolerate long dry periods alternating with waterlogging, despite the benefit of a relatively rich supply of nutrients in the fresh bedrock. Granitic bedrock clearly bars penetration of tree roots and limits the vegetation to relatively low plants. A range of perennial and annual herbaceous plants occurs.

Away from exposures of bedrock, vegetation height on the uplands over granite ranges from 4 m to 12 m. Trees occur only on loam and clay loam. Substantial deposits of granitic sandy loam in the general vicinity of Granite Exposures support vegetation of various heights, depending on profile thickness. Vegetation on sites with shallow hardpan is no shorter than that where rock is absent. Evidently tree roots penetrate the lime layer, and the good moisture-holding capacity of the associated loamy soil compensates for the presence of the hardpan. Gravelly sand bears vegetation of similar height to that of Sandplains generally. Gravel appears to behave similarly to deep sand as a substrate for plant roots: both are penetrable, but coarse and excessively drained, barring the growth of trees.

In those parts of the Study Area underlain by greenstone, surface porosity varies from good in sandy to poor in clay soils and appears to control vegetation height to some extent. Subsoils are distinguished by lime accumulations, or else stones (shallow soils on Hills and Undulating Plains) or salt (bottomlands of Salt Lake Features). Trees 12-15 m high occur on the most favourable loamy soils on plains, grading to trees 5-10 m high on the rocky uplands and a few patches of excessively drained sand on the lowlands. Vegetation is low where both clay and salt content are great: 4 m in subsaline clay basins and only 0.5 m on saline flats. In the salt lakes themselves vegetation is absent. Both the shallow or sandy soils and the deep clay soils appear to have poorer moisture availability to deep roots, such as those of trees, than do some deep clay loams of moderate texture. The latter collect extra water running off from elevated areas. This more than compensates for their poor porosity and lime subsoils, and consequently poor rates of infiltration of rainfall. Kankar apparently does not impede the growth of plant roots. The heaviest bottomland soils are clearly impermeable to plant roots. This is exaggerated by poor infiltration of moisture at depth and a tendency to crack at the

surface. Saline flats receive much extra moisture from runoff, and infiltration at the surface is rapid, but salt and the other adverse edaphic factors limit the vegetation to the lowest plants.

Climate and soil combine inextricably to determine the flora of the Kurnalpi-Kalgoorlie Study Area. The Eremaean (xeric) floristic elements generally hug the low-lying landforms and hills and rises on Undulating Plains (freshly weathered soils of greenstone and granite). The South-western (mesic) floristic elements generally hug Sandplains and Breakaways. The xeric types are represented by trees or tall shrubs of *Casuarina*, shrubs of *Eremophila* and low shrubs of Chenopodiaceae or, on sandy soil, the hummock grass *Triodia*. The mesic types have distinctive forms and a relatively diverse array of *Eucalyptus*, over shrubs containing southwestern elements such as Myrtaceae (e.g. *Baeckea*) and Proteaceae. *Eucalyptus* and *Acacia* are generally important in both types of landscape although the species differ between the landscapes. Examples of the dichotomy of floristic elements are: *Atriplex, Casuarina, Enchylaena, Frankenia, Halosarcia, Heterodendrum, Pittosporum, Ptilotus, Rhagodia, Sclerolaena* and *Sclerostegia* versus *Allocasuarina, Leptospermum, Melaleuca, Thryptomene, Keraudrenia, Phebalium, Westringia, Hakea* and *Olearia.*

Although part of the pattern can be accounted for by the slightly drier climate in the northern and northeastern parts of the Study Area, soils are obviously a major factor responsible. A major influence of climate is apparent in the generally deep loamy soils of the Study Area which gradually develop of a subsoil hardpan towards the north-northeast. The xeric flora grows mainly on Calcareous Earths, Red Earths, Subsaline Soils and Saline Soils. The mesic flora grows mainly on Deep Sands, Gravelly Sands and Granite Soils derived from highly leached lateritic podzols.

The scarcity of taxa of ephemerals (Asteraceae, Amaranthaceae) on Breakaways, Sandplains and parts of Broad Valleys, is attributable mainly to soil nutrient poverty here. The phenomenon cannot be explained by moisture relations as good rain fell on all landforms during the survey period. Striking links in the floras of extreme uplands and extreme bottomlands support this interpretation. Many ephemeral species are as restricted in their distribution and as habitat-specific as are the perennials. However, several species have an interesting duality in their habitats, being found on shallow soils freshly weathering from granite and other rocks, as well as at the other end of the landscape catena, in depressions of deep and in places subsaline soil of alluvial or aeolian origin. Some stands in these opposite situations may have more species in common that either has with the intervening plains of loam, gravel and sand.

This leads to the question of species-richness within vegetation types. The vegetation with the greatest number of coexisting species in the mesic southwest of Western Australia is found on sandplains, while that on base-rich soils (loamy or clay bottomlands) is relatively poor in species or dominated by abundant plants of one or two species (Lamont *et al.* 1984). In the Kurnalpi-Kalgoorlie Study Area the reverse is true. Purely siliceous, sandy soils have simple communities (as few as 30 species per quadrat). A single species, *Triodia scariosa*, dominates where the sand is red. Where there is a

considerable number of perennials (small-leafed dwarf shrubs) on yellow sand and gravel, there are virtually no species or individuals of annuals or ephemerals. In nearby depressions on cracking clay over greenstone, up to 80 species are found growing together in a small area.

The richness of perennials differs modestly between these nutrient-poor and base-rich soils and it is mainly the ephemerals which produce the contrast. The vegetation of intermediate soils, e.g. *Acacia aneura* communities, are intermediate in the diversity and composition of the ephemerals. The direct comparison possible in 1980 when all landforms received similar, plentiful rainfall suggested that soil moisture differences were not responsible. The richest communities of herbaceous plants are associated with *Eucalyptus salubris*. This tree also characterises soils relatively rich in nutrients in the wheatbelt of Western Australia which favour agricultural crops with a minimum of artificial fertilization. The richest communities of ephemerals in the Kurnalpi-Kalgoorlie Study Area far exceed their accompanying perennial communities in the number of co-existing species.

One observation supporting the critical role of nutrients is the obvious restriction of the few ephemerals on Sandplains to patches of litter, even where these are shallow or shaded. This is particularly true of the litter under *Santalum* spp., which are root hemi-parasites with relatively nutritious leaves (Keay & Bettenay 1970). Another observation is that some very loose, excessively drained sands bear rich communities of ephemerals on Salt Lake Features. These sands are rich in calcium and other bases (Keay & Bettenay, 1970).

The Kurnalpi-Kalgoorlie Study Area contains eight Vegetation Systems according to Beard (1972, 1975). In order of decreasing area within the Study Area, these are (percentage of the total area of each Vegetation System in parentheses): Kurnalpi, 9 950 km^2 (84.5%), Coolgardie, 3 925 km^2 (36.1%), Zanthus, 2 240 km^2 (21.6%), Kunanalling, 2 180 km^2 (66.2%), Randell, 1 760 km^2 (61.2%), Boorabbin, 915 km^2 (5.0%), Broad Arrow 775 km^2 (100%) and Jaurdi 330 km^2 (5.5%). From this it can be seen that the Broad Arrow Vegetation System is confined to the Study Area. All of these Vegetation Systems are restricted to the Eastern Goldfields except for the Kurnalpi and Zanthus Vegetation Systems. However only 0.6% of the Kurnalpi Vegetation System is outside the Eastern Goldfields and the only other Study Area in which it occurs is the Edjudina-Menzies Study Area immediately to the north. Although 78.4% of the Zanthus Vegetation System lies outside the Eastern Goldfields, the Kurnalpi-Kalgoorlie Study Area is the only part of the Eastern Goldfields in which it is represented. In addition, the Kurnalpi-Kalgoorlie Study Area contains 1 950 km^2 (i.e. 2.7%) of the Barlee Vegetation Sub-region (of the Murchison Region) which is largely (73%) confined to the Eastern Goldfields.

The Broad Arrow Vegetation System, located in the western part of the Kurnalpi-Kalgoorlie Study Area, is dominated by relatively broken Banded Ironstone country on Undulating Plains. The vegetation is essentially a unique mixture of surrounding elements. *Eucalyptus* species (*E. salmonophloia, E. lesouefii, E. salubris, E.*

transcontinentalis, E. oleosa) are found on run-on zones, replaced by *Acacia aneura* on excessively drained soils. In composition and location this Vegetation System is therefore typical of the mulga-eucalypt line. Low trees of *Casuarina cristata* and low shrubs of *Maireana sedifolia* are found throughout the landscape, with an additional stratum on stony ridges of *Acacia quadrimarginea, A. acuminata, Allocasuarina campestris* and *Eremophila oldfieldii* ssp. *angustifolia* (Beard 1972). The Kurnalpi Vegetation System, of which the Kurnalpi-Kalgoorlie Study Area is also the stronghold, similarly forms a complex mosaic of overstorey and understorey in independent combinations. However the topography is subdued. It may be summarized as mixed (*Acacia-Casuarina-Eucalyptus*) low woodland on Undulating Plains and the adjacent parts of Broad Valleys (Beard 1975).

The most detailed previously existing vegetation maps covering the Kurnalpi-Kalgoorlie Study Area were assessed for reliability. As shown by Carnahan (1976), the vegetation is transitional between *Eucalyptus* woodland, over low shrubs or in places low trees, and the drier *Casuarina* low woodland over tall shrubs. In the vicinity of salt lakes this changes to *Casuarina* low open woodland over low shrubs of Chenopodiaceae. This picture is generally accurate although the scale of Carnahan's map is such that fairly large patches of *Eucalyptus*/*Acacia* tall open shrubland over hummock grasses, *Triodia*, are not shown. Beard's maps cover the Study Area at a scale of 1:250 000 for the Kalgoorlie area (published in 1972) and 1:1 000 000 for the remainder (compiled in 1970 and published in 1975). Considering the scale, these maps provide an adequate view of the vegetation, based on structure and dominant floristics. Black Flag is shown as woodland of *Eucalyptus salmonophloia* and *E. lesouefii*, with areas of bluebush (*Maireana sedifolia*) and, associated with salt lakes, succulent steppe of saltbush (*Atriplex*) lightly wooded with *Casuarina cristata* and *Myoporum*; Kurnalpi is shown as mallee and spinifex (*Eucalyptus oleosa* over *Triodia scariosa*) on sandplain, and low woodland of *Acacia aneura, Casuarina cristata* and *Eucalyptus* species elsewhere (Beard 1972, 1975).

While most of the Kurnalpi-Kalgoorlie Study Area has retained a semi-natural state, and a few small areas are in virtually pristine condition, the only substantial area of Class A reserve currently contained within the Study Area is the south end of Goongarrie National Park (No. 35637). This conservation reserve includes small areas of only three landforms (Broad Valleys, Sandplains and Granite Exposures) supporting four vegetation types: low woodlands of *Eucalyptus concinna, E. oleosa, E. salubris* and *Acacia aneura.*

Existing conservation reserves in the Kurnalpi-Kalgoorlie Study Area are listed below. Those marked with an asterisk are not vested in the National Parks and Nature Conservation Authority (N.P.N.C.A.).

Although there has been encouraging recovery from past woodcutting and overgrazing, adequate protection of designated areas remains important in view of the needs of the large town of Kalgoorlie-Boulder for water, firewood and recreation. Owing to the patchiness of the vegetation it is unlikely that a single reserve would adequately

Reserve No.	Location (°S °E)		Area (ha)
32178*	30°45′	121°30′	9
8787*	30°48′	121°25′	799
19214*	30°50′	121°35	3 787
19825*	30°30′	121°45′	13 313
195/25*	30°55′	121°55′	16 350
19640*	30°50′	122°55′	37 061
39148	30°56′	122°33′	29
4274	30°35′	120°50′	404
35453	30°50′	121°25′	621
7634	30°35′	120°50′	1 926
35637	30°00′	121°30′	20 000

cover the types present in the Study Area. The so-called "Green Belt" around Kalgoorlie has no entrenched status and is virtually limited to vegetation types widespread in the Widgiemooltha-Zanthus Study Area to the south (Newbey & Hnatiuk 1984). Any new conservation area should embrace a large tract of the mixed low woodlands of *Eucalyptus oleosa, Casuarina cristata* and *Acacia aneura*, extensive within the Study Area but rare outside it, and possibly threatened by mining and other long-term disturbance.

The flora of the Study Area is still incompletely known and in particular a further search of the inaccessible northeastern parts should reveal additional species where the Study Area just enters the southwestern edge of the Great Victoria Desert (Beard 1974, Burbidge *et al.* 1976). The introduced flora found in disturbed areas such as old town sites was inadequately documented (see Buckley 1981), as also were the moss and lichen floras. The vegetation and flora of the extreme western and eastern parts of the Study Area would repay further investigation. Remarks by Cole (1973) suggest that this is also true for localized occurrences of nickel-rich rocks in the southwestern parts. Apart from these considerations, there is still scope for intensive botanical collections and Breakaways, Granite Exposures and Salt Lake Features are the landforms most likely to yield additional species important for conservation. The rich ephemeral communities of outcrops and bottomlands are particularly vulnerable to overgrazing and erosion and deserve further study.

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