Louisa Murray

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Lake Cargelligo 1890

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COVER

Man and landscape — Sunday afternoon, Lake Cargelligo

Human influences — houses, horse paddocks, selective clearing of eucalypts (*Eucalyptus* species) and cypress pines (*Callitris glaucophylla*), and ploughed lands — are already evident at Lake Cargelligo by 1890. Yet to come are the levee banks and dams that will control the natural water flow. For current picture, see Sivertsen and Metcalfe paper, pp. 103–128.

Photograph courtesy of E. McInnes.

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Notes on the anthecology of *Pterostylis curta* (Orchidaceae)

Peter Bernhardt

Bernhardt, Peter[1] *(National Herbarium of New South Wales, Royal Botanic Gardens, Sydney, Australia 2000) 1995. Notes on the anthecology of* Pterostylis curta *(Orchidaceae).* Cunninghamia *4(1): 1–8.* Field observations suggest that *P. curta* R.Br. is pollinated by male fungus gnats in the genus *Mycomya* (Diptera; Mycetophilidae). The viscidium is deposited dorsally on the gnat's thorax. The labellum is self-motile and irritable. Manipulations of *P. curta* under controlled temperatures show that the majority of labella reset and regained irritability (responsive to direct contact) two to three hours after they had been triggered the first time. Flowers of cultivated plants fail to self-pollinate. These three observations suggest that some populations of *P. curta* require cross-pollination by insect vectors.

Introduction

Pterostylis R.Br. (Orchidaceae) is a geophytic genus of about 120 species (Johns & Molloy 1985; Clements 1989) endemic to Australasia, reaching its centre of diversity through the wet temperate and coastal regions of south-eastern Australia, Tasmania and New Zealand (Bernhardt 1995). As in the Australasian genus *Caleana* (*sensu* Bernhardt 1994), *Pterostylis* species are usually characterised by 'spring trap' flowers (Dressler 1981). In a spring trap flower the labellum petal is both irritable and self-motile. Direct but slight pressure on the lamina causes the labellum to change position spontaneously and rapidly so it collides with the winged column.

In *Pterostylis* species, labellum movement should trap the prospective pollinator between the labellum lamina and the column wings and rostellum for 30–90 seconds until the labellum hinge begins to reset spontaneously. As the labellum begins to return to its original position the pollinator is released and can escape through a sinus formed by the inflated hood (galea) and the fused lateral sepals (Jones 1981).

Despite similarities in the floral mechanisms of *Caleana* and *Pterostylis*, the two genera have different flowering seasons and attract different pollinators. *Caleana* flowers appear from mid-spring through early summer. They appear to be pseudocopulatory systems pollinated exclusively by male sawflies (Cady 1965; Bates 1989).

In contrast, the floral phenology of *Pterostylis* species in south-eastern Australia peaks in late winter through mid-spring (August to early October). The pollination syndrome of *Pterostylis* has been open to several interpretations since the turn of this century (see review by Jones 1981).

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Pterostylis appears to belong to a guild of terrestrial, winter-early spring-flowering orchids (*Acianthus*, *Corybas*, *Rhizanthella*) that are pollinated exclusively by micro-dipterans in the families Culicidae, Phoridae and Mycetophilidae (George & Cook 1981; Jones 1981; Dafni & Bernhardt 1990). Species pollinated by mycetophilids (fungus gnats) tend to produce greenish to rusty to deep-iodine-coloured flowers that either lack a discernible fragrance or smell like carrion or ripe fungi (Vogel 1973). *Acianthus* flowers produce nectar, while nectarless *Corybas* species appear to mimic mushrooms and appear to be pollinated by ovipositing females (Dafni and Bernhardt 1990).

Pterostylis flowers are also nectarless. The pigmentation of a few species may suggest fungal or carrion mimesis (e.g. *P. pedunculata* R.Br.) but the majority of flowers in the genus are green or boldly striped with green. Jones (1981) suggested that some *Pterostylis* species are 'window flowers' and fungus gnats are attracted to the rays of light shining through translucent, dorsal portions of the inflated hood. However, the few gnats captured in the flowers have all been males, suggesting a pseudocopulatory syndrome (Beardsell & Bernhardt 1982; Jones 1988; Dafni & Bernhardt 1990).

The actual role of fungus gnats as agents of cross-pollination of the geophytes throughout the forests of the world remains uncertain. For example, although *Asarum* has been treated as a classic example of a gnat-pollinated genus, most seedset in *A. hartwegii* Wats. derives from mechnaical self-pollination (Mesler & Lu 1993). Whatever the mode of floral mimesis may be in *Pterostylis*, pollination appears to be vector-mediated in most species studied. In fact, mechanical, self-pollination has been recorded far less often in the tribe *Pterostylideae* (*sensu* Burns-Balogh & Funk 1986) than in any other tribe of terrestrial orchids in Australia (Dafni & Bernhardt 1990; Catling 1990).

Some degree of cross-pollination must occur in some species of *Pterostylis* since some uncommon taxa have had to be reclassified as recurrent hybrids (Clements 1989). Mycetophilids have been implicated in the recurrent production of *P. curta* X *P. pedunculata* where populations of the parent species are sympatric. However, Bates and Weber (1983) did not find the orchid gnats carrying pollinaria and did not identify the genera or gender of prospective pollinators.

Therefore, additional field and glasshouse observations on *Pterostylis curta* should be useful since published accounts of the floral biology in the genus remain so fragmentary. *Pterostylis curta* is one of the most widely distributed members of the genus through eastern Australia and natural clones are very floriferous (Woolcock & Woolcock 1984; Jones 1988). Therefore, brief observations on the floral biology of this species should help clarify some aspects of pollination mechanisms within a troublesome genus.

Materials and methods

Floral presentation, morphology and visitors

Flowering specimens for morphological studies were collected along Woola Track 2 of Royal National Park, New South Wales, from a population of about 30 flowering shoots. The population of *Pterostylis curta* was found in wet, shady, sclerophyll forest, co-blooming with *Acianthus fornicatus* R.Br., *P. grandiflora* R.Br., *P. nutans* R.Br. and *P. longifolia* R.Br. Field observations were made between 7 July 1991 and 22 July 91. Dried vouchers and spirit collections of flowers were made by R. Coveny and deposited at the Royal Botanic Gardens Sydney (NSW). Insect vouchers were deposited at the CSIRO Division of Entomology in Canberra, ACT. A pollinarium carried by an insect was checked against the pollinarium morphology of other orchid genera flowering at the same time of year and from the columns of living flowers.

Labellum manipulations

The living collection of *P. curta* (910182, 910654) at the Missouri Botanical Garden consisted of a total of four pots, housed in Greenhouse B1 and maintained at day temperatures of 19–22 C and night temperatures of 11–13 C. A total of 22 living flowers were labeled and used to record the floral lifespan and response of labella to direct contact between 27 January 1993 and 13 March 1993. Flowers were considered open on the first day the bud showed both expansion of the opening of the floral sinus and labellum irritability. Flowers were recorded as dead when the lateral petals dried or collapsed, obscuring the sinus, and the labellum failed to move when provoked.

Sixty-three test manipulations were conducted over the flowering period of the greenhouse collection from 10 am to 3 pm. A flower's labellum was tapped gently with a probe to make it spring. If it did not spring after the third tap it was recorded as non-responsive. Flowers in which the labellum had 'tripped' were monitored hourly, and the time required for the labellum to reset was recorded. Once the labellum had returned to its original position it was recorded as reset. Hourly attempts were then made to retrigger the mechanism by tapping the labellum three times with the probe. Therefore, the labellum of any study flower could be triggered more than once during each day of experimental manipulations.

Results and discussion

Floral presentation and gross morphology

Jones (1981) subdivided floral presentation of *Pterostylis* species into two groups. In the first group, the fused lateral sepals are so relaxed or deflexed that the labellum lamina is completely visible outside the galea. The labellum lamina is short-truncated and highly sculptured with marginal hairs and papillae. This form of presentation was not employed by *P. curta*.

Pterostylis curta employs the second mode of presentation. The lateral sepals are erect-ascending and embrace the galea, narrowing the sinus dimensions. The labellum lamina is much longer than wide, and less than half of the lamina protrudes through the sinus, often contacting the median cleft formed by the fused lateral sepals. In *P. curta* the apical half of the lamina appears to twist to the right of the viewer (Fig. 1).

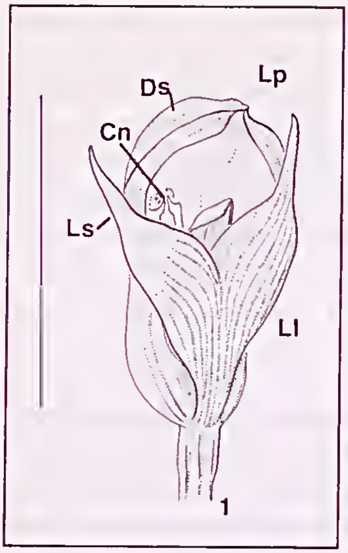

Fig. 1. Front view of the flower of *Pterostylis curta*. Cn = column; Ds = dorsal sepal; Ll = labellum lamina; Lp = lateral petal; Ls = lateral petal.

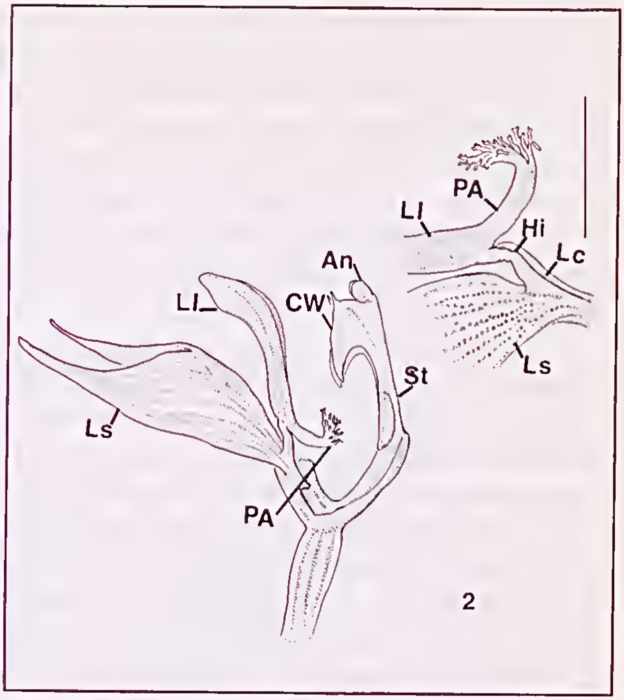

Fig. 2 (above right). Labellum and column details of *P. curta* (galea removed and lateral sepals spread). Abbreviations as in Fig. 1 including An = anther; CW = column wings; Hi = claw hinge; Lc = Lamina claw; PA = penicillate appendage; St = style.

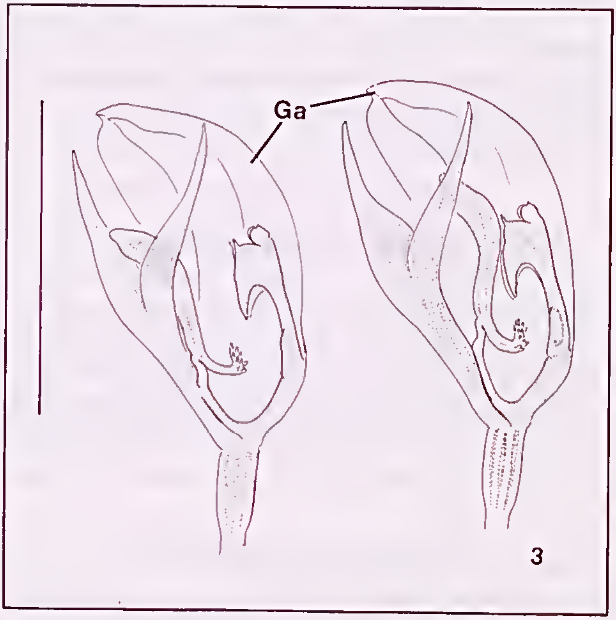

Fig. 3. Movement of the labellum lamina within the galea (Ga); Scale = 3 cm. Left = labellum lamina not triggered; Right = labellum lamina triggered (note that it contacts the column wings).

Fig. 4. Male *Mycomya* species carrying *P. curta* pollinarium (scale = 3 mm). P = pollinium; V = viscidium attached to mesonotum of insect.

As in most *Pterostylis* species within the second type of presentation the labellum lamina of *P. curta* is entire, longer than wide and its base bears a penicillate and vasculated appendage that is elongated, curved and terminates in an angled, fringed, brushlike crest of branched and webbed trichomes (Fig. 2). The lamina is connected to the claw by a flexible hinge. The claw is fused to the base of the lateral sepals (Figs. 2 & 3). When the spring mechanism is triggered the entire lamina is withdrawn completely into the inflated galea, contacting the expanded, hatchet-like wings of the column (Fig. 3).

Collection and observations of floral visitors

On 7 July 1991 examination of a *Pterostylis curta* flower at the study site located a dead gnat that had become attached to the outer surface of the galea. The anther in the flower was empty of pollinia, but a *Pterostylis* pollinarium was deposited dorsally on the mesonotum of the gnat's thorax (Fig. 4). The gnat had apparently died of exposure, as the visicidium of the pollinarium had welded the insect to the outer surface of the galea before it could fly away. Half an hour later a second gnat was found alive and fluttering inside the floral chamber of a second *P. curta*. The lamina of the labellum had not reset completely and one anther loculus lacked its pollinium. The entire flower was placed inside a plastic bag. The gnat crawled out of the flower via the sinus but the *Pterostylis* pollinia it had been carrying was knocked off against the side of the bag. Examination of the specimen under a dissecting microscope showed that the mesonotum had lost hairs and remaining hairs had been matted by viscidial residue. Both insects were identified as males of *Mycomya* species (Mycetophilidae). Both were less than 4 mm long.

The deposition of the pollinarium on the body of a gnat may be similar in different *Pterostylis* species. Colour photographs of unidentified, male mycetophilids collected in living flowers of *P. nutans* R.Br. (Jones 1981) and *P. furcata* R. Rogers (Bates & Weber 1990) also show the pollinarium fixed dorsally to the mesonotum.

Although each anther in a *Pterostylis curta* flower contains four pollinia, only one pollinium was attached to the body of the male gnat (Fig. 4). When dissecting needles, pin tips and the tips of needle forceps were inserted into the sinus of a *P. curta* flower and then withdrawn under the column, these instruments never withdrew more than one or two pollinia at a time. This observation concurred with the colour photographs of Jones (1981) and Bates and Weber (1990). Van der Pijl and Dodson (1966) were among the first to note that *Pterostylis* species were among the few orchids to release their pollinia separately. They suggested this was an adaptive feature since a tiny dipteran could not support the weight of four pollinaria in flight.

Floral lifespan and labellum sensitivity

Individual flowers of *P. curta* in the glasshouse collection survived and responded to probes for an average of three weeks. One flower responded to probes for five weeks. All flowers of cultivated plants wither without successful self-pollination. Labellum sensitivity appeared to be greatest during the first week after anthesis, when the labella of both wild and greenhouse plants proved so sensitive that the spring mechanism was activated by merely tapping the flower's peduncle. No flower of *P. curta* at Royal National Park was observed to reset its labellum within five hours after triggering. Field observations of labelled flowers indicated that under natural conditions, i.e. where daily temperatures fluctuated and were less than 19°C, flowers of *P. curta* did not reset labella fully for an average of 9–24 hours after the spring mechanism was triggered.

In contrast, experimental series showed that, under higher controlled temperatures, *P. curta* flowers reset much more rapidly, with the majority of flowers fully reset within two to three hours after the first triggering (Table 1). Restoration of labellum irritability peaked between two to three hours after initial triggering. However, no lamina was found to respond to the probe stimulus unless it had reset and protruded from the sepal cleft.

Over 40% of all labella that reset following experimental probing still failed to spring upwards the second time the lamina was tapped (Table 1). The labellum mechanism could be triggered a maximum of three times during two experimental series. Twenty-nine out of 63 tests recorded that the labellum had been triggered twice over a five hour period.

Experimental procedures suggested that the resting of the labellum often occurred independently of the actual restoration of irritability. Table 1 shows that the process of resetting the position of the lamina occurred more rapidly than the restoration of the irritability response. Since the resetting process is gradual but slow, a pollinator the size of a gnat would be able to escape from the floral chamber before the labellum begins to protrude from the sinus. This appeared to be the case for the second gnat collected.

Table 1. Response of labella to artificial manipulations over time

Time period	**Labellum activity**		
	No response or partial reset	Reset but not irritable	Reset and irritable[1]
1. End of first hour	59	28	10
2. End of second hour	23	29	41
3. End of third hour	6	4	29
4. End of fourth hour	1	3	10
5. End of fifth hour	2	0	0

[1] Refers to a labellum that reset and the spring mechanism responded to pressure.

It is still not understood why these insects entered the floral chamber in the first place and perched, one presumes, on the labellum lamina. As both were male, the pseudocopulatory explanation seems most likely. Jones (1981) suggested that the appendage at the base of the lamina functions as a counterweight to the tripping mechanisms. I will present a second hypothesis. The appendage has a crested tip resembling the stalked osmophores of other orchid taxa as depicted by Vogel (1990). Perhaps it is a dummy female and plays some role in the visual and/or olfactory deception of the male gnat.

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The floral ecology of *Dianella caerulea* var. *assera* (Phormiaceae)

Peter Bernhardt

Bernhardt, Peter[1] *(National Herbarium of New South Wales, Royal Botanic Gardens, Sydney, Australia 2000) 1995. The floral ecology of* Dianella caerulea *var.* assera *(Phormiaceae).* Cunninghamia *4(1): 9–20.* Two populations of *Dianella caerulea* var. *assera* R. Henderson were observed over two years in eastern Australia. Both populations flowered in spring, with inflorescences opening only 5% of their flowers at the same time. Only 20% of all flowers on an inflorescence set fruit, suggesting that they do not self-pollinate. The nodding, nectarless flowers had elongated anthers, each opening via two terminal pores, and the anthers formed a loose cone around the style. Flowers were buzz-pollinated by female bees primarily in the families Anthophoridae (*Exoneura* spp.) and Halictidae (*Lasioglossum, Nomia* spp.). Bees less than 6 mm long (*Homalictus holochorous* and *Trigona* spp.) removed pollen from anthers, but did not contact stigmas while foraging. Examination of pollen loads indicated that most bees were polylectic foragers that had visited at least one nectar-secreting taxon (e.g. *Ceratopetalum gummifera, Haloragis* spp., papilionoid legumes, Myrtaceae) before foraging on *D. caerulea*. However, bees were never observed grasping, probing or combing the swollen, brightly coloured and papillate apices of the staminal filaments. The absence of this behaviour indicated that these structures did not function as nectaries or as a source of pseudopollen as proposed by earlier authorities.

Introduction

An examination of spring-flowering species in southern Australia suggests convergent and/or parallel trends in floral presentation. A conspicuous proportion of vernal herbs and shrubs produce flowers that nod on their scapes or pedicels and have brightly coloured perianths, emphasising yellow or blue-purple pigmentation. These perianth segments are often reflexed or are expanded so broadly that the androecium is fully exposed (see Cochrane et al. 1980; Willis et al. 1975).

The androecium of such flowers often contrasts sharply in colour to the perianth and consists of relatively few stamens (oligandrous) with porose-porate anthers (Vogel 1978; Gack 1979; Buchmann 1983; Faegri 1986). These elongated/inflated anthers are clustered to form a cone around the protruding style, or may form an arched and elevated tuft above the stigma or stigmas (e.g. *Hibbertia*; Bernhardt 1984, 1986). Dissection of these flowers shows an absence of nectaries, oileries or food bodies, indicating that pollen is the only edible reward offered (Buchmann 1983; Bernhardt 1984, 1986; Bernhardt & Burns-Balogh 1986).

Vogel (1978) reviewed this mode of floral presentation within many families of flowering plants and termed it the *Solanum*-type flower. The *Solanum*-type appears

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to be pandemic, as it has evolved independently within more than 65 angiosperm families (Buchmann 1982; Barth 1985) that are not confined to Australia. However, Vogel's initial descriptions of *Solanum*-type flowers included examples of many genera that are indigenous or endemic to Australia; e.g. *Arthropodium, Bulbine, Calectasia, Dianella, Hibbertia, Solanum, Sowerbaea, Stypandra, Xyris*, etc. Faegri (1986) much expanded the list of genera of *Solanum*-type flowers in Australia by examining specimens native to the south-west of the continent and suggested it was a particularly common, floral form in the Mediterranean south-west. In fact, *Solanum*-type flowers are so common in southern Australia that their mode of floral presentation appears to be exploited by some mimetic orchids that are cross-pollinated via pseudanthery (Bernhardt & Burns-Balogh 1986; Dafni & Bernhardt 1990).

In general, *Solanum*-type flowers are most likely to be buzz-pollinated. That is, pollen is repeatedly 'shaken' out of the terminal pores through the stereotyped vibration of flight muscles within the insect's thorax (Buchmann 1983). The major pollen vectors are female bees and, to a much lesser extent, large syrphid flies in the genus *Volucella*.

The study of buzz-pollination in Australia has been infrequent and inconsistent. A review of *Solanum*-type forms in the flora of south-eastern Australia would suggest, though, that it may be a particularly common mode of pollination in some petalloid monocots with a broad lilioid base. Of the genera listed above, *Dianella* would appear to make the most promising model of fieldwork. There are two reasons for this tentative conclusion.

First, *Dianella* species are widely distributed throughout coastal Australia, often forming dense, easily located, clonal colonies (Wilson 1993). They are common roadside perennials throughout the south-east (Bernhardt, personal observation). In fact, the genus has a broad but disjunctive distribution throughout Australasia, Indo-Malaysia and the islands of the South Pacific, and is also found as far west as Africa, Madagascar and the Mascarenes (Dahlgren et al. 1985). This phytogeography offers potential for future studies comparing the adaptive radiation of pollination mechanisms of allopatric species.

Second, pollination studies of *Dianella* species are required to clarify contradicting interpretations of androecium morphology. In most *Dianella* species the distal portion of each staminal filament is swollen, densely papillate and often referred to as a struma (*sensu* Henderson 1987). This structure has been interpreted as an androecial nectary (Daumann 1970; Dahlgren & Clifford 1982). In contrast, Vogel (1978) and Faegri (1986) interpreted strumae as shifts towards deception. It was assumed that the enlarged and gaudy struma made the smaller anther look larger and more attractive to prospective foragers. Neither hypothesis involved direct observation of pollinators on the flowers. Therefore, the following observations are presented to help clarify earlier hypotheses concerning the functions of floral organs in *Dianella*.

Materials and methods

Study sites

Two discontinuous populations of *Dianella caerulea* var. *assera* (*sensu* Henderson 1987) were observed weekly at sites in Royal National Park between November 1990 and October–November 1991. Description of sites follows Specht et al. (1974) for major plant communities at Royal National Park.

Site 1. Gray's Farm

Open riparian forest of wet sclerophyll grading to disturbed, dry sclerophyll. *Dianella caerulea* population in discrete clumps along roadside or within disrupted and successional sections colonised by mixed, shrubby Myrtaceae, *Hibbertia scandens* and *Pteridium esculentum*.

Site 2. Lady Carrington Track

Tall closed forest grading from dense, wet sclerophyll (*Syncarpia glomulifera* and rainforest elements) to warm-temperate rainforest. *Dianella caerulea* forming spreading rhizomatous colonies on exposed banks and in light gaps.

Recording data on reproductive features

Flowering shoots were selected while walking the entire length of each site. Since *Dianella* species are both rhizomatous and clonal, only every third flowering shoot was used for measurements in order to expand the sample of potential genotypes. Each inflorescence consists of an apical cluster of flowers (terminal florescence) and one or more side branches (paracladia). One side branch was selected on each inflorescence to represent the average number of flower buds or berries/branch. However, infructescences containing one or more obviously galled ovaries were not recorded for fruiting details. Vouchers have been deposited at the Missouri Botanical Garden (MO).

Flowers required for morphological examinations were stored in plastic bags or placed in vials containing 70% ethanol for long-term storage. Flowers were picked only on days when the perianth had expanded, exposing the androecium.

To sample floral odour, fresh flowers were placed in clean, glass vials and sealed for two hours. The vials were placed in a warm, sunny location, then reopened at the end of the two hour period and smelled (Buchmann et al. 1978). To determine the possible sites of scent glands (osmophores), fresh flowers of *D. caerulea* var. *assera*, *D. ensifolia* (Royal Botanic Garden Living Collection no. 781020) and *Dianella* sp. aff. *longifolia* (Royal Botanic Garden Living Collection no. 17047) were stained in a 1% solution of Neutral Red in distilled water for two hours, then washed in distilled water for 18 hours. The staminal filaments were checked for the presence of nectar secretions by observing fresh flowers under a dissecting microscope and by probing filament apices of flowers at field sites with microcapillary tubes.

Analyses of foraging insects

Foraging behaviour of prospective pollinators was observed over the days of fieldwork. Insects were collected from 9 am until 1 pm, as foraging behaviour became negligible by early afternoon. Insects were netted only if they were observed foraging on open flowers. Foraging is defined here as the active removal of pollen from the anthers, or the probing of floral organs with mouthparts. Insects were killed in jars containing fumes of ethyl acetate. To determine the deposition of pollen, each insect was observed under a dissecting microscope. To analyse pollen taxa carried by insects, each insect was placed on a clean glass slide and 'bathed' in a couple of drops of 100% ethanol. When the ethanol evaporated, the residue remaining on the slide was mounted in two or three drops of Calberla's fluid (Ogden et al. 1974). Identification of pollen was made under light microscopy. However, since different insects were killed in the same jar, contamination was possible. Therefore, a pollen taxon was not recorded as present unless more than 25 individual monads could be counted under each cover slip.

In contrast to the majority of lilioid monocots, the pollen of Phormiaceae are readily distinguished from the vast majority of angiosperm pollens in Australia, as they are both distinctly trichotomosulcate (Dahlgren & Clifford 1982; Dahlgren et al. 1985) and the monads appear to have such a thin exine that they always stain a light pink in the presence of Calberla's fluid (Bernhardt, personal observation). Although the genus *Stypandra* (Phormiaceae; *sensu* Dahlgren et al. 1985) is also distributed throughout eastern Australia, it was not found in either study site. Insects were washed, air-dried, measured (from base of mouthparts to abdomen tip), pinned, and labelled to cross-reference with their respective pollen slides. Insect vouchers were deposited in the National Museum of Victoria, Abbotsford.

Results

Inflorescence structure and floral phenology

Dianella caerulea var. *assera* has paniculate flowering shoots indicative of the genus. Each scape terminates in an apical cluster of flowers. Below this terminal florescence, the scape produces an average of seven alternative side branches or paracladia (Table 1). Each paracladium contains a similar number of flower buds as are found in the terminal florescence. Flowering began in late October and concluded by the end of November. Fruiting was contiguous with flowering and a paracladium often contained one or more ripe, blue berries, while flower buds continued to open on the same branch. The average number of fruits produced by a single infructescence deviated far more than any other reproductive feature recorded (Table 1). The conversion rate of individual flowers on a single inflorescence into fruits was approximately 20%.

The order in which individual flower buds opened within the same panicle was either subacropetal or did not follow any stereotyped program of anthesis. However, flowering within each paracladium was acropetal. The perianth of a flower opened

Table 1. Flower and fruit production of the inflorescences of *Dianella caerulea* var. *assera*

Reproductive structure	n[1]	Mean	Range	SD
Number of branches/inflorescence	32	7.9	3–13	2.2
Number of flowers/branch[2]	43	8.0	2–23	5.2
Number of open flowers/inflorescences	52	3.5	1–12	2.8
Number of fruits/branch	27	2.6	1–9	16.3

[1] n = The number of inflorescences sampled.
[2] Branch = either one paracladium or the terminal florescence on each inflorescence.

and withered within a 24 to 48 hour period. Over two seasons of observation no paracladium was found to have more than one open flower at a time. Only 5% of all flowers on an inflorescence were ever open at the same time and 44% of all branches on the same inflorescence displayed one open flower on the same day (Table 1).

Floral presentation, attractants and rewards. Open flowers of *D. caerulea* nodded on their pedicels (Fig. 1) or were held horizontally. Illustrations of flowers of *Dianella* species often depict the perianth as bell-like or funnelform, with tepals obscuring the androecium (e.g. see *D. ensifolia* and *D. nigra* in Dahlgren et al. 1985). This was not observed in populations of *D. caerulea* var. *assera*. The tepals of fresh, first-day flowers tended to be reflexive, exposing whole stamens to full view from the side (Fig. 1). The anthers formed a loose cone around the style. The stigma protruded from the centre of the anther cone. The style often curved or twisted below the tip of the anther cones, but there was no evidence of enantiomorphy as has been described in *Cyanella* and some *Solanum* species (Bowers 1975; Dulberger & Ornduff 1980). The anthers were extrorsive, each anther tip bearing two terminal pores (Fig. 1). There was no evidence of dimorphic pollen as in the enantiomorphic taxa discussed above (Dulberger 1981).

The pigmentation of floral organs was distinct and contrasting. Tepals of both whorls were blue with accentuated, dark-blue veins. The six stamens have blue filaments terminating in swollen, papillose, golden-orange tips embracing the greenish, straw-yellow anthers. The struma is about half the length of its anther, but each struma is about equal the length of the geniculate filament (Fig. 1). The globular ovary was a bright, polished green with a blue style and stigma.

When flowers were smelled on their inflorescences it was not possible to record a discernible scent. Flowers sampled two hours after they were placed in vials had a distinct but non-sweet odour reminiscent of baked pumpkin or squash.

In all three *Dianella* species sampled the strongest positive response to Neutral Red occurred repeatedly and consistently on the stigma, anther pores, pollen, inner surfaces of the tepals and on all strumae. The papillae of each struma turned an opaque, brick-red, while the geniculate filaments either showed no response (*Dianella* sp. aff. *longifolia*) or stained a translucent light pink (*D. caerulea* and *D. ensifolia*).

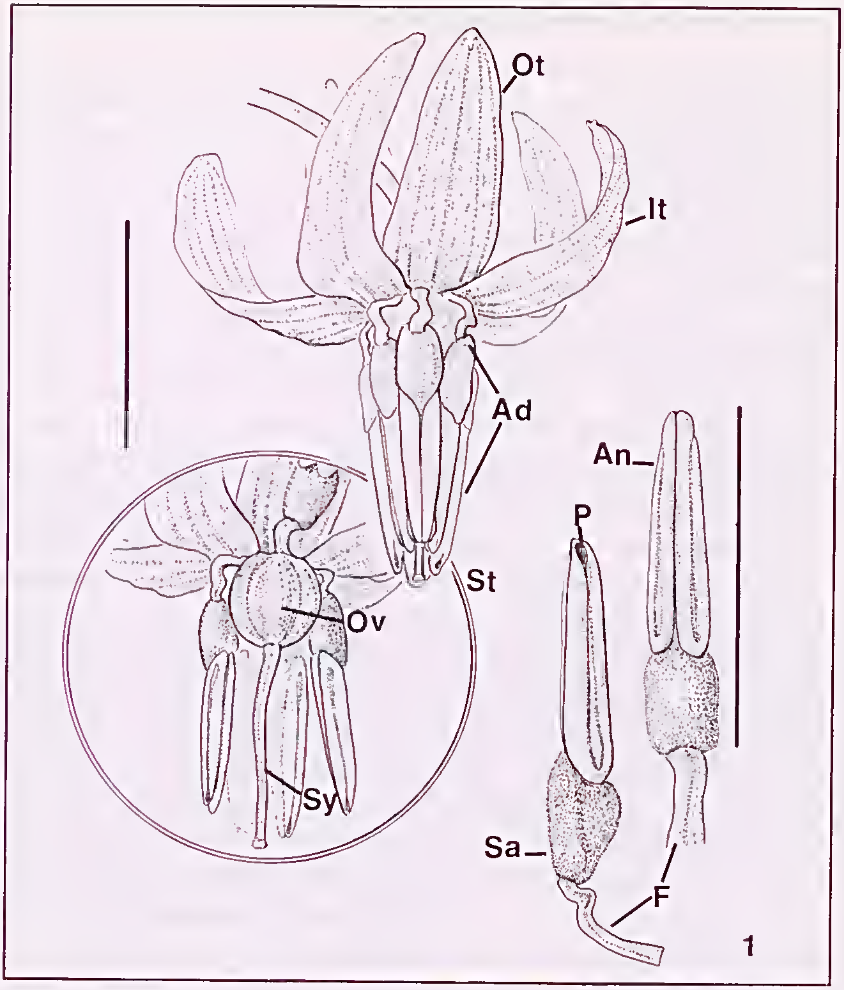


Fig. 1. The flower of *Dianella caerulea* var. *assera* (scale = 5 mm). Above, side presentation of flower, Ad = androecium; It = inner tepal; Ot = outer tepal; St = protruding stigma. Below left, side presentation of flower exposing the gynoecium, Ov = ovary; Sy = style. Lower right, stamens; An = anther; F = geniculate filament; P = pore; Sa = struma (note papillae).

The papillate surface of the strumae of *D. caerulea* var. *assera* remained dry over three seasons of sampling. No fluids were drawn into microcapillary tubes in the three species sampled and their strumae never felt damp or sticky.

Pollination mechanism

Female bees were the only successful pollen foragers on flowers of *D. caerulea* (Tables 1 and 2). Bees collected represented four out of the five families of Apoideae distributed throughout Australia (*sensu* Armstrong 1979). Bees observed at both sites rarely visited more than one open flower on each inflorescence, but regularly visited more than one inflorescence during a pollen foraging bout.

The introduced honey bee, *Apis mellifera* was observed to hover in front of the flowers, but rarely clung to the floral organs. The single *A. mellifera* collected on

Table 2. Pollen loads of bees collected on *Dianella caerulea* var. *assera*

Bee taxon	Bee length[1]	Pollen load		
		Dianella only	*Dianella* + other species	Other species (no *Dianella*)
Anthophoridae				
Exoneura spp.	6.5	1	5	1
Apidae				
Apis mellifera	14.0	0	0	1
Trigona spp.	4.5	4	5	0
Colletidae				
Hylaeus sp.	8.0	0	1	0
Halictidae				
Homalictus holochorus	5.0	0	1	0
Lasioglossum subgenera				
Australictus sp.	9.0	0	1	0
Callalictus sp.	9.0	1	2	
Chilalictus				
L. convexum	7.0	1	1	0
Lasioglossum spp.	6.0	0	0	1
Nomia spp.	11.5	0	2	0
Totals (n = 28)	–	6	18	3

[1] Mean length in mm

D. caerulea failed to carry the host plant's pollen (Table 1). No native bee was ever observed to land or perch on the strumae, attempt to scrape the papillae with their claws or probe them with their mouthparts.

Pollination was accomplished by bees at least 6 mm long or longer (Table 2) in the genera *Exoneura* (Anthophoridae), *Lasioglossum* and *Nomia* (Halictidae). All bees observed landed on the anthers and never on strumae or tepals. These insects always foraged upside down while clinging directly to the anthers, as even a horizontally held flower bent under the weight of the smallest foragers. *Exoneura* and the larger halictid bees appeared to shake the anthers using thoracic vibration. Pollen released from the anther pores was deposited ventrally on the bee's thorax. The bee combed this pollen off her thorax, depositing the grains between scopal hairs on the hind legs or into a patch of scopal hairs at the base of the abdomen. During the process of pollen collection the stigma contacted the bee's thorax or the base of the abdomen.

Although the *Hylaeus* species (Colletidae) carried *Dianella* pollen (Table 2), it was not observed to shake the androecium or contact the stigma. Bees less than 6 mm long regularly failed to contact the stigma while foraging for pollen. In particular, the eusocial *Trigona* species (subgenus *Tetragona*) were so small that worker bees regularly grasped the tip of only one anther on one flower at a time and scraped out pollen by inserting a foreleg directly into the anther pores. No thoracic vibration was ever observed in *Trigona* on *Dianella* anthers.

The majority of bees collected on *D. caerulea* carried the pollen of more than one plant in flower in the study site (Table 2). All bees carrying mixed loads of pollen carried pollen from at least one nectar-producing species within the study site (Table 3; Figs. 2 and 3). The larger halictid bees (*Lasioglossum* and *Nomia* species) carried a maximum of four recognisable pollen taxa in their scopae with a mean of more than two pollen taxa/insect (n = nine bees bearing pollen). *Exoneura* species (Anthophoridae) carried a maximum of five pollen taxa with a mean of more than three pollen taxa/insect (n = six bees bearing pollen).

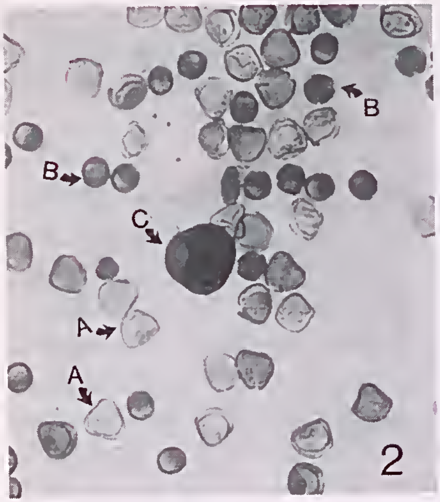
Discussion

The conversion of flowers into fruit is so low in *D. caerulea* var. *assera* it seems most likely that the rate of mechanical self-pollination (autogamy) is negligible in this taxon. Since anthers do not release pollen unless struck or shaken, pollination must be vector-mediated. The foraging pattern of insects combined with the flowering pattern of the plant suggests that a pollinator is more likely to deliver pollen from a second flowering shoot than from a second flower on the same inflorescence. In this respect, the adaptive phenology and morphology of the pollination system of *D. caerulea* var. *assera* overlaps broadly with some other buzz-pollinated taxa in the genera *Echeandia* (Bernhardt & Montalvo 1979), *Hibbertia* (Bernhardt 1984, 1986), *Dodecatheon* (Macior 1974) and *Solanum sensu stricto* (Macior 1974; Bowers 1976; Buchmann 1983). In all of these species the number of open flowers on an inflorescence at any time is always a fraction, compared to the original number of flower

Table 3. Pollen loads of bees carrying grains of *Dianella caerulea* mixed with the pollen of at least one more species

Bee taxon	Pollen taxa							
	CG+	DC-	HC-	HS+	MM+	PL+	SG+	UE+[1]
Exoneura spp.	4	5	3	0	3	3	1	0
Homalictus holochorous	0	1	1	0	0	1	0	0
Hylaeus sp.	1	1	0	0	0	0	0	0
Lasioglossum subgenera								
Australictus	0	1	1	0	0	1	1	0
Callalictus	0	2	2	0	0	2	0	1
Chilalictus								
L. convexum	0	1	0	1	0	0	0	0
Nomia sp.	0	2	0	0	1	1	0	0
Trigona sp.	0	5	1	0	4	0	0	0
Totals (n = 18)	5	18	8	1	8	8	2	1

[1] CG = *Ceratopetalum gummifera*; DC = *Dianella caerulea*; HC = *Hibbertia scandens*; HS = *Haloragis* spp.; MM = Mixed, unidentified Myrtaceae (e.g. *Angophora*, *Baeckea*, *Eucalyptus*, *Kunzea*, *Leptospermum* spp.); PL = papilionoid legumes; SG = *Stylidium graminifolium*; UE = unidentified Epacridaceae (in tetrads); + = secretes floral nectar; - = no floral nectar.



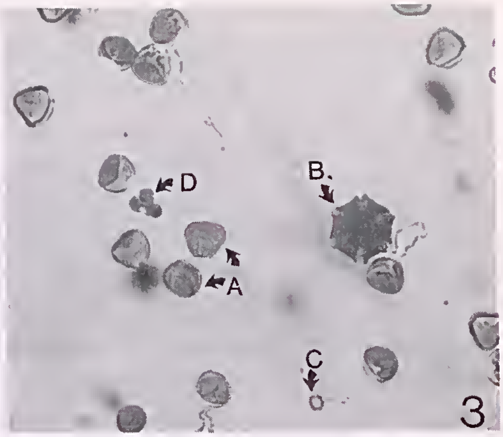


Fig. 2. Pollen grains from a section of the scopal load of a female *Lasioglossum* (subgenus *Callalictus*) X 98. A = *Dianella caerulea* var. *assera*; B = *Hibbertia scandens*; C = Unidentified Epacridaceae. Figure 3. Pollen grains from a section of the scopal load of a female *Exoneura* sp. X 98. A = *Dianella caerulea*; B = *Stylidium graminifolium*; C = *Ceratopetalum gummifera*; D = papilionoid legume.

buds produced by the inflorescence. This mode of flowering is known as the steady state syndrome (Gentry 1974).

The highly variable yet comparatively low rate of conversion of flowers into fruits converged with *Echeandia* (Bernhardt & Montalco 1979), suggesting that *D. caerulea* was probably dependent on outbreeding (Richards 1986). The sharply contrasting pigmentation of the *D. caerulea* flower is largely duplicated in *Solanum* and *Dodecatheon* species. As in the majority of *Solanum*-type flowers, the perianth of *D. caerulea* expanded to expose the andreocium. The staminal filaments were relatively short compared to the length of the anthers, and such anthers were clustered and positioned so that the bee could not extract pollen without contacting the stigma.

Both long-tongue (Anthophoridae) and short-tongue (Halictidae) families of bees pollinated *D. caerulea*, but this is also typical of *Solanum*-type flowers. When pollen is the only edible reward, the length of the bee's glossa (proboscis) is inconsequential and many *Solanum*-type flowers in the western hemisphere are also pollinated by long-tongue Apoideae, especially bumblebees (*Bombus* species) and anthophorids (Macior 1974; Bowers 1975; Bernhardt & Montalvo 1979; Buchmann 1983).

Dianella caerulea received a greater diversity of foragers in the halictid genus, *Lasioglossum* (four subgenera), than any nectarless, bee-pollinated species studied previously in southern Australia (e.g. Bernhardt 1984, 1986, 1989; Bernhardt & Burns-Balogh 1986). *Lasioglossum* species appear to be dominant foragers on many genera with nectarless flowers in Australia (Bernhardt 1989). The failure of *Apis mellifera* to remove pollen from *D. caerulea* has been recorded in other *Solanum*-type flowers (Buchmann 1983; Barth 1985).

Do the strumae of *Dianella* species have a recognisable function? The strumae of the three species examined are definitely not nectaries. This may not be indicative of all taxa in this genus, but it should be noted that nectariferous secretions were not found in living flowers of *D. revoluta* or *D. longifolia* var. *longifolia* examined by the author from 1990–1992 (unpublished). Furthermore, no bee was ever observed mistaking strumae for anthers by attempting to scrape off the papillose cells as if they were pseudopollen or, as has been observed of some female bees, scraping the calli or trichome brushes in some orchid flowers (Dafni & Bernhardt 1990) or the hairy staminodes of some species within the Commelinaceae (Faden 1992). The papillae on the strumae of *D. caerulea* did not appear to secrete volatiles attractive to male bees as on the anther connectives of *Cyphomandra endopogon* var. *endopogon* (Solanaceae) which is pollinated by neotropical euglossines (Gracie 1993). How could the strumae make the anthers of *D. caerulea* appear larger when the anthers of *D. caerulea* var. *assera* are twice as long as the strumae, smooth, and a completely different colour?

It should be noted that androecia bearing some form of ornamentation and/or distal swelling are extremely common in the flowers of petalloid monocots that are buzz-pollinated. In *Xyris* and *Commelina*, for example, fertile stamens alternate with ornamented-brushy staminodes (Vogel 1978; Faden 1992). However, in Australia some monocot genera with *Solanum*-type flowers have fertile stamens in which the filament tips are enlarged and/or ornamented, including *Arthropodium, Bulbine, Caesia, Dichopogon, Herpolirion, Tircoryne* (Vogel 1978; Dahlgren et al. 1985; Bernhardt & Burns-Balogh 1986, and descriptions by Willis 1978) and *Stypandra* (a sister genus of *Dianella*) (Dahlgren at al. 1985). All but *Herpolirion* are currently placed within only two families in the order Asparagales, suggesting a strong trend towards parallel evolution (Dahlgren et al. 1985).

In the flowers of these five genera and *Dianella* the colour of the swollen filaments or their ornaments often contrasts vividly with the anther colours. Since these flowers tend to nod on their pedicels, ornamented filaments probably contribute to the overall visual cue of the flower's profile or side view. Epidermal sculptures on each filament could also help mesh stamens together, keeping the anther tuft tightly clustered.

Strumae may also function as scent glands but further investigation is required to test this hypothesis. The oily pollen coat of insect-pollinated flowers usually serves as a matrix for pollen scents and such scents appear to attract some pollinators (Buchmann 1983; Bernhardt 1984, 1986; Dobson et al. 1990). However, the pollen grains of buzz-pollinated flowers are retained inside inflated chambers so pollen odours are not exposed directly to the air until after the grains are removed by the bees. Scents attracting female bees to the source of pollen in a *Solanum*-type flower could be secreted by the filament apices.

Swollen, stalked and ornamented appendages are very common in the Asclepiadaceae, Aristolochiaceae, Burmanniaceae and Orchidaceae and these structures have been identified as osmophores (Vogel 1990). Therefore, the positive response to the

Neutral Red test of the strumae of *Dianella* species suggests that they may serve as both visual and olfactory cues to female bees searching actively for inverted and dangling anthers.

Acknowledgements

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The phenologies of six native forbs (*Aphanes australiana, Isoetopsis graminifolia, Triptilodiscus pygmaeus, Hypericum gramineum, Solenogyne dominii* and *Vittadinia muelleri*) occurring in grazed grassy communities on the Northern Tablelands of New South Wales

R.M. Trémont

Trémont, R.M. (Department of Botany, University of New England, Armidale, New South Wales, Australia 2351) 1995. The phenologies of six native forbs (Aphanes australiana, Isoetopsis graminifolia, Triptilodiscus pygmaeus, Hypericum gramineum, Solenogyne dominii and Vittadinia muelleri) *occurring in grazed grassy communities on the Northern Tablelands of New South Wales.* Cunninghamia *4(1): 21–34.* Information on the phenologies of native forbs occurring in grassy vegetation of the temperate Australian mainland is lacking. This has serious implications if we are to manipulate natural grassy communities to favour the continued existence of both common and uncommon native forbs, and the species richness they provide. The occurrence and duration of major life cycle events for three annual (*Aphanes australiana, Isoetopsis graminifolia, Triptilodiscus pygmaeus*) and three perennial (*Hypericum gramineum, Solenogyne dominii* and *Vittadinia muelleri*) forb species commonly found in grazed natural grasslands on the Northern Tablelands of New South Wales are reported in the present study. Growth took place in all seasons, across species, but reproduction was restricted to the spring–summer period. Particular life cycle events occurred over specific intervals, which varied between species. Such variation in the timing of key reproductive events can be utilised to enhance or suppress the survival of particular populations and so manipulate community composition. However, if native forbs and species-rich natural grassy communities are to be conserved or enriched, systematic data collection is required for many species. Comparative and functional group approaches may be the most effective strategies for documenting and synthesising the urgently-needed information on morphological and response characteristics of numerous native herbaceous species and their grassy communities.

Introduction

The phenologies of many species of native forbs found in natural grassy communities of the temperate Australian mainland are unknown. However, the major contribution made by native forbs to the species richness of these communities (e.g. Patton 1936; Stuwe & Parsons 1977; Walsh et al. 1986; Lunt 1990a; McIntyre et al. 1993; Prober & Thiele 1993; Trémont 1993, 1994), the depleted status of a number of previously plentiful forb species and the probable under-representation of these plants in

Australian lists of rare and threatened plants (McIntyre 1992) suggest an urgent need for systematic studies of their biology and ecology. Furthermore, particular groups of forbs are often characterised by specific attributes, including phenological characteristics. Studies of such attributes may facilitate the differentiation and characterisation of plant communities and provide for an understanding of processes affecting population and community dynamics, structure and composition (e.g. Friedel et al. 1988; Leishman & Westoby 1992; Bell et al. 1993; McIntyre & Lavorel 1994; McIntyre et al. 1995).

Considerable attention has been given to the biology of native grasses of temperate communities as a result of their contribution to pastoral industries. The knowledge so gained has led to the development of techniques for establishing some species (e.g. McDougall 1989; Stafford 1991), as well as manipulating the compositions of grass components of pastures and rangelands (e.g. Harradine & Whalley 1980; Lodge & Whalley 1985; McDougall 1989). No such information is available for native forbs. However, if we are to help their populations survive the expansion of 'synthetic communities' (after Bridgewater 1990), this has to change. We must gain an understanding of life-history attributes of, at least, the common forb species.

The life cycles of some threatened forbs have been well documented, and particular aspects of life cycle events studied for a small collection of other notable species (see Trémont & McIntyre 1994). However, published phenological information for common native forbs of the temperate Australian mainland is generally confined to comments on flowering times in relevant floras.

This paper describes the occurrence and duration of the main life cycle events of six native forbs commonly found in grazed natural pastures on the Northern Tablelands of New South Wales. The information reported was collected in conjunction with that for a wider study of herbaceous species and species groups occurring in grazed and ungrazed grasslands on the Northern Tablelands (Trémont 1993, 1994). The vegetation structure and the composition, diversity and life-history attributes of the flora at the study site have been described by Trémont (1993, 1994).

Materials and methods

Site description

The 1.2 ha study site (2 x 0.6 ha plots) was located on the Northern Tablelands of New South Wales, Australia, on the *Chiswick* CSIRO Pastoral Research Laboratory property (30°37′50″S, 151°32′42″E; 1060 m asl) near Armidale.

Meteorological data for *Chiswick* have been recorded by George et al. (1977) for the period 1949–1976 (Figure 1a). The site has a cool temperate climate, with mean maximum summer temperatures reaching about 25° C and mean winter minima of around –1° C. However, extreme maximum temperatures such as 38° C have been recorded and overnight frosts are common during autumn, winter and spring, with minima of –5 to –10° C occurring often (George et al. 1977). A mean annual precipitation

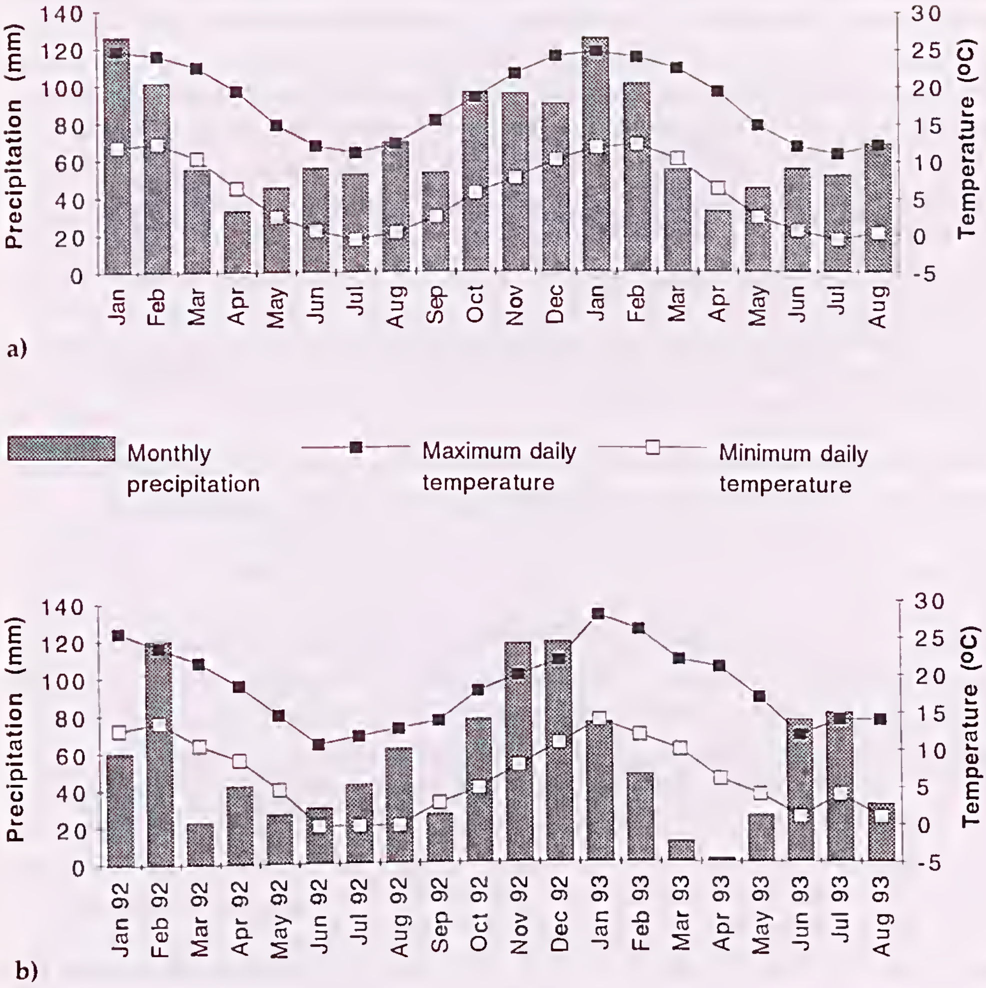

Fig. 1. Monthly precipitation and mean maximum and minimum daily temperatures for *Chiswick* Pastoral Research Laboratory, Armidale, NSW: a, as reported by George et al. (1977) for the period 1949–1976 (inclusive); b, as recorded during the present study from January 1992 to August 1993 (inclusive).

of 870 mm has been recorded at *Chiswick,* with approximately 60% falling during the five months from October to February (George et al. 1977). For the duration of the present study, recordings of maximum and minimum daily air temperatures and daily precipitation were obtained from the *Chiswick* weather station (Figure 1b).

Parent material at the study site consists of laterized basalt colluvium and sediments. Soils are grey-brown podzolics which are mildly to strongly leached and highly differentiated (King 1989). The site is gently undulating and has a convex mid-slope. Aspect is north to north-north-westerly and drainage is generally good.

At the time of European settlement, the study site was probably part of a *Eucalyptus melliodora–E. blakelyi* woodland community, with a graminaceous understorey dominated by *Poa sieberiana, Themeda australis* and *Sorghum leiocladum* (Whalley et al. 1978; Lodge & Whalley 1989). Native herbaceous legumes, such as the warm-season *Desmodium varians, Glycine tabacina* and *Psoralea tenax*, may have also been common (Whalley et al. 1978). However, little is known about other forbs in the pre-European grassy communities. These communities were replaced by a temperate tallgrass grassland community (King 1989) following the introduction of domestic stock and tree clearing in the mid-nineteenth century (Lodge & Whalley 1989). Until 1976, the site was unfenced and supported unfertilised pasture grassland grazed intermittently by sheep. From 1976, the 1.2 ha (2 x 0.6 ha plots) used for the present study were grazed continuously by mature fine-woolled non-Peppin Merino wethers at a stocking rate of 6.6 sheep per hectare. The natural pasture has remained unfertilised and unseeded (King 1989, pers. comm.).

During the present study (April 1992–August 1993, inclusive) the grass matrix of the grazed natural pasture generally consisted of small-statured grass species; bare ground was readily observable; sheep dung, lichen and moss were common; and there was relatively little plant litter. However, there were also areas which contained relatively more litter, less bare ground and sheep dung, and which were dominated by grass tussocks to about 25 cm diameter. This heterogeneity within the grassy vegetation was probably due to the effects of the camping behaviour of the sheep (Trémont 1993). Heavily utilised camp areas were dominated by small-statured grasses including the exotics *Vulpia* spp., *Poa annua* L. and *Bromus brevis* Steud., as well as native *Danthonia* spp.. Forb species such as *Paronychia brasiliana* DC., *Oxalis* spp. and *Capsella bursa-pastoralis* (L.) Medikus were also common. Moderately utilised areas had a more diverse flora (of mixed origin), generally dominated by *Bothriochloa macra* (Steud.) S. T. Blake, *Danthonia* spp. and *Vulpia* spp., as well as the forbs *Hypochoeris radicata* L., *Triptilodiscus pygmaeus* Turcz., *Gnaphalium* spp., *Trifolium campestre* Schreber and *T. cernuum* Brot.. Areas which were least utilised by the sheep were characterised by the native grasses *Themeda australis* (R. Br.) Stapf and *Poa labillardieri* Steud./*P. sieberiana* Spreng. and native forbs such as *Hypericum gramineum* Forster f., *Haloragis heterophylla* Brongn., *Desmodium varians* (Labill.) Endl. and *Leptorhynchos squamatus* (Labill.) Less. (Trémont 1993).

Species studied

Six native forb species were selected for phenological studies. The species chosen included three annuals — *Aphanes australiana* (Rothm.) Rothm. (Rosaceae), *Isoetopsis graminifolia* Turcz. (Asteraceae) and *Triptilodiscus pygmaeus* Turcz. (Asteraceae); and three perennials — *Hypericum gramineum* Forster f. (Clusiaceae), *Solenogyne dominii* L. Adams (Asteraceae) and *Vittadinia muelleri* N. Burb. (Asteraceae). *Aphanes australiana, I. graminifolia* and *T. pygmaeus* typically occurred in the moderately utilised areas of the plots, while *S. dominii* was found in places between the heavily and moderately utilised areas. *Vittadinia muelleri* and *H. gramineum* occurred in places used moderately or least by the sheep. The three annuals were selected as they appeared to be the most abundant non-leguminous native forbs which germinated on the study site during autumn 1992. Among the perennials, *S. dominii* was chosen because it was the most common native species with a rosette life form. *Vittadinia muelleri* and *H. gramineum* were selected as they were two of the three most abundant of the taller native forbs in little-utilised areas (see Trémont 1993). Voucher specimens of each species have been deposited with the New England Herbarium (Botany Department, University of New England, Armidale, NSW).

The life cycle continuum of the annual species was divided into the following phases:

- germination — from the time both cotyledons appeared until two true leaves were present
- vegetative growth — increased leaf number or size, or plant height
- flower buds — flower buds present but unopened
- flowering
- fruiting — development of fruits and shedding of fruits or seeds
- senescing — yellowing and drying of the plant.

The life cycles of the perennial species were divided slightly differently:

- vegetative only, growing — leaf number or size, or plant height, increased but no reproductive organs visible
- vegetative only, not growing — leaf number or size, or plant height, unchanged, no reproductive organs visible
- flower buds — as for annuals
- flowering
- fruiting — as for annuals
- senescing — as for annuals.

Each phase of the life cycle for each species began or ended when at least one plant was observed to be the first or last, respectively, to bear the relevant structures.

Observations on the annual species began around the time of germination (April–May 1992). On 9 May 1992 ten individuals of each of *A. australiana* and *I. graminifolia*, and 14 for *T. pygmaeus*, were randomly selected from the populations present on the study site. These plants were then marked using wooden kebab sticks, driven into the ground approximately 2–4 cm from each plant, and were protected from grazing by the placement of wire mesh exclosures (100 cm high x 55 cm x 153 cm). Records of life cycle events (see above) from marked plants were supplemented with general observations of non-marked plants from the same cohort. Between 9 May 1992 and 31 October 1992 observations were made at 6 to 31-day intervals, becoming more frequent in late winter–early spring, as growth rates increased. From 31 October 1992 observations were made every 14 days until all plants had senesced, at the end of January 1993.

For *S. dominii* (a perennial), 13 randomly chosen plants were marked (eight on 9 May 1992, five on 23 May 1992) in the same way as for the annuals. The ages of *S. dominii* plants were unknown. Each had at least three and up to six leaves at the time of marking but excavation of plants would have been necessary to determine if the leaves were from seedlings or resprouting mature plants. Observations were made at the same time as those for the annuals but the fortnightly records begun on 31 October 1992 were continued until 29 May 1993. Two further censuses were then made, on 24 July 1993 and 28 August 1993.

Casual observations of the sprouting behaviour of established *H. gramineum* and *V. muelleri* plants were made during May, June and July 1992. Then, on 25 August 1992, 16 mature plants for each species were marked using alloy tent pegs, one driven into the ground about 4–5 cm from each plant. Observations of marked plants were made on 19 September, 10 October and 31 October 1992. Then, from the end of October, until the study concluded (28 August 1993), observations were as for *S. dominii*.

On each observation day each plant was recorded as having grown or not grown — on the basis of the number or size of leaves, or plant height; and the presence of buds, flowers, seeds or fruits and some degree of senescence were determined. For *H. gramineum* and *V. muelleri* the presence and height of newly sprouted leaves and stems were also recorded during the autumn and winter of 1993, following senescence of the previous season's foliage. These sproutings originated at, or within, 0.5 cm of ground level and were hence designated 'basal sprouts'.

Results

Seasonal weather

Overall, mean maximum and minimum daily temperatures for all months of the present study were similar to those reported by George et al. (1977) for *Chiswick* (Figure 1). However, mean temperatures for January and February 1993 were two to three degrees higher than those reported previously. The total precipitation recorded for January 1992 to August 1993 (inclusive) was 1090 mm, approximately 77% of the total mean precipitation reported by George et al. (1977) for the same sequence of months. This occurred because the total monthly rainfall for each of January and March 1992, January, February, March, April and May 1993 was no more than half that recorded for each month, respectively, over 27 years by George et al. (1977) (Figure 1).

Plant responses

a) Annuals

Germination of *Aphanes australiana, Isoetopsis graminifolia* and *Triptilodiscus pygmaeus* had begun by May 1992 (Figure 2). This coincided with declining maximum and minimum daily temperatures during autumn and was probably aided by the higher rainfall in April, compared with that of a relatively dry March (Figure 1). Vegetative growth continued through winter until late August–early September 1992. At this time maximum and especially minimum daily temperatures had started to rise (Figure 1b), and reproductive structures were observed for all species (Figure 2).

Flowering of *A. australiana* and *I. graminifolia* occurred from September until mid-November 1992 (Figure 2), despite August, September and October rainfalls which were 10 to 30 mm lower than average (Figure 1). Fruiting was then observed for these species from mid/late-October until late-November/early-December, during which time maximum and minimum daily temperatures continued to increase and total rainfall was about 20 mm above average (Figures 1 & 2). Fruiting was of a slightly longer duration for *I. graminifolia* (Figure 2). All *A. australiana* and *I. graminifolia* plants had senesced by mid-to-late December 1992 (Figure 2), in the face of increasing daily temperatures and despite average rainfall (Figures 1 & 2).

Triptilodiscus pygmaeus developed buds from early-September 1992 and flowering took place from late-September 1992 until mid/late-January 1993 (Figure 2). Consequently, flowering was slightly later and continued for almost twice the length of time compared with *A. australiana* and *I. graminifolia*. It also continued into the period of highest daily temperatures. Fruits of *T. pygmaeus* were present from late-October/early-November 1992 until late-January/early-February 1993 and all plants had senesced by mid-February 1993 (Figure 2). Thus the life cycle of *T. pygmaeus* continued for longer than that of *A. australiana* or *I. graminifolia* - starting at a similar time in the autumn but continuing well into mid-summer (Figure 2). The senescence of *T. pygmaeus* occurred during the first two months of a period (January to May 1993) during which rainfall was 20 to 50 mm below average for each of five months (Figures 1 & 2).

b) Perennials

Hypericum gramineum and *Vittadinia muelleri* had life cycles for which the various phases occurred at comparable times (Figure 2). In contrast, *Solenogyne dominii* had a notably restricted reproductive period and a relatively long time of senescence/dormancy (Figure 2).

Hypericum gramineum and *S. dominii* showed growth of basal sprouts or new leaf production, respectively, from at least mid-May 1992, while *V. muelleri* produced basal sprouts from mid-June, despite this being a time of lowest daily temperatures (Figures 1b & 2). For *H. gramineum*, vegetative growth ceased between mid-June and mid/late-September 1992 (when mean daily temperatures were at their lowest), but basal sprouts again increased in length from the latter time, when temperatures began to rise (Figures 1b & 2). For *V. muelleri*, growth of basal sprouts ceased from

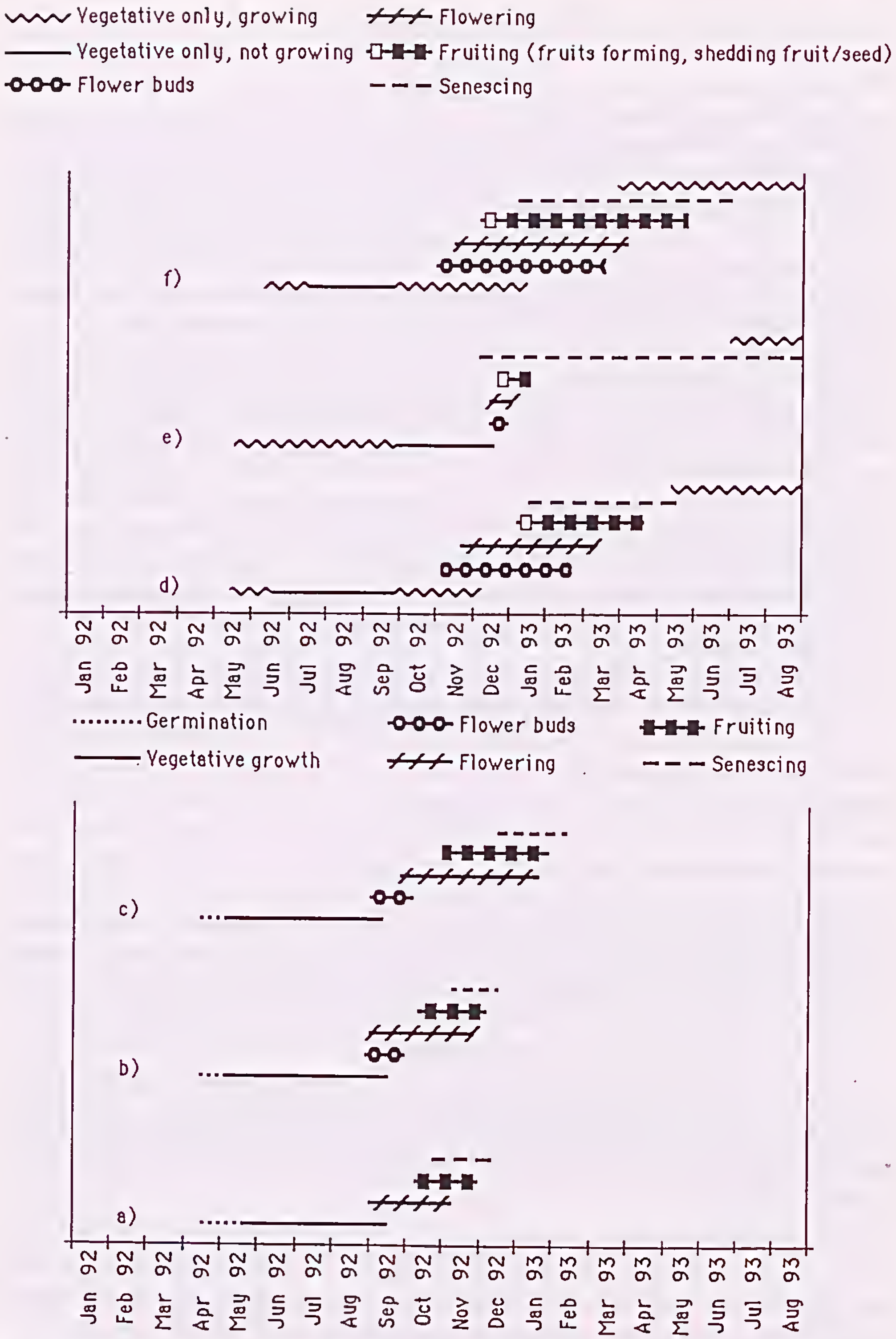

Fig. 2. Occurrence and duration of life cycle phases for the three annual species: a, *Aphanes australiana*; b, *Isoetopsis graminifolia*; c, *Triptilodiscus pygmaeus*; and the three perennials: d, *Hypericum gramineum*; e, *Solenogyne dominii*; and f, *Vittadinia muelleri* at Chiswick Pastoral Research Laboratory, Armidale, NSW.

late-July/early-August 1992 but also recommenced in mid–late September (Figure 2). New leaves were produced by *S. dominii* plants throughout the winter, from May until late-September/early-October 1992. From then, until late-November/early December 1992 no growth occurred for *S. dominii* but a small proportion (4.3%) of plants produced flowers and fruits during December (early summer), a comparatively warm, moist period (Figures 1b & 2).

Vittadinia muelleri began to produce flower buds in late-October 1992, as mean maximum daily temperatures increased, and flowers first opened in early-November (Figures 1b & 2). New buds continued to be produced until early March 1993 and flowering finished in late-April/early-May 1993 (Figure 2). Flowering continued despite spanning the hottest period of the year and a summer–autumn season that was notably dry, especially during January, February, March and April 1993, when monthly rainfalls were 30 to 50 mm below average (Figures 1 & 2). Fruits of *V. muelleri* began forming in early-December 1992 and mature fruits were released until the end of May/early-June 1993 (Figure 2). Signs of senescence began in January 1993 but it was not until the end of June 1993 that the growth for the 1992–93 season, for all 16 plants, had died (Figure 2). However, basal sprouts were first observed (for at least one plant) in late-March 1993 (despite three consecutive months of below-average rainfall) and by late-August 1993 (following some rain, but cool mean daily temperatures) all but two plants had new growth (Figures 1 & 2). As these two plants were seen to senesce during the hot, dry months of January and February 1993 and had not shown new growth by the end of the study, they were possibly dead. Basal sprouts of *V. muelleri* plants grew at least slowly from the time they appeared during autumn 1993 until the end of the study in late winter (28 August 1993).

Hypericum gramineum grew vegetatively from late-September until early-December 1992 and buds, then flowers, were observed in early and late-November 1992, respectively (Figure 2), as mean daily temperatures and monthly rainfall increased (Figure 1b). New buds continued to be produced until late-February 1993, while flowering continued until early/mid-March. This was despite the occurrence of highest daily temperatures and below-average rainfall during this time (see above and Figure 1). Fruits began to form in early-January 1993 (a time of highest temperatures and decreasing rainfall) and seeds were released until mid/late-April 1993 (Figure 2). Signs of senescence were first observed concurrently with fruit formation and continued so that all plants appeared to be 'dead' by late-April/early May 1993 (Figure 2), as temperatures fell towards winter minima (Figure 1b). During mid-May 1993 one plant produced basal sprouts. By the end of May four individuals had resprouted and at the late-July and late-August 1993 winter censuses all but four plants had resprouted (Figure 2). As these four had appeared 'dead' since the hot, dry period of late-January/early-February 1993, it is possible that they, too, had completed their life cycles.

Following the brief reproductive period of a small proportion of the *S. dominii* plants, in December 1992 a protracted period of senescence and dormancy began. It continued through the hot, dry summer and dry autumn, and for some plants extended at least until the end of the study (Figure 2), despite a mild winter and some rain (Figure 1). However, between late-May and late-July 1993, during a cool, relatively moist period, over 50% (7/13) of marked plants produced new leaves (Figures 1 & 2), some individuals reappearing following a period of absence. From late-December 1992/ early-January 1993 to late-May 1993 all marked *S. dominii* plants had decreasing numbers of leaves and all but two plants were completely absent for at least one census. Of those plants that became absent and had not resprouted by the end of the study, one disappeared in early-December, one in early-January, one in early-February, two in late-March and one in early-April. Of the plants that became dormant and subsequently reappeared, small numbers disappeared gradually over several months (January to March 1993) and resprouted after a dormant period of two to three months. *Solenogyne dominii* plants then showed leaf growth under the cool, moist conditions of winter 1993. This growth was similar to that of May to September 1992, but began slightly later in 1993 — probably because substantial rains did not fall until June (Figures 1 & 2).

Discussion

In the present study, *Hypericum gramineum*, *Vittadinia muelleri* and *Triptilodiscus pygmaeus* had flowering times which were up to two or three months longer than those indicated in the relevant floras (Harden 1990, 1992; Beadle 1976, 1980; Stanley & Ross 1983, 1986). *Hypericum gramineum* and *V. muelleri* continued to flower into late-summer and autumn (particularly *V. muelleri*) and *T. pygmaeus* flowered until mid-summer. Although this was possibly due to the mild climate of the Northern Tablelands, these extended flowerings were despite a dry mid-to-late summer and autumn. A study over numerous growing seasons would be required to establish whether the reproductive period of the annual *T. pygmaeus* might be longer under more favourable conditions, or whether it is strongly determinate and hence dependent on the time of germination and the initiation of reproductive events.

Hosking (1990, 1991) recorded the flowering times of plants found in Oxley Park, Tamworth. Tamworth is located approximately 110 km south-west of Armidale and although the altitude of Oxley Park is 200–600 m lower than that of *Chiswick*, and despite the two sites being in separate botanical divisions of NSW, they have many herbaceous species in common. Hosking (1990, 1991) recorded the presence of and flowering times for all species of the present study, except *Solenogyne dominii*. In general, the findings of Hosking concur with those of this study. However, flowering times of *H. gramineum* and *V. muelleri* near Tamworth were less restricted, presumably as the frost-free period is longer. Flowering periods for *Aphanes australiana*, *Isoetopsis graminifolia* and *T. pygmaeus* were shorter near Tamworth than on the tablelands, probably due to the longer and hotter summers typical of the north-western slopes. However, *A. australiana*, *I. graminifolia* and *T. pygmaeus* are all small, inconspicuous annuals which may be easily overlooked, perhaps resulting in artifically few records of flowering times (Hosking 1990, 1991).

Flowering times for *I. graminifolia* and *T. pygmaeus* (*Helipterum australe*) in grazed *Danthonia caespitosa* grasslands of southern NSW have been reported by Williams (1961, 1971). For *I. graminifolia*, flowering occurred between late-August and mid-to-late-October, while for *H. australe* it was from late-August to late-September, with isolated flowering in October. Groves (1965) also recorded flowering times for these two species, but from a *Themeda* grassland in southern Victoria. Groves (1965) reported *I. graminifolia* as flowering in October and November and *H. australe* in October.

The flowering times for *I. graminifolia* and *T. pygmaeus* (*H. australe*) in both southern NSW and Victoria are little different from that reported in this study. It is likely that changes in day length determine the season of flowering (Williams 1961, 1971) but latitudinal, seasonal and yearly differences in temperature and rainfall between northern NSW, southern NSW and southern Victoria are possibly responsible for the within-season variation in flowering times of these species between studies. Similarly, variations in flowering times are likely to occur at *Chiswick* given the variability of seasonal weather from year to year.

The germination ecology of *V. muelleri* (and several other native forbs) has been studied by Willis and Groves (1991), using seed collected in Canberra. These authors found that *V. muelleri* germinated best under an alternating temperature regime of 25° C for 8 hours/15° C for 16 hours. However, germination rates greater than 80% were also achieved under other temperature regimes. In addition, light, storage of seed at high temperatures and cold stratification of seed promoted germination of *V. muelleri*. There was little effect of an after-ripening treatment and the application of gibberellic acid was inhibitory. These findings confirm that at least some of the physical conditions occurring within grazed grassy communities on the Northern Tablelands of NSW are suitable for the germination of *V. muelleri*. However, the present study did not consider the germination of any of the perennial species observed. Thus no comparison can be made for this aspect of the life cycle of *V. muelleri* on the Northern Tablelands.

Flowering and germination are two key events in any life cycle, determining potential seed production and plant establishment. Seed production, germination rates and seedling survival can be enhanced or suppressed by the timely application of agents such as burning, slashing or grazing, or by the application of herbicides or soil disturbance. These agents can be used in grassy communities of temperate Australia to minimise seed production and seedling (or sprout) survival, if applied with sufficient intensity or frequency at times when reproductive growth or seedling establishment are occurring. Conversely, the exclusion of destructive agents at these critical times may enhance reproductive potential of plant populations, provided seasonal conditions are those required by the target species (e.g. see Lodge & Whalley 1985).

A further consideration in the manipulation of native forb populations is the status of the grassy matrix (Hitchmough et al. 1989). Where grass plants are large and abundant and litter has accumulated, forb populations are frequently small in number and communities are of limited species richness (e.g. Carr & Turner 1959; Stuwe &

Parsons 1977; Wimbush & Costin 1979; Trémont 1993, 1994). In these situations the vigour and cover of grasses need to be reduced, using a strategy involving one or more of the agents listed above which does not favour undesirable (e.g. exotic or highly competitive) species. Such strategies may need to utilise agents which reduce grass biomass without causing soil disturbance or providing significant nutrient or water enrichment (McIntyre & Lavorel 1994a, 1994b; McIntyre et al. 1995). In some communities, however, a potentially useful agent such as fire may also be unsuitable, stimulating unwanted germination of exotics when they are present in the soil seed bank (e.g. Lunt 1990b). Where the grass matrix can be reduced and the invasion of unwanted species minimised, resources can be made available for the introduction or expansion of native forb populations, the relative abundances of which can then be manipulated, in turn, by the application of suitable agents at certain life cycle phases of target species.

The phenological data obtained during the present study provides the type of information upon which species manipulations and the conservation of endangered species and remnant grassy communities should be based. However, similar information for the dominant grasses and other forbs (desirable and undesirable) in the community should be gathered before large-scale strategies or particular manipulative agents are applied. The collection of this additional data might be conducted utilising a comparative (e.g. Jurado & Westoby 1992; Leishman & Westoby 1992) or functional group (e.g. Friedel et al. 1988) approach, over a number of seasons. In this way, information could be recorded for a variety of characteristics and responses of many more species (using consistent definitions and methods), and correlations among species characteristics and between these and environmental factors determined. This information would then be available for the development of strategies for manipulating the composition, structure and dynamics of native forb populations and grassy communities. In this way it should be possible to conserve many species of native forbs, as well as the grassy communities of which they are an essential part.

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Post-fire regeneration and growth of *Senecio garlandii* (Asteraceae) — a vulnerable plant of the South Western Slopes, NSW

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Burrows, G.E. (Ron Potter Centre, Charles Sturt University – Riverina, PO Box 588, Wagga Wagga, New South Wales, Australia, 2678) 1995. Post-fire regeneration and growth of Senecio garlandii *(Asteraceae) — a vulnerable plant of the South Western Slopes, NSW.* Cunninghamia *4(1): 35–44. Senecio garlandii* F. Muell. ex Belcher (Asteraceae) is a perennial subshrub that has been recorded from less than 10 sites, mostly on the South Western Slopes of NSW. In conservation terms *S. garlandii* is currently classified as vulnerable. Its site of greatest abundance is The Rock Nature Reserve (340 ha), 30 km south east of Wagga Wagga. In March 1991 the first major fire in 40 years burnt more than 90% of the reserve and less than 5% of the original *Senecio* population remained in leaf. Over the next 3 years post-fire regeneration was assessed in a permanent quadrat (4 x 5 m) located in an area of pre-fire *Senecio* abundance. Following above-average rainfall during winter 1991, 453 *Senecio* seedlings were recorded in September 1991, ranging in density from 4–45 seedlings/m^2. After 4 months of below-average rainfall, seedling numbers declined to 171 by February 1992. In comparison to this 62% mortality (average of 2.23 deaths/day), the other 35 species of annuals and herbaceous perennials present in the quadrat had either died or had died back to a rootstock or similar organ at least two months previously. After February 1992 there was a low constant mortality (average 0.07 deaths/day) for the remaining 22 months of the study. By their first summer *S. garlandii* seedlings consisted of a single shoot 8–15 cm height. By the second summer this shoot had senesced to be replaced by 1–5 shoots (mean = 2.2, average height 65 cm) and by the third summer these shoots also senesced to be replaced by 1–12 shoots (mean = 3.9, average height 92 cm). No seedlings of *S. garlandii* flowered in their first summer, while 44% of the surviving 143 seedlings flowered in their second year and over 95% of the surviving 122 plants flowered in their third year. A small number of plants survived the fire and resprouted from rootstocks. This study indicates that the conservation status of *S. garlandii* has not been harmed by the fire.

Introduction

Senecio garlandii F. Muell. ex Belcher (Asteraceae) is a perennial subshrub, usually up to one metre in height. The stems and lower leaf surfaces are densely lanate, which explains the common name of 'Woolly Ragwort'. The first known collection of *S. garlandii* was made in 1890 by J. R. Garland who sent his material to Ferdinand von Mueller. Mueller prepared a manuscript description of this material under the specific epithet 'garlandii' but never published this species name. The name was formally published almost 100 hundred years later (Belcher 1986).

Belcher (1986) describes the distribution of *S. garlandii* as 'Very local along the 147° E. meridian on the western slopes of the Dividing Range between West Wyalong and Albury.' Belcher lists five localities for the herbarium specimens he examined: i) The Rock Hill, ii) Tabletop Range, iii) a site '15 miles' ESE of The Rock, iv) Gidginbung and v) 'near Albury'. In addition, *S. garlandii* has been recorded at Flowerpot Hill (4 km S of The Rock), Ulandra Nature Reserve (7 km SE of Bethungra) and Benambra State Forest (20 km W of Holbrook)(personal observation). *Senecio garlandii* is classified as a 3V (vulnerable) species (Endangered Flora Network for the Australian & New Zealand Environment and Conservation Council 1993) as its range is greater than 100 km but it only occurs in small populations that are mostly restricted to highly specific habitats.

At only 340 ha, The Rock Nature Reserve (lat. 35° 16' S, long. 147° 05' E) is a small island of remnant native vegetation, surrounded by extensive agricultural lands. The Rock Nature Reserve is an important area for the protection of *S. garlandii* as it supports the largest known population of the species (personal observation) and is one of the few formally protected areas within which the species grows. While *S. garlandii* has a restricted geographical distribution, it also has a restricted distribution within The Rock Nature Reserve. It occurs almost exclusively on the exposed upper slopes and ridges of the reserve and thus occupies only a small percentage of a small reserve. The same habitat requirements are evident at Tabletop and Ulandra Nature Reserves and Benambra State Forest.

After less than 75 mm of rain during November 1990 to March 1991 (average 208 mm for this period) the first major fire (15–17 March 1991) in 40 years burnt more than 90% of The Rock Nature Reserve (personal observation). Personal estimates indicated that pre-fire there were several thousand *S. garlandii* plants in the reserve but post-fire there were probably less than 100 plants in leaf and these were confined to inaccessible rock ledges on the eastern cliff.

Given: i) the restricted distribution of *S. garlandii*, ii) the importance of The Rock Nature Reserve to this species' formal protection and iii) the major reduction in plant numbers in the reserve due to the March 1991 fire, it was considered useful to study the post-fire regeneration and subsequent growth of *S. garlandii*. In addition two other aspects of the biology of *S. garlandii* were investigated to help understand seedling establishment and survival. Firstly, *S. garlandii* possesses large leaves of mesophytic appearance while all other perennial species at The Rock Nature Reserve that stay in leaf during summer have smaller xerophytic leaves. Thus leaf anatomy was studied to better understand seedling survival during summer. Secondly, a study of seed viability was conducted as prior tests indicated that a period of dry heat was needed to overcome dormancy. A similar response has only been described in a small number of native species (Bell et al. 1993).

Materials and methods

An area 50 m to the east of the main cliff was selected for the establishment of a permanent quadrat, 4 x 5 m. This area was chosen as it supported, excluding the herbaceous stratum, an almost monospecific stand of *S. garlandii* prior to the fire and thus was considered favourable for regeneration. The quadrat was 250 m above the surrounding plains and was on the easterly facing scree slopes of a north–south ridge. The quadrat had a slope of 30° and consisted of about 80% bare soil and 20% rock and was divided into 20 1 x 1 m contiguous sub-quadrats. The site was well-drained and was shaded from the early afternoon onwards by a 100 m high cliff to the west. Rainfall and temperature data were obtained from the Bureau of Meteorology's station at Forest Hill, Wagga Wagga, about 35 km NE of the study site.

The quadrat was assessed for a total of 28 months, usually at six-weekly intervals. At each trip the following parameters were assessed: i) number of seedlings and rootstocks of *S. garlandii*/m^2, ii) average height and number of basal shoots of seedlings and rootstocks of *S. garlandii*, iii) reproductive stage of seedlings and rootstocks of *S. garlandii* and iv) presence/absence and reproductive stage of species other than *S. garlandii*.

Mature seed of *S. garlandii* was collected from plants that recovered from rootstocks and 30 month old plants in late December 1993 and stored dry at ambient temperature. Seed viability was tested (3 replicates of 50 seeds) at about one month intervals by direct germination on filter paper supported on moistened vermiculite in petri dishes subject to a 16 hr photoperiod (45 μmol/m^2/sec) at 23° C and 8 hrs dark at 20° C. For light microscopy leaves were fixed in glutaraldehyde, processed using standard procedures for plastic embedding and transverse sectioned at 1–2 μm and stained with toluidine blue (O'Brien & McCully 1981).

Results

Seed germination

The seeds were roughly cylindrical (about 2.5 mm length, 0.6 mm diameter), averaged 0.29 mg in weight and had a thin seed coat. Immediately upon wetting the acheneal hairs released several intertwined spiral bodies and within 24 hrs the seeds were surrounded by a mucilaginous sheath. Seed tested within one week of collection exhibited low (< 6%) germination. After 1.5, 2.5 and 3.5 months dry storage at ambient temperatures average germination percentages of 69, 90 and 92%, respectively, were recorded.

Leaf anatomy

In cross-section the leaves showed typical dorsiventral anatomy with a layer of palisade mesophyll, a layer of spongy mesophyll and a layer of mesophyll intermediate between the palisade and the spongy mesophyll in position and cell arrangement (Fig. 1). A large proportion of the leaf was intercellular air space and little or no sclerenchyma was present. Xerophytic modifications to this basically mesophytic structure included: i) the large diameter upper epidermal cells possessed a thick (10–15 µm) outer cell wall, with a thin cuticle, ii) all stomata were restricted to the lower leaf surface, and iii) the lower surface had numerous single-celled trichomes that formed a dense mat about 200 µm thick (Fig. 1).

Field assessment

i) Species other than *Senecio garlandii*

The overstorey surrounding the quadrat consisted of *Eucalyptus macrorhyncha*, with some *E. polyanthemos*, *E. albens* and *Brachychiton populneus*, but these species were not recorded in the quadrat. A total of 35 species, excluding *S. garlandii*, were recorded in the quadrat over the assessment period. In terms of origin 22 species (63%) were naturalised and 13 (37%) were native species. In terms of life cycle and growth form 26 (74%) were annual herbs and 9 (26%) were perennial herbs.

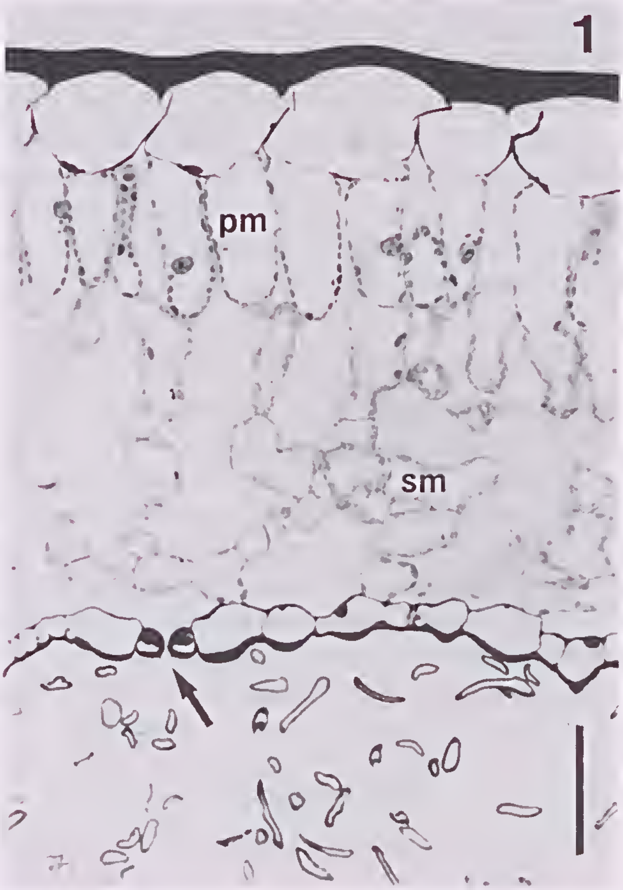

Fig. 1. Transverse section of a mature leaf of *Senecio garlandii*. Note the thick outer epidermal cell walls, the large adaxial epidermal cells, the palisade (pm) and spongy mesophyll (sm) layers, the stoma (arrowed) and the abaxial trichome layer. Scale = 50 µm.

ii) Survival of *Senecio garlandii*

While the fire killed many of the existing *Senecio* plants some survived by resprouting from a rootstock. Survivors could be identified by their greater shoot growth compared with *Senecio* seedlings and often by the presence of the charred stumps of the previous year's growth. By early September 1991 at least 2 rootstocks had not resprouted in the quadrat, 2 rootstocks both had a single shoot 3 cm in height and one rootstock had 7 shoots all about 8 cm high. Six weeks later one of the smaller rootstocks had died, while of the two remaining, one had a shoot 28 cm high and the other five shoots 50–75 cm high, all with flower primordia. This represents a rapid elongation of 1–1.5 cm/day over the intervening 6 weeks for many of the rootstock shoots. These two plants remained alive for the duration of the study.

iii) *Senecio garlandii* seedling establishment and mortality

In early September 1991, 5 months after the fire and with average or above average rainfall in the preceding 3 months (Fig. 2), 453 *S. garlandii* seedlings were recorded in the 20 m^2 quadrat (Fig. 3), ranging from 4–45 seedlings/m^2, at an average of 22.7 seedlings/m^2. The seedlings were no greater than 2 cm in height and most were 1 cm or less. Seedling numbers remained largely unchanged over the next 6 weeks (Fig. 3). Several annual species, e.g. *Carduus tenuiflorus*, *Daucus glochidiatus*, *Parietaria debilis*, *Ranunculus sessiliflorus* and *Stellaria media*, were more abundant and vigorous than the *Senecio* seedlings and tended to smother the smaller individuals. By late November 1991, a relatively small 7.3% reduction in seedling numbers had occurred (Fig. 3), although rainfall had been well below average for October and November (Fig. 2). Seedlings that had germinated in thin, loose ash on the top of boulders had died and many of the smaller individuals appeared to be water-stressed. Well-developed seedlings had 5–8 fully expanded leaves, were 10–15 cm high and did not elongate further. All the annual species that had previously overgrown the smaller, slower growing *Senecio* were dead and the perennial herbs died back to some form of rootstock or bulb by mid-summer. At mid-January 1992 the preceding 6 weeks had been relatively dry with only 31 mm of rainfall recorded. Combined with the excellent drainage and warmer temperatures this resulted in the most rapid rate of seedling mortality during the study (Fig. 3) with a 44% reduction in numbers, at an average of 4 deaths/day. In late February 1992, a further 27% reduction in numbers from the previous assessment period (average of 1.5 deaths/day) was recorded. The second half of summer 1991/1992 was relatively wet (93.4 mm of rainfall) and cool (January and February mean monthly maxima were about 2 degrees below average). These conditions had allowed hundreds of *Carduus tenuiflorus* seedlings to germinate in the quadrat, but a new cohort of *Senecio* seedlings did not germinate. During the winter and spring of 1992 no new *Senecio* seedlings germinated, even in the organic material and soil on top of the rocks where suitable germination conditions occurred without competition from existing plants. In spring 1992, as per the previous year, the *Senecio* seedlings were partially smothered by annuals but given their greater size and greater competitive ability the effects were not as pronounced. After the high mortality rate recorded during summer 1991/1992 seedling mortality was low during the remainder of the study (Fig. 3) even during the summer of

1992/1993 when there were 10 consecutive weeks where only 33.4 mm of rainfall was recorded and there were 11 consecutive days with maxima greater than 35° C.

In spring 1991 there were about 450 *Senecio* seedlings in the quadrat, ranging in density from 4–45/m^2. In December 1993, 28 months later, there were 122 *Senecio* seedlings, ranging in density from 1–14/m^2. This represents an overall mortality of 73%, ranging from a high of 89–94% in 3 sub-quadrats, to a low of 44% in one sub-quadrat.

iv) Growth form

In their first year of growth the *Senecio* seedlings developed a single upright shoot but by early winter this shoot had usually senesced and axillary buds at its base began to slowly elongate. Rapid elongation of the new basal shoots commenced in mid-August 1992 and by late September most shoots had increased in average height by 8 cm in the preceding 6 weeks. This elongation was greatest during October (about 4.5 cm/week) and began to slow in December when plants reached their average maximum height of 65 cm. Seedlings averaged 2.2 shoots in their second year, and some plants had up to 5 equal-sized shoots. In early May 1993 the shoots produced during the previous spring and summer began to senesce and, as in the previous year, the shoot system was gradually replaced by new shoots which were initiated in the basal leaf axils of the existing shoots. These shoots were often initiated just below ground level and grew horizontally for a short distance before becoming upright, thus giving a single individual the appearance of several plants growing in close proximity. In December 1993 most plants were at full adult-size (average plant height 92 cm), with an average of 3.9 shoots per plant (range 1–12). These main shoots were unbranched for most of their length but near the apex several axillary buds had elongated and initiated flowers to form a corymbose inflorescence.

v) Flowering

In their first year no seedlings in the quadrat flowered or had formed flower primordia, while the two rootstocks had finished flowering by late November but fruits had not been released. In September 1992 many *Senecio* plants had initiated flower primordia and by early November the primordia had developed into large flower buds. In mid-December 1992, 44% of the 143 remaining *Senecio* plants were flowering or had finished flowering and in late January 1993 flowering had finished. However December 1992 was unusually moist (Fig. 2) and cool, and in January 1993 the lower axillary buds in some plants had rapidly elongated and initiated new flower primordia. In mid-March 1993, after a dry finish to summer (Fig. 2), the flower buds that had been initiated in mid-January had been aborted. In December 1993 more than 95% of the 122 plants surviving their third summer had flowered or were flowering.

General observations throughout the reserve revealed that *S. garlandii* had: i) re-established monospecific thickets where they existed pre-fire, ii) increased plant density where previously only scattered plants had been present, and iii) a limited increase in range but was still restricted to the ridge areas.

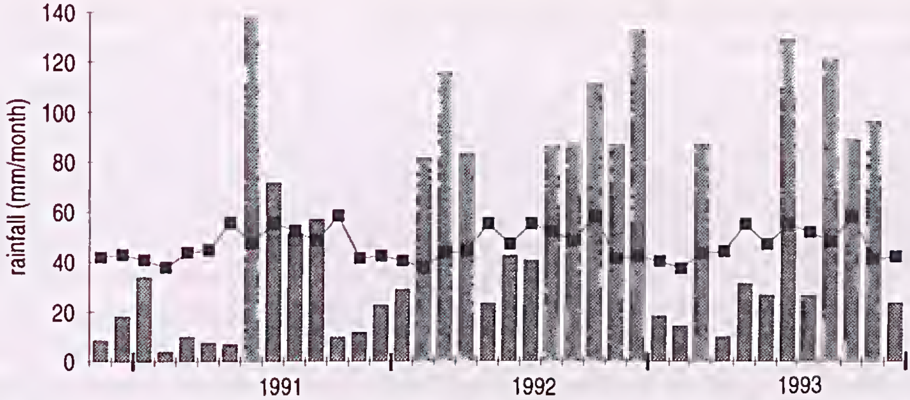

Fig. 2. Monthly rainfall during the study period with long-term average (■ – ■) values. Values are for Forest Hill, Wagga Wagga (35 km NE from site). Arrow indicates time of the fire.

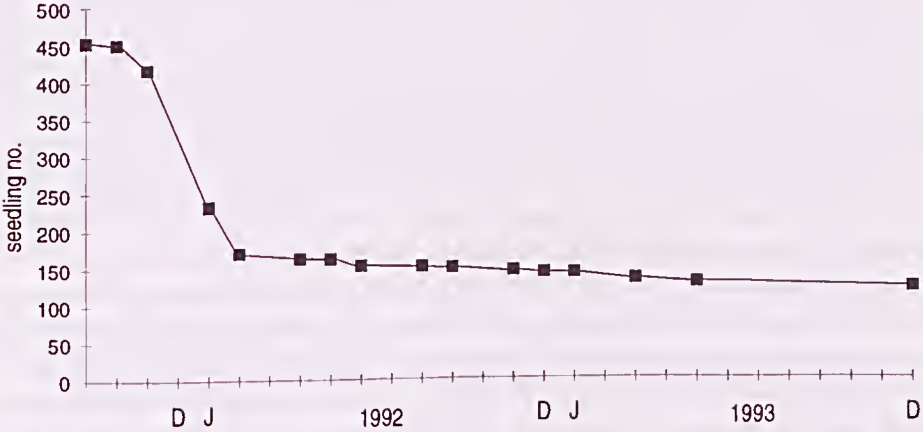

Fig. 3. Number of *Senecio garlandii* seedlings in the permanent quadrat during the study period.

Discussion

The principal finding of this study is that *Senecio garlandii*, a vulnerable species reduced to a few individuals after the 1991 fire at The Rock Nature Reserve, has regenerated successfully from seed and, to a lesser extent, from rootstocks. It has maintained its almost monospecific stands in its areas of pre-fire dominance, has increased in density where previously only scattered individuals existed and has expanded its distribution but is still principally restricted to the upper ridge areas. Several *Senecio* species are known as fire ephemerals or 'fire weeds' (Gill 1993). While *S. garlandii* shares with these species the ability to successfully regenerate after fire it would not be considered a fire weed because: i) seeds do not need a heat treatment to germinate, ii) individual plants appear to be relatively long lived through their annual resprouting habit, i.e. they do not have the short life span of a fire ephemeral, and iii) populations can persist in low fire frequency conditions, e.g. plants on cliff ledges.

Lawrence (1985) investigated the reproductive biology of 32 mainly native species of *Senecio*, with *S. garlandii* listed as *Senecio* species A (Belcher 1986). Lawrence noted, as in the present study, that *S. garlandii* is a perennial, is early flowering, produces lightweight seeds, the seeds produce a mucilaginous sheath upon wetting and that these seeds can have high germination percentages. From observations on pollen-ovule ratios and inflorescence morphology it was possible for Lawrence to deduce that *S. garlandii* was self-incompatible. Lawrence noted that stable environments favour outbreeding perennials but only 5 of the 15 self-incompatible perennials she investigated were usually restricted to comparatively stable environments. Three of the five, including *S. garlandii*, are found on rocky outcrops of drier inland areas.

The most common criterion for classifying a species response to fire is whether persistence is by seed ('seeders') or by vegetative means ('sprouters') (Gill & Bradstock 1992). This study indicates that *S. garlandii* is principally a seeder although some plants function as sprouters after a low-intensity fire. Gill & Bradstock (1992) list three categories of seed regeneration: i) from viable canopy-stored seed, ii) from soil-stored seed, and iii) from seed brought in, because no propagules remain on site after fire. In *S. garlandii* the mature achenes are easily dislodged from the head's receptacle with little force, therefore no seed-store exists on the plant. Many species of the Asteraceae have small air-borne fruits and are capable of recolonising burnt areas with seed blown in from unburnt areas (Purdie & Slatyer 1976). However, because the fire eliminated almost the complete *Senecio* population, except for some isolated individuals on cliff ledges, there were no seeds on unburnt plants to be used for recolonisation of burnt areas. In addition, while the achenes of *S. garlandii* have numerous slender pappus bristles they are not persistent (Belcher 1986), and thus long-distance wind dispersal of the fruits would not be expected. Thus it is most probable that the re-establishment of *S. garlandii* was from a seed-store in the soil, as were the 7 composites described by Purdie & Slatyer (1976). Purdie (1977) noted that seeds in litter are often destroyed in fires, while many seeds in the soil survive. Purdie (1977) noted that germination of herbaceous species, including *Senecio quadridentatus* and *Hypochoeris* spp., was lower in burnt than unburnt areas. She suggests that the seed may not be stored for long periods in the soil or are trapped in the litter by their pappus and thus destroyed by fire.

Studies by Hobbs & Atkins (1991) and Purdie & Slatyer (1976) found, as did the present study, that germination of perennial species occurred in the first year after the fire, but not in subsequent years. Hobbs & Atkins (1991) also found that seedlings of perennial species that survived their first summer generally continued to survive or, conversely, mortality is greatest in the seedling phase (Fig. 3).

Bell et al. (1993) noted that obligate re-seeding species tend to grow vertically initially then produce an 'umbrella shape', while resprouting species have more of an 'urn shape'. *Senecio garlandii* combines these two strategies as initially it produces a vertically growing shoot that only branches near the apex; however, after plants have become established they branch from near the base and form a more spreading canopy.

While *S. garlandii* operates as a resprouter in its annual growth cycle, the shoots originate above or close to ground level and a specialised rootstock or similar organ does not appear to be present. Thus fire-induced mortality of mature plants is to be expected. The degree of water-stress experienced by shrubs at and following the time of fire may be an important factor in determining the proportion of shrubs that resprout (Hodgkinson & Griffin 1982). This suggests that a low fire intensity, combined with more than the about 25 mm of rainfall received in the 2.5 months after the March fire (Fig. 2), then more *Senecio* rootstocks may have resprouted.

Over 200 vascular plant species have been recorded at The Rock Nature Reserve (Benson & Melrose 1993) but only about 50 species remain in leaf over summer. Most (> 90%) of these species possess small leaves and/or pronounced xerophytic modifications to their leaf anatomy. Thus it is remarkable that *S. garlandii* has the largest leaves of any species at The Rock Nature Reserve (personal observation) and possesses a mesophytic dorsiventral leaf anatomy that appears unsuited to the semi-arid conditions. The thickening of the outer epidermal cell wall, the restriction of stomata to the abaxial surface and the extremely dense abaxial trichome covering are probably effective in controlling water loss, in both seedlings and adults. This contributes to a relatively low mortality rate for a mesophytic species growing in semi-arid conditions and allows the seedlings a competitive advantage as they are able to continue vegetative and reproductive growth when the other species are dead or dormant. The lack of sclerenchyma results in wilting of leaves during times of pronounced water-stress.

After more than 70 mm of rainfall in early February 1992, combined with 13 consecutive days with temperature maxima below the monthly mean, there was an extensive germination of *Carduus* seedlings but no *Senecio garlandii* seedlings were observed. All the thistle seedlings died of water-stress before flowering. This observation, combined with the germination tests, suggests that the *Senecio garlandii* seeds may possess some mechanism to prevent germination after periods of wet weather in summer. A period of after-ripening, consisting of several months of dry heat has been described for a small number of Australian species of the Asteraceae and Poaceae (Mott & Groves 1981, Bell et al. 1993).

From a conservation viewpoint it is of concern that 22 weed species were present in the quadrat. General observation and the findings of other studies (Purdie & Slatyer 1976, Hobbs & Atkins 1991) indicate that the abundance and diversity of weeds should progressively be reduced as the *S. garlandii* re-establishes. *Senecio garlandii* is able to reach reproductive maturity relatively quickly as shown by 45% of the surviving seedlings flowering in their second summer and greater than 95% flowering in their third summer. This indicates that this species would not be eliminated at this site even if the fire frequency increased, although further study is required to determine what length of time and conditions are required to establish an effective seed-store in the soil. In summary, it appears that *S. garlandii* could tolerate a wide variation in fire frequency and no specific fire management practices are needed to maintain the population at The Rock Nature Reserve.

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Long-term revegetation of a denuded area in the Sydney region

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Morrison, David A., McCluskey, Lesley and Houstone, Michael A. (Department of Environmental Biology & Horticulture, University of Technology Sydney, PO Box 123, Broadway, New South Wales, Australia 2007) 1995. Long-term revegetation of a denuded area in the Sydney region. Cunninghamia *4(1): 45–62.* A 3 ha area near Yanderra, New South Wales, where the plant and soil cover had been completely removed in 1918 to expose the underlying sandstone rock surface was examined in 1989, 71 years after the initial disturbance (and had also been examined in 1923 and 1962). The area has remained more or less undisturbed since 1918, and the revegetation has been allowed to proceed unhindered. In total, 108 species were encountered in and around the area, 92 of them occurring in the denuded area (18 of which were found only along the disturbed strip next to the adjacent railway line) and 16 found only in the adjacent undisturbed native vegetation. Twelve of these species are not native to the area, but only one of these occurs there outside of the railway strip. There were no consistent patterns of plant species composition within the denuded area, although many of the plants occurred in clumps. The most significant environmental factor influencing the distribution of the plant species within the denuded area was soil depth, with a number of species having increased abundance in areas with deeper soil. There was a clear distinction between the plant species composition of the denuded area and the adjacent undisturbed area, with 17% of the native species encountered not occurring in the denuded area and a further 16% showing a significantly lower abundance in this area. The soil structure and fertility both showed significant differences between the native area and the denuded area. There has been a large change in the floristic composition of the denuded area through the 71 years of revegetation, although the rate of change has apparently decreased in recent years. However, the floristic composition of the denuded area does not appear to be becoming more similar to the adjacent undisturbed area.

Introduction

Primary succession is usually defined as the replacement through time of one group of species by another on substrates with no previous history of biota (Miles 1979). The best-known examples include newly-exposed debris around active volcanoes and retreating glaciers, although examples from rock faces, fellfield, sand-dunes and saltmarsh are also known (Miles & Walton 1993). The temporal trends in floristic composition observed during primary successions are usually thought of as being quite different from the temporal trends in plant dynamics of vegetated areas (secondary successions and fluctuations), and they are likely to be a response to quite different environmental factors. The factors that are generally considered to be important in primary successional dynamics include nitrogen deficiency, substrate instability, and lack of an indigenous seed source (Miles & Walton 1993).

Australia is almost completely unglaciated and is tectonically relatively stable, and so the opportunities for studying primary succession are relatively limited. However, human disturbance often results in the exposure of virgin surfaces, which can act as substrates for colonisation. This paper reports the results of a study of a 3 ha area near Yanderra, N.S.W., which had its plant and soil cover completely removed in 1918 to expose the underlying rock surface. This area has remained more or less undisturbed since that time, and the revegetation has been allowed to proceed unhindered. Our study was conducted in August and September of 1989, 71 years after the initial disturbance.

Earlier stages of the revegetation process on the denuded area have previously been reported, including studies in 1923 by Cambage (1923) and 1962 by Hannon & Evans (1963), but there appear to have been no recent detailed studies. Our study seeks to answer five general questions: 1. What is the pattern of plant species composition on the denuded area? 2. Does this pattern relate to any environmental factors? 3. What is the pattern of plant species composition between the denuded area and the adjacent undisturbed area? 4. Does this pattern relate to any environmental factors? and 5. What has been the temporal pattern of plant species composition since the area was denuded?

Geographic setting

Yanderra (34°19'S, 150°34'E), approximately 110 km south-west of Sydney, is on the dissected sandstone plateau of the Nepean Ramp between Bargo and Mittagong. The surrounding vegetation is typical Sydney sandstone dry sclerophyll forest (Beadle 1981). The immediately surrounding area is relatively undisturbed, being mainly public land surrounding the upper reaches of the Bargo River to the north-west and the catchment of the Nepean Reservoir immediately to the south-east.

During the construction of the main southern railway line from Picton to Mittagong in 1916–1918, areas adjacent to the line were excavated to supply construction fill. The largest excavated area, immediately west of Yanderra, is 3.2 ha, forming the segment of a circle of 350 m radius and having a chord of 500 m (Figure 1). The railway line forms the circumference of this circle, and a fence (erected immediately after the clearing) forms the chord running NE–SW, bordering an area of undisturbed native vegetation. Approximately 1–1.5 m depth of soil was removed from the area, leaving the exposed rock with a slope of about 2% from the adjacent undisturbed area towards the railway line.

Most of the denuded area has remained relatively undisturbed since excavation. A dirt vehicular access track runs around the circumference inside the railway line, and the line is elevated above this track for nearly half the circumference (Figure 1). The narrow area between the line and the track is extremely disturbed, and was excluded from our study (as was the track), leaving a study area of about 460 m along the fence and about 100 m from the excavation embankment at the widest point (c. 2.5 ha; Figure 1). Small areas (c. 4% of the study area) near the junction of the circumference and chord at each end were cleared in the early 1980s and used as construction stockpiles, and these areas were also excluded from sampling (Figure 1). There is no evidence of any major disturbance in the adjacent area of native forest.

The surface features and topography of the denuded area were described in detail by Hannon & Evans (1963), and their description largely remains current. However, the series of stone-covered ridges that they reported is less in evidence than it apparently was. The plants present on the area 5 years after the excavation are listed by Cambage (1923), and Hannon & Evans (1963) report those present 39 years later. Various unpublished floristic lists have been produced since then, including one by D. Benson and H. Fallding in 1979, and one by S. Krauss and D. Mackay in 1984.

Materials and methods

Plant data

The floristic composition was determined from fourteen 10 m x 10 m quadrats in the denuded area and five similar quadrats in the adjacent vegetation (Figure 1). In the denuded area, five of the quadrats were placed in a line parallel to the fence and about 15 m from it , with about 100 m between the quadrats. Another line of five quadrats was placed a further 15 m from the fence, three quadrats were placed another 20 m from the second line, and one quadrat was placed a further 20 m from this line. Within the native vegetation, the five quadrats were placed in a line parallel to the fence and about 20 m from it.

The abundance of each vascular plant species was estimated for each sample using the nested-quadrat technique of Outhred (1984), with importance scores assigned to each species in each quadrat using seven square sub-quadrats varying from 1 to 100 m^2. This technique produces abundance scores (on a scale of 1–7) that are functionally equivalent to frequencies (Morrison et al. 1995), which are directly related to plant density (Bonham 1989).

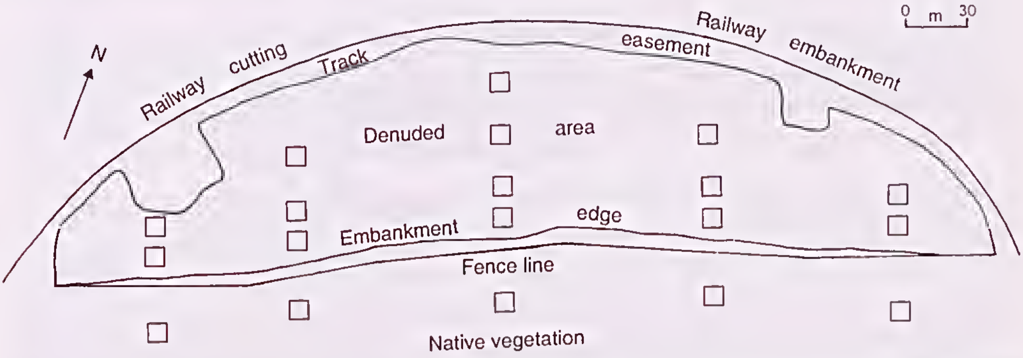

Fig. 1. Map of the study area at Yanderra. The squares indicate the location of the 14 quadrats used for the determination of floristic composition.

All plants in the denuded area that were taller than 2 m were also mapped, and their height was measured using an inclinometer. Within the adjacent native area, five 20 m x 20 m quadrats were laid out centred on the nested quadrats, and the number of plants of each tree species was counted in each quadrat. All species nomenclature follows Harden (1990–1993).

Environmental data

A 100 cm^3 soil sample was taken from near the centre of each of the 19 quadrats, and removed to the laboratory for physical and chemical analysis. The soil depth throughout the denuded area was recorded by hammering a marked pole into the ground every 5 m along 46 transects running at right angles to the fence and 10 m apart (a total of 541 measurements).

In the laboratory, the oven-dried soil samples were analysed using the methods of Grimshaw (1989) for: m-eq cation exchange capacity by the sodium acetate method; % soil organic matter by loss on ignition at 650°C; % coarse sand (particles 0.5–2 mm diam.), % fine sand (0.1–0.5 mm diam.) and % silt and clay (<0.1 mm diam.) by the sieving method.

Data analysis

Species-centred principal components analysis (PCA) of the floristic data (ter Braak 1988) was used to analyse the pattern of variation in plant species composition among the quadrat samples. Two separate analyses were run, one using only the data for the 14 quadrats from the denuded area, and one using all 19 quadrats.

The effects of the soil characteristics on the plant species composition were analysed by redundancy analysis (RDA) (ter Braak 1988). This is a constrained ordination technique based on principal components analysis that, in a joint analysis of the two data sets (i.e. floristic and environmental), assesses the degree to which they show co-variation (ter Braak & Prentice 1989). That is, it seeks patterns among the quadrats that occur in both data sets, while ignoring patterns that are unique to either one of the data sets alone; this is thus a direct gradient analysis technique. Once again, two separate analyses were run, one using only the data for the 14 quadrats from the denuded area, and one using all 19 quadrats.

We also undertook a PCA analysis of our floristic data in conjunction with the data of Cambage (1923) and of Hannon & Evans (1963), using only the presence-absence data for each species with extra weighting for the twelve most abundant species. The data from the unpublished floristic lists was unsuitable for our analysis.

The average height and density for each of the tree species (those > 2 m high) were calculated for 33 homogeneous sub-areas within the denuded area, varying in size from 275 to 1,250 m^2. These data were then correlated with the average soil depth for these areas using Pearson product-moment correlation coefficients (Wilkinson 1987), significance being assessed at the p=0.05 level. The quadrat frequency data for each species were also correlated with the average quadrat soil depth using Pearson product-moment correlation coefficients.

The degree of spatial clustering of plants in the denuded area was investigated by comparing the frequency distribution of the replicate samples for each species to a normal distribution using Kolmogorov-Smirnov one-sample tests (Wilkinson 1987), significance being assessed at the p=0.001 level. The frequency data from the 14 quadrats were arcsin(x/7) transformed prior to analysis, because frequency data expressed as proportions are likely to approximate a binomial distribution if the plants are randomly distributed (Bonham 1989); and the tree density data for the 33 sub-areas were ln(x+1) transformed, since randomly-distributed density data are likely to approximate a Poisson distribution (Bonham 1989).

The pattern of abundance of each species between the denuded area and the adjacent native area was investigated using non-parametric Mann-Whitney U-tests of the quadrat data (Wilkinson 1987), significance being assessed at the p=0.05 level. It should, however, be remembered that about 4 out of these 82 results could have a probability value of 0.05 or less by chance alone. The density of each of the tree species in the denuded and adjacent areas were also compared using Mann-Whitney U-tests, based on the 33 sub-areas in the denuded area and the 5 tree quadrats in the adjacent area.

Results

In total, 108 species were encountered in this study (Appendix 1), 92 of them occurring in the denuded area (18 of which were found only along the disturbed strip next to the railway line) and 16 found only in the adjacent native area. Twelve of these species are not native to the area, but only one of them (*Cirsium vulgare*) occurs there outside of the railway strip.

The ordination of the quadrats from the denuded area shows no consistent spatial pattern of floristic composition within this area (Figure 2a), although the western-most quadrat of the line closest to the fence was distinctly different in plant species composition from the other quadrats. This result implies that the majority of species either did not show any particular spatial pattern or that they were not sufficiently abundant for our sampling to detect any patterns that may have existed. The analyses of spatial clustering indicate that at least 14 of the species are not randomly distributed within the denuded area: *Allocasuarina littoralis, Daviesia corymbosa, Entolasia stricta, Eucalyptus agglomerata, E. gummifera, E. sclerophylla, E. sieberi, Grevillea buxifolia, Hakea dactyloides, H. sericea, Kunzea ambigua, Patersonia glabrata, Petrophile sessilis,* and *Platysace linearifolia*. However, the ordination analysis suggests that most of these non-random distributions are not correlated with each other.

A total of 765 plants was found to be taller than 2 m, although 121 (16%) of these were on the steep embankment between the denuded area and the adjacent native area (see Figure 1), and these were excluded from further analysis. Five of the species represented were multi-stemmed shrub species with only a few plants taller than 2 m, while six other species were single-stemmed trees/shrubs with low abundance (*Banksia ericifolia, Banksia serrata, Exocarpos cupressiformis, Leptospermum trinervium, Persoonia levis,* and *Xylomelum pyriforme*). The remaining seven species were more common

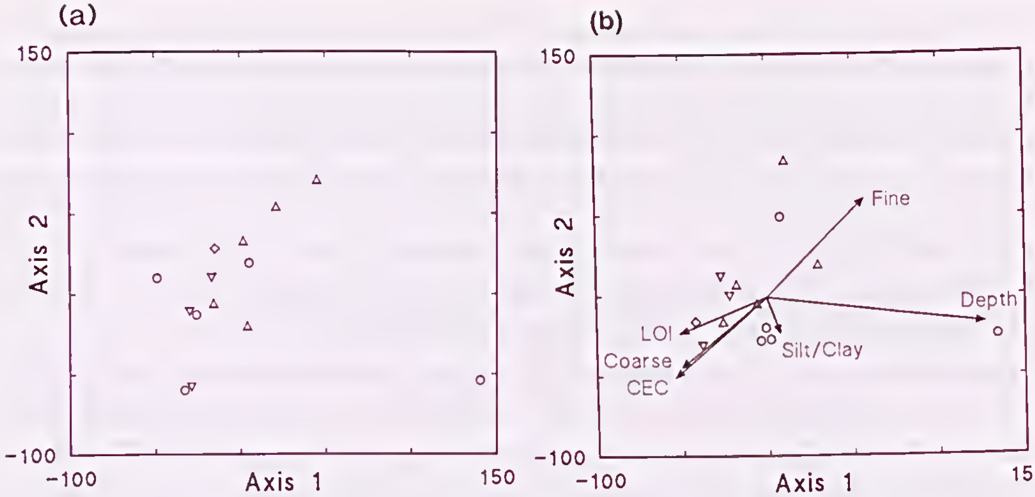

Fig. 2. Projection of the quadrats in the denuded area onto axes representing the first two components of **a**, the principal components analysis of the floristic data and **b**, the redundancy analysis of the floristic and soil variables data. (o) first, (◇) second, (▽) third and (Δ) fourth row of quadrats from the fence line; (Coarse) % coarse sand, (Fine) % fine sand, (Silt/Clay) % silt and clay, (LOI) % loss on ignition, (CEC) m-eq cation exchange capacity, (Depth) cm soil depth.

(Figure 3), with *Eucalyptus agglomerata*, *E. sieberi* and *E. sclerophylla* predominating. Of these species, the plants of *Allocasuarina littoralis* had three distinct height classes (Figure 3a), while those of *Hakea dactyloides* and *H. sericea* each had two height classes (Figure 3b); these height classes may represent distinct age classes. *Eucalyptus agglomerata*, *E. gummifera* and *E. sieberi* each had a small number of plants that were much taller then the others (Figure 3c–d), which may also represent a different age class.

The redundancy analysis of the quadrats from the denuded area shows a strong relationship between the pattern of floristic composition within the denuded area and the measured soil variables (Figure 2b), with the two axes shown accounting for 69% of the total sum of squares of the first two axes of the equivalent unconstrained ordination. In particular, soil depth is indicated as being an important characteristic, and the floristically-different quadrat (see above) was in an area with much deeper soil than were the other quadrats. About 16% of the denuded area was still without soil, and a further 36% of the area had soil less than 5 cm deep. However, there were many distinct pockets of deeper soil, particularly at the narrow ends of the segment and adjacent to the excavation embankment (Figure 4), and nearly 2% of the area had soil more than 40 cm deep (a maximum of 73 cm was recorded). For the tree species, the plants of *Eucalyptus sclerophylla* and *Hakea dactyloides* were denser in deeper soil, while the *Eucalyptus sieberi* and *Hakea dactyloides* plants were taller in deeper soil (Table 1); conversely, the plants of *Allocasuarina littoralis* were denser in shallower soil (Table 1). The more limited frequency data from the quadrats indicate that the abundance of a further nine species was positively related to the depth of the soil: *Acacia myrtifolia*, *A. suaveolens*, *Anisopogon avenaceus*, *Aristida ramosa*, *Cassinia quinquefaria*, *Cheilanthes tenuifolia*, *Danthonia tenuior*, *Lepidosperma laterale*, and *Mirbelia rubiifolia*.

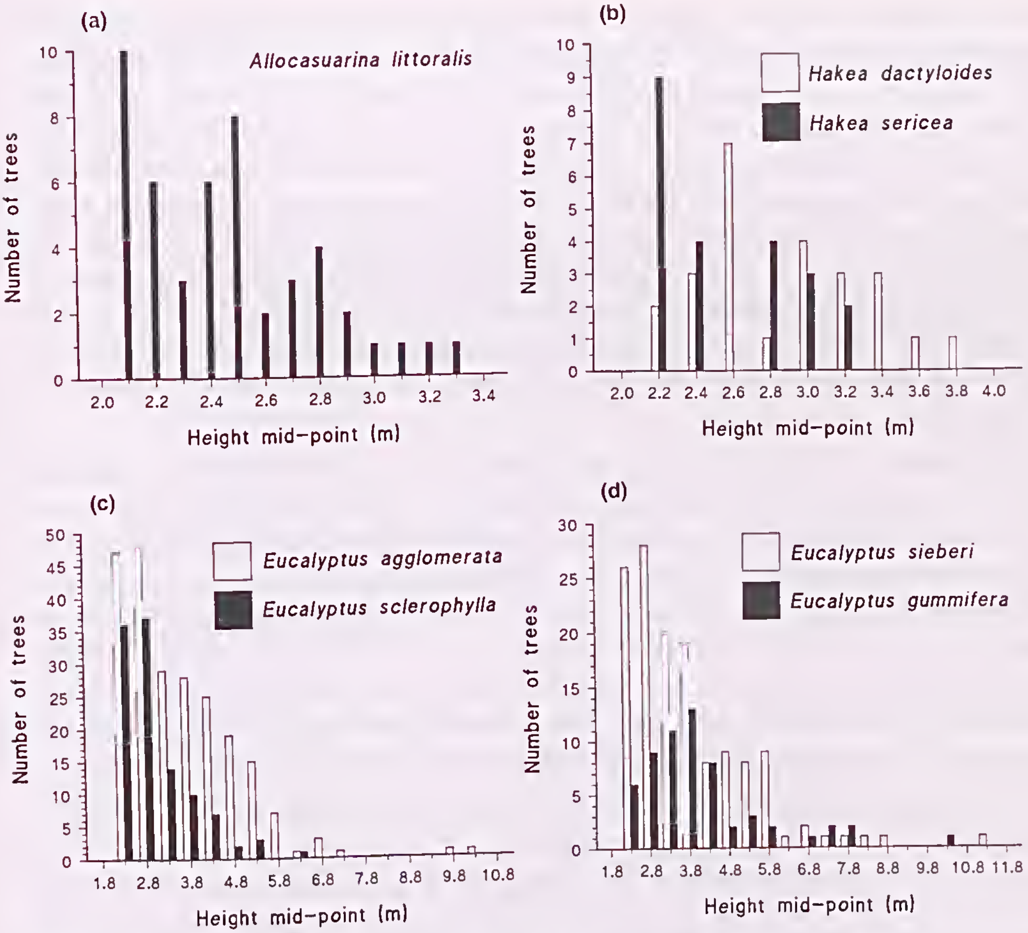

Fig. 3. Frequency of plant height classes for those species with more than ten plants >2.0 m tall in the denuded area.

Fig. 4. Schematic representation of the spatial distribution of areas where the soil depth was greater than or equal to 10 cm (shaded) in the denuded area.

The ordination comparison of the quadrats from the denuded area and the adjacent native area shows a clear floristic distinction between the two data sets (Figure 5a). This distinction corresponds to differences in abundance of 32 shrub, herb and monocot species (39% of those in both data sets), with 25 species showing greater abundance in the native area and 7 showing lower abundance (Table 2). The ordination spacing of the quadrats from the native area is greater than for the quadrats from the denuded area (Figure 5a), indicating that there was more spatial heterogeneity in floristic composition in the native area. Furthermore, the species composition of the tree storey was dramatically different between the two areas (Table 3), with a significantly lower abundance of *Eucalyptus gummifera* and *E. sieberi* in the denuded area (total tree density in the denuded area being only 36% of that in the adjacent native area).

The redundancy analysis of the quadrats from the denuded area and the adjacent native area shows a strong relationship between the pattern of floristic composition between the areas and the measured soil variables (Figure 5b), with the two axes shown accounting for 63% of the total sum of squares of the first two axes of the equivalent unconstrained ordination. All of the soil characteristics are indicated as being important in the distinction between the quadrats from the two areas, with the denuded area having sandier soil with less organic matter and lower cation exchange capacity than the adjacent area. However, the soil characteristics do not account for the spatial heterogeneity in floristic composition of the quadrats within the native area.

The ordination comparison of the historical data shows a clear change in floristic composition of the denuded area through time (Figure 6). The average annual rate of change in species composition was apparently more than twice as great during the first 5 years of revegetation as it was during the next 39 years, which was in turn more than twice that during the the subsequent 27 years. Most of the change in composition has not made the denuded area floristically any more similar to the adjacent undisturbed area, and the slight increase in similarity that has occurred has mainly been during the most recent years.

Table 1. Correlation of soil depth with plant height and density for each of the tree species

Species	Correlation coefficient	
	Height	Density
Allocasuarina littoralis	0.33	–0.41 *
Hakea dactyloides	0.62 *	0.40 *
Hakea sericea	–0.37	0.08
Eucalyptus agglomerata	–0.05	0.12
Eucalyptus gummifera	–0.05	–0.02
Eucalyptus sclerophylla	0.01	0.55 *
Eucalyptus sieberi	0.48 *	0.03

* significant at $p<0.05$

Table 2. Average importance scores for species showing significant differences in abundance between the native and denuded areas, as determined by Mann-Whitney U-tests

Species	Native area	Denuded area
[Number of quadrats	5	14]
More abundant in native area		
Thysanotus tuberosus	6.4	0.1
Eragrostis brownii	6.2	1.9
Bossiaea obcordata	6.0	0.0
Cyathochaeta diandra	6.0	0.4
Isopogon anemonifolius	5.6	0.4
Hovea linearis	5.4	0.0
Lambertia formosa	4.4	0.1
Leptospermum trinervium	4.2	0.8
Gompholobium huegelii	3.8	0.0
Pimelea linifolia	3.8	1.4
Cassytha glabella	3.2	0.0
Boronia ledifolia	3.2	0.0
Lepyrodia scariosa	3.2	0.1
Phyllanthus hirtellus	2.8	0.0
Hakea dactyloides	2.8	0.3
Phyllota phylicoides	2.8	0.6
Dianella caerulea	2.6	0.4
Gompholobium grandiflorum	2.6	0.6
?Callitriche stagnalis	2.4	0.0
Dillwynia retorta	2.4	0.9
Xylomelum pyriforme	2.2	0.0
Lomatia silaifolia	1.8	0.0
Eriostemon australasius	1.8	0.0
Tetratheca thymifolia	1.8	0.0
Goodenia bellidifolia	1.6	0.0
More abundant in denuded area		
Kunzea ambigua	0.0	4.7
Daviesia corymbosa	1.2	4.3
Grevillea buxifolia	1.8	4.2
Entolasia stricta	1.6	4.0
Grevillea mucronulata	1.6	2.7
Leptomeria acida	0.0	2.2
Acacia terminalis	0.2	2.1

Table 3. Mean (± s.e.) eucalypt densities and percentage contribution to tree species composition

Species	Density (stems / hectare)		Composition (percent)	
	Native area	Denuded area	Native area	Denuded area
Eucalyptus agglomerata	115(10)	111(19)	20	44
Eucalyptus gummifera	235(55)	25(12) *	40	10
Eucalyptus sclerophylla	50 (8)	7(11)	9	19
Eucalyptus sieberi	180(20)	67(12) *	31	27

* significant at $p<0.05$ as determined by Mann-Whitney U-test

Discussion

Our study detected no consistent patterns of plant species composition on the denuded area, although many of the plants are not randomly distributed within this area, the plants occurring in clumps. The floristic composition of the area is thus, in general, relatively uniform. A number of the tree species show distinct height classes, which may be interpretable as age classes. If this is so, then there have been a number of episodes of successful colonisation of the denuded area. However, for at least some species (e.g. *Hakea dactyloides* and *Eucalyptus sieberi*) plant height is related to soil depth, and height classes may not accurately reflect plant age for these species.

Almost all of the exotic species in the disturbed area are confined to the narrow strip along the edge of the railway line, where many of them are quite common. The

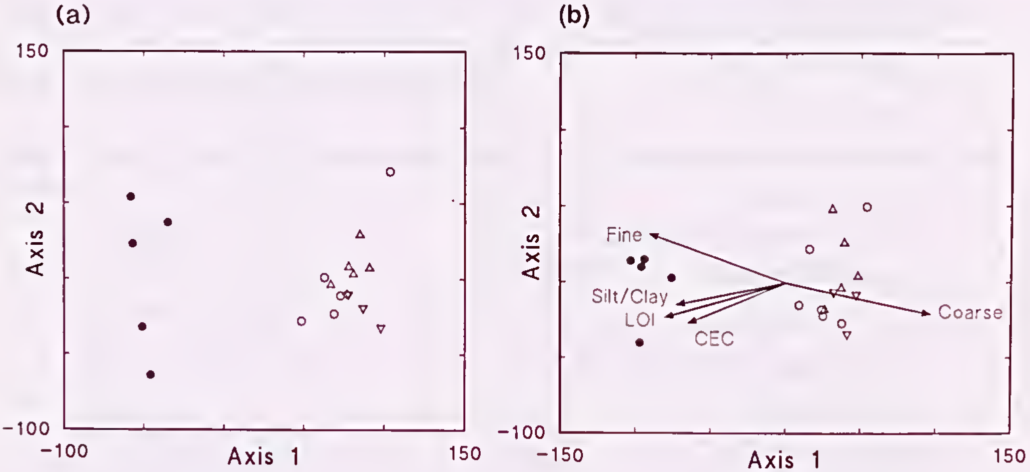

Fig. 5. Projection of the quadrats in the denuded and adjacent native areas onto axes representing the first two components of a, the principal components analysis of the floristic data and b, the redundancy analysis of the floristic and soil variables data. (o) first, (◊) second, (▽) third and (Δ) fourth row of quadrats from the fence line in the denuded area; (●) quadrats in the native area; (Coarse) % coarse sand, (Fine) % fine sand, (Silt/Clay) % silt and clay, (LOI) % loss on ignition, (CEC) m-eq cation exchange capacity.

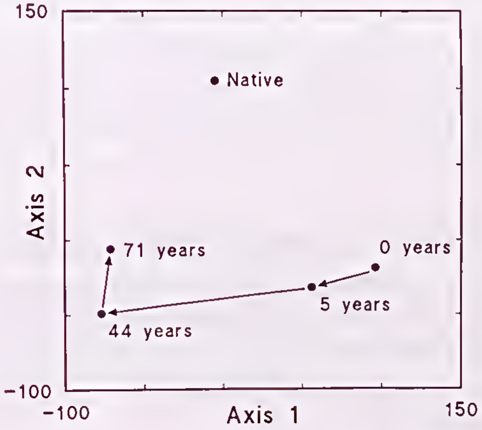

Fig. 6. Projection of the samples onto axes representing the first two components of the principal components analysis of the floristic composition, immediately after the area was denuded in 1918 (0 years), and from the studies of Cambage (5 years later), Hannon & Evans (44 years later) and this study (71 years later) in the denuded area, plus that of this study in the adjacent native area. The arrows indicate the presumed direction of change in species composition through time.

vehicular track thus forms a line of demarcation, dividing the excavated area into two distinct zones. The almost complete absence of exotics over most of the denuded area implies that this form of human disturbance is not amenable to the rapid establishment of non-native species (at least for sandstone bedrock), whereas at least 80 native species have successfully colonised the area. It is presumably the relatively thin and nutrient-poor nature of the soil that provides a suitable medium for the native species but not for the exotics (Hannon & Evans 1963).

The most significant environmental factor influencing the plant species within the denuded area is soil depth, with a number of species having increased abundance in areas with deeper soil. These species include trees, shrubs, herbs and grasses, their common denominator presumably being a lower drought tolerance (with a deeper root system?) than the other species. The only detected exception to this pattern was *Allocasuarina littoralis*, which was more abundant on the areas of shallow soil. This may indicate that this species is an early coloniser of the denuded area that competes less successfully with those species that are later colonisers. It may also be important that *A. littoralis* has nitrogen-fixing root nodules, thus surviving in areas of lower soil fertility.

Assuming that the adjacent native area has been the major seed source for those plants that have colonised the denuded area (passing trains are the only other likely source), then this must be the most relevant floristic comparison. There is a clear distinction between the plant species composition of the denuded area and the adjacent area, with 17% of the native species encountered not occurring in the denuded area and a further 16% showing a significantly lower abundance in this area. Once again, these species include trees, shrubs, herbs and grasses. The spatial heterogeneity of floristic composition was also much greater in the adjacent area than it was in the denuded area, presumably because of the greater species richness. Only seven native shrub and grass species had a greater abundance on the denuded area than in the adjacent area. The distinct differences in eucalypt species composition between the two areas and the much lower tree density in the denuded area may both be related to an inability to develop lignotubers in some of the species; and it may be instructive to test the possibility that *E. agglomerata* may not require a lignotuber for survival in the absence of fire.

The soil structure and fertility both showed significant differences between the native area and the denuded area, as presumably also did the soil depth (which could not be easily measured in the native area). It is therefore possible to hypothesise that it is these changes in the substrate that are the major determining factor as to which species have successfully colonised the denuded area. However, this hypothesis remains to be experimentally tested.

The most appropriate sampling technique for assessing the impact of human disturbance on the abundance of biological populations is a spatially and temporally replicated Before-After-Control-Impact design (Underwood 1991, 1992). This design was not possible in our study, because no samples were taken in the area before excavation in 1918 (allowing an assessment of the natural vegetation of the area), nor were detailed samples taken through time in the adjacent native area (to assess any temporal changes that may have occurred there as well). This certainly limits the possibilities for studying the primary successional sequence on the denuded area.

However, the limited analysis that we have undertaken indicates that there has been a large change in the floristic composition of the denuded area through time, that the rate of change has decreased in recent years, and that the change has not really made the denuded area floristically any more similar to the adjacent undisturbed area except possibly in recent decades. So, in spite of the relative success of the native plants in colonising the bare area, the revegetation to date can best be characterised as reclamation rather than restoration (using the terminology of Allen 1988). However, natural vegetation is rarely allowed to establish unaided after human disturbance, and this area provides an excellent opportunity for the continued study of natural rehabilitation.

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Appendix 1

Plant species found in the denuded area and the adjacent native area

(Nomenclature follows Harden [1990–1993])
* = introduced species
x = species found in the denuded area
† = species found only in the adjacent native area
r = species found mainly in the disturbed area next to the railway line

Botanical Name	Cambage (1923)	Hannon & Evans (1962)	Morrison et al. (1989)
PTERIDOPHYTES			
Adiantaceae			
Cheilanthes tenuifolia		x	x
Lindsaeaceae			
Lindsaea linearis		x	x
Schizaeaceae			
Schizaea bifida		x	x
ANGIOSPERMS–MONOCOTYLEDONS			
Anthericaceae			
Thysanotus tuberosus		x	x
Tricoryne simplex		x	x
Cyperaceae			
Cyathochaeta diandra		x	x
Lepidosperma laterale			x
Haemodoraceae			
Haemodorum planifolium	x	x	
Iridaceae			
Patersonia glabrata		x	x
Patersonia sericea	x	x	x
Juncaceae			
Juncus australis		x	x
Juncus subsecundus			x
Lomandraceae			
Lomandra cylindrica		x	x
Lomandra micrantha		x	x
Lomandra obliqua		x	x
Orchidaceae			
Caladenia carnea		x	
Calochilus robertsonii		x	x
Microtis unifolia		x	
Thelymitra ixioides		x	
Phormiaceae			
Dianella caerulea			x

Botanical Name	**Cambage (1923)**	**Hannon & Evans (1962)**	**Morrison et al. (1989)**
Poaceae			
Agrostis aemula	x		
Andropogon virginicus *		x	r
Anisopogon avenaceus		x	x
Aristida ramosa		x	x
Danthonia tenuior	x	x	x
Deyeuxia decipiens		x	x
Dichelachne rara		x	r
Entolasia stricta		x	x
Eragrostis brownii		x	x
Imperata cylindrica		x	r
Panicum effusum			r
Paspalum dilatatum *		x	r
Themeda australis			r
Vulpia myuros *	x		
Restionaceae			
Lepyrodia scariosa			x
Xanthorrhoeaceae			
Xanthorrhoea resinifera		†	†
ANGIOSPERMS–DICOTYLEDONS			
Apiaceae			
Platysace ericoides		x	x
Platysace linearifolia	x	x	x
Xanthosia pilosa		x	†
Asteraceae			
Cassinia aureonitens		x	
Cassinia quinquefaria			x
Cirsium vulgare *			x
Conyza albida *		x	r
Facelis retusa *		x	
Gnaphalium coarctatum *		x	
Helichrysum collinum		x	r
Hypochaeris radicata *	x	x	r
Olearia microphylla	x	x	x
Olearia sp.aff. *ramulosa*		x	
Olearia viscidula	x	x	
Ozothamnus diosmifolius		x	
Pseudo-gnaphalium luteo-album		x	
Senecio minimus		x	r
Vittadinia cuneata *		x	
Callitrichaceae			
Callitriche stagnalis			†
Campanulaceae			
Wahlenbergia gracilis		x	

Appendix 1 (cont.)

Botanical Name	Cambage (1923)	Hannon & Evans (1962)	Morrison et al. (1989)
Caryophyllaceae			
Silene gallica *			r
Casuarinaceae			
Allocasuarina littoralis	x	x	x
Dilleniaceae			
Hibbertia serpyllifolia		x	
Epacridaceae			
Brachyloma daphnoides		x	
Lissanthe sapida		†	†
Lissanthe strigosa		x	x
Monotoca scoparia		x	x
Euphorbiaceae			
Phyllanthus hirtellus			†
Poranthera corymbosa		†	
Poranthera ericifolia	x	†	†
Fabaceae subfam. Faboideae			
Bossiaea heterophylla			x
Bossiaea obcordata	x	x	†
Daviesia corymbosa	x	x	x
Daviesia ulicifolia		†	†
Dillwynia floribunda	x	x	x
Dillwynia parvifolia	x	x	x
Dillwynia retorta			x
Gompholobium grandiflorum	x	x	x
Gompholobium huegelii		x	†
Hovea linearis		†	x
Mirbelia rubiifolia	x	x	x
Phyllota phylicoides		x	x
Pultenaea villosa		x	
Sphaerolobium vimineum	x	x	
Trifolium arvense *		x	
Fabaceae subfam. Mimosoideae			
Acacia linifolia	x	x	x
Acacia myrtifolia	x	x	x
Acacia suaveolens	x	x	x
Acacia terminalis		x	x
Acacia ulicifolia	x	x	x
Gentianaceae			
Centaurium erythraea *		x	

Botanical Name	**Cambage (1923)**	**Hannon & Evans (1962)**	**Morrison et al. (1989)**
Goodeniaceae			
Goodenia bellidifolia		x	x
Goodenia hederacea	x	x	x
Scaevola ramosissima		x	†
Lauraceae			
Cassytha glabella			†
Cassytha pubescens		x	x
Myrtaceae			
Eucalyptus agglomerata	x	x	x
Eucalyptus gummifera		x	x
Eucalyptus sclerophylla	x	x	x
Eucalyptus sieberi	x	x	x
Kunzea ambigua		x	x
Leptospermum trinervium	x	x	x
Leptospermum polygalifolia		x	r
Olacaceae			
Olax stricta		†	
Phytolaccaceae			
Phytolacca octandra *			r
Pittosporaceae			
Billardiera scandens			†
Plantaginaceae			
Plantago lanceolata *		x	r
Polygalaceae			
Comesperma defoliatum		x	
Comesperma ericinum	x	x	x
Polygonaceae			
Acetosella vulgaris *	x	x	r
Primulaceae			
Anagallis arvensis *		x	r
Proteaceae			
Banksia serrata		x	x
Banksia spinulosa	x	x	x
Conospermum longifolium		x	x
Grevillea mucronulata		x	x
Grevillea buxifolia	x	x	x
Hakea dactyloides		x	x
Hakea sericea		x	x

Appendix 1 (cont.)

Botanical Name	Cambage (1923)	Hannon & Evans (1962)	Morrison et al. (1989)
Isopogon anemonifolius		x	x
Isopogon anethifolius		x	
Lambertia formosa		x	x
Lomatia silaifolia		x	†
Persoonia lanceolata		x	x
Persoonia laurina		†	x
Persoonia levis		x	x
Persoonia linearis		†	
Petrophile pedunculata		x	x
Petrophile sessilis	x	x	x
Xylomelum pyriforme		†	x
Rubiaceae			
Pomax umbellata		x	x
Rutaceae			
Boronia ledifolia		†	†
Eriostemon australasius		†	†
Santalaceae			
Choretrum pauciflorum		†	
Exocarpos cupressiformis			x
Leptomeria acida		x	x
Scrophulariaceae			
Verbascum virgatum *			r
Thymelaeaceae			
Pimelea linifolia	x	x	x
Tremandraceae			
Tetratheca thymifolia		†	†
Verbenaceae			
Verbena bonariensis *			r
Violaceae			
Hybanthus monopetalus		†	
Total no. of species in the denuded area	**33**	**100**	**92**

The vegetation of Mungo National Park, Western New South Wales

M.E. Westbrooke and J.D. Miller

Westbrooke, M.E. and Miller, J.D. (University of Ballarat, PO Box 663, Ballarat, Victoria, Australia, 3353) 1995. The vegetation of Mungo National Park, Western New South Wales. Cunninghamia *4(1): 63–80.* The vegetation of Mungo National Park and the adjacent Joulni Station (latitude 33°43'S and longitude 143°02'E) in south-western New South Wales within the Balranald local government area was assessed using intensive quadrat sampling and mapped using extensive ground truthing, aerial photograph interpretation and Landsat Thematic Mapper satellite image analysis. Two hundred and thirty five species of vascular plants were recorded from 55 families including 62 (26%) exotic species. Twenty vegetation communities were identified of which the most widespread were *Maireana* spp. low open-shrubland, *Atriplex vesicaria* subsp. *vesicaria* low open-shrubland, *Bromus rubens/Hordeum marinum* herbland, *Eucalyptus* spp. open-shrubland and *Casuarina pauper* woodland/open-woodland. One hundred and fifty years of grazing by introduced herbivores has resulted in degradation of many of these communities.

Introduction

Mungo National Park (latitude 33°43'S and longitude 143°02'E) is located in far south western New South Wales 100 km north east of Mildura. It is located within the Balranald local government area. It was established in 1979, following significant archaeological finds, to protect the geomorphological, cultural and biological features of this portion of the Willandra Lakes system. Joulni Station immediately south of the Park, includes part of Lake Mungo and was included in this study. Mungo N.P. and Joulni Station together occupy approximately 47 000 ha incorporating most of Lake Mungo and parts of Lakes Arumpo and Leaghur, as well as extensive areas of dunes and sand plains to the east of the Lakes.

History of the area

Aboriginal occupation of Lake Mungo dates from least 40 000 years ago at which time the lake contained fresh water from Willandra Creek (Bowler & Thorne 1976). Since that time the climate has fluctuated and Aboriginal occupation probably fluctuated as the lake levels rose and fell. From 1838 grazing was established in south-western New South Wales, initially on the Murray and Darling Rivers, but later, areas away from the rivers were also utilised. Gol Gol Station (203 000 ha) which included Lake Mungo was established in the 1860s. The land was overstocked and large quantities of perennial vegetation were cut for feed. The arrival of rabbits, coupled with the onset of severe drought in the late 1890s, led to massive soil erosion including the exposure of the Lake Mungo lunette. At its peak the Mungo woolshed on Gol Gol Station was used to shear up to 50 000 sheep but in 1922 the Station was broken up into a number of 16 000 ha 'soldier settlement' blocks including Mungo, Zanci and Joulni. The three properties were owned by members of the Barnes family until the purchase of Mungo by the NSW National Parks and Wildlife Service in 1978 and the addition of the adjacent Zanci Station in 1984. The area forms part of the 35 000 km^2 Willandra Lakes World Heritage area.

Climate

The climate is classified as cool semi-arid (Dick 1975), the area being within climatic zone 1B for New South Wales (Edwards, 1979): temperatures are high in summer and mild in winter with average daily maximum of 32° C in February and 15° C in July and average daily minimum of 16° C in February and 5° C in July; the mean annual rainfall is approximately 250 mm; the seasonal distribution of rainfall is fairly even but annual variation is high.

Geology and geomorphology

The study area lies within the Murray Basin geological province and consists of Quaternary material, with little rock outcropping (Lawrie and Stanley 1980). The area is dominated by parts of the Willandra Lakes System, relic features from the Pleistocene when they were filled by the Willandra Creek flowing through to the Murrumbidgee River (Magee undated). Three broad land systems are present (Walker 1991):

- the lake beds consisting of slightly saline calcareous clays and their associated lunettes of deep loosely cemented white sands and clay formed by deposition of particles from the lake bed
- dunefields consisting of low parallel ridges running east-west composed of red earthy sands and sandy solonised brown soils overlying sandy clays
- calcareous sandplains of loam or sandy loam solonised brown soils often with limestone nodules at the surface.

Previous studies

The most complete study of the vegetation of far western New South Wales is that by Beadle (1945, 1948) who included Mungo and Joulni within the '*Kochia pyramidata*–*K. sedifolia*', '*Atriplex vesicaria*' and '*Casuarina-Heterodendron*' associations. Noy-Meir (1971) carried out a quantitative analysis of the large area of mallee shrubland in south-western New South Wales and north-western Victoria. More recently the National Herbarium of NSW, Sydney, has undertaken mapping of the vegetation of the area at 1: 250 000 scale: reports on Ana Branch-Mildura sheet (Fox 1991) to the west, Balranald-Swan Hill sheet (Scott 1992) to the south of the study area and the Hay Plain sheet (Porteners 1993) to the east of the study area have been published. A study of the vegetation of the Willandra Lakes World Heritage Area was undertaken for the New South Wales Department of Planning and Environment (Rice 1987). Magee (undated) includes notes on the vegetation in his resource survey of the Willandra Lakes Region. A detailed survey and map of vegetation in Mallee Cliffs National Park to the south west of Mungo has also been published (Morcom & Westbrooke 1990). Mills (1984) undertook a preliminary vegetation survey of Mungo National Park but no systematic survey of the vegetation of the Park has been undertaken.

Methods

Two hundred 0.09 ha. (30 m x 30 m) quadrats were sampled and all vascular plant species occurring were recorded, together with a cover abundance value for each species modified from Braun-Blanquet (1928). Quadrats were subjectively located following the method of Gullan et al. (1979). This method ensured that all communities were sampled and provided data on floristic variability within the communities. Communities were in general sampled in proportion to the area they covered, however, since many quadrats were located along transects wherever community type was observed to change, those with a discontinuous distribution may tend to be over-sampled. Sampling was undertaken from the 8th to 16th September 1992.

The vegetation was classified using the computer based PATN (Belbin 1993) statistical package. The method used was an hierarchical, polythetic agglomerative classification using the Bray-Curtis (Belbin 1993) measure of association in conjunction with the Unweighted Pair Group Mean Arithmetic (UPGMA) fusion strategy. The resultant dendrogram displaying the relationships between quadrats, was assessed and subjectively and cut at the 17 group level. Each quadrat grouping on the dendrogram corresponded to a vegetation community and was deemed to adequately represent the vegetation communities recorded intuitively in the field. A further three restricted and/or interesting communities recorded during the field work but not evident from the numeric classification were added to the final classification to provide 20 vegetation communities. All vascular plant species recorded, from sampled quadrats and from opportunistic collection, were identified and a species list compiled (Appendix 2). For each quadrat the mean species richness and number of exotic species as a proportion of the total number of species was calculated (Table 1).

During a survey in September 1992 ground truthing was undertaken by driven (240km) and walked (210 km) transects. Information from these transects was used in conjunction with study of black and white aerial photographs and Landsat Thematic Mapper satellite image data (Scene 96–83 acquired on 13 April 1990) to produce a vegetation map at 1:50 000, subsequently reduced to 1:100 000 scale for publication. The vegetation communities mapped were defined by floristic and structural characteristics (Specht 1970).

All processing and manipulation of the digital satellite data was conducted using microBRIAN ver. 3.1 (MPA 1992). A supervised classification of the image, based on training sets derived from the vegetation classification, was undertaken. Due to wide variation in the density and composition of the understorey species across the quadrats it was not possible to distinguish between many of the communities with any confidence. It was however possible to distinguish between the overstorey dominants. As a result, the 20 communities from the vegetation classification were reduced to six vegetation types (e.g. Tall Shrubland – Mallee spp.) for the mapping phase. The minor vegetation types of very restricted occurrence, e.g. *Acacia aneura, A. loderi,* were unable to be mapped at this scale. Difficulty was experienced with the classification of the *Callitris* woodland due to the sparseness of the the community and the background of herbland. This community was later added to the image. The classified image was then transferred to the Environmental Resources Mapping System Geographic Information System database for final production at a 30 m cell size, which co-incided with the minimum area on the map.

Results

The vegetation of the study area consists predominantly of *Casuarina pauper* open-woodland, *Eucalyptus gracilis/ E. dumosa/ E. socialis* open scrub, and Chenopod open-shrublands but 20 distinct communities were recognised (Table 1). While several of the communities are of limited distribution they add significantly to the conservation values of the area. The approximate area occupied by each community, the sampling intensity, mean species richness and mean % weediness of these communities are given in Table 1.

Vegetation communities are described below, grouped according to structural attributes. The distribution of vegetation types is shown on the vegetation map of Mungo National Park and Joulni Station provided inside the back cover.

223 vascular plant species from 55 families were recorded from the Park including 50 (22%) exotics. The seven species of mistletoe recorded in this study and the hosts on which they occurred are given in Table 2. An additional 12 species were recorded as artificial plantings. Though not naturalised these may be of historic or cultural significance.

The following species have not been previously recorded from South Far Western Plains Botanical subdivision (Jacobs and Pickard 1981; Jacobs and Lapinpuro 1986; Harden 1990, 1991; Morcom and Westbrooke 1990; Scott 1992): *Dianella revoluta* var. *revoluta, Pterostylis biseta, Brachycome perpusilla* var. *tenella, Harmsiodoxa brevipes* var. *brevipes* and *Lysiana linearifolia.*

Fieldwork was conducted in cool weather over two weeks following good rains. Mean percentage occurrence of exotic species ranged from 12% in the *Eucalyptus* open-shrubland with *Triodia* understorey (2b) to 47% in the herblands (Table 1). The highest levels of occurrence of exotic species were in communities subject to the greatest grazing pressure, i.e. the *Nitraria billardierei* open-shrubland found close to tanks, the herblands also associated with tanks and the *Callitris glaucophylla* open-woodland on the dunes which had been exposed to high grazing pressure from rabbits. A high negative correlation between occurrence of exotic species and distance from water in studies at Mallee Cliffs National Park and Nanya Station was found by Westbrooke (1990)

Table 1. Community, percentage of area, sampling intensity, species richness (species per quadrat) and weediness (percentage of exotics) of the plant communities of Mungo National Park and Joulni Station

Community	Area (%)	No. of quadrats	Mean species per quadrat	Exotics (%)
1a *Eucalyptus largiflorens*, Black Box open-woodland	<1	2	23	33
1b *Casuarina pauper*, Belah woodland/open-woodland	8	55	19	26
1c *Callitris glaucophylla*, Cypress-pine open-woodland	1	21	14	44
2a *Eucalyptus* spp. open-shrubland with shrub understorey		18	22	18
2b *Eucalyptus* spp. open-shrubland with *Triodia* understorey	22	18	12	2
3a *Acacia aneura*, Mulga open-woodland	<1	1	27	26
3b *Acacia melvillei*, Yarran tall open-shrubland	1	8	18	33
3c *Acacia loderi*, Nealie tall open-shrubland	<1	2	23	27
3d *Acacia ligulata*, Sandhill Wattle low open-shrubland	1	2	11	38
4a *Dodonaea viscosa* subsp. *angustissima*, Hopbush shrubland	1	5	26	26
4b *Maireana pyramidata/M. sedifolia*, Bluebush low open-shrubland	24	29	15	33
4c *Atriplex vesicaria* subsp. *vesicaria*, Bladder Saltbush low open-shrubland	20	18	13	31
4d *Atriplex nummularia*, Old-man Saltbush low open-shrubland	<1	4	17	31
4e *Nitraria billardierei*, Dillon Bush low open-shrubland	4	29	23	39
4f *Chenopodium nitrariaceum*, Nitre Goosefoot low open-shrubland	<1	2	7	46
4g *Muehlenbeckia florentula*, Lignum low open-shrubland	<1	1	10	33
4h *Lycium australe*, Austral Boxthorn low open-shrubland	<1	1	32	28
5a *Eragrostis australasica*, Canegrass tussock grassland	<1	3	13	20
5b *Bromus rubens*, Red Brome/*Hordeum marinum*, Sea Barley-grass herbland	17	13	17	47
5c *Atriplex lindleyi*, Annual Saltbush herbland	1	3	8	12

Table 2. Species of mistletoe and their hosts

Mistletoe	Hosts
Amyema linophyllum subsp. *orientale*	*Casuarina pauper*
Amyema miquelii	*Eucalyptus gracilis*
Amyema miraculosum subsp. *boormanii*	*Alectryon oleifolius*
Amyema preissii	*Casuarina pauper*
Amyema quandong	*Acacia melvillei*
Lysiana exocarpi	*Alectryon oleifolius, Casuarina pauper, Geijera parviflora, Myoporum platycarpum, Pittosporum phylliraeoides*
Lysiana linearifolia	*Casuarina pauper*

Description of plant communities

1. Woodlands

1a. *Eucalyptus largiflorens* open-woodland

Two small patches of *Eucalyptus largiflorens* open-woodland (10 metres tall) occur on heavy soil in the south western corner of Joulni Station adjacent to Box Tank. The understorey consists largely of exotic herbs and grasses including those widespread throughout the study area and others associated with moister fertile soils such as *Marrubium vulgare, Chenopodium murale* and *Sonchus oleraceus.*

1b. *Casuarina pauper* woodland/open-woodland

Casuarina pauper growing to 10–12 metres tall, occurs as a dominant species throughout the National Park on the brown loamy sands of interdune areas (Fig. 1). It is frequently associated with *Alectryon oleifolius* subsp. *canescens* and/or *Myoporum platycarpum* and *Geijera parviflora.*

Most commonly associated understorey shrubs are *Enchylaena tomentosa, Chenopodium curvispicatum, Maireana pyramidata* and *Sclerolaena patenticuspis.* Frequently occurring native herbs include *Tetragonia tetragonoides, Zygophyllum ammophilum, Pycnosorus pleiocephalus* and *Omphalolappula concava.* The widespread occurrence of exotic herbs including *Brassica tournefortii, Hordeum marinum, Medicago minima* and *M. polymorpha* reflects the long pastoral history of the area (Fig. 2).

The following five sub-communities can be recognised, although these may relate to past land-use rather than edaphic factors:

- *Casuarina pauper/Alectryon oleifolius* with a diverse, shrubby understorey
- *Casuarina pauper* occurring as dense mono-specific stands
- *Alectryon oleifolius* occurring as dense groves
- *Myoporum platycarpum* open-woodland

Fig. 1. *Casuarina pauper,* Belah, woodland/open-woodland with a diverse shrubby understorey near the western border of Mungo National Park.

Fig. 2. Much of the *Casuarina pauper*, Belah, woodland/open-woodland of Mungo National Park and Joulni Station has a sparse understorey.

- *Myoporum platycarpum/Geijera parviflora* woodland resulting from past removal of *Casuarina pauper* from the community by ringbarking (Western Lands Files).

1c. *Callitris glaucophylla* open-woodland

Callitris glaucophylla (10 metres tall) occurs as the dominant tree on sandy ridges to the east of Lake Mungo. The community carries an open understorey of herbs and grasses including the native species *Actinobole uliginosum, Calandrinia eremaea, Calotis hispidula, Crassula colorata* var. *acuminata, Rhodanthe moschata, Tetragonia tetragonoides* and *Zygophyllum ammophilum* with a very high occurrence of exotic weeds including *Brassica tournefortii, Bromus rubens, Erodium cicutarium, Hypochaeris glabra, Medicago polymorpha* and *Sisymbrium irio*.

2. Eucalypt shrublands (mallee)

2a. *Eucalyptus gracilis/ E. dumosa/ E. socialis* open-shrubland

Eucalyptus open-shrubland dominated by *E. gracilis, E. dumosa*, and *E. socialis* (8m tall) occurs on interdune plains of sandy-loam solonised soils. *Eucalyptus leptophylla* and *E. oleosa* occur less frequently. Associated understorey shrubs include *Atriplex stipitata, Dodonaea viscosa* subsp. *angustissima, Eremophila glabra, Maireana pentatropis* and *Enchylaena tomentosa*.

Native ground layer species include *Brachycome lineariloba, Calandrinia eremaea, Omphalolappula concava, Ptilotus seminudus, Sclerolaena diacantha, S. patenticuspis, Tetragonia tetragonoides* and *Zygophyllum ammophilum*.

There are few exotic species in this community.

2b. *Eucalyptus* open-shrubland with *Triodia* understorey

On low dune ridges where shallow sands overlie sandy clays a Eucalyptus open-shrubland community characterised by the presence of *Triodia scariosa* subsp. *scariosa* as the dominant component of the understorey occurs (Fig. 3).

Most frequent eucalypt dominants are *Eucalyptus socialis, E. gracilis, E. oleosa, E. costata* and *E. dumosa*. *Eucalyptus leptophylla* is an occasional associate.

Commonly associated shrubs include *Dodonaea viscosa* subsp. *angustissima*, *Maireana pentatropis*, *Eremophila glabra*, and *Grevillea huegelii*. Of interest is the occurrence of *Exocarpos sparteus* reported as infrequent in south west New South Wales (Cunningham et al., 1981). Native herbs include *Calandrinia eremaea*, *Waitzia acuminata* and *Lomandra leucocephala*. This is the least weedy of the communities of the study area.

3. Acacia shrublands

3a. *Acacia aneura* open-woodland

In the west of the Park is a patch of *Acacia aneura* open-woodland growing to 12 metres high. It is surrounded by *Casuarina pauper* woodland. The understorey is dominated by native and exotic herbs and grasses.

3b. *Acacia melvillei* tall open-shrubland

This community tends to occur on heavier soils and thus most sites are close to tanks and have been subjected to heavy grazing pressure. The understorey is dominated by exotic herbs and grasses, in particular *Hordeum marinum*, *Erodium cicutarium*, *Medicago polymorpha*, *Bromus rubens* and *Brassica tournefortii* along with the native *Tetragonia tetragonoides*.

3c. *Acacia loderi* tall open-shrubland

There are two small areas of *Acacia loderi* open-shrubland to 6 m, both on Joulni. The understorey is dominated by native and exotic herbs and grasses.

3d. *Acacia ligulata* low open-shrubland

Areas of *Acacia ligulata* low open-shrubland occur to 4 m on the Lake Mungo lunette. The understorey consists largely of native and exotic herbs. It is likely that this community has declined with erosion of the lunette.

4. Low open-shrublands

4a. *Dodonaea viscosa* subsp. *angustissima* shrubland

In a number of sites, *Dodonaea viscosa* subsp. *angustissima* forms dense stands to approximately two metres. This species is also found as a common understorey component of the *Eucalyptus* open-shrublands.

Fig. 3. *Eucalyptus* open-shrubland with *Triodia* understorey, an extensive community east of Lake Mungo, occupies 22% of the study area.

Fig. 4. *Maireana pyramidala/M. sedifolia* low open-shrubland is the most widespread community of Mungo National Parkand Joulni Station, occupying 24% of the area.

4b. *Maireana pyramidata/M. sedifolia* low open-shrubland

Low open-shrubland dominated by *Maireana pyramidata* is the most extensive community of the lake beds (Fig. 4). It is frequently associated in various proportions with *M. sedifolia. Maireana georgei* is also frequently associated. A large number of herbs occur in the ground layer but the most frequent are the exotics *Hordeum marinum, Bromus rubens* and *Medicago polymorpha* and the native *Tetragonia tetragonoides.*

4c. *Atriplex vesicaria* low open-shrubland

An open shrub community dominated by *Atriplex vesicaria* subsp. *vesicaria* is extensive in the lake bed. Frequently associated species include *Dissocarpus paradoxus, Tetragonia tetragonoides* and *Bulbine bulbosa.*

4d. *Atriplex nummularia* low open-shrubland

An open shrub community dominated by *Atriplex nummularia* occurs in localised sites in Lake Mungo. A number of commonly associated species are those associated with moist soils. These include *Atriplex holocarpa, Chenopodium nitrariaceum, Osteocarpum acropterum* var. *deminuta* and *Bulbine bulbosa*. The exotic grass *Hordeum marinum* was recorded from all quadrats.

4e. *Nitraria billardierei* low open-shrubland

Low open shrubland dominated by *Nitraria billardierei* occurs in the lake beds particularly around tanks and also on parts of the lunette. Associated shrubs include *Atriplex holocarpa, A. lindleyi, Chenopodium curvispicatum, C. nitrariaceum, Enchylaena tomentosa* and *Maireana pyramidata.* There is a high percentage weediness with *Bromus rubens, Hordeum marinum, Medicago polymorpha, Sisymbrium irio* and *Sonchus* spp. present in most quadrats.

4f. *Chenopodium nitrariaceum* low open-shrubland

Open shrubland to 2 m tall dominated by *Chenopodium nitrariaceum* occurs in similar situations to the *Nitraria* community. The ground layer consists largely of exotic herbs including *Hordeum marinum* and *Brassica tournefortii* along with native herbs such as *Omphalolapula concava* and *Harmsiodoxa blennodioides.*

4g. *Muehlenbeckia florentula* low open-shrubland

A low shrubland dominated by *Muehlenbeckia florentula* occurs in low lying sites in the Mungo lake bed associated with *Atriplex vesicaria* subsp. *vesicaria.*

4h. *Lycium australe* low open-shrubland

Small areas dominated by *Lycium australe* occur on both Mungo National Park and Joulni.

5. Grasslands/Herblands

5a. *Eragrostis australasica* tussock grassland

Small patches of *Eragrostis australasica* grassland occur in wetter areas of the lake bed generally in the vicinity of the *Atriplex nummularia* community 4d.

5b. *Bromus rubens/Hordeum marinum* herbland

Extensive herbland/open-herbland growing to 0.8 metres tall dominated by the exotic grasses *Bromus rubens* and *Hordeum marinum* with the exotic herbs *Brassica tournefortii, Erodium cicutarium, Medicago minima, Salvia verbenaca* and *Sisymbrium irio* and the native herbs *Tetragonia tetragonoides, Pycnosorus pleiocephalus, Erodium crinitum* and *Omphalolappula concava.*

The relative dominance of species varies dramatically with seasonal conditions, with the extent and seasonal distribution of rainfall being critical in determining relative species abundance.

5c. *Atriplex lindleyi* annual chenopod herbland

On scald areas of the lake beds an annual herbland has developed. This is dominated by *Atriplex lindleyi* but other chenopod species including *Dissocarpus paradoxus, Osteocarpum acropterum* var. *deminuta, Sclerolaena divaricata, Mareana ciliata* and the exotic *Hordeum marinum* are associated.

Discussion

The distribution and species composition of vegetation communities within Mungo National Park is largely determined by variation in topography, landform position and soil type. *Eucalyptus* open-shrubland with a *Triodia scariosa* understorey is associated with sandy soils on the low dunes. *Eucalyptus* open-shrubland with a shrub understorey occurs on the sandy loam, solonised brown soils of the calcareous sand plains. *Casuarina* woodland/low woodland occurs on calcareous plains of loamy solonised brown soils and chenopod shrublands on the calcareous clays of the lake beds. A number of other factors, notably fire and past grazing history, have also played a role in determining the present distribution and floristic composition of the communities present.

Eucalyptus open-shrubland communities are highly flammable and most of those in the Park and Joulni were burnt in the extensive wildfires of 1974/75 (Pickard 1987). Fire leads to an increase in certain species such as *Halgania cyanea, Exocarpos sparteus,* and *Haloragis odontocarpa,* but these species decline as *Triodia* hummocks redevelop (Noble and Mulham 1980). The Park is at the stage of post-fire succession where fire-promoted species are declining.

The pastoral history of the area is reflected in the high percentage weediness (mean 18%) and low native species richness (mean 18 spp.) of much of the *Eucalyptus* open-shrubland (community 2a) and the presence of extensive herblands dominated by exotic grasses and herbs particularly in the vicinity of earth tanks. Mitchell (1991) noted that introduced weed species colonised many of the scald areas left as a result of high grazing pressure prior to the 1950s. The earth tanks and their associated channels support areas that remain wetter or receive greater run-off than would be the case in an unmodified environment. This factor, together with the disturbance

Fig. 5. Whilst only occupying a small proportion of Mungo National Park *Callitris glaucophylla*, Cypress-pine, open woodland is a prominent feature of the dunes to the west of Lake Mungo but is severely degraded with the understorey consisting largely of exotic species.

caused by clearing and grazing, has contributed to the relative high number of weed species in the herblands. Westbrooke (1990) noted the high correlation between weediness and grazing pressure in the vicinity of earth tanks. It appears likely that the herblands originally carried other communities, i.e. chenopod shrublands or arid woodlands. Rabbits, goats and high kangaroo populations, partially sustained by permanent water in tanks, maintain grazing pressure on the herblands, possibly limiting recovery of the original communities. Dense stands of unpalatable *Nitraria billardierei* found around tanks are another effect of past grazing pressure (Cunningham et al. 1981, Scott 1992). Bracken and Gorman (1987) recommended the gradual closing of the majority of the tanks on Mungo National Park. This measure is strongly supported.

The *Dodonaea viscosa* subsp. *angustissima* shrublands (4a) are likely to result from past land-use, particularly the clearing of *Eucalyptus* open-shrubland and subsequent replacement by unpalatable species such as *Dodonaea*. Noble (1984) and Harrington et al. (1984) report an increase of *Dodonaea* spp. in response to grazing and the genus is also reported as an early coloniser following the clearing of mallee (Beadle 1948, Onans & Parsons 1980)

Callitris glaucophylla open-woodland has few native species (mean 7) and a high level of exotic species in the understorey (Fig. 5). Scott (1992), discussing the Balranald area immediately south of Mungo notes evidence for this community being more extensive in the past. Craven (unpubl.) has suggested that the decline of this community is related to a number of factors including harvesting, grazing pressure

Fig. 6. *Acacia melvillei*, Yarran, tall open-shrubland is in a severely degraded condition with no recruitment. The conservation status of this community should be viewed with concern.

and changes in pasture composition from native grasses and forbs to exotic annual grasses and weeds.

Acacia melvillei tall open-shrubland is severely degraded (Fig. 6). Surviving shrub dominants are senescent, there is no regeneration and the conservation status of this community should be viewed with considerable concern. Scott (1992) and Batty and Parsons (1992) have raised concerns regarding this community elsewhere in the region and Mungo National Park is the only conservation reserve in which it is represented. It is important that steps are taken to protect and ensure rehabilitation of this community.

Whilst the vegetation of Joulni Station has been modified through its long pastoral history there would be a number of benefits from its addition to Mungo National Park. Most important is the complete protection of Lake Mungo and its associated geomorphological and archaeological features. Additionally the inclusion of a number of areas of *Acacia melvillei* shrubland, noted earlier as a community under threat, two patches of *Acacia loderi* and two patches of *Eucalyptus largiflorens* woodland which, whilst not significant in their own right, would add to the diversity of the Park. In the west of Joulni are some of the best examples of *Eucalyptus* open shrubland with *Triodia* understorey and associated with this a number of species not recorded within Mungo. These include *Convolvulus erubescens, Dianella revoluta* var. *revoluta, Eremophila oppositifolia* subsp. *rubra, Jasminum lineare, Lepidium leptopetalum, Olearia subspicata* and *Ptilotus spathulatus*.

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Appendix 1

List of vascular plant species recorded from Mungo National Park and Joulni Station September 1992.

Taxonomy according to Harden (1990–1993).
* Denotes exotic species
# Denotes cultural plantings
[ ] Denotes name in Harden that has since changed.

Gymnosperms

CUPRESSACEAE

Callitris glaucophylla
Callitris verrucosa

Ferns and fern allies

ADIANTACEAE

Cheilanthes austrotenuifolia

Monocotyledons

AGAVACEAE

#*Agave sp.

CYPERACEAE

Schoenus subaphyllus

LILIACEAE

*Asphodelus fistulosus
Bulbine bulbosa
Dianella revoluta var. revoluta
*Myrsiphyllum asparagoides
Thysanotus baueri

ORCHIDACEAE

Pterostylis biseta

POACEAE

#*Arundo sp.
*Bromus rubens
*Bromus tectorum
*Hordeum marinum
Eragrostis australasica
*Rostraria pumila
*Schismus barbatus
Stipa spp.
Triodia scariosa subsp. scariosa
*Vulpia bromoides
*Vulpia muralis
*Vulpia myuros

LOMANDRACEAE

Lomandra leucocephala

Dicotyledons

AIZOACEAE

Disphyma crassifolium subsp. clavellatum
*Mesembryanthemum crystallinum
*Psilocaulon tenue
Tetragonia tetragonoides

AMARANTHACEAE

Ptilotus seminudus
Ptilotus spathulatus

ANACARDIACEAE

#*Schinus areira

APIACEAE

Daucus glochidiatus
Trachymene cyanopetala

ASCLEPIADACEAE

Marsdenia australis

ASTERACEAE

Actinobole uliginosum
*Arctotheca calendula
Brachycome ciliaris var. ciliaris
Brachycome lineariloba
Brachycome perpusilla var. tenella
Calotis hispidula
*Centaurea melitensis
Chthonocephalus pseudevax
Gnephosis tenuissima
*Hypochaeris glabra
*Hypochaeris radicata
Isoetopsis graminifolia
Millotia macrocarpa
Millotia perpusilla
Minuria cunninghamii
Minuria leptophylla
Myriocephalus stuartii
Olearia muelleri
Olearia pimeleoides
Olearia subspicata
*Onopordum acaulon

Podolepis capillaris
Pycnosorus pleiocephalus
Rhodanthe corymbiflora
Rhodanthe moschata
Senecio glossanthus
Senecio lautus
*Sonchus asper subsp. glaucescens
*Sonchus oleraceus
Vittadinia cuneata var. hirsuta
Waitzia acuminata

BORAGINACEAE
*Echium plantagineum
Halgania cyanea
Omphalolappula concava
Plagiobothrys plurisepaleus

BRASSICACEAE
Alyssum linifolium
Arabidella nasturtium
*Brassica tournefortii
*Capsella bursa-pastoris
*Carrichtera annua
Geococcus pusillus
Harmsiodoxa blennodioides
Harmsiodoxa brevipes var. brevipes
Lepidium fasciculatum
Lepidium leptopetalum
Lepidium papillosum
Pachymitus cardaminoides
Phlegmatospermum eremaeum
*Sisymbrium erysimoides
*Sisymbrium irio
*Sisymbrium orientale
Stenopetalum lineare
Stenopetalum sphaerocarpum

CACTACEAE
#*Opuntia sp.
#*Cylindropuntia imbricata

CAMPANULACEAE
Wahlenbergia gracilenta

CARYOPHYLLACEAE
*Herniaria cinerea [H. hirsuta]
Scleranthus minusculus
*Silene apetala
*Spergularia diandra
*Spergularia rubra
*Stellaria media

CASUARINACEAE
Casuarina pauper

CHENOPODIACEAE
Atriplex holocarpa
Atriplex lindleyi
Atriplex nummularia
Atriplex spongiosa
Atriplex stipitata
Atriplex vesicaria subsp. vesicaria
*Chenopodium album
Chenopodium curvispicatum
Chenopodium desertorum subsp. rectum
*Chenopodium murale
Chenopodium nitrariaceum
Dissocarpus paradoxus
Einadia nutans subsp. nutans
Enchylaena tomentosa
Maireana appressa
Maireana brevifolia
Maireana georgei
Maireana pentatropis
Maireana pyramidata
Maireana sclerolaenoides
Maireana sedifolia
Maireana trichoptera
Maireana turbinata
Malacocera tricornis
Osteocarpum acropterum var. deminuta
Salsola kali var. kali
Scleroblitum atriplicinum
Sclerolaena brachyptera
Sclerolaena diacantha
Sclerolaena divaricata
Sclerolaena lanicuspis
Sclerolaena muricata var. muricata
Sclerolaena obliquicuspis
Sclerolaena parviflora
Sclerolaena patenticuspis
Sclerostegia tenuis

CONVOLVULACEAE
Convolvulus erubescens

CRASSULACEAE
Crassula colorata var. acuminata
#*Crassula arborescens

CUCURBITACEAE
*Cucumis myriocarpus

FABACEAE – FABOIDEAE
Bossiaea walkeri
*Medicago laciniata
*Medicago minima
*Medicago polymorpha
Templetonia egena

FABACEAE – CAESALPINOIDEAE [CAESALPINACEAE]
- Senna artemisioides subsp. filifolia
- Senna artemisioides subsp. petiolaris
- Senna artemisioides nothosubsp. coriacea

FABACEAE – MIMOSOIDEAE [MIMOSACEAE]
- Acacia aneura
- Acacia colletioides
- Acacia ligulata
- Acacia loderi
- Acacia melvillei
- Acacia montana
- Acacia rigens
- #Acacia stenophylla
- Acacia wilhelmiana

FUMARIACEAE
- *Fumaria muralis

GERANIACEAE
- *Erodium cicutarium
- Erodium crinitum

GOODENIACEAE
- Goodenia fascicularis
- Goodenia pinnatifida
- Goodenia pusilliflora

HALORAGACEAE
- Haloragis odontocarpa forma odontocarpa

LAMIACEAE
- *Marrubium vulgare
- *Salvia verbenaca
- Teucrium racemosum
- Westringia rigida

LAURACEAE
- Cassytha melantha

LORANTHACEAE
- Amyema linophylum subsp. orientale
- Amyema miquelii
- Amyema miraculosum subsp. boormanii
- Amyema preissii
- Amyema quandong
- Lysiana exocarpi subsp. exocarpi
- Lysiana linearifolia

MALVACEAE
- *Malva parviflora
- Sida corrugata

MYOPORACEAE
- Eremophila glabra
- Eremophila longifolia
- Eremophila oppositifolia subsp. rubra
- Eremophila sturtii
- Myoporum platycarpum
- #Myoporum acuminatum

MYRTACEAE
- #Eucalyptus cladocalyx
- Eucalyptus dumosa
- Eucalyptus gracilis
- Eucalyptus largiflorens
- Eucalyptus leptophylla
- Eucalyptus oleosa
- Eucalyptus socialis
- #Melaleuca armillaris

NITRARIACEAE
- Nitraria billardierei

OLEACEAE
- Jasminum lineare

OXALIDACEAE
- Oxalis perennans
- *Oxalis pes-caprae

PITTOSPORACEAE
- Pittosporum phylliraeoides

PLANTAGINACEAE
- Plantago cunninghamii

POLYGONACEAE
- *Acetosa vesicaria
- *Emex australis
- Muehlenbeckia florulenta
- *Rumex crispus
- Rumex tenax

PORTULACACEAE
- Calandrinia calyptrata
- Calandrinia eremaea

PROTEACEAE
- Grevillea huegelii
- Hakea leucoptera
- Hakea tephrosperma

RHAMNACEAE
- Cryptandra propinqua

RUTACEAE
- Geijera parviflora

SANTALACEAE
- Exocarpos aphyllus
- Exocarpos sparteus

SAPINDACEAE
- Alectryon oleifolius subsp. canescens
- Dodonaea bursariifolia
- Dodonaea viscosa subsp. angustissima

SCROPHULARIACEAE
- Limosella australis
- Stemodia florulenta

SOLANACEAE
- Lycium australe
- *Lycium ferocissimum
- *Nicotiana glauca
- Nicotiana velutina
- Solanum coactiliferum
- *Solanum nigrum

STERCULIACEAE
- #*Brachychiton populneus subsp. trilobus

TAMARICACEAE
- #*Tamarix aphylla

THYMELAEACEAE
- Pimelea microcephala subsp. microcephala
- Pimelea simplex subsp. continua
- Pimelea trichostachya

URTICACEAE
- Parietaria debilis
- *Urtica urens

ZYGOPHYLLACEAE
- Zygophyllum ammophilum
- Zygophyllum angustifolium
- Zygophyllum apiculatum
- Zygophyllum aurantiacum
- Zygophyllum crenatum
- Zygophyllum eremaeum
- Zygophyllum iodocarpum

The vegetation of Nombinnie and Round Hill Nature Reserves, central-western New South Wales

J.S. Cohn

Cohn, J.S. (NSW National Parks and Wildlife Service, PO Box 1967, Hurstville, NSW, Australia, 2220) 1995. The vegetation of Nombinnie and Round Hill Nature Reserves, central-western New South Wales. Cunninghamia *4(1): 81–101.* A vegetation survey and a map (1:100 000 scale) of Nombinnie and Round Hill Nature Reserves (33°46'S, 45°48'E) in central-western New South Wales, are presented. Ground survey sites were selected from aerial photos, geological, and land system maps. Floristic data were processed using multivariate analysis (PATN). Nineteen communities were mapped (7 mallee, 12 non-mallee), with a total of 227 taxa (218 native, 9 introduced) recorded. A number of communities are considered to be inadequately conserved and two taxa (*Acacia curranii* and *Lomandra patens*) are of nationally rare and threatened status.

Introduction

Nombinnie and Round Hill Nature Reserves (NR), together with adjoining Yathong NR, form the largest continuous stretch of mallee communites managed by the National Parks and Wildlife Service (NPWS) in New South Wales. Mallee communities are dominated by multi-stemmed species of *Eucalyptus* (Walker & Hopkins 1984). Mallee communities also occur in Victoria and South Australia. Much of the mallee occurring on public land in north-west Victoria has been surveyed and mapped at 1:100 000 scale by Cheal & Parkes (1989). Mallee in South Australia has been surveyed by Sparrow (1989a, b). A number of studies have mapped mallee communities in the south-west of NSW (Morcom & Westbrooke 1990, Fox 1991, Scott 1992).

Nombinnie and Round Hill NRs have been included in a number of previous vegetation surveys and mapping exercises; for example, the vegetation maps of western NSW at a scale of 1 inch:16 miles (Beadle 1948) and Australia at a scale of 1:1 000 000 (Beadle 1981), land system maps at 1:250 000 scale (Soil Conservation Service of NSW 1984, 1986), surveyed sites within the Nombinnie NR during its acquisition (Brickhill et al. undated). None of these surveys, however, provides consistent information on the communities at a scale suitable for conservation management.

The aims of this vegetation survey were to:

- record data for vascular plant species and environmental attributes for a representative sample of the Nombinnie and Round Hill NRs
- define and map plant communities at 1:100 000 scale, compatible with Victorian and South Australian surveys

- produce a map of plant communities readily usable by field managers
- relate plant community distributions to environmental attributes
- assess the conservation status of plant communities and rare plant taxa.

Study area

The study area is located in the south-western plains of NSW, 33°46′S, 145°48′E, about 200 km south of Cobar (Figure 1). It comprises Nombinnie NR (70 000 ha) and Round Hill NR (13 630 ha). Another 57 000 ha of the old Nombinnie and Lysmoyle properties are managed by NSW National Parks and Wildlife Service but are subject to mineral exploration (Wells 1989); a block of this area was not surveyed. A small portion of leasehold land outside and adjacent to Nombinnie NR was also included in the survey.

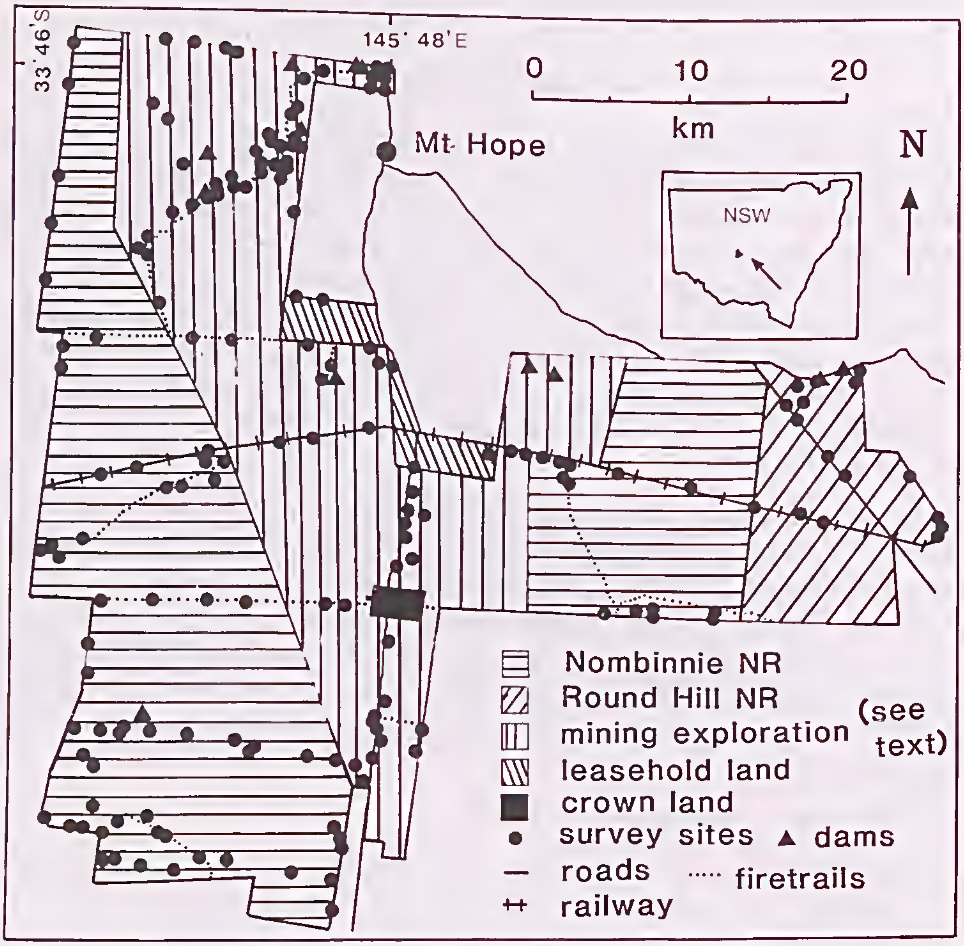

Fig 1. Locality map of Nombinnie and Round Hill Nature Reserves.

The study area lies between the 350–450 mm annual rainfall isohyets. Temperatures range from a mean monthly maximum of 33.2° C in January to a mean minimum of 4.5° C in July (Lawrie & Stanley 1980).

Land systems and geology

Land systems display characteristic and recurring patterns of topography, soils and vegetation (Christian & Stewart 1953). Approximately 80% of the study area is dominated by plains land systems, which include Lachlan Downs (Ld), Nombinnie (Nb),Wylona (Wy), Karwarn (Kn), Lysmoyle (Ls, Figure 2). The relief may be as high as 7 m, but is more commonly up to 4 m. Mallee vegetation predominates. Calcareous red earths and solonised brown soils are commonly found on plains, with sandy earths on dunes (Soil Conservation Service 1984, 1986).

Land systems Yackerboon (Yb), Kopyje (Kp) and Penshurst (Ph), included in the landtype rolling downs and lowlands, constitute about 15% of the study area. Relief is up to 20 m. These are typified by non-mallee communities, with red earths and

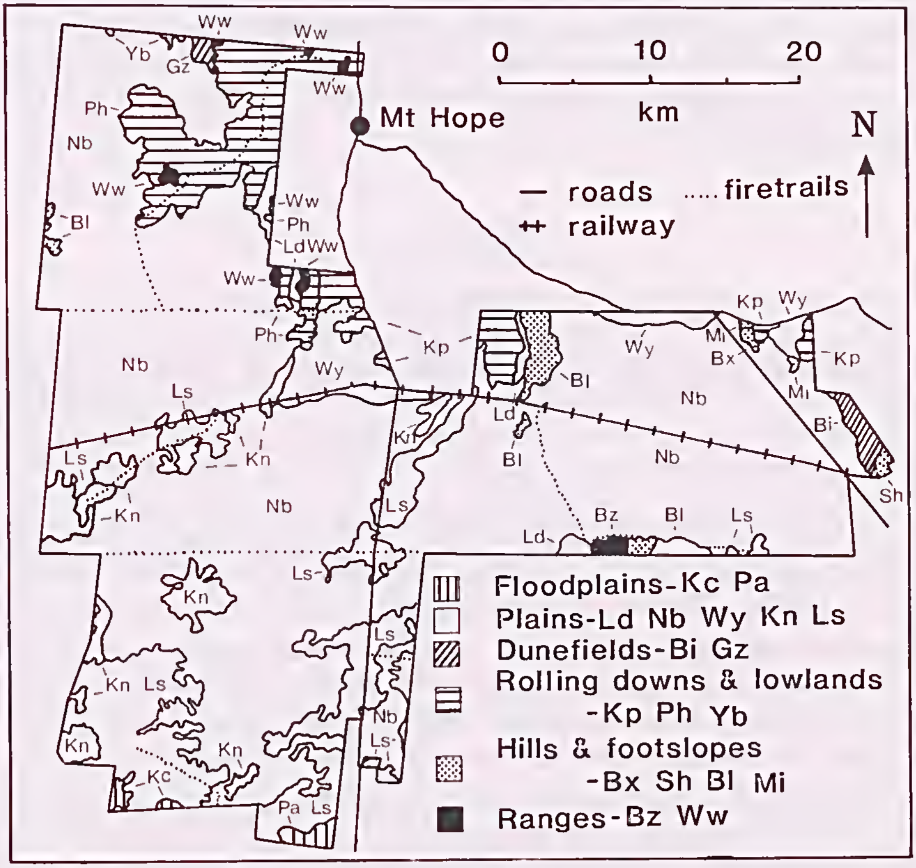

Fig 2. Land systems of the study area (Soil Conservation Service 1984, 1986).

lithosols on higher crests and deep sandy soils on lower slopes (Soil Conservation Service 1984, 1986).

Land systems making up the remaining 5% of the study area are included in the following landtypes: floodplains; dunefields; hills and footslopes; and ranges. The floodplains land systems have relief to 1 m and are covered by Quaternary alluvium. Land system Kiacatoo (Kc) has grey cracking and brown clays and land system Pangee (Pa) has deep calcareous red earths with hardpan at depth. The vegetation consists of non-mallee species (Soil Conservation Service 1984, 1986).

Dunefields to 10 m relief are aligned in an east-west direction and are characterised by Quaternary deposits of red and brown clayey sand, loam and lateritic soils and irregular deposits of aeolian sand; land systems include Bindi (Bi) and Glenlea (Gz). These are dominated by mallee vegetation (Soil Conservation Service 1984, 1986).

The hills and footslopes have relief to 150 m. Sandy lithosols on the upper slopes usually grade into red earths downslope. The vegetation is characteristically mallee (Soil Conservation Service 1984, 1986). The geology of land systems Boppy (Bx), Mineshaft (Mi) and Belford (Bl) is sedimentary, whilst that of land system Shepherds Hill (Sh) is volcanic (Geological Survey of New South Wales 1967, 1968).

The ranges have relief to 200 m, and are covered with sandy lithosols which become deeper down-slope. Vegetation in land system Booroondarra (Bz) is mallee and in land system Wynwood (Ww) non-mallee (Soil Conservation Service 1984, 1986). The geology of Bz is sedimentary and Ww is derived from volcanic material (Geological Survey of NSW 1967, 1968).

Methods

Field survey

The field survey was undertaken from May 1991 to March 1992. At selected sampling sites information on floristics, structure and environmental factors was collected. All vascular plant species were recorded and assigned a cover abundance value based on the Braun-Blanquet scale (Westhoff et al. 1978). Height and percentage projected foliage cover were estimated for each stratum (Specht 1970,1981; Muir 1977). The description of environmental factors at each site included slope, aspect, soil texture, elevation and physiography (McDonald et al. 1984). The size of the quadrat at each site was 30 m x 30 m (900 m^2). Since trees occurred in lower densities in the non-mallee and hill/range mallee communities compared with plains mallee communities, information on the tree stratum within these two broad categories was also collected in an extra 1600 m^2, nested outside the 30 m x 30 m quadrat (mallee eucalypts are included here as trees).

A total of 184 sites were sampled (Figure 1). One hundred and twenty of these were in the non-mallee and hill/range mallee areas. Sites were positioned to sample homogeneous patterns on aerial photographs which were further stratified by geological and land system information (1:50 000 and 1:60 000 scale black/white aerial photos; Commonwealth Mapping Authority, 1977, 1987; Geological Survey of NSW, 1967, 1968; Soil Conservation Service 1984, 1986). The number of quadrats allocated to a homogeneous pattern was proportional to the area it covered (Table 1). A pattern < 0.4 km^2 was considered too small to survey. The remaining 64 sites were positioned in plains mallee vegetation and its six coincident land systems (Ld,Nb,Wy,Ls,Gz,Bi; Soil Conservation Service 1984, 1986). Homogeneous patterns from aerial photos were identified and further stratified by land system information. Topographic, structural and floristic homogeneity of much of the plains mallee, however, made allocation of sites by aerial photographic interpretation (API) too difficult. The number of quadrats were allocated to each homogeneous pattern in proportion to the area covered (Table 1). Although plains mallee vegetation covered most of the study area, the lower number of quadrats compared with the non-mallee and hill/range mallee represents the former's greater homogeneity identified from aerial photos and land system information.

The position of a quadrat within a given homogeneous pattern in the non-mallee and hill/range mallee was decided in the field. Quadrats were placed away from the edges of patterns and in an area where the vegetation appeared floristically and structurally representative of that pattern. The same technique for quadrat positioning was used for plains mallee, which showed structural/floristic differences or topographic relief on the aerial photos. For the remainder of the plains mallee, however, quadrats were positioned to sample a broad range of floristic and structural differences in the understorey.

In a few cases, extra informal surveys were undertaken during the ground truthing phase. These consisted of pacing out quadrats and noting floristic and structural information of the tree and shrub layers.

Ground truthing

Extensive ground truthing of patterns delineated on aerial photos was carried out mostly within the non-mallee and hill/range mallee areas, since the structurally homogeneous nature of most of the plains mallee areas made extensive ground truthing unneccessary.

Data analysis

A numerical classification of the vegetation sites was derived using the Pattern Analysis Package (PATN, Belbin, 1990). The analysis was restricted to perennial native species as defined by Cunningham et al. 1981 (see back of map).

Mallee (plains) and non-mallee (including hill/range mallee) sites were analysed separately, due to the different quadrat sizes employed to sample trees in each group. Floristic composition was analysed using PATN (Belbin 1990). The cover abundance information for the non-mallee was adjusted to include the extra quadrat: a tree species occurring in the 1600 m^2 quadrat and not in the 900 m^2 quadrat was assigned a cover abundance value of 1. As a consequence, cover abundance values for all species recorded in the 900 m^2 quadrat increased by 1, i.e. 1 became 2, and so on. From this point onwards the mallee and non-mallee data were treated the same.

Table 1. Proportion of area for each landtype and land system (see text for codes) showing allocation of sampling quadrats for land systems, geology and topographic position

Landtype and land system	Area (% of total study area)	Proportion of land system in landtype	Geology	Topographic position	Number of quadrats
Floodplains	**< 5**				**2**
Kc		0.5	Qcp	plain	1
Pa		0.5	Qd	plain	1
Plains	**c. 80**				**116**
Ld		<0.1	Qd	slope	1
			Qrt/Smv		1
			Qrd	dune	1
				swale	1
Nb		0.6	Qd	plain	61
			Qrd	dune	1
				swale	1
			Qcp	depression	1
Wy		<0.1	Qd	plain	1
Kn		0.1	Qd	plain	11
			Qcp	plain	0
Ls		0.2	Qd	plain	36
Dune fields	**< 5**				**3**
Bi		0.7	Qrd	swale	1
				crest	1
Gz		0.3	Qd	slope	1
Rolling downs and lowlands	**c. 15**				**48**
Kp		0.2	Qrt/Suc	crest	1
				slope	1
				plain	4
Ph		0.8	Qrt/Smv	plain	2
				slope	4
				depression	1
			Qrt/Suc	plain	13
				depression	9
				slope	1
			Qrt	plain	5
				slope	3
			Qd & Qrs	slope	1
				plain	1
Yb		<0.1	Qrd/Smv	plain	1
			Qrt/Scu		1
Hills/footslopes	**< 5**				**6**
Bx		0.25	Sub	east slope	1
Sh		0.25	Qrt/Scu	footslope	1
			Scu	east slope	1
Mi		0.15	Sub	knoll	0
Bl		0.35	Qd	plain	2
			Duc	slope	1
Range	**< 5**				**9**
Bz		0.3	Duc	crest	1
			Qrt/Duc	plain	1
			Qrt/Duc	north slope	1
Ww		0.7	Smv	crest	1
				east slope	1
				south slope	2
				west slope	1
				north slope	1
Total					**184**

To weight abundant and uncommon species evenly, cover abundances were standardised between 0 and 1. The Bray Curtis measure was used to compare each site to all others in terms of floristic composition (Bray & Curtis 1957). The UPGMA clustering algorithm was then applied to derive a hierarchical classification of the sites (dendrogram).

The homogeneity algorithm of Bedward et al. (1992; Figures 3a,b) was used in conjunction with the dendrogram, physical information (topography, geology, soil texture), structural information and the aerial photographic mapping base to determine the final plant communities to be mapped.

Formation of mapped communities from groups

Groups resulting from the analyses were mapped as communities only if the mapping base (aerial photos) allowed their delineation. A group identified within a group was mapped separately if it was structurally different or located in different physiographic circumstances with recognisably different floristics.

The homogeneity algorithm (Bedward et. al 1992) showed the plains-mallee to be relatively floristically continuous (Figure 3a). The structural and floristic homogeneity of the plains-mallee on the aerial photographic mapping base restricted the final mapped communities to only those recognisable on this base: Shrub Mallee (P1); Shrub Mallee with Spinifex (P2); Shrub Mallee with Mallee Pine (P3); and Tree Mallee (P4). A two-way table describing the relationships between taxa and communities is shown on the back of the map.

The analysis identified fifteen floristically discrete groups of non-mallee and hill/range mallee (Figure 3b). These original 15 groups are shown in a two-way table on the back of the map. Some of these groups were modified for the purposes of mapping: the first group has been subdivided into three communities, since D1a and D4 are floristically different and occurring in different physiographic circumstances to that of D1; two groups which have been identified as separate have been combined, since they both constitute grassland (F9); one group has been subdivided into two communities (F1, F2), since they are structurally different; community F5 encompasses 3 groups which could not be differentiated on the aerial photographic mapping base; another group has been called two communities since the overstorey species are different (H1, R1); and community P8 describes two groups which are indistinguishable on the mapping base.

Results

Four plains mallee communities and fifteen non-mallee and hill/range mallee communities were mapped. A description of the mapped vegetation communities is given below. Communities are grouped by the landtypes in which they mostly occur and each community is given an alpha-numeric code for quick referral: Alluvial plains (F1–2); Plains (P1–9); Rolling downs and lowlands (D1–4); Hills (H1); Ranges (R1–2). Geological information is taken from Geological Survey of NSW (1967, 1968) and land system information is taken from Soil Conservation Service (1984, 1986).

Descriptions of mapped communities

Alluvial Plains (F1–2)

F1. Black Rolypoly Shrubland

Dominant species: *Sclerolaena muricata.*

Structure: Low open shrubland.

Site numbers: 88.

Land system: Alluvial plain (Kc).

Geology: Floodplains of red and black clayey silt sand and gravel (Qrs).

Soil texture: Heavy clay.

Trees: *Eucalyptus largiflorens.*

Shrubs: *Sclerolaena muricata.*

Herbs and grasses: *Leptorhynchos panaetioides, Vittadinia pterochaeta, Teucrium racemosum, Helipterum floribundum.*

Comments: Occurs in only one small area on the southern boundary of Nombinnie NR. The northern half of the community is dominated by ephemeral grasses, which were unidentifiable at the time of the survey.

F2. Black Box Woodland

Dominant species: *Eucalyptus largiflorens.*

Structure: Low open woodland.

Site numbers: 91.

Land systems: Alluvial plain (Kc).

Geology: Playas, claypans and lakes of black and grey silty clay and silt (Qcp).

Soil texture: Heavy clay.

Trees: *Eucalyptus largiflorens.*

Shrubs: *Solanum esuriale, Sclerolaena muricata, Pittosporum phylliraeoides.*

Herbs and grasses: *Atriplex spinebractea.*

Comments: Occurs over one small area adjacent to the Black Rolypoly Shrubland. All *Eucalyptus largiflorens* in this community were apparently ringbarked during 1880–1900 and as a result are now multi-stemmed (J. Brickhill, pers. comm.).

Plains (P1-9)

P1. Shrub Mallee

Dominant species: *Eucalyptus socialis, E. dumosa.*

Structure: Very open shrub mallee (< 8 m tall).

Site numbers: 23, 13, 100, 105, 156, 158, 73, 98.

Land system: Plains (Nb,Ls).

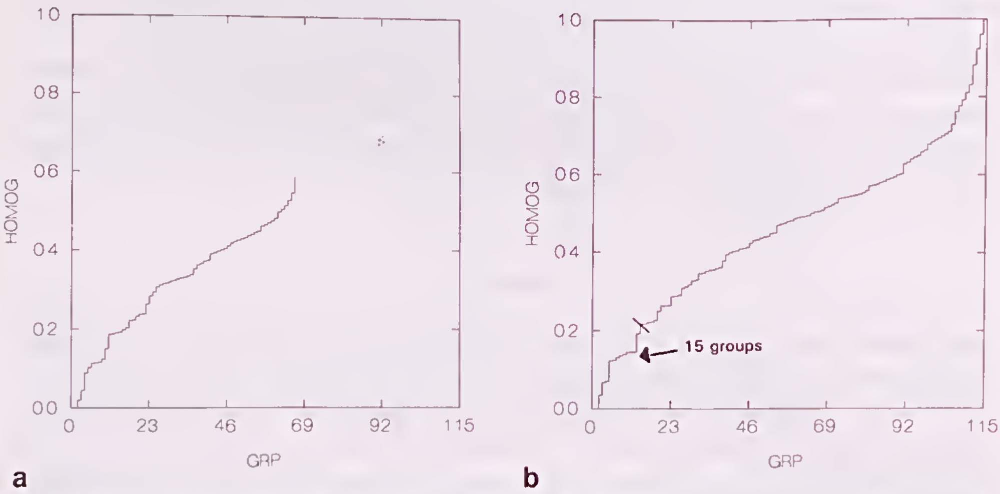

Fig. 3. Homogeneity curves for site classification based on standardised Bray Curtis co-efficient. a. Plains mallee data. b. Hill mallee and non-mallee data.

Geology: Flat to gently undulating plains of red and brown clayey sand loam and lateritic soils (Qd).

Soil texture: Sandy clay-clayey sand.

Trees: *Eucalyptus socialis, E. dumosa.*

Shrubs: *Eremophila glabra.*

Herbs and grasses: *Olearia pimelioides.*

Comments: This community, with characteristically little in the understorey, is found:

- on the western slopes of ranges where the soil is sandy
- where the mallee has apparently been cleared and is regenerating
- where there have been fires in quick succession on medium-textured soils (see discussion).

P2. Shrub Mallee with Spinifex

Dominant species: *Eucalyptus socialis, E. dumosa, Triodia irritans.*

Structure: Very open to open shrub mallee (< 8 m tall).

Site numbers: 26, 48, 52, 99, 101–119, 121–152, 154, 155, 213.

Land system: Plains (Nb, Ls, Wy).

Geology: Flat to gently undulating plains of red and brown clayey sand loam and lateritic soils (Qd).

Soil texture: Light medium clay–loamy sand.

Trees: *Eucalyptus socialis, E. dumosa, E. gracilis, E. leptophylla.*

Shrubs: *Acacia tindaleae, A. rigens, A. brachybotrya, A. colletioides, A. havilandiorum, Melaleuca uncinata, Eremophila glabra, Bossiaea walkeri, Dodonaea viscosa* subsp. *cuneata, Senna artemisioides, Beyeria opaca, Templetonia aculeata.*

Herbs and grasses: *Dianella revoluta, Halgania cyanea, Lomandra effusa, Sclerolaena diacantha, Olearia pimelioides, Triodia irritans.*

Comments: Compared with the other mallee communities identified in this survey, the understorey in this community has greater floristic diversity and cover. The composition and density of the over and understorey species vary with subtle changes in the topography and soils (see results).

P3. Shrub Mallee with Mallee Pine

Dominant species: *Eucalyptus socialis, Callitris preissii* subsp. *verrucosa.*

Structure: Very open shrub mallee (< 8 m tall).

Site numbers: 42.

Land system: Plains (Nb,Ls).

Geology: Flat to gently undulating plains of red and brown clayey sand loam and lateritic soils (Qd).

Soil texture: Sandy clay loam.

Trees: *Callitris preissii* subsp. *verrucosa, Eucalyptus socialis, E. leptophylla.*

Shrubs: *Acacia brachybotrya.*

Herbs and grasses: *Helichrysum apiculatum.*

Comments: *Callitris preissii* subsp. *verrucosa* provides a very dense understorey of approximately 30% cover. The shade and the absence of fire may both contribute to the very low cover and diversity of shrubs, grasses and herbs.

P4. Tree Mallee

Dominant species: *Eucalyptus socialis, E. dumosa.*

Structure: Very open tree mallee (> 8 m tall).

Site numbers: 75.

Land system: Plains (Nb,Ls).

Geology: Flat to gently undulating plains of red and brown clayey sand loam and lateritic soils (Qd).

Soil texture: Silty clay.

Trees: *Eucalyptus socialis, E. dumosa.*

Herbs and grasses: *Einadia nutans* subsp. *nutans.*

Comments: Characteristically very low species richness and cover in the understorey. It appears to have been unburnt for many years (see discussion).

P5. Belah and Wilga Woodland

Dominant species: *Casuarina cristata, Geijera parviflora, Apophyllum anomalum, Alectryon oleifolius* subsp. *canescens.*

Structure: Open woodland.

Site numbers: 38, 79, 94, 208, 85, 30, 86, 57, 56, 87, 19, 12, 37, 211, 205.

Land system: Plains (Kn,Ls), Rolling downs/ lowlands (Ph).

Geology: Playas, claypans and lakes of black and grey silty clay and silt (Qcp). Residual and collvial deposits (Qrt). Flat to gently undulating plains of red and brown clayey sand loam and lateritic soils (Qd).

Soil texture: Clay loam-medium clay.

Trees: *Casuarina cristata, Geijera parviflora. Alectryron oleifolius* subsp. *canescens* and *Apophyllum anomalum* often occur in the overstorey. Occasionally, especially in ecotones *Eucalyptus populnea* subsp. *bimbil* and *E. intertexta* also occur in the overstorey.

Shrubs: The shrub and herb/grass layers are usually very sparsely distributed and species poor. Common species include *Eremophila mitchellii, E. sturtii.*

Herbs and grasses: *Sclerolaena diacantha, Cheilanthes sieberi, Olearia pimelioides.*

Comments: Found on the heavier-textured soils, often in playas and claypans.

P6. Gum Coolibah Woodland

Dominant species: *Eucalyptus intertexta, Dodonaea viscosa* subsp. *cuneata, Eremophila desertorum, E. sturtii.*

Strucure: Open woodland.

Site numbers: 31, 35, 77, 32, 78, 83, 63.

Land system: Plains (Kn,Ls), Range (Ww).

Geology: Residual and colluvial deposits overlying Mt Hope Volcanics (Qrt/Smv). Flat to gently undulating plains of red and brown clayey sand loam and lateritic soils (Qd); Playas of grey silty clay (Qcp).

Soil texture: Silty clay-clay loam.

Trees: *Eucalyptus intertexta* and occasionally *Callitris glaucophylla.*

Shrubs: The understorey varies from a sparse to a more dense shrub cover of *Dodonaea viscosa* subsp. *cuneata, Eremophila desertorum, E.remophila sturtii, Bertya cunninghamii, Senna artemisioides, Callitris glaucophylla, Helichrysum tuckeri.* At one site the rare *Acacia curranii* occurs rather densely.

Herbs and grasses: *Cheilanthes sieberi, Einadia nutans, and Harmsiodoxa brevipes* var. *major.*

Comments: Often occurs on the heavier-textured soils adjacent to mallee communities.

P7. Bimble Box Woodland

Dominant species: *Eucalyptus populnea* subsp. *bimbil, Eremophila sturtii, Digitaria* spp., *Stipa* spp..

Structure: Open woodland.

Site numbers: 60, 76, 89, 90, 97, 98A, 200.

Land system: Plains (Ls) and rolling downs and lowlands (Ph); Floodplains (Pa).

Geology: Flat to gently undulating plains of red and brown clayey sand loam and lateritic soils (Qd); Residual and colluvial deposits (Qrt).

Soil texture: Sandy clay-sandy clay loam.

Trees: *Eucalyptus populnea* subsp. *bimbil* and occasionally *Callitris glaucophylla.*

Shrubs: Scattered to dense *Eremophila sturtii.*

Herbs and grasses: *Digitaria* sp., and *Stipa* sp., with scattered *Einadia nutans* subsp. *nutans.*

Comments: Usually located in run on areas with heavier-textured soils and varies from having a dense understorey of *Eremophila sturtii* to an understorey dominated by grasses.

P8. Pine Woodland

Dominant species: *Callitris glaucophylla, Abutilon otocarpum, Cheilanthes sieberi.*

Structure: Open woodland/woodland.

Site numbers: 72, 209, 95, 2, 29, 14, 6, 11B, 20C, 11C, 24A, 28, 24B, 27, 25, 24C, 71, 92, 81, 82, 84, 58.

Land system: Plains (Ls,Kn), Rolling downs/ lowlands (Ph).

Geology: Flat to gently undulating plains of red and brown clayey sand loam and lateritic soils (Qd). Residual and colluvial deposits (Qrt); Cobar Group largely obscured by Qrt (Qrt/Suc(?)).

Soil texture: Sandy clay to sandy clay loam.

Trees: Whilst *Callitris glaucophylla* is the dominant overstorey species, *Eucalyptus populnea* subsp. *bimbil, E. intertexta* and *Geijera parviflora* may also occur.

Herbs and grasses: The understorey is comprised mostly of herbs and grasses. Common herbs, north of the railway line, are *Abutilon otocarpum,* *Sida corrugata, Chenopodium desertorum, Sclerolaena diacantha, Cheilanthes sieberi,* and *Sida cunninghamii.* The understorey south of railway line is mostly of ephemeral grasses, which were unidentifiable at the time of the survey, as were those in the north.

P9. Grassland

Dominant species: *Aristida* spp..

Structure: Grassland.

Site numbers: 40, 41, 80, 201, 202, 19, 12, 47, 22, 71.

Land system: Plains (Ls, Kn) and Rolling downs/ lowlands (Ph).

Geology: Flat to gently undulating plains of red and brown clayey sand loam and lateritic soils (Qd); Residual and colluvial deposits (Qrt); Cobar Group largely obscured by Qrt (Qrt/Suc?).

Soils: light clay-sandy clay loam.

Trees: Scattered *Geijera parviflora, Casuarina cristata, Eucalyptus dumosa, E. socialis, E. intertexta, E. populnea* subsp. *bimbil, Apophyllum anomalum, Alectryron oleifolius, Hakea tephrosperma, Callitris glaucophylla.*

Shrubs: Scattered *Prostanthera leichhardtii, Eremophila longifolia, Acacia homalophylla, Eremophila mitchellii, Dodonaea viscosa* spp. *angustissima, Atriplex stipitata.*

Herbs and grasses: Scattered *Einadia nutans* spp. *nutans, Helipterum pygmaeum, Cuphonotus humistratus, Aristida* spp., *Cheilanthes sieberi* spp. *sieberi, Heliotropium europaeum, Echium plantagineum, Erodium crinitum, Oxalis corniculatum, Medicago* spp., *Sclerolaena diacantha, Maireana* spp..

Comments: Highly variable in its species composition, probably because it has usually resulted from clearing, and has therefore partially adopted the character of its previous community and/or has taken on species from surrounding communities. Many of the grasses were unidentifiable at the time of the survey.

Rolling Downs and Lowlands (D1-4)

D1. Pine and Bimble Box Woodland

Dominant species: *Callitris glaucophylla, Eucalyptus populnea* subsp. *bimbil, Senna artemisioides, Chenopodium desertorum, Sclerolaena diacantha.*

Structure: Open woodland.

Site numbers: 20D, 64, 96, 7, 20F, 93, 3, 4, 20G, 44, 20C.

Land systems: Plains (Ls), Rolling downs/lowlands (Ph).

Geology: Flat to gently undulating plains of red and brown clayey sand loam and lateritic soils (Qd); Residual and colluvial deposits (Qrt); Mt Hope Volcanics largely obscured by Qrt (Qrt/Smv); Cobar Group largely obscured by Qrt (Qrt/Suc(?)).

Soil texture: Sandy clay-silty loam.

Trees: On the slopes of ranges/hills and undulating plains *Callitris glaucophylla* tends to occur on the higher ground, whilst *Eucalyptus populnea* subsp. *bimbil* is found along creek lines. *Eucalyptus intertexta* may also occur in the overstorey on the higher ground.

Shrubs: The understorey has very scattered shrubs: *Dodonaea viscosa* subsp. *angustissima, Eremophila sturtii, E. glabra, E. longifolia, E. mitchellii, Senna artemisioides.*

Herbs and grasses: *Chenopodium desertorum, Einadia nutans* subsp. *nutans, Sclerolaena diacantha, Sida corrugata.*

Comments: Much of this community appears to have been cleared, leaving scattered trees only.

D1a. Bimble Box Woodland

Dominant species: *Eucalyptus populnea* subsp. *bimbil, Eremophila sturtii, Chenopodium desertorum, Sclerolaena diacantha.*

Structure: Open woodland.

Site numbers: 17, 10, 21C, 33, 21D, 45, 34A, 34B, 36, 61.

Land system: Rolling downs and lowlands (Ph).

Geology: Flat to gently undulating plains of red and brown clayey sand loam and lateritic soils (Qd); Residual and colluvial deposits (Qrt); Mt Hope Volcanics largely obscured by Qrt (Qrt/Smv).

Soil texture: Medium clay-sandy clay loam.

Trees: *Eucalyptus populnea* subsp. *bimbil* and *Callitris glaucophylla. Eucalyptus intertexta* may become the dominant overstorey species over small areas especially those closer to the mallee.

Shrubs: *Eremophila longifolia, E.glabra, E.mitchellii, E. sturtii, Dodonaea viscosa* subsp. *angustissima, Acacia colletoides, A.homalophylla, Acacia deanei, Senna artemisioides, Dodonaea* *viscosa* subsp. *spatulata, D. viscosa* subsp. *cuneata, Eremophila desertii,* and *Pittosporum phylliraeoides*.

Herbs and grasses: *Digitaria* sp., and *Stipa* sp., with scattered *Einadia nutans* subsp. *nutans*.

Comments: Occurs in low lying areas on heavier-textured soils.

D2. Gum Coolibah and Pine Woodland

Dominant species: *Eucalyptus intertexta, Callitris glaucophylla, Eremophila mitchelli, E. glabra, Sclerolaena diacantha.*

Structure: Open woodland.

Site numbers:1, 55, 65, 59, 54, 15, 18, 66, 69, 203, 46, 206, 50, 51, 67, 207, 215, 74, 216, 212.

Land systems: Plains (Ls,Ph,Kp); Hills and footslopes (Bl); Ranges (Bz).

Geology: Flat to gently undulating plains of red and brown clayey sand loam and lateritic soils (Qd); Residual and colluvial deposits (Qrt); Cobar Group largely obscured by Qrt (Qrt/Suc); Cocoparra sediments largely obscured by Qrt (Qrt/Duc); Mt Hope Volcanics largely obscured by Qrt (Qrt/Smv); Floodplains of clayey silt, sand and gravel (Qrs); Cobar Group largely obsured by Qrt (Qrt/Suc).

Soil texture: Light clay to sandy clay loam.

Trees: *Eucalyptus intertexta, Callitris glaucophylla, E. populnea* subsp. *bimbil, Casuarina cristata, Geijera parviflora, Alectryon oleifolius.*

Shrubs: The understorey may have very scattered shrubs to a more dense cover of *Bertya cunninghamii, Dodonaea viscosa* subsp. *cuneata, Eremophila glabra, E. longifolia, E. mitchellii, Hakea tephrosperma, Senna artemisioides, Olearia pimelioides.*

Herbs and grasses: *Chenopodium desertorum, Sclerolaena diacantha, Enchylaena tomentosa.*

D3. Emubush Shrubland

Dominant species: *Eremophila longifolia.*

Structure: Tall open shrubland.

Site numbers: 62.

Land system: Rolling downs/lowlands (Ph).

Geology: Residual and colluvial deposits (Qrt).

Soil texture: Sandy clay.

Shrubs: Eremophila longifolia is common and present as a tall shrub (>2m). Other shrub species are *Dodonaea viscosa* subsp. *angustissima, Eremophila glabra, E. sturtii, Callitris glaucophylla, Solanum coactiliferum.*

Herbs and grasses: *Maireana humillima, Ptilotus obovatus, Sclerolaena diacantha, Sida cunninghamii, Thyridolepsis mitchelliana.*

Comments: This community may have been burnt in 1985 and the large cover of *Eremophila longifolia* is a response to that (see discussion). The density of this community made boundary checking too difficult.

D4. Green Mallee Shrubland

Dominant species: *Eucalyptus viridis, Dodonaea lobulata.*

Structure: Open woodland/low open shrubland.

Site numbers: 217 and informal survey.

Land system: Rolling downs/lowlands.

Geology: Quartz-feldspar, porphyry, rhyolite, tuff and interbedded sediments (Smv); Residual and colluvial deposits (Qrt).

Soil texture: Loam.

Trees: *Eucalyptus viridis. Eucalyptus intertexta, E.populnea, Callitris glaucophylla, Brachychiton populneus* subsp. *trilobus* and *Geijera parviflora* may also occur, especially on the slopes of the knolls.

Shrubs: *Acacia aneura, A. decora, Dodonaea lobulata, Senna artemisioides, Eremophila serrulata, E. longifolia, E. mitchellii. Acacia curranii* is sparsely distributed on the side of one knoll.

Herbs and grasses: *Sclerolaena convexula, Maireana humillima, Atriplex stipitata.*

Comments: Restricted to small rocky knolls in the northern half of Nombinnie NR, occurring as an open shrubland on the knoll tops and becoming an open woodland on the sides.

Hills (H1)

H1. Dwyer's Mallee Shrubland

Dominant species: *Eucalyptus dwyeri, Acacia doratoxylon.*

Structure: Very open shrub mallee.

Site numbers: 68, 49.

Land system: Hills and footslopes (Sh,Mi,Bx).

Geology: Rhyolite, rhyolite breccia, quartz feldspar porphyry, chert and tuff (Scu); Conglomerate, sandstone, orthoquartzite and siltstone (Sub).

Soil texture: Clayey sand.

Trees: This community can be quite variable and there may be an influence of aspect. The tops of these hills are characteristically dominated by *Eucalyptus dwyeri* and *Acacia doratoxylon*. On the slopes other species may include *Brachychiton populneus* subsp. *trilobus*, *Geijera parviflora*, *Eucalyptus intertexta*, *Eucalyptus viridis*, *E. morrisii*, *Pittosporum phylliraeoides*.

Shrubs: The slopes may be similar to the top or dominated by dense short *Callitris glaucophylla*. Other species include *Dodonaea lobulata*, *Acacia aneura*, *A. decora*, *Prostanthera nivea*, *P. striatiflora*, *Indigofera australis*, *Eremophila serrulata*, *E. longifolia*, *Helichrysum bractea*, *Pimelea microcephala*, *Helichrysum viscosum*, *Platysace lanceolata*, *Solanum ferocissimum* var. *ferocissimum*.

Herbs and grasses: *Lomandra patens*, *Diuris maculata*, *Cheilanthes sieberi*, *Pandorea pandorana*.

Ranges (R1-2)

R1. Grey Mallee Shrubland

Dominant species: *Eucalyptus morrisii*.

Structure: Very open shrub mallee.

Site numbers: 214.

Land systems: Range (Bz).

Geology: Cocoparra sediments, largely obscured by Qrt (Qrt/Duc).

Soil texture: Clayey sand.

Trees: *Eucalyptus morrisii on the top*, *E. dwyeri on the slope and E. viridis* on the footslopes. Other species include *Callitris glaucophylla*, *Brachychiton populneus* subsp. *trilobus*, *Eucalyptus populnea* subsp. *bimbil*, *Geijera parviflora*.

Shrubs: On the range footslopes species incude *Eremophila serrulata*, *Acacia aneura*, *A. doratoxylon*, *Dodonaea viscosa* subsp. *angustissima* and *Pandorea pandorana*.

Herbs and grasses: *Wahlenbergia stricta*, *Stipa nodosa*, *Goodenia glabra*, *Lomandra patens*, *Cheilanthes sieberi*, *Amphipogon caricinis* var. *caricinis*, *Indigofera australis*, *Sida filiformis*, *Brunonia australis*, *Parsonsia eucalyptophylla*, *Thyridolepis mitchelliana*.

R2. Pine and Wattle Woodland

Dominant species: *Callitris glaucophylla*, *Acacia decora*.

Structure: Low open woodland to open woodland.

Site numbers: 5, 9B, 9C, 43, 9A, 8.

Land systems: Ranges (Ww), Rolling downs/lowlands (Ph).

Geology: Quartz-feldspar, porphyry, rhyolite, tuff and interbedded sediments (Smv); Mt Hope Volcanics largely obscured by Qrt (Qrt/Smv).

Soil texture: Sandy clay loam.

Trees: *Callitris glaucophylla*, and occasionally *Eucalyptus intertexta*.

Shrubs: The shrub understorey is dominated by dense low/tall *Callitris glaucophylla* shrubs on the slopes with some *Acacia decora*. The tops of the ranges are more open.

Herbs and grasses: Common species include *Glycine canescens*, *Sida cunninghamii*, *Cheilanthes sieberi* and *C. lasiophylla*. The rare *Lomandra patens* also occurs.

Trends in species and community distribution

Plains mallee

Although much of the plains mallee proved to be floristically continuous, as evidenced by the relatively consistent slope of the homogeneity curve (Figure 3a), there were trends in the occurrence of some species, which were identified by the multivariate analysis and are discussed below (see two-way table on back of map).

In the sandier soils (loamy sand–sandy clay loam), which were found on dune crests and slopes, *Eucalyptus leptophylla* occurred in the overstorey with *E. socialis* and occasionally *Callitris preissii* subsp. *verrucosa*. The understorey consisted of a sparse cover of *Acacia brachybotrya*, and a dense cover of *Triodia irritans*. In the medium- and heavier-textured soils (light medium clay-loamy sand), *Eucalyptus socialis* occurred with *E. dumosa* and *E. gracilis*. The shrub understorey was usually more dense than on sandier soils and was more likely to have *Melaleuca uncinata* present as well as *Acacia* species. In general, *Triodia irritans* contributed less to ground cover than on the sandier soils.

Non-mallee and hill/range mallee

Communities varied in their degree of floristic discretion (see two-way table on back of map). Those dominated by *Casuarina cristata/Geijera parviflora* (Belah and Wilga Woodland, P5), *Eucalyptus largiflorens* (Blackbox Woodland, F2), *E. dwyeri/Acacia doratoxylon* (Dwyer's Mallee Shrubland, H1) and *E. morrisii* (Grey Mallee Shrubland, R1), which are relatively restricted in their distribution, each had a relatively discrete suite of associated species. Other communities dominated by more widespread trees such as *Callitris glaucophylla*, *Eucalyptus populnea* subsp. *bimbil* and *E. intertexta* were more likely to share common groups of equally widespread understorey species, although there were some exceptions. *Eucalyptus intertexta* dominated communities were more likely to have the following taxa in their understorey *Dodonaea viscosa* subsp. *cuneata*, *Eremophila desertii*, *E. mitchellii*, *Sida cunninghamii*, *Maireana humillima* and *Bertya cunninghamii*. *Eucalyptus populnea* subsp. *bimbil* dominated communities commonly had *Dodonaea viscosa* subsp. *angustissima*, *Acacia colletioides*, *Goodenia glabra*, *Eremophila sturtii*, *Acacia deanii*, *Einadia nutans* subsp. *nutans* and *Abutilon otocarpum* in the understorey. *Callitris glaucophylla* dominated communities were commonly found with *Cheilanthes sieberi* and *Sida corrugata* in the understorey. The more widespread understorey taxa include *Eremophila longifolia*, *E. glabra*, *Hakea tephrosperma*, *Senna artemisioides*, *Chenopodium desertorum* subsp. *desertorum*, and *Sclerolaena diacantha*.

The occurrence of some communities may be partly explained by topography and soil texture. Communities dominated by *Sclerolaena muricata* (Black Rolypoly Shrubland, F1) and *Eucalyptus largiflorens* (Black Box Woodland, F2) were found on heavy clay soils on floodplains. *Casuarina cristata/Geijera parviflora* (Belah and Wilga Woodland, P5) and *Eucalyptus populnea* subsp. *bimbil* (Bimble Box Woodlands, P7, D1a) communities occurred in soils of high clay content usually in closed or open depressions. Communities dominated by *Eucalyptus dwyeri/Acacia doratoxylon* (Dwyer's Mallee Shrubland, H1) and *Eucalyptus morrisii* (Grey Mallee Shrubland, R1) were restricted to rocky hills in sandy soils, similar to the *Callitris glaucophylla/Acacia decora* community (Pine and Wattle Woodland, R2). The occurrences of *Callitris glaucophylla/Eucalyptus populnea* subsp. *bimbil* (Pine and Bimble Box Woodland, D1), *Callitris glaucophylla* (Pine Woodland, P8) *and Eucalyptus intertexta* (Gum Coolibah/Pine Woodlands, P6, D2) communities were more difficult to explain. In general they were found on plains and on hills in drier situations. *Eucalyptus intertexta* woodland (P6) was more likely to be found near and surrounded by plains mallee communities than other communities.

Limitations of the study

Mapping the communities identified by the multivariate analysis was limited by the amount of recognisable detail on the aerial photos. This was particularly so for the plains mallee vegetation where structural and topographic homogeneity made mapping of floristically different vegetation patterns difficult. Aerial photos could not be used to map differences in the lower strata.

Discussion

Comparison with other relevant surveys

Within the plains mallee, changes in the topography and the soil texture were often very subtle in Nombinnie and Round Hill NRs. Most of the mallee occurred on plains, where the gentle undulations (<4 m) were kilometres apart. Parsons & Rowan (1968) have shown that the distribution of some mallee *Eucalyptus* species, in north-western Victoria was related to subtle soil differences. Within Nombinnie and Round Hill NRs *Eucalyptus dumosa* and *E. gracilis* were widespread, but absent from the sandiest soils on dune crests, to which *E. leptophylla* was usually restricted. *Eucalyptus socialis* occurred on a large range of soil types.

Other areas of mallee in NSW have a more clearly defined dune and swale pattern. Morcom & Westbrooke (1989) were able to separately map the communities which dominated the dunes and the swales in Mallee Cliffs NP. Similarly in parts of Yathong NR there are east-west dunes which support mallee communities, whilst the adjacent swales are characterised by *Eucalyptus intertexta* open woodlands (pers. obs). Some surveys of mallee have found the soil to be sufficiently high in clay content in the swales to support *Casuarina cristata*/*Alectryron oleifolius* communities (Morcom & Westbrooke 1990, Fox 1991, Scott 1992, Parker et al. unpub.).

Norris and Thomas (1991) in their survey of vegetation on rocky outcrops adjacent and south of Nombinnie and Round Hill NRs, found that the occurrence of tree species did not appear to be influenced by the rock type. However, results from the present study were mixed. Whilst the *Eucalyptus dwyeri*/*Acacia doratoxylon* community (H1) was found on hills derived from both volcanic and sedimentary origins, *Callitris glaucophylla*/*Acacia decora* community (R2) was restricted to volcanically-derived hills.

Fire

Fire recording for Nombinnie and Round Hill NRs began in 1957 (Brickhill, undated). The most recent extensive fire in January 1985, burnt much of the study area (Brickhill, undated). Because fire history was not one of the factors used in the allocation of sites, its effect on community floristics and structure was noted only at a very coarse level.

Both mallee and non-mallee communities are prone to fires in summer if plentiful rain has promoted the growth of ephemerals, especially grasses, during the spring (Noble 1984). Fires can burn large areas very quickly if the conditions are favourable.

Community P4 (*Eucalyptus socialis/E. dumosa*) consists of 'bull mallees', trees (8 m tall), with a few large stems protruding from the lignotuber. This community was found in silty clay on flat land with a very sparse understorey, mainly of herbs. Noble (1982) has found that 'bull mallee' grows in the more open swales where fires are infrequent, only occurring when there is sufficient ephemeral fuel (e.g. *Stipa variabilis*). Cheal and Parkes (1989) describe a similar structured community called 'big mallee' occurring in Victoria. They attribute the structure of their 'big mallee' to the long-term absence of fire, greater soil fertility and favourable moisture status. Similarly, the existence of tall, dense stands of *Callitris preissii* subsp. *verrucosa* (community P3) in sandy soils on dune crests indicate the absence of fire, since it is a fire-sensitive species (Bradstock 1989). Bradstock (1989) predicts that in the long-term if there is an absence of fire for a hundred years, *C. preissii* subsp. *verrucosa* may overtop mallee *Eucalyptus* species and eventually dominate the community.

Widely-spaced whipstick mallee eucalypts (community P1) may result from frequent fires in Autumn (Noble 1984). Only mallee communities on medium-textured soils, capable of a relatively high water-holding capacity and able to support dense swards of spear grass (*Stipa scabra*) at the appropriate time, are capable of this high fire frequency (Noble 1984).

Eremophila longifolia in Emubush Shrubland (D3) may have resprouted from a fire during 1985 when the adjacent mallee burnt (Water Resources Colour Aerial Photos 1990; Brickhill undated). The dominance of *E. longifolia* (5 m tall) may relate to its ability to resprout from the roots and stems both below and above the ground after fire (Hodgkinson & Griffin 1982). Other plants occurring in this community at lower densities, e.g. *Dodonaea viscosa* subsp. *angustissima*, *Senna artemisioides* and *Callitris glaucophylla* are more fire-sensitive (Hodgkinson & Griffin 1982, Harrington et al. 1984).

Clearing, grazing and exotic plants

Although much of the mallee appears relatively undisturbed, some woodland areas have been modified since the advent of grazing by cattle and sheep. Woodlands, especially those dominated by *Callitris glaucophylla* have been thinned or cleared of trees for grazing (pers. obs). Grazing has also prevented regeneration of *C. glaucophylla* seedlings (Harrington et al. 1984). On the other hand, selective grazing can also lead to a higher density of some shrub species, for example, *Acacia aneura*, *Senna artemisioides*, *Dodonaea viscosa*, *Eremophila mitchellii* and *E. sturtii* (Harrington et al. 1984).

The presence of rabbits (*Oryctolagus cuniculus*) and to a lesser extent goats (*Capra hircus*) was noted more often in the non-mallee communities than the mallee. Obvious damage ranged from the ring-barking and severe pruning of some shrubs (*Eremophila* spp., *Acacia* spp.) by rabbits and goats, to browse lines on trees, especially *Geijera* *parviflora* by goats. The regeneration of a number of tree and shrub species in semi-arid eastern Australia has been inhibited by the introduction of herbivores (Parsons 1989). Species known to have problems regenerating elsewhere and which occur in Nombinnie and Round Hill NRs, include *Alectryron oleifolius, Casuarina cristata, Callitris preissii* subsp. *verrucosa, Myoporum platycarpum, Acacia oswaldii, Hakea tephrosperma* and *H. leucoptera* (Parsons 1989).

Exotic plant taxa were uncommon in terms of both richness and cover in the study area at the time of the survey (9 exotic taxa/227 total taxa; see back of map). These exotics are ephemeral, so they may be more common at other times (e.g. after rainfall and after fire). Fox (1989) found that both the number of species and the particular combination represented in both mallee and non-mallee communities were a function of seasonal rainfall. Bradstock (pers. comm) suggests that species richness of ephemerals is greater sooner rather than later after fire, assuming there is adequate rain.

Conservation of communities

Nombinnie, Round Hill and Yathong NRs and Mallee Cliffs NP conserve large areas of the *Eucalyptus socialis/E. dumosa/E. gracilis* alliance (Benson 1988), and it is therefore considered adequately conserved in NSW (Groves & Parsons 1989). On the other hand, *Eucalyptus morrisii* (R1) and *E. viridis* (D4) communities are considered inadequately conserved in NSW (Groves & Parsons 1989) and it is unlikely that the small areas in Nombinnie and Round Hill reserves will greatly change this status. Little is known of the conservation status of *Eucalyptus leptophylla*, since its occurrence is sporadic (Groves & Parsons 1989); they are scattered throughout Nombinnie and Round Hill NRs on the sandier soils, and have been recorded in Mallee Cliffs NP (Morcom & Westbrook 1989).

Benson (1988) considers communities dominated by *Eucalyptus populnea* (P7, D1, D1a) and *E. intertexta* (P6) as poorly conserved in NSW. The relatively widespread occurrence of these communities in Nombinnie, Round Hill and Yathong NRs (Parker et al. undated), increases their conservation status.

Although *Casuarina cristata* communities occur throughout the Western Division (Benson 1988), the associated subdominant species change. *Casuarina cristata / Alectryon oleifolius* communities occur further west (Fox 1991) and are reserved in Mallee Cliffs NP (Morcom & Westbrook 1990), whilst *Casuarina cristata* occurs more commonly with *Geijera parviflora* (P5) further east in the Nombinnie/Round Hill area. This latter community is also found in Yathong NR (Parker et al. undated).

Eucalyptus largiflorens communities (F2) are widespead on alluvial country in southern Australia (Fox 1991). They are found in a number of reserves throughout their range in NSW (Kinchega NP, a small area within Mallee Cliffs, Willandra NP, Macquarie Marshes NR, Narran NR,Goonawarra NR, Kajuligah and Morrisons Lake NR; Brickhill pers. comm.).

Conservation of rare plants

During this survey two rare and threatened plants *Acacia curranii* (3V) and *Lomandra patens* (3RCa),(Briggs & Leigh 1988) were recorded within Nombinnie NR and on adjacent leasehold land (Table 2).

Table 2. Rare or restricted plants recorded in the study area

Family	Species	Ratings A*	Ratings B**
Fabaceae	*Acacia curranii*	3V	3A
	Acacia calamifolia	–	4B
Santalaceae	*Choretrum glomeratum*	–	3B
Xanthorrhoeaceae	*Lomandra patens*	3RCa	3A

A*= Ratings according to Briggs & Leigh 1988.
3: range over 100 km, but restricted to highly specific habitats; V: vulnerable species, at risk over a 20–30-year period; R: rare species, not currently considered endangered or vulnerable; Ca: species known to be adequately reserved in a NP or other proclaimed reserve.

B**= Ratings according to Pressey et al. 1990.
3: restricted distribution in the western division (NSW) and also occurring interstate; A: small range and/or few records interstate; B: wide range and/or many populations interstate.
4: disjunct occurrences in the western division; B: main population or a significant part of main population in NSW.

Acacia curranii was found in three localities: two of these on leasehold land (c. 2500 plants over approximately 5 ha) and one within Nombinnie NR (with < 10 plants). All other populations of *A. curranii* are outside the reserve system (Pickard 1993). *Acacia curranii* is found on the northern sides of rocky hills in a low open woodland with a scattered overstorey of *Eucalyptus intertexta*, *E. populnea* subsp. *bimbil and Callitris glaucophylla*. At one site, *Acacia curranii* plants (4 m tall) appear to have been killed by fire in 1985, since the resulting post-fire regeneration is approximately 1 m tall (J. Brickhill, pers. comm.). At this site there was also evidence of goat damage to the stems of *Acacia curranii* (J. Brickhill, pers. comm.).

Lomandra patens was found on rocky hills at two sites within Nombinnie NR. It occurred in open woodland with an overstorey of *Callitris glaucophylla* or very open shrub mallee dominated by *Eucalyptus morrisii*. *Lomandra patens* is reserved in Mootwingee NP, Yathong NR, Cocoparra NP, and now Nombinnie NR, and is considered well reserved by Benson (1988).

The occurrence of *Acacia curranii* and *Lomandra patens* in a small number of locations in Nombinnie NR and adjacent leasehold land are unlikely to influence the current distribution and conservation rating for each.

Brickhill et al. (undated) found *Swainsona laxa* during their survey of Nombinnie NR in 1985, but it was not reported during the present survey. *Swainsona laxa* has a rating of 3VCa (Briggs and Leigh 1988). It is well conserved in Victoria, but is considered vulnerable in NSW due to current fire and grazing regimes (Benson 1988).

Pressey et al. (1990) consider *Acacia calamifolia* and *Choretrum glomeratum* to have restricted distributions (Table 2). The occurrence of these species at one site each within Nombinnie NR is unlikely to change this restricted status.

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Natural vegetation of the southern wheat-belt (Forbes and Cargelligo 1:250 000 map sheets)

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Remnant, native, woody vegetation of the southern wheat-belt on the Forbes and Cargelligo 1:250 000 map sheets is mapped and described. The study area is defined by the Lachlan River and latitude 33°S in the north, longitude 145°30′E in the west, latitude 34°S in the south and by a line which separates the western slopes and the western plains in the east; the study area thus excludes areas of the western slopes and the Western Division of New South Wales. The study area includes the towns of West Wyalong, Condobolin, Lake Cargelligo and Hillston; it also includes all or part of the Bland, Carrathool, Forbes, Lachlan, Parkes and Weddin Local Government Areas. Vegetation delineation, preliminary classification and sampling stratification are based largely on stereoscopic air photo interpretation. Pattern analysis, using data from 290 formal sites, is used to test and refine the above classification and map unit definition is based on the results. Twenty different remnant vegetation map units are described and mapped. Native woody vegetation is dominated by various eucalypt woodlands, the composition of which reflects position in the landscape and soils; *Eucalyptus camaldulensis* and *E. largiflorens* dominate on the floodplains, *E. populnea* subsp. *bimbil*, *E. microcarpa*, *E. conica* and *E. intertexta* dominate on heavier peneplain soils; *E. socialis*, *E. gracilis*, *E. dumosa* and *E. oleosa* dominate on lighter peneplain soils. Hill and footslopes remnants are dominated by *E. dwyeri* and *E. sideroxylon*. White Cypress Pine (*Callitris glaucophylla*) occurs throughout the area.

Of the 582 vascular plant taxa recorded, a high proportion (117 taxa) are exotic and only three are listed as nationally rare or threatened. The amount of native woody vegetation remaining (16% of the area), together with remnant size, threat of clearing, heavy grazing regimes, shape and condition demonstrate serious implications for biodiversity conservation and land management in the area.

Introduction

This is the first in a series of papers, with accompanying maps, delineating and describing the remaining native vegetation in the New South Wales wheat-belt study area (Figure 1). This paper deals specifically with the remnant vegetation of those parts of the Forbes and Cargelligo 1:250 000 map sheets occurring in the study area.

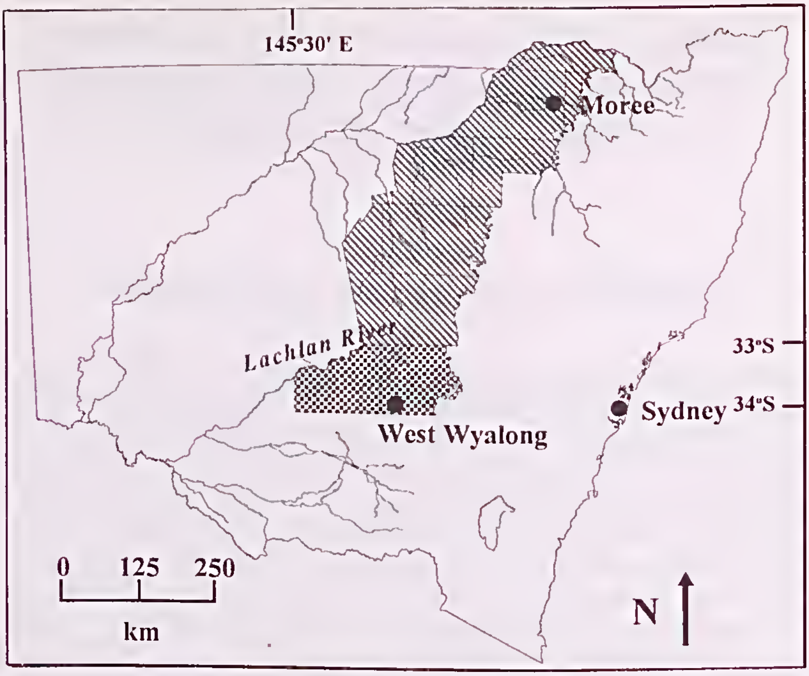

Fig. 1. The entire wheat-belt study area. The combined Forbes and Cargelligo 1: 250 000 map sheet area is indicated by the darker stippling.

The Forbes and Cargelligo areas comprise the southern-most part of New South Wales wheat-belt study area. This area has undergone far-reaching changes since European settlement due mainly to its importance for agriculture (Goldney & Bowie 1990). These changes have included removal of up to 95% of the original native vegetation for cropping and pasture improvement (Murray–Darling Basin Ministerial Council 1987), and widespread removal of native shrub and grass species by domestic and feral grazing animals (Adamson & Fox 1982; Benson 1991).

Land management agencies such as the NSW National Parks and Wildlife Service (NPWS), and community-based land management groups such as Landcare and Catchment Management Committees have a pressing need for information relating to remnant native vegetation. This is particularly true for land-types which have been favoured for agricultural and pastoral development such as the western plains. Native vegetation in the southern wheat-belt has not been well documented and mapped to date (Murray–Darling Basin Ministerial Council 1987). Mapping has either been very broad scale (e.g. Beeston et al. 1980) or of limited extent (Norris & Thomas 1991). Mapping exercises have been mostly based on qualitative assessments. Quantitative data is scarce.

The aims of this project are to map the remnant native vegetation of the study area at a scale of 1:250 000 and to describe those remnants in terms of their floristic assemblages and abiotic environments. Vegetation communities *sens. strict.* are therefore not the mapping units, although the primary breakdown of remnant types will be on floristics. This study is part of a longer-term project to map and describe, quantitatively, the remnant native vegetation of the entire New South Wales wheatbelt.

Limitations of scale

A mapping scale of 1:250 000 was chosen because it allows for a reasonable amount of detail and a rapid coverage of the area. A 1:100 000 scale series of maps covering the same area would take decades to complete, and a large percentage of the vegetation may well have been cleared by that time. However, this scale does present a number of limitations, which are detailed below.

It is important when reading any map to be aware of its scale and hence the level of accuracy that can be expected from it. For example, if a feature on a 1:25 000 scale map is misplaced by one millimetre this will translate to a 25 m displacement on the ground. The same displacement on a 1:100 000 map will be 100 m on the ground. The current maps are published at a scale of 1:250 000. At this scale every millimetre of displacement will translate into a 250 m displacement on the ground. Errors of this magnitude can be expected from the mapping and publishing processes alone. For example, some displacements of up to one millimetre may occur in transferring boundaries from air photographs to maps; and paper stretch during printing may create errors of this magnitude.

Another important aspect of scale which should be borne in mind is the limitation on the effective size of remnants that can be displayed. As the map scale decreases (as the area of land represented by each cm^2 of map increases) it becomes more difficult to map fine detail or small-scale patchiness. For example, whilst it may be quite feasible to map small patches, perhaps consisting of only a few trees of white cypress pine in a mallee community at 1:25 000 scale, it is not practically possible to do so at a scale of 1:250 000. Such patches would be too small to represent on the finished map.

Finally it should be noted that all thematic mapping is somewhat subjective, particularly with respect to placement of boundaries. Boundary lines of remnants should be regarded as falling within interzones and not as depicting immutable lines of change. The possible exception to this is the line between cleared and uncleared land.

Users of these maps are therefore exhorted to bear these limitations in mind. Remnant types are not homogeneous and often include small patches of other vegetation types which are not included in the description and which may appear quite large on the ground. Similarly, hoping to encounter a boundary on the ground exactly where you calculated it to be from the map may be an unrealistic expectation.

Study area

The study is confined to the western plains and isolated ranges on the Forbes and Cargelligo 1:250 000 scale map sheets. The area is bounded by the Lachlan River and latitude 33° to the north, longitude 145°30'E to the west, latitude 34°S to the south and by a line which separates the western slopes and the western plains in the east; an area of 2,400,650 ha (Figure 1). The study area includes the towns of West Wyalong, Condobolin, Lake Cargelligo and Hillston; it also includes all or part of the Bland, Carrathool, Forbes, Lachlan, Parkes and Weddin Local Government Areas.

Whilst these boundaries intentionally exclude the western slopes of the Great Divide and parts of the Western Division of New South Wales that occur on these maps, this is no reflection on the relative importance of these areas, but a way of confining the study to a manageable area with similar ecology and land-use practices throughout. This study will concentrate on the plains, as opposed to the hills, since it is the plains which have undergone the greatest change since European settlement (Murray–Darling Basin Commission 1987) and are most likely to be the subject of conflicting land-use proposals in the future.

Geology

Geologically the study area is complex. Most of the area is mapped as Unconsolidated Cainozoic deposits (fluvial and/or aeolian sand, silt and clay), but many other formations are scattered throughout (Pogson 1967; Bowman 1977). In the far west Dune deposits (clayey sands) and Playa formations (silt and silty clay) appear sporadically throughout the Quaternary deposits. Further east, from about Lake Ballyrogan (Lake Brewster), the study area contains a number of prominent, generally north–south aligned ranges of hills, the geologies of which are diverse. For example, the Lachlan Range is mapped as comprising three different Devonian sedimentary formations overlaying two Silurian sedimentary formations.

Other prominent ranges in the study area are:

- the Ural Range (Silurian volcanics & sediments and Tertiary basalt)
- the Tabbita, Melbergen, Naradhan and Cocoparra Ranges complex (Devonian sediments with some Tertiary basalt)
- the Goobothery Range (Ordovician metamorphics & sediments)
- the Narriah Hills (Devonian sediments & volcanics and Ordovician metamorphics & sediments)
- Mt Tilga and the surrounding hills (Ordovician and Devonian sediments)
- the Wyrra Hills (Silurian sediments)
- the Jemalong, Cordadgery and Gunning Ranges (Devonian sediments)
- the Currawong and Wheoga Hills (Devonian volcanics and sediments).

There are a number of other formations which do not form prominent ranges and are commonly obscured by Cainozoic material. These are most commonly Silurian and Ordovician sediments or Silurian granites.

Topography

Topographically, the study area is also complex. It is a peneplain which dips gently from 250 m elevation in the east to 120 m in the west. This peneplain also changes character from west to east. In the west it is flat to gently undulating and becomes progressively more undulating to rolling in the east. This general trend is locally disrupted by the ranges of hills already discussed, which may exceed 550 m elevation. Many of these ranges rise prominently and steeply from the surrounding plain. For example, the Lachlan Range rises to 362 m from the plain over a distance of only one kilometre.

There are also a number of floodplain zones, most of which are associated with the Lachlan River, although narrow bands of floodplain are recognisable along most tributary streams. The Lachlan floodplain varies in width from about 10 km to about 2 km.

Climate

Average annual rainfall ranges from 526 mm at Forbes to 365 mm at Hillston; a fall of 180 mm/year from east to west over a distance of 260 km (Table 1). Rainfall is distributed more or less evenly throughout the year but is erratic (Bureau of Meteorology 1992). Temperatures vary little across the study area; the hottest month is January with average daily maxima between 33.4° C (Lake Cargelligo) and 32° C (Forbes); the coldest month is July with average daily minima between 2.4° C (Forbes) and 3.7° C (Hillston).

Table 1. Summary of meteorological data for selected weather stations in the study area

	Highest maximum mean daily temperature °C	Lowest minimum mean daily temperature °C	Highest mean monthly rainfall mm	Lowest mean monthly rainfall mm	Average annual rainfall mm
Forbes	32.0 (Jan)	2.4 (July)	49 (Jan)	40 (Feb)	526
Condobolin	32.8 (Jan)	3.6 (July)	43(Jan&Oct)	30 (Sept)	443
Wyalong	32.2 (Jan)	2.6 (July)	46 (Oct)	35 (Nov)	485
Lake Cargelligo	33.4 (Jan)	2.8 (July)	40 (Oct)	31 (Sept)	427
Hillston	32.9 (Jan)	3.7 (July)	35 (Oct)	26 (Feb)	365

Methods

Definition of remnant vegetation

For this project remnant native vegetation was defined as comprising at least 5% native tree or shrub crown cover; where crown cover was <5% the area in question was visited in the field before it was mapped as native vegetation. Treeless remnants were only mapped when observed in the field because native low shrub, herb and grass communities are often difficult to distinguish from exotic pastures, weed infestations and even cropped land on high level aerial photography and satellite imagery.

Since the maps accompanying this report are 1:250 000 scale, it is important to note that mapping of small scale patchiness and very small remnants is not practically possible at this scale. Remnants of less than 10 ha are not mapped.

Sampling

Several possible sampling methods were considered. These included site stratification based on environmental gradients (Gillison 1984; Austin & Heyligers 1989), simple grid survey and random sampling. However, because of the difficulty in applying any of these methods due to the fragmented nature of the vegetation, limited access (sample sites were restricted to public land) and the difficulty in applying a gradient approach on the plains, interpreted high-level aerial photography was chosen. Restriction on access to private land, a government policy of the day, makes quantitative comparisons between remnants on public and private land impossible. This may present a limitation for some users.

Stereoscopic examination of air photos (air photo interpretation or API) allows recognition of vegetation/landform/soil patterns. Such patterns have been used to stratify sampling in vegetation and land resource surveys in Australia as early as 1946 (Christian & Stewart 1953) and are still currently used (e.g. Benson 1992). Using photopattern as a means of observing the effects of environmental gradients is convenient, particularly in a case such as this, where those gradients are not immediately apparent.

High level aerial photography, ca 1:85 000 scale (Commonwealth, 1980 for Cargelligo and 1989 for Forbes), covering the whole of the study area, was examined stereoscopically. Vegetation remnants were delineated and classified into 'phototypes' based on photopattern and position in the landscape. Upon completion of the API the photos were re-examined and possible field site localities were allocated so that all delineated phototypes were sampled, with replication, over the whole of their geographical range where possible. Replication varied according to the size and area of each phototype. For example, the strictly riparian remnant type (R1) was described at a total of 23 sites, whilst the less extensive 'floodplain mosaic' (R2) was sampled only seven times. This sampling of phototypes was applied to both plains and hills, thus all possible combinations of aspect, altitude and geology have not been investigated for the hills. In addition to stratification based on photopattern, sites were located taking into account access and location on public land, predominantly state forest, nature reserve, road reserve and travelling stock reserve.

Each site consisted of a measured 20 x 20 m (400 square metre) quadrat except where the nature of the remnant made this shape inappropriate, e.g. narrow riparian communities. In such cases the length and breadth of the quadrat were altered so that a constant area was sampled. Each site was described in terms of morphological terrain type, landform pattern, soil surface texture and colour, site drainage (run-off), site disturbance (soil erosion and exotic grazers), vegetation structure, floristic composition and species abundance. Vegetation structure was described in the following terms: heights of all strata, crown cover of the upper strata (Walker & Hopkins 1984), an estimate of total ground cover for the lowest stratum, and a cover abundance rating for each species present (Braun-Blanquet 1932). Observations of soil erosion and the effects of exotic grazers were non-quantitative, evidence of sheet, rill and gully erosion was noted (McDonald et al. 1984); grazing by exotic species was inferred from faecal remains, trampling and warrens.

Descriptions of geology, landform, soil and vegetation structure follow the terminology of McDonald et al. (1984). Botanical classification and nomenclature generally follow Jacobs and Pickard (1981) and Harden (1990, 1991–93); any exceptions to this are noted. Primary data were collected in all cases except for cover/abundance ratings of individual plant species which are pre-classified according to the Braun-Blanquet (1932) 1–7 scale.

A total of 290 formal sites were described. These were supplemented by numerous field notations made during the survey. Field work was carried out from October 1991 to February 1992. The study area had been subject to several years of drought before the survey. During the survey, however, the drought was broken by local heavy rains, notably in the east.

Data analysis

Recognition and description of vegetation patterns is integral to this project. Vegetation patterns were first classified intuitively on the basis of API. They were subsequently classified using multivariate analysis, using the PATN software package (Belbin 1988, 1991).

Cluster analysis with a hierarchical classification was used since the main aim was reduction of data to manageable groups and description of the data in terms of those groups (Faith, 1991). The Kulczynski coefficient and flexible UPGMA were used to calculate similarity and to generate the hierarchical classifications respectively (Belbin 1988).

Ephemeral and annual species were eliminated from the analysis because of the 'noise' introduced by sites on the eastern side of the study area. Here, drought-breaking rains produced rapid germination and maturation amongst the ephemerals and annuals. Exotic herbaceous species were also eliminated from the pattern analysis. These species, by virtue of their tendency to grow in a wide range of environments and native communities, also introduce considerable 'noise' into the analysis. All woody species (trees and shrubs) and perennial herbaceous species were included in the analysis. In all, approximately 290 taxa were eliminated from the final analysis.

Groups were defined from the resulting PATN dendrogram by considering as well as species composition, abiotic factors such as soil type, soil surface texture, landform, run-off, slope, geology and altitude. The site groupings so developed were then compared with the original API classification. A final classification was devised which equated site groupings with the map units; API boundaries were then amended as necessary.

Results

Some 84 families, 281 genera and 582 taxa (species and subspecies) of plants were recorded from the 290 formal sites. Of these 465 taxa were native, 117 exotic and three (*Lomandra patens*, *Phebalium obcordatum* and *Stipa eremophila*) are listed as nationally rare or threatened Australian plants [ROTAP] (Briggs & Leigh 1988). The families represented by most species were: Poaceae, 100 species; Asteraceae, 82 species; and Fabaceae and Chenopodaceae each with 32 species. The families Myrtaceae and Mimosaceae, which contain most of the canopy and small tree taxa, had 25 and 23 species respectively. The greatest species diversity is evident among families and genera containing mainly herbaceous species. The importance of the herbaceous components of the vegetation is seen in the full map unit descriptions (Table 2). Genera comprising seven or more species records, and the characteristic life forms of those genera, are shown in Table 3. A list of species recorded and their occurrence by map unit appears on the back of the published maps.

The results of the pattern analysis are expressed as a dendrogram revealing 15 major PATN groups (Figure 2). The initial API recognised 30 phototypes including seven floodplain and wetlands phototypes, 14 hills and footslopes phototypes, and nine plains phototypes. Whilst the disparity in the number of units in these two classifications may appear great, there are in fact many close parallels.

Five Riparian/Floodplain and two Wetland API phototypes were initially recognised based on canopy type, crown separation, position in the landscape and landforms. Of the 59 sites in these phototypes, 26 or 44% belonged to one PATN group (characterised by *Eucalyptus camaldulensis*); 25 or 42% fell into a second distinct PATN group (*E. largiflorens*); the remaining sites fell into other PATN groups because of codominance of another species or because of infrequently occurring species achieving dominance. Based on the analysis, therefore, two riparian map units, characterised by *E. camaldulensis* and *E. largiflorens* respectively, were recognised. Based on the API a third map unit was recognised which contained elements of these two, together with open grassy areas forming a mosaic, the elements of which could not be mapped separately at a scale of 1:250 000. Three additional floodplain units have been described based on photopattern and contain the sites which did not fit into the two main riparian groups. Therefore, the combination of pattern analysis and API has allowed identification of six riparian/floodplain map units.

In the initial API, ten hills and four footslopes phototypes were recognised based mainly on crown densities and mapped geologies. However, PATN analysis revealed few real differences between most of these phototypes. Based on the analysis, two main groups (mallee and non-mallee vegetation) could be recognised. Amongst the non-mallee vegetation some differences were evident between sites occurring on sedimentary or metamorphic geologies, and those occurring on volcanic geologies. These two groups have therefore been differentiated in the mapping. Amongst the volcanic geologies it was not possible to describe any sites on basalts. However, API and informal observations revealed that areas of basalt tended to be substantially cleared and that, where remnants of native vegetation occurred, they were similar to those described on the sedimentary geologies. The final result is that four Hills map units have been recognised. The four footslopes API types were later reduced to three based on density of woody vegetation cover and floristic composition.

By a similar process of comparison and combination between API and PATN classifications, the nine original phototypes occurring on the Peneplain were reduced to seven map units.

Remnant types containing species with narrow geographical distributions, for example riparian, wetland and hill species, fell into discrete PATN groups. On the other hand, remnant types of the plains and footslopes containing species with broader geographical distributions tended to have sites dispersed among numerous PATN groups (Figure 2). On the peneplain, API allowed two distinct types of box community to be distinguished; an Open Woodland (P3) that shows evidence of having been partially cleared and heavily grazed, and a Woodland or Open Forest (P4) displaying less evidence of clearing and grazing. The difference between these two map units was not immediately apparent from the pattern analysis, although close examination of the site data reveals substantial floristic differences. Conversely, two *Callitris glaucophylla* dominated remnant types were recognised in the initial API which showed no substantial difference either in the pattern analysis or in terms of crown cover. In this instance, therefore, the two initial categories were combined.

PATN analysis and API comparison has resulted in the formulation of 20 map units, the full descriptions of which appear in Table 2.

The four broad geomorphic zones adopted as the primary breakdown for the map units display distinct combinations of environmental factors which are reflected in the floristic composition of the map units (Tables 4, 5, & 6). The Riparian and Floodplain zone is characterised by channels, backplains and floodplains; grey cracking clay soils; very low slopes; and very slow to nil run-off (Table 4).

The Peneplain units fall into three main categories (Table 5). P1, P2, and P5 (mallee units) are characterised by sandy soils; low slopes; very slow to slow run-off; and flat to gently undulating terrain. P3, P4 and P6 are characterised by loamy red earth soils; low slopes; slow run-off; and generally flat terrain. P7 occupies an interzone between the Floodplain and Peneplain units. Landforms tend to be flat, although occupying a higher position in the landscape than surrounding 'R' units. Soils are dark red-brown clayey earths.

The Footslopes zone is characterised by lower slopes and flats; loamy red and red-brown earth soils; slopes of up to 3°; and slow to rapid run-off. The Hills zone comprises upper slopes and crests; shallow (frequently skeletal) brown earth soils; moderate to steep slopes; and rapid to very rapid run-off (Table 6).

Table 2. Map unit descriptions

The following map unit descriptions summarise the landforms, soils, vegetation structures and species occurring in each unit. These remnants are not homogeneous with respect to all of these factors, hence, the descriptions deal with the most common and characteristic features. Variations are discussed in the 'comments' section. Each map unit is described in the following terms:

Name: Map unit code (characteristic vegetation community).

Sites: The number of formal sites described in the mapping unit.

Landforms: Most frequently occurring morphological terrain types.

Soils: Main soil types encountered. This typing of soils is based on field observations (as previously described) and, where available, mapped information; they should not be interpreted as resulting from formal profile descriptions.

Structure: Main vegetation structural types, following Walker and Hopkins (1984).

Species: Dominant and most frequently occurring species in each stratum are listed. For convenience the strata are labelled 'Trees', 'Low Trees', 'Tall Shrubs', 'Shrubs', 'Herbs' and 'Grasses'. Where one or more of these strata do not commonly occur they are omitted.

Comments: This section is devoted to general descriptions of the unit and descriptions of the range of variation expected.

Note: Exotic species are indicated in the species lists on the back of the maps.

RIPARIAN AND FLOODPLAIN REMNANTS

Name: R1. (River Red Gum Forests)

Sites: 23.

Landforms: Banks, channels and backplains.

Soils: Grey cracking clay and polygenetic alluvial soils.

Structure: Tall Open Forest.

Species: Trees *Eucalyptus camaldulensis*; Low Trees *Acacia stenophylla, Acacia saligna*; Shrubs *Muehlenbeckia florulenta*; Herbs *Pratia concolor, Rumex brownii, Echium plantagineum, Sonchus oleraceus, Onopordum acanthium* subsp. *acanthium, Oxalis corniculata, Centipeda cunninghamii*; Grasses *Cynodon dactylon, Paspalidium jubiflorum, Lolium rigidum*.

Comments: This remnant type is characteristic of streamline and river margins. The dominant community most commonly comprises two strata; the canopy and a herbaceous understorey, usually dominated by exotics. The shrub stratum is patchy in occurrence and is frequently absent.

Name: R2. (Floodplain Mosaic)

Sites: 7.

Landforms: Backplains, floodplains and banks.

Soils: Grey cracking soils.

Structure: Tall Open Forests and Closed Grassland.

Species: Trees *Eucalyptus largiflorens, Eucalyptus camaldulensis*; Low Trees *Acacia salicina* and

Acacia stenophylla; Shrubs *Muehlenbeckia florulenta;* Herbs *Carex inversa, Centipeda cunninghamii, Marrubium vulgare, Echium plantagineum*; Grasses *Lolium rigidum, Hordeum leporinum, Phalaris paradoxa, Agrostis avenacea.*

Comments: This remnant type comprises a mosaic of R1, R3 and Grasslands where the individual elements are too small to map separately. It is mainly associated with backplain and floodplain areas of the Lachlan and other major rivers and characteristically contains a network of minor stream channels.

Name: R3. (Black Box Woodlands)

Sites: 23.

Landforms: Floodplains, closed depressions and very gentle rises.

Soils: Mainly grey cracking clays with some red earths and brown clays.

Structure: Mid-High Open Forests, Mid-High Woodlands and Mid-High Open Woodlands.

Species: Trees *Eucalyptus largiflorens, Eucalyptus camaldulensis, Eucalyptus populnea* subsp. *bimbil*; Low Trees *Acacia salicina, Acacia pendula*; Shrubs *Muehlenbeckia florulenta*; Herbs *Einadia nutans, Sclerolaena muricata, Rhodanthe corymbiflora, Oxalis corniculata*; Grasses *Danthonia setacea, Lolium rigidum, Hordeum leporinum, Phalaris paradoxa.*

Comments: Associated with broad floodplain areas and isolated closed depressions which often pond water for several days following rain. *Eucalyptus camaldulensis* tends to replace *E. largiflorens* in about the eastern third of the study area. Minor areas of *E. populnea* subsp. *bimbil* and *Casuarina cristata*, forming a mosaic pattern, occur on higher ground within this unit in the west. Typical Black Box (*Eucalyptus largiflorens*) communities in this area contain either a scattered Lignum (*Muehlenbeckia florulenta*) shrub layer or the shrub layer is absent. The ground cover may vary considerably from site to site and tends to be less dominated by exotics than is the case with river frontage remnants (R1 & R2).

Name: R4. (Lignum Shrublands)

Sites: 1.

Landforms: Flats and Closed Depressions.

Soils: Brown clay.

Structure: Tall Shrublands.

Species: Shrubs *Muehlenbeckia florulenta;* Grasses *Stipa aristiglumis, Enteropogon acicularis, Phyla nodiflora, Lolium perenne.*

Comments: Remnant type of limited extent; associated with the Lachlan River and Lakes.

Name: R5. (Myall Woodlands)

Sites: 1.

Landforms: Gilgaied flats.

Soils: Grey clay.

Structure: Mid-High Woodland to Mid-High Open Forest.

Species: Trees *Acacia pendula*; Shrubs *Amyema quandong, Einadia nutans;* Herbs *Ixiolaena tomentosa, Marsilea hirsuta*, Grasses *Danthonia setacea, Lolium rigidum.*

Comments: This remnant type is difficult to distinguish from grassed land on the 1: 85,000 aerial photography used in this project and hence, may be more common than indicated on the map. However, whilst it is possible to see scattered Myall (*Acacia pendula*) throughout the area, very few sizeable remnants were observed. The mistletoe *Amyema quandong* is a characteristic stem parasite of Myall.

Name: R6. (Yellow Box/River Red Gum Forests)

Sites: 4.

Landforms: Flats, floodplains.

Soils: Brown earthy soils and clays.

Structure: Tall Open Forest to Tall Woodland.

Species: Trees *Eucalyptus melliodora, Eucalyptus camaldulensis*; Low Trees *Acacia stenophylla;* Shrubs *Muehlenbeckia florulenta;* Herbs *Onopordium acanthium* subsp. *acanthium;* Grasses *Lolium perenne, Lolium rigidum, Avena ludoviciana.*

Comments: This remnant is characterised by the presence of Yellow Box (*Eucalyptus melliodora*), usually in combination with River Red Gum

(*Eucalyptus camaldulensis*), and has many features in common with remnant type R1. However, it is does not occur on banks and tends to be confined to low-lying areas on the floodplains. The shrub layer tends to be both patchy and sparse and the ground cover is dominated by exotic species.

UNDULATING PENEPLAINS REMNANTS

Name: P1. (Mallee Woodlands)

Sites: 11.

Landforms: Flats and very gentle rises.

Soils: Sandy red earths.

Structure: Low to Mid-High Mallee Woodlands.

Species: Trees *Eucalyptus socialis, Eucalyptus gracilis, Eucalyptus dumosa, Callitris glaucophylla;* Shrubs *Melaleuca uncinata, Olearia pimeleoides, Eremophila glabra, Acacia* spp., *Halgania cyanea;* Herbs *Chrysocephalum apiculatum, Hyalospermum semisterile, Stackhousia viminea, Lomandra effusa, Dianella revoluta, Daucus glochidiatus;* Grasses *Triodia scariosa* subsp. *scariosa, Stipa elegantissima.*

Comments: This remnant type is characterised by Mallee Woodlands on red sands. These communities support diverse and variable shrub and herbaceous understoreys. Small areas of *Callitris* open woodlands occur on hard-setting red earth soils within the mallee.

Name: P2. (Open Mallee Woodlands)

Sites: 8.

Landforms: Flats and gentle rises.

Soils: Sandy red earths.

Structure: Low Mallee Woodlands and Mid-High Woodlands.

Species: Trees *Callitris glaucophylla, Casuarina cristata;* Low Trees *Eucalyptus socialis, Eucalyptus dumosa, Eucalyptus oleosa, Eucalyptus leptophylla;* Shrubs *Olearia pimeleoides, Geijera parviflora, Acacia* spp., *Hakea tephrosperma, Pittosporum phylliraeoides;* Herbs *Chrysocephalum apiculatum, Dianella revoluta, Vittadinia pterochaeta, Daucus glochidiatus, Echium plantagineum, Hyalosperma semisterile, Hypochaeris radicata;* Grasses *Bromus rubens, Stipa scabra* var. *scabra, Vulpia myuros, Stipa elegantissima.*

Comments: In this remnant type the vegetation communities are structurally diverse. The Mallee communities are frequently more open than in P1 as a result of past clearing and grazing, and are interspersed patches of White Cypress Pine (*Callitris glaucophylla*) and Belah (*Casuarina cristata*) dominated communities.

Where the shrub and grass layers have been removed and disturbed by grazing, exotic species dominate the understorey.

Name: P3. (Open Box Wood-lands)

Sites: 27.

Landforms: Flats and gentle slopes <2 degrees.

Soils: Loamy red earths, minor sandy red earths and brown earths.

Structure: Mid-high Open Woodland, Tall Open Woodlands, Tall Woodlands and Tall Grassland

Species: Trees *Callitris glaucophylla, E. populnea* subsp. *bimbil, Eucalyptus intertexta, Eucalyptus microcarpa, Allocasuarina luehmannii;* Low Trees *Geijera parviflora, Acacia oswaldii;* Tall Shrubs *Dodonaea viscosa, Eremophila mitchellii;* Shrubs *Maireana enchylaenoides, Einadia nutans;* Herbs *Sida corrugata, Echium plantagineum;* Grasses *Danthonia setacea, Enteropogon acicularis, Stipa scabra* var. *scabra, Vulpia myuros, Elymus scaber* var. *scaber, Lolium rigidum.*

Comments: A generally open pattern with scattered denser areas on the aerial photographs. Site descriptions suggest previous clearing and moderate to heavy grazing patterns.

Name: P4. (Box Woodlands)

Sites: 52.

Landforms: Flats, very gentle slopes and minor drainage lines.

Soils: Loamy red earth soils, minor occurrences of sandy and clayey red and brown earths.

Structure: Tall Woodland to Tall Open Woodland and Mid-High Woodland.

Species: Trees *Eucalyptus populnea* subsp. *bimbil, Callitris glaucophylla, Eucalyptus microcarpa, Eucalyptus conica, Eucalyptus intertexta,* and *Allocasuarina luehmannii;* Tall Shrubs *Dodonaea viscosa, Pittosporum phylliraeoides, Acacia deanei, Senna artemisioides* and *Santalum acuminatum;* Shrubs *Einadia nutans, Maireana enchylaenoides;* Herbs *Calotis cuneifolia, Dichondra repens, Sida corrugata, Vittadinia dissecta, Oxalis chnoodes;*

Grasses *Danthonia setacea, Stipa scabra* var. *scabra, Lolium rigidum, Enteropogon acicularis, Vulpia myuros, Elymus scaber* var. *scaber.*

Comments: Very similar to P3 in composition but differing in having a consistently denser and more even canopy. Possibly not thinned as P3 has been. Varying dominance of the main eucalypt species; frequently with *Callitris glaucophylla* co-dominant.

Name: P5. (Mallee/White Cypress Pine intergrade)

Sites: 5.

Landforms: Flats.

Soils: Sandy and loamy red earths.

Structure: Mid-High Mallee Woodland or Tall Woodland to Mid-High Woodland.

Species: Trees *Callitris glaucophylla*; Low Trees *Eucalyptus socialis, Eucalyptus dumosa*; Tall Shrubs *Eremophila glabra, Pittosporum phylliraeoides, Melaleuca uncinata*; Shrubs *Maireana enchylaenoides*; Herbs *Dianella revoluta, Hyalosperma semisterile, Hypochaeris radicata*; Grasses *Danthonia setacea, Triodia scariosa* subsp. *scariosa, Vulpia myuros.*

Comments: Intergrade remnant between White Cypress Pine and Mallee remnants with cypress pine and mallee in discrete communities forming a mosaic, the individual units of which are too small to map separately.

Name: P6. (White Cypress Pine Woodlands)

Sites: 48.

Landforms: Flats and gentle rises.

Soils: Loamy red earth soils.

Structure: Tall Open Woodland, minor Mid-High Open Woodland and Tall Woodland.

Species: Trees *Callitris glaucophylla*, (minor *Eucalyptus populnea* subsp. *bimbil, Eucalyptus microcarpa, Eucalyptus intertexta, Brachychiton populneus* and *Allocasuarina luehmannii)*; Tall Shrubs *Acacia deanei, Dodonaea viscosa, Geijera parviflora, Senna artemisioides* Shrubs *Einadia nutans, Maireana enchylaenoides*; Herbs *Cheilanthes austrotenuifolia, Calotis cuneifolia, Oxalis chnoodes, Sida corrugata, Hypochaeris radicata, Stackhousia viminea, Bracteantha bracteata*; Grasses *Stipa scabra* var. *scabra, Vulpia myuros, Danthonia setacea, Elymus scaber* var. *scaber, Pentaschistis airoides.*

Comments: White Cypress Pine woodlands and forests dominate but contain elements of other plains communities. Eucalypts may be locally dominant or co-dominant and thus this type overlaps with P4. This remnant type often comprises a dense stratum of regrowth pine with Eucalypts as isolated emergents.

Name: P7. (Bull Oak/Belah Woodlands)

Sites: 10.

Landforms: Flats, shallow depressions and minor drainage lines.

Soils: Gilgaied clays and red earths.

Structure: Tall Woodlands (minor Tall Open Woodland and Mid-high Open Woodland).

Species: Trees *Allocasuarina luehmannii, Callitris glaucophylla, Casuarina cristata, Acacia homalophylla*; Low Trees *Myoporum montanum, Acacia deanei*; Shrubs *Einadia nutans, Enchylaena tomentosa*; Herbs *Sida corrugata, Vittadinia dissecta*; Grasses *Danthonia setacea, Lolium rigidum, Vulpia myuros, Stipa wakoolica, Enteropogon acicularis, Elymus scaber* var. *scaber.*

Comments: Confined to the eastern third of the study area, this remnant occupies a zone of transition between the floodplain and peneplain remnants.

FOOTSLOPE REMNANTS

Name: F1. (Grasslands)

Sites: Nil

Landforms: Slopes, low crests and flats.

Soils: Lithosols and colluvial soils.

Structure: Tall Grassland, (minor Mid-High Open Woodland).

Species: Trees *Callitris glaucophylla, E. populnea* subsp. *bimbil*; Grasses *Stipa scabra* var. *scabra, Danthonia setacea.*

Comments: No access was available for formal sites in this remnant type. However, it appears from the API to be mainly cleared and consists of grasslands with clumps of trees remaining; it is otherwise similar to F2.

Name: F2. (Open Pine and Box Woodlands)

Sites: 18.

Landforms: Footslopes and flats.

Soils: Colluvial red earths.

Structure: Tall Open Woodland, Tall Woodland and Mid-High Open Woodland.

Species: Trees *Callitris glaucophylla, Eucalyptus populnea* subsp. *bimbil, Eucalyptus intertexta, Eucalyptus dwyeri, Eucalyptus sideroxylon, Brachychiton populneus*; Low Trees *Acacia doratoxylon, Acacia deanei, Myoporum montanum, Pittosporum phylliraeoides, Leptospermum divaricatum*; Shrubs *Chenopodium desertorum, Dodonaea viscosa, Cassinia laevis Maireana enchylaenoides, Einadia nutans*; Herbs *Calotis cuneifolia, Hypochaeris radicata, Sida corrugata, Cheilanthes austrotenuifolia*; Grasses *Vulpia myuros, Danthonia setacea, Stipa scabra* var. *scabra, Bromus rubens.*

Comments: White Cypress Pine dominates over most of this remnant type. It displays elements of both hill and plains remnants as is to be expected with an interzone.

Name: F3. (Pine and Box Wood-lands)

Sites: 8.

Landforms: Footslopes and flats.

Soils: Red and brown earths.

Structure: Tall Woodland.

Species: Trees *Callitris glaucophylla, Eucalyptus microcarpa, Eucalyptus populnea* subsp. *bimbil*; Tall Shrubs *Acacia deanei, Hakea tephrosperma, Eremophila mitchellii*; Shrubs *Senna artemisioides, Einadia nutans*; Herbs *Oxalis chnoodes, Cheilanthes austrotenuifolia, Sida corrugata*; Grasses *Danthonia setacea, Stipa scabra* var. *scabra, Vulpia myuros, Pentaschistis airoides.*

Comments: A denser version of F2 with White Cypress Pine dominating overall, although any of the main tree species may be locally dominant.

HILL AND RIDGE REMNANTS

Sedimentary and metamorphic geologies

Name: H1. (Dwyers Red Gum and Pine Woodlands)

Sites: 30.

Landforms: Upper and mid slopes, crests and ridges.

Soils: Lithosols and shallow brown earths.

Structure: Mid-High Woodland, Mid-high Open Woodland, (minor Tall Open Woodland and Low Open Woodland).

Species: Trees *Callitris glaucophylla, Eucalyptus dwyeri, Callitris endlicheri, Eucalyptus sideroxylon, Brachychiton populneus, Acacia doratoxylon, Allocasuarina verticillata*; Tall Shrubs *Leptospermum divaricatum, Cassinia laevis, Dodonaea viscosa, Calytrix tetragona*; Shrubs *Grevillea floribunda, Hibbertia obtusifolia, Melichrus urceolatus, Platysace lanceolata*; Herbs *Gonocarpus elatus, Cheilanthes austrotenuifolia, Wahlenbergia queenslandica*; Grasses *Vulpia myuros, Danthonia setacea, Pentaschistis airoides, Stipa scabra* var. *scabra.*

Comments: Three main associations are represented: *E. dwyeri/Callitris glaucophylla, E. dwyeri/Callitris endlicheri* and *Callitris glaucophylla/E. sideroxylon.*

In some areas *Acacia doratoxylon* or *Allocasuarina verticillata* may form the canopy layer but usually form a dense understorey where they occur.

Name: H2. (Green Mallee Woodlands)

Sites: 9.

Landforms: Low crests, gentle hillslopes and flats.

Soils: Lithosols and shallow brown earths.

Structure: Mid-High Mallee Woodland (structurally diverse, varying from Low to Tall formations).

Species: Trees *Eucalyptus viridis, Eucalyptus sideroxylon, Callitris endlicheri, Eucalyptus dumosa, Eucalyptus gracilis, Eucalyptus polybractea, Eucalyptus dwyeri*; Low Trees *Melaleuca uncinata, Acacia doratoxylon, Acacia cultriformis, Santalum acuminatum*; Tall Shrubs *Cassinia laevis, Olearia floribunda, Pultenaea largiflorens, Cassinia uncata, Dodonaea viscosa*; Shrubs *Melichrus urceolatus, Platysace lanceolata*; Herbs *Dianella revoluta, Cassytha melantha, Helichrysum viscosum, Helichrysum obcordatum, Calotis cuneifolia*; Grasses *Danthonia setacea, Vulpia myuros, Stipa scabra* var. *scabra.*

Comments: Mallee on hills, often associated with *E. dwyeri* and Cypress Pine.

VOLCANIC GEOLOGIES

Name: H3 (Pine and Poplar Box Open Woodlands)

Sites: 6.

Landforms: Hillslopes, ridges and crests on granites and volcanics.

Soils: Lithosols and shallow brown earths.

Structure: Mid-High Open Woodland.

Species: Trees *Callitris glaucophylla, Eucalyptus populnea* subsp. *bimbil, Eucalyptus dwyeri, Brachychiton populneus*; Low Trees *Acacia doratoxylon, Allocasuarina verticillata*; Shrubs *Prostanthera nivea, Grevillea floribunda, Hibbertia riparia*; Herbs *Cheilanthes austrotenuifolia, Hypochaeris radicata, Oxalis chnoodes*; Grasses *Stipa scabra* var. *scabra, Pentaschistis airoides, Danthonia setacea, Vulpia myuros.*

Comments: Similar in many instances to H1 but differing in that *E. populnea* subsp. *bimbil or E. intertexta* may dominate or be co-dominant with White Cypress Pine in the canopy. This may reflect the fact that these geologies often display gentler slopes and lower hills than the steeply dipping sedimentaries.

Name: H4 (Cypress Pine Woodlands)

Sites: Nil.

Landforms: Low crests and hillslopes on basalts.

Soils: Basalt-derived clays.

Structure: Mid-High Open Woodland and Grasslands.

Species: Trees *Callitris glaucophylla, Eucalyptus dwyeri*; Grasses *Stipa scabra* var. *scabra, Danthonia setacea.*

Comments: There are very few basalt hills in the study area and most of these have been cleared. What vegetation remains appears similar to that of H1 on the aerial photographs. There was no access to this remnant for formal sites.

Table 3. Genera with the highest species diversity in the study area

T=tree, S=shrub, G=grass, H=herb, P=stem parasite.

Genus Name	No. of species	Growth form/s
Acacia	23	S,T
Eucalyptus	18	T
Stipa	17	G
Danthonia	10	G
Goodenia	10	H
Dodonaea	10	S
Lomandra	9	H
Juncus	9	H
Wahlenbergia	8	H
Chenopodium	8	H,S
Sida	8	H,S
Paspalidium	7	G
Rumex	7	H
Amyema	7	P

Discussion

Native vegetation in the study area has undergone many changes since European settlement in the mid-1800s. The most obvious change has been clearing, although grazing by domestic stock and feral grazers has also had profound effects on the vegetation (Adamson & Fox 1982). Other processes of change include the introduction of exotic species (see Tables 4, 5 & 6); active management of state forests and private woodlots to encourage the growth of some species (e.g. *Callitris glaucophylla*) at the expense of others (for example, eucalypt box species, see remnant type P6); alterations to pre-settlement fire regimes; pollution and damming of waterways; aerial application of pesticides and fertilisers; and isolation of remnant vegetation in time and space; these are the main 'threatening processes' operating in the wheat-belt. Discussion of the full effects of these threatening processes are not within the scope of this paper and are not well understood in all cases (see Saunders et al. 1991 and Bradstock et al. (in prep.) for an introduction to the subject). There seems little doubt that these processes have led to declines in native species diversity and an increase in the likelihood of extinctions in the medium and long term (Adamson & Fox 1982; Benson 1991; Hobbs 1987; Saunders et al. 1991). None of the sites visited during this survey could be described as completely undisturbed. The results clearly demonstrate high levels of grazing (by domestic and feral grazers), widespread soil erosion and partial clearing within the remnant native vegetation.

Clearing is the most readily observable threatening process in the study area. It is not an historical practice that has now ceased, but is continuing in much of the agricultural lands of New South Wales. Between 1974 and 1989, in the area covered by the Condobolin 1:100 000 map sheet (Figure 3), 57 400 ha of the native vegetation were cleared; an average of 3 800 ha per year and a reduction of 61% of the remaining native vegetation over 15 years (Sivertsen 1993). Virtually all this clearing was confined to the plains and the lower footslopes.

Clearing affects all communities described in this paper, with the possible exception of those occurring on steep hillslopes. Most affected are the Riparian communities and Box woodlands which occupy the prime agricultural lands. Box species have also been selectively logged from state forests to encourage White Cypress Pine regrowth.

An important aspect of remnant vegetation management must be an understanding of extent and condition of those remnants. For example, 34 400 ha of River Red Gum (R1) are mapped (Table 7), making it the third most extensive remnant type but, as the map indicates, most of the River Red Gum occurs as narrow bands along the major river corridors and often only as a single line of trees on either side of the channel. This is not the potential extent of the River Red Gum community. In many instances this species will occur as a narrow band adjacent to the channel, but not as a single row of trees with well spaced crowns as is the case currently. Towyal and Cadow State Forests (Lachlan River) and Gunning Gap State Forest on Goobang Creek demonstrate River Red Gum's potential to spread at least a kilometre from the channel under favourable conditions. The narrow corridors which remain are

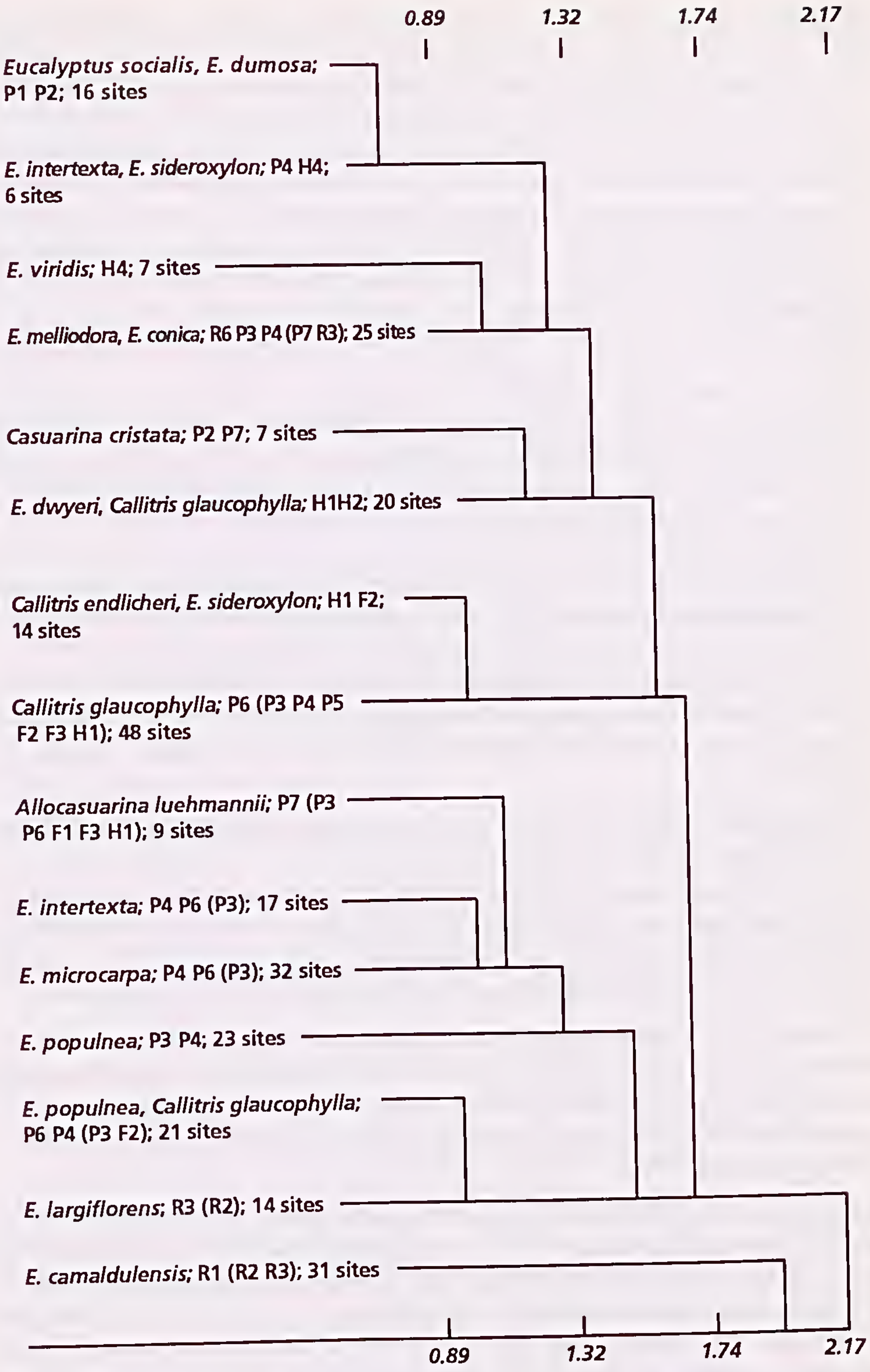

Fig. 2. Dendrogram showing the major group boundaries from the southern wheat-belt survey. The species shown are the major tree species only. Alphanumeric codes show the remnant types associated with each group. Brackets indicate minor occurrences in groups. The vertical scale of the dendrogram is proportional to the number of sites in each group.

also frequently isolated from other remnant vegetation (again as indicated by the maps) and, therefore, present many management difficulties. They have very high boundary length to area ratios and are therefore more prone to weed infestations and the adverse effects of altered light, water and wind regimes. Loss of this vegetation type comprises a substantial loss of habitat for native plants and for both vertebrate and invertebrate native fauna and indicates the possibility of increased soil erosion, degraded water quality and loss of natural flood mitigation. The riparian community is no longer there to filter pollutants and suspended solids from local runoff and to reduce and baffle over-bank flow rates. Mallee (P1 & P2), Box Woodland (P3 & P4) and Dwyers Red Gum/Pine Woodlands (H1) remnants are also frequently long and narrow, thus presenting similar management problems.

Tables 4, 5, 6 and 8 give some indication of remnant condition. High proportions of sites display evidence of grazing (83%), feral animal damage (60%) and partial clearing (70%) (Table 8). The Riparian/Floodplain remnants have characteristically high levels of site disturbance and exotic species and tend to be dominated by exotics in the herb layer. About 40% of plant species recorded for the Riparian/Floodplain remnants are exotics (Table 4), among the Box and Cypress Pine remnants of the Peneplain and Footslopes this figure falls to an average of 22% (Table 5). The Mallee and Hills remnants have the lowest exotic components, an average of 13% and 14% respectively. Thinned and unthinned remnants were recognised during API. P2 is a more open form of mallee than P1; and P3 is a generally more open Box Woodland than P4. In both cases the more open remnant type shows evidence of higher levels of grazing and feral animal damage and support a higher proportion of exotic plant species.

Very little native vegetation remains in the Forbes and Cargelligo study area. A total of 16% (376 800 ha) of the area remained under native vegetation at the time of survey. Of the total study area less than 10%, 230 800 ha, remained on the plains, a figure in close agreement with the Murray-Darling Basin Ministerial Council (1987); a further 145 700 ha supports native vegetation on the steep and rocky hills, which are unlikely to be subjected to further major habit disruption in the foreseeable future.

The results of this study demonstrate that there is a very small, dwindling and degraded native vegetation resource to be conserved in the Forbes and Cargelligo area, particularly on the plains. However, the results also show how important these remnants are in the conservation of native biodiversity remaining in the agricultural lands of New South Wales.

This study recorded 465 taxa of native plants, including three which are classified as rare or threatened nationally (Briggs & Leigh 1988). Sampling was limited to public lands and by drought conditions. Many other species, particularly ephemerals and those with restricted distributions, can be expected to occur in the area as indicated by the work of Fox (1990). A total of 12 ROTAP species are known from the study area (Briggs & Leigh 1988). Many other species are likely to be rare or threatened, at least in the regional context; 41% of the plant species recorded during this study occurred only once or twice (Sivertsen 1993). Whilst this alone cannot confer rare or threatened status, it does indicate that more detailed investigations of the status of

Table 4. Summary of physical and species count data for riparian and floodplain remnants

Landforms: B=Bank, Ch=Channel, BP=Backplain, CD=Closed Depression, F=Flat; Soils: AS=Alluvial Soil, GCC=Grey Cracking Clay, BC=Brown Clay, BE=Brown Earths; Runoff: 0=Nil, VS=Very Slow, S=Slow.

	R1	**R2**	**R3**	**R4**	**R5**	**R6**
Main landforms	B, Ch, BP	B, F	F, BP	F, CD	F	F
Main soil types	AS, GCC	GCC	GCC	BC	GCC	BE
Slopes (degrees)	0	0	0	0	0	0
Altitude range (m.a.s.)	130–250	120–185	100–230	207	190	200–240
Site runoff	0-S	VS	0-S	VS	VS	VS–S
Total species	183	91	185	20	28	65
Exotic species	67	38	59	11	7	28
% exotic species	37	42	32	55	25	43

Table 5. Summary of physical and species count data for Peneplain remnants

Landforms: S= slope, F=Flat; Soils: sRE=sandy Red Earth, lRE=loamy Red Earth, lRBE=loamy Red-Brown Earth; Runoff: 0=Nil, VS=Very Slow, S=Slow.

	P1	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**
Main landforms	F	F	F	F	F	F, S	F
Main soil types	sRE	sRE	lRE	lRE	sRE	lRE	lRBE
Slopes (degrees)	0–2	0–1	0–1	0–1	0	0–2	0
Altitude range (m)	120–200	100–155	110–270	170–185	140–260	190–325	215–235
Site runoff	S	S	VS–S	S	S	S	S
Total species	93	70	173	249	64	218	105
Exotic species	8	12	39	53	16	40	20
% exotic species	9	17	22	21	25	18	19

Table 6. Summary of physical and species count data for footslope and hills remnants

Landforms: LS=Lower Slope, MS=Mid-Slope, UP=Upper Slope, C=Crest, S=Slope (unspecified), F=Flat; Soils: RE=Red Earth, RBE=Red-Brown Earth, BE=Brown Earth; sBE= Sandy Brown Earth; Runoff: S=Slow, R=Rapid, VR=Very Rapid.

	F2	**F3**	**H1**	**H2**	**H4**
Main landforms	LS	LS, F	MS-C	US, C	F, S, C
Main soil types	RBE	RE, BE	BE	BE	sBE
Slopes (degrees)	0–3	0–3	2–6	2–19	1–4
Altitude range (m)	180–330	180–335	210–380	280–320	275–310
Site runoff	S–R	S–R	R–VR	R–VR	S–R
Total species	130	87	164	79	81
Exotic species	23	24	23	13	9
% exotic species	18	28	14	16	11

those populations is warranted. The conservation of all native plant and animal species in the region hinges on the management and protection of vegetation remnants.

The current criteria which define rare or threatened plant species are now well established (Briggs & Leigh, 1988) although refinement of techniques for classification continues (Chalson & Keith, 1995). There is a well recognised procedure for classification and listing of rare or threatened plant species. However, the same cannot be said for plant communities. There is difficulty in achieving an accepted definition of 'community' amongst ecologists; the debate over what constitutes a plant community and even whether or not such concepts have any ecological meaning has spanned many years (e.g. Beadle, 1948 to Austin, 1991). If, however, we can agree that there exist assemblages of species which form recognisable entities, called communities in the absence of a better term (e.g. Poplar Box woodlands, Brigalow, Belah, River Red Gum forests), we can then recognise and define levels of threat facing these communities.

The dominant species in many communities are trees or shrubs which tend to be long-lived by human standards. Hence, changes may occur over a long period of time and so go relatively unnoticed or be accepted as natural. The historical record is very poor in providing information on past crown and stem densities, recruitment rates, tree age and tree size. As a result there is no adequate standard against which to judge modern conditions (Walker et al. 1993). However, introduced grazers, notably sheep, rabbits and goats are capable of preventing effective recruitment amongst long-lived species by grazing seedlings very efficiently (Robertson et al. 1987). Considering the long-term effects of clearing, reduced or zero recruitment amongst canopy species and the already well established changes in the shrub and herb layers (*sensu* Adamson & Fox 1982, Hobbs 1987, and Saunders et al. 1991) it seems likely that most of the communities in the study area face a very uncertain long-term future and could be legitimately regarded as 'threatened'. Grazing affects all communities. Little recruitment was observed in the riparian (*Eucalyptus camaldulensis, E. largiflorens, Acacia pendula*), and Box communities. However, there is an urgent need for more flora and fauna population and community based research and for development of appropriate landscape management procedures.

Conservation

Acknowledging the need for more research should not be a recipe for inaction. Conservation planning is imperative if we, as a society, hope to maintain the systems and processes which support our native plants and animals, and which allow the continued functioning of our agricultural and pastoral industries.

The degree of reliance of agricultural and pastoral systems on fully functional natural ecosystems is clearly demonstrated by Davidson and Davidson (1992). The role of native predators, parasites and diseases in routinely controlling populations of agricultural pests is clearly established in this work, as is the role of native fauna, particularly invertebrate fauna, in nutrient cycling and in maintaining healthy soil environments. Davidson and Davidson argue that the continued functioning of rural systems relies ultimately on the maintenance and conservation of remnant native vegetation in the rural landscape. It is not only species and communities which are in need of conservation. It is the natural processes that sustain them.

The largest remnants are in state forests (Crown land) and the steep ranges of hills (Crown and private land) whilst smaller remnants occur on various Crown tenures

Fig. 3. The Condobolin 1:100 000 map sheet area. The native woody vegetation present in 1974 is represented by ▨ + ■. In 1989 only the ■ area remained.

Table 7. Area of each map unit shown on Forbes/Cargelligo map sheets

Map unit code	Remnant area (ha)	%of study area
R1	34 400	1.4
R2	16 400	0.7
R3	24 200	1.0
R4	1 400	0.1
R5	200	<0.1
R6	2,100	0.1
P1	15 300	0.6
P2	24 700	1.0
P3	39 200	1.7
P4	24 800	1.0
P5	4 400	0.2
P6	33 000	1.4
P7	14 800	0.6
F1	3 600	0.2
F2	21 100	0.9
F3	9 700	0.4
H1	79 400	3.3
H2	20 600	0.9
H3	600	<0.1
H4	10 700	0.5
Total	**380 600**	**16.0**

Table 8. Summary of site disturbance data

Type of disturbance	No. of sites affected	Percentage of total
Soil erosion	151	52
Logging/clearing	203	70
Feral animal damage	175	60
Grazing (exotics)	241	83

such as road reserves and travelling stock reserves. (State forests are marked on the maps and road reserve remnants can be inferred from road positions). Most land in the study area is held in freehold title and many individual remnants are on private land. The inference to be drawn from this is that private land-holders, the local community and the government all share responsibility for the future of remnant native vegetation and associated fauna in the Forbes and Cargelligo study area.

Existing State legislation provides the legal framework for biodiversity conservation either by addressing the issue directly (National Parks and Wildlife Act, 1974; Endangered Fauna [Interim Protection] Act, 1989; Environmental Planning and Assessment Act, 1979; Forestry Act, 1916), or by containing mechanisms whereby biodiversity conservation can be approached indirectly (Soil Conservation Act, 1938; Crown Lands Act, 1989; Pastures Protection Act, 1934). This subject is dealt with more fully by Farrier (1989), who discusses the scope and applications of each relevant piece of legislation. However, effective biodiverstiy conservation need not be constrained by a legislative framework.

Two complementary strands of conservation effort are applicable in this area: reservation, and off-park conservation. These are discussed separately so that the issues involved in each remain clear, but remain two aspects of a single conservation effort.

Reservation

Most remnants in the study area are small and often made up of narrow corridors. The majority of remnants are not suited to reservation although a number of the larger ones may be. The largest remnants on the plains are state forests, some of which are undergoing assessment for their economic viability. Should any state forest be identified for disposal, there would be a strong case for it to be considered for inclusion in the National Parks and Wildlife Service reserve system. These areas already form important core areas for broader, human community-based conservation initiatives. They are important refugia in their own right. They can provide seed for local tree plantings. They are important sources for recolonisation by beneficial native fauna and are repositories of genetic diversity. The long-term survival of these areas, and their regeneration to something approaching their original and more biological diverse state, is most assured under the statutory protection such as that offered by the National Parks and Wildlife Act, 1979.

Some existing nature reserves in the study area, for example, Gubatta (162 ha); Loughlan (385 ha); and Pulletop (145 ha), may be too small for the long-term survival of many of the species they contain. Any opportunity to expand these reserves would be of considerable long-term ecological advantage.

Given the cost of land acquisition and management, decisions relating to the choice of areas for expansion of the reserve network must be taken carefully. The map and information bases produced by this study will make it possible to apply systematic reserve selection techniques (*sensu* Pressey & Nicholls 1989; Bedward et al. 1992) to aid in the decision-making process. These techniques are equally applicable to off-park biodiversity conservation planning. Analysis of this type is yet to be undertaken for the study area and will be the subject of future papers.

Off-park conservation

Most additional conservation efforts in the New South Wales wheat-belt are likely to be undertaken outside the formal reserve network primarily due to the cost and lack of suitable land for reservation. Local resistance to formal reserves is often very strong and is also a reason for trying a less formal approach. Off-park conservation can be of two main types:

- that initiated by Local or State government authorities (Protected Lands Mapping under the Soil Conservation Act; State Environmental Planning Policies under the Environmental Planning and Assessment Act; and Local Environmental Plans)
- community-based consultation (Landcare, Greening Australia, Australian Association of Bush Regenerators and Trees on Farms) through mechanisms such

as Conservation Agreements (National Parks and Wildlife Act), covenants on title (Conveyancing Act, 1919) and Farm Plans. These are important aspects of off-park conservation which can be explored on a case-by-case basis.

In off-park conservation, the unit of action is likely to be an individual paddock or farm, the scale at which most people operate. However, it is increasingly evident that the processes which determine the long-term viability of our conservation efforts operate at landscape or regional levels (Friedel & James in prep.; Noss 1990). These processes, such as movement of nutrients and pollutants, runoff, groundwater movement and nutrient cycling are usually only partly within a single landholder's sphere of influence. In order to be successful in the long term it is essential for off-park conservation to be planned at the regional level and implemented locally. For example, no amount of farm planning will solve a salinity problem if the source of that salinity is not addressed. Similarly, on-farm conservation may not save individual species if primary habitat sources are destroyed elsewhere in the landscape.

Effective Landcare and Total Catchment Management groups are already functioning in the area and issues such as water quality, soil conservation, private forestry and drought relief lands are already on their agendas. These very important agenda items dovetail neatly with nature conservation and can complement more formal conservation practices.

Although degraded, the ecological infrastructure exists for effective bush regeneration. This affords the opportunity to re-establish riparian and dryland corridors and other important repositories of native biodiversity using material of local provenance.

A large number of animal species are already extinct in this part of New South Wales and there is a trend towards substantial additional extinctions in the near future (Goldney & Bowie 1986; Dickman 1994). This trend, observable in the New South Wales wheat-belt, is a common trend throughout the world. As early as 1948 Fairfield Osborn maintained that: 'The tide of Earth's population is rising, the reservoir of Earth's living resources is falling...' (Osborn 1948). Expansion of the human population and sphere of influence and the attendant loss of habitat has grave implications for species extinctions. Modern extinction rates, calculated on a per species basis, may be as high as those which existed in the 'great extinction events' of the Paleozoic and Mesozoic (Wilson 1989). This means a rate of extinction not seen on Earth for 65 million years, and all due to the activities of one species — *Homo sapiens*. Wilson (1989) also points out one very important difference between the ancient and modern extinction events. In the past these events have tended to affect mainly faunal species, and usually particular taxonomic groups (echinoderms, cephalopods and reptiles), whilst the modern event is universal in its application. Plants, invertebrates and vertebrates are all affected. 'The ultimate result of this is impossible to predict, but it is not something, I think, with which humanity will want to gamble' (Wilson 1989). If May (in press) is correct and 'something like half of all terrestrial species are likely to become extinct over the next 50 years' then we have precious little time to reverse some frightening trends in our agricultural heartlands.

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Bryophytes in the vicinity of Wombeyan Caves, New South Wales

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Downing, A.J., Oldfield, R.J. and Selkirk, P.M., (Macquarie University, NSW, 2109) 1995. Bryophytes in the vicinity of Wombeyan Caves, New South Wales. Cunninghamia *4(1):129–141.* Collections of bryophytes in the vicinity of Wombeyan Caves, 34°19'S, 149°58'E, indicate that the bryophyte assemblages on marble and associated calcareous soils are similar to those which occur on limestone and associated soils at sites previously investigated in south-eastern Australia. Species that grow in abundance on calcareous substrates at Wombeyan are either not common or not present on the granites and sandstones in the vicinity of Wombeyan Caves. The bryoflora is dominated by acrocarpous mosses and thallose liverworts. Many of the species growing on calcareous substrates at Wombeyan are more usually associated with calcareous soils of arid and semi-arid areas of Australia. Consistent with findings at other calcareous sites, a number of introduced and cosmopolitan species occur on marble-derived soils in heavily grazed, open grassy areas.

Introduction

Although the distribution of bryophytes on limestones in south-eastern Australia has been well documented (Brotherus & Watts 1912, Downing 1992, Downing et al. 1991, Downing & Selkirk 1993), there are no published records of bryophyte distribution on marble or soils derived from marble.

The Wombeyan Caves (34°19'S, 149°58'E, 600–650 metres above sea level) are located 125 km south-west of Sydney at the boundary between the Central Tablelands and the Central Coast botanical divisions of New South Wales on the eastern side of the Great Dividing Range. The caves occur in rounded hills in the valleys of Wombeyan and Mares Forest Creeks, tributaries of the Wollondilly River. The karst landscape at Wombeyan forms low hills and knolls in places incised by steeply-sided gorges. Unlike most of the popular tourist cave systems in south-eastern Australia, which are formed from limestone, the caves at Wombeyan are formed from marble. Wombeyan also differs from other eastern Australian limestone cave systems in having an underlying basement of impervious rock (Jennings et al. 1982).

The grey/white marble at Wombeyan is considered to be Late Silurian limestone that has been almost completely marmorised by surrounding Middle Devonian intrusive rocks such as granite, quartz porphyry, dacite tuff, hypersthene porphyry and a small outcrop of gabbro, which form the adjoining higher and steeper ridges and V-shaped valleys (Lishmund et al. 1986). With the exception of gabbro, all are igneous rocks that contain much quartz (Jennings et al. 1982). Carne & Jones (1919) analysed samples of marble from Wombeyan as being between 91.82% and 98.62% calcium carbonate.

At Wombeyan, the soil that occurs in the marble outcrops is unusual, consisting of grains of very coarse calcite sand and fine calcite gravel, together with dark-brown humus. In other, less rocky areas, marble weathers to produce red, calcareous, silty clay soils (Jennings et al. 1982). In contrast, igneous rocks in the vicinity of the caves weather to produce acidic, nutrient-deficient sandy soils (Clements 1982).

An early visitor to Wombeyan, Dr James Cox (1862) observed a sharp line of demarcation between the granite and marble country and the sudden change occurring in both vegetation and topography. From the top of the marble cliffs he considered it easy to map with accuracy the extent of the 'limestone' by the differing forms of vegetation. Cambage (1906) noted the sparse flora on the 'limestone' in the vicinity of the Caves compared with that on the granite and quartz porphyry nearby and commented on the similarity between the vegetation on the decomposed granite sands to the west of Wombeyan and the sandstone formations of the Blue Mountains. Similarly, Phipps (1950), in his survey of the geology of the Taralga–Wombeyan Caves district, commented that, despite their low-nutrient status, soils derived from granite, sandstone, conglomerate and shale in the vicinity of the Caves gave rise to heavier vegetation than did the 'limestone'.

More recently, Clements (1982) carried out a detailed study of the vegetation in the vicinity of the caves. On soils derived from igneous rocks, *Eucalyptus globoidea* and *Eucalyptus sieberi* dominate a forest community which has an understorey of shrubby vegetation that includes numerous species of Epacridaceae. In contrast, grassland is a significant feature of calcareous soils and is common on exposed, north-facing slopes. Woodland communities occur on sheltered, south-facing slopes and valleys (Clements 1982). *Brachychiton populneus* and *Ficus rubiginosa* both grow on marble outcrops. *Acacia chalkeri* grows in grassland on exposed marble ridges and occurs only at Wombeyan Caves (Harden 1991). Numerous exotic tree and shrub species have been planted in the valley of Wombeyan Creek and weeds such as *Conium maculatum*, *Cotoneaster glaucophylla*, *Pinus radiata*, *Prunus persica*, *Pyracantha rogersiana*, *Rosa rubiginosa* and *Verbascum thapsus* thrive on the calcareous soils.

Wombeyan has warm to hot summers and cool to cold winters with severe frosts and occasional light snowfalls. Rainfall figures for three surrounding weather stations, Moss Vale (672 m a.s.l., 990 mm per annum), Taralga (882 m a.s.l., 808 mm per annum) and Goulburn (702 m a.s.l., 679 mm per annum) (Bureau of Meteorology 1985) indicate that rainfall is relatively evenly distributed throughout the year. Wombeyan lies in the rainshadow of both the high plateau to the east and the ranges to the west, so its mean annual rainfall is likely to be less than the 808 mm recorded for Taralga (17km south-west) (Halbert & Michie 1982).

Methods

During four visits to Wombeyan Caves in 1992 and 1993, bryophytes were collected from marble, granite and sandstone and their associated soils. Epiphytic bryophytes were also collected at each site. Reference was made to collections of S. Claxton. Voucher specimens of all species collected will be deposited at the National

Herbarium of New South Wales. All collections were returned to the laboratory for identification. Nomenclature and authorities follow Streimann and Curnow (1989) for mosses; Scott and Bradshaw (1986) for liverworts and hornworts, and Harden (1990, 1991, 1992) for vascular plants (see Appendix 1). As a result of severe drought throughout 1992 and 1993, some annual and/or ephemeral species of bryophytes may not have been present when collections were made.

Results and discussion

Many more species of mosses and liverworts were collected from marble substrates than were collected from granite and/or sandstone (Table 1). Fifty-eight species of bryophytes, including 48 moss species and 9 liverwort species, were collected in the vicinity of the Caves. Of these, 39 moss and 8 liverwort species (81% of species present) were collected from marble; and 11 moss species (20%) (no liverworts) were collected from granite and sandstone.

Mosses were abundant on calcareous soils, not only on moist soil and rocks in shaded, sheltered areas, but also on hot, dry, exposed, sparse open grassland on the top of rounded knolls. The moss flora on marble and its derived soils was dominated by acrocarpous ('upright') mosses from two families: Pottiaceae with 18 species and Bryaceae with 8 species. Few pleurocarpous ('creeping') mosses (6 species) were collected from marble.

The moss flora on both granite and sandstone substrates was also dominated by acrocarpous mosses. The majority were from the Bartramiaceae, Dicranaceae, Ditrichaceae and Polytrichaceae families and were found exclusively on siliceous substrates.

Liverworts were collected from moist soil in sheltered and shaded habitats in soil-filled rock crevices, seepage areas and damp creek banks in gorges. One species, *Riccia limbata*, was collected from dry soil on an exposed marble knoll. The liverwort flora on marble was dominated by thallose liverworts from the Marchantiales, *Reboulia hemisphaerica, Targionia lorbeeriana, Lunularia cruciata* and *R. limbata.* Three leafy liverworts, *Frullania squarrosula, Lophocolea bidentata* and *Porella crawfordii*, were collected from marble. Eight moss and two liverwort species were collected from the bark of shrubs or trees.

A number of cosmopolitan (*Bryum argenteum*) and introduced species (*Aloina aloides* var. *ambigua* and *Trichostomum brachydontium*) were conspicuous components of the microbiotic crust at Wombeyan and were probably introduced through the practice of allowing sheep to graze on the marble outcrops (Cambage 1906, Clements 1982). The presence of introduced and cosmopolitan species has been observed elsewhere on limestones, where damage to soil and pastures by grazing animals appears to be reflected in the bryoflora in much the same way that introduced weeds (vascular plants) invade disturbed urban bushland (Downing 1992, 1993; Downing & Selkirk 1993).

The development of karst appears to play a significant part in the presence of so many arid zone bryophytes on marble at Wombeyan and on eastern Australian

Table 1. Bryophytes collected from calcareous and non-calcareous sites at Wombeyan (marble, non-marble), Jenolan (limestone, non-limestone), Googong (limestone, non-limestone), Tamworth (limestone, non-limestone), Wee Jasper (limestone), Mungo National Park (calcareous earth) and Nullarbor Plain (calcareous soils)

Key ᶜ=exclusive calciphile, #=exclusive calcifuge, *=calcareous substrate, M=marble, G=granite, S=sandstone, E=epiphyte, Sh=shale, Si=siltstone. a=this study, b=Downing 1992, d=Downing 1993, e=Downing et al. 1991, f=Downing & Selkirk 1993, g=Stoneburner et al. 1993.

MOSSES	Wombeyan Marble	Wombeyan Non Marble	Jenolan	Googong	Tamworth & Attunga	Wee Jasper	Mungo	Nullarbor Plain
	a	a	b d e	b d	b d	d	f	g
Pottiaceae								
ᶜ*Aloina aloides* var. *ambigua*	M			*	*	*	*	
Barbula calycina	M		*	*	*	*		
Barbula crinita	M	E	*	* S	* Si	*	*	*
ᶜ*Barbula hornschuchiana*	M			*	*	*	*	*
Barbula unguiculata	M		*		*			
Desmatodon convolutus	M		*		* Si	*	*	*
Didymodon torquatus	M		*	*	* Si	*	*	*
ᶜ*Gymnostomum aeruginosum*	M		*	*	*	*		*
Tortella cirrhata	M		*					*
Tortula antarctica	M		* Sh	* S	*	*	*	*
Tortula muralis	M		*					
Tortula pagorum		E	*	* S	*	*	*	*
Tortula papillosa	M	E	*			*	*	
Tortula ruralis	M				*			
Trichostomum brachydontium	M	G E	*	* S	* Si	*		
Triquetrella papillata	M		*	* S	* Si	*		*
Weissia controversa	M	G	*	*	*	*		
Weissia controversa var. *gymnostoma*	M		*					

Bryaceae								
Bryum argenteum	M		* Sh	* S	* Si	*	*	
Bryum billarderi	M	G E	* Sh	* S	* Si	*		
Bryum campylothecium	M		* Sh	* S	* Si	*	*	
Bryum dichotomum	M	G	* Sh	* S	* Si	*	*	
Bryum pachytheca	M		*	*	* Si	*	*	
[c]*Bryum radiculosum*	M		*					
[c]*Bryum torquescens*	M			*	*	*		
Leptobryum pyriforme	M							
Fissidentaceae								
[c]*Fissidens leptocladus*	M		*			*		
Fissidens taylorii	M	G	*		* Si			
Fissidens vittatus	M		*	*	*	*	*	*
Brachytheciaceae								
Chamberlainia salebrosa	M		*					
Encalyptaceae								
[c]*Encalypta vulgaris*	M		*	*		*		
Gigaspermaceae								
Gigaspermum repens	M		*	*	* Si	*	*	*
Grimmiaceae								
Grimmia laevigata		S	*	S		*		
Grimmia pulvinata	M		* Sh	* S		*		*
Hypopterygiaceae								
Hypopterygium rotulatum	M		*			*		
Lembophyllaceae								
Camptochaete arbuscula	M							

Table 1. continued.

	Wombeyan Marble	Wombeyan Non Marble	Jenolan	Googong	Tamworth & Attunga	Wee Jasper	Mungo	Nullarbor Plain
	a	a	b d e	b d	b d	d	f	g
Leskeaceae								
[c]*Pseudoleskeopsis imbricata*	M	E	*	*		*		
Orthotrichaceae								
Orthotrichum assimile		E						
[c]*Orthotrichum cupulatum* var. *cupulatum*	M		*	*		*		
Racopilaceae								
Racopilum cuspidigerum var. *cuspidigerum*	M		*			*		
Thuidiaceae								
Thuidium sparsum	M		* Sh					
Bartramiaceae								
#*Breutelia affinis*		G						
Dicranaceae								
#*Campylopus introflexus*		G S	Sh	S				
#*Dicnemoloma pallidum*		G S	Sh					
#*Dicranoloma billarderii*		G						
Ditrichaceae								
#*Ditrichum difficile*		G	Sh	S				

Fabroniaceae							
Fabronia australis		E	*	*			
Polytrichaceae							
#Polytrichum juniperinum		G					
LIVERWORTS							
Aytoniaceae							
[c]*Reboulia hemisphaerica*	M		*			*	
Codoniaceae							
Fossombronia sp.	M		*		*	*	
Frullaniaceae							
Frullania probosciphora		E	*				
Frullania squarrosula	M	E	Sh	S			
Geocalycaceae							
Lophocolea bidentata	M		*				
Marchantiaceae							
Lunularia cruciata	M			*	*		
Porellaceae							
Porella crawfordii	M		*				
Ricciaceae							
Riccia limbata	M			*	*	*	*
Targioniaceae							
[c]*Targionia lorbeeriana*	M		*			*	

limestones. The lack of surface water in karst landscapes can be extreme, even when annual rainfall exceeds 2000 mm and thus biological productivity is usually much lower on calcareous than non-calcareous rocks (Jennings 1985). Arid zone mosses and liverworts are able to survive in this extremely dry microenvironment and to cope with high light levels and extremely high soil surface temperatures (Amman 1928).

Our observations on the bryophyte flora on Wombeyan marble are consistent with findings from other limestone sites in Australia where we have found that bryophytes are more abundant, both in percent groundcover and in species number on calcareous substrates, than they are on non-calcareous substrates, such as sandstones, shales and siltstones (Downing 1992, Downing 1993, Downing & Selkirk 1993). Acrocarpous mosses dominate the limestone moss flora, with two families, Pottiaceae and Bryaceae, being most abundant in terms of number of species. Several species are considered to be indicator species, *Gigaspermum repens, Fissidens vittatus* and either *Bryum pachytheca* on drier soils or *Bryum dichotomum* in wetter situations (Downing 1993). All four species occur at Wombeyan.

The presence of open grasslands on exposed ridge tops and slopes with northerly aspects rather than *Eucalyptus* woodlands and forests that occur on nearby non-calcareous substrates may be an indication of the aridity of the karst geomorphology. Botanists and geologists have commented on the sparse vegetation on marble compared with that on other rock substrates at Wombeyan (Cambage 1906, Clements 1982, Cox 1862, Phipps 1950). The absence of eucalypts from the marble may benefit arid zone bryophyte species, by reducing the amount of smothering leaf litter, reducing bushfire hazards and by ensuring high light levels necessary to compensate for specialised morphology which protects photosynthetic structures.

In previous studies, the ratio of acrocarpous to pleurocarpous moss species on limestones and calcareous soils has been found to increase with decreased rainfall (Downing 1993). At Wombeyan, the ratio on marble substrates is 33:6, consistent with the trend established at other sites in New South Wales (Table 2).

Thallose liverworts from the Marchantiales, in particular from the Aytoniaceae, Marchantiaceae, Ricciaceae and Targioniaceae, and from the family Codoniaceae (Metzgeriales), dominate the marble liverwort flora at Wombeyan. Again, this is consistent with results from limestone sites in south-eastern Australia (Table 1).

In Australia there are very few bryophytes that are exclusively calciphiles or exclusively calcifuges. Some species such as *Aloina aloides* var. *ambigua, Encalypta vulgaris, Gymnostomum aeruginosum, Pseudoleskeopsis imbricata* and *Targionia lorbeeriana* are commonly accepted as calciphiles. Most species that do occur on calcareous substrates can be regarded as opportunists and grow on both calcareous and non-calcareous substrates (Downing 1993), although many appear to favour substrates with a greater percentage of calcium carbonate than others. Only 9 moss and 2 liverwort species collected from marble substrates at Wombeyan are considered to be exclusive calciphiles (Downing 1993) (Table 1).

Table 2. Mean annual rainfall and number of acrocarpous and pleurocarpous moss species that occur on marble at Wombeyan Caves, on limestone at Jenolan, Wee Jasper, Googong and Attunga, and on the calcareous soils of Mungo National Park

	Jenolan **33°47'S** **150°05'E**	**Wee Jasper** **35°07'S** **148°40'E**	**Wombeyan** **34°19'S** **149°58'E**	**Googong** **35°31'S** **149°16'E**	**Attunga** **30°56'S** **150°50'E**	**Mungo** **33°45'S** **142°59'E**
Mean annual rainfall (mm)	968	916	650–800	633	595	246
Acrocarpous species	37	35	33	24	19	22
Pleurocarpous species	10	7	6	1	1	0

At Wombeyan, six species from the four families Bartramiaceae, Dicranaceae, Ditrichaceae and Polytrichaceae appear to be exclusive calcifuges and were only collected from granite and/or sandstone. The calcifuge species collected at Wombeyan, *Breutelia affinis, Campylopus introflexus, Dicnemoloma pallidum, Dicranoloma billarderii, Ditrichum difficile* and *Polytrichum juniperinum*, all commonly occur on the sandstones and shales of the nearby Blue Mountains plateau. In contrast, the majority of species that grow on marble substrates at Wombeyan and on other eastern Australian limestone sites are not present or not common on shales and sandstones. These species have more in common with bryophyte assemblages that can be found on calcareous soils, which are extensive throughout semi-arid and arid areas of southern Australia. Many species collected at Wombeyan are present on calcareous earths and clays of Mungo National Park (33°45'S, 142°59'E, 91 m a.s.l) in far south-western New South Wales (Downing & Selkirk 1993) and on the calcareous soils of the Nullarbor Plains (Stoneburner et al. 1993) (Table 1).

In semi-arid and arid areas mosses and liverworts can be important as components of microbiotic soil crusts that may also include lichens, fungi, algae and cyanobacteria. At Wombeyan, microbiotic soil crusts can be found in the open grassland that occurs over the Victoria Arch and on the top of the rounded hillslopes adjacent to the Arch. The crusts are similar to those crusts at Mungo, both in appearance and in the bryophyte species present. Species abundant in, and common to, both locations include *Bryum argenteum, Bryum pachytheca, Didymodon torquatus, Gigaspermum repens* and *Riccia limbata*. Cyanobacteria and lichens are also abundant as components of the crusts at Wombeyan. In dry conditions, the crusts form low, rough, dark (reddish brown/brown/black) turfs 1–3 mm high. However, light rain or mist is sufficient to change the appearance to green as leaves and thalli unroll exposing photosynthetic tissue.

Mosses and liverworts that occur in arid and semi-arid areas of Australia and on calcareous soils and rocks, such as the Wombeyan Caves marble, in relatively high rainfall areas of eastern Australia, have many characteristics which enhance survival in an exposed, dry environment. In most cases, these characteristics serve to enhance moisture retention, reduce water loss or protect photosynthetic tissue from high light levels. Possibly their greatest survival characteristic is the ability to reproduce from a few cells. Thus, mere stem or leaf fragments can grow rapidly after a rainfall event.

Some characteristics of species of Pottiaceae (the dominant moss family on marble at Wombeyan [18 species] and at Mungo National Park) that enhance survival include: dark pigmentation of leaves and stems; leaves twisted around the stem when dry; costa ('nerve'), thickened and glossy on abaxial surface of the leaf; costa exposed (and reflecting light) when the leaf is twisted around the stem; simple or complex papillae on leaf cells, leaf margins incurved or recurved and leaves with long hair points that enhance the uptake of moisture; leaves with photosynthetic papillae or lamellae on adaxial surfaces protected by overlapping hyaline tissue or by incurved leaf margins.

Species of Bryaceae possess some of these same characteristics, such as incurved or recurved leaf margins and long hair points. However, many species (*Bryum pachytheca, Bryum dichotomum*) produce gemmae (vegetative reproductive structures) in terminal or axillary clusters and/or rhizoidal gemmae ('tubers') on underground stems (*Bryum torquescens, Bryum radiculosum*). Gemmae appear to play a significant role in survival of these species in dry environments and are not unique to this family. *Tortula pagorum* (Pottiaceae) produces gemmae in the stem apex and *Tortula papillosa* (Pottiaceae) produces gemmae on the adaxial surface of its upper leaves. Both commonly grow on calcareous rocks and as epiphytes in limestone areas. At Wombeyan, *T. papillosa* was recorded both on marble and as an epiphyte.

The upper leaves of both *Bryum argenteum* and *Gigaspermum repens* are hyaline and provide a protective layer for green, photosynthetic lower leaves. *Gigaspermum repens* also has well developed underground stems that appear to play an important role in surviving both extreme drought and fire (Downing 1993).

Thallose liverworts, such as *Riccia limbata, Targionia lorbeeriana* and *Reboulia hemisphaerica*, have dark, glossy scales on the lower surface of the thallus. As conditions become increasingly dry, the edges of the thallus roll inwards, thus the glossy scales form an effective barrier that reduces evaporation of moisture and protects photosynthetic tissue on the upper surface of the thallus. *Riccia limbata* is an extremely common liverwort throughout Australia's arid areas and, although not confined to calcareous substrates, appears to thrive on them.

Many annual or ephemeral bryophytes avoid arid environments and grow only after rainfall events. Species such as the mosses *Entosthodon muehlenbergii* (*Funaria glabra*), *Funaria hygrometrica*, and the liverworts *Riccia crystallina* and *Riccia cavernosa*, have been recorded from eastern Australian limestone sites and commonly occur at Mungo National Park. They were not found at Wombeyan during this study, but may well occur there in other than the drought conditions experienced during the period in which collections were made.

Conclusion

Bryophyte assemblages on marble substrates at Wombeyan are similar to those found on limestone substrates in south-eastern Australia. Acrocarpous mosses, in particular Pottiaceae and Bryaceae, dominate the moss flora and thallose liverworts (Marchantiales) dominate the liverwort flora. Certain species, considered to be key elements of limestone bryoflora, *Didymodon torquatus, Gigaspermum repens, Bryum pachytheca, B. dichotomum* and *Fissidens vittatus*, were present on marble at Wombeyan.

Many of the species that occurred on marble at Wombeyan are species often associated with arid and semi-arid areas of Australia and have morphological characteristics that enhance their survival in dry environments. The development of karst landscapes is considered to be an important element in creating an arid microclimate on both limestone and marble in south-eastern Australia.

Certain introduced and cosmopolitan bryophyte species appear to be common in areas of grassland on marble at Wombeyan that are frequently grazed by sheep.

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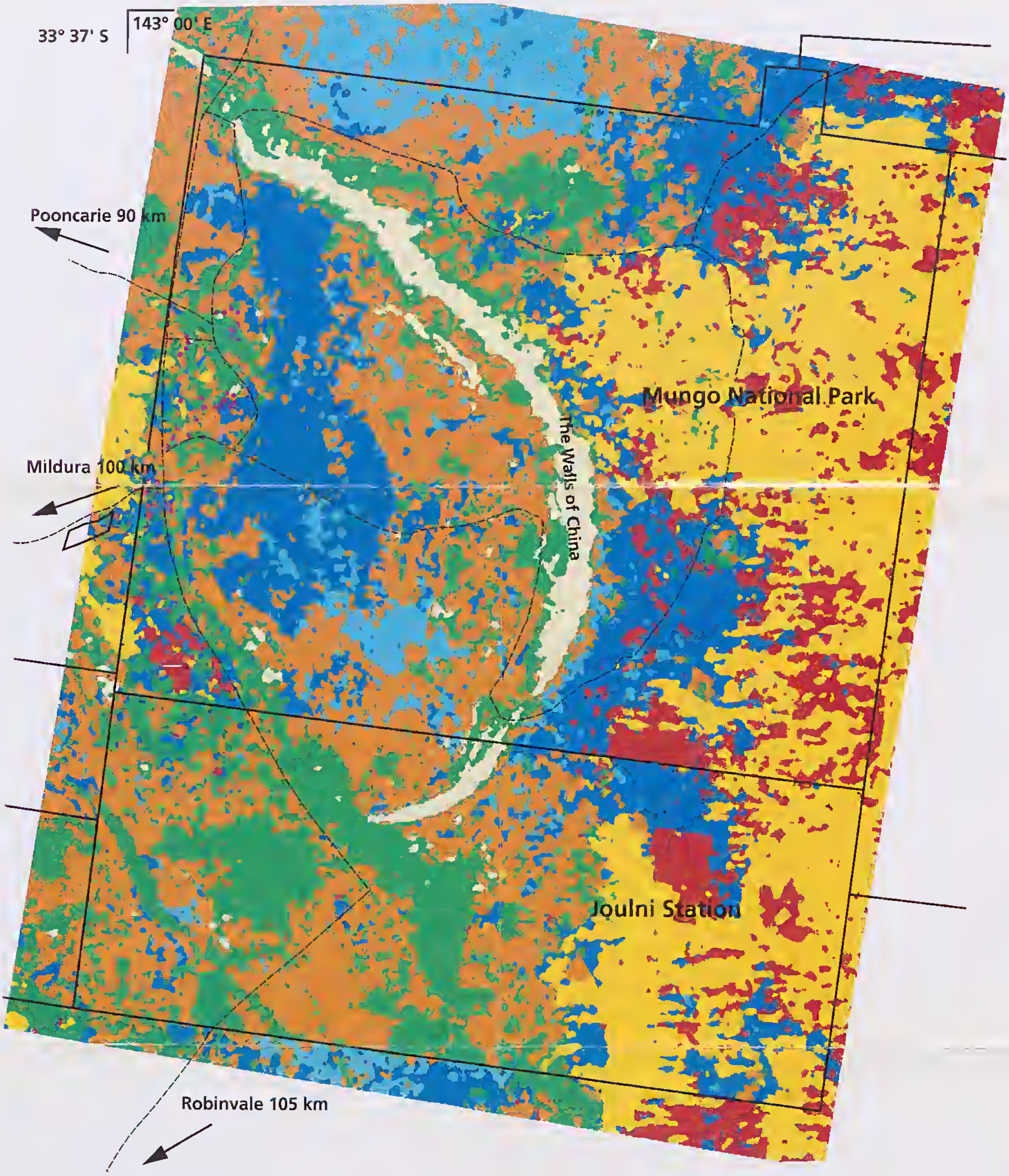
Appendix 1. Authorities for bryophytes and vascular plants

Bryophytes

Aloina aloides (Schultz) Kindb.
var. *ambigua* (B.S.G.) Craig
Barbula calycina Schwaegr.
Barbula crinita Schultz
Barbula hornschuchiana Schultz
Barbula unguiculata Hedw.
Breutelia affinis (Hook.) Mitt.
Bryum argenteum Hedw.
Bryum billarderi Schwaegr.
var. *billarderi*
Bryum campylothecium Tayl.
Bryum dichotomum Hedw.
Bryum pachytheca C. Muell.
Bryum radiculosum Brid.
Bryum torquescens Bruch ex De Not.
Camptochaete arbuscula (Sm.) Rchdt.
Campylopus introflexus (Hedw.) Brid.
Chamberlainia salebrosa (Web. & Mohr) H. Rob.
Desmatodon convolutus (Brid.) Grout
Dicnemoloma pallidum (Hook.) Wijk & Marg.
Dicranoloma billarderii (Brid. ex anon.) Par.
Didymodon torquatus (Tayl.) Catches.
Ditrichum difficile (Dub.) Fleisch.
Encalypta vulgaris Hedw.
Entosthodon muehlenbergii (Turn.) Fife
(*Funaria glabra*)
Fabronia australis Hook.
Fissidens leptocladus C. Muell. ex Rodw.
Fissidens taylorii C. Muell.
Fissidens vittatus Hook. f. & Wils.
Fossombronia Raddi sp.
Frullania probosciphora Tayl.
Frullania squarrosula (Hook. f. & Tayl.) Tayl.
ex Gottsche et al.
Funaria hygrometrica Hedw.
Gigaspermum repens (Hook.) Lindb.
Grimmia laevigata (Brid.) Brid.
Grimmia pulvinata (Hedw.) Sm.
Gymnostomum aeruginosum Sm.
Hypopterygium rotulatum (Hedw.) Brid.
Leptobryum pyriforme (Hedw.) Wils.
Lophocolea bidentata (L.) Dumort.
Lunularia cruciata (L.) Dumort.
Orthotrichum assimile C. Muell.
Orthotrichum cupulatum Hoffm. ex Brid. var.
cupulatum
Polytrichum juniperinum Hedw.
Porella crawfordii Stephani
Pseudoleskeopsis imbricata (Hook. f. & Wils.) Ther.
Racopilum cuspidigerum (Schwaegr.) Aongstr. var.
cuspidigerum
Reboulia hemisphaerica (L.) Raddi
Riccia crystallina L.
Riccia cavernosa Hoffm.
Riccia limbata Bischoff in Gottsche, Lindb. & Nees
Targionia lorbeeriana K. Muell.
Thuidium sparsum (Hook. f. & Wils.) Reichdt.
Tortella cirrhata Broth.
Tortula antarctica (Hpe.) Wils.
Tortula muralis Hedw.
Tortula pagorum (Milde) De Not.
Tortula papillosa Wils.
Tortula ruralis (Hedw.) G.M.S.
Trichostomum brachydontium Bruch.
Triquetrella papillata (Hook. f. & Wils.) Broth.
Weissia controversa Hedw.
Weissia controversa Hedw. var. *gymnostoma* (Dix.)
Sainsb.

Vascular plants

Acacia chalkeri Maiden
Brachychiton populneus (Schott & Endl.) R. Br.
Conium maculatum L.
Cotoneaster glaucophylla Franchet
Eucalyptus globoidea Blakely
Eucalyptus sieberi L.A.S. Johnson
Ficus rubiginosa Desf. ex Vent.
Pinus radiata D. Don
Prunus persica (L.) Batsch
Pyracantha rogersiana Bean
Rosa rubiginosa L.
Verbascum thapsus L.



Vegetation of Mungo National Park and Joulni Station

Detailed descriptions of plant communities are given in *Cunninghamia* 4(1) 1995 published by the Royal Botanic Gardens, Sydney.

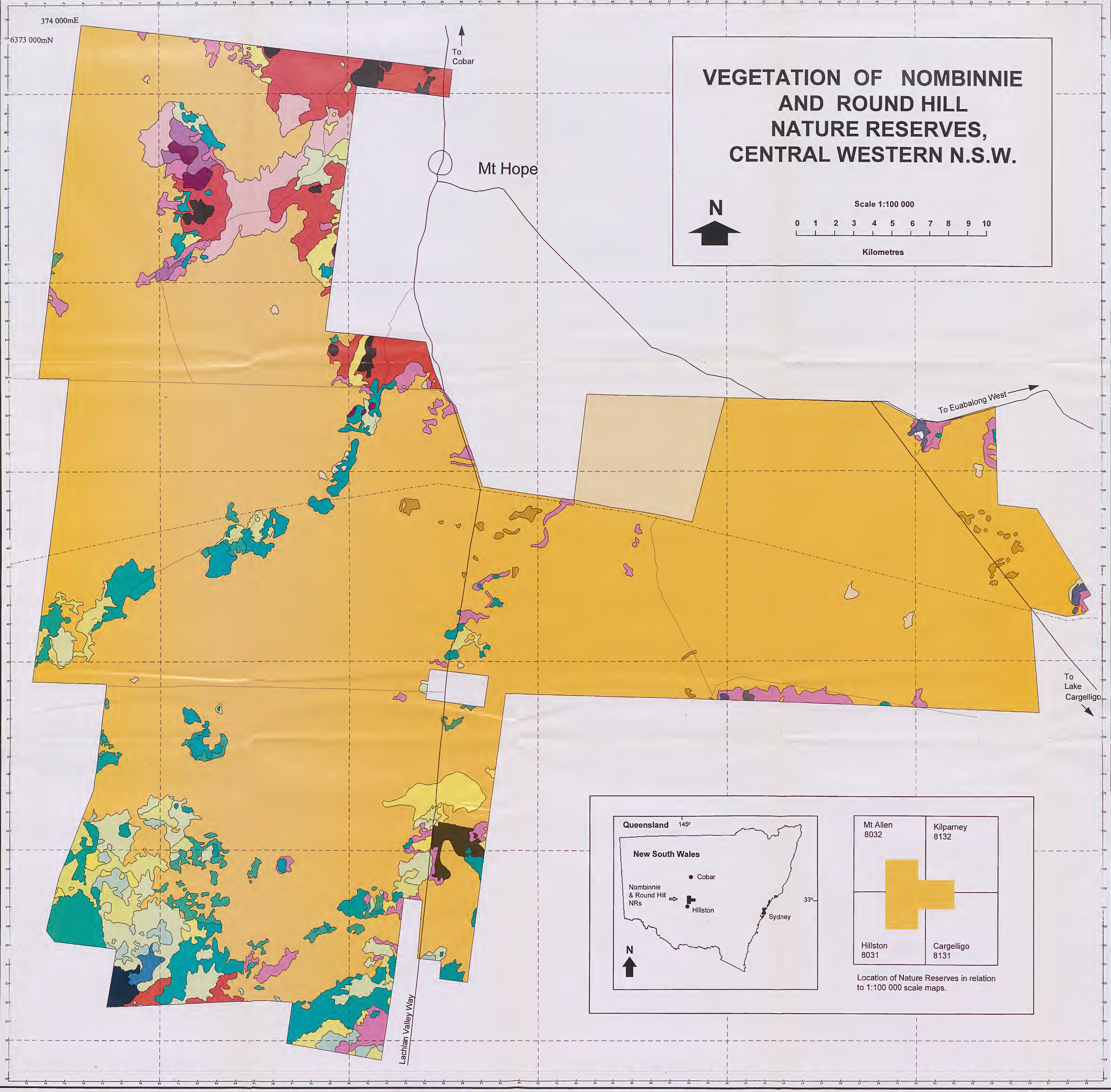
- 🟥 1b: *Casuarina pauper* Woodland/Open-woodland
- ⁘ 1c: *Callitris glaucophylla* Open-woodland
- 🟨 2a: *Eucalyptus* spp. 2b: Open-shrubland
- 🟧 4b: *Maireana pyramidata/M. sedifolia* Low open-shrubland
- 🟦 4c: *Atriplex vesicaria* Low open-shrubland
- ▤ 4e: *Nitraria billardieri* Low open-shrubland
- 🟩 5b: *Bromus rubens/Hordeum murinum* Herbland
- ⬜ Dunes and bare areas
- \- - - Roads
- —— Property boundaries

Scale 1:100 000

0 1 2 3 4 5

Kilometres

M.E. Westbrooke and J.D. Miller, University of Ballarat, Australia 1995.



VEGETATION OF NOMBINNIE AND ROUND HILL NATURE RESERVES, CENTRAL WESTERN N.S.W.

Location of Nature Reserves in relation to 1:100 000 scale maps.

	Community	Dominant species	Structure	Habitat
■	**Black Rolypoly Shrubland (F1)**	*Sclerolaena muricata*	Low open shubland	Small area on floodplain of the Lachlan River on heavy clay.
■	**Black Box Woodland (F2)**	*Eucalyptus largiflorens*	Low open woodland	Small area on claypans (adjacent to above) on heavy clay.
■	**Shrub Mallee (P1)**	*Eucalyptus socialis* *Eucalyptus dumosa*	Very open shrub mallee	Flat to gently undulating plains on medium textured soils where mallee has been cleared or there have been fires in quick succession or on sandy soil on the western footslopes of ranges.
■	**Shrub Mallee with Spinfex (P2)**	*Eucalyptus socialis* *Eucalyptus dumosa* *Triodia irritans*	Very open to open shrub mallee	Flat to gently undulating plains of red and brown clayey sand loam and lateritic soils.
■	**Shrub Mallee with Mallee Pine (P3)**	*Eucalyptus socialis* *Eucalyptus dumosa* *Callitris preissii* subsp. *verrucosa*	Very open shrub mallee	In small pockets of above habitat where fire has been excluded for some time.
■	**Tree Mallee (P4)**	*Eucalyptus socialis* *Eucalyptus dumosa*	Very open tree mallee	Over larger areas of above mallee habitat.
■	**Belah and Wilga Woodland (P5)**	*Casuarina cristata* *Geijera parviflora* *Apophyllum anomalum* *Alectryron oleifolius* subsp. *canescens*	Open woodland	On claypans or flat to gently undulating plains on medium to heavier textured soils.
■	**Gum Coolibah Woodland (P6)**	*Eucalyptus intertexta* *Dodonaea viscosa* subsp. *cuneata* *Eremophila desertorum* *Eremophila sturtii*	Open woodland	Flat to gently undulating plains, adjacent to plains mallee on medium to heavier textured soils.
■	**Bimble Box Woodland (P7)**	*Eucalyptus populnea* subsp. *bimbil* *Eremophila sturtii* *Digitaria* spp., *Stipa* spp.	Open woodland	Run-on areas on flat to gently undulating plains on the heavier textured soils
■	**Pine Woodland (P8)**	*Callitris glaucophylla* *Abutilon otocarpum* *Cheilanthes sieberi*	Woodland to open woodland	Flat to gently undulating plains on a variety of soil textures.
■	**Grassland (P9)**	*Aristida* spp.	Grassland	
■	**Pine and Bimble Box Woodland (D1)**	*Callitris glaucophylla* *Eucalyptus populnea* *Senna artemisioides* *Chenopodium desertorum* subsp. *microphyllum* *Sclerolaena diacantha*	Open woodland	Plains and rolling downs/ lowlands on a variety of soil types and textures.
■	**Bimble Box Woodland (D1a)**	*Eucalyptus populnea* subsp. *bimbil* *Eremophila sturtii* *Chenopodium desertorum* subsp. *microphyllum* *Sclerolaena diacantha*	Open woodland	Run-on areas of rolling downs and lowlands on medium to heavier textured soils.
■	**Gum Coolibah & Pine Woodland (D2)**	*Callitris glaucophylla* *Eremophila mitchellii* *Eremophila glabra* *Sclerolaena diacantha*	Open woodland	On a range of soils and habitats, often adjacent to plains mallee.
■	**Emubush Shrubland (D3)**	*Eremophila longifolia*	Tall open shrubland	Few areas around Mount Nombinnie on sandy clay, possibly resulting from a fire in 1985.
■	**Green Mallee Shrubland (D4)**	*Eucalyptus viridis* *Dodonaea lobulata*	Open to low open woodland	Rocky knolls within rolling downs and lowlands.
■	**Dwyer's Mallee Shrubland (H1)**	*Eucalyptus dwyeri* *Acacia doratoxylon*	Very open shrub mallee	Crests of ranges derived from sediments.
■	**Grey Mallee Shrubland (R1)**	*Eucalyptus morrisii*	Very open shrub mallee	Upper slopes of ranges of volcanic origin.
■	**Pine and Wattle Woodland (R2)**	*Callitris glaucophylla* *Acacia decora*	Low open to open woodland	Crests and upper slopes of ranges of volcanic origin.
■	**Not Surveyed (see Methods)**			

Tickmarks : Australian Map Grid at 1000 m intervals.
Grid lines : Australian Map Grid at 10 000 m intervals

Tracks ....
Railway -·-·-·-
Main roads ———

Bimble Box Woodland (D1a)

VEGETATION OF NOMBINNIE AND ROUND HILL NATURE RESERVES, CENTRAL WESTERN N.S.W.

J. S. COHN

Produced by J. S. Cohn
NSW National Parks and Wildlife Service
to accompany
CUNNINGHAMIA VOLUME 4 NUMBER 1, 1995.
Royal Botanic Gardens Sydney

FLORA OF NOMBINNIE AND ROUND HILL NATURE RESERVES

To accompany: Vegetation of Nombinnie and Round Hill Nature Reserves, central western New South Wales by Janet Cohn, (1995). The nomenclature follows Jacobs and Pickard (1981), and Harden (1990, 1991).

Codings:
* introduced taxa (not included in analysis);
(E) ephemerals or annuals (Cunningham *et al.* 1981; not included in analysis);
(B) taxa from Brickhill *et al.* (undated) not collected in this survey.

PTERIDOPHYTES

SINOPTERIDACEAE
Cheilanthes austrotenuifolia (B)
C. distans
C. lasiophylla
C. sieberi subsp. *sieberi*

OPHIOGLOSSACEAE
Ophioglossum polyphyllum (E)

GYMNOSPERMS

CUPRESSACEAE
Callitris endlicheri (B)
C. glaucophylla
C. preissii subsp. *verrucosa*

ANGIOSPERMS

ACANTHACEAE
Rostellularia pogonanthera

AMARANTHACEAE
Alternanthera sp. A
Ptilotus atriplicifoli
P. exaltatus var. *exaltatus*
P. obovatus
P. spathulatus

APIACEAE
Daucus glochidiatus (B)
Platysace lanceolata

APOCYNACEAE
Parsonsia eucalyptophylla

ASCLEPIADACEAE
Leichhardtia australis
Rhyncharrhena linearis
Sarcostemma australe

ASTERACEAE
Brachycome ciliaris var. *ciliaris* (B)
B. multifida
Calotis cuneifolia
Cassinia laevis
Gnaphalium luteo-album (E)
Helichrysum apiculatum
H. apiculatum / semipapposum
H. bracteatum
H. semipapposum
H. tuckeri
H. viscosum
Helipterum diffusum (E)
H. floribundum (E)
H. jessenii (B)
H. pygmaeum (E)
Leptorhynchos panaetioides
Minuria leptophylla
Olearia decurrens
O. muelleri
O. pimeleoides
O. ramulosa
O. rudis
O. subspicata
O. aff. *teretifolia*
Senecio glossanthus (B)
S. lautus subsp. *dissectifolius (E)*
S. platylepis (B)
S. quadridentatus (E)
* *Sonchus oleraceus* (E)
Vittadinia cuneata
V. dissecta var. *hirta* (E)
V. pterochaeta
V. triloba (B)

BIGNONIACEAE
Pandorea pandorana

BORAGINACEAE
* *Echium plantagineum* (E)
Halgania cyanea
* *Heliotropium europaeum* (E)

BRASSICACEAE
Cuphonotus humistratus (E)
Harmsiodoxa blennodioides (B)
H. brevipes var. *major* (E)
Lepidium papillosum (E)
L. pseudohyssopifolium (E)

BRUNONIACEAE
Brunonia australis

CAMPANULACEAE
Wahlenbergia communis
W. gracilis (E)
W. luteola
W. stricta subsp. *alternanthera*

CAPPARACEAE
Apophyllum anomalum

CASUARINACEAE
Casuarina cristata

CHENOPODIACEAE
Atriplex semibaccata
A. spinibractea
A. stipitata
Chenopodium cristatum (B)
C. desertorum subsp. *desertorum*
C. desertorum subsp. *microphyllum*
Einadia nutans subsp. *linifolia*
E. nutans subsp. *nutans*
Enchylaena tomentosa
Maireana aphylla
M. enchylaenoides
M. excavata (B)
M. humillima
Salsola kali (E)
Sclerolaena birchii
S. convexula
S. diacantha
S. muricata

CONVOLVULACEAE
Convolvulus erubescens

CYPERACEAE
Schoenus subaphyllus
Scirpus marginatus (B)

EUPHORBIACEAE
Bertya cunninghamii
Beyeria opaca
Chamaesyce drummondii
Phyllanthus fuernrohrii

FABACEAE
Acacia aneura
A. brachybotrya
A. burkittii
A. buxifolia subsp. *buxifolia*
A. calamifolia
A. colletioides
A. curranii
A. deanei
A. decora
A. doratoxylon
A. hakeoides
A. havilandiorum
A. homalophylla
A. montana
A. murrayana
A. oswaldii
A. rigens
A. tindaleae
A. trineura
A. triptera
A. wilhelmiana
Bossiaea walkeri
Daviesia arenaria
Eutaxia microphylla
Glycine canescens
Indigofera australis
* *Medicago laciniata* (E)
* *M. polymorpha* (E)
Senna artemisioides
nothosubsp. *artemisioides*
S. artemisioides subsp. filifolia
S. artemisioides subsp. *petiolaris*
S. artemisioides subsp. *zygophylla*
Swainsona laxa (B)
Templetonia aculeata
T. egena (B)

GERANIACEAE
Erodium crinitum (E)

GOODENIACEAE
Goodenia cycloptera
G. glabra
G. pusilliflora (E)
G. willisiana
Scaevola humilis
Velleia paradoxa (B)

HALORAGACEAE
Gonocarpus elatus (B)
Haloragis odontocarpa (B)

LAMIACEAE
Ajuga australis
Prostanthera leichhardtii
P. microphylla (B)
P. nivea
P. serpyllifolia
P. striatiflora
Teucrium racemosum
Westringia rigida

LAURACEAE
Cassytha melantha

LILIACEAE
Bulbine bulbosa (B)
B. semibarbata (B)
Dianella revoluta
Thysanotus patersonii (B)

LORANTHACEAE
Amyema miquelii (B)
A. quandang (B)

MALVACEAE
Abutilon cryptopetalum (B)
A. fraseri
A. otocarpum
A. oxycarpum (B)
Hibiscus sturtii (B)
* *Pavonia hastata*
Sida corrugata
S. cunninghamii
S. filiformis

MYOPORACEAE
Eremophila bignoniiflora
E. deserti
E. glabra
E. longifolia
E. mitchellii
E. serrulata
E. sturtii
Myoporum montanum
M. platycarpum

MYRTACEAE
Eucalyptus dumosa
E. dwyeri
E. gracilis
E. intertexta
E. largiflorens
E. leptophylla
E. morrisii
E. populnea subsp. *bimbil*
E. socialis
Melaleuca uncinata
Micromyrtus sessilis
M. striata

OLEACEAE
Jasminum lineare

ORCHIDACEAE
Caladenia carnea (E)
Diuris maculata (E)
Pterostylis mutica (E)
P. nana (E)

OXALIDACEAE
Oxalis corniculata

PITTOSPORACEAE
Billardiera versicolor
Pittosporum phylliraeoides

PLANTAGINACEAE
Plantago turrifera (B)

POACEAE
Amphipogon caricinus (E)
Aristida behriana (E)
A. calycina (B)
A. contorta (E)
A. jerichoensis (E)
A. ramosa var. *scaberula* (E)
Danthonia caespitosa (E)
D. linkii var. *fulva* (E)
Elymus scabrus (E)
Eragrostis lacunaria (E)
E. setifolia (E)
Monachather paradoxa (E)
Paspalidium constrictum (E)
P. jubiflorum (E)
* *Pentaschistis airoides* (E)
Stipa aristiglumis (B)
S. drummondii (B)
S. nitida (E)
S. nodosa (E)
S. platychaeta (E)
S. scabra (E)
S. tuckeri (B)
Themeda australis (E)
Thyridolepis mitchelliana (E)
Triodia irritans
* *Vulpia bromoides* (E)

POLYGALACEAE
Comesperma integerrimum

PORTULACACEAE
Calandrinia eremaea (B)

PROTEACEAE
Grevillea anethifolia
G. huegelii
Hakea leucoptera
H. tephrosperma

RANUNCULACEAE
Clematis microphylla var. *microphylla*

RHAMNACEAE
Cryptandra leucophracta
Spyridium eriocephalum

RUTACEAE
Eriostemon difformis
subsp. *difformis*
E. brevifolius (B)
E. myoporoides subsp. *acutus*
Geijera parviflora
Phebalium obcordatum (B)

SANTALACEAE
Choretrum glomeratum
Exocarpos aphyllus

SAPINDACEAE
Alectryon oleifolius
subsp. *canescens*
A. oleifolius subsp. *elongatus*
Dodonaea boroniifolia
D. lobulata
D. peduncularis
D. viscosa subsp. *angustissima*
D. viscosa subsp. *cuneata*
D. viscosa subsp. *spatulata*

SOLANACEAE
Anthocercis albicans
Nicotiana goodspeedii (B)
N. suaveolens (B)
Solanum coactiliferum
S. ellipticum
S. esuriale
S. ferocissimum
* *S. nigrum* (E)

STACKHOUSIACEAE
Stackhousia monogyna

STERCULIACEAE
Brachychiton populneus
subsp. trilobus

THYMELACEAE
Pimelea curviflora
P. microcephala
P. trichostachya (E)

VERBENACEAE
Clerodendrum tomentosum

VIOLACEAE
Hybanthus floribundus
subsp. *floribundus*

XANTHORRHOEACEA
Lomandra effusa
L. glauca
L. leucocephala
L. leucocephala subsp. *leucocephala*
L. leucocephala subsp. *robusta*
L. patens

ZYGOPHYLLACEAE
Zygophyllum eremaeum
Z. glaucum (E)

Two way table of native, perennial (Cunningham *et al.* 1981), plains mallee taxa against site numbers, showing cover abundances (Westhoff *et al*, 1978). Nomenclature follows Jacobs & Pickard (1981) and Harden (1990, 1991). Refer to Results for abreviations of plant community names. Read site numbers vertically; the last letter refers to the topography of the site i.e. F Flat to undulating, S Swale, D Dune crest, R Range.

```
Plant Community                           P2                                      P1       P2    P P1 P
                                                                                                 3    4
                                          -------------------------------------------------- -------- ----- - -- -
Site Number                               CHHHMMMCCMCKHHHHHMMHHMMCHHHHHHHHMMCKCHCMHHHHHHMMMMHH HMMMHMMM CHHMH M HH H
                                          11111111111101111111111110111111111111111111111111 01010111 11012 0 00 0
                                          34230113405192440122005245333431131523242424001034 21102055 55411 4 79 7
                                          69514239022193873578174122234350879568452496684901 36306568 10873 2 38 5
Taxon                                     FSFFFFFDSFSFFFSDFFSFFFDFFFFFFFFFSFFSSFFFFFFFFFFFFF FFFFFFRR DDFDF F FF F
Acacia bracybotrya                        --2-3-2-2-----1---2---------1----------------1---- -------- 121-- 1 -- -
Eucalyptus leptophylla                    ---22-32--12-------------------------------------- -------- 2222- 1 -- -
Grevillea anethifolia                     ----2---2----------------------------------------- -------- ----- - -- -
Cryptandra leucophracta                   ---21-2---------1----------1-----1---------------- -------- ----- - -- -
Lomandra glauca                           ---2222-11---------------------------------------- ------2- ----- - -- -
Prostanthera serpyllifolia subsp. microphylla ---222--------------------2--------------1----- ----1--- ----- - -- -
Helichrysum apiculatum                    ---32--322---------2------------------3-2----- -------- ----- 1 -- -
Acacia hakeoides                          ------------------11--------------1---11------ -------- ----- - -- -
Minuria leptophylla                       ------------------2-------2-1------------3------- -------- ----- - -- -
Bertya cunninghamii                       --------------1-------------------12-121----12 -------- --1-- - -- -
Eremophila longifolia                     ----1--------2---112--------------------------2 -----1-- --2-- - -- -
Grevillea huegelii                        --------------1----1------------------------------ -------- ----- - -- -
Callitris preisii subsp. verrucosa        -1121--11---------22---------1-------------------- ----1--- ----1 5 -- -
Eutaxia microphylla                       2-13------2-------22--2311--1--------------------- -------- ----- - -- -
Stackhousia monogyna                      1--1------2--------------2------------------------ -------- --1-- - -- -
Acacia wilhelmiana                        ---2---------1-----1-3-------------11--11-------- -------- 12--- - -- -
Micromyrtus sessilis                      -2--------------2--------------------------------- -------- -2--- - -- -
Eucalyptus intertexta                     -1---------1-------------------------11-1--11-- -------- ----- - 1- -
Westringia rigida                         ------2-----------12---------1---------11---2-2-- -2------ ----- - -- -
Acacia colletoides                        ------2------22---2-21-3---123-------22-11-1222-12 -2--1--- --121 - -- -
Dodonaea viscosa subsp. cuneata           -------2--2----------1---1--------1--121--33322-1- 23--1--- 1---- - -- -
Senna artemisioides                       -----------2--------11---22----------121--1122-122 13-1---1 1---- - -- -
Sclerolaena diacantha                     ---------2----------22---------1-----22-1---22--33 1--2-1-- ----- - -- -
Solanum coactiliferum                     ------1-----------2--2---------------------21222-1- -------- -2--1 - -- -
Acacia havilandiorum                      ----1-2--32----234--21---------------3-----3333-- -2------ -1-2- - -- -
Bossiaea walkeri                          ---1-22--2---22122---3232-----2-------1-1---2121-- -------- 2---- - -- -
Acacia rigens                             ---2432----2-----3-------1222323221--1-----111-3-- -------- ----- - -- -
Halgania cyanea                           121322221--2---2231212------2--2-2---2--4----324-- -3--1--- ----- - -- -
Acacia tindaleae                          2--131---2---3--312-11---2112----2--1-----2---22-- ----1--- -1--1 - -- -
Dianella revoluta                         12-12211111-1222222222---212---12-----2--11----1-- -1--2--- -2--2 - -- -
Lomandra effusa                           -------22-22212-222222--122-1--121-------1-------- -------- ----- - -- -
Melaleuca uncinata                        ---2-2-2232--223-314-31-235322243-----2-1-2---23-- ---1---- 2---- - -- -
Eremophila glabra                         ---------122122212221-22122---1------121212-212111 ---21321 1-2-- - -- -
Olearia pimelioides                       -----2-2-2222--1-2122-23--2--1---21--1231123-1---- ---22132 --2-1 - -- -
Eucalyptus dumosa                         1--222-32221222221323322 2----222223112-3-21322222 3254-221 1---- - 11 2
Eucalyptus socialis                       31223233322232223222 43323--21221-31332122232332223 22533333 22221 2 32 1
Eucalytus socialis/ E. dumosa             34333232222232222232223-31223221121313333 32332-33- 33--2423 21-21 - -- -
Triodia irritans                          323343242-22-33341-34-244--12323211--12--1--332--- -2--3-2- 5422- - -- -
Eucalyptus gracilis                       --2-----212--12-22-2-2--321211--2222222233----2--- 11------ ----- - -- -
Eucalyptus gracilis/ E. leptophylla       --233-32-----1---211-1-33-2322---11-122222----1--- -------- 121-- - -- -
Acacia burkittii                          ---------------------------------2---------------- -------- ----- - -- -
Hakea leucoptera                          -----------2----------------1-2------------------- -------- ----- - -- -
Olearia ramulosa                          1----2-1---------------------112---------1----1-- -------- ----- - -- -
Acacia triptera                           --------2--2-------------342---42-1--------------- -------- ---1- - -- -
Beyeria opaca                             2------14----------3-----2222-33222--221-1-------- -3------ --1-- - -- -
Bracycome multifida                       -------233-2------------------22------------------ -------- ----2 - -- -
Helichrysum apiculatum/ semipapposum      -----1----22-----2-------------32-------------2--- -------- 2---3 - -- -
Dodonaea peduncularis                     2322---112-2--------------------1--1-------------- -------- ----- - -- -
Callitris glaucophylla                    ------2---------------------33-------------------- -------2 1-1-- - -- -
Eriostemon difformis subsp. difformis     -------------------------1-1--1------------------- -------- ----- - -- -
Spyridium eriocephalum                    ---------------------------1--11------------------ -------- ----- - -- -
Helichrysum viscosum                      ---------------------------2----1----------------- -------- ----- - -- -
Acacia buxifolia subsp. buxifolia         ---------------------------------1-1-------------- -------- ----- - -- -
Myoporum platycarpum                      -----------------1--1-------1---12-2-1-2--2-111--- -------- ----- - -- -
Apophyllum anomalum                       -------------------------------------1------------ -------- ----- - 1- -
Eremophila mitchellii                     -------------------------------------2------------ -------- ----- - -- -
Acacia deanei                             -----------2-------------------------------------- -------- ----- - -- -
Goodenia willisiana                       ----2-----22--------12---------------------------- ------2- ----- - -- -
Goodenia glabra                           -----------2--------1----------------------2------ -------- ----- - -- -
Ptilotus exaltatus var. exaltatus         -------------------------------------------1------ -------- ----- - -- -
Brachychiton populneus subsp. trilobus    --------------------1----------------------------- -------- ----- - -- -
Dodonaea viscosa subsp. angustissima      --------------------1---1---------------------1-- ---1-21- ----- - -- -
Ajuga australis                           ----------------------------------------------2- -------- ----- - -- -
Eremophila sturtii                        ----------2-1---------------------------------2- -1-1---- ----- - -- -
Choretrum glomeratum                      ------------------------------------1------------- -------- ----- - -- -
Hakea tephrosperma                        ---------2---------------------------------------- -------- ----- - -- -
Myoporum montanum                         ---------------------------1---------------------- -------- ----- - -- -
Rhyncharrhena linearis                    -------------------------------------------------- -------- ----- - -1 -
Alectryon oleifolius                      ------------------------------------------1------ -------- ----- - -- -
Einadia nutans                            ------------------------------------------1------ 1------- ----- - -- 1
Maireana enchylaenoides                   -------------------------------------------------- 2------- ----- - -- -
Chenopodium desertorum                    --------------------2---------------------21---- 2222--1- ----- - -- -
Pittosporum phylliraeoides                -------------------------------------------------- 1111---- ----- - -- -
Eucalyptus populnea subsp. bimbil         -------------------------------------------------- --1----- ----- - -- -
Dodonaea lobulata                         -------------------------------------------------- -------- --1-- - -- -
Geijera parviflora                        ----------------------1--------------------------- -------- --1-- - -- -
Helichrysum semipapposum                  --------------1-------2------------2----1--------- -------- ----- - -- -
Olearia subspicata                        ----------------------1--------------------------- -------- ----- - -- -
Olearia rudis                             --1---1---------------1--------------------------- -------- ----- - -- -
Anthocercis albicans                      -------------------------------------------------1 -------- ----- - -- -
Olearia muelleri                          -------------------------------------------------1 -------- ----- - -- -
Ptilotus obovatus                         ------------------------1------------------------1 -------- ----- - -- -
Clematis microphylla var. micropylla      -----------------------11------------------------- -------- ----- - -- -
Micromyrtus striata                       ------------------------1------------------------- -------- ----- - -- -
Eremophila deserti                        ------2-----1-11---------1---------------1-------- -------- ---1- - -- -
Templetonia aculeata                      ---1----11----11--1--1-1-2--1--------------------- ----2-1- ----- - -- -
Acacia montana                            -------2--2---1----------------------------------- ----2--- ----- - -- -
Platysace lanceolata                      -------31----------------------------------------- ----3--- 3---- - -- -
Acacia murrayana                          -------------------------------------------------- ----1--- ----- - -- -
Dodonaea boroniifolia                     -----------2-------------------------------------- ----3--- ----- - -- -
Billardiera versicolor                    --------------------1-1-----1--------------------- ----1--- ----- - -- -
Cassytha melantha                         -------------------------------------------------- ----1111 ----- - -- -
Comesperma integerrimum                   ------------------------------------------1------- ------11 ----- - -- -
Lomandra leucocephala subsp. leucocephala -------------------------------------------------- ---2---2 -2--- - -- -
Sida cunninghamii                         -------------------------------------------------- -----2-- ----- - -- -
Lomandra leucocephala subsp. robusta      -------------------------------------------------- -------- ---2- - -- -
Olearia aff. teretifolia                  -----------2-------------------------------------- -------- ---3- - -- -
Schoenus subaphyllus                      ----1--------------------------------------------- ---2---- 1--2- - -- -
Cassinia laevis                           -------------------------------------------------- -------- 1---- - -- -
Hybanthus floribundus subsp. floribundus  -------------------------------------------------- ---------2---- - -- -
Daviesia arenaria                         -----------------------------------1-------------- ---------22--- - -- -
Helichrysum tuckeri                       -----------------------------------------1-------- ---------1---- - -- -
Zygophyllum eremaeum                      -----------------------------------------1-------- ------------- - -- -
```

Two way table of native, perennial (Cunningham *et al.* 1981), non mallee and hill / range mallee taxa against site numbers showing cover abundances (Westhoff *et al.*, 1978). Nomenclature follows Jacobs & Pickard (1981) and Harden (1990, 1991). Refer to Results for abreviations of plant community names. Read site numbers vertically; last letter refers to the topography of the site i.e. F Flat to undulating, C Creek, S Swale, D Dune crest, H Hill, R Range.

```
Plant Community                      D1, D1a & D4             D3    D2                    P6      P7    P9  F1        P5           H1  R2          P8
                                                                                                            F2                     R1
                                     ------------------------ ----- --------------------- ------- ----- --- -- ---- - ------------ --- ----------- ---------- ---------
Site Number                          CMMHMMMMMMMMMMMMMMMHMMMMM HHMMM CKMHMMMCHHHKKMHHHCCHH HHHHHHM HHHHH H H HH CHHH H HHHHHMHMHHMM CKC HHHMMMMMMMM MMMMMMMMMM HHHHHHHHM
                                     0200000220200330020000020 00000 000000002020002220202 0000000 00092 0 0 00 0202 0 000200000000 002 02000000000 0121202002 020000200
                                     5069011013146443619000004 24016 565511660405560017171 3373786 89980 4 4 89 7131 8 379083855811 641 70902109949 0101424224 307988085
                                     3D46770FC3D50AB6173384G4 27162 559458693660175754662 1572833 907A0 0 1 81 0071 0 894850676792 894 2952945BC3A 6BCCA8B75C 941212248
Taxon                                FFRFFFFFFFFFFFFFFFFFCHFFH FFFFF FFFHFFFHFFFFFFFFFHRFF FFFFFFR FFFFF F F FF HFFF F FFFFFFFFFFFF HHR FFFFFRHHRHH FFFFFFFFF FFFFFFFF
Abutilon fraseri                     --------------------2--- ----- --------------------- ------- ----- - - -- ---- - ------------ --- ----------2 ---------- ---------
Pandorea pandorana                   ------------------------ ----- --------------------- ------- ----- - - -- ---- - ------------ --- -------2--4 ---------- ---------
Pimelea curviflora                   --------------2--------- ----- --------------------- ------- ----- - - -- ---- - ------------ --- ----------3 ---------- ---------
Sclerlaena birchii                   ------------------------ ----- --------------------- ------- ----- - - -- ---- - ------------ --- ----------2 ---------- ---------
Acacia decora                        -----------------------2 ----- --------------------- ------- ----- - - -- ---- - ------------ --- -----243333 ---------- ---------
Cheilanthes lasiophylla              --------------------45-- ----- --------------------- ------- ----- - - -- ---- - ------------ --- ------433-4 ---------- ---------
Glycine canescens                    ------------------------ ----- --------------------- ------- ----- - - -- ---- - ------------ --- ------2--33 ---------- ---------
Acacia havilandiorum                 ---------------------2-- ----- --------------------- ------- ----- - - -- ---- - ------------ --- ----------- ---------- ---------
Eremophila bignoniiflora             ---------------------2-- ----- --------------------- ------- ----- - - -- ---- - ------------ --- ----------- ---------- ---------
Convolvulus erubescens               ---------------------22- ----- --------------------- ------- ----- - - -- ---- - ------------ --- ----------- ---------- ---------
Euphorbia drummondii                 ---------------------232 ----- --------------------- ------- ----- - - -- ---- - ------------ --- ----------- ---------- ---------
Solanum ferocissimum                 ------------2------222-- ----- -------------2------- ------- ----- - - -- ---- - ------------ --- ----------- ---------- ---------
Alternanthera sp. .A                 --------2-------------2- ----- --------------------- ------- ----- - - -- ---- - ------------ --- ----------- ---------- ---------
Abutilon otocarpum                   -2-----23323-333------3- ----- --------------------- ------- ----- - - -- ---- - ------------ --- ----------- 2233322333 ---------
Sida corrugata                       3-4-4---333-4-----3----- ----- 2-----------------3-- ------- ----- - - -- ---- - ------------ --- ----------- ----2223-2 ---------
Chenopodium desertorum               3244444334323------2--2- ----- 3-32---------33233--2 ----3-- ----- - - -- ---- - -------2---- --- ----------- ---2-2---- ---------
Sclerolaena diacantha                333444444443------32---- -4--3 433234-4434--3453--33 ---4--- ----- - - -- ---- - ------342--- --- ----------- -23------- ---------
Einadia nutans subsp. nutans         --23333-4332--3---432222 ----2 3------------2---3--2 --23----3-23- - 2 -2 ---- - -----2-22---- --- ---------2- ---------- ---------
Eucalyptus populnea subsp. bimbil    ---3253255--24543236---1 --1-- 5------22--------2352 --------55122 - - -- 1--2 - ----1------- --- -2--------1 --1---2--1 ---1-----
Maireana enchylaenoides              --3-3---23---------3--22 ----- ---------------22----3 ------- ----- - - -- ---- - ------2----- --- ----------- ---------- ---------
Acacia colletoides                   -2----323222------------ ----- ----22--------------- --2---- ----- - - -- ---- - ------------ --- ----------- ---------- ---------
Dodonaea viscosa subsp. angustissima --22243223-5---2-------- -3-34 ----22--------------- ------- ----- - - -- -2-- - ------------ --- ----------- --2------- ---------
Goodenia glabra                      3--2----2223--23------23 ----- ----4---------------- ------- ----- - - -- ---- - ------------ --3 ----2------ ---------- ---------
Eremophila glabra                    322-----2323-233-------- ---22 2-3322-2-22233---223- --3---- ----- - - -- -2-- - -----2-3---- --- ----------- ---------- ---------
Senna artemisioides                  3233--22--2--22334---22- ----2 33333333---22-------- -22-3-4 ----- - - -- 2--- - ------------ --- ----------- ---------- ---------
Eremophila longifolia                32---42-32-2-23332--2--- 22543 3-22452-----33------- ------- ----- - - -- 2--- - -3-----2---- 2-- ---------4- ---------- 3--------
Eremophila deserti                   223----------32--------- ----- ----------2--------2- 33322-- ----- - - -- ---- - -----2------ --- -----2----- ---------- ---------
Eremophila sturtii                   -----5-24342222-2-----2- ----- ----2---------------- 45-5--- --344 - - -- --3- - 2---34------ --- ----------- ---------- ---------
Callitris glaucophylla               42233131-2---2-233254455 -2-22 323-3-23252322-3233-2 ------- 1-2-- - - -- 43-- - ------------ 4-- 55555556565 -523331521 222222223
Cheilanthes sieberi                  -2--------23-322-----535 --3-- -----23-----3-------- -4----- ----- - - -- 4--- - ----2----334 443 --3434-3342 33333233-3 ---------
Sida cunninghamii                    --4---3---2---3---3332-4 --2-3 --3--2--------------- ------3 ----- - - -- ---- - ------------ --- -----332-3- ---------- ---------
Acacia burkitti                      ------------------------ ----- -----4--------------- ------- ----- - - -- ---- - ------------ --- ----------- ---------- ---------
Acacia deanei                        --------2--2-244-------- ----- --------------------- ------- ----- - - -- ---- - ------------ --- ----------- ---------- ---------
Eucalyptus gracilis                  ----------------2------- ----- --------------------- ------- ----- - - -- ---- - ------------ --- ---2------- ---------- ---------
Calotis cuneifolia                   --3------23----4-------- ----- 3----2--------------- ------- ----- - - -- ---- - ------------ --- ----------- ---------- ---------
Acacia curranii                      ------------------------ ----- --------------------- ------4 ----- - - -- ---- - ------------ --- ----------- ---------- ---------
Phyllanthus fuernrohrii              ------------------------ ----- -----------------4--- ------3 ----- - - -- ---- - ------------ --- ------4---- ---------- ---------
Wahlenbergia luteola                 ------------------------ ----3 -----------------3--- ------- ----- - - -- ---- - ------------ --- ----------- ---------- ---------
Dodonaea viscosa subsp. spatulata    ------------2-242---2--- ----2 -----------3--------- ------- ----- - - -- -2-- - -------3---- --- ----------- ---------- ---------
Solanum coactillferum                ------------------------ ---43 --------------------- ------- ----- - - -- ---- - ------------ --- ----------- ---------- ---------
Maireana humillima                   32-----3-3--4----3---2-- ----4 --------------------- ------- ----- - - -- ---- - ------------ --- ----2------ --3------- ---------
Ptilotus spathulatus                 ------------2----------- ----- --------------------- ------- ----- - - -- ---- - ------------ --- ----------- ---------- ---------
Olearia ramulosa                     ---------2-------------- ----- --------------------- ------- ----- - - -- ---- - ------------ --- ----------- ---------- ---------
Ptilotus obovatus                    ---------2-------------- ----3 --------4-----3------ ------- ----- - - -- ---- - ------------ --- ----------2 ---------- ---------
Zygophyllum eremaeum                 ------------------------ ----- ---------------3----2- ------- ----- - - -- ---- - ------------ --- ----------- ---------- ---------
Acacia hakeoides                     ------2----------------- ----- -----2--------------- ------- ----- - - -- ---- - ------------ --- ----------- ---------- ---------
Senecio quadridentatus               ------42----3----------- ----- --------------------- ------- ----- - - -- ---- - ----2------- --- ----------- 2--3------ ---------
Wahlen bergia communis               ------------------------ ----- --------------------- ------- ----- - - -- ---- - ------------ --- ----------- 2--------- ---------
Einadia nutans subsp. linifolia      -----2------------------ ----- --------------------- ------- ----- - - -- ---- - ------------ --- ----------- ---------- ---------
Olearia muelleri                     ------------------------ ----- --------------------- ------- 5---- - - -- ---- - -3---------- --- ----------- ---------- ---------
Stackhousia monogyna                 ------------------------ ----- --------------------- ------- -2--- - - -- ---- - ------------ --- ----------- ---------- ---------
Acacia trineura                      ------------------------ ----- -------------------2-- ------- ----- - - -- ---- - ------------ --- ----------- ---------- ---------
Sclerolaena convexula                --2---2---------3-2----- ----- -------------------4-- ------- ----- - - -- ---- - ------------ --- --------32- ---------- ---------
Atriplex semibaccata                 ------------------------ ----- ---------------------2 ------- ----- - - -- ---- - ------------ --- ----------- ---------- ---------
Atriplex stipitata                   ------------------------ -2--- 32------------3---323 ------- ----- - - -- ---2 - ---3-------- --- ----------- ---------- ---------
Eremophila mitchellii                ------1-1----2--32------ ----- 334---3223-223--22324 ------- ----- - - -- 4--3 - --12---32--- --- ----------- ------1--- ---------
Olearia pimelioides                  ------------------------ ----- -3--2----23------233 2------ ----- - - -- ---- - 22---------- --- ----------- ---------- ---------
Alectryon oleifolius                 ------------------------ ----- ------2---------2-2- ------- ----- - - -- ---- - --12-222-22- --- ----------- ---------- ---------
Apopophyllum anomalum                ------------------------ ----- -------------------2- --3---- 2---- - - -- ---- - 22--332332-- --- -2--------- ---------- ---------
Casuarina cristata                   ------------------1----- ----- -1-----------25------ ------- ----- - - -- -322 2 55552532-1-- --- ----------- ---------- -1-------
Geijera parviflora                   ------1------2---1-2---- ----- -3-----1---3122-521-- ------- ----- - - -- 2221 - 33525522-5-- --- -2--------- ---------- --11-----
Brachychiton populneus subsp. trilobus ---------------------- ----- ---2---2---2--------- ------- ----- - - -- ---- - ------------ --- -----1----- 1--------- ---------
Jasminum lineare                     ------------------2----- ----- -------2------------- ------- ----- - - -- ---- - ------------ --- ----------- ---------- ---------
Pittosporum hylliraeoides            ----------22--2---2----- ----- -------2-4-33-------- ------- ----- - - -3 ---- - ------------ --- ----------- ---------- ---------
Cheilanthes distans                  ------------------------ ----- --------------------- ------- ----- - - -- ---- - ------------ --- ---2-3----- ---------- ---------
Enchylaena tomentosa                 ------------------------ ----- -----------333------- ------- ----- - - -- ---- - -----43----- --- ----------- ---------- ---------
Pimelea micocephala                  ------------------------ ----- -----------322------- ------- ----- - - -- ---- - ------------ -3- ----------- ---------- ---------
Parsonsia eucalyptophylla            ------------------------ ----- ------------22------- ------- ----- - - -- ---- - ------------ --2 ----------- ---------- --------2
Solanum ellipticum                   ------------------------ ----- ------------2-------- ------- ----- - - -- ---- - ------------ --- ----------- ---------- ---------
Goodenia cycloptera                  -----------------------2 ----- 2-------------------- ------- ----- - - -- ---- - ------------ --- ------2---- ---------- ---------
Hakea leucoptera                     2----------------------- ----- ------------2-------- --2---- ----- - - -- ---- - ------------ --- ----------- ---------2 ---------
Scaevola humilis                     ------------------------ ----- --------------------- ------- ----- - - -- ---- - ------------ --- ----------- ---------2 ---------
Helichrysum semipapposum             3----------------------2 ----- ---------------2----- ------- ----- - - -- -2-- - ------------ --- ----------- ---------- ---------
Pavonia hastata                      3----------------------- ----- --------------------- ------- ----- - - -- ---- - ------------ --- ----------- ---------- ---------
Eucalyptus socialis                  -----------1------------ ----- ------2---2--2------- ------- ----- - - -- ---- - ------------ --- ----------- ---------- 22-------
Lomandra effusa                      ------------------------ ----- -----------2--------- ------- ----- - - -- ---- - ------------ --- ----------- ---------- ---------
Melaleuca uncinata                   ------------------------ ----- ------5-------------- ------- ----- - - -- ---- - ------------ --- ----------- ---------- ---------
Micromyrtus striata                  ------------------------ ----- ------3-------------- ------- ----- - - -- ---- - ------------ --- ----------- ---------- ---------
Acacia homalophylla                  ------------------------ ----- --------------------- -21---- ----2 - - -- ---- - ------------ --- ----------- ---------- ---------
Helichrysum tuckeri                  ------------------------ ----- ---------------2----- -32---- ----- - - -- ---- - ------------ --- ----------- ---------- ---------
Dianella revoluta                    ------------------------ ----- 2-------------------- -2----- ----- - - -- ---- - ------------ --- ----------- ---------- ---------
Bertya cunninghamii                  ------------------------ ----- 32-2------2----23---- -22---- ----- - - -- -3-- - ------------ --- ----------- ---------- ---------
Dodonaea viscosa subsp. cuneata      ---2---------2---------- ----- 3434-43-2-------3---- 34332-- ----- - - -- ---- - -2-2-2------ --- ----------- ---------- ---------
Eucalyptus intertexta                1--2------51--------2--1 --2-- 52232532234312-31---- -332551 --2-- - - -- 1--- - -1---------- --- ----22----3 ---------- -------32
Hakea tephrosperma                   ---1-----2-3------3----- -2--- 221-2--------2-33---- -5----- ----- - - -- 21-- - ------1----- --- --21------- ---------- ---------
Olearia decurrens                    ------------------------ ----- -332---------2------- ------- ----- - - -- ---- - ------------ --- ----------- ---------- ---------
Acacia oswaldii                      ------------------------ ----- --------------------- 2-2---- ----- - - -- 2222 - ------------ --- ----------- ---------- ---------
Exocarpos aphyllus                   ------------------------ ----- --------------------- ------- ----- - - -- 22-- - ------------ --- ----------- ---------- ---------
Leichhardtia australis               ------------------------ ----- --2------------------ ------- ----- - - -- 2--- - ------------ --- ----------- ---------- ---------
Eucalyptus dumosa                    ------------------------ ----- ---2----------------- ------- ----- - - -- --22 - ------------ --- ----------- ---------- ---------
Prosanthera leichhardtii             ------------------------ ----- --------------------- ------- ----- - 5 -- ---- - ------------ --- ----------- ---------- ---------
Eriostemon myoporoides subsp. acutus -----------2------------ ----- --------------------- ------- ----- - - -- ---- - ------------ --- ----------- ---------- ---------
Ptilotus atriplicifolius             -----------3------------ ----- --------------------- ------- ----- - - -- ---- - ------------ --- ----------- ---------- ---------
Halgania cyanea                      -2---------------------- ----- --------------------- ------- ----- - - -- ---- - ------------ --- ----------- ---------- ---------
Vittadinia cuneata                   -2---------------------- ----- --------------------- ------- ----- - - -- ---- - ------------ --- ----------- ---------- ---------
Helichrysum apiculatum               -2-------------------2- ----- --------------------- ------- ----- - - -- ---- - ------------ --- ----------- ---------- 5--------
Acacia aneura                        ------------------4----- ----- --------------------- ------- ----- - - -- ---- - ------------ 2-- ----------- ---------- ---------
Dodonaea lobulata                    ------------------3----- ----- -------------------2-- ------- ----- - - -- ---- - ------------ 2-- ----------- ---------- ---------
Eremophila serrulata                 --2--------------------- ----- -------2------------- ------- ----- - - -- 2--- - ------------ 2-- ----------- ---------- ---------
Eucalyptus socialis/ E. dumosa       ------------------------ ----- --------------------- ------- ----- - - -- ---- - ------------ 2-- ----------- ---------- ---------
Prostanthera striatiflora            ------------------------ ----- --------------------- ------- ----- - - -- ---- - ------------ 2-- ----------- ---------- ---------
Cassytha melantha                    --2--------------------- ----- --------------------- ------- ----- - - -- ---- - ------------ --- ------2---- ---------- ---------
Rostellularia pogonanthera           --3--------------------- ----- --------------------- ------- ----- - - -- ---- - ------------ --- ----------- ---------- ---------
Atriplex spinibractea                ------------------------ ----- --------------------- ---3--- ----- - - -3 ---- - ------------ --- ----------- ---------- ---------
Eucalyptus largiflorens              ------------------------ ----- --------------------- ------- ----- - - -5 ---- - ------------ --- ----------- ---------- ---------
Solanum esuriale                     --------2--------------- -33-- --------------------- ------- ----- - - -3 ---- - ------------ --- ----------- ---------- ---------
Maireana aphylla                     ------------------------ ----- --------------------- ---4--- ----- - - -- ---- - ------------ --- ----------- ---------- ---------
Sarcostemma australe                 ------------------------ ----- --------------------- ---2--- ----- - - -- ---- - ------------ --- ----------- ---------- ---------
Myoporum platycarpum                 ------------------------ ----- -------2------------- ---3--- ----- - - -- ---- - ------------ --- ----------- ---------- ---------
Acacia doratoxylon                   ------------------------ ----- ------2-------------- ------- ----- - - -- ---- - ------------ -5- ----------- ---------- ---------
Helichrysum bracteatum               ------------------------ ----- --------------------- ------- ----- - - -- ---- - ------------ -3- ----------- ---------- ---------
Helichrysum viscosum                 ------------------------ ----- -----------2--------- ------- ----- - - -- ---- - ------------ -3- ----------- ---------- ---------
Eucalyptus dwyeri                    ------------------------ ----- --------------------- ------- ----- - - -- ---- - ------------ 34- ----------- ---------- ---------
Prostanthera nivea                   ------------------------ ----- ---3----------------- ------- ----- - - -- ---- - ------------ -3- ----------- ---------- ---------
Leptorhynchos panaetioides           ------------------------ ----- --------------------- ------- ----- - - 4- ---- - ------------ --- ----------- ---------- ---------
Teucrium racemosum                   ------------------------ ----- --------------------- ------- ----- - - 4- ---- - ------------ --- ----------- ---------- ---------
Vittadinia pterochaeta               ------------------------ ----- --------------------- ------- ----- - - 3- ---- - ------------ --- ----------- ---------- ---------
Sclerolaena muricata                 ------------------------ ----- --------------------- ------- ----- - - 42 ---- - ------------ --- ----------- ---------- ---------
Brunonia australis                   ------------------------ ----- --------------------- ------- ----- - - -- ---- - ------------ --3 ----------- ---------- ---------
Eucalyptus morrissii                 ------------------------ ----- --------------------- ------- ----- - - -- ---- - ------------ --3 ----------- ---------- ---------
Sida filiformis                      ------------------------ ----- --------------------- ------- ----- - - -- ---- - ------------ --3 ----------- ---------- ---------
Wahlenbergia stricta
subsp. alternanthera                 ------------------------ ----- --------------------- ------- ----- - - -- ---- - ------------ --3 ----------- ---------- ---------
Indigofera australis                 ------------------------ ----- --------------------- ------- ----- - - -- ---- - ------------ 2-3 ----------- ---------- ---------
Lomandra patens                      ------------------------ ----- --------------------- ------- ----- - - -- ---- - ------------ --3 -----2----- ---------- ---------
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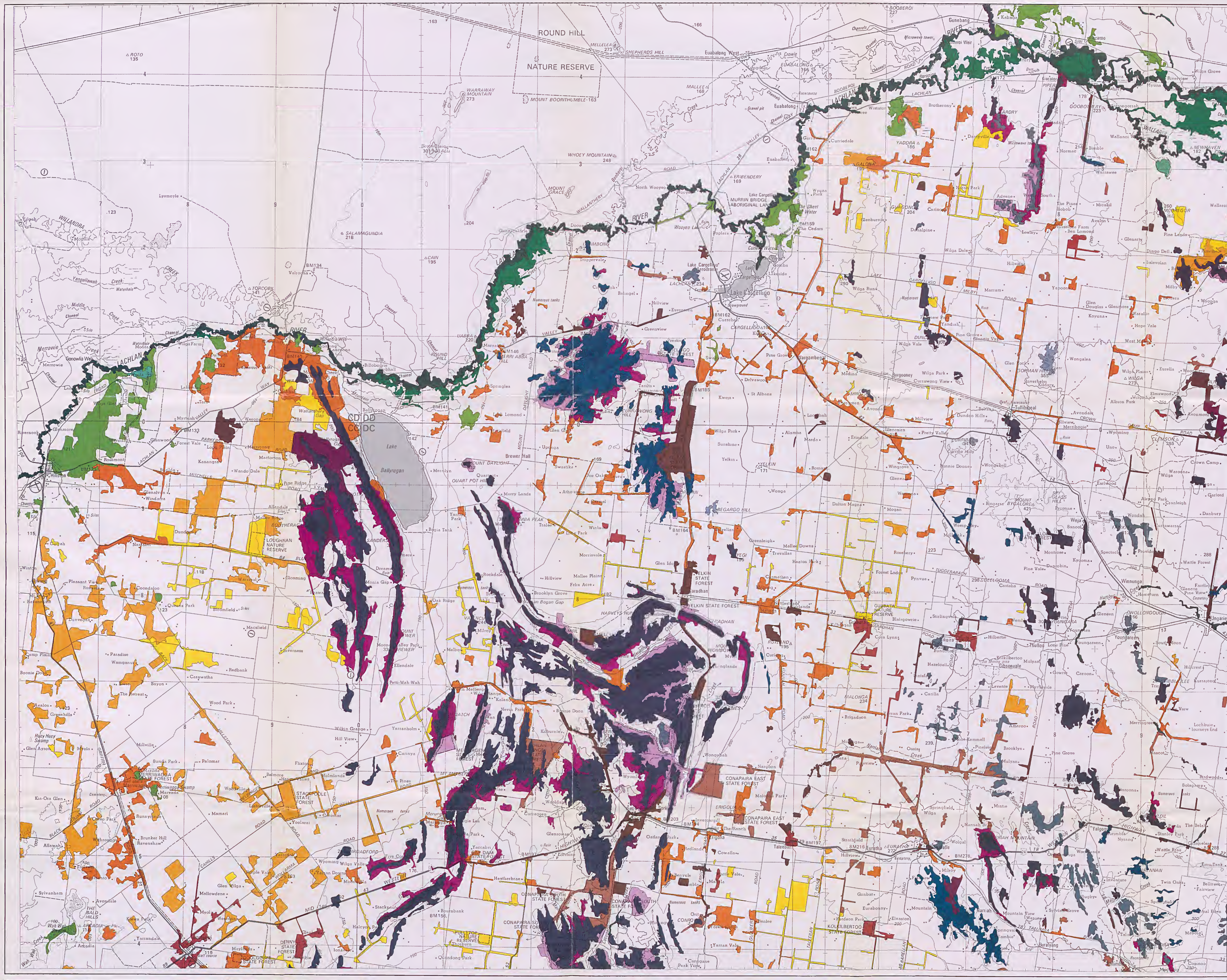


Pattern*	Remnant Type	Vegetation: Characteristic Species**	Landforms and Soils
		Riparian and Floodplain Remnants	
R1	River Red Gum Forests	*Eucalyptus camaldulensis, Acacia stenophylla, A. saligna.*	Banks, channels and backplains; grey cracking clay and polygenetic alluvial soils.
R2	Floodplain Mosaic	*Eucalyptus largiflorens, E. camaldulensis, Acacia salicina, Muehlenbeckia florulenta.*	Backplains, floodplains and banks; grey cracking soils.
R3	Black Box Woodlands	*Eucalyptus largiflorens, E. camaldulensis, E. populnea* subsp. *bimbil, Acacia salicina, Acacia pendula, Muehlenbeckia florulenta.*	Floodplains, closed depressions and very gentle rises; grey cracking clays with some red earths and brown clays.
R4	Lignum Shrublands	*Muehlenbeckia florulenta, Stipa aristiglumis.*	Flats and closed depression; brown clay.
R5	Myall Woodlands	*Acacia pendula, Amyema quandang, Danthonia setacea.*	Gilgaied flats; grey clay.
R6	Yellow Box / River Red Gum Forests	*Eucalyptus melliodora, E.camaldulensis.*	Flats and floodplains; brown earthy soils and clays.
		Undulating Peneplain Remnants	
P1	Mallee Woodlands	*Eucalyptus socialis, E. gracilis, E. dumosa, Callitris glaucophylla, Melaleuca uncinata, Stipa aristiglumis, Triodia scariosa* subsp. *scariosa.*	Flats and very gentle rises; sandy red earths.
P2	Open Mallee Woodlands	*Eucalyptus socialis, E. dumosa, E. oleosa, E. leptophylla, Callitris glaucophylla, Casuarina cristata s.lat., Chrysocephalum apiculatum.*	Flats and gentle rises; sandy red earths.
P3	Open Box Woodlands	*Callitris glaucophylla, Eucalyptus populnea* subsp. *bimbil, E. intertexta, E. microcarpa, Allocasuarina luehmannii.*	Flats and gentle slopes; loamy red earths minor sandy red and brown earths.
P4	Box Woodlands	*Eucalyptus populnea* subsp. *bimbil, E. microcarpa, E. conica, E. intertexta, Callitris glaucophylla, Allocasuarina luehmannii.*	Flats, very gentle slopes and minor drainage lines; loamy red earths, minor sandy and clayey red and brown earths.
P5	Mallee / White Cypress Pine Intergrade	*Callitris glaucophylla, Eucalyptus socialis, E. dumosa, Eremophila glabra, Melaleuca uncinata, Eremophila glabra, Triodia scariosa* subsp. *scariosa.*	Flats; sandy and loamy red earths.
P6	White Cypress Pine Woodlands	*Callitris glaucophylla, Eucalyptus populnea* subsp. *bimbil, E. microcarpa, Acacia deanei* subsp. *paucijuga, Dodonaea viscosa* subsp. *angustissima.*	Flats and gentle rises; loamy red earths.
P7	Bull Oak / Belah Woodlands	*Allocasuarina luehmannii, Callitris glaucophylla, Casuarina cristata s. lat., Acacia homalophylla, Myoporum montanum.*	Flats, minor drainage lines and shallow depressions; gilgaied clays and red earths.
		Footslope Remnants	
F1	Grasslands	*Stipa scabra* subsp. *scabra, Danthonia setacea.*	Slopes, low crests and flats; lithosols and colluvial soils.
F2	Open Pine and Box Woodlands	*Callitris glaucophylla, Eucalyptus populnea* subsp. *bimbil, E intertexta, E. dwyeri, Acacia doratoxylon, Brachychiton populneus.*	Footslopes and flats; colluvial red earths.
F3	Pine and Box Woodlands	*Callitris glaucophylla, Eucalyptus microcarpa, E. populnea* subsp. *bimbil, Acacia deanei* subsp. *deanei, Senna artemisioides.*	Footslopes and flats; red and brown earths.
		Hill and Ridge Remnants	
H1	Dwyer's Red Gum and Pine Woodlands	*Callitris glaucophylla, Eucalyptus dwyeri, E. sideroxylon, Callitris endlicheri, Brachychiton populneus, Acacia doratoxylon, Allocasuarina verticillata.*	Upper and mid-slopes, crests and ridges; lithosols and shallow brown earths.
H2	Green Mallee Woodlands	*Eucalyptus viridis, E. sideroxylon, E. dumosa, E. gracilis, E. polybractea, E. dwyeri, Callitris endlicheri, Melaleuca uncinata, Acacia doratoxylon.*	Low crests, gentle hillslopes and flats; lithosols and shallow brown earths.
H3	Pine and Poplar Box Open Woodlands	*Callitris glaucophylla, Eucalyptus populnea subsp. bimbil, E. dwyeri, Acacia doratoxylon, Casuarina verticillata.*	Hillslopes, ridges and crests; lithosols and shallow brown earths.
H4	Cypress Pine Woodlands	*Callitris glaucophylla, Eucalyptus dwyeri, Stipa scabra* subsp. *scabra, Danthonia setacea.*	Low crests and hillslopes on basalt; basalt derived clays.

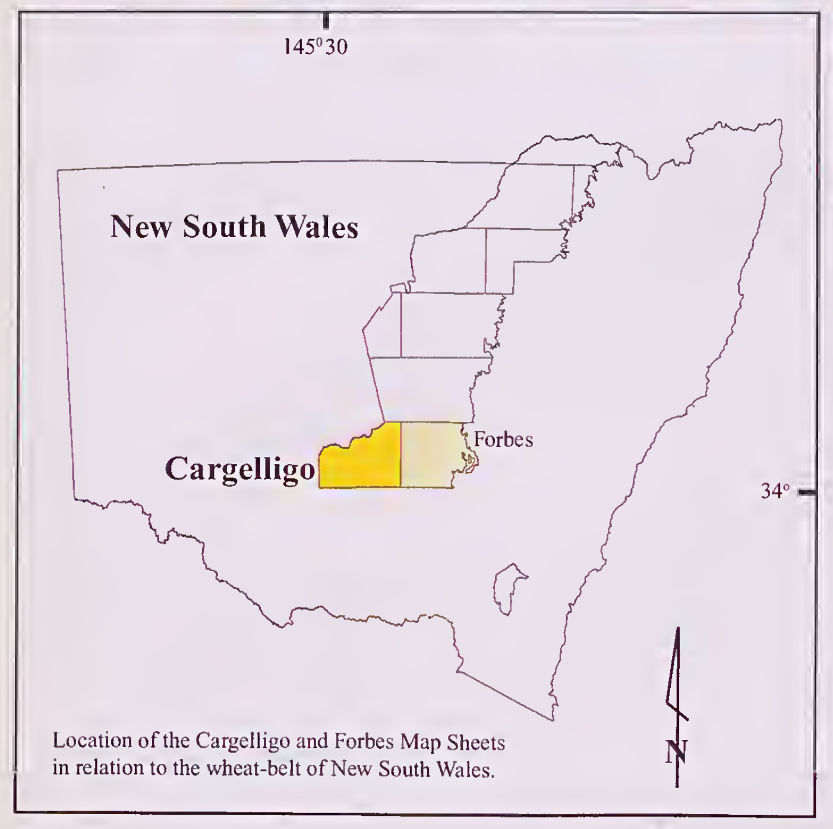
*The alpha / numeric codes refer to remnant vegetation descriptions in Table 2 of the accompanying report.
** Complete species lists for each map units can be found on the reverse side of this map.

NATURAL VEGETATION
of the
SOUTHERN WHEAT-BELT
CARGELLIGO
1:250 000 Map

Dominic Sivertsen and Lisa Metcalfe

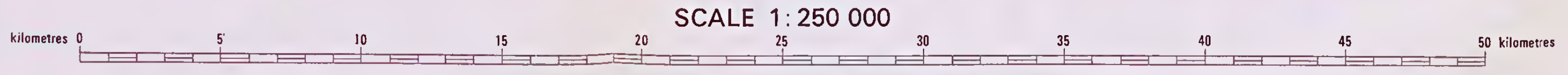
NSW National Parks and Wildlife Service to accompany

CUNNINGHAMIA VOLUME 4 NUMBER 1, 1995.
Royal Botanic Gardens Sydney



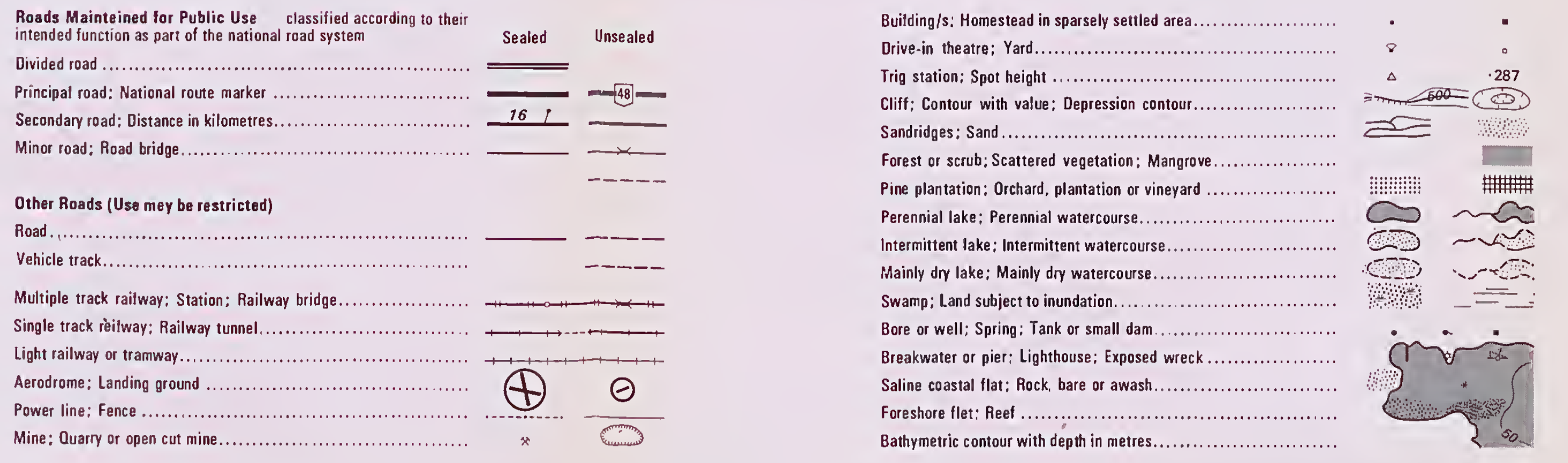
Location of the Cargelligo and Forbes Map Sheets in relation to the wheat-belt of New South Wales.

SCALE 1: 250 000



HEIGHTS IN METRES. CONTOUR INTERVAL 50 METRES

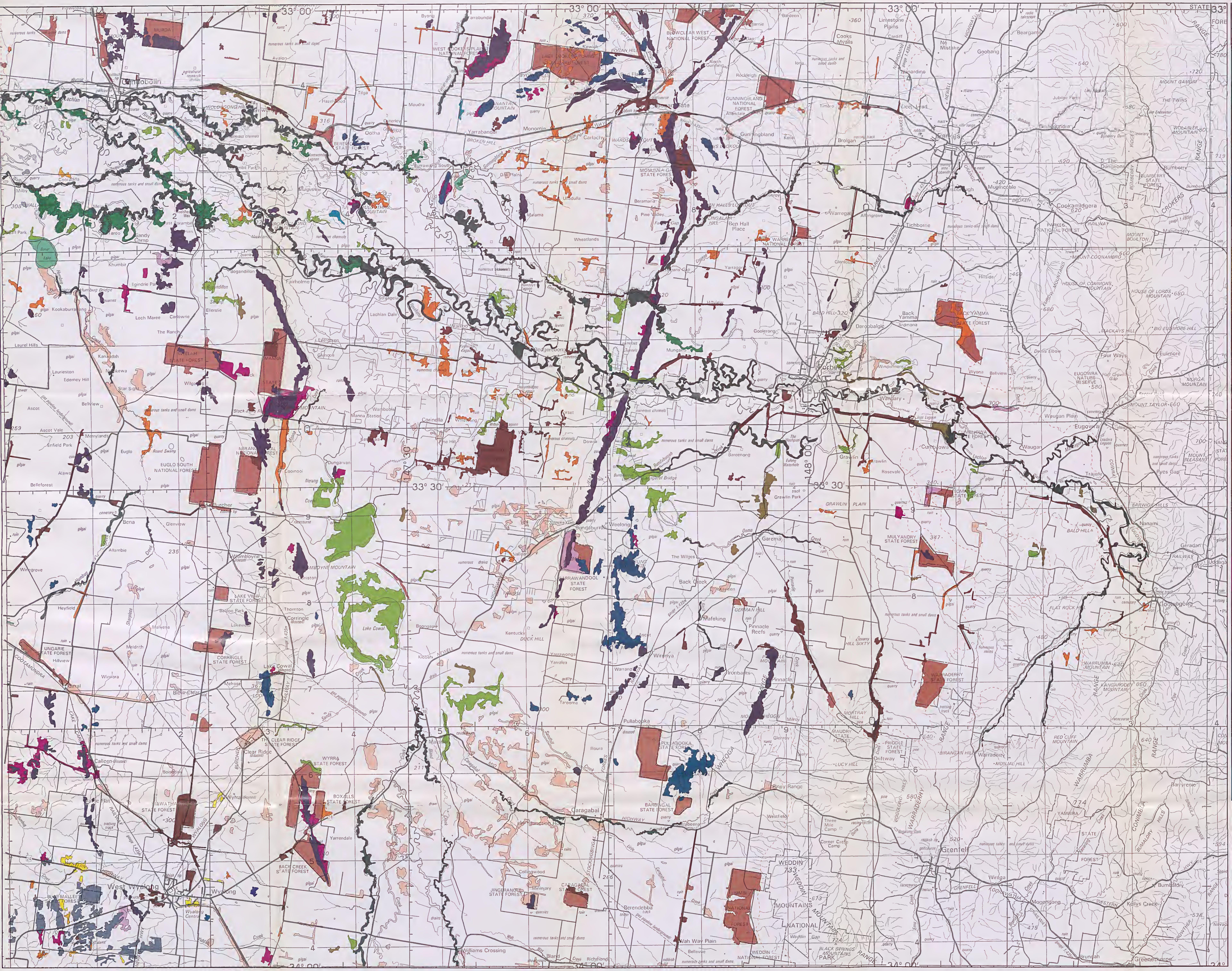
Horizontal Datum: Australian Geodetic Datum 1966
Vertical Datum: Australian Height Datum 1971
Transverse Mercator Projection: Australian Map Grid



Species list for the Forbes/Cargelligo Study Area.

Species are listed alphabetically by family then genus. The alphanumeric codes are the remnant types, as mapped, in which the species was recorded. Asterisks (*) denote exotic species.

FAMILY / Species	Common Name	R1	R2	R3	R4	R5	R6	P1	P2	P3	P4	P5	P6	P7	F2	F3	H1	H2	H4
ACANTHACEAE																			
Brunoniella australis	Blue Trumpet												P6				H1		
Rostellularia adscendens var. *pogonathera*	Pink Tongues			R3						P3	P4								
AIZOACEAE																			
Tetragonia tetragonoides	New Zealand Spinach									P3									
Glinus lotoides							R6												
AMARANTHACEAE																			
Alternanthera denticulata	Lesser Joyweed	R1	R2	R3						P3	P4		P6	P7					
Alternanthera nana	Hairy Joyweed		R2							P3	P4		P6						
**Amaranthus hybridus*	Slim Amaranth	R1																	
Ptilotus atriplicifolius var. *atriplicifolius*	Crimson Foxtail												P6	P7	F2				
Ptilotus erubescens	Hairy Tails																	H2	
Ptilotus indivisus	Tangled Silver Tails								P2										
Ptilotus macrocephalus	Green Pussy Tails							P1			P4	P5	P6						
Ptilotus obovatus var. *obovatus*	Silver Tails								P2	P3		P5							
Ptilotus semilanatus	Lamb Tails									P3	P4		P6	P7					
Ptilotus spathulatus	Pussy Tails										P4		P6						
AMARYLLIDACEAE																			
Calostemma purpureum	Garland Lily																H1		
Crinum flaccidum	Darling Lily			R3															
ANTHERICACEAE																			
Arthropodium minus	Small Vanilla Lily	R1									P4		P6	P7	F2	F3	H1	H2	
Dichopogon fimbriatus	Nodding Chocolate Lily										P4		P6						
Dichopogon strictus	Chocolate Lily										P4		P6						
Thysanotus baueri										P3			P6		F2			H2	
Thysanotus tuberosus	Common Fringe Lily	R1								P3	P4		P6				H1		
Tricoryne elatior	Yellow Autumn Lily										P4		P6		F2		H1		
APIACEAE																			
Daucus glochidiatus	Native Carrot							P1	P2	P3	P4	P5	P6		F2	F3	H1		
Eryngium rostratum	Blue Devil	R1																	
Hydrocotyle laxiflora	Stinking Pennywort												P6						
Platysace lanceolata																	H1		H4
Trachymene cyanopetala	Purple Parsnip																H1		
Trachymene ornata	Sponge-fruit														F2		H1		
APOCYNACEAE																			
Parsonsia eucalyptophylla	Gargaloo											P5	P6		F2	F3	H1		
ASCLEPIADACEAE																			
**Gomphocarpus fruticosus*	Narrow-leaved Cotton Bush												P6						
Marsdenia australis	Doubah							P1									H1		
Rhyncharrhena linearis										P3								H2	
ASPHODELACEAE																			
**Asphodelus fistulosus*	Onion Weed	R1																	
Bulbine bulbosa	Bulbine Lily		R2	R3					P2		P4		P6		F2		H1	H2	
Bulbine semibarbata	Leek Lily			R3							P4		P6						
ASPLENIACEAE																			
Pleurosorus subglandulosus																	H1		
ASTERACEAE																			
Actinobole uliginosum	Flannel Cudweed							P1	P2	P3	P4		P6		F2		H1	H2	
**Arctotheca calendula*	Cape Weed									P3	P4								
Brachycome ciliaris	Variable Daisy	R1						P1			P4								
Brachycome lineariloba	Hard-headed Daisy			R3															
Brachycome melanocarpa	Black-seeded Daisy							P1				P5							
Brachycome trachycarpa	Smooth Daisy	R1																	
Bracteantha bracteata	Golden Everlasting	R1						P1		P3	P4		P6	P7	F2	F3	H1	H2	H4
Bracteantha viscosa	Sticky Everlasting	R1						P1		P3	P4	P5	P6		F2	F3	H1		H4
**Calendula arvensis*	Field Marigold	R1											P6						
Calocephalus sonderi	Pale Beauty-heads			R3															
Calotis anthemoides	Cut-leaved Burr-daisy						R6				P4								
Calotis cuneifolia	Purple Burr-daisy	R1	R2	R3				P1		P3	P4		P6	P7	F2	F3	H1	H2	H4
Calotis hispidula	Bogan Flea								P2										
Calotis lappulacea	Yellow Burr-daisy										P4		P6						
Calotis scabiosifolia	Rough Burr-daisy	R1		R3							P4								
Calotis scapigera	Tufted Burr-daisy	R1	R2	R3							P4								H4
**Carduus tenuiflorus*	Winged Slender Thistle	R1	R2								P4		P6						
**Carthamus lanatus*	Saffron Thistle							P1	P2										
Cassinia aculeata	Dolly Bush										P4								
Cassinia adunca																			H4
Cassinia laevis	Cough Bush										P4		P6	P7	F2		H1		H4
Cassinia uncata	Sticky Cassinia							P1			P4						H1		H4
**Centaurea calcitropa*	Star Thistle	R1		R3						P3			P6			F3	H1		
**Centaurea melitensis*	Maltese Cockspur	R1		R3				P1	P2	P3	P4		P6		F2	F3	H1		
Centipeda cunninghamii	Common Sneezeweed	R1	R2	R3							P4								
Centipeda thespidioides	Desert Sneezeweed			R3															
**Chondrilla juncea*	Skeleton Weed	R1									P4		P6	P7		F3			
Chrysocephalum apiculatum	Common Everlasting	R1	R2	R3	R4		R6	P1	P2	P3	P4	P5	P6	P7		F3	H1	H2	
Chrysocephalum semipapposum	Clustered Everlasting							P1		P3	P4		P6	P7	F2		H1		H4
**Cichorium intybus*	Chicory	R1																	
**Cirsium vulgare*	Spear Thistle										P4		P6						
**Conyza bonariensis*	Flaxleaf Fleabane		R2	R3															
Eclipta platyglossa		R1		R3															
Euchiton sphaericus				R3															
**Hedypnois rhagodioloides* subsp. *cretica*	Cretan Weed	R1	R2	R3						P3			P6						
Helichrysum rutidolepis	Pale Everlasting										P4								
Helichrysum semifertile	Dainty Everlasting																	H2	
Hyalosperma glutinosum subsp. *glutinosum*		R1		R3				P1	P2	P3	P4		P6	P7		F3			H4
Hyalosperma semisterile				R3				P1	P2	P3		P5	P6		F2	F3			
**Hypochaeris radicata*	Catsear	R1		R3				P1	P2	P3	P4	P5	P6	P7	F2	F3	H1	H2	H4
Ixiolaena brevicompta				R3															
Ixiolaena leptolepis				R3						P3	P4								
Ixiolaena tomentosa	Woolly Ixiolaena					R5													
Kippistia suaedifolia											P4		P6	P7					
**Lactuca saligna*	Willow-leaved Lettuce	R1	R2	R3	R4				P2	P3	P4		P6	P7	F2	F3	H1		H4
**Lactuca serriola*	Prickly Lettuce	R1									P4						H1		
**Leontodon taraxacoides* subsp. *taraxacoides*	Lesser Hawkbit		R2																
Microseris lanceolata																		H2	
Millotia myosotidifolia	Broad-leaved Millotia																H1		
Minuria denticulata											P4							H2	
Minuria integerrima		R1					R6												
Minuria leptophylla										P3	P4		P6						
Olearia floribunda																			H4
Olearia pimeleoides								P1	P2	P3	P4	P5			F2				
Olearia ramulosa																	H1		
Olearia tenuifolia											P4				F2				
**Onopordum acanthium* subsp. *acanthium*	Scotch Thistle	R1	R2	R3			R6				P4	P5	P6		F2				
Ozothamnus obcordatus subsp. *obcordatus*											P4		P6						H4
Ozothamnus tuckeri														P7					
**Picris hieracioides*	Hawkweed Picris	R1											P6						
Podolepis arachnoidea	Clustered Copper-wire Daisy										P4		P6		F2	F3	H1		
**Podospermum resedifolium*														P7					
Pterocaulon redolens															F2				
Pycnosorus chrysanthus		R1																	
Pycnosorus globosus				R3															
**Reichardia tingitana*	False Sowthistle		R2						P2	P3	P4								
Rhodanthe corymbiflora	Small White Sunray			R3			R6			P3	P4		P6	P7				H2	
Rhodanthe diffusa subsp. *diffusa*	Ascending Sunray			R3															
Rhodanthe floribunda		R1							P2	P3									
Rhodanthe polygalifolia	Brilliant Sunray									P3	P4								
Senecio quadridentatus	Cotton Fireweed										P4		P6						
Solenogyne bellioides		R1		R3							P4						H1		
**Sonchus oleraceus*	Common Sowthistle	R1	R2	R3	P4		R6			P3	P4	P5	P6	P7	F2	F3	H1		
**Taraxacum officinale*	Dandelion								P2								H1		
Triptilodiscus pygmaeus											P4								
Vittadinia cuneata var. *cuneata*	Fuzzweed						R6				P4								
Vittadinia cuneata var. *hirsuta*	Fuzzweed			R3							P4					F3			
Vittadinia dissecta var. *hirta*		R1		R3				P1	P2	P3	P4	P5	P6	P7	F2	F3	H1		H4
Vittadinia gracilis											P4								
Vittadinia pterochaeta	Rough Fuzzweed	R1		R3			R6	P1	P2	P3	P4	P5	P6	P7	F2			H2	
**Xanthium occidentale*	Noogoora Burr	R1	R2	R3															
**Xanthium spinosum*	Bathurst Burr	R1	R2								P4								
BIGNONIACEAE																			
Pandorea pandorana	Wonga Wonga Vine																H1	H2	
BORAGINACEAE																			
**Burglossoides arvensis*	Sheepweed			R3															
Cynoglossum australe		R1									P4							H2	
**Echium plantagineum*	Paterson's Curse	R1	R2	R3	F4		R6		P2	P3	P4		P6	P7	F2	F3	H1	H2	
Halgania cyanea	Rough Halgania							P1		P3		P5		P7					
Heliotropium asperrimum	Rough Heliotrope												P6						
Heliotropium europaeum	Common Heliotrope	R1																	
**Heliotropium supinum*	Prostrate Heliotrope	R1		R3															
BRASSICACEAE																			
Harmsiodoxa brevipes var. *major*				R3							P4								
**Lepidium africanum*		R1	R2	R3			R6			P3	P4	P5							
**Lepidium bonariense*											P4								
Lepidium pseudohyssopifolium	Peppercress	R1	R2	R3			R6			P3	P4		P6	P7					
**Rapistrum rugosum*	Turnip Weed	R1	R2	R3															
**Sinapis arvensis*	Charlock			R3															
**Sisymbrium altissimum*	Tall Mustard	R1																	
**Sisymbrium erysimoides*	Smooth Mustard	R1	R2	R3				P1		P3	P4			P7		F3			
Sisymbrium irio	London Rocket	R1	R2	R3			R6	P1	P2		P4	P5			F2				
**Sisymbrium orientale*	Indian Hedge Mustard			R3						P3					F2				
Stenopetalum lineare	Narrow Thread-petal								P2										
CACTACEAE																			
**Opuntia stricta*	Spiny Pest-pear									P3	P4						H1		
CAMPANULACEAE																			
Pratia concolor		R1		R3			R6			P3	P4								
Wahlenbergia communis	Tufted Bluebell										P4	P5	P6			F3			
Wahlenbergia fluminalis	River Bluebell	R1	R2	R3						P3	P4	P5	P6	P7	F2		H1		H4
Wahlenbergia gracilis		R1																	
Wahlenbergia luteola				R3															
Wahlenbergia planiflora subsp. *planiflora*		R1																	
Wahlenbergia queenslandica											P4		P6				H1	H2	
Wahlenbergia stricta subsp. *alterna*	Tall Bluebell	R1						P1		P3							H1		
CAPPARACEAE																			
Apophyllum anomalum	Warrior Bush									P3	P4			P7	F2				
CARYOPHYLLACEAE																			
**Arenaria serpyllifolia*	Thyme-leaved Sandwort												P6						
**Petrorhagia nanteuilii*	Proliferous Pink	R1									P4	P5	P6				H1	H2	
**Silene gallica* var. *quinquevulnera*	French Catchfly									P3	P4		P6		F2				
**Spergularia diandra*	Lesser Sandspurry			R3															
**Spergularia rubra*	Sandspurry		R2	R3			R6			P3	P4			P7	F2		H1	H2	
Stellaria angustifolia	Swamp Starwort			R3															
**Stellaria media*	Common Chickweed	R1																	
CASUARINACEAE																			
Allocasuarina luehmannii	Bulloak									P3	P4		P6	P7	F2	F3	H1		
Allocasuarina verticillata	Drooping Sheoak																H1	H2	
Casuarina cristata	Belah			R3				P1	P2	P3	P4		P6	P7	F2				
Casuarina cunninghamiana subsp. *cunninghamiana*	River Sheoak	R1																	
CHENOPODIACEAE																			
Atriplex leptocarpa	Slender-fruit Saltbush	R1		R3															
Atriplex semibaccata	Creeping Saltbush	R1	R2	R3		R5				P3	P4		P6	P7	F2				
Atriplex spinibractea											P4								
Atriplex stipitata	Mallee Saltbush									P3	P4								
Chenopodium cristatum	Crested Goosefoot	R1		R3						P3									
Chenopodium desertorum subsp. *desertorum*	Desert Goosefoot			R3					P2	P3	P4	P5	P6	P7	F2	F3		H2	H4
Chenopodium desertorum subsp. *microphyllum*	Desert Goosefoot								P2	P3						F3			
Chenopodium melanocarpum	Black Crumbweed		R2																
**Chenopodium murale*	Nettle-leaf Goosefoot		R2							P3									
Chenopodium nitrariaceum	Nitre Goosefoot		R2																
Chenopodium pumilio	Small Crumbweed	R1	R2										P6					H2	
Einadia hastata	Berry Saltbush										P4						H1		
Einadia nutans subsp. *nutans*	Climbing Saltbush	R1	R2	R3	R4	R5	R6	P1	P2	P3	P4	P5	P6	P7	F2	F3	H1		H4
Enchylaena tomentosa	Ruby Saltbush		R2	R3		R5				P3	P4		P6	P7		F3			H4
Maireana aphylla	Cotton Bush					R5	R6			P3	P4		P6		F2			H2	
Maireana decalvans	Black Cotton Bush			R3															
Maireana enchylaenoides	Winglass Fissure-weed			R3				P1		P3	P4	P5	P6	P7	F2	F3	H1	H2	
Maireana humillima										P3	P4		P6	P7		F3			
Maireana microphylla	Eastern Cotton Bush	R1								P3	P4		P6	P7	F2	F3			
Neobassia proceriflora	Soda Bush			R3															
Rhagodia spinescens	Thorny Saltbush		R2	R3		R5				P3	P4	P5	P6	P7					
Rhagodia ulicina																			H4
Salsola kali var. *kali*	Buckbush			R3						P3	P4			P7					
Sclerolaena bicornis var. *horrida*	Goathead Burr			R3				P1		P3	P4		P6	P7	F2				H4
Sclerolaena birchii	Galvanised Burr			R3						P3	P4		P6						
Sclerolaena divaricata	Tangled Copperburr			R3															
Sclerolaena muricata var. *villosa*	Black Rolypoly	R1	R2	R3	R4	R5	R6		P2	P3	P4			P7					
Sclerolaena parviflora	Mallee Copperburr								P2										
Sclerolaena stelligera	Star Copperburr						R6												
Sclerolaena tetracuspis	Brigalow Burr		R2	R3															
Threlkeldia inchoata	Tall Bonefruit			R3															
COLCHICACEAE																			
Wurmbea dioica	Early Nancy															F3			
CONVOLVULACEAE																			
**Convolvulus arvensis*	Bindweed									P3	P4								
Convolvulus erubescens	Australian Bindweed	R1								P3	P4		P6						
Dichondra repens	Kidney Weed	R1		R3						P3	P4		P6	P7	F2	F3	H1	H2	H4
Evolvulus alsinoides var. *decumbens*	Climbing Bindweed																	H2	
CRASSULACEAE																			
Crassula colorata	Dense Stonecrop			R3						P3	P4		P6	P7			H1	H2	
CUCURBITACEAE																			
**Cucumis myriocarpus*	Paddy Melon			R3															
CUPRESSACEAE																			
Callitris endlicheri	Black Cypress Pine	R1									P4				F2		H1		H4
Callitris glaucophylla	White Cypress Pine	R1						P1	P2	P3	P4	P5	P6	P7	F2	F3	H1	H2	
CYPERACEAE																			
Carex appressa	Tall Sedge	R1					R6												
Carex bichenoviana		R1																	
Carex inversa	Knob Sedge	R1	R2	R3			R6				P4			P7					
**Cyperus eragrostis*	Umbrella Sedge	R1																	
Cyperus exaltatus	Giant Sedge	R1																	
Cyperus gymnocaulos	Spiny Sedge	R1																	
Eleocharis pallens	Pale Spike-rush			R3															
Eleocharis plana	Ribbed Spike-rush	R1																	
Eleocharis pusilla	Small Spike-rush			R3															
Eleocharis sphacelata	Tall Spike-rush	R1																	
Lepidosperma laterale	Variable Sword-sedge																H1		
DILLENIACEAE																			
Hibbertia obtusifolia	Hoary Guinea-flower																H1		
Hibbertia riparia	Erect Guinea-flower																H1	H2	H4
ELATINACEAE																			
Bergia trimera	Small Water-fire	R1																	
EPACRIDACEAE																			
Astroloma humifusum	Native Cranberry																H1		
Melichrus urceolatus	Urn Heath												P6		F2		H1		H4
EUPHORBIACEAE																			
Bertya cunninghamii	Gooma Bush							P1		P3	P4		P6				H1		H4
Beyeria opaca	Smooth Wallaby-bush							P1											
Beyeria viscosa	Sticky Wallaby-bush																H1		
Chamaesyce drummondii	Caustic Weed	R1	R2	R3							P4		P6	P7			H1	H2	
Phyllanthus fuernrohrii	Sand Spurge																H1		
Phyllanthus hirtellus																	H1		
FABACEAE: CAESALPINIOIDEAE																			
Senna artemisioides subsp. *filifolia*	Silver Cassia							P1	P2		P4				F2	F3			
Senna artemisioides subsp. *zygophylla*	Silver Cassia							P1		P3	P4		P6	P7	F2				
FABACEAE: FABOIDEAE																			
Aotus mollis				R3															
Bossiaea walkeri	Cactus Pea							P1											
Daviesia genistifolia	Broom Bitter Pea												P6						
Daviesia ulicifolia	Gorse Bitter Pea														F2				
Dillwynia sericea	Showy Parrot Pea																		H4
Eutaxia microphylla	Mallee Bush Pea								P2										
Glycine canescens	Silky Glycine										P4		P6	P7	F2	F3	H1	H2	
Glycine clandestina	Twining Glycine	R1									P4		P6		F2				
Glycine latifolia		R1		R3			R6				P4		P6			F3			
Glycine tabacina	Variable Glycine									P3	P4		P6	P7		F3	H1		
Glycine tomentella	Rusty Glycine										P4							H2	
Glycyrrhiza acanthocarpa	Native Liquorice	R1																	
Hardenbergia violacea	False Sarsaparilla																H1		
Indigofera australis	Hill Indigo																H1		
Indigofera colutea	Rusty Indigo	R1																	
Indigofera psammophila															F2				
**Medicago laciniata*	Cut-leaved Medic	R1	R2	R3						P3	P4	P5	P6			F3			
**Medicago minima*	Woolly Burr Medic						R6				P4		P6			F3			
**Medicago polymorpha*	Burr Medic	R1	R2	R3			R6			P3	P4	P5	P6	P7	F2	F3			
**Medicago praecox*	Small-leaved Burr Medic	R1																	
**Medicago truncatula*	Barrel Medic			R3			R6				P4								
Psoralea tenax	Emu-foot	R1		R3															
Pultenaea cinerascens																	H1		
Pultenaea largiflorens															F2		H1		H4
Pultenaea microphylla	Spreading Bush Pea														F2				
Templetonia aculeata	Spiny Mallee Pea							P1											
**Trifolium angustifolium*	Narrow-leaved Clover	R1		R3			R6			P3	P4		P6			F3	H1		
**Trifolium arvense*	Haresfoot Clover	R1	R2	R3	R4					P3	P4		P6	P7	F2	F3	H1	H2	
**Trifolium campestre*	Hop Clover	R1		R3			R6				P4		P6	P7	F2	F3	H1	H2	
**Trifolium glomeratum*	Clustered Clover	R1	R2	R3						P3	P4		P6						
**Trifolium subterraneum*	Subterranean Clover			R3			R6												
**Trifolium tomentosum*	Woolly Clover	R1		R3									P6						
FABACEAE: MIMOSOIDEAE																			
Acacia brachybotrya	Grey Mulga							P1		P3									
Acacia burkittii	Sandhill Wattle							P1											
Acacia calamifolia	Wallowa								P2		P4				F2				
Acacia cultriformis	Knifed-leaved Wattle																		H4
Acacia deanei subsp. *deanei*	Green Wattle									P3	P4		P6	P7	F2	F3	H1		
Acacia deanei subsp. *paucijuga*	Green Wattle								P2	P3	P4		P6	P7					
Acacia decora	Western Golden Wattle										P4				F2	F3	H1		
Acacia difformis	Drooping Wattle									P3		P5							H4
Acacia doratoxylon	Currawang							P1		P3	P4		P6	P7	F2		H1	H2	H4
Acacia hakeoides	Hakea Wattle									P3	P4		P6		F2				
Acacia havilandiorum	Haviland's Wattle							P1		P3	P4		P6		F2				
Acacia homalophylla	Yarran							P1			P4			P7					
Acacia lineata	Streaked Wattle							P1	P2										H4
Acacia microcarpa	Manna Wattle												P6				H1		
Acacia oswaldii	Miljee							P1		P3	P4		P6	P7					H4
Acacia pendula	Weeping Myall			R3		R5				P3				P7					
Acacia pravifolia	Coil-pod Wattle																H1		
Acacia rigens	Needle Wattle							P1	P2										
Acacia salicina	Cooba		R2																
**Acacia saligna*	Golden Wreath Wattle	R1	R2	R3															
Acacia spectabilis	Mudgee Wattle												P6						
Acacia stenophylla	River Cooba	R1	R2				R6												
FUMARIACEAE																			
**Fumaria bastardii*	Bastard Fumitory	R1																	
GENTIANACEAE																			
Centaurium spicatum	Spike Centuary												P6						
**Centaurium tenuiflorum*													P6						
GERANIACEAE																			
**Erodium botrys*	Long Storkbill			R3															
Erodium crinitum	Blue Crowfoot									P3									
**Erodium malacoides*																	H1		
Geranium solanderi var. *solanderi*	Native Geranium	R1					R6			P3	P4	P5	P6			F3	H1		H4
Pelargonium inodorum		R1											P6				H1		
GOODENIACEAE																			
Brunonia australis	Blue Pincushion																H1		
Dampiera lanceolata	Grooved Dampiera												P6		F2				
Goodenia cycloptera	Serrated Goodenia			R3			R6	P1			P4	P5	P6	P7	F2	F3	H1	H2	H4
Goodenia fascicularis	Silky Goodenia			R3						P3			P6						
Goodenia glabra	Smooth Goodenia		R2	R3							P4	P5	P6	P7		F3			
Goodenia glauca	Pale Goodenia	R1		R3			R6												
Goodenia hederacea var. *hederacea*	Forest Goodenia							P1			P4		P6				H1		
Goodenia heteromera	Spreading Goodenia										P4		P6				H1		
Goodenia ovata																F3			H4
Goodenia pinnatifida	Scrambled Eggs							P1		P3	P4		P6	P7	F2	F3	H1		
Goodenia sp. *mallee*	Mallee Goodenia							P1	P2		P4		P6			F3	H1		
Scaevola aemula	Common Fan-flower										P4		P6						
HALORAGACEAE																			
Gonocarpus elatus	Hill Raspwort	R1									P4		P6		F2	F3	H1	H2	H4
Haloragis aspera	Rough Raspwort	R1		R3			R6										H1		
Haloragis glauca	Grey Raspwort	R1	R2	R3			R6												
Haloragis heterophylla	Variable Raspwort	R1																	
Myriophyllum verrucosum	Common Water-milfoil	R1																	
IRIDACEAE																			
**Romulea rosea* var. *australis*	Onion Grass									P3			P6	P7	F2				
JUNCACEAE																			
Juncus aridicola	Tussock Rush	R1	R2	R3															
Juncus australis				R3															
**Juncus bufonius*	Toad Rush	R1																	
Juncus flavidus		R1								P3	P4			P7					
Juncus homalocaulis	Jointed-leaf Rush	R1																	
Juncus radula	Hoary Rush		R2	R3		R5	R6				P4					F3			
Juncus remotiflorus		R1		R3			R6			P3	P4								
Juncus subsecundus	Finger Rush		R2	R3			R6				P4		P6	P7			H1		
LAMIACEAE																			
Ajuga australis	Austral Bugle							P1											
**Marrubium vulgare*	Horehound	R1	R2	R3			R6			P3	P4	P5	P6		F2				
Mentha diemenica	Slender Mint			R3									P6						
Mentha satureioides	Creeping Mint	R1		R3															
Prostanthera aspalathoides	Scarlet Mint-bush							P1											H4
Prostanthera serpyllifolia var. *microphylla*	Smalled-leaved Mint-bush							P1											
Prostanthera nivea	Snowy Mint-bush														F2			H2	
**Prunella vulgaris*	Self-heal	R1		R3															
**Salvia verbenaca*	Wild Sage										P4			P7					
Teucrium racemosum	Grey Germanda									P3	P4								
Westringia cheelii	Mallee Rosemary								P2										
LAURACEAE																			
Cassytha melantha	Mallee Strangle-vine							P1			P4	P5					H1		H4
LOGANIACEAE																			
Logania albiflora	Narrow-leaf Logania																H1		
Mitrasacme paradoxa	Wiry Mitrewort														F2				
LORANTHACEAE																			
Amyema linophyllum subsp. *orientale*	Slender-leaf Mistletoe									P3				P7					
Amyema miquelii	Box Mistletoe	R1	R2	R3						P3	P4		P6						H4
Amyema miraculosum subsp. *boormanii*	Fleshy Mistletoe																		H4
Amyema quandang var. *bancroftii*	Grey Mistletoe			R3		R5				P3									
Amyema quandang var. *quandang*	Grey Mistletoe													P7					
LYTHRACEAE																			
Lythrum hyssopifolia	Hyssop Loosestrife			R3															
MALVACEAE																			
Abutilon otocarpum	Desert Chinese Lantern														F2				
Hibiscus trionum	Bladder Ketmia	R1																	
**Malvastrum americanum*	Malvastrum	R1																	
**Modiola caroliniana*		R1									P4								
Sida corrugata	Corrugated Sida	R1	R2	R3			R6			P3	P4	P5	P6	P7	F2	F3	H1	H2	
Sida cunninghamii	Ridge Sida	R1		R3				P1		P3	P4		P6	P7	F2	F3		H2	
Sida fibulifera	Pin Sida	R1				R5					P4					F3			
Sida intricata	Twiggy Sida			R3						P3									
Sida petrophila	Rock Sida										P4								
**Sida rhombifolia*	Paddy's Lucerne			R3			R6												
Sida sp. C			R2	R3		R5							P6						
Sida trichopoda	High Sida	R1		R3															
MARSILEACEAE																			
Marsilea drummondii	Common Nardoo	R1	R2	R3	R4		R6				P4								
Marsilea hirsuta	Short-fruit Nardoo		R2	R3		R5				P3									
MYOPORACEAE																			
Eremophila bignoniiflora	Eurah										P4		P6		F2				
Eremophila debilis	Winter Apple		R2	R3		R5				P3	P4		P6	P7		F3			
Eremophila deserti	Turkeybush							P1		P3				P7					
Eremophila glabra	Tar Bush							P1	P2			P5	P6						
Eremophila longifolia	Berrigan									P3	P4								
Eremophila mitchellii	Budda							P1		P3				P7		F3			
Eremophila polyclada	Flowering Lignum		R2	R3															
Myoporum montanum	Western Boobialla							P1		P3	P4		P6	P7	F2				H4
MYRTACEAE																			
Calytrix tetragona	Common Fringe Myrtle							P1							F2		H1		
Eucalyptus albens	White Box												P6			F3	H1		
Eucalyptus blakelyi	Blakely's Red Gum													P7					
Eucalyptus camaldulensis	River Red Gum	R1	R2	R3			R6				P4								
Eucalyptus conica	Fuzzy Box						R6				P4		P6	P7					
Eucalyptus dumosa	Congoo Mallee							P1	P2	P3		P5	P6						H4
Eucalyptus dwyeri	Dwyer's Mallee Gum	R1											P6		F2		H1	H2	H4
Eucalyptus gracilis	Yorell							P1											H4
Eucalyptus intertexta	Red Box							P1		P3	P4		P6	P7	F2		H1	H2	
Eucalyptus largiflorens	Black Box	R1	R2	R3															
Eucalyptus leptophylla	Narrow-leaved Red Mallee							P1	P2										
Eucalyptus melliodora	Yellow Box	R1		R3			R6		P2	P3	P4		P6	P7	F2				
Eucalyptus microcarpa	Grey Box	R1					R6			P3	P4		P6	P7		F3	H1	H2	H4
Eucalyptus oleosa	Glossy-leaved Red Mallee							P1	P2										
Eucalyptus polybractea	Blue Mallee																		H4
Eucalyptus populnea subsp. *bimbil*	Poplar Box			R3						P3	P4	P5	P6		F2	F3		H2	
Eucalyptus sideroxylon	Mugga Ironbark							P1			P4		P6		F2		H1		H4
Eucalyptus socialis	Red Mallee							P1	P2	P3		P5							
Eucalyptus viridis	Green Mallee														F2				H4
Leptospermum divaricatum															F2		H1		H4
Leptospermum polygalifolium subsp. *transmontanum*																	H1		
Melaleuca lanceolata	Moonah																		H4
Melaleuca uncinata	Broombush							P1	P2			P5							H4
Micromyrtus ciliata	Fringed Heath-myrtle								P2								H1		
Micromyrtus sessilis								P1											
NYCTAGINACEAE																			
Boerhavia dominii	Tarvine	R1		R3			R6				P4		P6	P7		F3			
OLEACEAE																			
Jasminum lineare	Desert Jasmine										P4				F2				
ONAGRACEAE																			
Ludwigia peploides subsp. *montevidensis*	Water Primrose	R1																	
**Oenothera stricta*	Evening Primrose												P6						
ORCHIDACEAE																			
Caladenia patersonii	Spider Orchid																H1		
Pterostylis biseta									P2			P5			F2		H1		
OXALIDACEAE																			
Oxalis chnoodes		R1	R2	R3	R4	R5	R6			P3	P4		P6	P7	F2	F3	H1	H2	
PAPAVERACEAE																			
**Argemone ochroleuca* subsp. *ochroleuca*	Mexican Poppy			R3															
PHORMIACEAE																			
Dianella longifolia var. *longifolia*		R1	R2	R3				P1		P3	P4		P6	P7	F2		H1		
Dianella revoluta var. *revoluta*	Spreading Flax-lily							P1	P2	P3	P4	P5	P6		F2	F3	H1		H4
Stypandra glauca	Nodding Blue-lily																H1	H2	
PITTOSPORACEAE																			
Pittosporum phylliraeoides	Weeping Pittosporum			R3					P2	P3	P4	P5	P6	P7	F2				H4
PLANTAGINACEAE																			
Plantago cunninghamii		R1		R3							P4		P6	P7					
Plantago turrifera				R3							P4								
POACEAE																			
Agrostis avenacea		R1	R2	R3			R6				P4		P6				H1		H4
Amphipogon caricinus var. *caricinus*	Long Grey-beard Grass														F2		H1		
Aristida behriana	Bunched Wiregrass			R3						P3	P4	P5	P6				H1	H2	
Aristida jerichoensis var. *subspinulifera*	Jerico Wiregrass										P4				F2		H1	H2	
Aristida ramosa		R1									P4								
Aristida vagans	Threeawn Speargrass									P3									
Astrebla elymoides	Hoop Mitchell Grass										P4								
Astrebla lappacea	Curly Mitchell Grass	R1				R5													
**Avena ludoviciana*	Ludo Wild Oats	R1	R2	R3	R4		R6			P3	P4	P5	P6	P7	F2	F3	H1	H2	H4
**Avena sativa*	Oats	R1								P3	P4								
Bothriochloa decipiens	Red Grass									P3									
**Briza minor*	Shivery Grass																H1		H4
Bromus arenarius	Sand Brome			R3															
**Bromus catharticus*	Prarie Grass	R1	R2	R3			R6			P3	P4							H2	
**Bromus diandrus*	Great Brome	R1	R2	R3		R5			P2	P3	P4						H1		
**Bromus molliformis*	Soft Brome	R1	R2	R3	R4	R5	R6			P3	P4	P5	P6	P7	F2	F3	H1	H2	
**Bromus rubens*	Red Brome	R1	R2	R3				P1	P2	P3	P4	P5	P6	P7	F2	F3	H1	H2	H4
Chloris divaricata var. *divaricata*	Slender Chloris		R2																
Chloris truncata	Windmill Grass		R2	R3						P3			P6						
Cymbopogon refractus	Barbed Wire Grass																H1		
Cynodon dactylon	Couch	R1	R2																
**Cynodon incompletus*		R1																	
Danthonia auriculata	Lobed Wallaby Grass														F2		H1	H2	
Danthonia caespitosa	Ringed Wallaby Grass			R3				P1	P2		P4		P6	P7	F2			H2	
Danthonia duttoniana				R3			R6			P3	P4					F3	H1		
Danthonia eriantha											P4				F2		H1		H4
Danthonia linkii var. *fulva*		R1		R3		R5					P4	P5	P6				H1		H4
Danthonia linkii var. *linkii*											P4								
Danthonia monticola										P3	P4	P5	P6			F3	H1	H2	H2
Danthonia richardsonii													P6						
Danthonia setacea	Small-flowered Wallaby Grass	R1	R2	R3		R5	R6	P1	P2	P3	P4	P5	P6	P7	F2	F3	H1	H2	H2
Dichelachne micrantha	Shorthair Plume Grass		R2								P4		P6						H4
Echinopogon ovatus	Forest Hedgehog Grass			R3															
**Ehrharta calycina*	Perennial Veldtgrass			R3															
**Ehrharta longiflora*	Annual Veldtgrass										P4								
Elymus scaber var. *scaber*	Common Wheatgrass	R1		R3			R6	P1		P3	P4	P5	P6	P7	F2	F3	H1	H2	H4
Enteropogon acicularis		R1	R2	R3	R4	R5	R6		P2	P3	P4	P5	P6	P7	F2	F3	H1	H2	H4
Eragrostis falcata	Sickle Lovegrass	R1																	
Eragrostis lacunaria	Purple Lovegrass										P4			P7					
Eragrostis leptostachya	Paddock Lovegrass										P4								
Eragrostis parviflora	Weeping Lovegrass			R3															
Eragrostis setifolia	Neverfail			R3															
Eragrostis sororia				R3															
Eriochloa procera	Spring Grass								P2		P4								
Eriochloa pseudoacrotricha	Early Spring Grass			R3															
Eulalia aurea	Silky Brown Top	R1																	
**Hainardia cylindrica*	Common Barbgrass		R2	R3							P4								
Homopholis proluta		R1																	
**Hordeum leporinum*	Barley Grass	R1	R2	R3	R4	R5				P3	P4		P6		F2	F3		H2	H4
**Lamarckia aurea*	Golden Top			R3															
Leptochloa digitata	Umbrella Canegrass	R1		R3															
**Lolium perenne*	Perennial Ryegrass	R1		R3	R4		R6				P4								
**Lolium rigidum*	Wimmera Ryegrass	R1	R2	R3		R5	R6			P3	P4	P5	P6	P7	F2	F3			H4
Monachather paradoxa	Bandicoot Grass																H1		
Panicum effusum										P3	P4							H2	
Panicum queenslandicum var. *queenslandicum*	Yadbila Grass										P4								
Panicum subxerophilum	Gilgai Grass									P3	P4		P6				H1		
Paspalidium albovillosum											P4								
Paspalidium aversum		R1		R3															
Paspalidium constrictum	Knottybutt Grass	R1																	
Paspalidium distans		R1		R3															
Paspalidium globoideum	Shotgrass	R1																	
Paspalidium gracile	Slender Panic			R3									P6				H1		
Paspalidium jubiflorum	Warrego Grass	R1	R2	R3						P3							H1		
**Paspalum dilatatum*	Paspalum	R1	R2																
**Pentaschistis airoides*	False Hairgrass	R1						P1	P2	P3	P4		P6	P7	F2	F3	H1	H2	H4
Perotis rara	Comet Grass	R1		R3						P3									
**Phalaris minor*	Lesser Canary Grass			R3															
**Phalaris paradoxa*	Paradoxa Grass	R1	R2	R3		R5	R6			P3		P5	P6			F3			
Poa fordeana			R2	R3															
Poa labillardieri	Tussock Grass			R3							P4		P6				H1		
Poa sieberiana var. *sieberiana*											P4								
**Rostraria cristata*	Annual Cat's Tail									P3			P6		F2		H1		
**Rostraria pumila*	Rough Tail																	H2	
Sporobolus mitchellii	Rat's Tail Couch			R3			R6												
Stipa acrociliata											P4								
Stipa aristiglumis	Plains Grass	R1			R4						P4		P6	P7					
Stipa bigeniculata										P3									
Stipa blackii													P6						
Stipa densiflora		R1									P4		P6		F2		H1		
Stipa elegantissima	Feather Speargrass							P1	P2	P3	P4	P5	P6	P7					H4
Stipa eremophila												P5							
Stipa metatoris												P5							
Stipa nitida											P4								
Stipa nodosa													P6						
Stipa platychaeta	Flat-awn Speargrass									P3									
Stipa ramosissima	Stout Bamboo Grass						R6				P4		P6				H1		
Stipa scabra subsp. *scabra*	Speargrass	R1		R3				P1	P2	P3	P4	P5	P6	P7	F2	F3	H1	H2	H4
Stipa stuposa				R3						P3		P5	P6	P7			H1		
Stipa trichophylla								P1			P4					F3			
Stipa tuckeri										P3	P4		P6		F2	F3	H1		H4
Stipa verticillata										P3									
Stipa wakoolica		R1				R5				P3	P4		P6	P7	F2		H1	H2	
Thyridolepis mitchelliana	Mulga Mitchell Grass			R3					P2	P3	P4		P6		F2		H1	H2	
Triodia scariosa subsp. *scariosa*	Porcupine Grass							P1	P2			P5							
**Triticum aestivum*	Wheat	R1																	
**Vulpia bromoides*	Squirrel Tail Fescue	R1	R2	R3	R4					P3	P4		P6		F2	F3	H1	H2	H4
**Vulpia muralis*											P4		P5	P7					
**Vulpia myuros*	Rat's Tail Fescue	R1	R2	R3				P1	P2	P3	P4	P5	P6	P7	F2	F3	H1	H2	H4
POLYGONACEAE																			
**Emex australis*	Three Cornered Jacks									P3									
Muehlenbeckia florulenta	Lignum	R1	R2	R3	R4		R6				P4								
Persicaria decipiens	Slender Knotweed		R2																
Persicaria hydropiper	Water Pepper	R1																	
Persicaria orientalis	Princes Feathers	R1																	
Persicaria prostrata	Creeping Knotweed	R1	R2	R3															
**Polygonum arenastrum*	Wireweed										P4								
**Polygonum aviculare*	Wireweed	R1		R3			R6												
**Polygonum patulum*	Tree Hogweed						R6												
Polygonum plebeium	Small Knotweed			R3															
Rumex bidens		R1																	
Rumex brownii	Mud Dock	R1	R2	R3			R6			P3	P4		P6	P7		F3	H1		
**Rumex conglomeratus*	Clustered Dock	R1																	
**Rumex crispus*	Curled Dock	R1	R2																
Rumex crystallinus	Shiny Dock			R3															
Rumex stenoglottis											P4		P6						
Rumex tenax	Shiny Dock			R3															
PORTULACACEAE																			
Anacampseros australiana																		H2	
Calandrinia eremaea				R3				P1	P2							F3	H1		
PRIMULACEAE																			
**Anagallis arvensis*	Scarlet Pimpernel						R6			P3			P6			F3			
PROTEACEAE																			
Grevillea floribunda	Rusty Spider Flower																H1	H2	
Grevillea rosmarinifolia								P1											
Hakea tephrosperma								P1	P2		P4		P6		F2	F3	H1	H2	
RANUNCULACEAE																			
Clematis microphylla var. *microphylla*	Small-leaved Clematis							P1	P2	P3		P5					H1		
**Ranunculus muricatus*	Sharp Buttercup	R1																	
RHAMNACEAE																			
Ventilago viminalis	Supple Jack															F3			
ROSACEAE																			
**Rosa rubiginosa*	Sweet Briar	R1					R6												
RUBIACEAE																			
Asperula cunninghamii	Twining Woodruff										P4		P6	P7					
Canthium odoratum	Shiny-leaved Canthium														F2				
**Galium aparine*	Goosegrass			R3	R4		R6			P3	P4		P6						
**Galium divaricatum*	Slender Bedstraw										P4								
RUTACEAE																			
Eriostemon difformis subsp. *difformis*	Small-leaf Waxflower												P6						
Eriostemon myoporoides subsp. *acutus*	Long-leaf Waxflower																H1		
Geijera parviflora	Wilga			R3				P1	P2	P3	P4	P5	P6		F2		H1	H2	
Phebalium glandulosum subsp. *glandulosum*	Desert Phebalium							P1			P4								
Phebalium obcordatum	Club-leaf Phebalium														F2		H1		H4
Philotheca salsolifolia																	H1		
Philotheca sp. *A*											P4								
Zieria aspalathoides																	H1		
SANTALACEAE																			
Exocarpos cupressiformis	Native Cherry																		H4
Santalum acuminatum	Sweet Quandong										P4			P7					H4
Santalum lanceolatum	Northern Sandalwood																		H4
SAPINDACEAE																			
Alectryon oleifolius subsp. *elongatus*	Western Rosewood					R5			P2	P3	P4								
Atalaya hemiglauca	Whitewood										P4								
Dodonaea boroniifolia	Fern-leaf Hopbush																H1		
Dodonaea heteromorpha																			H4
Dodonaea peduncularis								P1	P2										
Dodonaea viscosa subsp. *angustissima*	Narrow-leaf Hopbush							P1	P2	P3	P4		P6			F3	H1		
Dodonaea viscosa subsp. *cuneata*	Narrow-leaf Hopbush							P1			P4		P6	P7	F2		H1		H4
Dodonaea viscosa subsp. *mucronata*	Narrow-leaf Hopbush	R1									P4				F2				
Dodonaea viscosa subsp. *spatulata*	Narrow-leaf Hopbush									P3	P4		P6		F2		H1		
SCROPHULARIACEAE																			
**Kickxia elatine* subsp. *crinita*	Twining Toadflax		R2				R6												
Mimulus gracilis	Slender Monkey-flower									P3							H1		
Orobanche cernua var. *australiana*	Australian Broomrape												P6			F3			
Veronica plebeia	Trailing Speedwell												P6						H4
SINOPTERIDACEAE																			
Cheilanthes austrotenuifolia	Rock Fern	R1		R3						P3	P4		P6	P7	F2	F3	H1	H2	H4
Cheilanthes distans	Bristle Cloak Fern									P3							H1		
Cheilanthes lasiophylla	Woolly Cloak Fern																H1		
SOLANACEAE																			
**Lycium ferocissimum*	African Boxthorn					R5				P3	P4		P6	P7					
Nicotiana simulans		R1																	
Solanum cinereum	Narrawa Burr												P6						
**Solanum elaeagnifolium*	Silver-leaved Nightshade			R3															
Solanum esuriale	Quena	R1	R2	R3	R4					P3	P4		P6						
Solanum ferocissimum													P6		F2		H1		
**Solanum nigrum*	Black-berry Nightshade	R1	R2	R3									P6		F2				
Solanum tetrathecum													P6						
STACKHOUSIACEAE																			
Stackhousia monogyna	Creamy Candles										P4								
Stackhousia viminea	Slender Stackhousia							P1	P2	P3	P4	P5	P6	P7	F2	F3	H1		
STERCULIACEAE																			
Brachychiton populneus subsp. *trilobus*	Kurrajong	R1								P3	P4		P6		F2	F3	H1	H2	
Brachychiton populneus subsp. *populneus*	Kurrajong	R1								P3	P4		P6		F2	F3	H1	H2	
THYMELAEACEAE																			
Pimelea flava subsp. *dichotoma*								P1											
Pimelea micrantha																	H1		
Pimelea microcephala	Shrubby Rice-flower							P1	P2										
Pimelea neo-anglica											P4								
Pimelea stricta	Gaunt Rice-flower								P2										
TYPHACEAE																			
Typha domingensis	Narrow-leaved Cumbungi		R2																
URTICACEAE																			
Parietaria debilis															F2				
VERBENACEAE																			
**Phyla nodiflora*	Carpet Weed	R1	R2	R3	R4						P4								
**Verbena bonariensis*	Purple Top			R3			R6												
Verbena officinalis	Common Verbena	R1	R2	R3		R5					P4								
**Verbena supina*	Trailing Verbena	R1		R3			R6												
VIOLACEAE																			
Hybanthus monopetalus	Slender Violet-bush														F2		H1	H2	
XANTHORRHOEACEAE																			
Lomandra confertifolia subsp. *rubiginosa*								P1											
Lomandra effusa	Scented Mat-rush							P1			P4	P5					H1		
Lomandra filiformis subsp. *coriacea*	Wattle Mat-rush												P6						
Lomandra glauca	Pale Mat-rush							P1					P6						
Lomandra leucocephala subsp. *leucocephala*	Woolly Mat-rush	R1									P4		P6			F3			
Lomandra longifolia	Spiny-headed Mat-rush	R1									P4		P6						
Lomandra multiflora subsp. *multiflora*	Many-flowered Mat-rush										P4		P6		F2		H1	H2	
Lomandra patens										P3	P4								
ZYGOPHYLLACEAE																			
**Tribulus terrestris*	Cat-head									P3	P4								
Zygophyllum glaucum	Pale Twinleaf			R3					P2				P7						



Pattern*	Remnant Type	Vegetation: Characteristic Species**	Landforms and Soils
		Riparian and Floodplain Remnants	
R1	**River Red Gum Forests**	*Eucalyptus camaldulensis, Acacia stenophylla, A. saligna.*	Banks, channels and backplains; grey cracking clay and polygenetic alluvial soils.
R2	**Floodplain Mosaic**	*Eucalyptus largiflorens, E. camaldulensis, Acacia salicina, Muehlenbeckia florulenta.*	Backplains, floodplains and banks; grey cracking soils.
R3	**Black Box Woodlands**	*Eucalyptus largiflorens, E. camaldulensis, E. populnea* subsp. *bimbil, Acacia salicina, Acacia pendula, Muehlenbeckia florulenta.*	Floodplains, closed depressions and very gentle rises; grey cracking clays with some red earths and brown clays.
R4	**Lignum Shrublands**	*Muehlenbeckia florulenta, Stipa aristiglumis.*	Flats and closed depression; brown clay.
R5	**Myall Woodlands**	*Acacia pendula, Amyema quandang, Danthonia setacea.*	Gilgaied flats; grey clay.
R6	**Yellow Box / River Red Gum Forests**	*Eucalyptus melliodora, E.camaldulensis.*	Flats and floodplains; brown earthy soils and clays.
		Undulating Peneplain Remnants	
P1	**Mallee Woodlands**	*Eucalyptus socialis, E. gracilis, E. dumosa, Callitris glaucophylla, Melaleuca uncinata, Stipa aristiglumis, Triodia scariosa* subsp. *scariosa.*	Flats and very gentle rises; sandy red earths.
P2	**Open Mallee Woodlands**	*Eucalyptus socialis, E. dumosa, E. oleosa, E. leptophylla, Callitris glaucophylla, Casuarina cristata s.lat., Chrysocephalum apiculatum.*	Flats and gentle rises; sandy red earths.
P3	**Open Box Woodlands**	*Callitris glaucophylla, Eucalyptus populnea* subsp. *bimbil, E. intertexta, E. microcarpa, Allocasuarina luehmannii.*	Flats and gentle slopes; loamy red earths minor sandy red and brown earths.
P4	**Box Woodlands**	*Eucalyptus populnea* subsp. *bimbil, E. microcarpa, E. conica, E. intertexta, Callitris glaucophylla, Allocasuarina luehmannii.*	Flats, very gentle slopes and minor drainage lines; loamy red earths, minor sandy and clayey red and brown earths.
P5	**Mallee / White Cypress Pine Intergrade**	*Callitris glaucophylla, Eucalyptus socialis, E. dumosa, Eremophila glabra, Melaleuca uncinata, Eremophila glabra, Triodia scariosa* subsp. *scariosa.*	Flats; sandy and loamy red earths.
P6	**White Cypress Pine Woodlands**	*Callitris glaucophylla, Eucalyptus populnea* subsp. *bimbil, E. microcarpa, Acacia deanei* subsp. *paucijuga, Dodonaea viscosa* subsp. *angustissima.*	Flats and gentle rises; loamy red earths.
P7	**Bull Oak / Belah Woodlands**	*Allocasuarina luehmannii, Callitris glaucophylla, Casuarina cristata s. lat., Acacia homalophylla, Myoporum montanum.*	Flats, minor drainage lines and shallow depressions; gilgaied clays and red earths.
		Footslope Remnants	
F1	**Grasslands**	*Stipa scabra* subsp. *scabra, Danthonia setacea.*	Slopes, low crests and flats; lithosols and colluvial soils.
F2	**Open Pine and Box Woodlands**	*Callitris glaucophylla, Eucalyptus populnea* subsp. *bimbil, E intertexta, E. dwyeri, Acacia doratoxylon, Brachychiton populneus.*	Footslopes and flats; colluvial red earths.
F3	**Pine and Box Woodlands**	*Callitris glaucophylla, Eucalyptus microcarpa, E. populnea* subsp. *bimbil, Acacia deanei* subsp. *deanei, Senna artemisioides.*	Footslopes and flats; red and brown earths.
		Hill and Ridge Remnants	
H1	**Dwyer's Red Gum and Pine Woodlands**	*Callitris glaucophylla, Eucalyptus dwyeri, E. sideroxylon, Callitris endlicheri, Brachychiton populneus, Acacia doratoxylon, Allocasuarina verticillata.*	Upper and mid-slopes, crests and ridges; lithosols and shallow brown earths.
H2	**Green Mallee Woodlands**	*Eucalyptus viridis, E. sideroxylon, E. dumosa, E. gracilis, E. polybractea, E. dwyeri, Callitris endlicheri, Melaleuca uncinata, Acacia doratoxylon.*	Low crests, gentle hillslopes and flats; lithosols and shallow brown earths.
H3	**Pine and Poplar Box Open Woodlands**	*Callitris glaucophylla, Eucalyptus populnea subsp. bimbil, E. dwyeri, Acacia doratoxylon, Casuarina verticillata.*	Hillslopes, ridges and crests; lithosols and shallow brown earths.
H4	**Cypress Pine Woodlands**	*Callitris glaucophylla, Eucalyptus dwyeri, Stipa scabra* subsp. *scabra, Danthonia setacea.*	Low crests and hillslopes on basalt; basalt derived clays.

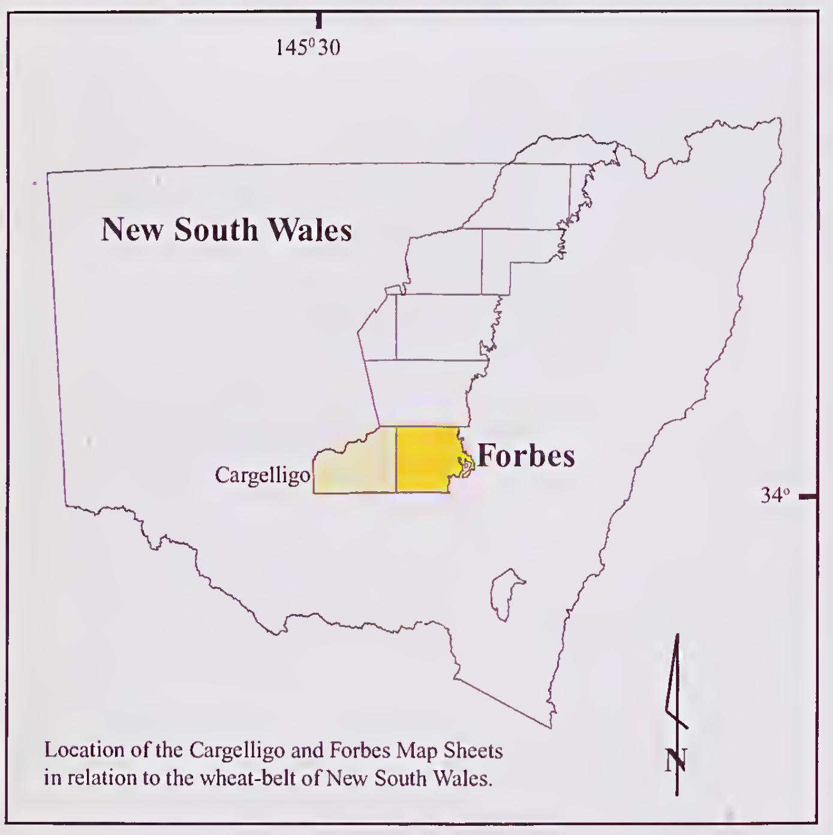
*The alpha / numeric codes refer to remnant vegetation descriptions in Table 2 of the accompanying report.
** Complete species lists for each remnant type can be found on the reverse side of this map.

NATURAL VEGETATION of the SOUTHERN WHEAT-BELT FORBES 1:250 000 Map

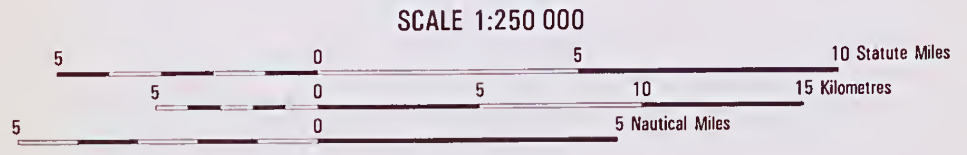
Dominic Sivertsen and Lisa Metcalfe

NSW National Parks and Wildlife Service to accompany

CUNNINGHAMIA VOLUME 4 NUMBER 1, 1995.
Royal Botanic Gardens Sydney



Location of the Cargelligo and Forbes Map Sheets in relation to the wheat-belt of New South Wales.



POPULATED PLACES
Built-up area; Homestead; Located object
Town/Settlement: Large; Small; Yard
ROADS
Sealed two or more lanes; Sealed one lane
Unsealed two or more lanes; Unsealed one lane
Vehicle track; Foot track or trail
HYDROGRAPHY
Lake: Perennial; Intermittent; Mainly dry
Marsh or swamp; River or creek; Mangrove
Subject to inundation; Ledge; Reef or rocks
Nipa; Intertidal flat; Shoal
Saline coastal flat; Wreck exposed
Rock bare or awash; Depth curve
RAILWAYS
Multiple track with station; Single track
BOUNDARIES
International; Other administrative
Interterritorial state, territory or province

Species list for the Forbes/Cargelligo Study Area.

Species are listed alphabetically by family then genus. The alphanumeric codes are the remnant types, as mapped, in which the species was recorded. Asterisks (*) denote exotic species.

FAMILY / Species	Common Name	R1	R2	R3	R4	R5	R6	P1	P2	P3	P4	P5	P6	P7	F2	F3	H1	H2	H4
ACANTHACEAE																			
Brunoniella australis	Blue Trumpet												P6				H1		
Rostellularia adscendens var. pogonathera	Pink Tongues			R3						P3	P4								
AIZOACEAE																			
Tetragonia tetragonoides	New Zealand Spinach									P3									
Glinus lotoides							R6												
AMARANTHACEAE																			
Alternanthera denticulata	Lesser Joyweed	R1	R2	R3						P3	P4		P6	P7					
Alternanthera nana	Hairy Joyweed		R2							P3	P4		P6						
*Amaranthus hybridus	Slim Amaranth	R1																	
Ptilotus atriplicifolius var. atriplicifolius	Crimson Foxtail												P6	P7	F2				
Ptilotus erubescens	Hairy Tails																	H2	
Ptilotus indivisus	Tangled Silver Tails								P2										
Ptilotus macrocephalus	Green Pussy Tails							P1			P4	P5	P6						
Ptilotus obovatus var. obovatus	Silver Tails								P2	P3		P5							
Ptilotus semilanatus	Lamb Tails									P3	P4		P6	P7					
Ptilotus spathulatus	Pussy Tails										P4		P6						
AMARYLLIDACEAE																			
Calostemma purpureum	Garland Lily																H1		
Crinum flaccidum	Darling Lily			R3															
ANTHERICACEAE																			
Arthropodium minus	Small Vanilla Lily	R1									P4		P6	P7	F2	F3	H1	H2	
Dichopogon fimbriatus	Nodding Chocolate Lily										P4		P6						
Dichopogon strictus	Chocolate Lily										P4		P6						
Thysanotus baueri										P3			P6		F2			H2	
Thysanotus tuberosus	Common Fringe Lily	R1								P3	P4		P6				H1		
Tricoryne elatior	Yellow Autumn Lily										P4		P6		F2		H1		
APIACEAE																			
Daucus glochidiatus	Native Carrot							P1	P2	P3	P4	P5	P6		F2	F3	H1		
Eryngium rostratum	Blue Devil	R1																	
Hydrocotyle laxiflora	Stinking Pennywort												P6						
Platysace lanceolata																	H1		H4
Trachymene cyanopetala	Purple Parsnip																H1		
Trachymene ornata	Sponge-fruit														F2		H1		
APOCYNACEAE																			
Parsonsia eucalyptophylla	Gargaloo											P5	P6		F2	F3	H1		
ASCLEPIADACEAE																			
*Gomphocarpus fruticosus	Narrow-leaved Cotton Bush												P6						
Marsdenia australis	Doubah							P1									H1		
Rhyncharrhena linearis										P3								H2	
ASPHODELACEAE																			
*Asphodelus fistulosus	Onion Weed	R1																	
Bulbine bulbosa	Bulbine Lily		R2	R3					P2		P4		P6		F2		H1	H2	
Bulbine semibarbata	Leek Lily			R3							P4		P6						
ASPLENIACEAE																			
Pleurosorus subglandulosus																	H1		
ASTERACEAE																			
Actinobole uliginosum	Flannel Cudweed							P1	P2	P3	P4		P6		F2		H1	H2	
*Arctotheca calendula	Cape Weed									P3	P4								
Brachycome ciliaris	Variable Daisy	R1						P1			P4								
Brachycome lineariloba	Hard-headed Daisy			R3															
Brachycome melanocarpa	Black-seeded Daisy							P1				P5							
Brachycome trachycarpa	Smooth Daisy	R1																	
Bracteantha bracteata	Golden Everlasting	R1						P1		P3	P4		P6	P7	F2	F3	H1	H2	H4
Bracteantha viscosa	Sticky Everlasting	R1						P1		P3	P4	P5	P6		F2	F3	H1		H4
*Calendula arvensis	Field Marigold	R1											P6						
Calocephalus sonderi	Pale Beauty-heads			R3															
Calotis anthemoides	Cut-leaved Burr-daisy						R6				P4								
Calotis cuneifolia	Purple Burr-daisy	R1	R2	R3				P1		P3	P4		P6	P7	F2	F3	H1	H2	H4
Calotis hispidula	Bogan Flea								P2										
Calotis lappulacea	Yellow Burr-daisy										P4		P6						
Calotis scabiosifolia	Rough Burr-daisy	R1		R3							P4								
Calotis scapigera	Tufted Burr-daisy	R1	R2	R3							P4								H4
*Carduus tenuiflorus	Winged Slender Thistle	R1	R2								P4		P6						
*Carthamus lanatus	Saffron Thistle							P1	P2										
Cassinia aculeata	Dolly Bush										P4								
Cassinia adunca																			H4
Cassinia laevis	Cough Bush										P4		P6	P7	F2		H1		H4
Cassinia uncata	Sticky Cassinia							P1			P4						H1		H4
*Centaurea calcitrapa	Star Thistle	R1		R3						P3			P6			F3	H1		
*Centaurea melitensis	Maltese Cockspur	R1		R3				P1	P2	P3	P4		P6		F2	F3	H1		
Centipeda cunninghamii	Common Sneezeweed	R1	R2	R3							P4								
Centipeda thespidioides	Desert Sneezeweed			R3															
*Chondrilla juncea	Skeleton Weed	R1									P4		P6	P7		F3			
Chrysocephalum apiculatum	Common Everlasting	R1	R2	R3	R4		R6	P1	P2	P3	P4	P5	P6	P7		F3	H1	H2	
Chrysocephalum semipapposum	Clustered Everlasting							P1		P3	P4		P6	P7	F2		H1		H4
*Cichorium intybus	Chicory	R1																	
*Cirsium vulgare	Spear Thistle										P4		P6						
*Conyza bonariensis	Flaxleaf Fleabane		R2	R3															
Eclipta platyglossa		R1		R3															
Euchiton sphaericus				R3															
*Hedypnois rhagadioloides subsp. cretica	Cretan Weed	R1	R2	R3						P3			P6						
Helichrysum rutidolepis	Pale Everlasting										P4								
Helichrysum semifertile	Dainty Everlasting																	H2	
Hyalosperma glutinosum subsp. glutinosum		R1		R3				P1	P2	P3	P4		P6	P7		F3			H4
Hyalosperma semisterile				R3				P1	P2	P3		P5	P6		F2	F3			
*Hypochaeris radicata	Catsear	R1		R3				P1	P2	P3	P4	P5	P6	P7	F2	F3	H1	H2	H4
Ixiolaena brevicompta				R3															
Ixiolaena leptolepis				R3						P3	P4								
Ixiolaena tomentosa	Woolly Ixiolaena					R5													
Kippistia suaedifolia											P4		P6	P7					
*Lactuca saligna	Willow-leaved Lettuce	R1	R2	R3	R4				P2	P3	P4		P6	P7	F2	F3	H1		H4
*Lactuca serriola	Prickly Lettuce	R1									P4						H1		
*Leontodon taraxacoides subsp. taraxacoides	Lesser Hawkbit		R2																
Microseris lanceolata																		H2	
Millotia myosotidifolia	Broad-leaved Millotia																H1		
Minuria denticulata											P4							H2	
Minuria integerrima		R1					R6												
Minuria leptophylla										P3	P4		P6						
Olearia floribunda																			H4
Olearia pimeleoides								P1	P2	P3	P4	P5			F2				
Olearia ramulosa																	H1		
Olearia tenuifolia											P4				F2				
*Onopordum acanthium subsp. acanthium	Scotch Thistle	R1	R2	R3			R6				P4	P5	P6		F2				
Ozothamnus obcordatus subsp. obcordatus											P4		P6						H4
Ozothamnus tuckeri														P7					
*Picris hieracioides	Hawkweed Picris	R1											P6						
Podolepis arachnoidea	Clustered Copper-wire Daisy										P4		P6		F2	F3	H1		
*Podospermum resedifolium														P7					
Pterocaulon redolens															F2				
Pycnosorus chrysanthus		R1																	
Pycnosorus globosus				R3															
*Reichardia tingitana	False Sowthistle		R2						P2	P3	P4								
Rhodanthe corymbiflora	Small White Sunray			R3			R6			P3	P4		P6	P7				H2	
Rhodanthe diffusa subsp. diffusa	Ascending Sunray			R3															
Rhodanthe floribunda		R1							P2	P3									
Rhodanthe polygalifolia	Brilliant Sunray									P3	P4								
Senecio quadridentatus	Cotton Fireweed										P4		P6						
Solenogyne bellioides		R1		R3							P4						H1		
*Sonchus oleraceus	Common Sowthistle	R1	R2	R3	R4		R6			P3	P4	P5	P6	P7	F2	F3	H1		
*Taraxacum officinale	Dandelion								P2								H1		
Triptilodiscus pygmaeus											P4								
Vittadinia cuneata var. cuneata	Fuzzweed						R6				P4								
Vittadinia cuneata var. hirsuta	Fuzzweed			R3							P4					F3			
Vittadinia dissecta var. hirta		R1		R3				P1	P2	P3	P4	P5	P6	P7	F2	F3	H1		H4
Vittadinia gracilis											P4								
Vittadinia pterochaeta	Rough Fuzzweed	R1		R3			R6	P1	P2	P3	P4	P5	P6	P7	F2			H2	
*Xanthium occidentale	Noogoora Burr	R1	R2	R3															
*Xanthium spinosum	Bathurst Burr	R1	R2								P4								
BIGNONIACEAE																			
Pandorea pandorana	Wonga Wonga Vine																H1	H2	
BORAGINACEAE																			
*Burglossoides arvensis	Sheepweed			R3															
Cynoglossum australe		R1									P4							H2	
*Echium plantagineum	Paterson's Curse	R1	R2	R3	R4		R6		P2	P3	P4		P6	P7	F2	F3	H1	H2	
Halgania cyanea	Rough Halgania							P1		P3		P5		P7					
Heliotropium asperrimum	Rough Heliotrope												P6						
Heliotropium europaeum	Common Heliotrope	R1																	
*Heliotropium supinum	Prostrate Heliotrope	R1		R3															
BRASSICACEAE																			
Harmsiodoxa brevipes var. major				R3							P4								
*Lepidium africanum		R1	R2	R3			R6			P3	P4	P5							
*Lepidium bonariense											P4								
Lepidium pseudohyssopifolium	Peppercress	R1	R2	R3			R6			P3	P4		P6	P7					
*Rapistrum rugosum	Turnip Weed	R1	R2	R3															
*Sinapis arvensis	Charlock			R3															
*Sisymbrium altissimum	Tall Mustard	R1																	
*Sisymbrium erysimoides	Smooth Mustard	R1	R2	R3				P1		P3	P4			P7		F3			
Sisymbrium irio	London Rocket	R1	R2	R3			R6	P1	P2		P4	P5			F2				
*Sisymbrium orientale	Indian Hedge Mustard			R3						P3					F2				
Stenopetalum lineare	Narrow Thread-petal								P2										
CACTACEAE																			
*Opuntia stricta	Spiny Pest-pear									P3	P4						H1		
CAMPANULACEAE																			
Pratia concolor		R1		R3			R6			P3	P4								
Wahlenbergia communis	Tufted Bluebell										P4	P5	P6			F3			
Wahlenbergia fluminalis	River Bluebell	R1	R2	R3						P3	P4	P5	P6	P7	F2		H1		H4
Wahlenbergia gracilis		R1																	
Wahlenbergia luteola				R3															
Wahlenbergia planiflora subsp. planiflora		R1																	
Wahlenbergia queenslandica											P4		P6				H1	H2	
Wahlenbergia stricta subsp. alterna	Tall Bluebell	R1						P1		P3							H1		
CAPPARACEAE																			
Apophyllum anomalum	Warrior Bush									P3	P4			P7	F2				
CARYOPHYLLACEAE																			
*Arenaria serpyllifolia	Thyme-leaved Sandwort												P6						
*Petrorhagia nanteuilii	Proliferous Pink	R1									P4	P5	P6				H1	H2	
*Silene gallica var. quinquevulnera	French Catchfly									P3	P4		P6		F2				
*Spergularia diandra	Lesser Sandspurry			R3															
*Spergularia rubra	Sandspurry		R2	R3			R6			P3	P4			P7	F2		H1	H2	
Stellaria angustifolia	Swamp Starwort			R3															
*Stellaria media	Common Chickweed	R1																	
CASUARINACEAE																			
Allocasuarina luehmannii	Bulloak									P3	P4		P6	P7	F2	F3	H1		
Allocasuarina verticillata	Drooping Sheoak																H1	H2	
Casuarina cristata	Belah			R3				P1	P2	P3	P4		P6	P7	F2				
Casuarina cunninghamiana subsp. cunninghamiana	River Sheoak	R1																	
CHENOPODIACEAE																			
Atriplex leptocarpa	Slender-fruit Saltbush	R1		R3															
Atriplex semibaccata	Creeping Saltbush	R1	R2	R3		R5				P3	P4		P6	P7	F2				
Atriplex spinibractea											P4								
Atriplex stipitata	Mallee Saltbush									P3	P4								
Chenopodium cristatum	Crested Goosefoot	R1		R3						P3									
Chenopodium desertorum subsp. desertorum	Desert Goosefoot			R3					P2	P3	P4	P5	P6	P7	F2	F3		H2	H4
Chenopodium desertorum subsp. microphyllum	Desert Goosefoot								P2	P3						F3			
Chenopodium melanocarpum	Black Crumbweed		R2																
*Chenopodium murale	Nettle-leaf Goosefoot		R2							P3									
Chenopodium nitrariaceum	Nitre Goosefoot		R2																
Chenopodium pumilio	Small Crumbweed	R1	R2										P6					H2	
Einadia hastata	Berry Saltbush										P4						H1		
Einadia nutans subsp. nutans	Climbing Saltbush	R1	R2	R3	R4	R5	R6	P1	P2	P3	P4	P5	P6	P7	F2	F3	H1		H4
Enchylaena tomentosa	Ruby Saltbush		R2	R3		R5				P3	P4		P6	P7		F3			H4
Maireana aphylla	Cotton Bush					R5	R6			P3	P4		P6		F2			H2	
Maireana decalvans	Black Cotton Bush			R3															
Maireana enchylaenoides	Winglass Fissure-weed			R3				P1		P3	P4	P5	P6	P7	F2	F3	H1	H2	
Maireana humillima										P3	P4		P6	P7		F3			
Maireana microphylla	Eastern Cotton Bush	R1								P3	P4		P6	P7	F2	F3			
Neobassia proceriflora	Soda Bush			R3															
Rhagodia spinescens	Thorny Saltbush		R2	R3		R5				P3	P4	P5	P6	P7					
Rhagodia ulicina																			H4
Salsola kali var. kali	Buckbush			R3						P3	P4			P7					
Sclerolaena bicornis var. horrida	Goathead Burr			R3				P1		P3	P4		P6	P7	F2				H4
Sclerolaena birchii	Galvanised Burr			R3						P3	P4		P6						
Sclerolaena divaricata	Tangled Copperburr			R3															
Sclerolaena muricata var. villosa	Black Rolypoly	R1	R2	R3	R4	R5	R6		P2	P3	P4			P7					
Sclerolaena parviflora	Mallee Copperburr								P2										
Sclerolaena stelligera	Star Copperburr						R6												
Sclerolaena tetracuspis	Brigalow Burr		R2	R3															
Threlkeldia inchoata	Tall Bonefruit			R3															
COLCHICACEAE																			
Wurmbea dioica	Early Nancy															F3			
CONVOLVULACEAE																			
*Convolvulus arvensis	Bindweed									P3	P4								
Convolvulus erubescens	Australian Bindweed	R1								P3	P4		P6						
Dichondra repens	Kidney Weed	R1		R3						P3	P4		P6	P7	F2	F3	H1	H2	H4
Evolvulus alsinoides var. decumbens	Climbing Bindweed																	H2	
CRASSULACEAE																			
Crassula colorata	Dense Stonecrop			R3						P3	P4		P6	P7			H1	H2	
CUCURBITACEAE																			
*Cucumis myriocarpus	Paddy Melon			R3															
CUPRESSACEAE																			
Callitris endlicheri	Black Cypress Pine	R1									P4				F2		H1		H4
Callitris glaucophylla	White Cypress Pine	R1						P1	P2	P3	P4	P5	P6	P7	F2	F3	H1	H2	
CYPERACEAE																			
Carex appressa	Tall Sedge	R1					R6												
Carex bichenoviana		R1																	
Carex inversa	Knob Sedge	R1	R2	R3			R6				P4			P7					
*Cyperus eragrostis	Umbrella Sedge	R1																	
Cyperus exaltatus	Giant Sedge	R1																	
Cyperus gymnocaulos	Spiny Sedge	R1																	
Eleocharis pallens	Pale Spike-rush			R3															
Eleocharis plana	Ribbed Spike-rush	R1																	
Eleocharis pusilla	Small Spike-rush			R3															
Eleocharis sphacelata	Tall Spike-rush	R1																	
Lepidosperma laterale	Variable Sword-sedge																H1		
DILLENIACEAE																			
Hibbertia obtusifolia	Hoary Guinea-flower																H1		
Hibbertia riparia	Erect Guinea-flower																H1	H2	H4
ELATINACEAE																			
Bergia trimera	Small Water-fire	R1																	
EPACRIDACEAE																			
Astroloma humifusum	Native Cranberry																H1		
Melichrus urceolatus	Urn Heath												P6		F2		H1		H4
EUPHORBIACEAE																			
Bertya cunninghamii	Gooma Bush							P1		P3	P4		P6				H1		H4
Beyeria opaca	Smooth Wallaby-bush							P1											
Beyeria viscosa	Sticky Wallaby-bush																H1		
Chamaesyce drummondii	Caustic Weed	R1	R2	R3							P4		P6	P7			H1	H2	
Phyllanthus fuernrohrii	Sand Spurge																H1		
Phyllanthus hirtellus																	H1		
FABACEAE: CAESALPINIOIDEAE																			
Senna artemisioides subsp. filifolia	Silver Cassia							P1	P2		P4				F2	F3			
Senna artemisioides subsp. zygophylla	Silver Cassia							P1		P3	P4		P6	P7	F2				
FABACEAE: FABOIDEAE																			
Aotus mollis				R3															
Bossiaea walkeri	Cactus Pea							P1											
Daviesia genistifolia	Broom Bitter Pea												P6						
Daviesia ulicifolia	Gorse Bitter Pea														F2				
Dillwynia sericea	Showy Parrot Pea																		H4
Eutaxia microphylla	Mallee Bush Pea								P2										
Glycine canescens	Silky Glycine										P4		P6	P7	F2	F3	H1	H2	
Glycine clandestina	Twining Glycine	R1									P4		P6		F2				
Glycine latifolia		R1		R3			R6				P4		P6			F3			
Glycine tabacina	Variable Glycine									P3	P4		P6	P7		F3	H1		
Glycine tomentella	Rusty Glycine										P4							H2	
Glycyrrhiza acanthocarpa	Native Liquorice	R1																	
Hardenbergia violacea	False Sarsaparilla																H1		
Indigofera australis	Hill Indigo																H1		
Indigofera colutea	Rusty Indigo	R1																	
Indigofera psammophila															F2				
*Medicago laciniata	Cut-leaved Medic	R1	R2	R3						P3	P4	P5	P6			F3			
*Medicago minima	Woolly Burr Medic						R6				P4		P6			F3			
*Medicago polymorpha	Burr Medic	R1	R2	R3			R6			P3	P4	P5	P6	P7	F2	F3			
*Medicago praecox	Small-leaved Burr Medic	R1																	
*Medicago truncatula	Barrel Medic			R3			R6				P4								
Psoralea tenax	Emu-foot	R1		R3															
Pultenaea cinerascens																	H1		
Pultenaea largiflorens															F2		H1		H4
Pultenaea microphylla	Spreading Bush Pea														F2				
Templetonia aculeata	Spiny Mallee Pea							P1											
*Trifolium angustifolium	Narrow-leaved Clover	R1		R3			R6			P3	P4		P6			F3	H1		
*Trifolium arvense	Haresfoot Clover	R1	R2	R3	R4					P3	P4		P6	P7	F2	F3	H1	H2	
*Trifolium campestre	Hop Clover	R1		R3			R6				P4		P6	P7	F2	F3	H1	H2	
*Trifolium glomeratum	Clustered Clover	R1	R2	R3						P3	P4		P6						
*Trifolium subterraneum	Subterranean Clover			R3			R6												
*Trifolium tomentosum	Woolly Clover	R1		R3									P6						
FABACEAE: MIMOSOIDEAE																			
Acacia brachybotrya	Grey Mulga							P1		P3									
Acacia burkittii	Sandhill Wattle							P1											
Acacia calamifolia	Wallowa								P2		P4				F2				
Acacia cultriformis	Knifed-leaved Wattle																		H4
Acacia deanei subsp. deanei	Green Wattle									P3	P4		P6	P7	F2	F3	H1		
Acacia deanei subsp. paucijuga	Green Wattle								P2	P3	P4		P6	P7					
Acacia decora	Western Golden Wattle										P4				F2	F3	H1		
Acacia difformis	Drooping Wattle									P3		P5							H4
Acacia doratoxylon	Currawang							P1		P3	P4		P6	P7	F2		H1	H2	H4
Acacia hakeoides	Hakea Wattle									P3	P4		P6		F2				
Acacia havilandiorum	Haviland's Wattle							P1		P3	P4		P6		F2				
Acacia homalophylla	Yarran							P1			P4			P7					
Acacia lineata	Streaked Wattle							P1	P2										H4
Acacia microcarpa	Manna Wattle												P6				H1		
Acacia oswaldii	Miljee							P1		P3	P4		P6	P7					H4
Acacia pendula	Weeping Myall			R3		R5				P3				P7					
Acacia pravifolia	Coil-pod Wattle																H1		
Acacia rigens	Needle Wattle							P1	P2										
Acacia salicina	Cooba		R2																
*Acacia saligna	Golden Wreath Wattle	R1	R2	R3															
Acacia spectabilis	Mudgee Wattle												P6						
Acacia stenophylla	River Cooba	R1	R2				R6												
FUMARIACEAE																			
*Fumaria bastardii	Bastard Fumitory	R1																	
GENTIANACEAE																			
Centaurium spicatum	Spike Centuary												P6						
*Centaurium tenuiflorum													P6						
GERANIACEAE																			
*Erodium botrys	Long Storkbill			R3															
Erodium crinitum	Blue Crowfoot									P3									
*Erodium malacoides																	H1		
Geranium solanderi var. solanderi	Native Geranium	R1					R6			P3	P4	P5	P6			F3	H1		H4
Pelargonium inodorum		R1											P6				H1		
GOODENIACEAE																			
Brunonia australis	Blue Pincushion																H1		
Dampiera lanceolata	Grooved Dampiera												P6		F2				
Goodenia cycloptera	Serrated Goodenia			R3			R6	P1			P4	P5	P6	P7	F2	F3	H1	H2	H4
Goodenia fascicularis	Silky Goodenia			R3						P3			P6						
Goodenia glabra	Smooth Goodenia		R2	R3							P4	P5	P6	P7		F3			
Goodenia glauca	Pale Goodenia	R1		R3			R6												
Goodenia hederacea var. hederacea	Forest Goodenia							P1			P4		P6				H1		
Goodenia heteromera	Spreading Goodenia										P4		P6				H1		
Goodenia ovata																F3			H4
Goodenia pinnatifida	Scrambled Eggs							P1		P3	P4		P6	P7	F2	F3	H1		
Goodenia sp. mallee	Mallee Goodenia							P1	P2		P4		P6			F3	H1		
Scaevola aemula	Common Fan-flower										P4		P6						
HALORAGACEAE																			
Gonocarpus elatus	Hill Raspwort	R1									P4		P6		F2	F3	H1	H2	H4
Haloragis aspera	Rough Raspwort	R1		R3			R6										H1		
Haloragis glauca	Grey Raspwort	R1	R2	R3			R6												
Haloragis heterophylla	Variable Raspwort	R1																	
Myriophyllum verrucosum	Common Water-milfoil	R1																	
IRIDACEAE																			
*Romulea rosea var. australis	Onion Grass									P3			P6	P7	F2				
JUNCACEAE																			
Juncus aridicola	Tussock Rush	R1	R2	R3															
Juncus australis				R3															
*Juncus bufonius	Toad Rush	R1																	
Juncus flavidus		R1								P3	P4			P7					
Juncus homalocaulis	Jointed-leaf Rush	R1																	
Juncus radula	Hoary Rush		R2	R3		R5	R6				P4					F3			
Juncus remotiflorus		R1		R3			R6			P3	P4								
Juncus subsecundus	Finger Rush		R2	R3			R6				P4		P6	P7			H1		
LAMIACEAE																			
Ajuga australis	Austral Bugle							P1											
*Marrubium vulgare	Horehound	R1	R2	R3			R6			P3	P4	P5	P6		F2				
Mentha diemenica	Slender Mint			R3									P6						
Mentha satureioides	Creeping Mint	R1		R3															
Prostanthera aspalathoides	Scarlet Mint-bush							P1											H4
Prostanthera serpyllifolia var. microphylla	Smalled-leaved Mint-bush							P1											
Prostanthera nivea	Snowy Mint-bush														F2			H2	
*Prunella vulgaris	Self-heal	R1		R3															
*Salvia verbenaca	Wild Sage										P4			P7					
Teucrium racemosum	Grey Germanda									P3	P4								
Westringia cheelii	Mallee Rosemary								P2										
LAURACEAE																			
Cassytha melantha	Mallee Strangle-vine							P1			P4	P5					H1		H4
LOGANIACEAE																			
Logania albiflora	Narrow-leaf Logania																H1		
Mitrasacme paradoxa	Wiry Mitrewort														F2				
LORANTHACEAE																			
Amyema linophyllum subsp. orientale	Slender-leaf Mistletoe									P3				P7					
Amyema miquelii	Box Mistletoe	R1	R2	R3						P3	P4		P6						H4
Amyema miraculosum subsp. boormanii	Fleshy Mistletoe																		H4
Amyema quandang var. bancroftii	Grey Mistletoe			R3		R5				P3									
Amyema quandang var. quandang	Grey Mistletoe													P7					
LYTHRACEAE																			
Lythrum hyssopifolia	Hyssop Loosestrife			R3															
MALVACEAE																			
Abutilon otocarpum	Desert Chinese Lantern														F2				
Hibiscus trionum	Bladder Ketmia	R1																	
*Malvastrum americanum	Malvastrum	R1																	
*Modiola caroliniana		R1									P4								
Sida corrugata	Corrugated Sida	R1	R2	R3			R6			P3	P4	P5	P6	P7	F2	F3	H1	H2	
Sida cunninghamii	Ridge Sida	R1		R3				P1		P3	P4		P6	P7	F2	F3		H2	
Sida fibulifera	Pin Sida	R1				R5					P4					F3			
Sida intricata	Twiggy Sida			R3						P3									
Sida petrophila	Rock Sida										P4								
*Sida rhombifolia	Paddy's Lucerne			R3			R6												
Sida sp. C			R2	R3		R5							P6						
Sida trichopoda	High Sida	R1		R3															
MARSILEACEAE																			
Marsilea drummondii	Common Nardoo	R1	R2	R3	R4		R6				P4								
Marsilea hirsuta	Short-fruit Nardoo		R2	R3		R5				P3									
MYOPORACEAE																			
Eremophila bignoniiflora	Eurah										P4		P6		F2				
Eremophila debilis	Winter Apple		R2	R3		R5				P3	P4		P6	P7		F3			
Eremophila deserti	Turkeybush							P1		P3				P7					
Eremophila glabra	Tar Bush							P1	P2			P5	P6						
Eremophila longifolia	Berrigan									P3	P4								
Eremophila mitchellii	Budda							P1		P3				P7		F3			
Eremophila polyclada	Flowering Lignum		R2	R3															
Myoporum montanum	Western Boobialla							P1		P3	P4		P6	P7	F2				H4
MYRTACEAE																			
Calytrix tetragona	Common Fringe Myrtle							P1							F2		H1		
Eucalyptus albens	White Box												P6			F3	H1		
Eucalyptus blakelyi	Blakely's Red Gum													P7					
Eucalyptus camaldulensis	River Red Gum	R1	R2	R3			R6				P4								
Eucalyptus conica	Fuzzy Box						R6				P4		P6	P7					
Eucalyptus dumosa	Congoo Mallee							P1	P2	P3		P5	P6						H4
Eucalyptus dwyeri	Dwyer's Mallee Gum	R1											P6		F2		H1	H2	H4
Eucalyptus gracilis	Yorell							P1											H4
Eucalyptus intertexta	Red Box							P1		P3	P4		P6	P7	F2		H1	H2	
Eucalyptus largiflorens	Black Box	R1	R2	R3															
Eucalyptus leptophylla	Narrow-leaved Red Mallee							P1	P2										
Eucalyptus melliodora	Yellow Box	R1		R3			R6		P2	P3	P4		P6	P7	F2				
Eucalyptus microcarpa	Grey Box	R1					R6			P3	P4		P6	P7		F3	H1	H2	H4
Eucalyptus oleosa	Glossy-leaved Red Mallee							P1	P2										
Eucalyptus polybractea	Blue Mallee																		H4
Eucalyptus populnea subsp. bimbil	Poplar Box			R3						P3	P4	P5	P6		F2	F3		H2	
Eucalyptus sideroxylon	Mugga Ironbark							P1			P4		P6		F2		H1		H4
Eucalyptus socialis	Red Mallee							P1	P2	P3		P5							
Eucalyptus viridis	Green Mallee														F2				H4
Leptospermum divaricatum															F2		H1		H4
Leptospermum polygalifolium subsp. transmontanum																	H1		
Melaleuca lanceolata	Moonah																		H4
Melaleuca uncinata	Broombush							P1	P2			P5							H4
Micromyrtus ciliata	Fringed Heath-myrtle								P2								H1		
Micromyrtus sessilis								P1											
NYCTAGINACEAE																			
Boerhavia dominii	Tarvine	R1		R3			R6				P4		P6	P7		F3			
OLEACEAE																			
Jasminum lineare	Desert Jasmine										P4				F2				
ONAGRACEAE																			
Ludwigia peploides subsp. montevidensis	Water Primrose	R1																	
*Oenothera stricta	Evening Primrose												P6						
ORCHIDACEAE																			
Caladenia patersonii	Spider Orchid																H1		
Pterostylis biseta									P2			P5			F2		H1		
OXALIDACEAE																			
Oxalis chnoodes		R1	R2	R3	R4	R5	R6			P3	P4		P6	P7	F2	F3	H1	H2	
PAPAVERACEAE																			
*Argemone ochroleuca subsp. ochroleuca	Mexican Poppy			R3															
PHORMIACEAE																			
Dianella longifolia var. longifolia		R1	R2	R3				P1		P3	P4		P6	P7	F2		H1		
Dianella revoluta var. revoluta	Spreading Flax-lily							P1	P2	P3	P4	P5	P6		F2	F3	H1		H4
Stypandra glauca	Nodding Blue-lily																H1	H2	
PITTOSPORACEAE																			
Pittosporum phylliraeoides	Weeping Pittosporum			R3					P2	P3	P4	P5	P6	P7	F2				H4
PLANTAGINACEAE																			
Plantago cunninghamii		R1		R3							P4		P6	P7					
Plantago turrifera				R3							P4								
POACEAE																			
Agrostis avenacea		R1	R2	R3			R6				P4		P6				H1		H4
Amphipogon caricinus var. caricinus	Long Grey-beard Grass														F2		H1		
Aristida behriana	Bunched Wiregrass			R3						P3	P4	P5	P6				H1	H2	
Aristida jerichoensis var. subspinulifera	Jerico Wiregrass										P4				F2		H1	H2	
Aristida ramosa		R1									P4								
Aristida vagans	Threeawn Speargrass									P3									
Astrebla elymoides	Hoop Mitchell Grass										P4								
Astrebla lappacea	Curly Mitchell Grass	R1				R5													
*Avena ludoviciana	Ludo Wild Oats	R1	R2	R3	R4		R6			P3	P4	P5	P6	P7	F2	F3	H1	H2	H4
*Avena sativa	Oats	R1								P3	P4								
Bothriochloa decipiens	Red Grass									P3									
*Briza minor	Shivery Grass																H1		H4
Bromus arenarius	Sand Brome			R3															
*Bromus catharticus	Prarie Grass	R1	R2	R3			R6			P3	P4							H2	
*Bromus diandrus	Great Brome	R1	R2	R3		R5			P2	P3	P4						H1		
*Bromus molliformis	Soft Brome	R1	R2	R3	R4	R5	R6			P3	P4	P5	P6	P7	F2	F3	H1	H2	
*Bromus rubens	Red Brome	R1	R2	R3				P1	P2	P3	P4	P5	P6	P7	F2	F3	H1	H2	H4
Chloris divaricata var. divaricata	Slender Chloris		R2																
Chloris truncata	Windmill Grass		R2	R3						P3			P6						
Cymbopogon refractus	Barbed Wire Grass																H1		
Cynodon dactylon	Couch	R1	R2																
*Cynodon incompletus		R1																	
Danthonia auriculata	Lobed Wallaby Grass														F2		H1	H2	
Danthonia caespitosa	Ringed Wallaby Grass			R3				P1	P2		P4		P6	P7	F2			H2	
Danthonia duttoniana				R3			R6			P3	P4					F3	H1		
Danthonia eriantha											P4				F2		H1		H4
Danthonia linkii var. fulva		R1		R3		R5					P4	P5	P6				H1		H4
Danthonia linkii var. linkii											P4								
Danthonia monticola										P3	P4	P5	P6			F3	H1	H2	H2
Danthonia richardsonii													P6						
Danthonia setacea	Small-flowered Wallaby Grass	R1	R2	R3		R5	R6	P1	P2	P3	P4	P5	P6	P7	F2	F3	H1	H2	H2
Dichelachne micrantha	Shorthair Plume Grass		R2								P4		P6						H4
Echinopogon ovatus	Forest Hedgehog Grass			R3															
*Ehrharta calycina	Perennial Veldtgrass			R3															
*Ehrharta longiflora	Annual Veldtgrass										P4								
Elymus scaber var. scaber	Common Wheatgrass	R1		R3			R6	P1		P3	P4	P5	P6	P7	F2	F3	H1	H2	H4
Enteropogon acicularis		R1	R2	R3	R4	R5	R6		P2	P3	P4	P5	P6	P7	F2	F3	H1	H2	H4
Eragrostis falcata	Sickle Lovegrass	R1																	
Eragrostis lacunaria	Purple Lovegrass										P4			P7					
Eragrostis leptostachya	Paddock Lovegrass										P4								
Eragrostis parviflora	Weeping Lovegrass			R3															
Eragrostis setifolia	Neverfail			R3															
Eragrostis sororia				R3															
Eriochloa procera	Spring Grass								P2		P4								
Eriochloa pseudoacrotricha	Early Spring Grass			R3															
Eulalia aurea	Silky Brown Top	R1																	
*Hainardia cylindrica	Common Barbgrass		R2	R3							P4								
Homopholis proluta		R1																	
*Hordeum leporinum	Barley Grass	R1	R2	R3	R4	R5				P3	P4		P6		F2	F3		H2	H4
*Lamarckia aurea	Golden Top			R3															
Leptochloa digitata	Umbrella Canegrass	R1		R3															
*Lolium perenne	Perennial Ryegrass	R1		R3	R4		R6				P4								
*Lolium rigidum	Wimmera Ryegrass	R1	R2	R3		R5	R6			P3	P4	P5	P6	P7	F2	F3			H4
Monachather paradoxa	Bandicoot Grass																H1		
Panicum effusum										P3	P4							H2	
Panicum queenslandicum var. queenslandicum	Yadbila Grass										P4								
Panicum subxerophilum	Gilgai Grass									P3	P4		P6				H1		
Paspalidium albovillosum											P4								
Paspalidium aversum		R1		R3															
Paspalidium constrictum	Knottybutt Grass	R1																	
Paspalidium distans		R1		R3															
Paspalidium globoideum	Shotgrass	R1																	
Paspalidium gracile	Slender Panic			R3									P6				H1		
Paspalidium jubiflorum	Warrego Grass	R1	R2	R3						P3							H1		
*Paspalum dilatatum	Paspalum	R1	R2																
*Pentaschistis airoides	False Hairgrass	R1						P1	P2	P3	P4		P6	P7	F2	F3	H1	H2	H4
Perotis rara	Comet Grass	R1		R3						P3									
*Phalaris minor	Lesser Canary Grass			R3															
*Phalaris paradoxa	Paradoxa Grass	R1	R2	R3		R5	R6			P3		P5	P6			F3			
Poa fordeana			R2	R3															
Poa labillardieri	Tussock Grass			R3							P4		P6				H1		
Poa sieberiana var. sieberiana											P4								
*Rostraria cristata	Annual Cat's Tail									P3			P6		F2		H1		
*Rostraria pumila	Rough Tail																	H2	
Sporobolus mitchellii	Rat's Tail Couch			R3			R6												
Stipa acrociliata											P4								
Stipa aristiglumis	Plains Grass	R1			R4						P4		P6	P7					
Stipa bigeniculata										P3									
Stipa blackii													P6						
Stipa densiflora		R1									P4		P6		F2		H1		
Stipa elegantissima	Feather Speargrass							P1	P2	P3	P4	P5	P6	P7					H4
Stipa eremophila												P5							
Stipa metatoris												P5							
Stipa nitida											P4								
Stipa nodosa													P6						
Stipa platychaeta	Flat-awn Speargrass									P3									
Stipa ramosissima	Stout Bamboo Grass						R6				P4		P6				H1		
Stipa scabra subsp. scabra	Speargrass	R1		R3				P1	P2	P3	P4	P5	P6	P7	F2	F3	H1	H2	H4
Stipa stuposa				R3						P3		P5	P6	P7			H1		
Stipa trichophylla								P1			P4					F3			
Stipa tuckeri										P3	P4		P6		F2	F3	H1		H4
Stipa verticillata										P3									
Stipa wakoolica		R1				R5				P3	P4		P6	P7	F2		H1	H2	
Thyridolepis mitchelliana	Mulga Mitchell Grass			R3					P2	P3	P4		P6		F2		H1	H2	
Triodia scariosa subsp. scariosa	Porcupine Grass							P1	P2			P5							
*Triticum aestivum	Wheat	R1																	
*Vulpia bromoides	Squirrel Tail Fescue	R1	R2	R3	R4					P3	P4		P6		F2	F3	H1	H2	H4
*Vulpia muralis											P4		P5	P7					
*Vulpia myuros	Rat's Tail Fescue	R1	R2	R3				P1	P2	P3	P4	P5	P6	P7	F2	F3	H1	H2	H4
POLYGONACEAE																			
*Emex australis	Three Cornered Jacks									P3									
Muehlenbeckia florulenta	Lignum	R1	R2	R3	R4		R6				P4								
Persicaria decipiens	Slender Knotweed		R2																
Persicaria hydropiper	Water Pepper	R1																	
Persicaria orientalis	Princes Feathers	R1																	
Persicaria prostrata	Creeping Knotweed	R1	R2	R3															
*Polygonum arenastrum	Wireweed										P4								
*Polygonum aviculare	Wireweed	R1		R3			R6												
*Polygonum patulum	Tree Hogweed						R6												
Polygonum plebeium	Small Knotweed			R3															
Rumex bidens		R1																	
Rumex brownii	Mud Dock	R1	R2	R3			R6			P3	P4		P6	P7		F3	H1		
*Rumex conglomeratus	Clustered Dock	R1																	
*Rumex crispus	Curled Dock	R1	R2																
Rumex crystallinus	Shiny Dock			R3															
Rumex stenoglottis											P4		P6						
Rumex tenax	Shiny Dock			R3															
PORTULACACEAE																			
Anacampseros australiana																		H2	
Calandrinia eremaea				R3				P1	P2							F3	H1		
PRIMULACEAE																			
*Anagallis arvensis	Scarlet Pimpernel						R6			P3			P6			F3			
PROTEACEAE																			
Grevillea floribunda	Rusty Spider Flower																H1	H2	
Grevillea rosmarinifolia								P1											
Hakea tephrosperma								P1	P2		P4		P6		F2	F3	H1	H2	
RANUNCULACEAE																			
Clematis microphylla var. microphylla	Small-leaved Clematis							P1	P2	P3		P5					H1		
*Ranunculus muricatus	Sharp Buttercup	R1																	
RHAMNACEAE																			
Ventilago viminalis	Supple Jack															F3			
ROSACEAE																			
*Rosa rubiginosa	Sweet Briar	R1					R6												
RUBIACEAE																			
Asperula cunninghamii	Twining Woodruff										P4		P6	P7					
Canthium odoratum	Shiny-leaved Canthium														F2				
*Galium aparine	Goosegrass			R3	R4		R6			P3	P4		P6						
*Galium divaricatum	Slender Bedstraw										P4								
RUTACEAE																			
Eriostemon difformis subsp. difformis	Small-leaf Waxflower												P6						
Eriostemon myoporoides subsp. acutus	Long-leaf Waxflower																H1		
Geijera parviflora	Wilga			R3				P1	P2	P3	P4	P5	P6		F2		H1	H2	
Phebalium glandulosum subsp. glandulosum	Desert Phebalium							P1			P4								
Phebalium obcordatum	Club-leaf Phebalium														F2		H1		H4
Philotheca salsolifolia																	H1		
Philotheca sp. A											P4								
Zieria aspalathoides																	H1		
SANTALACEAE																			
Exocarpos cupressiformis	Native Cherry																		H4
Santalum acuminatum	Sweet Quandong										P4			P7					H4
Santalum lanceolatum	Northern Sandalwood																		H4
SAPINDACEAE																			
Alectryon oleifolius subsp. elongatus	Western Rosewood					R5			P2	P3	P4								
Atalaya hemiglauca	Whitewood										P4								
Dodonaea boroniifolia	Fern-leaf Hopbush																H1		
Dodonaea heteromorpha																			H4
Dodonaea peduncularis								P1	P2										
Dodonaea viscosa subsp. angustissima	Narrow-leaf Hopbush							P1	P2	P3	P4		P6			F3	H1		
Dodonaea viscosa subsp. cuneata	Narrow-leaf Hopbush							P1			P4		P6	P7	F2		H1		H4
Dodonaea viscosa subsp. mucronata	Narrow-leaf Hopbush	R1									P4				F2				
Dodonaea viscosa subsp. spatulata	Narrow-leaf Hopbush									P3	P4		P6		F2		H1		
SCROPHULARIACEAE																			
*Kickxia elatine subsp. crinita	Twining Toadflax		R2				R6												
Mimulus gracilis	Slender Monkey-flower									P3							H1		
Orobanche cernua var. australiana	Australian Broomrape												P6			F3			
Veronica plebeia	Trailing Speedwell												P6						H4
SINOPTERIDACEAE																			
Cheilanthes austrotenuifolia	Rock Fern	R1		R3						P3	P4		P6	P7	F2	F3	H1	H2	H4
Cheilanthes distans	Bristle Cloak Fern									P3							H1		
Cheilanthes lasiophylla	Woolly Cloak Fern																H1		
SOLANACEAE																			
*Lycium ferocissimum	African Boxthorn					R5				P3	P4		P6	P7					
Nicotiana simulans		R1																	
Solanum cinereum	Narrawa Burr												P6						
*Solanum elaeagnifolium	Silver-leaved Nightshade			R3															
Solanum esuriale	Quena	R1	R2	R3	R4					P3	P4		P6						
Solanum ferocissimum													P6		F2		H1		
*Solanum nigrum	Black-berry Nightshade	R1	R2	R3									P6		F2				
Solanum tetrathecum													P6						
STACKHOUSIACEAE																			
Stackhousia monogyna	Creamy Candles										P4								
Stackhousia viminea	Slender Stackhousia							P1	P2	P3	P4	P5	P6	P7	F2	F3	H1		
STERCULIACEAE																			
Brachychiton populneus subsp. trilobus	Kurrajong	R1								P3	P4		P6		F2	F3	H1	H2	
Brachychiton populneus subsp. populneus	Kurrajong	R1								P3	P4		P6		F2	F3	H1	H2	
THYMELAEACEAE																			
Pimelea flava subsp. dichotoma								P1											
Pimelea micrantha																	H1		
Pimelea microcephala	Shrubby Rice-flower							P1	P2										
Pimelea neo-anglica											P4								
Pimelea stricta	Gaunt Rice-flower								P2										
TYPHACEAE																			
Typha domingensis	Narrow-leaved Cumbungi		R2																
URTICACEAE																			
Parietaria debilis															F2				
VERBENACEAE																			
*Phyla nodiflora	Carpet Weed	R1	R2	R3	R4						P4								
*Verbena bonariensis	Purple Top			R3			R6												
Verbena officinalis	Common Verbena	R1	R2	R3		R5					P4								
*Verbena supina	Trailing Verbena	R1		R3			R6												
VIOLACEAE																			
Hybanthus monopetalus	Slender Violet-bush														F2		H1	H2	
XANTHORRHOEACEAE																			
Lomandra confertifolia subsp. rubiginosa								P1											
Lomandra effusa	Scented Mat-rush							P1			P4	P5					H1		
Lomandra filiformis subsp. coriacea	Wattle Mat-rush												P6						
Lomandra glauca	Pale Mat-rush							P1					P6						
Lomandra leucocephala subsp. leucocephala	Woolly Mat-rush	R1									P4		P6			F3			
Lomandra longifolia	Spiny-headed Mat-rush	R1									P4		P6						
Lomandra multiflora subsp. multiflora	Many-flowered Mat-rush										P4		P6		F2		H1	H2	
Lomandra patens										P3	P4								
ZYGOPHYLLACEAE																			
*Tribulus terrestris	Cat-head									P3	P4								
Zygophyllum glaucum	Pale Twinleaf			R3					P2					P7					

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