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COVER
Roadside remnant of *Acacia pendula* (Myall) Woodlands
Photographer: Jaime Plaza

Allan Cunningham, botanist and explorer (1791–1839)

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The breeding systems of *Hicksbeachia pinnatifolia* and *Triunia youngiana* (Proteaceae)

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Abstract: The breeding systems of the rainforest shrubs *Hicksbeachia pinnatifolia* and *Triunia youngiana* were studied in north-east New South Wales, where the former is listed as a vulnerable species. *Hicksbeachia pinnatifolia* flowered in winter and spring, and produced an average of 36 inflorescences per plant with 155 flowers per inflorescence (5 580 flowers per plant). Inflorescences initiated and matured only a small number of fruits (c. 1–2 per inflorescence) in self-pollinated and open-pollinated treatments. This compared to about 17 fruits initiated and 4 fruits matured per inflorescence when cross-pollinated. *Triunia youngiana* flowered in spring and produced an average of 3 inflorescences per plant containing 23 flowers per inflorescence (69 flowers per plant). Plants were unable to initiate any fruit in autogamy and self-pollinated treatments. Plants in a cross-pollination treatment produced over three times as many fruit (3.5 matured per plant) compared to a control treatment (0.8 per plant), suggesting that plants were pollen-limited. Both treatments experienced substantial (80%) fruit abortion. These results indicate that *Triunia youngiana* is self-incompatible whereas *Hicksbeachia pinnatifolia* appears to be partially self-compatible.

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Introduction

Although species within the Proteaceae have been common subjects of pollination studies (Whelan & Goldingay 1986, Harriss & Whelan 1993, Vaughton 1993), most studies have focussed on the genus *Banksia* and *Grevillea* (Goldingay & Carthew 1998). This situation currently precludes a better understanding of the evolution of the breeding and mating systems within the Proteaceae because these genera are typically vertebrate pollinated and occur predominantly in heath and woodland habitats.

Study of the pollination ecology of rainforest Proteaceae is of great interest because these species may be quite primitive. However, *Macadamia* is the only genus of rainforest Proteaceae that has been studied (Heard 1993, Wallace et al. 1996), probably due to the commercial value of the fruits of these plants. There are another 23 genera that include rainforest species (CSIRO 1995), so an adequate understanding of the breeding systems of the Proteaceae is a long way off.

This study aims to examine flowering and the breeding systems of two rainforest Proteaceae, *Hicksbeachia pinnatifolia* F. Muell. and *Triunia youngiana* (C. Moore & F. Muell. ex F. Muell.) L.A.S. Johnson & B.G. Briggs. *Hicksbeachia pinnatifolia* is listed as a vulnerable species in NSW. *Triunia youngiana* is not a threatened species but the related *Triunia robusta* is highly endangered (Shapcott 2002). Data gathered on *Triunia youngiana* may be useful to the management of *Triunia robusta* populations.

Methods

Study area and study species

This study was conducted at three sites located approximately 20 km north of Lismore. The three sites include the Big Scrub Flora Reserve (FR) in Whian Whian State Forest, at Rocky Creek Dam, and along Rocky Creek Dam Road about 3 km from Rocky Creek Dam. All three sites were used in the study of *Hicksbeachia pinnatifolia* but only the first site was used in the study of *Triunia youngiana*. Opportunistic observations were made of animals visiting the flowers of these species during visits to each site. Observations were made during the first few hours of darkness on one occasion at each site in an attempt to observe nocturnal visitors.

Hicksbeachia pinnatifolia

Flowering and fruiting phenologies of *Hicksbeachia pinnatifolia* were recorded between August and December 1998. For this study, 23 trees (2–5 m high) were tagged in the Big Scrub Flora Reserve along a 500 m length of walking trail, and 9 were tagged at Rocky Creek Dam, scattered through a picnic area. The reproductive state of all inflorescences on the study trees was recorded at monthly intervals. In this species, fruits undergo a colour change from green to red as they complete maturation. Inflorescences were classified into one of six categories: in flower (at least one floret was open), completed flowering (all florets had withered), initiated fruit (at least one ovary was swollen), unripe fruit (at least one fruit was fully developed, but was still green), and ripe fruit (at least one fruit had changed to red). A subsample of tagged plants was examined to describe the number of flowers on an inflorescence and the number of fruits produced.

A breeding system experiment was conducted in 1998 on 13 plants located in a strip of roadside vegetation along Rocky Creek Dam Road. These plants contained many inflorescences at accessible heights for bagging whereas plants at the other two sites mostly carried inflorescences too high to use. Inflorescences were selected at the bud stage for each of the following four treatments: open-pollinated control (inflorescences were tagged and left untouched for the duration of the experiment), uncovered cross pollination (flowers were hand-pollinated with pollen from trees located >5 m from the experimental tree on 3–5 days), covered cross pollination (inflorescences bagged with nylon shade-cloth and cross-pollinated as above), self-pollination (inflorescences bagged and a separate cloth used to apply self-pollen from other inflorescences on the same plant to the flowers on 3–5 days), and autogamy (inflorescences bagged but not manipulated, in order to test for automatic self-pollination).

When conducting the cross-pollinations, all visible self-pollen on an inflorescence was removed with a cloth prior to hand-pollination. A separate cloth was used to collect pollen from another plant and the pollen was rubbed gently onto the treatment flowers. The timing of stigma receptivity is unknown. Florets on inflorescences opened over a period of approximately seven days and then withered. Thus, multiple hand-pollinations within this period should ensure that some pollen is applied at an appropriate time.

Several treatments were placed on the same plant. There were insufficient plants with accessible inflorescences to use whole-plant treatments. Plants carried large numbers of inflorescences (>20) which enabled more than one treatment to be placed on the same plant with a low chance of interfering with assessment of the breeding system. Of 13 plants used, four contained a single tagged inflorescence, six contained two tagged inflorescences (each a different treatment), one contained four tagged inflorescences (three treatments represented), and two contained five tagged inflorescences (four treatments represented).

The number of fruits developing on each of the experimental inflorescences was counted four and seven weeks after the completion of flowering (since the last flower had withered).

Triunia youngiana

Nineteen plants were assessed so that the average number of inflorescences could be described. A subsample of these was examined to describe the number of flowers on an inflorescence.

A breeding system experiment was conducted in October 1999 on 18 plants. We used whole-plant treatments and reduced the number of inflorescences to three per plant. Plants were selected and tagged when inflorescences were still in bud. Plants were assigned at random to four treatments: open-pollinated control (plants were tagged and left untouched for the duration of the experiment), uncovered cross pollination (flowers were hand-pollinated with pollen from trees located >5 m from the experimental tree on three occasions), self-pollination (inflorescences were bagged and a separate cloth used to apply self-pollen to the flowers on three occasions) and autogamy (inflorescences bagged but not manipulated, in order to test for automatic self-pollination).

A count of the number of fruit initiated (indicated by swelling of the ovary) was conducted approximately 4 weeks after hand-pollinations were completed. A final count of mature fruit was conducted 3 months after this.

Results

Hicksbeachia pinnatifolia

Hicksbeachia pinnatifolia that flowered in 1998 at the three sites had an average of 36.3 ± 11.6 (s.e.) inflorescences per plant (n=24). Inflorescences contained an average of 154.5 ± 5.4 (n=51) flowers (range 76–242). Plants produced an average of 22.0 ± 7.9 infructescences (n=22). This equates to 61% of inflorescences producing fruit. Infructescences (n=50) averaged 3.1 ± 0.4 fruits each with a range of 0–11 (Fig. 1). This equates to a final fruit-set (fruits: flowers × 100) of 1.2%.

Fig. 1. *Hicksbeachia pinnatifolia* showing low fruit-set per inflorescence.

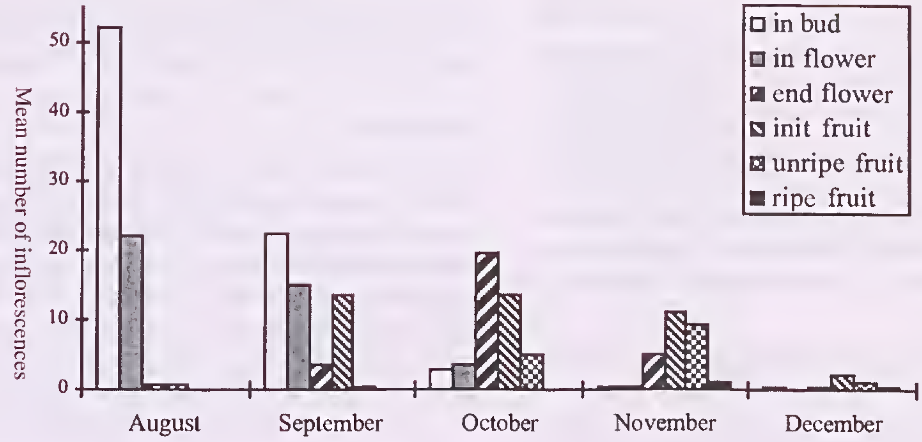

Fig. 2. Flowering phenology of *Hicksbeachia pinnatifolia* (n = 9) located at Rocky Creek Dam, 1998. Inflorescences were scored into one of six categories shown in legend (end flower = flowering completed; init fruit = initiated fruit).

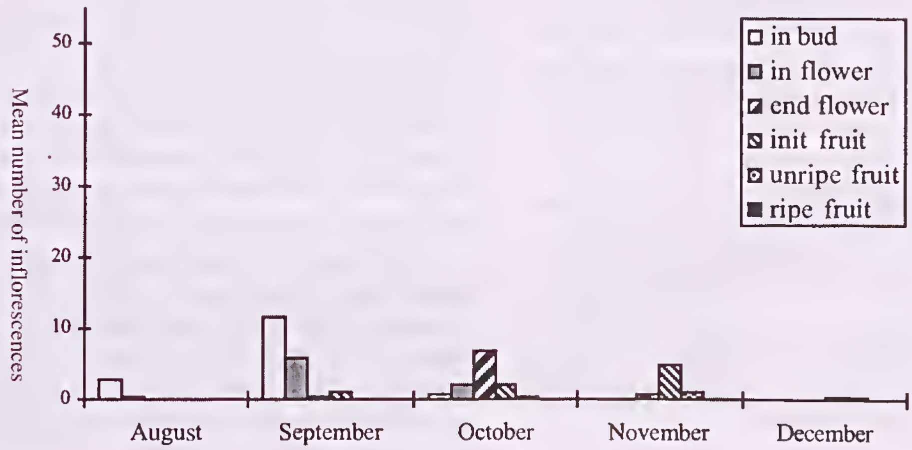

Fig. 3. Flowering phenology *Hicksbeachia pinnatifolia* (n = 23; in August n = 20) located at the Big Scrub Flora Reserve, 1998.

Table 1. Fruit-set per inflorescence in *Hicksbeachia pinnatifolia* in five pollination treatments.

Fruit-set values are means ± se; n = the number of plants; the number of inflorescences is shown in brackets.

Treatment/ pollination	n	Fruits initiated	Fruits matured	% aborted
Autogamy	4	–	0.4 ± 0.4 (5)	–
Self	6	2.0 ± 1.3 (5)	1.0 ± 0.7 (8)	50
Open/cross	7	14.6 ± 4.7 (7)	3.3 ± 1.3 (7)	77
Bagged/cross	3	23.3 ± 2.6 (3)	6.3 ± 3.4 (3)	73
Control (open)	6	1.3 ± 0.9 (6)	1.1 ± 0.6 (7)	15

The study trees had high numbers of inflorescences at the beginning of the phenology monitoring period in August (Figs 2, 3). The intensity of flowering was greater at Rocky Creek Dam compared to the Big Scrub FR. At Rocky Creek Dam, peak flowering occurred in August and the flowering period extended over at least three months. At the Big Scrub FR, peak flowering occurred in September and the flowering period extended little over two months. The uneven match between inflorescences in bud and subsequently in flower suggests large numbers of inflorescences were aborted. Few infructescences produced red fruits at either site, and these did not appear until November and December.

Inflorescences in the autogamy, self-pollination and control treatments initiated a small number of fruits (Table 1). This contrasts with the cross-pollination treatments in which the number of fruits initiated was an order of magnitude higher. A greater number of fruits was initiated in the bagged compared to the unbagged cross-pollination treatment but sample sizes were too small to test for any difference. When considered together, these treatments averaged 17.2 ± 3.6 (s.e.) fruits per inflorescence. A large number of fruits (>70%) aborted in the cross-pollination treatments compared to the self-pollination and control treatments (Table 1). Final fruit-set among treatments (excluding autogamy) was compared using the combined cross-pollination treatments. These latter treatments averaged 4.2 ± 1.3 fruits per inflorescence.

All data were ln (x + 1) transformed. Fruit-set among treatments was significantly different ($F_{2,22}$= 4.68, P=0.02), showing that crossing produced significantly higher numbers of fruit when compared to open pollination and self-pollination. This experiment indicates that plants are capable of producing fruit from self-pollination. Following self-pollination, 4 of 6 plants initiated fruits and 3 of 6 plants matured fruits. Fruit-set in control inflorescences was equivalent to that of selfed inflorescences. Final fruit-set in the control treatment for an average inflorescence of 36 flowers was about 3%.

Native and introduced honey bees were observed visiting *Hicksbeachia pinnatifolia* but mostly did not contact pollen presenters correctly for pollen transfer. Small moths visited for nectar at night but also failed to contact flowers in an effective way.

Triunia youngiana

Plants that flowered in 1999 had an average of 2.7 ± 0.5 (s.e.) inflorescences per plant (n=19). Only 48% of plants flowered at the site (n=40). Inflorescences contained an average of 23.2 ± 0.9 (n=44) flowers (range 12–36). Fruiting data were only collected for experimental plants.

Table 2. Fruit-set in *Triunia youngiana* in four pollination treatments.

Three inflorescences were treated per plant. Fruit-set values are means ± se; n = the number of plants.

Treatment/ pollination	n	Fruits initiated per plant	Fruits matured per plant	% aborted
Autogamy	4	0	0	–
Self	6	0	0	–
Open/cross	4	17.3 ± 3.3	3.5 ± 1.9	80
Control (open)	4	5.0 ± 2.7	0.8 ± 0.5	84

No plants in the autogamy or self-pollination treatments initated any fruits (Table 2). This contrasts with the cross-pollination treatment in which all inflorescences initiated some fruit. Only 5 of 12 inflorescences that were crossed matured any fruit (1.2 ± 0.7 per inflorescence) but all plants in this treatment matured some fruit. Control plants initiated significantly (P<0.05) fewer fruit per plant than the cross-pollinated treatment (Table 2). Control plants matured only 0.3 ± 0.2 fruits per inflorescence. The number of fruits matured per plant was substantially lower for the controls compared to the crossed plants but this was not significant. However, 2 of 4 control plants matured no fruits, and only 2 of 12 inflorescences matured fruits. Fruit abortion was high (80–84%) in both treatments. Final fruit-set in the control treatment for an average plant with 70 flowers was 1.2%.

Triunia youngiana was observed for a short period at night and it was visited by two moth species, one <1 cm long and the other 2 cm long. The larger species made some contact with the pollen presenter. Small flies, ants and beetles were observed on inflorescences during the day but did not contact the pollen presenter. At other times butterflies (c. 3 cm) visited and made contact with the pollen presenter.

Discussion

The pollination ecology of rainforest Proteaceae is poorly known. *Macadamia integrifolia* has been studied in some detail but essentially from a commercial perspective (Heard 1993; Wallace et al. 1996). This study describes the breeding system of two rainforest species. For *Hicksbeachia pinnatifolia*, the breeding system experiment could only be conducted at the inflorescence level because a small road-side population was the only one of three populations that produced inflorescences at a height where they could be readily manipulated. Sample sizes were also limited because flowering had passed its peak. This experiment demonstrated a small amount of fruit-set from self-pollination (1–2 fruits initiated and matured per inflorescence) which was equivalent to that observed on control inflorescences. In contrast, inflorescences that were cross-pollinated initiated 17 fruits and matured 4 fruits per inflorescence. A self-compatibility index (ratio of selfed to crossed fruit-set) based on initiated fruit (Hermanutz et al. 1998) was 0.16, suggesting partial self-compatibility in *Hicksbeachia pinnatifolia*. Open-pollinated plants monitored in the phenology study averaged more than 60 fruits per plant.

The experiment on *Triunia youngiana* was conducted at the whole-plant level, which is a more appropriate level for conducting this experiment (Goldingay & Whelan 1990, Goldingay et al. 1991). This showed that no fruits were produced by autogamy or self-pollination, indicating self-incompatibility. An assessment of pollen tubes following these pollination treatments is likely to reveal what type of incompatibility mechanism is present in this species (Hermanutz et al. 1998; Matthews & Sedgley 1998).

Due to the uneven coverage of Proteaceae in breeding system studies it is difficult to determine how widespread self-compatibility is in the family, or even to make predictions of its likely frequency among genera or habitats. Self-compatibility seems to be relatively widespread in *Grevillea* but less common in *Banksia* (Goldingay & Carthew 1998). Percentage fruit-set was low (<5%) in *Hicksbeachia pinnatifolia* and *Triunia youngiana*, though of a similar magnitude to that in many other Proteaceae (Goldingay & Carthew 1998). Denham & Whelan (2000) recently described self-compatibility in *Lomatia silaifolia* that had approximately 6% fruit set. Further studies are required to understand the high fruit abortion levels in cross-pollinated treatments (70–85%) in these rainforest species and to explore factors determining the low fruit-set.

Though not assessed specifically, it appears that populations of both species were pollen-limited (Goldingay & Whelan 1990, Vaughton 1991, Goldingay 2000). Cross-pollinated *Hicksbeachia pinnatifolia* initiated 13 times as many fruits and matured 4 times as many fruits as open-pollinated inflorescences. This is consistent with the apparent ineffectiveness of visitors observed at inflorescences. This species produces a pungent smell at dusk (CSIRO 1995), suggesting a nocturnal pollinator. The small size of the flowers (c. 1 cm long) and delicate attachment of the inflorescence suggests an insect pollinator. The current study did not aim to describe the pollinators of this species. Furthermore, it is not known how indicative visitors to the road-side plants used in the breeding system study would be. The disturbed location may account for the poor pollination success. Cross-pollinated *Triunia youngiana* initiated 3 times as many fruits and matured 4 times as many fruits as open-pollinated inflorescences. Appropriate contact with the pollen presenter by some moths and butterflies was observed.

A detailed understanding of the pollinators of these two plant species is required. This will be fundamental to the conservation of the threatened *Hicksbeachia pinnatifolia*. Low fruit-set in both species may be a direct consequence of reduced abundance of their pollinators. Moreover, despite the widespread occurrence of insect pollination in the Proteaceae, this type of pollination system remains poorly studied (Bernhardt & Weston 1996). It would also be beneficial to conduct studies to determine the extent to which pollen-limitation occurs in these species. This might provide important insights into aspects of the population ecology of these species (Goldingay 2000). Further research is needed to confirm that *Hicksbeachia pinnatifolia* shows partial self-compatibilty. Finally, there is a dearth of ecological studies of rainforest Proteaceae that must be rectified if we are to increase our understanding of the evolution of floral systems in this family. Such studies will also provide important data for conserving these species given that many rainforest Proteaceae are recognised as threatened species.

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Floristic composition and environmental relationships of *Sphagnum*-dominated communities in Victoria

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Abstract: Floristic community types and their environmental correlates are described for *Sphagnum*-dominated communities throughout Victoria. Current threats to the condition of these communities are outlined, with an assessment of their conservation status. Sites from lowland (350 m) to alpine (1780 m) areas were surveyed and seven floristic groups were recognised using cluster analysis and non-metric multi-dimensional scaling techniques. The strongest floristic gradients corresponded to altitude, temperature, rainfall, geology and current condition. Several of the sites surveyed were degraded, with some sites heavily impacted by cattle grazing or invaded by weeds. While some floristic groups, particularly sub-alpine bogs, are reserved in national parks, others such as montane and lowland bogs occur on forestry and private land tenures. Reservation has not protected some sites from threatening processes, most notably in alpine national parks, where cattle grazing has seriously degraded many of these *Sphagnum* peatland communities to either disclimax communities or isolated moss beds no longer functioning ecologically as peatlands. Further surveys of *Sphagnum*-dominated communities elsewhere in Victoria are warranted, especially montane and lowland areas. The results suggest *Sphagnum*-dominated communities will require conservation planning and management action throughout their geographic range in Victoria.

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Introduction

In Australia, *Sphagnum* peatlands (sensu Gore 1983) are found primarily in montane, sub-alpine and alpine areas in poorly-drained topographic settings with nutrient-poor, acidic conditions. *Sphagnum* peatlands can be defined as distinct ecosystems where *Sphagnum* moss provides at least 30% of species cover and is the dominant peat former (Whinam et al. 2003). They are generally small in area, restricted in distribution, and have relatively few plant species. The distribution of *Sphagnum* peatlands is largely limited by evapotranspiration in the warmest months (Whinam et al. 2003). They occur in areas where there is a seasonally stable high watertable and where there is a constant supply of surface or seepage water.

The bulk of Australian *Sphagnum* peatlands are found in Tasmania (Whinam et al. 2001), with occurrences in the Australian Capital Territory and New South Wales (Millington 1954, Clarke and Martin 1999, Costin 1954, Costin et al. 2000, Whinam and Chilcott 2002). *Sphagnum*-dominated communities influence the hydrology of catchments (Costin 1962), but are susceptible to disturbance (Wahren et al. 1999) and climate change (Whinam et al. 2003).

In Victoria, the most detailed floristic descriptions of peatlands are those of Kestel (1993) who described 37 peatland sites, including their prehistories, conservation values, threats and reservation status. The distribution and composition of Victorian subalpine and alpine *Sphagnum* communities have been described by McDougall (1982) and Walsh et al. (1986) who both recognise these communities as either 'alpine bog' or 'fen', or as part of a 'wet closed-heathland complex that occurs on deep peats'. Farrell and Ashton (1973) and Ashton and Hargreaves (1983) present local descriptions of wetlands for the Benison High Plains and Lake Mountain respectively. Most recently, Wahren et al. (1999) described the small-scale floristic composition and structure of wetlands, including *Sphagnum* bogs, on the Bogong High Plains with respect to peat depth, altitude and cattle disturbance. *Sphagnum* has been recorded as present, but not dominant, in other parts of Victoria, for example in the Otway Ranges (Meagher & Rankin 1996).

The ecology of subalpine *Sphagnum* bogs has been well studied in Victoria, particularly in relation to long-term disturbance impacts by, and recovery from, cattle grazing (Lawrence 1999, Wahren et al. 1999, 2001) and short-term recovery after fire (Wahren & Walsh 2000). The most potent threat to the survival of *Sphagnum* peatlands in Victoria is cattle grazing. The degradation of *Sphagnum* peatlands by cattle grazing in sub-alpine areas has been identified for more than 50 years (Wahren et al. 1999). The slope grooming and drainage works associated with ski slopes have led to severe degradation of the *Sphagnum* peatlands at Mt Buller. There has also been some illegal moss harvesting in parts of the Central Highlands (ANCA 1996, authors pers. obs.) while near Dinner Plain, trial harvesting of *Sphagnum* has been attempted (McDougall 2001). Due to a long history of disturbance and continuing threats, alpine and subalpine bogs have been listed as threatened communities in Victoria under the Flora and Fauna Guarantee Act (1988).

This study aims to: (a) determine the floristic composition and environmental gradients of *Sphagnum*-dominated peatlands across their altitudinal range in Victoria; (b) identify threats to these communities, and (c) describe the current condition of Victorian *Sphagnum* peatlands. We identify *Sphagnum* peatlands with significant nature conservation value, evaluate threats and propose mitigation methods.

Methods

Site selection

Sites were selected in Victoria for surveying from herbarium records, *A Directory of Significant Wetlands* (ANCA 1996), previous publications (especially Kestel 1993) and on the advice of our botanical colleagues. In total, 48 sites were identified and floristic surveys were conducted during January and March 2002 (see Appendix 1). In general, we defined *Sphagnum* peatlands as being usually greater than 0.25 ha (Whinam et al. 1989, 2001, Whinam & Chilcott 2002), but did survey smaller sites if the *Sphagnum* moss occupied distinct habitats (e.g. sinkholes, Whinam et al. 2001), or were remnants in larger degraded peatlands (Whinam & Chilcott 2002). Several sites that were reported to us as *Sphagnum* peatlands were found to be reduced to only handfuls of moss, and so are not included in these analyses (e.g. Mt Samaria Park, Mt Pilot State Park, Whitfield area, Mt Torbreck).

Field methods

As in previous comparative studies (Whinam et al. 2001, Whinam & Chilcott 2002), in each peatland, one 10 × 10 m quadrat was placed in a representative part of the vegetation and the percentage cover abundances of all species were recorded. Species nomenclature follows Ross (2000). At each site, we also recorded species present outside the quadrat and physical characteristics including aspect, slope, percent bare peat, mean peat depth (measured at three locations within the quadrat with a 2 m stainless steel probe) and mean height between hummocks and hollows to describe surface morphology (n = 3 observations). Moss stem length was recorded for *Sphagnum* as an indicator of growth rates (Clymo 1973), a measure of vigour and an indicator of the rate of decomposition (Whinam & Buxton 1997). A CSIRO Inoculo soil pH test kit was used to estimate the pH of the humified peat in each quadrat. Grid references were recorded with a GPS (accuracy ± 10 m), and altitudes were determined from 1:25 000 topographic maps. Geology was determined from 1:100 000 geological maps.

The condition of sites was scored based on the amount of damaged *Sphagnum* moss, the amount of bare ground, degree of pugging caused by hooves, and drainage alteration (e.g. edge erosion). Condition was assessed as undamaged (0); light damage, where only minimal surface disturbance was evident (1); degraded, where there was a breakdown of surface morphology e.g. through repeated hoof trampling (2); modified, where the surface and edge morphology had broken down i.e. edge erosion from trampling and pugging caused by hooves (3); highly modified and degraded, where the surface morphology had broken down and only patches of isolated *Sphagnum* moss remain in disturbed, bare peat (4). The condition classes were based on previous studies of *Sphagnum* communities and their conservation status (Whinam et al. 1989, Whinam 1995, Whinam et al. 2001, Whinam & Chilcott 2002). These indicators are readily identifiable in the field and represent important changes in the condition of peatlands that indicate temporal degradational trends.

Analytical methods

The data consisted of 48 sites and 269 vascular taxa, from which singleton species (i.e. species found at only one site) were then deleted, leaving 135 species in the dataset for analyses. *Sphagnum* spp. and *Polytrichum juniperinum* were the only lower plants recorded to species level. Other bryophytes were recorded at only 2 sites at cover values of <1%. Owing to the high number of taxa with less than 5% cover or cover values of >80% of dominant species, all data were converted to presence/absence prior to the analyses to give equal representation to species (Barmuta pers. comm.). Multivariate analysis of the data was performed using PATN (Belbin 1995). The Bray-Curtis coefficient (Faith et al. 1987) was used to represent floristic dissimilarity between sites.

Because floristic variation was anticipated to be relatively continuous, ordination was used to graphically represent the relationship between sites in multidimensional space with cluster analysis used to dissect the data for ease of description (Quinn & Keough 2002). Sites were ordinated by hybrid multidimensional scaling (HMDS) (Faith et al. 1987), with the semi-strong algorithm (Belbin 1991a). Multidimensional scaling has been shown to be the most robust method for ordinating community data (Kenkel & Orloci 1986, Minchin 1987, Quinn & Keough 2002). The ordination and classification methods used in these analyses follow those used for other regional analyses of *Sphagnum* communities (Whinam et al. 2001, Whinam & Chilcott 2002). The three-dimensional solution yielded a stress of 0.183. Groups were clustered by ß-flexible unweighted arithmetic average clustering (UPGMA) with ß=-0.1 (Belbin 1995).

The indicator value index (Dufrêne & Legendre 1997) was used to investigate the floristic characteristics of the groups in the resulting hierarchy. The indicator values were calculated by IndVal 2.0 (Dufrêne 1999) with equal weightings for the two components of the index, and 999 randomisations to assess significance at the 0.05 level.

To determine which climatic parameters, if any, may help to explain the vegetation patterns seen across sites, we used BIOCLIM to approximate energy and water balances at a given location (Nix & Bushby 1986). The BIOCLIM variables included in these analyses are defined in Table 1. Median values are given for environmental variables for each floristic group (Table 2), as they are more resistant to outlying values than means (Fowler & Cohen 1990).

Table 1. Codes and descriptions of bioclimatic variables from BIOCLIM (Houlder et al. 1999) and results of vector fitting of environmental variables and species richness to the three-dimensional ordination space.

n: number of observations; *R:* multiple correlation coefficient range of each variable. All correlations were significant to $P < 0.05$.

Variable name/(code)	*n*	*R*	Range
Altitude (m)(Alt)	48	0.891	500–1780
Geology (Geol)	48	0.470	sandstone, granite, phyllite schist/shale, Quaternary river terraces
Soil pH (PH)	48	0.651	4.5–6.5
Tendril length (cm) (AvTendril)	48	0.573	4–45
Peatland condition index (Condition)	48	0.623	0–4
[1]Annual mean temperature (°C), (AnMeTemp)	48	0.895	5.0–13.2
[2]Annual mean precipitation (mm), (AnnPrec)	48	0.843	938–2442
[3]Precipitation of driest period (mm), (PrecDP)	48	0.804	17–97

[1]The annual mean of weekly mean temperatures. Each weekly mean temperature is the mean of that week's maximum and minimum temperature.

[2]The sum of all the monthly precipitation estimates.

[3]The precipitation of the driest week

The environmental variables were fitted to the ordination space by a vector-fitting approach (Dargie 1984, Bowman & Minchin 1987). The vectors are the directions through the configuration where the sites have maximum correlations (r) with the environmental variables. For each fitted vector, significance was tested by a Monte-Carlo randomisation procedure (Table 1) that compares the derived maximum correlation with the distribution produced from random permutations of the values of the environmental variables These analyses were performed by the principal axis correlation (PCC) routines in PATN (Belbin 1991b).

Results

The location of *Sphagnum* peatlands surveyed in Victoria and their floristic groups are shown in Figure 1. There is a regional grouping of the floristics of Victorian *Sphagnum* communities, that reflects the environmental variables of altitude and geology. A summary of environmental variables for each floristic group is presented in Table 2.

Two hundred and sixty-nine vacular plant species, comprising 250 native and 19 exotic species, were recorded in the survey across 48 sites. A total of 134 singleton species (excluded from analysis) were recorded at 34 sites, varying from one to eleven singletons per site. The highest numbers of singleton species occur in Group 4 (29 species), Group 7 (28 species) and Group 6 (26 species). High numbers of singletons occur at lower altitude sites with generally higher species richness, reflecting higher levels of disturbance of *Sphagnum* peatlands. Mean species richness (indigenous and exotic species) across all sites was 20 species per 100 m^2.

Community classification

Pattern analysis of species data resulted in seven groups being identified (see dendrogram, Fig. 2). Further dissection of the groups was not supported by indicator values for

Table 2. *Sphagnum* communities in Victoria, (with group numbers from the clustering in brackets). Ranges and median values (bold type) of environmental variables and species richness.

Peatland condition: (0) undamaged; (1) light damage, where only minimal surface disturbance was evident; (2) degraded, where there was a breakdown of surface morphology, e.g. through repeated hoof trampling; (3) modified , where the surface and edge morphology has broken down, i.e. edge erosion from trampling and pugging caused by hooves; (4) highly modified and degraded where the surface morphology has broken down and only patches of isolated *Sphagnum* moss remain in disturbed, bare peat

Floristic group/community	No. plots	Altitude (m)	Mean annual temp. (°C) (mm	Mean annual precip.) (mm)	Precip-itation driest period	pH	Mean moss stem length	Peatland condition (cm)	Species richness (0–4)
Bogong *Sphagnum* sub-alpine plots (Group 1)	17	1350–1780 **1640**	5.0–7.4 **5.6**	1695–2442 **2282**	78–97 **92**	4.5–6.0 **5.0**	4–20 **8**	0–4 **1**	11–23 **15**
Ungrazed sub-alpine *Sphagnum* peatlands (Group 2)	11	1420–1620 **1480**	5.5–7.3 **5.9**	1785–1918 **1870**	76–84 **81**	5.0–6.0 **5.0**	8–34 **12**	0–1 **0**	15–34 **20**
Relic alpine *Sphagnum* peatlands (Group 3)	5	1700–1740 **1700**	5.2–5.3 **5.3**	1675–2434 **1675**	74–95 **74**	4.5–6.0 **5.0**	8–12 **10**	2–4 **3**	9–25 **21**
Montane fern-*Sphagnum* peatlands (Group 4)	5	500–1280 **900**	7.3–12.1 **9.3**	938–1767 **1601**	44–69 **59**	5.5–6.0 **5.5**	5–23 **20**	0–1 **1**	15–31 **22**
Aquatic *Sphagnum falcatulum* fen (Group 5)	1	1120 **1120**	8.6 **8.6**	1518 **1518**	66 **66**	6.0 **6.0**	14 **14**	2 **2**	15 **15**
Degraded *Sphagnum* valley fens (Group 6)	4	900–1750 **1250**	5.2–9.0 **7.5**	1228–2369 **1752**	17–95 **54**	4.5–6.5 **6.0**	8–10 **10**	1–4 **3**	20–31 **22**
Montane shrubby *Sphagnum* fens (Group 7)	5	350–500 **350**	12.1–13.2 **13.1**	940–1179 **1165**	43–56 **55**	6.0 **6.0**	20–45 **32**	1–3 **3**	23–32 **28**

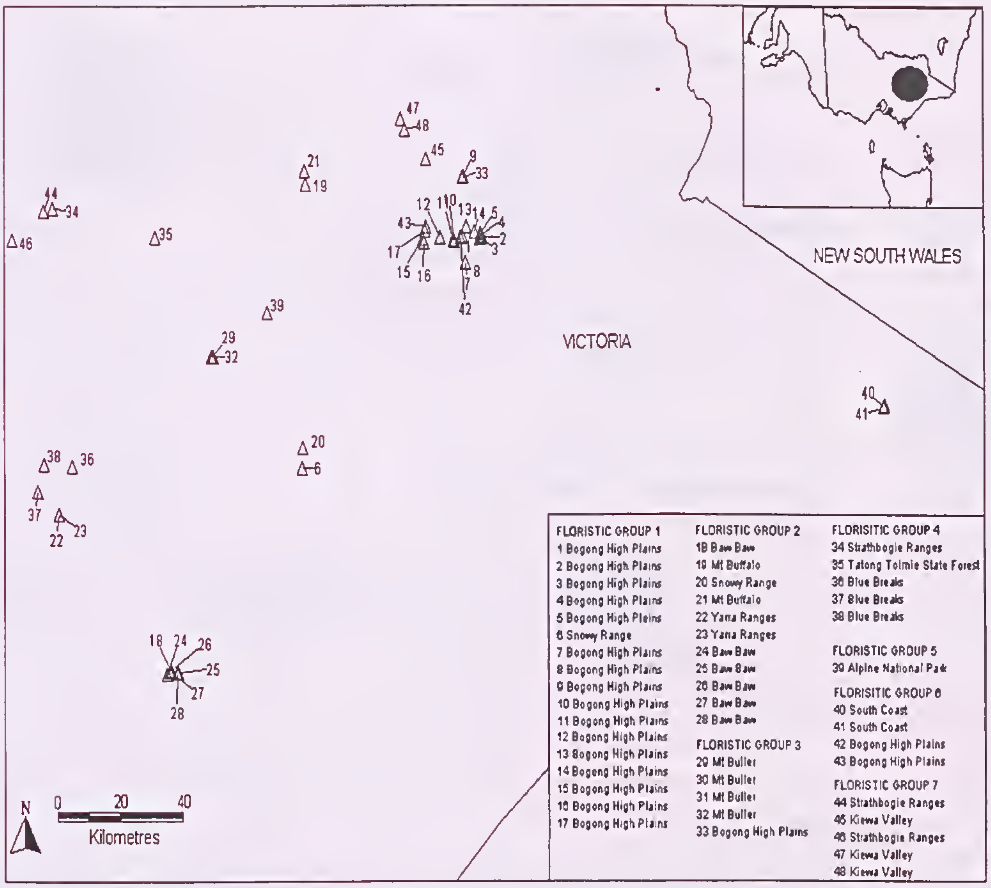

Fig. 1. Distribution of *Sphagnum* peatlands in Victoria. See text for descriptions of floristic groups.

species at lower nodes in the hierarchy because most of these nodes did not have significant ($P < 0.05$) indicator species associated with them.

The community classification, including significant ($P < 0.01$) indicator species for each of the final groups, is shown in Figs. 3 and 4, and the full hierarchically arranged two-way table of species by site groups together with indicator values is given in Appendix 2. A summary of species occurrence for each floristic group is shown in Appendix 3. The analysis yielded seven identifiable *Sphagnum* peatland types with a major split between alpine/sub-alpine sites (Groups 1 to 3) and montane sites (Groups 4 to 7), (Fig. 3). These seven types and their environmental attributes are described below.

Floristic group 1. Bogong *Sphagnum* sub-alpine peatlands

This group of Bogong sub-alpine peatlands has *Oreobolus distichus* as its distinguishing species, with *Astelia alpina, Baeckea gunnina, Richea continentis, Epacris petrophila* and *Celmisia tomentella* as constants. This was the most common *Sphagnum* community surveyed. *Sphagnum cristatum* cover ranged between 50–90% (median 80%), with one occurrence of *S. novo-zelandicum*. The condition of the sites varied considerably from two intact ungrazed sites to sites badly degraded by cattle grazing. Only one of the 17 sites in this group does not occur on the Bogong High Plains, but instead occurs on the Snowy Range. The altitude of sites in this group ranges from 1350 m to 1780 m (median 1640 m). While not having as cold annual mean temperature as Floristic Group 3 (median 5.6°C), these sites have the highest annual precipitation (median 2282 mm) and greatest precipitation in the driest period (median 92 mm). The landscape position of most of the sites is valley bogs. The geology is granite and phyllite schist/shale, and the median pH is 5.0. The sites have a moderate peat depth (median 70 cm), with short moss stem length (median 8.0 cm) and low to moderate species richness (median of 15) and low weediness (3 occurrences). Most of these sites show signs of 'pugging' caused by cattle hooves which results in exposed bare peat.

Floristic group 2. Ungrazed sub-alpine *Sphagnum* peatlands

The distinguishing species for this group is *Thelymitra venosa*, with *Acaena novae-zelandiae, Blechnum penna-marina* and *Lagenophora stipitata* common to the group. *Sphagnum cristatum* ranged between 15–95% cover (median 62%), with one occurrence of *Sphagnum falcatulum*. The absence of cattle damage in the *Sphagnum* peatlands and their intact condition is notable in this group of 11 sites. Ungrazed sub-alpine *Sphagnum* peatlands occur at Baw Baw, Mt Buffalo and the Snowy Range at altitudes ranging from 1420 m to 1620 m (median 1480 m). Annual mean temperature is 5.9 °C (median), with annual precipitation ranging from 1785 mm to 1912 mm (median 1870 mm). The geology for these sites is granite, with a median pH of 5.0 and a peat depth of 77 cm (median). The median moss stem length is 12.0 cm for the group, which has a moderate species richness (median 20) and low weediness (3 species). The landscape position of these sites is valley bog and headwater bog.

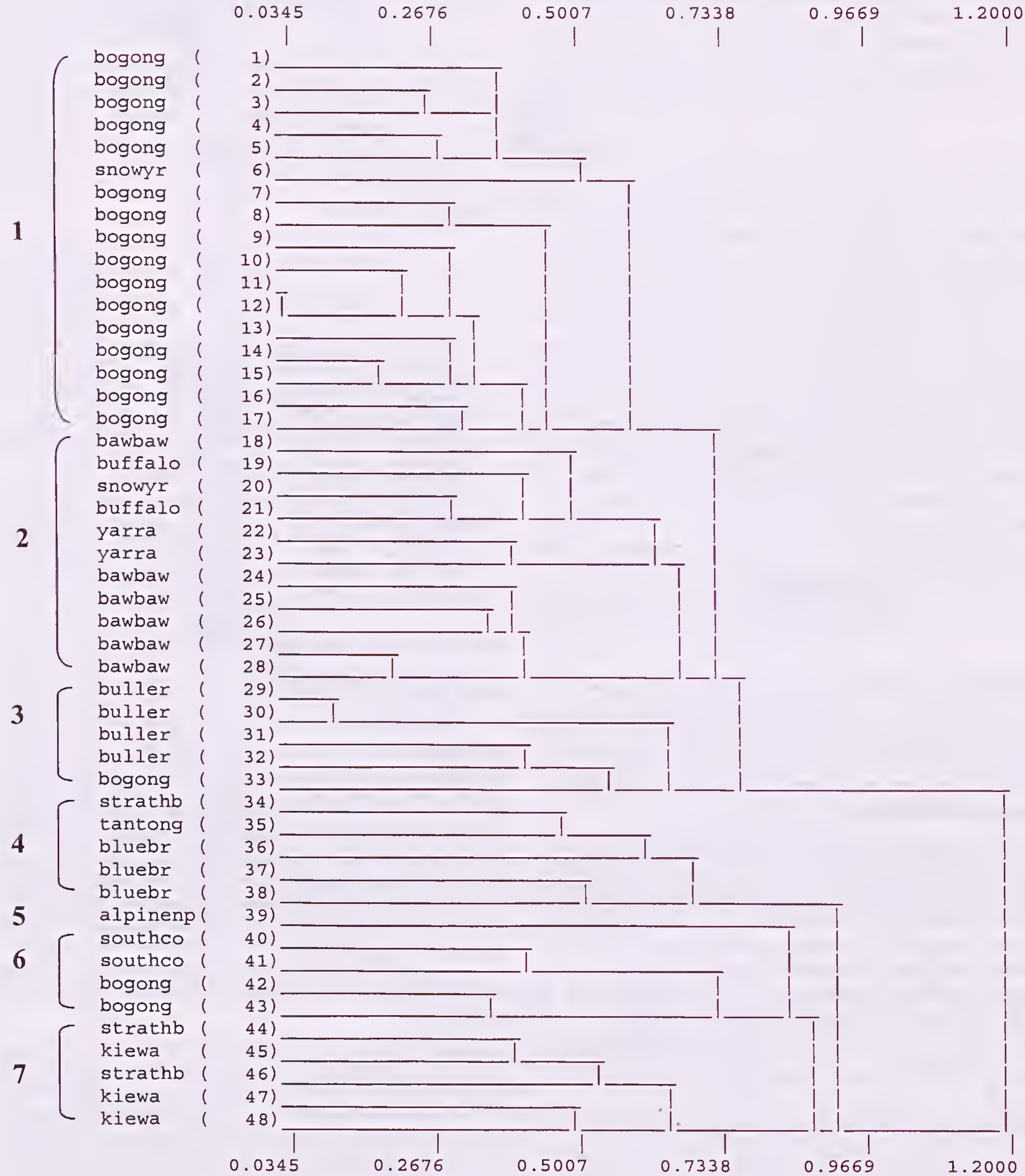

Fig. 2. Dendrogram from the UPGMA clustering of *Sphagnum* plots in Victoria. Plots are listed by region. The dissimilarity is displayed on the top edge of the dendrogram, while 'Level' (displayed) along the bottom edge of the dendrogram denotes the fusions for reference to the two-way table of indicator species displayed in Appendix 2.

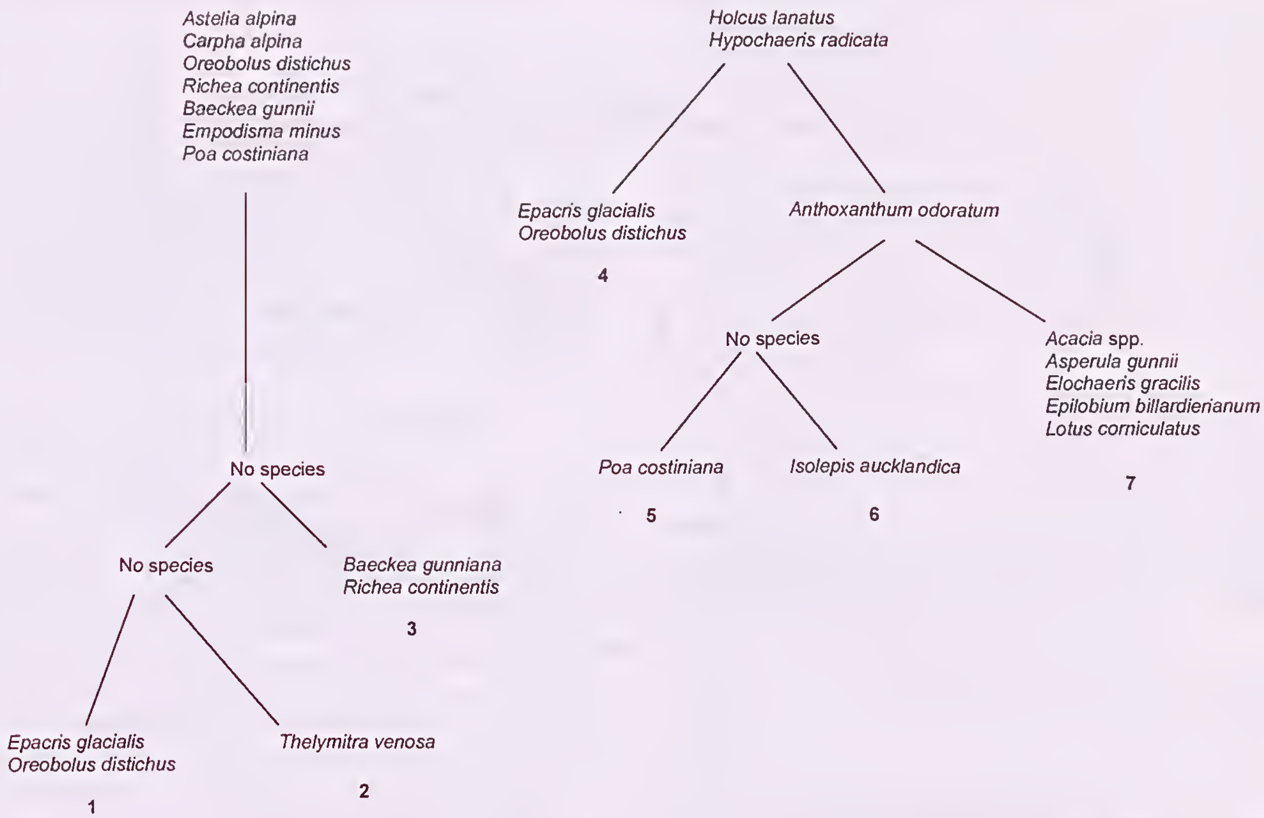

Fig. 3. Diagrammatic representation of floristic classification showing indicator species and levels significant at 0.001. Bold text denotes the 7 floristic groups (see text for group definitions).

Floristic group 3. Relic (sensu McDougall 1982) sub-alpine *Sphagnum* peatlands

The distinguishing species for this group is *Richea continentis*, with *Epacris paludosa*, *Oreobolus distichus*, and *Baeckea gunniana* common to the group. *S. cristatum* cover is low, ranging between 7–40% (median 20%). The sites in this group are seriously degraded or modified alpine *Sphagnum* peatlands, primarily headwater bogs at Mt Buller affected by ski trail development and associated maintenance. The sites range in altitude from 1700 to 1740 m and have an annual mean temperature of 5.3 °C (median) with annual precipitation ranging from 1785 to 1918 mm. The geology is primarily granite, with a median pH of 5.0, and a median peat depth of 51 cm. Median moss stem length is 10.0 cm and there is moderate species richness (median 21) which includes a high number of weeds (12 occurrences).

Floristic group 4. Montane fern-*Sphagnum* peatlands

The distinguishing species for montane fern-*Sphagnum* peatlands include *Blechnum penna-marina*, *Acaena novae-zelandiae* and *Carex appressa*, with *Chionogentias muelleriana* and *Olearia algida* constant. Cover of *Sphagnum cristatum* ranges between 60–95% (median 78%), with *Sphagnum novo-zelandicum* (5% cover) recorded at one site. These sites include generally small, valley bogs and hanging bogs that occur primarily in the Blue Breaks and Strathbogie Ranges in moderately good condition, although with extensive weed invasion from the surrounding vegetation (13 occurrences). They range in altitude from 500 m to 1280 m (median 900 m), with an annual mean temperature between 7.3 °C and 12.1 °C, and an annual precipitation ranging from 938 mm to 1767 mm. The geology for this group is mainly granite, with a median pH of 5.0 and peat depths ranging from 42 cm to 121 cm. The median moss stem length is 20 cm and median species richness is 22.

Floristic group 5. Aquatic *Sphagnum falcatulum* fen

This group consists of a single basin fen site at Lake Cobbler (altitude 1120 m), where *Sphagnum falcatulum* (55% cover) forms a fringe around part of the artificial lake and floats out across the water surface. Other distinguishing and common species include *Poa costiniana*, *Baumea gunnii*, *Lepidosperma* sp. and *Luzula modesta*. The fringing *Sphagnum* has been degraded by four wheel drive vehicles associated with camping at the lake. The pH is 6.0 at this sandstone site, with 94 cm peat depth and 14 cm moss stem length and low species richness (15), which includes only 1 weed species.

Floristic group 6. Degraded montane *Sphagnum* valley fens

The distinguishing species for this group of disturbed and/or modified sites is *Isolepis aucklandica*, with *Gonocarpus micranthus* and *Cotula alpina* common to the group. *Sphagnum cristatum* cover ranges between 25–100% (median 70%). These sites are generally montane valley fens that range from 900 m to 1750 m altitude (median 1250 m), with an annual mean temperature of between 5.2 °C and 9.0 °C (median 7.5 °C) and annual precipitation ranging from 1228 mm to 2369 mm (median 1752 mm). The geology is granite and phyllite schist/shale, with a pH ranging between 4.5 and 6.5 (median 6.0) and a peat depth of between 20 cm to 187 cm (median 65.5 cm). The median moss stem length is 10.0 cm for the group, which has moderate species richness (median 22), that reflects the high number of weed species (12 occurrences).

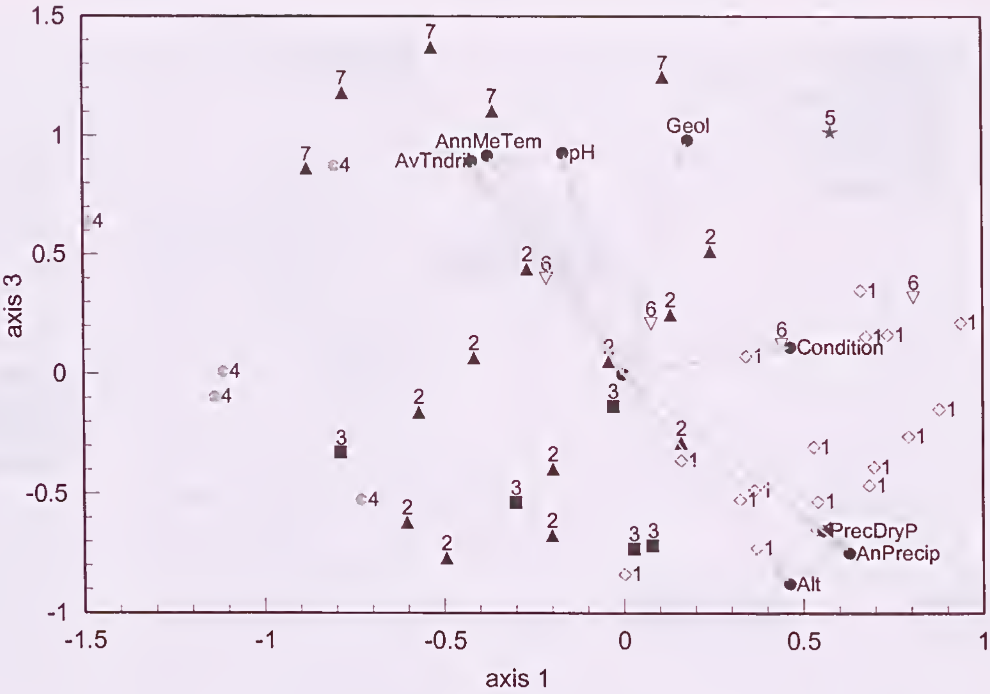

Fig. 4a

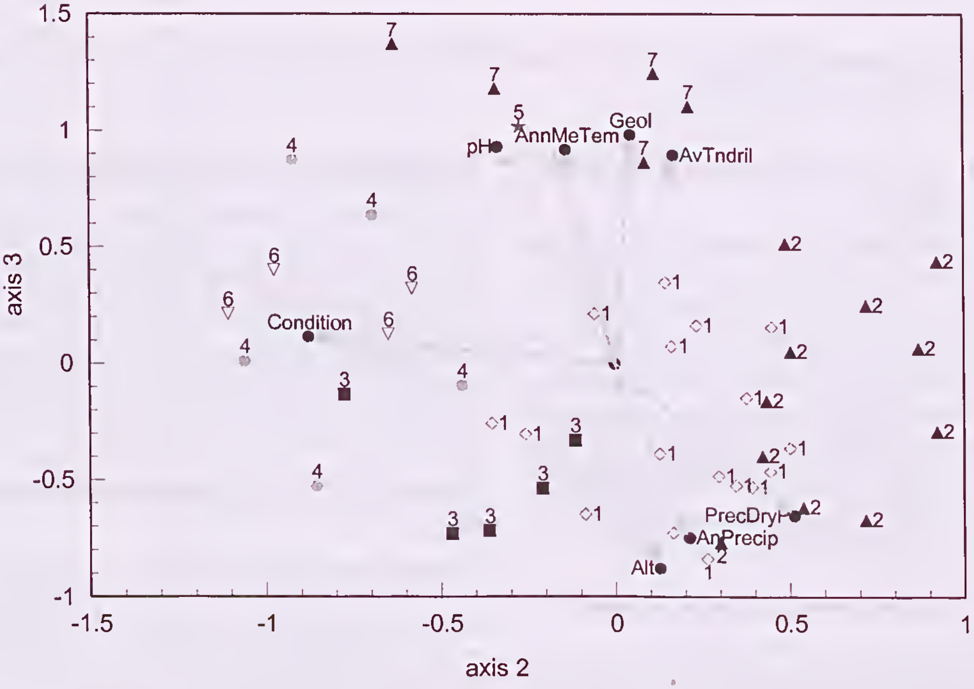

Fig. 4b

Fig. 4. HMDS in three dimensions, showing sites and significant (p<0.01) fitted vectors for environmental variables and species richness with respect to (a) axis 1 v 3, and (b) axis 2 v 3. Abbreviations for environmental variables are: Alt = altitude; Geol = Geology; AnMeTemp = annual mean temperature; AnnPrec = annual precipitation; PrecDP = precipitation of driest period.

Floristic group 7. Lowland shrubby *Sphagnum* fens

Distinguished by *Anthoxanthum odoratum*, *Eleocharis gracilis*, *Epilobium billardierianum*, *Lotus corniculatus* and *Asperula gunnii*, with a shrub overstorey of *Baeckea utilis*, *Callistemon pallidus*, these sites are valley fens. Cover of *Sphagnum cristatum* ranges between 35–80% (median 60%). All five sites are located on private land at altitudes of 350 m to 500 m in the Strathbogie Ranges and Kiewa Valley areas and subject to varying levels of cattle or horse grazing. The annual mean temperature is 13.1 °C (median), and annual precipitation is 1165 mm (median). The sites occur on granite and Quaternary river terraces, all with a pH of 6.0. The median peat depth for the group is 67 cm. The group has a median moss stem length of 32 cm, and a high species richness (median 28), that includes the highest number of weed species (27 occurrences).

Ordination of vegetation data and correlation with environmental variables

The MDS ordination (Fig. 4) shows how floristic groups are related to one another and the environmental vectors of maximum correlation ($P<0.01$). Group 7 is strongly influenced by increasing annual mean temperature, decreasing acidity and increased average moss stem length (Fig. 4a). Group 1 sites are strongly associated with increasing altitude, increasing annual precipitation and increasing precipitation in the driest month (Fig. 4a). Group 6 sites are strongly associated with decreasing condition (Fig. 4b) while Group 2 represents sites in the most intact condition (Figs 4a, b).

We recorded some form of disturbance at 60% of the sites surveyed, with more than one disturbance recorded at 15% of sites. Cattle trampling/grazing damage was the most common peatland disturbance recorded (29%). Other common signs of disturbance recorded were: weed invasion (13%), ski slope developments (8%), horse trampling (6%) and four wheel drive vehicles (4%), as well as drought, fire, moss poaching, deer damage, drainage alterations and trampling by humans. Most undisturbed *Sphagnum*-dominated communities were in Baw Baw National Park.

Discussion

The classification of the floristics of *Sphagnum*-dominated communities in Victoria shows regional clustering, a trend also found in *Sphagnum* peatlands in New South Wales and the Australian Capital Territory (Whinam & Chilcott 2002), and to a lesser extent, in Tasmania (Whinam et al. 2001). The regional clustering of the floristic composition of peatlands was related primarily to altitude, climate and geology.

The level of peatland degradation was also a significant environmental vector. The most disturbed sites surveyed contained the highest number of introduced species and also have a high native species richness. Almost half the sites (48%) contained at least one exotic species, with a total of 19 exotic species recorded. The most commonly recorded weeds were *Hypochoeris radicata* and *Holcus lanatus*. *Juncus effusus*, a recent serious invader of Victorian sub-alpine areas (McMorran 2002), was recorded at three sites. Weed eradication from *Sphagnum* peatlands is difficult, as eradication will generally be restricted to manual removal. The high water content of these peatlands and their role in catchment water dispersal generally precludes the use of chemical controls. These disturbed sites also tend to have a neutral pH (6.0), lacking the acidity commonly associated with *Sphagnum* bogs (Clymo 1973). This suggests that whilst *Sphagnum* is present, these sites can only be considered as marginal (restricted to peatland margins or drainage lines) or remnant *Sphagnum* peatlands, where *Sphagnum* moss now constitutes only a small percentage of the disclimax peatland vegetation cover. Further work could be done to develop more quantitative indices of change than the qualitative condition classes we have used.

The degraded state of many of the remaining *Sphagnum* peatlands suggests that there is a strong case for listing cattle grazing, under the Victorian Flora and Fauna Guarantee, as a threatening process to the conservation of *Sphagnum* peatlands in Victoria. Twenty-four plant species recorded in our survey are listed as rare and six as vulnerable in Victoria under the Flora and Fauna Guarantee 1988. Nationally, eight species are listed as rare (Leigh & Briggs 1996).

While many of the alpine and subalpine *Sphagnum* peatlands of Victoria are in the Alpine, Baw Baw and Mt Buffalo National Parks, few of the lowland and montane *Sphagnum* peatlands are reserved for conservation. The majority of *Sphagnum* peatlands surveyed are either *Sphagnum* remnants or severely degraded peatlands. Unfortunately, reservation has not equated with protection from the many activities that currently threaten the survival of *Sphagnum* peatlands in Victoria, including cattle grazing, forestry operations, ski slope development, fire and *Sphagnum* moss harvesting. There are two sub-alpine *Sphagnum* bogs in excellent condition on the Bogong High Plains, both of which are excluded from cattle grazing. One occurs on land outside the Alpine National Park (managed by the Alpine Resorts Commission) and the other in a long-term cattle exclosure at Rocky Valley (Maisie Carr's plot, Carr & Turner 1959, Wahren et al. 1999) within the National Park.

There have been repeated calls by researchers to remove cattle grazing from the Victorian Alps (Wahren et al. 1999, 2001) and our data supports these calls. We observed extensive damage by cattle and/or horses in montane, sub-alpine and alpine *Sphagnum* communities in Victoria. Damage varied from the occasional hoof print and exotic species presence (notably *Salix cinerea*), to the 'pugging' of the peatlands through to complete destruction of the peatlands, where rafts of dislodged vegetation were observed floating in streams. Preferential grazing of palatable forbs and graminoids (e.g. *Caltha introloba*, *Carex gaudichaudiana*) in *Sphagnum* bogs combined with trampling, can lead to increased dominance of unpalatable shrub species (Costin et al. 1959). Less immediate threats are posed by actions associated with forestry operations. The recent massive bushfires in the montane and alpine areas of Victoria demonstrate the vulnerability of this community to fire (Whinam 1995), but it is too early to predict the long-term ecological impacts of the fire on these sites. Our data provides a baseline from which to monitor changes in these peatlands, and post-fire studies are underway (C-H. Wahren & W. Papst, pers. comm.).

Modifications associated with ski slope development are likely to be influencing the *Sphagnum* moss beds at Mt Buller, Falls Creek and Mt Baw Baw. At Mt Buller only degraded remnants now occupy headwater depressions, suggesting that more extensive peatlands occurred in the past.

Moss harvesting also threatens the future integrity of peatlands in Victoria. The impacts of moss harvesting in *Sphagnum* peatlands in Australia and New Zealand have been previously identified (Whinam & Buxton 1997). The small total acreage of the available *Sphagnum* resource in Victoria indicates that moss harvesting would not be ecologically sustainable because of the long recovery periods required between harvests (Whinam & Buxton 1997).

The use of off-road vehicles has resulted in severe degradation of some *Sphagnum* peatlands. For example, at the aquatic *Sphagnum falcatulum* fen at Lake Cobbler, vehicular access has resulted in severe degradation of this very wet peatland. Vehicle barriers are necessary to prevent further degradation.

Several of the sites surveyed are of conservation significance due to their intact condition and floristic dissimilarity and have been identified in previous studies as requiring more formal protection. These sites include Snobs Creek, Tom Burns and Storm Creek in the Central Highlands (Kershaw et al. 1997), the Delegate River sites on the edge of the Errinundra Plateau (ANCA 1996), Tolmie State Forest in the Strathbogie Ranges and the Lake Cobbler fen. There should be more formal recognition of the outstanding condition and conservation significance of many of the *Sphagnum* peatlands at Mt Baw Baw. Continued protection of Maisie Carr's long-term ungrazed plots in the Alpine National Park is required.

Conclusion

Our analyses of *Sphagnum* peatlands in Victoria have shown a regional trend in the floristic variation of communities (related to geology, altitude and climate) and have, as in many previous surveys (ANCA 1996, Wahren et al. 1999, 2001), identified cattle grazing as the most immediate threatening process for the conservation of these peatlands. Other risks to the conservation of *Sphagnum* peatlands in Victoria include forestry operations, through fire and increased sedimentation, activities associated with ski resorts and moss harvesting (ANCA 1996).

This survey has described the floristic composition of *Sphagnum* peatlands in Victoria and their condition, prior to the 2003 bushfire, as well as identifying threats. The future for many of these *Sphagnum* peatlands is bleak, especially when the impacts of increased temperatures and altered rainfall patterns predicted with global warming are considered (Whinam et al. 2003). Many of the sites surveyed are likely to continue to deteriorate without management actions that mitigate against cattle grazing and related impacts.

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Appendix 1: Summary of site characteristics for *Sphagnum* peatlands in Victoria.

Abbreviations: F, Floristic Group; Pcc, Peatland conditon class*; Pd, Peat depth average (cm); SR, Species richness; Asp°, Aspect (degrees); S, slope (degrees); NP, National Park; Ski Res, Ski resort; SR, State Reserve; FSR, Forestry State Reserve; Quat: Quaternary

F	Region	Tenure	Pcc*	Alt.(m)	Geology	Threats	pH	Pd	SR	Asp°	S°
1	Bogong High Plains	NP	0	1600	phyllite schist/shale	none	4.5	72	15	150	2
1	Bogong High Plains	NP	3	1500	granite	none	4.5	65	13	100	7
1	Bogong High Plains	NP	0	1600	granite	none	5	120	15	180	0
1	Bogong High Plains	NP	1	1500	granite	none	6	65	17	300	130
1	Bogong High Plains	NP	1	1350	phyllite schist/shale	weeds	5	74	17	350	6
1	Snowy Range	NP	2	1600	granite	fire, cattle grazing/trampling	5	120	15	300	4
1	Bogong High Plains	NP	2	1520	granite	cattle grazing/trampling	5	40	23	270	2
1	Bogong High Plains	NP	2	1520	granite	cattle grazing/trampling	5	123	18	330	2
1	Bogong High Plains	NP	1	1750	phyllite schist/shale	none	4.5	72	15	5	5
1	Bogong High Plains	NP	0	1660	granite	none, fenced	5	104	17	360	2
1	Bogong High Plains	NP	2	1660	granite	cattle grazing/trampling	5	54	15	30	0.5
1	Bogong High Plains	NP	1	1640	phyllite schist/shale	cattle grazing/trampling	5.5	87	14	300	2
1	Bogong High Plains	Ski Res.	0	1740	phyllite schist/shale	none	4.5	42	11	150	0
1	Bogong High Plains	NP	1	1700	phyllite schist/shale	horse trampling	4.5	79	17	180	10
1	Bogong High Plains	NP	1	1780	phyllite schist/shale	weeds, cattle grazing/trampling	4.5	61	15	240	13
1	Bogong High Plains	NP	2	1780	phyllite schist/shale	cattle grazing/trampling	5.5	38	15	240	2
1	Bogong High Plains	NP	4	1710	phyllite schist/shale	cattle grazing/trampling	5.5	41	17	70	2
2	Baw Baw	NP	0	1450	granite	none	5	55	29	130	0
2	Mt Buffalo	NP	0	1420	granite	none	5	92	20	10	1
2	Snowy Range	NP	1	1620	granite	horse trampling	5	34	18	210	3
2	Mt Buffalo	NP	0	1480	granite	none	5.5	50	20	0	0
2	Yarra Ranges	NP	0	1520	granite	none	5.5	48	19	0	0
2	Yarra Ranges	NP	0	1520	granite	drought	6	106	19	160	1
2	Baw Baw	NP	0	1470	granite	none	5	77	22	60	7
2	Baw Baw	NP	0	1510	granite	none	5	58	34	10	3
2	Baw Baw	NP	0	1470	granite	none	5	88	28	260	1
2	Baw Baw	NP	0	1470	granite	none	5.5	92	15	60	5
2	Baw Baw	NP	0	1540	granite	none		80	18	30	1
3	Mt Buller	Ski Res.	3	1700	granite	skiing	5	89	10	340	8
3	Mt Buller	Ski Res.	4	1700	granite	skiing	4.5	75	9	340	12
3	Mt Buller	Ski Res.	2	1700	granite	skiing	5	51	31	330	90
3	Mt Buller	Ski Res.	4	1720	granite	skiing, weeds	6	50	21	240	4
3	Bogong High Plains	NP	2	1740	phyllite schist/shale	trampling (horses, people)	5	33	25	150	9
4	Strathbogie Ranges	private	1	500	granite	pigs, deer	5.5	75	31	30	4
4	Tatong-Tolmie SF	SR	1	800	phyllite schist/shale	weeds	6	42	25	60	<1
4	Blue Breaks	FSR	0	900	granite	none	5.5	122	22	0	0
4	Blue Breaks	FSR	0	1220	granite	4WD vehicles	5.5	112	17	310	0
4	Blue Breaks	FSR	1	1280	granite	moss poaching	5.5	93	15	180	2
5	Alpine NP	NP	2	1120	sandstone	4WD vehicles	6	94	15	40	1
6	South Coast	NP	0	900	granite	drought	6	187	21	0	0
6	South Coast	NP	2	900	granite	fire, drain construction, cattle grazing/trampling	4.5	98	20	0	
6	Bogong High Plains	NP	3	1600	phyllite schist/shale	drain construction, cattle grazing/trampling	6.5	33	23	130	0
6	Bogong High Plains	NP	4	1750	phyllite schist/shale	weeds, cattle grazing/trampling	6	30	31	45	6
7	Strathbogie Ranges	private	3	500	granite	cattle grazing/trampling	6	110	30	90	3
7	Kiewa Valley	private	3	350	Quat. river terraces	cattle grazing/trampling	6	75	26	20	1
7	Strathbogie Ranges	private	3	480	granite	cattle grazing/trampling, weeds	6	67	28	280	2
7	Kiewa Valley	private	1	350	Quat. river terraces	none	6	75	32	40	3
7	Kiewa Valley	private	2	350	Quat. river terraces	none	6	49	23	340	0

* Definitions of peatland condition class (Pcc): (0) undamaged; (1) light damage, where only minimal surface disturbance was evident; (2) degraded, where there was a breakdown of surface morphology e.g. through repeated hoof trampling; (3) modified, where the surface and edge morphology has broken down i.e. edge erosion from trampling and pugging caused by hooves; (4) highly modified and degraded where the surface morphology has broken down and only patches of isolated *Sphagnum* moss remain in disturbed, bare peat

Appendix 2: Two way table of species by final site groups (Groups 1–7).

Group size (in parentheses) and indicator values. * Denotes introduced species.

Species	L	1 (17)	2 (11)	3 (5)	4 (5)	5 (1)	6 (4)	7 (5)	IndVal (48)
Sphagnum cristatum	1	17	10	5	4	0	4	5	93.75
Empodisma minus	1	17	11	5	0	1	4	1	81.25
Baeckea gunnii	1	16	9	5	0	0	2	2	70.83
Poa castiniana	1	14	11	5	0	1	2	1	70.83
Carex gaudichaudiana	1	16	7	1	0	1	4	1	62.5
Epacris paludosa	1	7	8	5	3	0	2	3	58.33
Halcus lanatus *	2	0	0	0	2	1	3	5	73.33
Hypachaeris radicata *	2	0	1	3	4	0	3	3	56.41
Hypericum japonicum	2	2	0	0	3	0	3	2	47.89
Baeckea utilis	2	0	0	0	3	0	2	2	46.67
Hydracotyle sibthorpioides	2	0	0	0	1	0	1	2	26.67
Gonocarpus sp.	2	0	0	0	1	0	1	1	20
Eucalyptus camphora	2	0	0	0	1	0	0	1	13.33
Geranium potentilloides	2	0	0	0	1	0	0	1	13.33
Ganacarpus tetragynus	2	0	0	0	1	0	0	1	13.33
Gratiola peruviana	2	0	0	0	1	0	0	1	13.33
Richea cantinentis	2	16	11	5	2	0	1	0	77.88
Oreobolus distichus	2	14	5	1	0	0	0	0	60.61
Astelia alpina	2	11	10	1	0	0	1	0	60.61
Carpha alpina	2	10	6	1	0	0	0	0	51.52
Celmisia tamentella	2	11	3	2	0	0	0	0	48.48
Blechnum penna-marina	3	0	3	0	5	0	0	0	91.67
Acaena nova-zealandiae	3	0	1	1	5	0	1	0	86.16
Carex appressa	3	1	2	4	4	1	0	0	57.55
Rubus fruticasus *	3	0	0	0	3	0	0	2	45
Acacia melanoxylon	3	0	0	0	2	0	0	0	40
Histiopteris incisa	3	0	0	0	2	0	0	0	40
Hydracatyle hirta	3	0	0	0	2	0	0	0	40
Leptospermum grandifolium	3	0	0	0	2	0	0	0	40
Mentha australis	3	0	0	0	2	0	0	0	40
Tasmannia victoriana	3	0	0	0	2	0	0	0	40
Carex breviculmis	3	0	0	1	2	0	0	0	37.18
Isolepis sp.	3	1	2	0	3	0	0	3	36.33
Lagenifera stipitata	3	6	5	2	3	0	0	0	36.22
Euchitan involucratus	3	0	0	0	2	0	0	1	32
Epilobium gunnianum	3	0	1	0	2	0	0	2	25.38
Schoenus calyptratus	3	1	0	0	1	0	0	0	17.37
Sphagnum nova-zelandicum	3	1	0	0	1	0	0	0	17.37
Wittsteinia spp.	3	0	1	0	1	0	0	0	17.37
Deyeuxia brachyathera	3	0	2	0	1	0	0	0	15.35
*Anthoxanthum odoratum**	4	0	0	0	0	0	0	5	100
Eleocharis gracilis	4	0	0	0	0	0	0	4	80
Epilobium billardierianium	4	0	0	0	1	0	0	4	64
Acacia spp.	4	0	0	0	0	0	0	3	60
Lotus corniculatus *	4	0	0	0	0	0	0	3	60
Asperula gunnii	4	5	8	0	1	1	0	5	55.74
no species	4								
Nertera depressa	5	2	3	0	0	1	0	0	86.84
Lepidosperme sp.	5	0	0	0	0	1	1	0	80
Polytrichum sp.	5	1	1	0	1	1	0	0	79.33
Luzula modesta	5	0	4	2	0	1	0	2	63.22
Baloskion australe	5	7	0	0	0	1	0	2	62.03
Baumea gunnii	5	0	0	0	2	1	0	3	50
Isolepis aucklandica	5	4	2	2	0	0	4	0	80.49
Tasmannia xerophila	5	0	0	0	0	0	2	0	50
Trifolium repens *	5	0	0	0	0	0	2	0	50
Olearia algida	7	0	8	1	0	0	0	0	57.04
Callistemon sieberi	7	0	6	0	0	0	0	0	54.55
Chionagentias diemensis	7	0	6	0	0	0	0	0	54.55
Thelymitra venasa	7	5	8	0	0	0	0	0	51.78

Appendix 3: Summary of species occurrence in Victorian *Sphagnum* peatland floristic groups.

* denotes introduced species; spp. indicates genus where singleton species have been combined for analyses.

Floristic Group No. of sites	1 (17)	2 (10)	3 (5)	4 (4)	5 (1)	6 (4)	7 (5)
Acacia melanoxylon	0	0	0	2	0	0	0
Acacia spp.	0	0	0	0	0	0	3
Acaena novae-zelandiae	0	1	1	5	0	1	0
**Acetosella vulgaris*	0	0	2	0	0	0	0
**Agrostis capillaris*	0	0	1	0	0	1	0
Agrastis spp.	0	0	0	1	0	2	0
**Anthaxanthum odoratum*	0	0	0	0	0	0	5
Arthropodium milleflorum	0	0	0	0	0	0	2
Asperula gunnii	5	8	0	1	1	0	5
Astelia alpina	11	10	1	0	0	1	0
Baeckea gunniana	16	9	5	0	0	2	2
Baeckea utilis	0	0	0	3	0	2	2
Balaskian australe	7	0	0	0	1	0	2
Baumea gunnii	0	0	0	2	1	0	3
Blechnum penna-marina	0	3	0	5	0	0	0
Brachyscome obovata	0	2	0	0	0	0	0
Callistemon pallidus	1	0	0	0	0	0	1
Callistemon sieberi	0	4	0	0	0	0	0
Caltha introloba	0	6	0	0	0	0	0
Carex appressa	1	2	4	4	1	0	0

Floristic Group	1	2	3	4	5	6	7
No. of sites	(17)	(10)	(5)	(4)	(1)	(4)	(5)
Carex breviculmis	0	0	1	2	0	0	0
Carex gaudichaudiana	16	7	1	0	1	4	1
Carex spp.	2	0	2	0	0	1	1
Carpha alpina	10	6	1	0	0	0	0
Celmisia asteliifolia	3	2	0	0	0	0	0
Celmisia pugioniformis	1	4	0	0	0	0	0
Celmisia tomentella	11	3	2	0	0	0	0
Chiloglottis sp.	1	1	1	0	0	0	0
Chionogentias diemensis	0	6	0	0	0	0	0
Chionogentias muelleriana	1	1	0	0	0	0	0
Coprosma moorei	1	1	0	0	0	0	0
Cotula alpina	1	0	2	0	0	2	0
Craspedia coolaminica	0	3	1	0	0	0	0
Craspedia jamesii	0	3	0	0	0	0	0
Craspedia spp.	1	1	1	0	0	0	0
Deyeuxia brochyathera	0	2	0	1	0	0	0
Deyeuxia monticola	0	3	0	0	0	0	0
Diplapsis hydrocotyle	1	2	0	0	0	0	0
Diplaspis spp.	1	1	0	0	0	0	0
Drosera arcturi	5	5	0	0	0	0	0
Drosera spp.	1	0	0	0	0	0	1
Eleocharis gracilis	0	0	0	0	0	0	4
Empodisma minus	17	11	5	0	1	4	1
Epacris breviflora	0	2	0	1	0	2	0
Epacris glacialis	13	0	0	0	0	2	0
Epacris paludosa	7	8	5	3	0	2	3
Epacris petrophila	9	1	0	0	0	2	0
Epacris spp.	2	0	0	0	1	0	0
Epacris sp. A	0	2	0	0	0	0	0
Epilobium billardierianum	0	0	0	1	0	0	4
*Epilobium ciliatum	1	1	2	0	0	0	0
Epilobium gunnianum	0	1	0	2	0	0	2
Erigeron bellidioides	1	4	0	0	0	0	0
Erigeron nitidus	6	0	0	0	0	2	0
Eriocaulon scariosum	0	0	0	0	0	0	2
Erogrostis sp.	0	0	0	0	0	0	2
Eucalyptus camphora subsp. relicta	0	0	0	1	0	0	1
Eucalyptus ovata	0	0	0	0	0	1	2
Eucalyptus spp.	0	1	0	0	0	2	1
Euchiton collinus	1	0	0	1	0	1	0
Euchiton involucratus	0	0	0	2	0	0	1
Euchiton sp.	0	0	1	0	0	2	1
Euphrasia collina subsp. paludosa	0	1	1	0	0	0	0
Euphrasia gibbsiae	0	3	0	0	0	0	0
Euphrasia sp.	0	2	0	0	0	0	0
*Festuca rubra	0	0	2	0	0	0	0
Geranium potentilloides	0	0	0	1	0	0	1
Gonocarpus micranthus	5	2	1	0	0	3	2
Gonocarpus montanus	0	0	1	1	0	0	3
Gonocarpus sp.	0	0	0	1	0	1	1
Gonocarpus tetragynus	0	0	0	1	0	0	1
Gratiola peruviana	0	0	0	1	0	0	1
Hakea microcarpa	1	0	0	0	0	1	2

Floristic Group	1	2	3	4	5	6	7
No. of sites	(17)	(10)	(5)	(4)	(1)	(4)	(5)
Hierochloe redolens	0	1	2	0	0	0	0
Histiopteris incisa	0	0	0	2	0	0	0
*Holcus lanatus	0	0	0	2	1	3	5
Hydrocotyle hirta	0	0	0	2	0	0	0
Hydrocotyle sibthorpioides	0	0	0	1	0	1	2
Hydrocotyle sp.	1	1	0	1	0	1	3
Hypericum japonicum	2	0	0	3	0	3	2
*Hypochoeris radicata	0	1	3	4	0	3	3
Isachne globosa	0	0	0	0	0	0	2
Isolepis aucklandica	4	2	2	0	0	4	0
Isolepis sp.	1	2	0	3	0	0	3
Isolepis sp. B	0	2	0	0	0	0	0
Isotoma axillaris	0	0	0	0	0	0	2
Isotoma fluvitalis	0	0	0	0	0	0	2
*Juncus effusus	1	0	1	0	0	1	0
Juncus holoschoenus	0	0	0	0	0	0	2
Juncus prismatocarpus	0	0	0	0	0	0	2
*Juncus sp.	0	1	0	2	0	1	4
Lagenifera stipitata	6	5	2	3	0	0	0
Lepidosperma sp.	0	0	0	0	1	1	0
Leptospermum grandifolium	0	0	0	2	0	0	0
Leptospermum lanigerum	0	0	0	0	0	2	1
*Lotus corniculatus	0	0	0	0	0	0	3
Luzula modesta	0	4	2	0	1	0	2
Luzula novae-combriae	0	0	2	0	0	0	0
Luzula sp.	1	0	1	1	0	1	0
Lycopodium fastigiatum	4	0	2	0	0	0	0
Mentha australis	0	0	0	2	0	0	0
Myriophyllum pedunculatum	0	1	0	0	0	0	1
Nertera depressa	2	3	0	0	1	0	0
Olearia algida	0	8	1	0	0	0	0
Oreobolus distichus	14	5	1	0	0	0	0
Oreomyrrhis eriopoda	0	0	2	0	0	1	0
Oreomyrrhis pulvenifera	0	1	2	0	0	0	0
Pimelea alpina	1	1	0	0	0	0	0
Plantago euryphylla	0	0	2	0	0	1	0
Poa costiniana	14	11	5	0	1	2	1
Poa hothamensis	1	0	1	0	0	0	0
Polytrichum juniperinum	2	2	1	0	0	1	0
Polytrichum sp.	1	1	0	1	1	0	0
*Prunella vulgaris	0	0	0	1	0	0	2
Pultenaea sp.	0	2	0	0	0	0	0
Ranunculus pimpinellifolius	1	0	2	0	0	0	2
Rhynchospora brownii	0	0	0	0	0	0	2
Richea continentis	16	11	5	2	0	1	0
*Rubus fruticosus aggregate	0	0	0	3	0	0	2
Rytidosperma nivicola	0	2	0	0	0	0	0
Schoenus calyptratus	1	0	0	1	0	0	0
Schoenus sp.	0	2	0	0	0	0	0
Sphagnum cristatum	17	10	5	4	0	4	5
Sphagnum falcatulum	0	1	0	0	1	0	0
Sphagnum novo-zelandicum	1	0	0	1	0	0	0
Stylidium graminifolium	6	3	0	0	0	0	0
Tasmannia vickeriana	0	0	0	2	0	0	0
Tasmannia xerophila	0	0	0	0	0	2	0

Plant species first recognised as naturalised for New South Wales over the period 2000–2001

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Abstract: Information is provided on the taxonomy and distribution of 40 species of naturalised or naturalising plants newly recorded for New South Wales during the period 1 January 2000 to 31 December 2001. These species are: *Abrus precatorius* subsp. *precatorius, Acacia pulchella* var. *pulchella, Agave vivipara, Alnus glutinosa, Berberis thunbergii, Bryophyllum daigremontianum × Bryophyllum delagoense, Callisia fragrans, Celtis sinensis, Chamaesyce ophthalmica, Cotoneaster ?horizontalis, Cupressus arizonica, Cylindropuntia arbuscula, Cylindropuntia leptocaulis, Cylindropuntia spinosior, Cylindropuntia tunicata, Cyperus teneristolon, Deutzia crenata, Erica arborea, Erica glandulosa, Geranium robertianum, Hieracium murorum* species group, *Hippeastrum puniceum* hybrid, *Hyacinthoides non-scripta, Hypericum kouytchense, Hypericum patulum, Jacaranda mimosifolia, Jasminum polyanthum, Juglans regia, Justicia betonica, Koelreuteria formosana, Myagrum perfoliatum, Oenothera biennis, Pinus durangensis* (naturalising), *Pinus nigra* var. *corsicana, Schinus terebinthifolius, Scorpiurus muricatus, Tillandsia usneoides, Triadica sebifera, Viola riviniana* and *Vitis vinifera s. lat.*

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Introduction

The naturalised flora of Australia has received scant attention. In particular, there has been a general lack of concern about new naturalisations. Attention has traditionally focused on 'known' weedy species, and then frequently on weeds of agriculture. Species in the early stages of naturalisation, especially those from horticulture (including ornamentals), agriculture and pastures have typically fared worst, being deemed not worthy of scientific attention. This is reflected in the dearth of herbarium collections of a number of naturalised species, some of which have the potential to become serious weeds. This paper draws attention to a number of new naturalisations for the state of New South Wales over the period 2000–2001. Only species considered to be spreading from initial plantings or other naturalisations (e.g. from discarded garden refuse) are covered. 'Naturalised' in this paper refers to non-native species which are reproducing (sexually or vegetatively) in the wild for at least one generation.

Methods

Species are only listed here if there is at least one voucher specimen lodged at either the National Herbarium of New South Wales, Sydney (NSW) or the Australian National Herbarium, Canberra (CANB). A number of species listed were first collected prior to 2000 but are included as these records were overlooked for *Flora of New South Wales* accounts and were first noted in recent times at the National Herbarium of NSW in 2000 or 2001, or specimens were not forwarded until after 2000. Following recent collections a few old records of species stored at the end of genera and families in the National Herbarium of NSW collection were able to be determined to species. There are likely to be other records of recently naturalised species for NSW collected during 2000 and 2001 (or first noted at NSW herbarium during this period) housed at other Australian herbaria. For example a number of species from north-eastern NSW are likely to have been sent to the Queensland Herbarium, Toowong (BRI) and some from southern NSW to the National Herbarium of Victoria, South Yarra (MEL). We are not aware of these at present but 'Australia's Virtual Herbarium' project (http://plantnet.rgbsyd.nsw.gov.au/avh.html) should serve to highlight these in the future.

Names used for families and taxa are those currently used by the National Herbarium of NSW and can be viewed in PlantNET (Royal Botanic Gardens Sydney 18 March 2003). Herbarium codes follow Holmgren et al. (1990).

Information on the means of dispersal of the various taxa treated in this paper is given under 'Notes' for each taxon where this is known. Where the dispersal mechanism is not listed, then the plants are here presumed to be spread by seed. However, the actual means of dispersal in NSW is not known for a number of the taxa.

The format of this paper is based on that of Heenan et al. (1998, 1999, 2002) publications on recent plant naturalisations in New Zealand.

Discussion

The definition of the term 'naturalised' as used in this paper is outlined above. However, given that there is a degree of disagreement as to how this term should be applied (Richardson et al. 2000), we have provided additional information on numbers of plants present, area covered and reproductive status of all taxa treated in this paper to allow for these differences in interpretation.

There are many ways of detecting new plant naturalisations (Hosking et al. 2001). The records of plant naturalisations in the National Herbarium of New South Wales listed below are the result of (i) collections made by experts who have a reasonable knowledge of local floras, including local government weeds officers, environmental consultants, bush regenerators, professional botanists and staff from Landcare and Greening Australia and (ii) specimens retained by herbaria who provide plant identifications for the general public, government agencies and other professionals.

The species listed below include many succulents, particularly cacti. These are often not collected because of perceived difficulty in preparing good specimens. It is worthwhile summarising methods for preparing herbarium material of these plants. Succulents can be dealt with in a number of ways. Many can be frozen to destroy cell structure and then dried rapidly in warm air. Bulky succulents, such as cacti with large cladodes, can be cut parallel to the large faces of cladodes, frozen, and then dried rapidly in warm air. Another method of drying succulents, using a commercial hair-drier and a bag of tightly woven fire-resistant tissue, is described in Eggli and Leuenberger (1996). In this case high temperatures (65–70°C) maintained for 2–3 hours kill all plant tissue. The rest of the drying process takes 6–12 hours at a lower ventilation and temperature setting.

A number of species listed here, for example *Juglans regia* (walnut), *Schinus terebinthifolius* (broad-leaf pepper tree) and *Tillandsia usneoides* (Spanish moss) to name a few, are likely to have been recognised in the field for many years but have not been collected as many people are able to identify them. However, there is a need to collect specimens as a permanent record of when, where and how species begin to naturalise. This information is useful in calculating rates of spread and the time taken for species to become a problem.

It is hoped that publication of new records of plant species naturalised in NSW will prompt further collections of introduced species. In the long term, this approach will focus attention on potential problem species, and lead to their eradication before they have the opportunity to spread and become serious weeds.

Plant species first recognised as naturalised in New South Wales during 2000 and 2001

The species are grouped under Conifers and allies, Monocotyledons and Dicotyledons, then listed in alphabetical order (by scientific name), followed by vernacular name (where known). This is followed by references to published descriptions (including botanical illustrations and photographs), distribution within NSW according to botanical regions, habitat preferences (including areas where the species is likely to naturalise based on native range and areas where it has naturalised, if such information can be determined), the first known herbarium record, and additional herbarium records for the State, the region of origin and miscellaneous notes (including relative abundance, invasiveness and whether naturalised in other states). Authorities for native species are those currently recognised at the National Herbarium of NSW.

Conifers and allies

CUPRESSACEAE

Cupressus arizonica Greene

Arizona Cypress

DESCRIPTION: Tree to 20 m high. See Eckenwalder in Morin (1993).

REGION OF ORIGIN: Native to Arizona, California, New Mexico and Texas in the USA and Chihuahua and Sonora in Mexico.

NSW DISTRIBUTION / HABITATS: Southern Tablelands and Central Tablelands. The species is known to be naturalised in a few localities near existing plantings in NSW Tableland areas. At Majors Creek plants are growing in an area that was *Eucalyptus radiata* forest but is now cleared and dominated by mowed *Themeda australis*. Here it is growing on soil derived from granite. At Blackheath this species is growing in disturbed native *Eucalyptus sieberi* and *Eucalyptus oreades* shrubby woodland on sandy soil derived from sandstone.

FIRST RECORD: Majors Creek Township. Majors Creek Recreation Reserve, *G.W. Carr 9903-55 & P.J. Tucker*, 17 Mar 1999 (CANB, MEL, NSW).

ADDITIONAL RECORD: Native bush over road from 237 Hat Hill Road, Blackheath, *J.R. Hosking 2240 & C.H. Barker*, 25 Nov 2002 (CANB, MEL, NE, NSW).

NOTES: The taxonomy adopted here follows Eckenwalder in Morin (1993) and species previously included as varieties of *Cupressus arizonica* (var. *glabra* (Sudworth) Little, var. *nevadensis* (Abrams) Little and var. *stephonsii* (C.B. Wolf) Little)) or as the species *Cupressus glabra* Sudworth, *Cupressus nevadensis* Abrams and *Cupressus stephonsii* C.B. Wolf are all considered to be *Cupressus arizonica*. Notes with the Majors Creek specimen indicate that naturalised plants arise from about 45 trees planted 60+ years ago. At the time of collection there were thousands of plants present from tiny seedlings to small trees about 5 m high. At the Blackheath site there were three naturalised plants over the road from garden plants of the same species. Two of these plants were cone-bearing. There are a few other specimens of this species from the ACT held at CANB, but label data on these specimens does not indicate whether or not plants that have established naturally are reproducing or not. The earliest specimen of this type was collected by Mulvaney in March 1984 (*M.J. Mulvaney* s.n. ANU 30018 (CANB)). This species is also naturalised in Victoria (*G.W. Carr 9711–179* (CANB, MEL, NSW)). Spread occurs by seed via wind.

PINACEAE

Pinus durangensis Martinez

DESCRIPTION: Pine tree to 40 m high. See Farjon et al. (1997).

REGION OF ORIGIN: Native to northern Mexico.

NSW DISTRIBUTION / HABITATS: Northern Tablelands, naturalising alongside a trial plantation of this species.

FIRST RECORD: c. 400 m west of Ponderosa Picnic Area, Hanging Rock State Forest *J.R. Hosking 1876, T.L. & G.R. Hosking*, 13 Aug 2000 (CANB, MEL, NE, NSW).

NOTES: There are over 70 young plants to 4 m high growing alongside a plantation of this species. Plants are not yet cone-bearing. This species has not been recorded as naturalised or naturalising elsewhere in Australia or overseas to date.

Pinus nigra J.F.Arnold var. ***corsicana*** (Loudon) Hyl.

Corsican Pine

DESCRIPTION: Pine tree to 40 m high. See Jessop in Jessop & Toelken (1986, as *Pinus nigra* var. *maritima* (Aiton) Melville), Entwisle in Walsh & Entwisle (1994), Spencer (1995) and Hill in Orchard (1998).

REGION OF ORIGIN: Native to Corsica.

NSW DISTRIBUTION / HABITATS: Southern Tablelands. Naturalised near planted trees in disturbed scrub and the adjacent riparian community.

FIRST RECORD: Yass River, c. 1 km NE of Yass Post Office, *B.J. Lepschi 1062*, 29 Aug 1993 (CANB, NSW).

NOTES: A few plants are scattered through weedy native vegetation at the collection site. This species is also naturalised in Victoria and South Australia (Jessop in Jessop & Toelken 1986, Entwisle in Walsh & Entwisle 1994).

Monocotyledons

Fig. 1. *Agave vivipara* growing in native woodland at Yamba.

AGAVACEAE

Agave vivipara L.

DESCRIPTION: Succulent herb with trunk to 1 m high and inflorescence spikes to 5 m high. See Forster in George (1986).

REGION OF ORIGIN: Native to North America, but precise origin unknown.

NSW DISTRIBUTION / HABITATS: North Coast. Only known in NSW from native coastal woodland near Yamba where it was growing on sand (Fig. 1).

FIRST RECORD: North western edge of Yamba on sandy spit, alongside Clarence River, *J.R. Hosking 2145 & R.H. Holtkamp*, 28 Nov 2001 (CANB, MEL, NE, NSW).

NOTES: About 100 large plants and many smaller plants occur over an area of about 50 m × 50 m within *Banksia integrifolia* subsp. *integrifolia* woodland at the collection site. *Agave vivipara* is also naturalised and spreading in similar woodland on the beach side of the same track closer to Yamba. The species appears to be spreading via rhizomes. Large amounts of seed are being produced but it is not known if these are viable. This succulent probably originally reached this location as discarded garden waste. *Agave vivipara* is also recorded as naturalised from North Kennedy to Moreton pastoral districts in Queensland (Henderson 2002) with the first naturalised specimen collected by S.T. Blake at Rockhampton in May 1956 (G. Batianoff pers. comm. Dec 2002).

AMARYLLIDACEAE

Hippeastrum puniceum (Lam.) Kuntze hybrid

Barbados Lily

DESCRIPTION: Herb with flower scapes to 1.2 m high where collected. See Green in Orchard & Wilson (1994).

REGION OF ORIGIN: Hybrid developed in horticulture but the only known parent of the hybrid is *Hippeastrum puniceum*, which is native to the West Indies, Central America and northern South America.

NSW DISTRIBUTION / HABITATS: North Coast. Occurs in weedy *Eucalyptus* woodland.

FIRST RECORD: Vacant land alongside Warrawee Street, Sapphire Gardens, north of Coffs Harbour, *J.R. Hosking 1974*, 23 Nov 2000 (CANB, MEL, NE, NSW).

ADDITIONAL RECORDS: *Hippeastrum* sp., possibly the same taxon, Orana Park, Leumeah (small patch persistent on old homestead site), *E. McBarron* s.n., 5 Mar 1966 and 12 Mar 1966 (NSW).

NOTES: At Sapphire Gardens hundreds of plants were growing over more than 100 m at the edge of weed-infested *Eucalyptus* woodland between the Pacific Highway and a parallel side road. This infestation is likely to have originated from disposal of garden waste from nearby houses. This hybrid has not been recorded as naturalised in other Australian states.

BROMELIACEAE

Tillandsia usneoides (L.) L.

Spanish Moss

DESCRIPTION: Hanging epiphyte widely grown as an ornamental in NSW. See Conran in George (1987).

REGION OF ORIGIN: Native to south-eastern USA south to Chile and Argentina.

NSW DISTRIBUTION / HABITATS: North Coast. Occurs in a rainforest remnant, growing on *Araucaria cunninghamii* and *Grevillea robusta*. Likely to naturalise in warmer coastal areas of NSW.

FIRST RECORD: Rotary Park, Lismore, *J.R. Hosking 1961, R.G. Joseph & L.J. Wellman*, 20 Nov 2000 (BRI, CANB, MEL, NE, NSW).

ADDITIONAL RECORDS: Lismore (cult.?), *S.A. Flett* s.n., 29 Mar 1974 (NSW); Kirribilli (cult.), *J. Rogers* s.n., Aug 1968 (NSW).

NOTES: Naturalised in a remnant patch of rainforest, Rotary Park, in Lismore and reportedly naturalised at a number of other locations in Lismore (R. Joseph pers. comm. Nov 2000). This bromeliad is likely to be confused with native bryophytes and lichens. There is an earlier (1974) specimen from Lismore (*Flett* s.n.) that may represent an earlier naturalisation, but label data is ambiguous ('cult.?'). An earlier specimen collected in 1968 from Kirribilli (*Rogers* s.n.) has the following information on the label 'Growing on juniper, apparently spreading on this tree'. This suggests that the species was probably naturalised and spreading at this time. The species is also recorded as naturalised in south-eastern Queensland (Moreton and Wide Bay pastoral districts) (Conran in George 1987, Henderson 2002) with the first naturalised specimen collected by E.C. Cunning at Maryborough in November 1965 (G. Batianoff pers. comm. Dec 2002).

COMMELINACEAE

Callisia fragrans (Lindl.) Woodson

Fragrant Inch Plant

DESCRIPTION: Herb with inflorescence to 70 cm high. See Green in Orchard & Wilson (1994) and Hunt in Walters et al. (1984).

REGION OF ORIGIN: Native to Mexico.

NSW DISTRIBUTION / HABITATS: North Coast. Plants occur on a road cutting with introduced vegetation.

FIRST RECORD: Southern side of Bangalow Road cutting (planted on other side [of road] outside 162 Bangalow Road), Lismore, *J.R. Hosking 1964 & B.A. Scott*, 21 Nov 2000 (CANB, MEL, NE, NSW).

NOTES: At the collection site there were about 500 naturalised plants growing on and at the base of a steep cutting (slope to 60°). At the time of collection cultivated plants were being grown across the road from the naturalised plants. There are a number of cultivated plant specimens from NSW, dating from 1912 (held at NSW). The species is also recorded as naturalised in Queensland in the South Kennedy, Moreton and Wide Bay pastoral districts (Henderson 2002) with the first naturalised specimen collected by B. Lebler at Indooroopilly in September 1969 (G. Batianoff pers. comm. Dec 2002).

CYPERACEAE

Cyperus teneristolon Mattf. & Kuk. [syn. *Kyllingia pulchella* Kunth]

DESCRIPTION: Sedge with culms to 80 cm high. See Haines & Lye (1983) and Terry & Michieka (1987).

REGION OF ORIGIN: Native to eastern and southern Africa.

NSW DISTRIBUTION / HABITATS: Central Tablelands. Growing with other, mostly exotic, sedges and grasses in damp areas alongside a sandy watercourse.

FIRST RECORD: Minnehaha [as Minniehaha] Falls Reserve, c. 3 km N of Katoomba, *K.L. Wilson 9868*, 10 Mar 2000 (CANB, GENT, K, L, P, PRE, NSW, US).

ADDITIONAL RECORD: Alongside Yosemite Creek, Blue Mountains Refuse Tip, Katoomba, *J.R. Hosking 2009 & P.T. Gorham*, 7 Mar 2001 (CANB, MEL, NE, NSW).

NOTES: Locally abundant from Blue Mountains Refuse Tip downstream along Yosemite Creek to Minnehaha Reserve, North Katoomba, a distance of about 1.4 km. This species was first recognised as a new naturalisation by Van Klaphake in February 2000. The species is not known to be naturalised elsewhere in Australia. Likely to have been introduced to the tip area in garden refuse. This species spreads by stolons, rhizomes and possibly by seed and is reportedly an important weed of crops in highlands of eastern Africa (Terry & Michieka 1987). However, in Natal the species is 'Now becoming uncommon, probably due to interference with its natural habitats in Midlands' (Gordon-Gray 1995). *Cyperus teneristolon* is mainly found in open damp grassland areas or associated with rock outcrops in Natal (Gordon-Gray 1995). These habitats are similar to the area where it has naturalised in the Blue Mountains.

HYACINTHACEAE

Hyacinthoides non-scripta (L.) Chouard ex Rothm.

English Bluebell

DESCRIPTION: Herb with flowering culms to 45 cm high. See Healy & Edgar (1980, as *Scilla non-scripta* (L.) Hoffmanns. & Link).

REGION OF ORIGIN: Native to western Europe.

NSW DISTRIBUTION / HABITATS: Central Tablelands. Growing with native and exotic vegetation in disturbed areas. Most likely to naturalise in high altitude and high rainfall areas in NSW.

FIRST RECORD: Alongside Lone Pine Avenue, Gordon Falls Reserves, Leura, *J.R. Hosking 1921*, 5 Oct 2000 (CANB, MEL, NSW).

NOTES: Scattered through the Blue Mountains. Probably mainly growing as a result of disposal of garden waste. Also recorded as naturalised in the Southern Lofty botanical region of South Australia (Jessop 1993) and reportedly naturalised in Victoria (G. Carr pers. comm. Aug 1996). Listed as 'Garden outcast on roadsides and grassy waste places' in New Zealand (Healy & Edgar 1980).

Dicotyledons

ACANTHACEAE

Justicia betonica L.

Squirreltail

DESCRIPTION: *Justicia betonica* is an erect shrub that grows to 2 m high. See Immelman (1995).

REGION OF ORIGIN: Native to Asia and tropical Africa.

NSW DISTRIBUTION / HABITATS: North Coast from a *Casuarina* and *Melaleuca* swamp at Tweed Heads.

FIRST RECORD: Swamp at edge of road alongside golf course, Ukerebagh Nature Reserve, Tweed Heads, *J.R. Hosking 1973*, 22 Nov 2000 (AD, CANB, MEL, NE, NSW).

ADDITIONAL RECORD: Swamp at edge of road alongside golf course, Ukerebagh Nature Reserve, Tweed Heads, *J.R. Hosking 2025*, 14 Mar 2001 (AD, CANB, MEL, NE, NSW).

NOTES: *Justicia betonica* at present covers an area about 7 m × 3 m at Ukerebagh Nature Reserve. It appears to be spreading via stems that root where they contact the ground. Plants are producing large amounts of seeds but it is not known if these seeds are viable. The species probably reached this location as discarded garden waste. *Justicia betonica* is also recorded as naturalised in northern Queensland (Cook pastoral district) and south-eastern Queensland (Moreton pastoral district) (Henderson 2002) with the first naturalised specimen collected by A.E. Wilson at Townsville in October 1960 (G. Batianoff pers. comm. Dec 2002).

ANACARDIACEAE

Schinus terebinthifolius Raddi

Broad-leaf Pepper Tree

DESCRIPTION: Tree to 6 (rarely to 15) m high. See Taylor & Harden in Harden (2002) and Hussey et al. (1997).

REGION OF ORIGIN: Native to Argentina, southern Brazil and eastern Paraguay.

NSW DISTRIBUTION / HABITATS: North Coast, Central Coast and possibly North Western Plains. Grows on many substrates in woodland, open forest, pasture and disturbed areas. Most likely to naturalise in warmer coastal areas of NSW.

FIRST RECORD: Pittwater area, *N. Shields* s.n., 11 Jan 1995 (NSW).

ADDITIONAL RECORDS: Hastings Point, *G.N. Batianoff 980216*, 26 Feb 1998 (BRI, CANB, MEL, NSW); Byron Bay, Cape Byron, *G.N. Batianoff 980722, 980723*, 7 Jul 1998 (BRI, CANB, DNA, NSW); 'Old Brigalows' homestead [c. 80 km west of Moree] (seedling plants), *B. S. Wannan 1040 & M. E. Wannan*, 10 Jan 1999 (NSW); 1 km NW of Mullumbimby Post Office, *B. Scott* s.n., 2 Sep 2000 (NSW); farm of Jack Emery, Dudgeons Lane via Mullumbimby, *J.R. Hosking 1969 & P.E. Schweitzer*, 22 Nov 2000 (CANB, MEL, NE, NSW).

NOTES: The largest infestation known in NSW occurs near Mullumbimby (see *J.R. Hosking 1969 & P.E. Schweitzer*) where thousands of trees cover many hectares. Plants are spread by seed, mostly by birds and mammals, but also by water. *Schinus terebinthifolius* is widely planted as an ornamental and is now naturalised in temperate and subtropical Australia. The species is considered to be one of the most invasive naturalised plants in south-eastern Queensland (Batianoff & Butler 2002), an increasing problem in north-eastern NSW (B. Scott pers. comm. Nov 2000) and also occurs in the Perth region in Western Australia (Hussey et al. 1997). The first naturalised specimen collected in Queensland was collected by L.S. Smith at Bingera (Wide Bay pastoral district) in October 1948 and the first naturalised specimen collected in Western Australia was collected at Alfred Cove, on the south bank of the Swan River, 6 km upriver from Fremantle by R.J. Cranfield in August 1980 (P. Wilson pers. comm. Jan 2003). The species is a weed in South Africa (Henderson 2001) and a major weed in Florida, USA (Ferriter 1997). According to Ferriter (1997), *Schinus terebinthifolius* is a weed in sub-tropical areas between latitudes 15° and 30° N and S in many countries.

Fig. 2. *Hieracium murorum* growing in a bush regeneration area at Katoomba.

ASTERACEAE

Hieracium murorum L. species group

DESCRIPTION: Herb with inflorescence to 70 cm high. See Garnock-Jones in Webb et al. (1988) and Espie (2001).

REGION OF ORIGIN: Native to Europe and western Asia.

NSW DISTRIBUTION / HABITATS: Central Tablelands. Recorded growing in sandy humus and 'taubenite' shale (coal-like) at Katoomba in an area previously planted with *Pinus radiata* D. Don. (Fig. 2) and on red brown clay loam derived from basalt at Mt Irvine in a lawn and garden area. Most likely to naturalise in cooler tableland areas in NSW.

FIRST RECORD: Top NW corner of Frank Walford Park (above/adjacent to the old 'Catalina' racing circuit); and directly E of the SES [State Emergency Service] building by c. 150–180 m, West Katoomba, *M. Sherring* s.n., Nov 1998 (NSW).

ADDITIONAL RECORDS: Between Catalina Race Track and Great Western Highway, Katoomba, *J.R. Hosking 2000*, 5 Mar 2001 (CANB, CHR, MEL, NSW, NE); lawns and garden around entrance to 'Lindfield Park', Mt Irvine, *C.H. Barker 8 & J.R. Hosking*, 24 Mar 2003 (CANB, MEL, NE, NSW).

NOTES: The earliest record was for flowering material and was not identified to species until fruiting material was collected in 2001. The two records from Katoomba are from the same population that appears to be scattered over an area of less than 1 hectare. It is not known how the species reached the area. At the time of the initial collection there were approximately 1000 mature plants and rosettes but at the time of the second collection there were considerably fewer plants present (approximately 100 flowering plants and rosettes). The species is also known from Mt Irvine where over 100 plants were recorded from lawns and a garden around a carpark. A number of *Hieracium* species (hawkweeds) are considered to be problems in New Zealand (Espie 2001), although this species is not of major concern in that country at present (P. Syrett pers. comm. Apr 2001). *Hieracium murorum* is not known to be naturalised in other Australian states.

BERBERIDACEAE

Berberis thunbergii DC.

a barberry

DESCRIPTION: Multistemmed shrub to 4 m high. See Makino (1964) and Ohwi (1965).

REGION OF ORIGIN: Native to Japan.

NSW DISTRIBUTION / HABITATS: Central Tablelands. Growing in *Eucalyptus fastigata* and *Eucalyptus viminalis* tall open forest with a shrub understorey, on red brown clay loam derived from basalt. Likely to naturalise in cool high rainfall areas in NSW.

FIRST RECORD: Wollangambe Crown Reserve, 300 m north of Merriweather Lane, Mt Wilson, *J.R. Hosking 1927, M.J. Williams, C.K. Banffy & C.H. Barker*, 6 Oct 2000 (CANB, MEL, NE, NSW).

ADDITIONAL RECORD: Wollangambe Crown Reserve, 300 m north of Merriweather Lane, Mt Wilson, *J.R. Hosking 2011 & P.T. Gorham*, 7 Mar 2001 (CANB, MEL, NE, NSW).

NOTES: This species is not known to be naturalised elsewhere in Australia. Plants in the Reserve have green leaves whereas the most commonly planted form of this species is the red-leaved form known as *Berberis thunbergii* 'Atropurpurea'. There were about 20 flowering and fruiting shrubs at the collection site and a number of smaller non-flowering shrubs. Spread of *Berberis thunbergii* appeared to be by bird-dispersed seed, as for other *Berberis* species. *Berberis darwinii* Hook. is more widely naturalised in the Mt Wilson area than *Berberis thunbergii*.

BETULACEAE

Alnus glutinosa (L.) Gaertn.

Common Alder, Black Alder

DESCRIPTION: Tree to 18 m high. See Sykes in Webb et al. (1988), Fairhurst & Soothill (1989) and Sainty et al. (1998).

REGION OF ORIGIN: Native to Europe, western Asia and north Africa.

NSW DISTRIBUTION / HABITATS: Southern Tablelands and Central Tablelands, growing alongside streams. In Canberra it was growing with willows and other exotic species while at Katoomba it was collected from a wet sclerophyll forest of *Callicoma ceratifolia*, *Leptospermum polygalifolium*, *Eucalyptus oreades*, *Acacia elata*, *Gleichenia dicarpa*, *Blechnum indicum* and *Todea barbara*. Plants in the latter area were growing on grey sand derived from sandstone. Likely to naturalise in cool high rainfall areas in NSW.

FIRST RECORD: Canberra; suburb of Belconnen, large metropolitan park on west side of Lake Ginninderra, *G.W. Carr 9904-134*, 10 Apr 1999 (CANB, MEL, NSW).

ADDITIONAL RECORD: Base of upper part of Katoomba Cascades above Katoomba Falls, Katoomba, *J.R. Hosking 2243 & C.H. Barker*, 25 Nov 2002 (CANB, MEL, NE, NSW).

NOTES: This species has roots that are nitrogen-fixing and bind the substrate thereby checking erosion (Fairhurst &Soothill 1989). At the Canberra collection only a single naturalised tree was recorded although apparently a number of plants are naturalised around Lake Burley Griffin (Sainty pers. comm. 1998). Over 10 fruiting trees are naturalised alongside the Kedumba River alongside Katoomba Cascades. This species is reportedly naturalised in Victoria (Groves et al. 1997) but there are no herbarium specimens of naturalised plants for Australian states other than NSW and the ACT. Spread by seed via water and wind. Naturalised on the north and south islands of New Zealand where it can form almost pure stands (Webb et al. 1988).

BIGNONIACEAE

Jacaranda mimosifolia D. Don

Jacaranda

DESCRIPTION: Deciduous to semi-deciduous tree to 20 m high. See Henderson (2001).

REGION OF ORIGIN: Native to north-western Argentina and southern Bolivia.

NSW DISTRIBUTION / HABITATS: North Coast and Central Coast, naturalised near existing stands of *Jacaranda mimosifolia* in grasslands and woodlands. Associated vegetation in the area where *Hosking 1869* was collected comprised a number of weed species including *Lantana camara* L. Likely to naturalise in warmer coastal areas of NSW.

FIRST RECORD: Lake Parramatta near North Rocks Road [North Parramatta], *G. Dolman* s.n., 27 Sep 1983 (CANB).

ADDITIONAL RECORD: Alongside Bruxner Highway, above Mallanganee Nature Reserve (8.4 km from Mummulgum & 3.1 km from upper road into Mallanganee), *J.R. Hosking 1869*, 4 May 2000 (CANB, MEL, NE, NSW).

NOTES: The species is rarely collected as it is readily identified. Grown as an ornamental tree in many locations in NSW. The notes accompanying Dolman's specimen indicate that there were numerous seedlings growing in the collection area but do not give any indication of surrounding vegetation. Seedling trees rarely grow to adults in the Sydney region and the species is not reported to be a problem in this area (G. Sainty pers. comm. Oct 2003). Plants of all ages were present where *Hosking 1869* was collected. *Jacaranda mimosifolia* is considered to be an environmental weed in the Lismore area (B. Scott pers. comm. May 2000) and is also a weed in South Africa (Henderson 2001). Spread appears to be by seed from cultivated plants. The species is also recorded as naturalised in south-eastern Queensland (Burnett, Darling Downs, Moreton and Wide Bay pastoral districts) (Henderson 2002) with the first naturalised specimen collected by P.I. Forster at Munduberra in November 1987 (G. Batianoff pers. comm. Dec 2002).

BRASSICACEAE

Myagrum perfoliatum L.

Muskweed

DESCRIPTION: Herb to 1 m high. See Hewson in Jessop & Toelken (1986), Parsons & Cuthbertson (1992) and Entwisle in Walsh & Entwisle (1996).

REGION OF ORIGIN: Native to Europe and western Asia.

NSW DISTRIBUTION / HABITATS: North Western Slopes. A weed of cultivation on cracking clay soils (vertosols) and likely to be found on this soil type anywhere in cropping areas of NSW.

FIRST RECORD: Near Pump Station Creek, 'Windy Station', south-west of Quirindi, *J.R. Hosking 1875, A.M. Storrie & P.G. McKenzie*, 1 Aug 2000 (CANB, MEL, NE, NSW).

ADDITIONAL RECORD: Near Pump Station Creek, 'Windy Station', south-west of Quirindi, *J.R. Hosking 1930 & A.S. Cook*, 12 Oct 2000 (CANB, MEL, NE, NSW).

NOTES: Apparently identified by agricultural consultants in 1999 but no specimens were sent to herbaria for confirmation. The species is locally abundant in winter crops (such as canola – *Brassica napus* L., also in Brassicaceae) on the Liverpool Plains. Cruciferous weeds such as *Myagrum perfoliatum* are difficult to control in canola crops. *Myagrum perfoliatum* is spread by seed, either in contaminated grain or by water and mud. The species is not known to be naturalised elsewhere in NSW, but is recorded from South Australia, Victoria and Queensland where it is also considered to be a weed of cereals. The earliest naturalised specimen was collected by J.R. Tovey from the Wimmera district (Victoria) in February 1912 (V. Stajsic pers. comm. Jan 2003). For more information see Parsons and Cuthbertson (1992).

CACTACEAE

Cylindropuntia arbuscula (Engelm. & J.M.Bigelow) F.M.Knuth

DESCRIPTION: Small shrub cactus to 1.7 m high. See Benson (1982, as *Opuntia arbuscula* Engelm.).

REGION OF ORIGIN: Native to USA and Mexico.

NSW DISTRIBUTION / HABITATS: North Western Plains. Recorded from *Eucalyptus populnea* subsp. *bimbil* woodland.

FIRST RECORD: Northern side of Grawin, *J.R. Hosking 1889*, 19 Sep 2000 (BRI, CANB, MEL, NE, NSW).

NOTES: Segments have spines covered with detachable sheaths. Means of spread is not known but as with most cacti spread is likely to be through movement of segments and where seed is produced, by seed. Naturalised in disturbed areas around opal fields in northern New South Wales, although not common or widespread. Plants were being treated by the Prickly Pear Destruction Commission from the 1970s until cactus control was handed over to local councils in the late 1990s. Plants were only identified as cactus species at this time and specimens were not sent to any herbaria for identification. *Cylindropuntia arbuscula* is damaged by *Dactylopius tomentosus* (Lamarck) (L. Tanner pers. comm. Sep 2000), a cochineal insect that damages many species in the genus *Cylindropuntia*. This species is not known to be naturalised elsewhere in Australia.

Cylindropuntia leptocaulis (DC.) F.M.Knuth

Pencil Cactus

DESCRIPTION: Small shrub cactus to 1.5 m high. See Benson (1982, as *Opuntia leptocaulis* DC.).

REGION OF ORIGIN: Native to north western Mexico and adjoining areas of the USA.

NSW DISTRIBUTION / HABITATS: North Western Plains. Recorded from *Eucalyptus populnea* subsp. *bimbil* woodland.

FIRST RECORD: Northern side of Grawin, *J.R. Hosking 1890*, 19 Sep 2000 (BRI, CANB, MEL, NE, NSW).

NOTES: Segments pencil-like with spines covered with detachable sheaths. Means of spread is not known. Not common or widespread, only known to be naturalised on the northern side of Grawin township where it occurs with *Cylindropuntia arbuscula*, *Cylindropuntia tunicata*, *Austrocylindropuntia cylindrica* (Lam.) Backeb. (cristate form) and *Opuntia stricta* (Haw.) Haw. Other notes on early recognition and treatment as per *Cylindropuntia arbuscula* (above). Damage to *Cylindropuntia leptocaulis* by *Dactylopius tomentosus* is significant and this cochineal can be used to control this cactus (L. Tanner pers. comm. Mar 1993). This species is thought to be naturalised in the Barmera area of South Australia (Telford in George 1984).

Cylindropuntia spinosior (Engelm.) F.M.Knuth

DESCRIPTION: Small shrub cactus to 1.2 m high. See Benson (1982, as *Opuntia spinosior* (Engelm.) Tourney).

REGION OF ORIGIN: Native to USA and Mexico.

NSW DISTRIBUTION / HABITATS: North Far Western Plains. Recorded as growing with *Maireana pyramidata*.

FIRST RECORD: On hillslopes near dugouts and below plantings, above town area, White Cliffs, *C. Innes* s.n., 9 May 2000 (NSW).

NOTES: Segments have spines covered with detachable sheaths. Means of spread is not known. Scattered plants are recorded as growing near plantings. The species spread down slopes following heavy rains prior to collection (C. Innes pers. comm. May 2000). *Cylindropuntia spinosior* is likely to be damaged by *Dactylopius tomentosus*, a cochineal insect that damages many species in the genus

Cylindropuntia, although this cochineal has not been used to control *Cylindropuntia spinosior* in NSW. This cactus is not known to be naturalised elsewhere in Australia.

Cylindropuntia tunicata (Lehm.) F.M.Knuth

Hudson Pear (name used in New South Wales)

DESCRIPTION: Small shrub cactus to 1 m high although often mat-forming. See Swinbourne in Jessop & Toelken (1986), Stajsic & Carr in Walsh & Entwisle (1996) and Benson (1982). In all these references this species is under the name *Opuntia tunicata* (Lehm.) Link & Otto.

REGION OF ORIGIN: Native to Mexico, USA and Cuba.

NSW DISTRIBUTION / HABITATS: North Western Slopes, North Western Plains. Recorded from *Eucalyptus* woodland.

FIRST RECORD: Cumborah behind abandoned garage over road from turnoff to Lightning Ridge, *J.R. Hosking 1887, J.P., T.L. & G.R. Hosking*, 18 Sep 2000 (BRI, CANB, MEL, NE, NSW).

NOTES: Segments have spines covered with detachable sheaths. Means of spread is not known but as the species is now widely dispersed spread is likely to be both vegetative and by seed. Naturalised in disturbed areas in northern NSW (e.g. around towns such as Cumborah, Grawin, Glen Garry, Lightning Ridge and near Five Ways (west of Baradine)), where locally abundant. Present over many hundreds of hectares (G. Grimshaw pers. comm. Mar 2002). Other notes on early recognition and treatment as per *Cylindropuntia arbuscula* (above). *Cylindropuntia tunicata* is damaged by *Dactylopius tomentosus* (L. Tanner pers. comm. Sep 2000); damage may initially be significant but plants appear to recover. This cactus is naturalised in Victoria, South Australia (Telford in George 1984, Swinbourne in Jessop & Toelken 1986, Stajsic & Carr in Walsh & Entwisle 1996) and Western Australia (*S. Januskiewiecz* s.n., 22 Oct 2002, PERTH, NSW), and is also reported to be naturalised in South America (GRIN 21 June 2002) and South Africa (Zimmerman pers. comm. Feb 2003).

CLUSIACEAE

Hypericum kouytchense H.Lév.

DESCRIPTION: Shrubs in the collection area grow to 1.3 m high but plants reportedly grow to 1.8 m high. See Robson (1985).

REGION OF ORIGIN: Native to China (Guizhou province).

NSW DISTRIBUTION / HABITATS: Central Tablelands. Growing on brown sandy loam derived from sandstone with *Hypericum androsaemum* L., *Cytisus scoparius* (L.) Link, *Leycesteria formosa* Wall., *Lonicera japonica* Thunb., *Buddleja davidii* Franch., *Blechnum* sp., *Rubus anglocandicans* A. Newton and native and exotic herbs and rushes. Most common on banks of a small watercourse.

FIRST RECORD: Gordon Falls, Leura, *L. Thomas*, 2 Feb 2000 (NSW).

ADDITIONAL RECORDS: Gordon Falls Park, Leura, *J.R. Hosking 2007 & P.T. Gorham*, 7 Mar 2001 (BM, CANB, MEL, NE, NSW); Gordon Falls Park, Leura, *J.R. Hosking 2296*, 28 Mar 2003 (CANB, MEL, NE, NSW).

NOTES: The *Hosking 2007 & Gorham* collection was made from a single shrub 80 cm high. Two naturalised *Hypericum kouytchense* were seen in this area in November 2002. In March 2003 a scramble through weeds of many species, further down the hill, revealed over 100 fruiting shrubs and many immature plants growing over 70 m of creek front. The species has also been seen growing in a damp area below South Lawson Tip. Spread by seed. As not all specimens were available we were unable to check whether this species is the one referred to as *Hypericum × moserianum* André in Miller in Harden (2000). *Hypericum kouytchense* is not known to be naturalised elsewhere in Australia but it is recorded as naturalised near Lake Paringa on the South Island of New Zealand (Robson 1985).

Hypericum patulum Thunb.

DESCRIPTION: Multistemmed shrub to 2 m high. See Robson (1985), Li (1996) and Spencer (1997).

REGION OF ORIGIN: Native to south-western China and northern Vietnam.

NSW DISTRIBUTION / HABITATS: Central Tablelands. Growing on chocolate brown krasnozem derived from basalt, in an opening in montane rainforest with *Acer pseudoplanatus* L., *Leycesteria formosa* Wall., *Hymenanthera dentata* and ferns.

FIRST RECORD: Below house on lower side of Queen's Avenue, Mt Wilson, *J.R. Hosking 1845 & M.J. Williams*, 23 Feb 2000 (shrubs not visible from road) (BM, CANB, MEL, NE, NSW).

NOTES: Many hundreds of plants were present in an overgrown house yard and an opening in rainforest below the yard. This *Hypericum* is often planted as an ornamental but is not known to be naturalised elsewhere in Australia. The species is recorded as naturalised in Ecuador, Japan, South Africa and Taiwan (Robson 1985).

CRASSULACEAE

Bryophyllum daigremontianum (Raym.-Hamet & H.Perrier) A. Berger × *Bryophyllum delagoense* (Eckl. & Zeyh.) Schinz

Hybrid Mother-of-Millions

DESCRIPTION: Succulent herb with inflorescences to 1.2 m high. See Hannan-Jones & Playford (2002.

REGION OF ORIGIN: This hybrid was developed in the USA by A.D. Houghton of San Fernando, California using plant species that originated from Madagascar, although this hybrid is not known to occur naturally in Madagascar (Hannan-Jones & Playford 2002).

NSW DISTRIBUTION / HABITATS: North Coast, North Western Slopes and North Western Plains. Grows on many substrates in woodland, open forest, pasture and disturbed areas. Likely to naturalise in warmer areas of NSW.

FIRST RECORD: Wallangra, NE of Warialda, collector not mentioned, 24 Jul 1970 (NSW).

ADDITIONAL RECORDS: Oxley Park, Tamworth, *J.R. Hosking* s.n., 26 Sep 1987 (NE, NSW); W end entrance of Gooniwigal BR, 4 km SE Inverell, *G.J. Baldwin 84*, 11 Feb 1993 (NE); Garrieties Gully, Oxley Park, Tamworth, *J.R. Hosking 1880*, 31 Aug 2000 (BRI, CANB, MEL, NE, NSW); alongside Bucketts Road, Gloucester, *J.R. Hosking 2202 & M.W. Tull*, 1 Mar 2002 (CANB, MEL, NE, NSW); amongst otherwise mostly native vegetation opposite road to tip, Lightning Ridge, *J. R. Hosking 2344*, 4 Sep 2003 (BRI, CANB, MEL, NE, NSW).

NOTES: The first record was identified as *Kalanchoe daigremontiana* Raym.-Hamet & H. Perrier but is this species. This taxon was correctly identified by staff at NSW in 1987 but was overlooked for *Flora of New South Wales* treatments (Everett & Norris in Harden 1990, Harden & Murray 2000). This hybrid is locally dominant in many areas and is particularly common on the opal fields around Lightning Ridge. Most naturalised populations originate from old gardens or discarded garden refuse and in a number of areas the species grows with *Bryophyllum delagoense* (Eckl. & Zeyh.) Schinz. This hybrid spreads via movement of plantlets and does not appear to produce much (if any) viable seed (Hannan-Jones & Playford 2002). Outside Australia the hybrid is naturalised in the Cayman Islands and the Lesser Antilles (Hannan-Jones & Playford 2002). *Bryophyllum* spp. are the subject of a biological control program at present (Hannan-Jones & Playford 2002). For more information on this hybrid, and its distribution in south-eastern Queensland, see Hannan-Jones & Playford (2002).

ERICACEAE

Erica arborea L.

Tree Heath

DESCRIPTION: Tree to 8 m high. See Jessop in Jessop & Toelken (1986), Walsh in Walsh & Entwisle (1996) and Sykes in Webb et al. (1988).

REGION OF ORIGIN: Native to southern Europe, Asian Turkey, central to northern Africa and the Canary and Madeira Islands.

NSW DISTRIBUTION / HABITATS: Central Tablelands. Growing in disturbed *Eucalyptus* woodland amongst native and exotic shrubs below native and exotic trees. Most likely to naturalise in cool, high rainfall areas of NSW.

FIRST RECORD: Roadsides near corner of Ada and Wombat Streets, Blackheath (and also both sides of railway line above this location), *J.R. Hosking 1925, M.J. Williams, C.K. Bauffy & C.H. Barker*, 6 Oct 2000 (CANB, MEL, NE, NSW).

NOTES: Locally common in the area where the collection was made. In this area it was growing on vacant land, roadsides and between the road edge and railway line. This species appears to spread by seed. *Erica arborea* is not known to be naturalised elsewhere in NSW but is reported to be naturalised in South Australia and Victoria (Jessop in Jessop & Toelken 1986, Walsh in Walsh & Entwisle 1996). *Erica arborea* is also naturalised in New Zealand where it is not considered to be a problem (Sykes in Webb et al. 1988).

Erica glandulosa Thunb.

DESCRIPTION: Shrub to around 1 m high. See Schumann & Kirsten (1992) and Thiselton-Dyer (1909).

REGION OF ORIGIN: Native to South Africa (south-eastern Cape Province).

NSW DISTRIBUTION / HABITATS: Central Tablelands. Collected from a slashed high tension power line easement through shrubby *Eucalyptus–Angophora* woodland.

FIRST RECORD: 60 m N of the end of Allen St, North Lawson, *M. Williams* s.n., 17 May 2000 (NSW).

ADDITIONAL RECORDS: 60 m west north west of the end of Allen Street, *J.R. Hosking 2323 & C.H. Barker*, North Lawson, 20 Aug 2003 (AD, CANB, MEL, NE, NSW).

NOTES: Notes with the original collection indicate that that the species had naturalised from an adjacent residential area and that there were juvenile and mature plants present in an area of 25 square metres. Notes from a collection from the same area but three years later indicate that there were about 90 plants in an area the same size as previously, and that there were a few shrubs scattered for about 2 m below this area and an additional plant was located 45 m from the original area.

EUPHORBIACEAE

Chamaesyce ophthalmica (Pers.) D.G.Burch

DESCRIPTION: Prostrate to semi-erect herb to 10 cm high. See Harris (2001).

REGION OF ORIGIN: Native to southern Mexico to Ecuador.

NSW DISTRIBUTION / HABITATS: North Coast. Occurs as a weed of pavements, home gardens, lawns, road verges and other disturbed areas. Likely to become widespread and common in disturbed areas in northern NSW although we are uncertain as to the possible full extent of spread.

FIRST RECORD: Roadside outside Far North Coast County Council depot, Wyrallah Road, East Lismore, *J.R. Hosking 1965 & B.A. Scott*, 21 Nov 2000 (BRI, CANB, NE, NSW).

ADDITIONAL RECORDS: Edge of Bangalow Road near intersection with Donnans Road, Lismore, *J.R. Hosking 2020*, 13 Mar 2001 (CANB, MEL, NE, NSW); gardens and pavements at Twin Pines Motel, 49 Wooli Street (opposite Yamba Bowling Club), Yamba, *J.R. Hosking 2146*, 29 Nov 2001 (CANB, MEL, NE, NSW); lawns and gardens of Bellinger Valley Motor Inn, Bellingen, *J.R. Hosking 2269*, 13 Mar 2003 (CANB, MEL, NE, NSW).

NOTES: Locally abundant on roadsides (in gravelled areas) and in lawns, spread by seed. Frequency on roadside areas suggest the species is spread by graders and probably in soil attached to vehicles. It is unlikely that this species was deliberately introduced. First collected in Australia by N. Byrnes at Mt Ommaney (Brisbane) on 11 February 1981 (G. Batianoff pers. comm. Dec 2002), it now occurs in a number of locations in Brisbane (Harris 2001) and occurs as far south as Port Macquarie in NSW. This species is also naturalised in mainland USA (Long & Lakela 1971). *Chamaesyce ophthalmica* is similar in habit and often occurs in disturbed areas with other *Chamaesyce* spp. such as *Chamaesyce hirta* (L.) Millsp., *Chamaesyce maculata* (L.) Small (previously *Chamaesyce supina* (Raf.) Moldenke) and *Chamaesyce prostrata* (Aiton) Small.

Fig. 3. *Triadica sebifera* forming a dense stand on the edge of a wetland at Casino.

Triadica sebifera (L.) Small [syn. *Sapium sebiferum* (L.) Roxb.]

Chinese Tallow Tree

DESCRIPTION: Deciduous dioecious tree to 10 (rarely to 15) m high. See Ohba in Iwatsuki et al. (1999).

REGION OF ORIGIN: Native to China.

NSW DISTRIBUTION / HABITATS: North Coast. At Casino it occurs as scattered trees amongst herbs and grasses at the edge of roadside drains or forms thickets excluding other species on the edge of a lake (Fig. 3).

FIRST RECORD: Alongside Queensland Road adjacent to Jabiru-Geneebeinga wetland, northern edge of Casino, *J.R. Hosking 1863 & B.A. Scott*, 3 May 2000 (CANB, MEL, NE, NSW).

ADDITIONAL RECORDS: Alongside Queensland Road adjacent to Jabiru–Geneebeinga wetland, northern edge of Casino, *J.R. Hosking 1966* (male) and *J.R. Hosking 1967* (female), 21 Nov 2000 (BRI, CANB, MEL, NE, NSW).

NOTES: *Triadica sebifera* was apparently planted on the edge of the wetland alongside Casino golf course (B. Scott pers. comm. May 2000) where there are now thousands of *Triadica sebifera* trees. It was recognised as a weed a number of years earlier by a local resident but specimens were not sent to any herbaria (B. Scott pers. comm. May 2000). The species is grown as a street tree in Sydney and in northern NSW but is not known to be a problem elsewhere in NSW. It is a weed of a few wet areas in south-eastern Queensland; the first naturalised specimen was collected by C.T. White at Chermside (Brisbane) in December 1928 (G. Batianoff pers. comm. Dec 2002). Spread occurs by seeds that are water and bird-dispersed. Fruits float and accumulate on margins of areas from which floodwater recedes. *Triadica sebifera* is considered to be a weed of wet areas in the USA from south Texas eastwards to Florida and north to North Carolina

(Randall & Marinelli 1996, Bruce et al. 1997) and is also naturalised in Japan, Taiwan, India, Pakistan, central and southern Europe, Martinique and the Sudan (Ohba in Iwatsuki et al. 1999, Bruce et al. 1997). Over time, *Triadica sebifera* plants in the USA appear to have become more invasive as genotypes have adapted to high growth and low defence, for example leaves from invasive trees are more poorly defended from herbivores by tissues containing defensive compounds such as tannins than are trees from native sources (Siemann & Rogers 2001). This sort of adaptation may be occurring in Australia. Extracts from *Triadica sebifera* appear to enhance its own germination and growth rather than hinder growth of other species (Conway et al. 2002). *Triadica sebifera* has been cultivated in China for 14 centuries for soap (seed coat), fuel (wood), candles (seed coat), drying oil (seed kernel), black dye (leaves), honey (nectar) and protein meal (seed kernel) (Bruce et al. 1997).

FABACEAE (FABOIDEAE)

Abrus precatorius L. subsp. *precatorius*

Crabs Eye

DESCRIPTION: Climber growing to 10 m high on supporting vegetation at Chinderah Golf Range. See Stanley in Stanley & Ross (1983).

REGION OF ORIGIN: Native to northern Australia, Malesia, tropical Asia and tropical Africa.

NSW DISTRIBUTION / HABITATS: North Coast. Coastal areas in various types of *Banksia* and *Eucalyptus* forest. Likely to naturalise in other high rainfall areas of coastal north-eastern NSW.

FIRST RECORD: Chinderah Golf Range, 11 km south of Tweed Heads, *J.R. Hosking 2024 & R.L. Watson*, 14 Mar 2001 (CANB, MEL, NE, NSW).

ADDITIONAL RECORDS: Crabbes Creek, near Murwillumbah (NSW), *A.J. Beck* s.n., 29 Jun 1981; roadside S of nursery, Hulls Road, S of Mooball, *N. Nicholson & A. McKinley*, Dec 1996 (NSW).

NOTES: This vine is also apparently common at the southern end of the township of Kingscliff (R. Watson pers. comm. Mar 2001). Although considered native by Stanley & Ross (1983), the first specimen collected in south-eastern Queensland was not collected until January 1967 by B. Lebler from Amity Point, North Stradbroke Island (G. Batianoff, Dec 2002), suggesting that *Abrus precatorius* is introduced to south-eastern Queensland. The species is not recorded in *Flora of New South Wales* (Harden 2002) but there are two specimens at NSW herbarium (*Beck* s.n. and *McKinley* s.n.) that may be from naturalised plants. The Beck specimen was collected in 1981, but the label states 'Growing in old banana plantation' and is ambiguous with regard to whether or not the species was naturalised or planted, the McKinley specimen only mentions the roadside location where it was collected. Plants may cause death of supporting vegetation by smothering (R. Watson pers. comm. Mar 2001). Spread appears to be by seed that are mostly bird-dispersed. Viable seeds may be found in drift lines and on the fore dunes in south-eastern Queensland and north-eastern NSW (G. Batianoff pers. comm. Dec 2002). Seeds are decorative and often used as ornaments, but they are highly toxic (Everist 1981).

Scorpiurus muricatus L.

Scorpion Plant

DESCRIPTION: Annual prostrate to erect herb to 80 cm high. See Harden in Harden (2002).

REGION OF ORIGIN: Native to Mediterranean Europe, Crimea, Transcaucasia, Asia Minor and Mediterranean Africa.

NSW DISTRIBUTION / HABITATS: Central Western Slopes. Likely to naturalise in pasture to open forest areas as *Scorpiurus muricatus* is adapted to disturbance and survives grazing. Often planted on heavy clay soils.

FIRST RECORD: c. 18 km W of Bribbaree, *G. Howe* s.n., 20 Oct 1999 (AD, BRI, CANB, K, MEL, NSW).

NOTES: Planted as a pasture species at a number of locations in NSW. Notes accompanying the Howe specimen record that *Scorpiurus muricatus* was naturalised over a small area adjacent to a stock route. Spread is likely to be by seed. *Scorpiurus muricatus* is also recorded as naturalised in southern Queensland (Darling Downs and Maranoa pastoral districts) (Henderson 2002) with the first naturalised specimen collected by C.S. Clydesdale in Geham District (Darling Downs pastoral district) in September 1952 (G. Batianoff pers. comm. Dec 2002).

FABACEAE (MIMOSOIDEAE)

Acacia pulchella R.Br. var. *pulchella*

Prickly Moses

DESCRIPTION: Spiny, bipinnate shrubby wattle to 1.5 m high. See Maslin in Orchard & Wilson (2001).

REGION OF ORIGIN: Native to south-western Western Australia.

NSW DISTRIBUTION / HABITATS: Central Tablelands, recorded from a bushland nature-strip with native trees and shrubs.

FIRST RECORD: Corner of Livingstone and Cataract St, Lawson (in front of and beside 28 Livingstone in bushland nature-strip), *D. Coleby* s.n. *& M.J. Williams*, 27 Sep 2000 (NSW).

NOTES: The specimen cited above has notes indicating that there were 15 plants over an area of 160 square metres and that these plants varied from seedlings and juveniles to mature plants. There was one horticultural plant noted on a nearby property and this was thought to be the source of the naturalised plants.

GERANIACEAE

Geranium robertianum L.

Herb Robert

DESCRIPTION: Biennial (sometimes annual) herb to 60 cm (rarely to 80 cm) high. See Aedo (2000), Smith in Walsh & Entwisle (1999) and Sykes in Webb et al. (1988).

REGION OF ORIGIN: Native to Europe, Asia and north Africa but the species is widely naturalised and the exact native range is obscure.

NSW DISTRIBUTION / HABITATS: Central Tablelands. Disturbed areas and creeklines in woodland to forest. Widely grown and likely to naturalise in wetter areas of NSW.

FIRST RECORD: 42 Seventh Avenue, North Katoomba, *I. Lett* s.n., 21 Nov 2000 (NSW).

ADDITIONAL RECORD: Alongside Gordon Creek, Gordon Falls Park, Leura, *J.R. Hosking 2001*, 5 Mar 2001 (CANB, MEL, NE, NSW).

NOTES: Often planted as an ornamental and appears to have naturalised along a number of creeklines in the Blue Mountains. The Lett specimen was from plants that grew in soil imported into a garden during landscaping work. Probably more widely distributed in NSW but likely to be overlooked as it is easily confused with native *Geranium* spp. Naturalised in Victoria and South Australia (Jessop 1993, Smith in Walsh & Entwisle 1999). *Geranium robertianum* is closely related to *Geranium purpureum* Vill. with which it is frequently confused (Aedo 2000), the latter sometimes referred to as *Geranium robertianum* subsp. *purpureum* (Vill.) Nyman (Stace 1991). *Geranium purpureum* Vill. has been recorded as naturalised in the Wellington district (Harden 1992). *Geranium robertianum* is naturalised and widespread in the USA and southern Canada (Aedo 2000).

HYDRANGEACEAE

Deutzia crenata Siebold & Zucc.

Deutzia

DESCRIPTION: Multistemmed shrub to 4 m (rarely to 7 m) high with hollow stems. See Makino (1964), Ohwi (1965) and Spencer (2002).

REGION OF ORIGIN: Native to Japan.

NSW DISTRIBUTION / HABITATS: Central Tablelands, recorded from *Eucalyptus* woodland on riverbank.

FIRST RECORD: Near Jenolan River crossing, Moorara Boss Trail, *D.H. Benson 2417 & D. Keith*, 19 Nov 1985 (NSW).

ADDITIONAL RECORDS: Jenolan River system, *M. Sherring* s.n., Feb 2000 (NSW); alongside Jenolan River below Jenolan Caves and above power station, *J.R. Hosking 2213*, 23 Apr 2002 (CANB, MEL, NE, NSW).

NOTES: *Benson 2417 & Keith* was originally identified as *Deutzia scabra* Thunb., however that species has 4–5-rayed stellate hairs on the lower leaf surface, while *Deutzia crenata* has 10–15-rayed stellate hairs on the lower leaf surface (Ohwi 1965). *Deutzia crenata* is often referred to as *Deutzia scabra* in horticulture (Given & Webb in Webb et al. 1988). *Deutzia crenata* is locally dominant, and appears to be displacing native species, along the Jenolan River over at least 1 km and is known to occur along at least 9 km of the Jenolan River. Growth of *Deutzia crenata* is similar to many multistemmed *Salix* spp. *Deutzia crenata* is not recorded as naturalised elsewhere in Australia but is recorded in low numbers at two locations in New Zealand (Given & Webb in Webb et al. 1988).

JUGLANDACEAE

Juglans regia L

Walnut

DESCRIPTION: Tree to over 20 m high. See Sykes in Webb et al. (1988) and Lu Ammin et al. (1999, 2001).

REGION OF ORIGIN: Native to south-eastern Europe to temperate Himalayas, China.

NSW DISTRIBUTION / HABITATS: Southern Tablelands. Grows on very steep, rocky limestone slopes in cleared, grazed eucalypt woodland with a weedy understorey. Numerous plants of *Prunus persica* (L.) Batsch. var. *persica* and *Prunus persica* var. *nucipersica* (Suckow) C.K.Schneid. (*B.J. Lepschi 4638, 4639 & A.J. Whalen*) also occur at the Wee Jasper–Yass road site.

FIRST RECORD: North bank of Murrumbidgee River at Taemas Bridge, 19 km SSW of Yass, *B.J. Lepschi 1592*, 4 Mar 1994 (CANB, NSW).

ADDITIONAL RECORD: 0.6 km W of Mountain Creek Road turnoff on Wee Jasper–Yass road, 17 km NE of Wee Jasper, *B.J. Lepschi 4637 & A.J. Whalen*, 14 Nov 2001 (CANB, CDA, K.L, MEL, NSW, P, US).

NOTES: Numerous plants of different ages, ranging from saplings to 1 m high to adult trees to c. 12 m high, growing on steep slopes above the Murrumbidgee River/Burrinjuck Reservoir and at another site c. 3 km to the south-west, along c. 500 m of Mountain Creek Road, extending into grazed woodland. Probably originating from plantings, although the origin of the parent plants is obscure, as all plants occur on extremely steep, relatively inaccessible slopes, sites unlikely to have supported habitation or plantings of any sort. The species also appears to be naturalised in South Australia (*Pearce 224* (AD, CANB)) and is reportedly naturalised in Victoria (Groves et al. 1997, although there are no specimens to support this record). In New Zealand the species is listed as 'Spontaneous in the vicinity of parent trees, near old gardens and plantations.' (Sykes in Webb et al. 1988). This is also likely to be the case in many locations in temperate south-eastern Australia.

MALACEAE

Cotoneaster ?horizontalis Decne.

Prostrate Cotoneaster

DESCRIPTION: Prostrate shrub. See Cullen et al. (1995) and Spencer (2002).

REGION OF ORIGIN: Native to China.

NSW DISTRIBUTION / HABITATS: Central Tablelands. Known from a number of disturbed locations on sandstone-derived soils in *Eucalyptus* woodland.

FIRST RECORD: Alongside drainage line in Harold Hodgsen Park, Katoomba, *J.R. Hosking 1840*, 23 Feb 2000 (AD, CANB, MEL, NE, NSW).

ADDITIONAL RECORD: Amongst ruins of old building near corner of Narrow Neck Road and Furnells Road, Katoomba, *J.R. Hosking 2208*, 22 Apr 2002 (AD, CANB, MEL, NE, NSW).

NOTES: Similar to, and sometimes treated as a variety of, the related *Cotoneaster microphyllus* Wall. ex Lindl., which is also naturalised in the Blue Mountains (e.g. *J.R. Hosking* 1844 & *M.J. Williams* (AD, CANB, MEL, NE, NSW)). *Cotoneaster microphyllus* is an erect shrub to 5 m high with dull red mature fruit whereas *Cotoneaster horizontalis* is prostrate and has scarlet mature fruit. The taxonomic status of *Cotoneaster* spp. in Australia is presently under study by D.E. Symon at the State Herbarium of South Australia (AD). Therefore the name of this taxon is not certain. *Cotoneaster horizontalis* is widely planted in cool climate areas of Australia and was recorded as a garden escape from Mt Buffalo, Victoria but has now been eradicated from this area (Groves et al. 1997).

OLEACEAE

Jasminum polyanthum Franch.

Jasmine

DESCRIPTION: Layering, climbing shrub. See Sykes in Webb et al. (1988).

REGION OF ORIGIN: Native to China (Guizho, Sichuan, Yunnan).

NSW DISTRIBUTION / HABITATS: Central Tablelands. Often growing with other vines into the tree canopy. Notes on specimens suggest that it forms a groundcover as well as penetrating the edge of rainforests and into disturbed open forest to tall open forest. Grows in coastal areas and at altitudes to over 1000 m at Mt Wilson.

FIRST RECORD: Mungo Brush, *A.N. Rodd 3723*, 10 Sep 1981 (NSW).

ADDITIONAL RECORD: Near intersection of Purchase Road and New Line Road, Cherrybrook, *P. Kodela 74 & R. Rowe*, 11 Dec 1990 (NSW).

NOTES: Early specimen at NSW herbarium overlooked and Kodela & Rowe specimen was housed at the University of New South Wales herbarium prior to transfer to NSW. This species may be locally dominant and is listed as a problem weed in the Blue Mountains area (Harley 2000). According to Harley (2000) seeds are rarely produced and plants spread mainly vegetatively by layering and suckering from the roots. The specimen from Mungo Brush also notes that this plant was 'spreading by underground runners'. *Jasminum polyanthum* is also present in secondary forest margins, scrub, waste ground and abandoned gardens in New Zealand (Sykes in Webb et al. 1988).

ONAGRACEAE

Oenothera biennis L.

Evening Primrose

DESCRIPTION: Erect herb to 1.5 m high. See Sykes in Webb et al. (1988), Dietrich et al. (1997) and Spencer (2002).

REGION OF ORIGIN: Native to eastern USA and eastern Canada.

NSW DISTRIBUTION / HABITATS: Central Tablelands. Road verge near *Eucalyptus* woodland.

FIRST RECORD: Alongside Bells Line of Road, Mt Tomah, *J.R. Hosking 2035*, 10 Apr 2001 (CANB, MEL, NE, NSW, US).

NOTES: Not recorded as naturalised in Australia prior to 2000. As for most *Oenothera* species, *Oenothera biennis* is common on roadsides and in other disturbed areas. The species is naturalised in many other countries and occurrences in western North America west of the plains region may represent naturalised populations (Dietrich et al. 1997).

SAPINDACEAE

Koelreuteria formosana Hayata

Chinese Rain Tree

DESCRIPTION: Tree to 5 m high. See Meyer (1976).

REGION OF ORIGIN: Native to Taiwan.

NSW DISTRIBUTION / HABITATS: North Coast, recorded from woodland with many naturalised exotic species and likely to naturalise in northern coastal areas of NSW.

FIRST RECORD: Undeveloped land alongside City View Drive, East Lismore, *J.R. Hosking 2019*, 13 Mar 2001 (CANB, MEL, NE, NSW).

NOTES: *Koelreuteria formosana* is an ornamental that appears to have become popular in recent years. This species is often known as *Koelreuteria elegans* (Seem) A.C. Sm. subp. *formosana* (Hayata) F.G. Mey. However, Smith (1985) and D.J. Crayn (pers. comm. Aug 2002) suggest that *Koelreuteria elegans* subsp. *formosana* should be a separate species and referred to as *Koelreuteria formosana*. There are many hundreds of naturalised plants in the area where *Hosking 2019* was collected, and this tree is likely to be naturalised in other areas on the north coast of NSW. *Koelreuteria formosana* is also naturalised in south-east Queensland with the first naturalised specimen collected by J. Wright at Brisbane Forest Park (Brisbane) in March 2001 (G. Batianoff pers. comm. Dec 2002). *Koelreuteria formosana* has been recorded as a cultivation escape in Florida (Meyer 1976) and is listed (under *Koelreuteria elegans*) as an invasive environmental weed by Batianoff & Butler (2002).

Fig. 4. *Celtis sinensis* is spreading in coastal areas of north-eastern New South Wales via bird- and bat-dispersed seed.

ULMACEAE

Celtis sinensis Pers.

Chinese Celtis

DESCRIPTION: Tree to 15 m high. See Harden & Murray (2000).

REGION OF ORIGIN: Native to China, Korea and Japan.

NSW DISTRIBUTION / HABITATS: North Coast. Grows on many substrates in woodland, open forest, pasture and disturbed areas. Likely to naturalise in high rainfall areas of northern NSW.

FIRST RECORD: Evans Head, *J. Buchanan* s.n., 10 Mar 1986 (NSW).

ADDITIONAL RECORDS: Coffs Harbour, *A.G. Floyd* s.n., 30 Nov 1998 (NSW); farm of J. & J. Dibley, Chauvel Street, Kyogle, *J.R. Hosking 1962 & B.A. Scott*, 21 Nov 2000 (CANB, MEL, NE, NSW).

NOTES: Label data on *Buchanan s.n.* is ambiguous as to whether or not the specimen is from a naturalised plant, but recent observations and collections suggest that it is likely to have been naturalised in the area since at least 1986. *Celtis sinensis* is known to be naturalised near Kyogle, Lynchs Creek, The Risk and Coffs Harbour and is also likely to be naturalised in many other areas in north-eastern New South Wales. Seeds of *Celtis sinensis* are spread by birds and fruit bats (Fig. 4), but seeds rarely survive for more than two years (Panetta 2001). The species is naturalised in damp areas, particularly along banks of waterways, in south-eastern Queensland. The first naturalised specimen was collected by C.T. White at Warwick in July 1926 (although there is an earlier sterile specimen, presumed to be naturalised, collected by T.L. Bancroft at Eidsvold in 1912) (G. Batianoff pers. comm. Dec 2002). In south-eastern Queensland it is considered to be one of the most invasive naturalised plants (Batianoff & Butler 2002).

VIOLACEAE

Viola riviniana Rchb.

Common Dog Violet

DESCRIPTION: Perennial herb to 20 cm high. See Entwisle in Walsh & Entwisle (1996) and Garnock-Jones in Webb et al. (1988).

REGION OF ORIGIN: Native to Europe and Morocco.

NSW DISTRIBUTION / HABITATS: Southern Tablelands and Central Tablelands in woodlands to shrublands close to where it has been planted. Likely to naturalise in cooler tableland areas in NSW.

FIRST RECORD: Australian Capital Territory, [Australian] National Botanic Gardens, car park, *M.D. Crisp 7199*, 21 Dec 1983 (CANB).

ADDITIONAL RECORDS: Australian Capital Territory, Australian National Botanic Gardens, Canberra, *I.R. Telford 11768*, 29 Oct 1992 (CANB); under power lines, above Govett Street, Katoomba, *J.R. Hosking 1915*, 4 Oct 2000 (CANB, MEL, NE, NSW); alongside Jefferson Bridge, Waterfall Creek, Gregson Park (between Queens Avenue and Waterfall Road), Mt Wilson, *J.R. Hosking 2276 & C.H. Barker*, 24 Mar 2003 (CANB, MEL, NE, NSW).

NOTES: This violet is widely grown as an ornamental herb. Known to be naturalised in the Australian Capital Territory where it is recorded as naturalised in the Australian National Botanic Gardens. Apart from being recorded as adventive in the car park by M.D. Crisp, notes supplied by I.R.H. Telford record that his collection was from disturbed open forest in the Gardens. *Viola riviniana* is also naturalised at Katoomba in the Blue Mountains and at Mt Wilson. Label data for *Hosking 1915* record that the species is locally frequent (>30 clumps of plants where collected) and that the species is widely naturalised in disturbed bush in and around Katoomba and other urban areas within the Blue Mountains. Label data for *Hosking 2276 & Barker* indicate that there were many 1000s of naturalised plants in the collection area. Spread appears to be by seed from cultivated plants or via discarded garden waste. The species is also recorded as naturalised in Victoria (Entwisle in Walsh & Entwisle 1996).

VITACEAE

Vitis vinifera L. *s. lat.*

Grape

DESCRIPTION: Climber to 8 m high on supporting vegetation. See Sykes in Webb et al. (1988).

REGION OF ORIGIN: Native to Europe, western Asia, Asia Minor and North Africa.

NSW DISTRIBUTION / HABITATS: North Coast and Central Tablelands. Scattered on a number of substrates. At the site below South Lawson tip it is part of a weed plume, mostly a closed forest of *Salix cinerea* L., spreading down a watercourse from the tip site. This plume is surrounded by native Sydney sandstone flora.

FIRST RECORD: 'Weetaliba', Weetaliba, *J. Raybone s.n.*, 10 Feb 1971 (NSW).

ADDITIONAL RECORDS: Upper Bunya, on upper Wang Wank River in Wallis Lakes catchment, *L. Hill s.n.*, 15 Jan 2001 (NSW); about 100 m below South Lawson tip site at end of Ridge Street, South Lawson, *C.H. Barker 6 & J.R. Hosking*, 27 Nov 2002 (CANB, MEL, NE, NSW).

NOTES: The taxon found at Upper Bunya and South Lawson has cobwebby hairs on the lower surface, while the one recorded from near Weetaliba is likely to be a muscatel grape and has dissected leaves and is hairless. *Vitis vinifera* was not considered to be naturalised at the time that Harden (1992) was published but recent records suggest that it has naturalised although only weakly so at present. To date only known from single plants at each location but likely to be scattered elsewhere. Spread by bird-dispersed seed. *Vitis vinifera* has naturalised in Western Australia (PERTH specimen) and Victoria (MEL specimen). *Vitis vinifera s. lat.* is also naturalised in New Zealand and naturalised taxa under this name also vary in a number of characters (Sykes in Webb et al. 1988). In New Zealand the variation in characters is ascribed to variation in grape cultivars and hybrids introduced to that country, some of these involve crosses with North American *Vitis* species. This is also likely to be the explanation for variation occurring in Australia.

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Vegetation and flora of Arakoola Nature Reserve, North Western Slopes, New South Wales

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Abstract: The vegetation of Arakoola Nature Reserve (3189 ha), 29°17'S, 150°48'E, 100 km north-west of Inverell, in north western New South Wales is described. Seven vegetation communities are defined based on flexible UPGMA analysis of cover-abundance scores of all vascular plant taxa. These communities are mapped based on ground-truthing, air photo interpretation and geological substrate. They are: 1) Community 1: *Eucalyptus albens* (White Box) – *Eucalyptus melanophloia* (Silver-leaved Ironbark) Basalt Woodland, Community 2: *Angophora leiocarpa* (Smooth-barked Apple) – *Corymbia dolichocarpa* (Long-fruited Bloodwood) Sandstone Woodland, Community 3: *Angophora leiocarpa* (Smooth-barked Apple) – *Eucalyptus macrorhyncha* (Red Stringybark) Woodland, Community 4: *Chloris truncata* (Windmill Grass) Grassland, Community 5: Herbfield/Sedgeland, Community 6: *Eucalyptus camaldulensis* (Red Gum) – *Eucalyptus melliodora* (Yellow Box) Riparian Woodland, Community 7: *Angophora floribunda* (Rough-barked Apple) – *Callistemon viminalis* (Weeping Bottlebrush) Riparian Woodland.

There are 23 taxa considered significant within Arakoola Nature Reserve including the twining herb *Desmodium campylocaulon* and the shrub *Pomaderris queenslandica* (listed as Endangered under the NSW *Threatened Species Conservation Act*), and the grasses *Dichantheum setosum* and *Bothriochloa biloba*, and the perennial herbs *Goodenia macbarroni* and *Thesium australe* (all listed as Vulnerable under the *TSC Act*). A comprehensive species list of about 450 plant species is given for the Nature Reserve.

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Introduction

Arakoola Nature Reserve (29°17'S, 150°48'E) lies 2 km south from Coolatai and 100 km north-west of Inverell (Fig. 1), on the northern end of the Mastermans Range. Arakoola is within the North Western Slopes botanical region and straddles the current boundary between the Brigalow Belt South and the Nandewar Bioregions. Before gazettal, the land was maintained under two titles, *Sylvan* and *Arakoola*. The local government area is primarily the Inverell Shire, although a small portion of the Sylvan section of the reserve is in the Yallaroi Shire. Arakoola, in the county of Burnett, parish of Coolatai, comprises 3189 ha within the Graman 1: 50 000 9039, II and III, map sheet. The reserve is surrounded by private land and is divided into two sections by freehold titles. Almost all of the land surrounding the reserve has been extensively cleared, so that the reserve forms an 'island' of comparatively uncleared country.

This paper gives part of the results of a flora survey, carried out for the New England Tablelands Region of the NSW National Parks and Wildlife Service, to be used to develop appropriate management strategies (Hunter 2000a).

Climate

The climate of Arakoola is typical of the northern portion of the North Western Slopes with a distinct summer maximum rainfall. Winds are mainly from the south-west in summer.

Fig. 1. Map of locality of Arakoola Nature Reserve

Dry thunderstorms are common throughout spring. On average one in every five years will be drought years (Division of Mapping 1986). The five years including 1991–1995 were drought declared. Usually summers are hot with an average temperature around 33°C and winters are cold with an average minimum temperature of around 2°C (Lea et al. 1977). The annual precipitation is around 650 mm a year. The humidity is low in summer and around 55% to 76% in winter.

Landform

Arakoola Nature Reserve lies at the northern end of Mastermans Range on the western slopes of the Great Dividing Range. The reserve is of low relief but straddles the western fall of the range and thus has greater altitude and topography along the eastern boundary. Flatter terrain is associated Ottleys Creek on the western boundary. The highest point, 570 m, occurs at the north eastern boundary, the lowest point is 370 m. Flat alluvial plains are associated with the meandering bed of Ottleys Creek and they may extend laterally for up to 1 km from the creek bed. Spring Creek a smaller tributary of Ottleys Creek forms part of the northern boundary of the reserve and extends into the heart of the reserve. Its upper reaches dissect the hillier terrain of Mastermans Range and form deeper gullies without any fluvial terraces.

Geology

Arakoola Nature Reserve is within the Surat Basin of eastern Australia (Stroud 1990). Outcrops of Surat Basin sediments, along the western edge of the New England Orogen, consist of Pilliga Sandstone, late Jurassic in age. Tertiary basalt is another main rock type within the NR and this forms significant outcrops in the area. In addition, Tertiary sediments crop out within the Reserve and these appear to be associated closely with outcrops of the Tertiary basalt (Stroud 1990). Quaternary alluvial plain deposits are present along creeks.

European history and landuse

Lands near Arakoola were first taken up after Governor Bourke's official gazettal of the Lands Act of 1836. By 1846, most properties were gazetted and running sheep and cattle. R.B. Ottley came to the region in 1837 and took up the lands containing the reserve. His property was named *Mandoe* in 1841, being derived from the aboriginal word *mandoie* meaning 'big toe' or 'big foot' (Wiedemann 1981). As another property in the Inverell district had the same name the station was renamed *Coolatai*. The property carried 2500 cattle and covered 70 000 acres (c. 40000 ha). Later sheep were carried, but were replaced again by cattle in 1970 due to heavy losses by dingoes (Black 1988).

Most recently, the properties that now constitute Arakoola Nature Reserve were known as *Sylvan* and *Arakoola* and both were owned by B. Campbell who purchased the blocks in the 1950s. Before this, the main property was known as *White Rock*. The property has been extensively cleared on the alluvial flats and also on higher basalt country. The flats were used for cropping in recent years and the higher country including basalt areas was used for rough grazing and cropping of sorghum and wheat (B. Campbell pers. comm.).

Methods

Sixty four quadrats, each 20 × 20 m, were surveyed for vascular plants scored using the Braun-Blanquet (1982) six point cover abundance scale. Quadrats were placed using a stratified random method. Geology and Physiography (Crest & Upper Slope, Lower Slope & Flats, Open Depressions) were used to for strata delineation. Fifty sites were surveyed over five days in November and December 1999 and an additional 14 were conducted on one day in May 2003. Only the initial 50 sites were used in analyses.

Good quality material of species were retained as vouchers by the New England Tablelands Region of the NSW National Parks and Wildlife Service and duplicates of significant collections were submitted to the National Herbarium of NSW. Nomenclature follows that of Harden (1990–1993) except where recent changes have been made.

Analyses and data exploration were performed using options available in the PATN Analysis Package (Belbin 1995a, b). For final presentation of results all species and their relative abundance scores were used. Analysis was performed using Kulczynski association measure, which is recommended for ecological applications (Belbin 1995a, b) along with flexible Unweighted Pair Group arithmetic Averaging (UPGMA) and the default PATN settings.

Delineation of community boundaries in Figure 3 was based on the location of sites and their position within the multivariate analysis, air photograph interpretation, substrate and ground truthing. The vegetation map is based on a 1:50 000 scale. Structural names follow Specht et al. (1995) and are based on the most consistent uppermost stratum.

Results

Seven communities are recognised at the dissimilarity measure of c. 0.9. A summary of the community relationships is given by the dendrogram (Fig. 2). The first major division of the dendrogram separates alluvial and riparian areas. In all 450, vascular plant taxa, from 86 families and 287 genera were recorded from collation of existing records and this current sampling. Approximately 21% (95) were of taxa introduced to NSW.

Vegetation communities

The vegetation communities of Arakoola are broadly similar to many communities found on the North Western Slopes of New South Wales. Most of the vegetation communities are of woodland formation. The upper middle layer has a high cover of *Callitris endlicheri*. A distinct grassy component occurs in the areas influenced by basalt and a shrubby component in sandstone areas. Grasslands occur in valleys, heaths and shrublands occur in some cleared and disturbed localities, and small wetlands occur in oxbow sections of old creek channels. The communities are primarily determined by soil type and secondarily by landform. A summary of relevant statistics for each community are presented in Table 1. Extreme values are given in brackets within the following descriptions of communities. Within the following descriptions exotic species are not listed, their occurrence within each community is listed in Appendix 1. Species from each layer are listed in order of decreasing importance (cover × frequency).

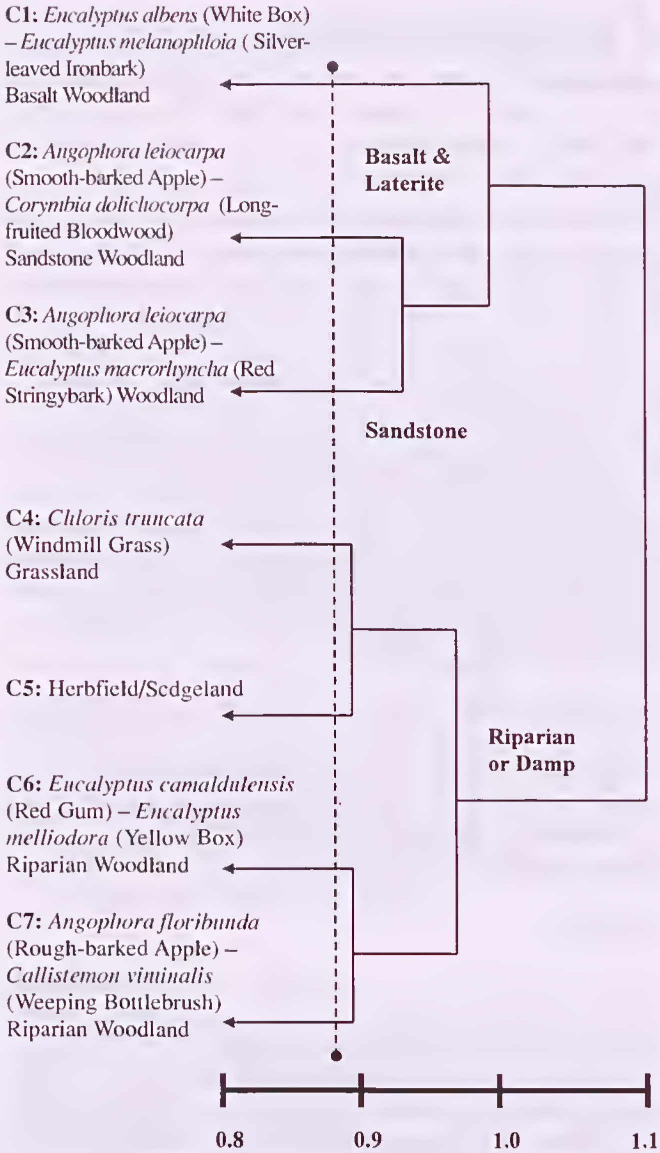

Fig. 2. Summary dendrogram of the full floristic dataset of sites using Kulczynski association and flexible UPGMA fusion strategy.

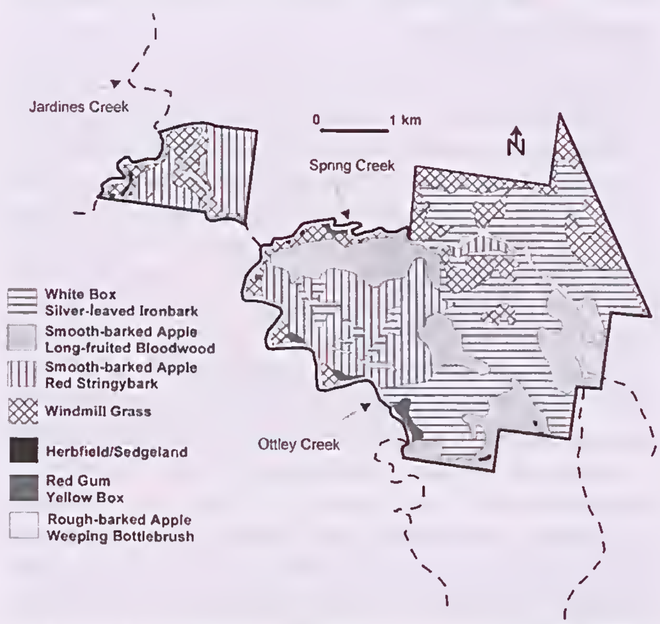

Fig. 3. Map of vegetation communities for Arakoola Nature Reserve

Fig. 4. Community 1: *Eucalyptus albens* and *Callitris endlicheri* on basalt soil.

Community 1: *Eucalyptus albens* (White Box) – *Eucalyptus melanophloia* (Silver-leaved Ironbark) Basalt Woodland

Distribution: primarily restricted to basalt or ironstone associated with the contact zone between sandstone and basalt. Soils are variable from clay loams to sandy loams, but usually not very heavily textured or very light. Soil colour is from red, light brown to black and are well drained to moist and from shallow to deep but never skeletal.

Structure: upper layer 15–30 m tall; 15–30 (–50)% cover. Upper middle layer 5–20 m tall; 10–40% cover. Lower middle layer 1–5 m tall; 10–60% cover. Ground layer to 1 m tall; 40–90% cover (Fig. 4).

Trees: *Callitris endlicheri*, *Eucalyptus albens*, *Eucalyptus melanophloia*, *Eucalyptus crebra*, *Eucalyptus sideroxylon*, *Angophora leiocarpa*, *Eucalyptus dealbata*, *Corymbia dolichocarpa*, *Brachychiton populneus*.

Shrubs: *Olearia elliptica*, *Desmodium brachypodum*, *Notelaea microcarpa*, *Leucopogon muticus*, *Melichrus urceolatus*, *Pultenaea* sp. C, *Dodonaea viscosa*, *Cassinia uncata*, *Pimelea neo-anglica*, *Pimelea micrantha*, *Hibbertia obtusifolia*, *Acacia sparsiflora*, *Acacia penninervis*, *Acacia amblygona*.

Climbers & trailers: *Desmodium varians*, *Glycine clandestina*, *Glycine tabacina*, *Parsonsia eucalyptophylla*, *Kennedia procurrens*, *Jasminum lineare*.

Ground cover: *Aristida ramosa*, *Brunonia australis*, *Cymbopogon refractus*, *Cyperus gracilis*, *Cheilanthes sieberi*, *Aristida vagans*, *Scleria mackaviensis*, *Wahlenbergia stricta*, *Vittadinia dissecta*, *Mentha satureioides*, *Dichondra repens*, *Swainsona greyana*, *Phyllanthus virgatus*, *Lomandra multiflora*, *Glossogyne tannensis*, *Eclipta platyglossa*, *Dichondra* sp. A, *Dichelachne micrantha*, *Senecio quadridentatus*, *Microlaena stipoides*, *Calotis lappulacea*, *Panicum simile*, *Austrostipa scabra*, *Ajuga australis*, *Stackhousia viminea*, *Senecio diaschides*, *Rostellularia adscendens*, *Oxalis chnoodes*, *Lomandra filiformis*, *Cheilanthes distans*, *Austrodanthonia richardsonii*, *Vittadinia sulcata*.

Variability: two very distinct and clear sub-assemblages that under finer scale mapping of 1:25 000 would probably have been recognised as separate entities. The first sub-assemblage is more extensive and is dominated by *Eucalyptus albens* and *Eucalyptus melanophloia*. It commonly has an understorey of *Olearia elliptica* and *Notelaea microcarpa*. At the highest points of the basalt hills *Olearia elliptica* forms very dense stands. In similar situations in the nearby Planchonella Hill Nature Reserve semi-evergreen vine thickets occur. The understorey is commonly very grassy but often this is of the introduced grass *Hyparrhenia hirta*. The soils are always distinctly basaltic and are loamy and dark brown to black. The second sub-assemblage is associated with the sandstone and basalt contact zones and as such the soils are somewhat intermediate, but generally heavier in texture than the adjacent sands. The soils are often Lateritic with imbedded ironstone and are red to light brown sandy loam. The dominants are *Eucalyptus crebra* and *Eucalyptus sideroxylon* with occasional associates not seen on true basalts such as *Angophora leiocarpa*. The understorey still contains substantial stands of *Olearia elliptica* but also may contain a number of other shrubby species such as *Acacia amblygona* and *Leucopogon muticus*.

Conservation status: Box woodlands are amongst the most poorly conserved ecosystems in Australia (Benson 1991, Prober 1996) and are highly vulnerable or endangered in agricultural lands. Benson (1991) highlighted Box woodlands on the western slopes as a priority for reservation. This type of Box association is reserved at Kwiambal NP where it occurs on metasediments and on metabasalts and at Planchonella Hill NR on basalt.

Fig. 5. Community 2: *Angophora leiocarpa* with dense understorey of *Pultenaea* sp. *C* on sandstone

Community 2: *Angophora leiocarpa* (Smooth-barked Apple) – *Corymbia dolichocarpa* (Long-fruited Bloodwood) Sandstone Woodland

Distribution: found throughout the sandstone areas but primarily in the central to western parts of the Reserve (Fig. 3). Soils are well drained and sandy or occasionally sandy loam in texture. The soil colour is white, creamy or rarely light brown and deep to skeletal.

Structure: upper 15–25 m tall; 20–30% cover. Upper middle layer usually absent to 8–15 m tall; 30–40% cover. Lower middle layer 1–3 m tall; 20–60% cover. Ground layer occasionally absent to 1 m tall; 10–20% cover (Fig. 5).

Trees: *Callitris endlicheri, Angophora leiocarpa, Corymbia dolichocarpa, Eucalyptus sideroxylon, Corymbia trachyphloia, Eucalyptus macrorhyncha, Eucalyptus dealbata.*

Shrubs: *Leucopogon muticus, Hovea lanceolata, Hibbertia acicularis, Brachyloma daphnoides, Pultenaea* sp. C, *Melichrus urceolatus, Calytrix tetragona, Grevillea triternata, Grevillea floribunda, Acacia sparsiflora, Acacia penninervis, Leucopogon attenuatus, Persoonia terminalis, Styphelia triflora, Persoonia sericea, Olearia ramosissima, Gompholobium virgatum, Dillwynia sieberi, Daviesia nova-anglica, Cryptandra amara, Allocasuarina inophloia, Xylomelum cunninghamianum.*

Climbers & trailers: *Cassytha glabella.*

Ground cover: *Triodia mitchellii, Fimbristylis neilsonii, Tricoryne elatior, Platysace ericoides, Goodenia macbarronii, Goodenia hederacea, Aristida ramosa, Isotoma axillaris, Goodenia bellidifolia, Dianella caerulea, Chrysocephalum apiculatum, Aristida acuta, Actinotus helianthi.*

Variability: *Angophora leiocarpa* may dominate in isolation with *Callitris endlicheri* scattered but subdominant with a generally sparse shrubby understorey. In other rockier localities, *Angophora leiocarpa* is subdominant to co-dominant with other species such as *Corymbia dolichocarpa* or *Eucalyptus sideroxylon*, with a dense shrubby understorey.

Notes: *Angophora leiocarpa* is usually only known from wide sandy valleys derived from sandstone primarily on the North Western Slopes and Plains of New South Wales north from Warialda and also much of south-central Queensland (Neldner 1984, Leach 1986, Hill 1991, Carr 1996). Beadle (1981) placed *Angophora leiocarpa* (as *A. costata*) in a Suballiance with *Eucalyptus crebra* and referred to it as being common in sandstone areas and noted that they have been termed 'sandstone woodlands' by other authors. *Corymbia dolichocarpa* usually occurs south of Charters Towers in Queensland and is infrequent in NSW with its southern limit at Narrabri. Both the dominant species in the case of this community are near the limits of their southern distribution and are more commonly associated with each other in Central to southern Queensland.

Conservation status: only small occurrences of *C. dolichocarpa* occur in New South Wales reserves, namely at Mt Kaputar NP, Torrington SRA and Kwiambal NP. *Angophora leiocarpa* is also conserved in Kwiambal NP west of the Divide. The two dominants of this community are at their southern limits and don't occur together in any other reserve in New South Wales. Hence, this community should be considered highly significant and uniquely reserved in NSW at Arakoola.

Fig. 6. Community 3: *Angophora leiocarpa* and *Eucalyptus macrorhyncha* with *Xylomelum cunninghamianum*

Community 3: *Angophora leiocarpa* (Smooth-barked Apple) – *Eucalyptus macrorhyncha* (Red Stringybark) Woodland

Distribution: on sandstone or sandstone/basalt intergrade zones in western parts of the Reserve (Fig. 3). Soils are highly variable but are always well drained. Texture is usually sandy but may be sandy loam or loamy clay depending on the amount of basalt influence or wash down. Soil colour is reddish, pink to brown on contact zones and yellow, pink light brown to white on pure sandy soils. The soil may be skeletal to deep.

Structure: highly variable: Upper layer (10–) 15–30 m tall; (10–) 20–30% cover. Upper middle layer usually absent on intergrading soils 8–15 m tall; 15–50% cover. Lower middle layer usually absent on sandy soils 1–3 m tall; 10–30% cover. Ground layer to 1 m tall; 15–90% cover (Fig. 6).

Trees: *Callitris endlicheri, Angophora leiocarpa, Eucalyptus macrorhyncha, Eucalyptus dealbata, Eucalyptus melanophloia, Brachychiton populneus, Xylomelum cunninghamianum, Eucalyptus chloroclada, Eucalyptus blakelyi, Eucalyptus sideroxylon.*

Shrubs: *Melichrus urceolatus, Hibbertia obtusifolia, Brachyloma daphnoides, Styphelia triflora, Jacksonia scoparia, Hovea lanceolata, Calytrix tetragona, Leucopogon muticus, Leucopogon attenuatus, Cassinia uncata, Bossiaea rhombifolia, Aotus mollis.*

Climbers & trailers: *Desmodium varians, Kennedia procurrens, Glycine* sp. A, *Glycine tomentella.*

Ground cover: *Calotis cuneifolia, Cheilanthes sieberi, Lomandra multiflora, Dichelachne micrantha, Aristida vagans, Wahlenbergia planiflora, Eragrostis elongata, Aristida acuta, Cymbopogon refractus, Tricoryne elatior, Poranthera microphylla, Podolepis arachnoidea, Chrysocephalum apiculatum, Cheilanthes distans, Aristida ramosa, Xanthorrhoea johnsonii, Wahlenbergia gracilenta, Schoenus apogon, Panicum simile, Lomandra filiformis, Imperata cylindrica, Glossogyne tannensis, Crotalaria mitchellii, Calotis lappulacea, Vittadinia dissecta, Triodia mitchellii, Evolvulus alsinoides, Dianella caerulea, Alloteropsis semialata, Ajuga australis, Actinotus helianthi.*

Variability: at least two distinct sub-assemblages are discernable and relate primarily to soil type. The first sub-assemblage occurs on sandstone and basalt intergrade soils on red to pink or brown to chocolate brown soils. The dominant trees include *Eucalyptus melanophloia* with *Eucalyptus dealbata* with occasional subdominants including *Eucalyptus sideroxylon, Eucalyptus populnea* or *Eucalyptus chloroclada*. The tree layer is often low between 10–20 m tall and any one of the understorey layers may be absent and in particular the tall shrub to low tree layer (10–15 m tall) is most often absent. Within this sub-assemblage, variation is notable between the red and lighter red soils and the light brown to chocolate brown soils. *Eucalyptus sideroxylon* and *Eucalyptus populnea* occurring on the red soils with a denser shrub layer but sparse herb layer and *Eucalyptus melanophloia* mostly on heavier brown soils with a sparser shrub layer and denser herb layer. The second major sub-assemblage is restricted to white to yellow or occasionally light pink to light brown sandstone soils. The tree layer is between 20–25 or up to 30 m tall and there is almost always a distinct tall shrub to lower tree layer around 6–15 m tall (primarily *Callitris endlicheri*). In contrast to the first sub-assemblage there is rarely a distinct shrub layer (1–3 m). The dominant tree is *Angophora leiocarpa* with occasional *Eucalyptus macrorhyncha*. Within the second sub-assemblage distinction is made for areas that have been cleared in the past that fringe the lower slopes and abut with the tongues of basalt near major creeks. In these localities the understorey is much the same but there are fewer trees.

Conservation status: closely allied assemblages of *Eucalyptus populnea, Eucalyptus melanophloia, Callitris glaucophylla* are reserved in Brigalow Park NR (Specht et al. 1995) and Kwiambal NP (Hunter et al. 1999) in NSW. *Angophora leiocarpa* occurs only as far south as Warialda in large stands, although there are records from Killarney State Forest near Narrabri. In Queensland, *Angophora leiocarpa* is more common, but *Eucalyptus macrorhyncha* is absent. This assemblage is therefore highly restricted, only occurring sporadically in the Inverell and Yallaroi shires. Arakoola is the only reserve in New South Wales with this unique assemblage.

Fig. 7. Community 4: *Chloris truncata* grasslands.

Community 4: *Chloris truncata* (Windmill Grass) Grassland

Distribution: restricted to poorly drained areas with dark brown to brown cracking basaltic soils. Found primarily adjacent to major creeks (Fig. 3).

Structure: upper layer usually not present to 5 m tall; c. 5% cover. Middle layer usually not present but to 1–3 m tall; c. 10% cover. Ground layer 90–100% (Fig. 7).

Trees: *Eucalyptus dealbata, Eucalyptus camaldulensis.*

Shrubs: *Leptospermum brevipes, Jacksonia scoparia.*

Climbers & trailers: *Desmodium varians, Convolvulus erubescens, Cassytha glabella.*

Ground cover: *Teucrium racemosum, Chloris truncata, Centaurium spicatum, Vittadinia muelleri, Sporobolus elongatus, Panicum simile, Mentha satureioides, Austrodanthonia fulva, Wahlenbergia gracilenta, Sida trichopoda, Schoenus apogon, Oxalis chnoodes, Juncus aridicola, Geranium solanderi, Fimbristylis dichotoma, Euchiton gymnocephalus, Cyperus leiocaulon, Cyperus bifax, Cynodon dactylon, Chrysocephalum apiculatum, Calotis lappulacea.*

Variability: occurring as small patches of regenerating grassland associated with past cropping areas. Floristic variability is based on the degree to which native vegetation has been restored from past cropping practices. Some structural variation is noticeable where trees such as *Eucalyptus dealbata* or *Eucalyptus camaldulensis* may be present as scattered individuals giving a low open woodland appearance. Grasslands such as this can change considerably in floristics over seasons and between years depending on rainfall and flooding (Hunter & Earl 2002). An additional 14 sites were placed within this community during May 2003 over which time the floristics had changed considerably. During the subsequent sampling in May, an additional 15 species were found and many areas were dominated by dense stands of *Bothriochloa biloba* and *Dichanthium setosum*, along with *Panicum queenslandicum* and *Digitaria brownii.*

Conservation status: despite its complement of introduced taxa (Appendix 1) this community is still largely native. Such grasslands are not recorded as reserved within NSW.

Fig. 8. Community 5: *Eleocharis plana* sedgeland in ox-bow sections of Ottleys Creek.

Fig. 9. Community 6: *Eucalyptus melliodora* woodlands.

Community 5: Herbfield/Sedgeland

Distribution: restricted to waterlogged or damp, dark brown often cracking clay.

Structure: upper usually not present but to 15 m tall; c. 5–10% cover. Ground layer to 1 m tall; 40–100% cover (Fig. 8).

Trees: *Eucalyptus camaldulensis.*

Shrubs: None apparent.

Climbers & trailers: *Jasminum suavissimum, Cuscuta australis, Convolvulus erubescens.*

Ground cover: *Rorippa eustylis, Eleocharis plana, Centipeda cunninghamii, Persicaria lapathifolia, Polygonum plebeium, Ranunculus inundatus, Plantago varia, Juncus ochrocoleus, Euchiton gymnocephalus, Chamaesyce drummondii, Chamaesyce dallachyana, Centaurium spicatum, Carex inversa, Calotis cuneifolia, Brunonia australis, Bothriochloa decipiens, Austrostipa ramosissima, Alternanthera* sp. *A.*

Variability: floristic composition largely depends on duration and extent of water logging. This varies seasonally and temporally over years depending on rainfall and flooding.

Conservation status: assemblages such as this are often neglected in broad scale survey work as they cover such a small area and they thus have been rarely documented. They are often highly modified and even when in conservation reserves they are very limited in extent. Many species in this community are probably at their eastern limit within the Reserve and thus the community is significant.

Community 6: *Eucalyptus camaldulensis* (Red Gum) – *Eucalyptus melliodora* (Yellow Box) Riparian Woodland

Distribution: restricted to deep, poorly drained chocolate brown to dark brown basalts soils adjacent to Ottleys Creek.

Structure: upper 15–25 m tall; 30–40% cover. Middle layer usually not present but can be 1–3 m tall; *c.* 10% cover. Ground layer to 1 m tall; 80–90% cover (Fig. 9).

Trees: *Eucalyptus camaldulensis, Eucalyptus melliodora, Brachychiton populneus, Angophora leiocarpa.*

Shrubs: *Lotus cruentus, Sida trichopoda, Sida corrugata, Rulingia dasyphylla, Notelaea microcarpa, Maireana microphylla, Lespedeza juncea, Hibbertia obtusifolia.*

Climbers & trailers: *Glycine tabacina, Desmodium varians, Boerhavia dominii, Glycine clandestina, Convolvulus erubescens.*

Ground cover: *Sorghum leiocladum, Einadia nutans, Aristida jerichoensis, Vittadinia dissecta, Poa labillardieri, Cyperus gracilis, Calotis cuneifolia, Sporobolus elongatus, Rumex brownii, Lepidium pseudohyssopifolium, Carex inversa, Calotis lappulacea, Aristida vagans, Pratia concolor, Mentha diemenica, Imperata cylindrica, Digitaria longiflora, Dichondra* sp. *A, Dichelachne micrantha, Desmodium brachypodum, Cymbopogon refractus, Brunonia australis, Bothriochloa decipiens.*

Variability: the ground layer is diverse and varied and contain many ephemeral grasses and forbs that respond quickly to rainfall and/or flooding. Understorey species composition will change over seasons and over longer time periods due to variation in flooding and deposition of seeds, day length and soil temperature. The community is primarily linear in occurrence and as such has a high edge to area ratio.

Conservation status: widespread in NSW but has been extensively modified across its entire range. Bowlay (1992) and Le Brocque and Benson (1995) noted that this community type is highly disturbed throughout the Ashford map sheet. Benson (1991) considers plant associations of inland watercourses as poorly conserved, however a number of areas of this assemblage appear to be reserved across the state (Specht et al. 1995).

Fig. 10. Community 7: *Angophora floribunda, Casuarina cunninghamiana* and *Callistemon viminalis* along major creek lines.

Community 7: *Angophora floribunda* (Rough-barked Apple) – *Callistemon viminalis* (Weeping Bottlebrush) Riparian Woodland

Distribution: associated with Ottleys Creek and Spring Creek (Fig. 3). Found both on basalt and on sandstone with additional alluvial material. Soils are also variable from creamy white sandy soils to dark brown or black cracking clays.

Structure: upper (15–) 20–30 m tall; 10–30% cover. Low tree layer (5–) 8–15 m tall; 20–60% cover. Shrub layer usually absent 1–3 m tall; c. 30% cover if present. Ground layer to 1 m tall; 30–80% cover (Fig. 10).

Trees: *Angophora floribunda, Callitris endlicheri, Eucalyptus macrorhyncha, Corymbia dolichocarpa, Angophora leiocarpa, Eucalyptus prava, Eucalyptus blakelyi, Casuarina cunninghamiana.*

Shrubs: *Callistemon viminalis, Notelaea microcarpa, Leptospermum arachnoides, Pultenaea* sp. C, *Brachyloma daphnoides, Hibbertia obtusifolia, Sida cunninghamii, Hovea lanceolata, Pomaderris queenslandica, Melichrus urceolatus, Leptospermum brevipes, Dillwynia sieberi, Cassinia uncata, Bursaria spinosa.*

Climbers & trailers: *Rubus parviflorus, Commelina cyanea, Clematis microphylla, Desmodium varians, Hardenbergia violacea.*

Ground cover: *Imperata cylindrica, Cyperus gracilis, Urtica incisa, Lomandra longifolia, Rumex brownii, Stellaria flaccida, Wahlenbergia planiflora, Setaria paspalidioides, Hydrocotyle laxiflora, Geranium solanderi, Dichondra repens, Cyperus bifax, Cheilanthes sieberi, Carex incomitata, Austrostipa verticillata, Ajuga australis, Thonandia longifolia, Ranunculus lappaceus, Pteridium esculentum, Pratia concolor, Microlaena stipoides, Juncus continuus, Juncus aridicola, Echinopogon ovatus, Desmodium brachypodum, Cyperus victoriensis, Austrostipa ramosissima, Aristida vagans, Wahlenbergia stricta, Solanum pseudocapsicum, Scutellaria humilis, Rostellularia adscendens, Ranunculus inundatus, Oxalis chnoodes, Luzula flaccida, Lomandra confertа, Hypericum gramineum, Einadia nutans, Cynodon dactylon, Cymbopogon refractus, Chionochloa pallida, Cheilanthes distans, Centaurium spicatum, Austrodanthonia richardsonii, Austrodanthonia bipartita, Aristida ramosa.*

Variability: highly variable in structure and floristics. *Callistemon viminalis* becomes dominant closer to the creek line.

Conservation status: This community probably occurs throughout the lower altitude parts of the north western slopes and north into similar country in Queensland. It is almost always highly disturbed across its range. Only small sections occur within reserves and these are generally also highly disturbed due to past practices and thus of poor quality (Hunter 2002). These systems are of high priority, if in reasonable condition, for further inclusion into the reserve network. Benson (1991) noted that vegetation along inland water courses were very poorly reserved and highlighted them as a priority for conservation even though similar assemblages are reserved in a number of areas across the state (Specht et al.1995).

Discussion

The number of 450 vascular plant taxa found within the reserve is very similar to the richness found in similar sized reserves on the North Western Slopes, for example Kwiambal NP with 407 (Hunter et al. 1999), Single NP with 424 (Clarke et al. 2000), Kings Plains with 441 (Hunter 2000b), and Ironbark NR and *Bornhardtia* VCA with 477 (Hunter & Hunter 2003). Based on the variability between sites Hunter (2003) predicted that up to 514 taxa may be within Arakoola NR. Site richness on a 0.04 ha site was only 36 taxa on average, but this is similar to that found by Le Brocque and Benson (1995) for the Ashford 1:100000 map sheet (37/0.04 ha), Hunter (2000e) in Severn River NR (38/0.04 ha), Hunter et al. (1999) in Kwiambal NP (40/0.04 ha) and Hunter and Hunter (2003) at Ironbark NR and the *Bornhardtia* Voluntary Conservation Agreement (35/0.04 ha).

Biogeographically Arakoola NR is placed on the edge of the Brigalow Belt South (BBS) and Nandewar (NAN) bioregions and includes the southern extent of a number of vegetation assemblages and species that are more common within southern central Queensland. It appears that despite overlap in species composition, and some similarity in Communities in a broad sense, much that is contained within Arakoola is rather unique or at least significantly under represented in other reserves in NSW. The affinities of the vegetation of the reserve are in part with Planchonella Hill and Kwiambal, but mainly only in the basaltic components. The sandstone communities of Arakoola NR are in a large part unique within the NSW reserve system and have their affinities with the larger sandstone areas of the Pilliga in New South Wales and south central Queensland. The distribution of these communities do extend, unreserved, to the south as far as Warialda and to the east on the western parts of the Ashford Map Sheet. The basaltic and more herbaceous communities within Arakoola have their greatest affinities with country of similar soils to the west of the reserve and possibly to the south as far as the Liverpool Plains and east as far as the Ashford Map Sheet.

Conservation issues

Benson (1999) stated that 2.5% of the NSW Brigalow Belt South (BBS) Bioregion was held in conservation reserves and 60% had been cleared. In total only 2% of the Inverell Shire and only 0.01% of the Yallaroi Shire are in conservation reserves. All communities within Arakoola Nature Reserve were either unreserved or under represented in the current reserve network. Some communities, in terms of reservation in NSW are unique and represent assemblages that are more common in Queensland. Communities 6 and 7 are rather widespread but these are very highly disturbed throughout their range. Community 4 is probably widespread yet not recorded for a conservation reserve. As such, Arakoola is a highly significant bioregional reserve.

There are 23 taxa considered significant within Arakoola Nature Reserve. Seven of these taxa are listed nationally as Rare or Threatened species (RoTAP) (Briggs & Leigh 1996) and six are included within the *NSW Threatened Species Conservation Act 1995* (five are shared on both lists).

Bothriochloa biloba (3V, listed as Vulnerable under the *TSC Act*) and *Dichanthium setosum* (listed as Vulnerable under the *TSC* Act) are threatened grasses. Very few individuals were found in grassland areas on heavy soil along Ottleys Creek during the initial survey, yet many areas of Community 4 were dominated by these grasses during May 2003.

Desmodium campylocaulon (listed as Endangered under the *TSC* Act) is a robust twining herb to 1m tall. The species is known from the Northern Territory and Queensland, and in NSW is generally found on the North Western Plains. This species was not discovered during this survey but was reported to be within the reserve after investigations by the Department of Land and Water Conservation. The species is reserved within Kirramingly Nature Reserve.

Goodenia macbarronii (3VC-, listed as Vulnerable under the *TSC Act*) is a perennial herb known from the Darling Downs in Queensland to north-eastern Victoria. The species is known to be reserved in Warrabah and Warrumbungle National Parks, Ironbark and Severn River Nature Reserves and the Torrington State Recreation Area. The species was sporadic but not uncommon within Arakoola NR.

Olearia gravis (3KC-) is a poorly known taxon that has a disjunct and sporadic distribution from Murgon to Sundown and Girraween National Park in Queensland, and Torrington State Recreation Area, Kings Plains, Gibraltar Range and Kwiambal National Parks in New South Wales. The species distribution is sporadic, but not uncommon on shallow sandstone soils within the Reserve.

Persoonia terminalis subsp. *recurva* and subsp. *terminalis* (2RCa and 2RC) are shrubs to 1 m tall. These taxa overlap in distribution within this region and east to Torrington. Both entities are restricted to sandstone areas within the Reserve.

Pomaderris queenslandica (listed as Endangered under the *TSC Act*) is a shrub to 3 m tall. The species is fairly common in Queensland but is threatened in New South Wales where it occurs in the Central and North Western Slopes and the North Coast. It is reserved within the Torrington State Recreation Area, Severn River Nature Reserve and Monablai National Park. Within the reserve less than 20 individuals were found in two locations.

Thesium australe (3VCi, listed as Vulnerable under the *TSC Act*) is a perennial herb which is currently known from a number of districts from south-east Queensland to the Bass Strait Islands. The species is known from at least 15 National Parks or Nature Reserves within New South Wales. Many hundreds of individuals were found within Arakoola NR on alluvial and basaltic soils in grassland.

Fourteen other taxa are considered to be of conservation significance, including those that are disjunct or thought to be at or near their geographic limit. These taxa are: *Allocasuarina gymnanthera, Angophora leiocarpa, Aristida acuta, Brachyloma daphnoides* subsp. *pubescens, Cheiranthera cyanea* var. *borealis, Corymbia dolichocarpa, Digitaria longiflora, Eucalyptus populnea* subsp. *bimbil, Evolvulus alsinoides* var. *villosicalyx, Haemodorum planifolium, Isotoma axillaris, Melaleuca erubescens* and *Rorippa eustylis*.

Conclusion

Arakoola Nature Reserve is a highly significant bioregional reserve as it contains large areas of highly significant vegetation assemblages. The reserve includes communities that are not currently represented in the NSW network of reserves and which are at their southern limit, as well as communities that are widespread but whose variation is very under-represented. 24 plant species are considered to be of significance. A number of species are at their distributional limits within the reserve and are thus highly significant in the regional context, six are highly significant from a state perspective (TSC Act Listed) and seven are of national significance (RoTAP).

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Appendix: Flora of Arakoola Nature Reserve

Taxa found within the survey sites are scored according to their occurrence in each of the seven communities defined. Some taxa were found in previous surveys or opportunistically and therefore are not assigned to a specific community.

Communities:

1 = *Eucalyptus albens – Eucalyptus melanophloia* Basalt Woodland

2 = *Angophora leiocarpa – Corymbia dolichocarpa* Sandstone Woodland

3 = *Angophora leiocarpa – Eucalyptus macrorhyncha* Woodland

4 = *Chloris truncata* Grassland

5 = Herbfield/Sedgeland

6 = *Eucalyptus camaldulensis – Eucalyptus melliodora* Riparian Woodland

7 = *Angophora floribunda – Callistemon viminalis* Riparian Woodland

+ = not assigned

Nomenclature follows Harden (1990–1993) except where recent changes have occurred. Introduced taxa are indicated by *.

Taxon	1	2	3	4	5	6	7	+
FERNS AND ALLIES								
Aspleniaceae								
Asplenium flabellifolium								+
Adiantaceae								
Cheilanthes distans	1	2	3				7	
Cheilanthes sieberi subsp. *sieberi*	1	2	3				7	
Dennstaedtiaceae								
Pteridium esculentum							7	
GYMNOSPERMS								
Cupressaceae								
Callitris endlicheri	1	2	3			6	7	
Callitris glaucophylla	1							
Zamiaceae								
Macrozamia heteromera			3					
MONOCOTYLEDONS								
Anthericaceae								
Arthropodium milleflorum	1		3				7	
Laxmannia gracilis	1		3				7	
Thysanotus tuberosus			3					
Tricoryne elatior		2	3			6		
Asphodelaceae								
Bulbine semibarbata								+
Commelinaceae								
Commelina cyanea	1		3				7	+
Murdannia graminea	1							
Cyperaceae								
Bulbostylis barbata			3					
Carex incomitata						6	7	
Carex inversa	1				5	6		+
Cyperus aggregatus			3					
Cyperus bifax			3	4			7	
Cyperus fulvus			3			6	7	
Cyperus gracilis	1		3			6	7	
Cyperus leiocaulon				4				
Cyperus rotundus				4				
Cyperus victoriensis	1						7	
Eleocharis plana					5			
Fimbristylis dichotoma	1		3	4		6		+
Fimbristylis neilsonii		2	3					
Gahnia aspera	1							
Lepidosperma laterale		2	3				7	
Schoenus apogon	1		3	4				

Scleria mockaviensis	1							
Haemodoraceae								
Haemodorum planifolium			3					
Iridaceae								
Patersonia glabrata		2						
Patersonia sericea		2	3				7	
Juncaceae								
Juncus aridicola				4			7	
Juncus continuus	1						7	+
Juncus ochrocoleus					5			
Juncus subsecundus			3					
Luzula flaccida							7	
Lomandraceae								
Lomandra confertifolia	1	2	3				7	
Lomandra filiformis subsp. *coriacea*	1	2	3					
Lomandra filiformis subsp. *flavior*	1							
Lomandra leucocephala						6		
Lomandra longifolia	1	2					7	
Lomandra multiflora subsp. *multiflora*	1	2	3			6	7	
Luzuriagaceae								
Eustrephus latifolius	1							
Orchidaceae								
Cymbidium canaliculatum								+
Microtis unifolia								+
Phormiaceae								
Dianella caerulea var. *caerulea*	1	2	3			6		
Dianella longifolia			3				7	
Dianella revoluta var. *revoluta*	1	2						
Poaceae								
Agrostis avenacea							7	
**Aira cupaniana*			3		5		7	
Alloteropsis semialata			3					
Aristida acuta		2	3			6		
Aristida jerichoensis subsp. *subspinulifera*	1		3			6		
Aristida latifolia				4				
Aristida ramosa var. *speciosa*	1	2	3	4			7	
Aristida vagans	1	2	3			6	7	
Arundinella nepalensis	1		3					
Austrodanthonia bipartita							7	
Austrodanthonia fulva				4				
Austrodanthonia induta				4				
Austrodanthonia racemosa var. *obtusata*	1		3					
Austrodanthonia richardsonii	1		3			6	7	
Austrostipa aristiglumis			3					
Austrostipa pubescens				4				
Austrostipa ramosissima	1				5		7	
Austrostipa scabra	1		3	4		6		
Austrostipa verticillata	1		3				7	
**Avena sativa*					5			
Bothriochloa biloba				4				
Bothriochloa bladhii subsp. *bladhii*	1			4			7	
Bothriochloa decipiens	1				5	6		
**Briza minor*				4				
**Bromus catharticus*					5			
**Bromus molliformis*							7	
**Cenchrus incertus*			3		5			+
Chloris truncata	1			4	5	6	7	
Cymbopogon obtectus			3					
Cymbopogon refractus	1		3			6	7	
Cynodon dactylon				4			7	+
**Cynodon incompletus*							7	
Dactyloctenium radulans								+
Dichanthium setosum	1		3					
Dichelachne micrantha	1		3			6	7	
Digitaria ammophila				4				
Digitaria breviglumis							7	
Digitaria brownii				4				
Digitaria longiflora						6		
Digitaria ramularis	1							
**Digitaria sanguinalis*								+
**Echinochloa frumentacea*					5			
Echinopogon ovatus							7	
Enneapogon nigricans	1							
Entolasia stricta	1	2	3					
**Eragrostis curvula*			3					
Eragrostis elongata	1	2	3					+
Eragrostis leptostachya	1		3					+
**Festuca elatior*			3					+
**Festuca nigrescens*	1						7	
**Hordeum distichon*								+
**Hyparrhenia hirta*	1		3	4	5	6	7	
Imperata cylindrica var. *major*			3			6	7	
Joycea pallida							7	
**Lolium perenne*	1			4	5		7	
Microlaena stipoides var. *stipoides*	1						7	
**Nassella hyalina*						6		
Notodanthonia longifolia							7	
Panicum miliaceum		2						
Panicum queenslandicum var. *acuminatum*				4				
Panicum simile	1		3	4			7	+
Paspalidium distans				4				
Paspalidium globoideum				4				
**Paspalum dilatatum*				4	5	6	7	
Perotis rara	1							+
**Phalaris paradoxa*					5			
Poa labillardieri						6		
Poa sieberiana var. *hirtella*	1		3					
**Rostraria pumila*								
**Setaria gracilis*								
Setaria paspalidioides		2	3				7	
**Sorghum halepense*				4				
Sorghum leiocladum	1					6	7	
Sporobolus creber			3					
Sporobolus elongatus				4		6		
Themeda australis	1		3			6		
Tragus australianus				4				
Triodia mitchellii		2	3					
Tripogon loliiformis							7	

**Urachlaa texana*					5		7	
**Vulpia bromoides*						6		
Xanthorrhoeaceae								
Xanthorrhaea johnsonii		2	3				7	
Xantharrhoea glauca subsp. *angustifalia*								+
Xyridaceae								
Xyris camplanata				4				
DICOTYLEDONS								
Acanthaceae								
Brunoniella australis			3					
Rastellularia adscendens subsp. *adscendens*	1		3				7	
Aizoaceae								
Glinus lataides					5			
Amaranthaceae								
Alternanthera sp. *A*					5	6		
**Gamphrena celosioides*						6		+
Apiaceae								
Actinatus helianthi		2	3					
**Ciclaspermum leptophyllum*	1		3	4	5		7	
**Daucus carota*								
Daucus glochidiatus	1		3					
Hydrocotyle laxiflora					5		7	
Hydrocotyle peduncularis							7	
Platysace ericaides		2						
**Tarilis nadosa*					5			
Apocynaceae								
Parsansia eucalyptophylla	1							
Araliaceae								
Astratricha longifolia			3					
Asclepiadaceae								
**Gamphacarpus fruticosus*	1		3			6	7	
Asteraceae								
**Arctatheca calendula*					5			
**Bidens pilosa*					5			
**Bidens subalternans*			3			6	7	
Brachyscome diversifolia var. *dissecta*			3			6		+
Calatis cuneifolia			3		5	6	7	
Calotis dentex			3			6		+
Calatis lappulacea	1		3	4		6	7	+
**Carduus pycnacephalus*								+
Cassinia laevis						6		
Cassinia uncata	1		3				7	
**Centaurea calcitrapa*					5			
**Centaurea melitensis*			3	4	5			
**Centaurea solstitialis*							7	
Centipeda cunninghamii					5	6		
**Chandrilla juncea*					5		7	
Chrysocephalum apiculatum	1	2	3	4		6		
Chrysocephalum semipapposum	1							
**Cirsium vulgare*	1				5	6	7	
**Canyza albida*	1		3	4	5	6	7	
**Conyza bonariensis*						6	7	
**Canyza parva*	1		3	4	5		7	
Cymbonotus lawsanianus	1		3			6		
Eclipta platyglossa	1				5	6		
Euchitan gymnocephalus	1		3	4	5			
Euchiton sphaericus	1							
Glossogyne tannensis	1		3	4		6		
**Gnaphalium coarctatum*				4				
**Gnaphalium polycaulan*	1		3	4	5		7	
**Hedypnais rhagadialaides* subsp. *cretica*				4	5		7	
**Hypachaeris glabra*	1			4	5			+
**Hypachaeris radicata*	1	2	3	4		6	7	
**Lactuca saligna*					5			
Lagenifera stipitata							7	
Olearia elliptica	1					6	7	
Olearia ramosissima		2						
Ozothamnus adnatus		2						
Ozothamnus diosmifolius		2						
Ozothamnus obcardatus subsp. *major*		2						
Padolepis arachnoidea			3					
Podolepis neglecta			3					
Senecio diaschides	1						7	
Senecio quadridentatus	1		3				7	
**Sigesbeckia orientalis* subsp. *arientalis*	1							
**Silybum marianum*				4				
**Sonchus asper* subsp. *glaucescens*					5			
**Sonchus aleraceus*	1		3	4	5	6	7	
**Tagetes minuta*							7	
**Taraxacum officinale*	1				5	6	7	+
Cyanthillium cinerea	1		3			6		
Vittadinia cuneata						6		
Vittadinia cuneata var. *morrisii*							7	
Vittadinia dissecta var. *hirta*	1		3			6		
Vittadinia muelleri				4				
Vittadinia sulcata	1			4				
Vittadinia pterochaeta				4				
**Xanthium italicum*					5			
**Xanthium orientale*					5			
**Xanthium spinasum*			3		5	6		
Boraginaceae								
**Buglossoides arvensis*			3					
Brassicaceae								
Hirschfeldia incana				4				
**Lepidium bonariense*								+
Lepidium hyssopifolium			3	4				
Lepidium pseudohyssapifalium					5	6		
**Rapistrum rugasum*					5		7	
Rorippa eustylis					5			
**Rorippa nasturtium–aquaticum*							7	
Cactaceae								
**Opuntia stricta* var. *stricta*	1	2	3			6	7	
Campanulaceae								
Wahlenbergia gracilenta	1		3	4		6		
Wahlenbergia planiflara subsp. *longipila*	1	2	3				7	+
Wahlenbergia stricta subsp. *stricta*	1		3			6	7	

Caryophyllaceae								
*Cerastium fontanum subsp. vulgare								+
*Cerastium glomeratum								+
*Petrorhagia nanteuilii	1		3	4	5		7	+
*Polycarpaea corymbosa var. minor								+
*Polycarpon tetraphyllum			3					
Scleranthus biflorus								+
Stellaria flaccida							7	
Casuarinaceae								
Allocasuarina gymnanthera	1							
Allocasuarina inophloia		2						
Casuarina cunninghamiana							7	
Chenopodiaceae								
Chenopodium carinatum	1		3					
Chenopodium melanocarpum				4				
Einadia nutans subsp. nutans	1		3			6	7	
Einadia polygonoides			3					
Maireana aphylla				4				
Maireana microphylla						6		
Sclerolaena birchii								+
Clusiaceae								
Hypericum gramineum	1		3	4			7	
Hypericum japonicum								+
Convolvulaceae								
Convolvulus erubescens			3	4	5	6		
Cuscuta australis					5			
Dichondra repens	1			4		6	7	
Dichondra sp. A	1					6	7	
Evolvulus alsinoides var. villosicalyx			3					+
Dilleniaceae								
Hibbertia acicularis	1	2					7	
Hibbertia obtusifolia	1	2	3			6	7	
Epacridaceae								
Brachyloma daphnoides subsp. pubescens	1	2	3				7	
Leucopogon attenuatus		2	3				7	
Leucopogon muticus	1	2	3					
Lissanthe strigosa								+
Melichrus urceolatus	1	2	3				7	+
Monotoca scoparia								+
Styphelia triflora	1	2	3				7	+
Euphorbiaceae								
Beyeria viscosa								+
Breynia cernua								+
Chamaesyce dallachyana					5			
Chamaesyce drummondii	1		3	4	5	6		
Phyllanthus virgatus	1							
Poranthera microphylla	1		3				7	
*Ricinus communis							7	
Fabaceae								
Acacia amblygona	1							
Acacia betchei			3					
Acacia buxifolia subsp. pubiflora								+
Acacia cheelii								+
Acacia conferta								+
Acacia deanei subsp. deanei								+
Acacia elongata var. elongata	1							
*Acacia farnesiana								+
Acacia juncifolia	1	2	3					
Acacia leiocalyx								+
Acacia leptoclada		2	3				7	
Acacia pendula								+
Acacia penninervis	1	2	3				7	
Acacia pruinosa								+
Acacia sparsiflora	1	2						
Acacia ulicifolia								+
Acacia uncinata		2						
Acacia viscidula								+
Aotus mollis			3					
Aotus subglauca var. filiformis		2	3					
Bossiaea rhombifolia subsp. rhombifolia		2	3					
Bossiaea scortechinii			3				7	
Crotalaria mitchellii subsp. laevis			3					
Daviesia nova-anglica		2						
Daviesia ulicifolia subsp. pilligaensis			3					
Desmodium brachypodum	1		3			6	7	
Desmodium varians	1		3	4		6	7	
Dillwynia sieberi	1	2					7	
Glycine clandestina	1		3			6		
Glycine sp. A			3					
Glycine tabacina	1		3			6		
Glycine tomentella			3					
Gompholobium virgatum var. aspalathoides		2						
Hardenbergia violacea	1						7	
Hovea apiculata		2	3				7	
Hovea heterophylla							7	
Indigofera australis							7	
Indigofera adesmiifolia								+
Jacksonia scoparia	1		3	4				
Kennedia procurrens	1		3					
Lespedeza juncea subsp. sericea	1					6		
Lotus australis								+
Lotus cruentus	1			4		6	7	
*Medicago lupulina				4	5	6	7	
*Medicago orbicularis				4				
*Medicago polymorpha					5	6	7	
Pultenaea foliolosa			3					
Pultenaea setulosa				4				
Pultenaea sp. C	1	2	3				7	
Swainsona galegifolia				4				
Swainsona greyana	1		3				7	
Swainsona queenslandica						6		
*Trifolium arvense					5			
*Trifolium campestre				4			7	
*Trifolium repens							7	
*Vicia sativa					5			
*Vicia tetrasperma	1				5			
Zornia dyctiocarpa subsp. dyctiocarpa			3					
Gentianaceae								
Centaurium erythraea	1			4	5			
Centaurium spicatum	1		3	4	5		7	
*Centaurium tenuiflorum								+

Geraniaceae								
Geranium solanderi var. *solanderi*	1			4		6	7	
Pelargonium inodorum								+
Goodeniaceae								
Brunonia australis	1				5	6		
Dampiera stricta								+
Goodenia bellidifolia subsp. *bellidifolia*		2						
Goodenia hederacea		2	3			6	7	
Goodenia hederacea subsp. *hederacea*	1							
Goodenia macbarronii		2	3				7	
Haloragaceae								
Gonocarpus micranthus subsp. *ramosissimus*								+
Gonocarpus tetragynus								+
Haloragis aspera				4			7	
Haloragis heterophylla				4				
Lamiaceae								
Ajuga australis	1		3			6	7	
**Marrubium vulgare*	1				5	6	7	
Mentha diemenica						6		
Mentha satureioides	1		3	4	5	6		
Prostanthera cryptandroides subsp. *euphrasioides*								+
**Salvia verbenaca*							7	
Scutellaria humilis							7	
**Stachys arvensis*					5			
Teucrium racemosum		2		4				
Teucrium sp. A							7	
Lauraceae								
Cassytha glabella		2	3	4			7	
Lentibulariaceae								
Utricularia dichotoma						6		
Lobeliaceae								
Isotoma axillaris		2	3					
Pratia concolor					5	6	7	
Pratia purpurascens	1							
Loranthaceae								
Amyema miquelii	1		3					
Dendrophthoe glabrescens	1		3					
Muellerina bidwillii	1							
Malaceae								
**Cotoneaster glaucophyllus*								+
Malvaceae								
**Malvastrum americanum*							7	
**Modiola caroliniana*					5		7	
**Pavonia hastata*								+
Sida corrugata						6		
Sida cunninghamii	1						7	
**Sida rhombifolia*	1				5		7	
Sida trichopoda				4		6	7	
Martyniaceae								
**Ibicella lutea*					5			
Moraceae								
Ficus rubiginosa								+
Myrtaceae								
Angophora floribunda	1		3				7	
Angophora leiocarpa	1	2	3			6	7	
Babingtonia densifolia							7	
Callistemon viminalis							7	
Calytrix tetragona	1	2	3				7	+
Corymbia dolichocarpa	1	2	3				7	
Corymbia trachyphloia		2						
Eucalyptus albens	1		3					
Eucalyptus andrewsii								+
Eucalyptus blakelyi			3				7	
Eucalyptus caleyi subsp. *caleyi*								
Eucalyptus camaldulensis					5	6		
Eucalyptus chloroclada			3					
Eucalyptus crebra	1						7	
Eucalyptus dealbata	1	2	3	4			7	
Eucalyptus macrorhyncha		2	3				7	
Eucalyptus melanophloia	1		3					
Eucalyptus melliodora						6		
Eucalyptus populnea subsp. *bimbil*			3					
Eucalyptus prava							7	
Eucalyptus sideroxylon	1	2	3					
Leptospermum arachnoides							7	
Leptospermum brevipes	1	2		4			7	
Leptospermum polygalifolium subsp. *transmontanum*								
Melaleuca erubescens								
Nyctaginaceae								
Boerhavia dominii					5	6		
Oleaceae								
Jasminum lineare	1						7	
Jasminum suavissimum					5			
Notelaea microcarpa	1		3			6	7	
Onagraceae								
Epilobium billardierianum subsp. *billardierianum*							7	
**Oenothera rosea*			3		5	6	7	
Oxalidaceae								
Oxalis chnoodes	1		3	4		6	7	
Oxalis perennans							7	
Papaveraceae								
**Argemone subfusiformis* subsp. *subfusiformis*	1			4	5			
Pittosporaceae								
Bursaria spinosa	1						7	
Cheiranthera cyanea var. *borealis*								
Pittosporum angustifolium	1							
Rhytidosporum diosmoides			3					
Plantaginaceae								
Plantago debilis	1						7	
**Plantago lanceolata*	1						7	
Plantago varia				4	5		7	
Polygalaceae								
Comesperma sphaerocarpum		2						
Polygala japonica							7	

Polygonaceae								
Persicaria lapathifolia					5			
*_Polygonum aviculare_					5			+
Polygonum plebeium					5			
Rumex brownii	1		3	4	5	6	7	
Rumex crispus							7	
Portulaceae								
Portulaca oleracea					5			
Primulaceae								
*_Anagallis arvensis_	1			4	5		7	+
Proteaceae								
Conospermum taxifolium								+
Grevillea arenaria								+
Grevillea floribunda		2	3					
Grevillea triternata	1	2					7	
Isopogon petiolaris		2						
Persoonia cornifolia		2						
Persoonia sericea		2	3					
Persoonia tenuifolia								+
Persoonia terminalis subsp. _recurva_	1	2	3				7	
Persoonia terminalis subsp. _terminalis_		2						
Xylomelum cunninghamianum		2	3					
Ranunculaceae								
Clematis glycinoides							7	
Clematis microphylla var. _microphylla_							7	
Ranunculus inundatus					5		7	
Ranunculus lappaceus	1						7	
Rhamnaceae								
Alphitona excelsa								+
Cryptandra amara var. _amara_	1	2						
Cryptandra amara var. _floribunda_		2					7	
Pomaderris queenslandica			3				7	
Rosaceae								
Acaena novae-zelandiae							7	
Acaena ovina						6		
Rubus parvifolius							7	
Rubiaceae								
Asperula conferta								+
Galium ciliare			3				7	
Pomax umbellata	1	2					7	
Psydrax odoratum	1					6		
Psydrax oleifolium	1							
Rutaceae								
Boronia glabra		2	3					
Correa glabra var. _glabra_							7	
Correa reflexa var. _reflexa_								+
Zieria aspalathoides			3					
Santalaceae								
Exocarpos cupressiformis		2						
Thesium australe	1					6		
Sapindaceae								
Alectryon subdentatus forma _subdentatus_								
Dodonaea heteromorpha								
Dodonaea peduncularis		2						
Dodonaea triquetra			3					
Dodonaea viscosa subsp. _angustifolia_	1	2						
Scrophulariaceae								
Euphrasia collina subsp. _paludosa_	1	2	3					
Gratiola peruviana				4				
Stemodia glabella						6		
*_Verbascum thapsus_ subsp. _thapsus_	1							
*_Verbascum virgatum_			3					+
Veronica calycina							7	
Simaroubaceae								
*_Ailanthus altissima_							7	
Solanaceae								
Solanum cinereum	1				5			
Solanum opacum			3					
*_Solanum pseudocapsicum_							7	
Stackhousiaceae								
Stackhousia viminea	1		3			6	7	
Sterculiaceae								
Brachychiton populneus subsp. _populneus_	1		3			6	7	
Rulingia dasyphylla						6		
Stylidiaceae								
Stylidium armeria			3					
Stylidium graminifolium								+
Thymelaeaceae								
Pimelea linifolia	1					6		
Pimelea micrantha	1	2	3					
Pimelea neo-anglica	1							
Pimelea stricta	1							
Urticaceae								
Urtica incisa						6	7	
Verbenaceae								
*_Verbena aristigera_				4	5			+
*_Verbena bonariensis_	1			4	5		7	
*_Verbena brasiliensis_	1		3	4	5	6	7	
*_Verbena officinalis_	1			4	5		7	
Violaceae								
Hybanthus monopetalus			3					
Zygophyllaceae								
*_Tribulus terrestris_				4				

Wallum and related vegetation on the NSW North Coast: description and phytosociological analysis

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Abstract: Wallum is the regionally distinct vegetation on coastal dunefields, beach ridge plains and sandy backbarrier flats in subtropical northern NSW and southern Queensland (22°S to 33°S). This study examined floristic patterns in the wallum and allied vegetation along 400 km of coastline in north-eastern NSW. Floristic and environmental data were compiled for 494 quadrats allocated on the basis of air photo pattern and latitude. A phytosociological classification displayed strong congruence with an initial classification based upon photo pattern, especially for single stratum vegetation, thereby suggesting that API (air photo interpretation) is a valuable technique for the recognition of floristic assemblages. The utility of API for depicting the spatial distribution of tallest stratum species in multi-stratum vegetation was also confirmed. Nonetheless, photo signatures of the tallest stratum are less satisfactory as surrogates for identifying noda for the full complement of species in multi-stratum vegetation. Ordination supported the numerical classification, and reinforced the value of API for capturing meaningful biological and environmental data. Plant – environment relationships were examined for a range of variables. The consistent trend to emerge was a comparatively strong correlation between floristic composition and topographic position, and in some instances also between floristic composition and geology. Mean species richness at the 25 m^2 scale was lower in wetter habitats, although differences were not consistently significant.

***Cunninghamia* (2003) 8(2): 202–252**

Introduction

Use of the term wallum

The coastal lowlands of southern Queensland and northern NSW were extensively forested at the time of European settlement, and in this setting sand mass vegetation would have been visually distinct. Aboriginal people apparently recognised the differences, and in south-eastern Queensland they applied the name 'wallum' to heathlands and associated *Banksia aemula* shrublands of beach ridge plains and backbarrier flats, or more specifically to either of two *Banksia* species (*B. aemula* and *B. oblongifolia*) (Baxter 1968, Blake 1938, 1947, 1968, Whitehouse 1967, 1968). The term wallum has since been used more generally to include not only sand mass heathland and shrubland, but also various forest, woodland, sedgeland and grassland communities (Batianoff & Elsol 1989, Coaldrake 1961).

It seems that wallum may be applied in either a narrow sense or a much broader one. Orchard (1995), in the glossary supplements to *Flora of Australia*, defines wallum as 'coastal vegetation on sandy acidic soils, in south-eastern Queensland'. However, wallum is also a recognised botanical term for NSW where it is applied to a particular habitat or ecosystem — 'sandy coastal sites with impeded drainage, usually supporting heath, scrubby communities or swamps' (Harden 1993). For the purposes of the present study, wallum is simply defined as the vegetation, across the full range of structural formations, occurring on dunefields, beach ridge plains and sandy backbarrier flats in southern Queensland and northern NSW. These sand masses are concentrated between Newcastle (33°S) and the Shoalwater Bay region (22°S) near Rockhampton, with scattered occurrences further north and south (Thompson 1983). 'Sand plain' vegetation in south-western Australia is similarly known by an Aboriginal name, 'kwongan' (Beard 1976, Brown 1989, Brown & Hopkins 1983, Hnatiuk & Hopkins 1980, Orchard 1995). Although heathlands and shrublands are conspicuous in the kwongan, Hopkins and Hnatiuk (1981) point to the presence of other structural formations such as woodland. On this basis, they favour a broader usage of kwongan for reference to sand plain vegetation generally.

Scope and objectives of the study

This study is concerned with wallum structural formations other than forest and woodland. Also considered are sod grassland, tussock grassland, heathland and shrubland formations on bedrock soils of headlands and coastal hills, or heavier-textured soils of backbarrier flats. These were included because of their close proximity to wallum, and because they support many of the same species (Griffith & Williams 1997). Alluvial floodplain vegetation,which includes various sedgelands, rushlands and forblands, often adjoins wallum vegetation at its inland extremities, but this was excluded from the study. Floodplain vegetation, in particular wetland, shares some species in common with wallum although it is generally distinguishable in terms of either species dominance or overall floristic composition, and also on the basis of substrate (Goodrick 1970, Pressey 1987a,b, Pressey & Griffith 1987). Estuarine and beach strand vegetation was also excluded. Existing accounts of estuarine vegetation include Adam et al. (1988) and West et al. (1984), while Clarke (1989) and Griffith et al. (2000) describe vegetation associated with beaches.

The practice of distinguishing vegetation types by their physiognomy has a strong tradition in Australian plant ecology (Beadle 1981, Beadle & Costin 1952, Beard 1981, Carnahan 1981, Specht 1981, Specht et al. 1974, Walker & Hopkins 1984, Webb & Tracey 1981). Spatial patterns in the wallum and associated vegetation of eastern Australia can be delineated on the basis of air photo signature (Durrington 1977, Griffith 1983, Griffith et al. 2000, Myerscough & Carolin 1986). Air photo interpretation (API) is a widely used technique for portraying patterns of physiognomy and floristic composition of the dominant (tallest) vegetation layer or stratum. API groups generally display a degree of floristic homogeneity for the tallest stratum, but this may not be the case for understorey strata. Conversely, it may be possible to distinguish different structural formations on aerial photographs (e.g. shrubland and heathland), even though there is little obvious difference in floristic composition. API is also scale dependent, and it is sometimes possible to further subdivide map units with the aid of larger scale photography.

The potential limitations of vegetation classifications based upon API have ramifications for the identification of plant communities where a consideration of complete floristic composition is desirable, and in turn for the interpretation of spatial, biogeographical and plant – environment relationships (Adam et al. 1989, Bridgewater 1981, Dale et al. 1988, Hunter & Clarke 1998). Even so, vegetation mapping derived from API forms the basis of resource management in many coastal reserves of northern NSW, particularly in the design of fire management prescriptions to maximise species biodiversity (NSW National Parks & Wildlife Service 1997, 1998a,b). This application of API has proceeded in the absence of a regional phytosociological analysis of heathland and related formations (cf. NSW National Parks and Wildlife Service 1999, for forest and woodland).

In view of the known or perceived limitations of vegetation classifications based solely upon API, a methodology was designed to achieve the following objectives:

(a) explore phytosociological relationships in the wallum and related vegetation of northern NSW, using cover-abundance data for all vascular species;

(b) examine the phytosociological groups for plant – environment relationships;

(c) as a measure of the utility of API for depicting spatial and biogeographic relationships, and plant – environment relationships, assess the degree of congruence between the floristic groups derived in (a) and existing API groups.

The study area (Fig. 1) extended from Crowdy Bay National Park (NP) near Taree (31°53'S 152°39'E) northwards to Newrybar Swamp near Lennox Head (28°44'S 153°36'E). This coincided with available vegetation mapping at the time the study was initiated in 1996. More recently, vegetation maps were prepared for Booti Booti NP (Griffith et al. 2000) and Khappinghat NP (Griffith & Wilson 2000) to the south of Crowdy Bay NP. The study area occurs within the North Coast botanical subdivision (Anderson 1961).

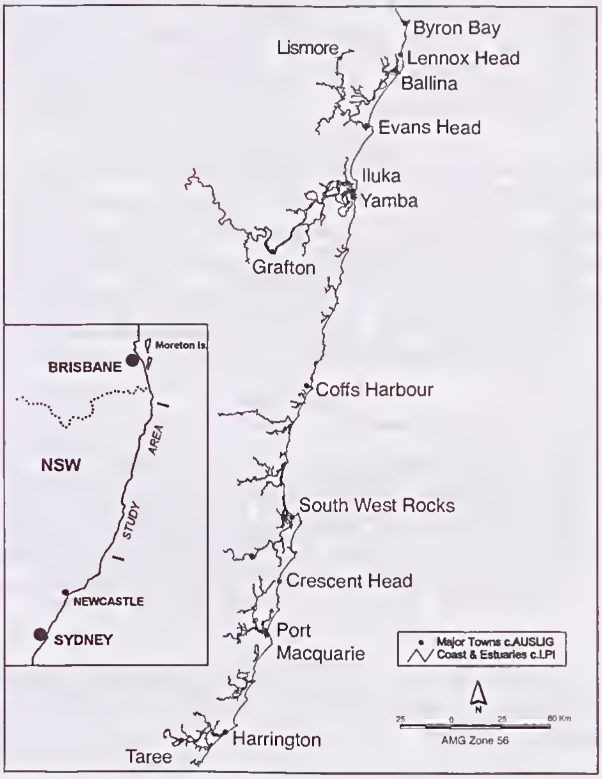


Fig. 1. The study area along the coast of north-eastern NSW

Climate

The climate of coastal northern NSW and southern Queensland is subtropical with summer-dominant rainfall (Colls & Whitaker 1990). The general pattern is one of hot, wet and humid summers followed by drier, cooler winters. Periods of heavy summer rainfall may be associated with the passage of tropical cyclones (Bureau of Meteorology 1972, NSW Water Conservation & Irrigation Commission 1970, Thompson & Moore 1984). More southerly parts of coastal NSW experience cooler conditions and a less pronounced dry season, and this climatic pattern is described as temperate with uniform rainfall (Colls & Whitaker 1990).

Climatic data for several coastal weather stations in northern NSW were sourced from the Bureau of Meteorology (pers. comm. 2000). These stations were selected on the basis of location, and the duration and completeness of their data – Byron Bay, Yamba, Coffs Harbour, South West Rocks, Port Macquarie, Harrington and Newcastle. Mean monthly rainfall and temperature data the upper (Byron Bay), mid- (South West Rocks) and lower (Newcastle) North Coast are summarised in Figure 2.

Mean annual rainfall ranges from 1144 mm at Newcastle to 1746 mm at Byron Bay, and the lowest totals occur on the lower North Coast (Harrington and Newcastle). The three consecutive months with the highest average rainfall generally occur between January and May inclusive.

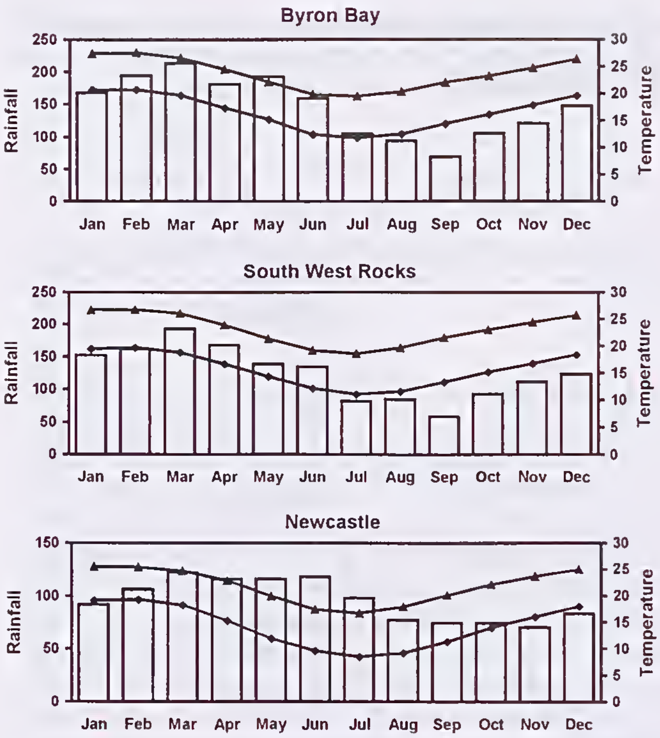


Fig. 2. Climatic data for the coast of northern NSW. Mean monthly trends for total rainfall (mm), and maximum and minimum temperature (°C).

However, on the lower North Coast the wettest three-month period occurs from March to June inclusive, and therefore the heaviest monthly falls may extend into early winter. Total mean rainfall for the three wettest months varies from 356 mm at Newcastle to 637 mm at Coffs Harbour. Total mean rainfall for the three driest months ranges from 215 mm at Yamba to 267 mm at Byron Bay. Although each weather station records a seasonal period of lower rainfall from mid-winter into spring, the difference between wet and dry seasons is less pronounced on the lower North Coast. Late winter–spring is generally a period of water stress in coastal southern Queensland where evaporation is high relative to monthly rainfall (Coaldrake 1961, Thompson & Moore 1984). An equivalent period of water deficit is also likely in coastal northern NSW, particularly in years of below-average rainfall (NSW Water Conservation & Irrigation Commission 1970). This is the so-called period of late winter–spring 'drought' (Coaldrake 1961).

Exceptionally high monthly rainfall totals in excess of 500 mm have been recorded for each weather station, with the highest at Port Macquarie (1388 mm in January) and Harrington (1045 mm in February). Unusually high monthly totals have also occurred in months that are, on average, relatively dry. Rainfall variability is also reflected in the incidence of extremely low monthly totals, and all weather stations other than Byron Bay have at some time recorded monthly totals of 20 mm or less during the seasonally wettest three-month period.

There is a general north – south gradient in temperature, from a mean annual maximum of 23.7°C at Byron Bay to 21.8°C at Newcastle. The latitudinal trend for mean annual minimum temperature is not so well defined, although there is nonetheless a tendency to lower values with increasing latitude. Byron Bay has recorded the highest mean annual minimum temperature (16.5°C), and the lowest is recorded for Port Macquarie (13.0°C). The three months with the highest mean daily maximum temperature occur in the period December to March inclusive (26.6–27.5°C at Byron Bay, down to 24.9–25.5°C at Newcastle). June, July and August register the lowest mean daily maxima (19.4–20.3°C at Byron Bay, down to 16.7–17.9°C at Newcastle).

Maximum daily temperatures in excess of 40°C are known for six of the seven weather stations, and the highest readings are reported for Harrington (43.3°C), Coffs Harbour (43.3°C) and Port Macquarie (42.3°C). Coffs Harbour, Harrington and Newcastle have recorded minimum daily temperatures of 0°C or less. Frosts are rare or uncommon along the immediate coastline in northern NSW and southern Queensland, although they can be expected at short distances inland during the coldest months (Coaldrake 1961, NSW Water Conservation & Irrigation Commission 1966, 1968, 1970).

Across all weather stations, mean annual 9 am relative humidity ranges from 68–78%. Similarly, mean annual 3 pm relative humidity ranges from 63–71%. There is a tendency for mean monthly relative humidity to be lower in the winter –spring period, which is also the time of generally lower rainfall.

Strong winds often associate with tropical cyclones and thunderstorm squalls, or occasionally with tornadoes, and these can be very destructive in northern NSW and southern Queensland (Bureau of Meteorology 1972, Coaldrake 1961, NSW Water Conservation & Irrigation Commission 1968, 1970, Thompson & Moore 1984). Coaldrake (1961) noted complete defoliation of eucalypt forest during cyclonic winds on the coastal lowlands of southern Queensland. The highest monthly maxima in northern NSW are registered for Newcastle (171 km/hr) and Coffs Harbour (124 km/hr). Hail can also result in severe localised damage to vegetation, and the Bureau of Meteorology (1972) estimates that any particular location along the far North Coast of NSW may experience hail at a frequency of about once in five years, particularly in October and November. Hail is frequently associated with thunderstorms (Coaldrake 1961), and under these conditions strong wind gusts are likely.

Landforms, geology and soils

Quaternary sediments of marine-aeolian and estuarine origin are extensive along the coast of northern NSW and southern Queensland (Coaldrake 1961, Roy & Hann 1983, Thompson & Moore 1984). These sediments are most evident as dunefields, beach ridge (strand) plains and backbarrier flats, and sand mass deposits in particular are noted to have a complex pre-depositional history (Tejan-Kella et al. 1991). Beach ridge plains display a characteristic pattern of ridge and swale topography, although in time slope processes operate to subdue this pattern (Thom et al. 1981). Compound dunes reach maximum elevations of around 260–280 m in southern Queensland (Coaldrake 1962, Thompson & Hubble 1980, Thompson & Moore 1984), and it is not uncommon for dunefields to contain perched swamps in swales well above sea level where a concave layer of indurated sand retards drainage (Coaldrake 1962, Heyligers et al. 1981, Reeve & Fergus 1982).

Apart from instances of aeolian reworking (Thom et al. 1981, Roy 1982), and despite apparent high wind intensities during the Last Glacial, geomorphic and pedological evidence suggests that extensive pre-glacial beach ridge plains and dunefields still evident today in northern NSW and southern Queensland have carried vegetation since deposition (Pickett et al. 1984, Thompson 1981, 1992, Walker et al. 1981). This indicates that precipitation levels remained effective for plant growth, and fossil evidence suggests that the continuous vegetative cover throughout the Last Glacial was very similar to contemporary wallum (Anon 1984, Ball 1924; Coaldrake 1962, Longmore 1997, Pickett et al. 1984, Walsh & Roy 1983, Whitehouse 1968).

Thompson and Hubble (1980) recognise three general forms of B horizon and hence soil type in sand masses, with differences linked to the degree of drainage and duration of weathering (see also Maze 1942). Iron Podzols display shallow or rudimentary profile development, and sesquioxide strongly dominates the B horizon in the absence of prominent organic enrichment. Humus-Iron Podzols of older, free-draining sites have B horizons in which both sesquioxide and organic compounds are prominent. Humus Podzols develop where influenced by intermittent or permanent watertables, and organic compounds are strongly dominant in the B horizon whereas iron accumulations other than thin pans are generally lacking. Under increasingly waterlogged conditions, Humus Podzols are replaced by Peaty Podzols (with a peat-rich A1), and then in turn by Acid Peats. With continued weathering of deep sand deposits over a long period of time, B horizons may migrate to depths of 4–10+ m below the ground surface. Although B horizons retard soil water drainage, they are nonetheless permeable to a varing extent (Reeve & Fergus 1982).

For use in agriculture and forestry, wallum soils are relatively infertile and deficient in various plant nutrients (Atkinson 1999, Coaldrake 1961, Thompson & Hubble 1980). Nonetheless, dunefields and beach ridge plains may support well-developed rainforest, or sclerophyll forest of *Eucalyptus*, *Corymbia* and allied genera in which the tallest stratum reaches heights of 35 m or more (Floyd 1990, Walker et al. 1981, Young & McDonald 1987). Despite the extremely siliceous composition of the soil parent material, proximity to the ocean ensures comparatively high inputs of seawater-derived nutrients such as the common metallic cations and sulphur (Charley & Richards 1991, Charley & Van Oyen 1991). Other nutrients such as phosphorus are a minor component of seawater, and therefore may be limiting.

The soils supporting heathland, shrubland and grassland on headlands, coastal hills, and flats associated with plains and backplains are often heavier-textured than soils associated with wallum on dunefields and beach ridge plains. Bedrock outcrops supporting coastal heathland and allied vegetation in north-eastern NSW have varied lithology, for example adamellite, rhyolite, sandstone or shale (Geological Survey of NSW 1970, 1971), and it appears that cyclic salt accessions are comparatively important to soil formation processes (e.g. Atkinson 1999). Soils on headlands and coastal hills include Lithosols, Yellow Earths, Yellow Podzolic Soils, Soloths and, after Parbery (1947), Black Headland Soils. Soils to be expected on flats include Acid Peats, Humic Gleys, Yellow Earths, and Yellow and Brown Podzolic Soils (Atkinson 1999, Griffith 1992a, Stone 1982). From an agricultural perspective, these soils are likely to display low fertility and nutrient deficiencies, low available waterholding capacity, and high aluminium toxicity potential (e.g. Atkinson 1999). The soils on elevated aspects are susceptible to waterlogging after high rainfall events, and those in low-lying areas are periodically saturated or inundated by a rising watertable.

South-eastern Queensland and north-eastern NSW are geologically similar. Shared soil parent materials are associated with strata of the Mesozoic Clarence–Moreton Basin (McElroy 1962, 1969), and older basement sequences such as the Palaeozoic Beenleigh Association (Korsch 1977). Tertiary basalts and associated rock types occur in both regions (eg. the Lamington Volcanics), along with extensive Quaternary sand mass, estuarine and floodplain deposits. Similarities in the coastal vegetation of both regions are noted in various studies (Beadle 1981, Griffith et al. 2000, McDonald & Elsol 1984, Myerscough & Carolin 1986).

Landuse and fire history

The coastal lowlands of north-eastern NSW are ancestral homelands to several groups of Aboriginals, for example the Bundjalung north of the Clarence River, the Kumbaingirri to the south, and the Biripi further south again. Material evidence of an extensive Aboriginal culture remains as camp sites, middens, rock shelters, fish traps, ceremonial grounds, tool manufacture sites, and marked or otherwise scarred trees. Many landforms are also important to Aboriginal mythology and customs, for example Lake Ainsworth at Lennox Head, Salty Lagoon in Broadwater NP, Goanna Headland at Evans Head, and North Brother, Middle Brother and South Brother Mountains between the Hastings and Manning Rivers. A large Kurrajong tree, *Brachychiton populneus*, still stands on an extensive midden along the bank of the Evans River in Bundjalung NP. It appears that Aboriginals from as far inland as Glen Innes travelled to the coast to trade. Kurrajong seed was one such item of trade, and this was used to prepare a beverage (Martin 1976). Despite the upheaval of their culture since European occupation, the Aboriginal groups of north-eastern NSW maintain a strong affinity with the lowlands.

The first European settlers in far north-eastern NSW were cedar getters, and they moved progressively northward in the early to mid 1800s. Graziers followed, at first relying upon native pasture. Cropping commenced on the Clarence River floodplain in 1864 with the establishment of sugar cane farms, and subsequently on the Richmond and Tweed River floodplains. Mining has occurred since the first half of the 1800s, particularly for gold, tin, antimony, silver, copper, manganese and mineral sands (NSW National Parks & Wildlife Service 1995). In 1948, A.P. Roux produced four tonnes of mixed concentrates at Jerusalem Creek near Evans Head, so beginning a period of rutile and zircon mining (Morley 1981). Mineral sand mining operations still continue over limited areas, and sand extraction for glass manufacture occurs in dunefields on the lower North Coast. These latter operations quarry thick deposits of bleached sand (the A2 horizon of podzols).

In 1968 the NSW Parliament held an inquiry into conflicts between mineral sand mining and nature conservation (the 'Sim Committee' enquiry), and as a result examples of wallum along the North Coast were set aside for conservation. Extensive areas of relatively undisturbed wallum and associated vegetation are now reserved in national parks and nature reserves in north-eastern NSW, in addition to many regenerating mine paths. Other reminders of European landuse in these reserves include broken and fallen fencelines, waterholes, ringbarked trees, stumps and disused log dumps, the ruins of stockyards and buildings, and the small clearings of beekeepers. Feral horses and pigs disturb soil and native vegetation in some areas, and illegal cattle grazing occurs from time to time. Invasive weeds include *Chrysanthemoides monilifera* subsp. *rotundata* (Bitou Bush) and *Baccharis halimifolia* (Groundsel Bush), particularly along foredunes and estuaries, although the older, strongly podzolised sand masses remain comparatively weed-free.

John Oxley provided a brief account of wallum on the North Coast. He and his men travelled south through what is now Crowdy Bay NP in October 1818: '... the low part of the country was an entire fresh water swamp, interspersed with thick barren brush ...' (in Birrell 1987).

Wallum is very flammable, and wet heathland can be regularly burnt at three-year intervals if conditions are conducive for ignition (S. Griffith unpub. data). It appears that most fires in the wallum of northern NSW over the last few decades have been unplanned and deliberately ignited (NSW National Parks & Wildlife Service 1997, 1998a,b). This scenario probably also reflects trends for a longer period of European settlement because prior to reservation for nature conservation wallum was utilised as unimproved pasture and also for harvesting of Christmas Bell, *Blandfordia grandiflora*. Both activities were promoted by regular burning.

Fire ecology studies on the upper South Coast, Central Coast and lower North Coast of NSW collectively suggest that fires of optimal intensity at intervals of around 10–15 years are likely to promote adequate regeneration of both resprouter and seeder species (Auld 1987, 1990, Benson 1985, Bradstock 1990, Bradstock & O'Connell 1988, Fox & Fox 1986, Nieuwenhuis 1987, Vaughton 1998). Nonetheless, some variation in the length of inter-fire intervals may facilitate the maximisation of species richness (Morrison et al. 1995). Current fire management prescriptions advocate a general avoidance of successive fires at intervals of less than 8 years, avoidance of successive fires at intervals greater than 15 years, and a maximum inter-fire interval of 30 years (NSW National Parks & Wildlife Service 1997, 1998a,b).

Methods

Vegetation mapping and classification using air photo interpretation

Detailed vegetation mapping is available for all major occurrences of wallum and related vegetation in NSW north from the Forster district (Griffith et al. 2000). Several national parks and nature reserves sample this vegetation in northern NSW, and from north to south these include Broadwater NP, Bundjalung NP, Yuraygir NP, Moonee Beach Nature Reserve (NR), Hat Head NP, Limeburners Creek NR, Lake Innes NR, Kattang NR, Crowdy Bay NP, Booti Booti NP, Myall Lakes NP and Tomaree NP. Significant areas of wallum also occur on freehold or crown land outside the reserve system, for example Newrybar Swamp at Lennox Head, and lands at Evans Head north and south of the Evans River.

Conventional API techniques were used to map vegetation in the study area. R. Wilson (formerly NSW National Parks and Wildlife Service) completed this task in collaboration with S.J. Griffith. The mapping program was initiated in the early 1980s to provide a basic understanding of the spatial distribution of coastal vegetation along the North Coast for the purposes of conservation planning and management. The methodology and limitations are discussed in Griffith et al. (2000).

The structural classification of Walker and Hopkins (1984) was used for mapping and vegetation description, and height and crown cover of the tallest stratum are expressed using classes (e.g. mid-high closed heathland, tall closed sedgeland). Subformation names were adopted from the classification proposed by Beadle and Costin (1952), although with some modifications and additions (e.g. wet or dry heathland, and swamp or dry sclerophyll shrubland).

As is generally the case for vegetation description based upon photo pattern, the API groups were named after dominant indicator species of the tallest (dominant) stratum. Most of the groups so described could be considered associations using the definition of Beadle (1981), 'a community in which the dominant stratum exhibits uniform floristic composition, the community usually exhibiting uniform structure (also)'. In applying Beadle's definition, it was assumed that a particular stand was structurally uniform if it spanned two or less height classes, and two or less crown cover classes. In this way, for example, *Banksia aemula* tall sparse to open shrubland (crown cover very sparse to sparse) could be considered a separate association from *B. aemula* tall shrubland and closed shrubland (crown cover mid-dense to dense). Five-digit numeric codes were used for mapping purposes to delineate API groups. The first four digits of each code identify the formation, subformation and dominant tallest stratum species. As an illustration, map codes 5200–5599 are reserved for formations in which the tallest stratum is dominated by shrubs i.e. shrubland. In the shrubland formation, map codes 5400–5499 are used for API groups in the dry sclerophyll shrubland subformation. Dry sclerophyll shrubland in which *Banksia aemula* is the characteristic dominant has the map code 5402. A fifth digit is used on vegetation maps to signify the crown cover range of the tallest stratum in each polygon: 1 = mid-dense to dense (e.g. 5402<u>1</u> for *B. aemula* shrubland and closed shrubland); and 2 = very sparse to sparse (e.g. 5402<u>2</u> for *B. aemula* sparse shrubland and open shrubland). Sun et al. (1997) compare this method of vegetation classification and mapping (as 'NSW National Parks and Wildlife Service Coastal Vegetation Mapping') with systems in use for other parts of NSW and Australia.

Sample stratification

The existing mapping was used for sample stratification. Sites were allocated on an area-proportional basis to each API group, and spread by initially subdividing the study area into four roughly equal bands of latitude (Table 1). Rare API groups were deliberately captured in the stratification process by assigning a minimum of one site per latitude band regardless of the area occupied. The total area of wallum and associated vegetation considered during the stratification process exceeded 27 000 ha.

Sites were remotely chosen using the vegetation mapping and additional API, and predetermined locations were marked on aerial photographs prior to entering the field. Once in the field, every endeavour was made to locate each site within 50 m of its predetermined location (i.e. within 2 mm at a scale of 1: 25 000); although where unavoidable due to disturbance or other unforeseen limitations, sites were relocated at a distance of no more than 100 m. In rare instances a site was relocated to a distance greater than 100 m. This was necessary where an error in the vegetation mapping became apparent during the fieldwork, or where the vegetation had changed. An example of the latter is the conversion of *Banksia ericifolia* subsp. *macrantha* swamp sclerophyll shrubland into wet heathland with the passage of fire. *Banksia ericifolia* subsp. *macrantha* is a bradysporous obligate seeder, and adult shrubs are readily killed by fire. Upon the death of the *B. ericifolia* subsp. *macrantha* overstorey, understorey species assume dominance as a structurally lower heathland formation.

Data collection

Each site generally consisted of a 30 × 20 m rectangular plot aligned across the slope, and this plot was in turn subdivided using a 10 × 10 m grid. A 15 × 10 m rectangular plot was used for structurally and floristically simple vegetation such as sedgeland. Two 10 × 10 m quadrats were randomly selected in each rectangular plot or, for the simpler vegetation, two 5 × 5 m quadrats. Species-area curves were used to determine these quadrat sizes. A complete list of vascular species was compiled for each quadrat, and each species was assigned to one of six foliage cover classes: 1 (<1%); 2 (1–5%); 3 (6–25%); 4 (26–50%); 5 (51–75%); and 6 (76–100%). Foliage cover is the percentage of a quadrat occupied by the vertical projection of foliage and branches (Walker & Hopkins 1984). To facilitate comparisons of species richness at a standard scale (in this case 25 m^2), a 5 × 5 m quadrat was nested within each 10 × 10 m quadrat and a separate list of vascular species compiled. Vegetation structure was recorded for every quadrat, in particular the height and total foliage cover of each stratum.

In addition to observations of structure and floristic composition, the following categorical and numerical environmental variables were determined for each quadrat:

(a) geology, as unconsolidated Quaternary sediments or one of three rock types (sedimentary–undifferentiated, igneous–adamellite, volcanic–rhyolite);

(b) aspect (°);

(c) slope (°);

(d) altitude above sea level (m);

(e) topographic position (after Speight 1984) using categories for landform morphological type (C = crest, D = closed depression, F = flat, L = lower slope, M = mid-slope, R = ridge, S = simple slope, U = upper slope, V = open depression) and landform element (BKP = backplain, BRI = beach ridge, DDE = drainage depression, DUN = dune, FOR = foredune, HCR = hillcrest, HSL = hillslope, LAK = lake, PLA = plain, SWL = swale, SWP = swamp);

(f) geographic location (easting and northing);

(g) degree of exposure, determined as the azimuth (°) for each of the eight principal compass bearings; and

(h) time elapsed since last burnt (0–5 years, 5–10 years, or >10 years), determined from fire history records held by the National Parks and Wildlife Service or otherwise estimated by field observation of incremental post-fire branching in species calibrated prior to sampling (*Banksia ericifolia* subsp. *macrantha* and *B. oblongifolia*).

Sampling of 494 randomly paired quadrats at 247 sites proceeded between March and October 1996, and at this time each site was permanently marked. Unfortunately, large areas of *Banksia ericifolia* subsp. *macrantha* shrubland (API group 55031) identified for sampling had reverted to heathland following the passage of fire. The target number of sites for this API group was not achieved, and only two were successfully allocated. A total of 441 plant taxa were observed during sampling. The nomenclature is generally consistent with current usage at the Royal Botanic Gardens (Sydney), and authorities are provided in Harden (1990–3, 2002) or Harden and Murray (2000).

Table 1. Areas of API groups of wallum and associated vegetation in latitude bands used to stratify sampling sites.

Band A: Newrybar Swamp (Lennox Head) to near Yamba. Band B: Yamba to Coffs Harbour. Band C: Coffs Harbour to Crescent Head. Band D: Crescent Head to Harrington. Each latitude band ranged over 40–50'. Plant communities were mapped using conventional API techniques at 1: 25 000 scale and a minimum polygon size of approximately 1 ha. Missing API codes apply to vegetation types (from broader inventory projects) not sampled in the present study.

Formation, subformation	API code	API group	Latitude band (hectares)				
			A	B	C	D	Total
Dry sclerophyll tree mallee	50021/2	*Eucalyptus pilularis*	703	9	0	25	737
	50031/2	*Eucalyptus signata*	13	0	0	7	20
	50041/2	*Eucalyptus planchoniana*	109	244	0	85	438
	50071	*Eucalyptus pilularis – E. planchoniana – Corymbia gummifera*	0	0	420	0	420
Swamp sclerophyll tree mallee	51021/2	*Eucalyptus robusta*	4	2	0	2	8
Dry sclerophyll shrubland	54021/2	*Banksia aemula*	2179	390	181	749	3499
	54031/2	*Banksia aemula – Allocasuarina littoralis*	39	0	0	45	84
	54051	*Banksia serrata – Allocasuarina littoralis – Leptospermum trinervium*	14	0	0	0	14
Swamp sclerophyll shrubland	55031	*Banksia ericifolia* subsp. *macrantha*	121	32	24	445	622
	55041	*Leptospermum juniperinum*	4	0	0	32	36
	55061/2	*Melaleuca quinquenervia*	202	21	46	1	270
	55081/2	*Melaleuca sieberi*	44	13	0	9	66
	55101	*Leptospermum speciosum*	1	0	0	0	1
	55111	*Leptospermum whitei – L. polygalifolium* subsp. *cismontanum*	5	0	0	0	5
Dry sclerophyll shrub mallee	56021	*Lophostemon confertus*	1	0	0	0	1
	56031/2	*Eucalyptus pilularis*	336	0	0	0	336
	56041	*Eucalyptus planchoniana*	32	0	0	0	32
Swamp sclerophyll shrub mallee	57022	*Eucalyptus robusta*	12	0	0	3	15
Dry heathland	58021	*Banksia aemula*	1168	653	115	785	2721
	58031	*Banksia aemula – Allocasuarina littoralis*	24	20	3	87	134
Graminoid clay heathland	59021	*Banksia oblongifolia – Allocasuarina littoralis – Aristida warburgii – Ptilothrix deusta*	40	1167	0	0	1207
	59031	*Banksia oblongifolia – Allocasuarina littoralis – Hakea teretifolia* subsp. *teretifolia – Aristida warburgii – Ptilothrix deusta*	0	0	0	105	105
	59041	*Banksia oblongifolia – Allocasuarina littoralis – Hakea teretifolia* subsp. *teretifolia – Aristida warburgii – Themeda australis*	0	0	21	0	21
Wet heathland	60021	*Banksia oblongifolia – Leptospermum liversidgei – Sporadanthus interruptus – Sprengelia sprengelioides – Xanthorrhoea fulva*	3350	1266	471	3582	8669
	60031	*Leptospermum juniperinum*	30	19	58	36	143
	60041	*Xanthorrhoea fulva*	309	121	0	1057	1487
	60071	*Banksia oblongifolia – Leptospermum polygalifolium* subsp. *cismontanum – Melaleuca nodosa*	29	44	0	39	112
Tussock grassland	62031	*Ischaemum australe – Ptilothrix deusta – Schoenus brevifolius – Themeda australis*	72	48	0	0	120
Sod grassland	63021	*Themeda australis*	9	28	9	14	60
Sedgeland	64031	*Leptocarpus tenax – Baloskion pallens – Schoenus brevifolius*	995	225	270	1928	3418
	64041	*Baumea rubiginosa*	74	364	44	398	880
	64051	*Lepironia articulata*	59	66	8	23	156
	64061	*Baumea articulata*	5	25	100	28	158
	64071	*Baloskion pallens – Baumea teretifolia – Melaleuca quinquenervia*	418	5	0	0	423
	64081	*Gahnia sieberiana – Gleichenia mendellii*	262	104	0	0	366
	64101	*Eleocharis sphacelata*	160	0	90	0	250
	64111	*Cladium procerum*	16	0	0	43	59
	64121	*Baumea arthrophylla*	0	0	24	78	102
	64141	*Baloskion pallens – Schoenus brevifolius*	39	0	0	0	39
	64181	*Gahnia sieberiana – Gleichenia dicarpa*	0	0	36	1	37
Rushland	65041	*Typha orientalis*	2	0	0	6	8
Fernland	67021	*Blechnum indicum*	4	0	0	6	10
							27289

Data analysis

Patterns in floristic composition were examined using ordination and numerical (cluster) analysis. These techniques facilitate a process of data reduction and exploration, often for the purpose of subsequent hypothesis generation (Kent & Coker 1992).

Numerical analysis of foliage cover scores (1 to 6) without further transformation was performed using PATN (Belbin 1993). The Bray-Curtis association coefficient was employed in combination with the flexible UPGMA (unweighted pair group arithmetic averaging) clustering algorithm and a slightly negative (-0.1) beta value. Kent and Coker (1992) suggest that an appropriate numerical method, and hence classification, is one 'which enables a clear ecological interpretation to be made'. The Bray-Curtis coefficient was found to satisfy this requirement, and such an outcome is consistent with a view that it provides a good estimate of ecological distance, primarily because greater emphasis is placed upon similarity between common and abundant species, than upon similarity between rare species and those with low cover-abundance (Belbin 1992, 1993, Faith et al. 1987).

Measures of constancy and fidelity were derived to facilitate the characterisation of plant communities (floristic groups). Constancy is the number of quadrats in which a species occurs (Kent & Coker 1992), and five classes were employed: I = 1–20% of quadrats; II = 21–40%; III = 41–60%; IV = 61–80%; and V = 81–100%. Fidelity may be expressed using semi-quantitative categories (Kent & Coker 1992) where, for example, an *exclusive species* is completely or almost completely restricted to a single plant community and an *indifferent species* has no obvious affinity for any single community. Benson and Ashby (2000) employ a more quantitative approach for the recognition of species with comparatively high fidelity. This approach, based upon the algorithm of Westhoff and van der Maarel (1978), examines the full complement of plant communities for the purpose of identifying the maximum proportion of occurrence for a particular species. This maximum value is then divided by the sum of proportions of occurrence in all plant communities. The resulting *fidelity index* values for proportion of occurrence range from 0.0 to 1.0, and Benson and Ashby (2000) distinguish *indicator* (high-fidelity) species as those with a fidelity index equal to or greater than 0.8, with the added proviso of occurrence in at least 50% of samples (quadrats) for the respective plant community. The approach of Benson and Ashby (2000) was employed in the present study, with all calculations based upon a simultaneous consideration of the entire data set. However, it is important to appreciate that measures of fidelity are scale-dependent in terms of the geographic extent of the vegetation under consideration, and the level of detail to which the vegetation is being examined (Kent & Coker 1992). Software to compute fidelity index and constancy values was written by Dr G. Watson (Armidale, NSW).

Numerical analysis was performed on the entire data set and various subsets. Homogeneity analysis facilitated the delineation of an appropriate number of plant communities. Bedward et al. (1992) discussed the concept of homogeneity, which is a measure of the average within-group association between samples (quadrats). Measures of heterogeneity are first derived from the Bray-Curtis association values of a numerical analysis routine. Heterogeneity is calculated as the ratio of the average within-group association between quadrats to the average association for the entire data set. Homogeneity is then expressed as 1 minus heterogeneity. In this way, on an indexed scale of 0.0–1.0, a value of 0.0 represents complete heterogeneity whereas a value of 1.0 indicates complete homogeneity. A plot of homogeneity index (vertical axis) against number of plant communities or floristic groups (horizontal axis, where the maximum number of floristic groups = the total number of quadrats) allows visual recognition of the point (or zone) at which the resultant curve trends away from a predominantly vertical relationship (analogous to species-area curves for spatially homogenous vegetation), after which much smaller proportional gains in homogeneity are achieved by subdivision of the data set into additional floristic groups. The homogeneity analyses were performed using an unpublished software program (Dr G. Watson), and this incorporates the algorithm in Bedward et al. (1992). Despite the potential benefits of homogeneity analysis in terms of utility and relative objectivity, particularly for data sets where many species display indifferent fidelity, there are likely to be instances when it is appropriate to distinguish plant communities at different levels of similarity on a dendrogram (e.g. Webb et al. 1984). Such intuitive decisions are probably best exercised where they make 'ecological sense' (Kent & Coker 1992).

Spatial relationships between plant species and environmental variables were examined using Canonical Correspondence Analysis (CCA). This is a multivariate method of direct ordination in which correlation and regression procedures are integrated. It depicts both patterns in floristic composition and the principal relationships with environmental variables. To achieve this outcome CCA selects the linear combinations of environmental variables along which the distributions of the species are maximally separated. Species – environment response surfaces are assumed to be unimodal (in particular Gaussian or bell-shaped), although the method is considered to be reasonably robust when this assumption does not hold (Kent & Coker 1992, ter Braak 1986, 1987, ter Braak & Prentice 1988). Biplots present the ordination output, and these depict quadrats as points, numerical environmental variables as vectors, and categorical environmental variables as centroids. The ordinations were performed in an unconstrained manner (i.e. without *a priori* intuitive weighting of variables) using CANOCO (ter Braak 1988).

Patterns in species richness were examined using analysis of variance (ANOVA) and multiple comparison (Tukey-Kramer) tests. Data were log or square root transformed where appropriate. These analyses were performed using StatView (SAS Institute Inc., Cary USA 1998).

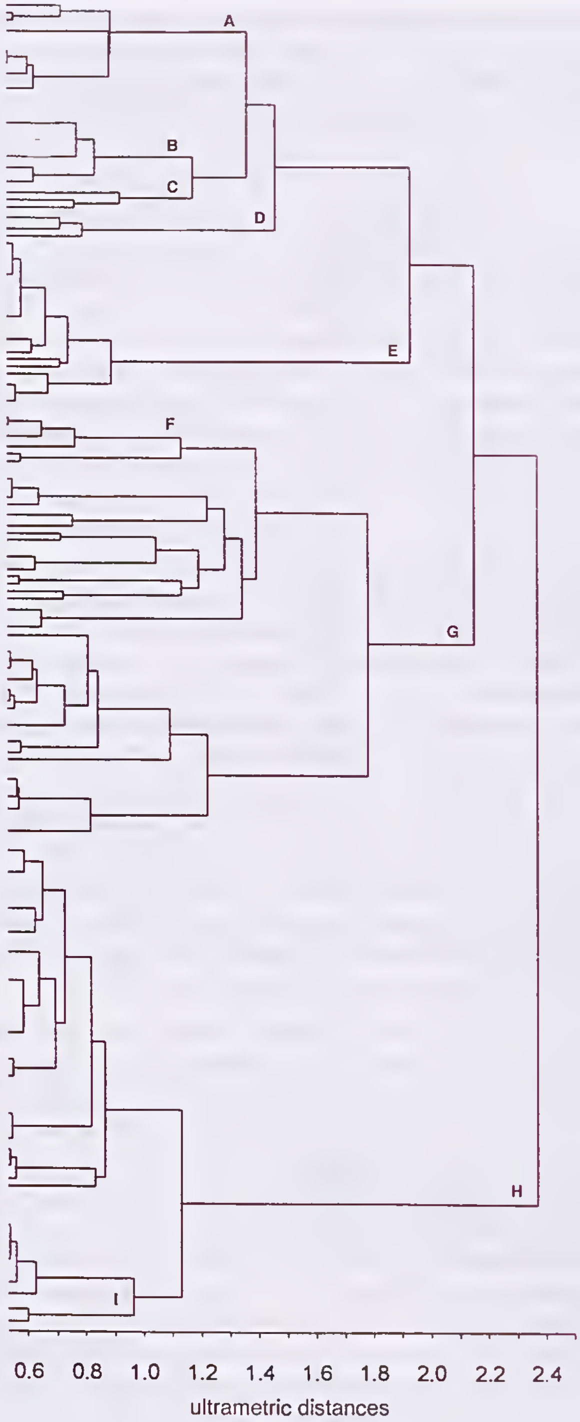


Fig. 3. Dendrogram for all samples of single stratum vegetation showing relationships of API groups

A: *Xanthorrhoea fulva* wet heathland (API group 60041) and *Ischaemum australe – Ptilothrix deusta – Schoenus brevifolius – Themeda australis* tussock grassland (62031). B: Graminoid clay heathland (59021, 59031, 59041). C: *Banksia oblongifolia – Leptospermum polygalifolium* subsp. *cismontanum – Melaleuca nodosa* wet heathland (60071). D: *Themeda australis* sod grassland (63021). E: *Banksia aemula* dry heathland (58021) and *Banksia aemula – Allocasuarina littoralis* dry heathland (58031). F: *Leptospermum juniperinum* wet heathland (60031). G: Sedgeland (64031, 64041, 64051, 64061, 64071, 64101, 64111, 64121, 64141), rushland 65041) and fernland (67021). H: *Banksia oblongifolia – Leptospermum liversidgei – Sporadanthus interruptus – Sprengelia sprengelioides – Xanthorrhoea fulva* wet heathland (60021). I: *Gahnia sieberiana – Gleichenia* sedgeland (64081, 64181).

Plant community circumscription and description

One of the distinguishing features of wallum is its often low stature and structural simplicity. Extensive areas are less than two metres high, and frequently lower than one metre. In these instances only a single vegetation stratum is discernible, and when shorter species are present (e.g. sedges and grasses in heathland) these are generally closely continuous in height with taller species such as heath shrubs (Durrington 1977, Griffith et al. 2000). Where only a single stratum is obvious, the air photo pattern is most likely a signature for the entire floristic composition. However, this may not be the case for taller, multi-layered vegetation where the tallest stratum (overstorey, canopy) obscures a lower stratum or strata. For the following examination of phytosociological relationships, a three-step process was therefore adopted:

1. Treatment of vegetation with a single stratum (fernland, heathland, rushland, sedgeland, sod grassland, tussock grassland);
2. Treatment of taller vegetation with two or more strata (shrubland, shrub mallee, tree mallee);
3. Simultaneous treatment of both single stratum and multi-stratum vegetation.

Floristic assemblages derived from numerical and homogeneity analyses in Steps 1 and 2 were elevated to plant community status, and these are generally named after the highest-ranked species in terms of constancy and mean foliage cover score (calculated for presence data only). The phytosociological classification so derived is reasonably comprehensive, but not definitive. The development of a formal hieriarchical classification into associations, alliances and so on would require analysis of samples for a wider geographic area (e.g. the inclusion of wallum in south-eastern Queensland).

A synoptic table (Appendix 2) provides the constancy class and mean cover score of every species in each plant community (although note that some constancy classes are not available where a community is represented by fewer than five quadrats). Each quadrat has a unique alpha-numeric code (e.g. HCR012.1 and HCR012.2 for Site No. 12 in Crowdy Bay NP, sampled at quadrats 12.1 and 12.2): 'H' distinguishes the data set (coastal 'heathlands') from others: AR = Arakoon State Recreation Area (SRA); BR = Broadwater NP; BU = Bundjalung NP; CR = Crowdy Bay NP; EV = Evans Head; HA = Hat Head NP; KA = Kattang NR; LA = Lake Innes NR; LI = Limeburners Creek NR; MO = Moonee Beach NR; NE = Newrybar Swamp; YU = Yuraygir NP.

Results and discussion

Vegetation with a single stratum

Single stratum vegetation was sampled in 364 randomly paired quadrats, and numerical analysis of this data for the entire complement of vascular species strongly supported the API group classification (Fig. 3). This outcome suggests that air photo signatures of structurally simple vegetation are useful for the recognition of floristic assemblages, although the utility of aerial photographs will depend upon limits of scale (i.e. degree of resolution). Numerical analysis also suggests that the data is strongly autocorrelated in terms of spatial distribution, with only a single pair of quadrats failing to re-unite at lower ultrametric distances.

This initial analysis provides preliminary insights into ecological relationships between floristic groups (Fig. 3). For example, *Leptospermum juniperinum* wet heathland (API group 60031) is floristically more similar to sedgeland, rushland and fernland vegetation than to another large group of wet heathland sites (API group 60021). *Leptospermum juniperinum* often occupies narrow drainage lines in association with sedgeland species. All sedgeland, rushland and fernland sites cluster in the analysis with the exception of sedgeland characterised by *Gahnia sieberiana* and either of two *Gleichenia* species (API groups 6408, 6418). This sedgeland clusters with wet heathland sites in API group 60021. The majority of sedgeland, rushland and fernland communities occur in closed depressions where standing water is present after periods of high rainfall if not more regularly. However, *Gahnia–Gleichenia* sedgeland more typically occupies the margins of open depressions where the soil receives groundwater seepage. In these situations *Gahnia–Gleichenia* sedgeland supports various heath shrubs in common with wet heathland (API group 60021), albeit at relatively minor foliage cover values. The analysis also suggests that vegetation on bedrock headlands and coastal hills (API groups for graminoid clay heathland and *Themeda australis* sod grassland) is more similar to *Xanthorrhoea fulva* wet heathland (API group 60041) and an associated tussock grassland (API group 62031) in clayey soils, than to most vegetation on strongly podzolised Quaternary sands (e.g. wet heathland API group 60021). Griffith et al. (2000) made a similar finding when comparing headland and sand mass vegetation.

Having established a general pattern of congruence between floristic groups derived from numerical analysis and those previously recognised by air photo pattern, it is appropriate to develop a phytosociological classification of plant communities using the site-derived data. This outcome could be achieved either for groups of samples within particular formations and subformations of single stratum vegetation, or without regard to structure. However, it is apparent from the clustering within API groups (Fig. 3) that strong links exist between floristic composition, structure and general habitat type. Homogeneity analysis indicated that at least 20 floristic groups could be recognised for the entire data set; and at this level of discrimination a clear separation of formations and subformations is maintained with the sole exception of *Xanthorrhoea fulva* wet heathland (API group 60041) and two sites for an associated tussock grassland (API group 62031). These API groups are topographically contiguous across somewhat gradational boundaries. Therefore, apart from the potential risk of failing to recognise the over-riding influence of floristic composition for two of 182 sites, it seemed reasonable to take a utilitarian approach in developing a phytosociological classification of single stratum vegetation by first assigning subsets of the data to particular groups of formations and subformations:

Subset: sedgeland, rushland and fernland;
Subset: sod grassland and tussock grassland;
Subset: heathlands – graminoid clay heathland;
Subset: heathlands – wet heathland;
Subset: heathlands – dry heathland.

Sedgeland, rushland and fernland

Wallum sedgeland in northern NSW is largely dominated by herbaceous species (Cyperaceae and Restionaceae), although in the least waterlogged sites certain heath shrubs may be subsidiary or occasionally co-dominant (e.g. *Callistemon pachyphyllus*, *Melaleuca quinquenervia*, *M. squamea*, *M. thymifolia*). Beadle (1981) uses the term 'sedge-heath' to describe communities in which both sedges and shrubs co-occur. A distinctive sedgeland in which ferns (*Gleichenia* spp.) co-dominate with *Gahnia sieberiana* is also recognised. *Typha orientalis* dominates limited areas of rushland in the wallum, and a fernland of *Blechnum indicum* has a widely scattered distribution. Sedgeland, rushland and fernland are common in interdunal swamps, lakes and other closed depressions. In a numerical analysis for this vegetation (Fig. 4), all sites except two (n=58) align with the respective API groups. This outcome suggests a high degree of congruence between the two systems of classification.

Zonation along a moisture gradient is often apparent in larger closed depressions with sloping or concave floors, where one API group replaces another as standing water depth increases away from the margins. The sedgelands of API groups 64031, 64071 and 64141 characterise relatively shallow levels of inundation; and a major floristic dichotomy (Fig. 4) is apparent between these and the sedgelands (and rushland) in depressions with generally deeper, more permanent standing water (e.g. API groups 65041 (*Typha orientalis* rushland), 64111 (*Cladium procerum* sedgeland) and 64101 (*Eleocharis sphacelata* sedgeland)). Numerical analysis also suggests that *Blechnum indicum* fernland (API group 67021) and *Gahnia sieberiana – Gleichenia* sedgeland (API groups 64081, 64181) have a relatively distinct floristic composition.

The sedgelands of shallower water bodies often support a larger number of species than sedgelands in deeper, more permanent water. The API groups of these shallow sedgelands have a notably variable floristic composition, and species mosaics are often discernible within individual closed depressions at scales measured in tens of metres. This is particularly so for the widespread API group 64031 (Griffith et al. 2000). *Leptocarpus tenax*, *Baloskion pallens* and *Schoenus brevifolius* are characteristic of this API group, although one (occasionally two) of these may be replaced locally by such species as *Baumea arthrophylla*, *B. teretifolia*, *Chorizandra sphaerocephala*, *Sporadanthus caudatus* or *Xyris operculata*. Certain heath shrubs (e.g. *Callistemon pachyphyllus*, *Melaleuca thymifolia*) can also make a significant contribution to total foliage cover. Although short-distance variation in floristic composition is often evident,

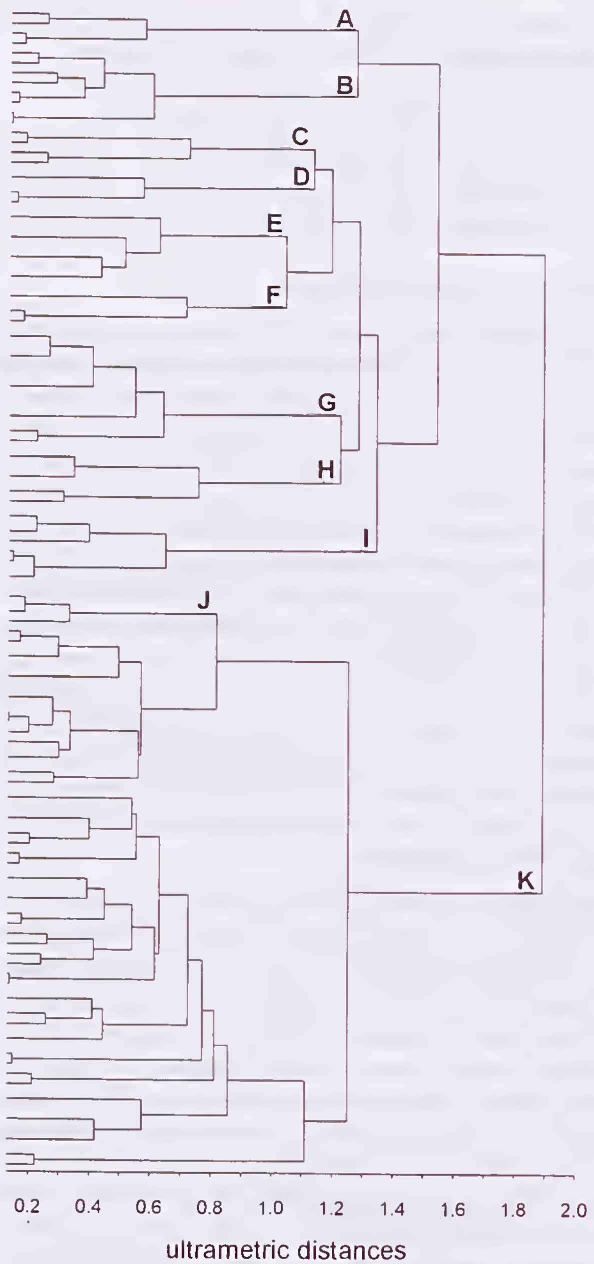


Fig. 4. Dendrogram for sedgeland, rushland and fernland samples, showing relationships of API groups.

Two of 58 sites did not align with the API groups to which they have been assigned a priori (HYU006.1/2, HYU008.1/2). These are discussed in Appendix 1.

A: *Blechnum indicum* fernland (API group 67021). B: *Gahnia sieberiana – Gleichenia mendellii* (64081) and *Gahnia sieberiana – Gleichenia dicarpa* (64181) sedgelands. C: *Typha orientalis* rushland (65041). D: *Cladium procerum* sedgeland (64111). E: *Baumea articulata* sedgeland (64061). F: *Eleocharis sphacelata* sedgeland (64101). G: *Baumea rubiginosa* sedgeland (64041). H: *Baumea arthrophylla* sedgeland (64121). I: *Lepironia articulata* sedgeland (64051). J: *Baloskion pallens – Baumea teretifolia – Melaleuca quinquenervia* sedgeland–heathland (64071). K: *Leptocarpus tenax – Baloskion pallens – Schoenus brevifolius* sedgeland (64031) and *Baloskion pallens – Schoenus brevifolius* sedgeland (64141).

shallow sedgelands of Newrybar Swamp on the far North Coast of NSW are notable for the complete absence of *L. tenax*. This apparent disjunction is curious, as *L. tenax* is found further north in south-eastern Queensland (Stanley & Ross 1989). A distinct API group (64141) was established to accommodate this regional anomaly, although it is most likely a geographic variant of the more widespread API group 64031. Numerical analysis confirmed the overall similarities in floristic composition for API groups 64031 and 64141 (Fig. 4).

Homogeneity analysis suggested that a maximum of around 17 floristic groups could be recognised for sedgeland, rushland and fernland, and below this level of group recognition all API groups other than 64031 and 64141 are readily discerned in Figure 4. Additional numerical analysis of API groups 64031 and 64141 in isolation confirmed their heterogenous composition, and subsequent homogeneity analysis indicated a three-group separation to be most appropriate. As an illustration of the considerable overlap in floristic composition between these shallow segelands, *Baloskion pallens* and *Baumea teretifolia* occurred in 89% of quadrats, *Schoenus brevifolius* occurred in 69%, and *Leptocarpus tenax* (which is absent in the north) occurred in 61%. It was also apparent for quadrat pairs (separated by distances of less than 15 metres) that a particular species may be abundant in one quadrat, although relatively uncommon in the second. This trend supports the utilitarian approach of mapping shallow sedgelands as floristically variable API groups.

Thirteen sedgeland, rushland and fernland plant communities are now recognised on the basis of phytosociological relationships (Appendices 1, 2), and very few indicator species occur in these wetlands:

Community 1: *Baumea rubiginosa* tall to very tall closed sedgeland (API group 64041);

Community 2: *Lepironia articulata* very tall closed sedgeland (API group 64051);

Community 3: *Baumea articulata* very tall sedgeland and closed sedgeland (API group 64061);

Community 4: *Eleocharis sphacelata* tall to very tall closed sedgeland (API group 64101);

Community 5: *Baumea arthrophylla* tall to very tall closed sedgeland (API group 64121);

Community 6: *Cladium procerum* very tall closed sedgeland (API group 64111);

Community 7: *Typha orientalis* very tall rushland and closed rushland (API group 65041);

Community 8: *Blechnum indicum* tall to very tall closed fernland (API group 67021);

Community 9: *Baloskion pallens – Melaleuca quinquenervia* mid-high to tall closed sedgeland–heathland (API group 64071);

Community 10: *Gahnia sieberiana – Gleichenia* tall to very tall closed sedgeland (API groups 64081, 64181);

Community 11: *Leptocarpus tenax – Baloskion pallens* tall to very tall closed sedgeland (part API group 64031);

Community 12: *Schoenus brevifolius – Baumea teretifolia* tall to very tall closed sedgeland (part API group 64031); and

Community 13: *Baloskion pallens – Baumea teretifolia* tall to very tall closed sedgeland (API groups 64031 (part), 64141).

Ordination revealed considerable overlap between several sedgelands, most notably communities 1, 9, 11 and 12 (Fig. 5). This trend is consistent with similarities in floristic composition and habitat, particularly for shallower sedgelands. Most of the sedgeland and rushland communities cluster about the closed depression (D), lake (LAK) and swamp (SWP) centroids, and this trend is consistent with the sampled field situation. Samples for *Gahnia sieberiana–Gleichenia* sedgeland (10) behave differently, although again consistent with field observations, by clustering around the drainage depression (DDE), dune (DUN), swale (SWL) and open depression (V) centroids. In contrast to correlations with categorical variables for landform element and morphology, it is evident that vectors for the numerical variables are very short and therefore likely to be relatively unimportant in influencing community distribution.

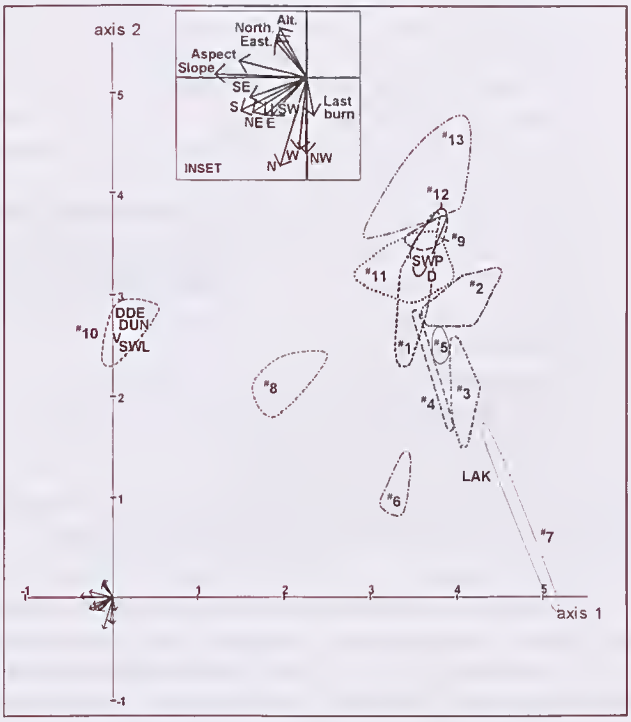


Fig. 5. Ordination for sedgeland, rushland and fernland. Plant communities (1–13) are numbered as they appear in the text. Eigenvalues: axis 1 = 0.7603; axis 2 = 0.4250. Vectors represent numerical variables. To improve interpretation, quadrats are shown as clusters (polygons) rather than points. The dune and ridge (R) centroids coincided (latter not shown). See the Methods for details of centroid and vector codes.

Sod grassland and tussock grassland

Two grassland formations associate with wallum in northern NSW, and these are distinguished on the basis of growth habit (after Walker & Hopkins 1984). Sod grassland has a closely interfacing leaf canopy in which individual grass plants are not obvious. In tussock grassland individual plants display a clumping or tufted habit and shoots are discrete. *Themeda australis* is common to both formations. Native grasslands appear to be relatively uncommon along the coast of northern NSW.

Numerical analysis demonstrated a clear dichotomy between sod grassland along the seaward extremities of coastal headlands, and tussock grassland of flats and drainage (open) depressions further inland from the sea (Griffith 2002). Homogeneity analysis supported this two-group separation, although it needs to be remembered that tussock grassland is floristically similar to a particular wet heathland (API group 60041), as previously discussed. A single plant community is recognised for each grassland formation (Appendices 1, 2), and both support indicator species (e.g. *Bracteantha bracteata* in 14, and *Rutidosis heterogama* in 15):

Community 14: *Themeda australis* low to tall closed sod grassland (API group 63021); and

Community 15: *Themeda australis – Ptilothrix deusta* mid-high to tall closed tussock grassland (API group 62031).

Ordination maintained the distinction established by numerical analysis (eigenvalues: axis 1 = 0.7885; axis 2 = 0.3909), and it was evident from vector length that the numerical environmental variables have comparatively little influence upon community distribution (Griffith 2002). Samples representing community 15 clustered about the centroids for backplain, drainage depression and Quaternary alluvium, whereas samples for community 14 enveloped the mid-slope, upper slope and sedimentary rock centroids. These outcomes were consistent with sampled field conditions.

Heathlands

Heathland is generally less than two metres high (Walker & Hopkins 1984), and coastal heathlands in northern NSW support a range of woody species, particularly from the families Proteaceae, Myrtaceae, Epacridaceae, Fabaceae and Rutaceae (Griffith & Williams 1997). Heath shrubs often, but not always, have ericoid leaves of nanophyll or smaller size. Heathland is a significant component of wallum, and two subformations are generally distinguished on sandy Quaternary sediments: wet heathland in open depressions where a shallow watertable is present following rain; and dry heathland on free-draining dunes and beach ridges (Beadle 1981, Griffith et al. 2000, Myerscough & Carolin 1986, Specht 1979, Williams 1982). A third subformation known as graminoid clay heathland occurs in clayey soils derived from bedrock of various lithologies (e.g. sandstone, adamellite, rhyolite). Grasses and sedges form a large component of the aboveground biomass in this subformation, hence the term 'graminoid' (Griffith et al. 2000). Other Australian studies distinguish between heathlands on sand masses and those on bedrock strata (Brown & Hopkins 1983, Froend 1988, Hnatiuk & Hopkins 1981, Hopkins & Hnatiuk 1981). All three subformations support a wide variety of herbaceous species, particularly from the families Cyperaceae, Poaceae and Restionaceae (Griffith & Williams 1997), and these are generally continuous in height with the heath shrubs. Numerical analysis preserved the three-group dichotomy into subformations (Griffith 2002; also Fig. 3), although this and subsequent homogeneity analysis indicated that further subdivision was warranted.

Graminoid clay heathland

Three API groups are recognised for graminoid clay heathland at the following localities: Evans Head to Red Rock on the upper North Coast (API group 59021); South West Rocks (Macleay River entrance) on the lower North Coast (API group 59041); and further south in Crowdy Bay NP (API group 59031). Graminoid clay heathland has a widely scattered, disjunct pattern of occurrence on headlands and coastal hills, and therefore tends to vary in floristic composition from one locality to the next as species reach their geographic limit of distribution (e.g. *Hakea teretifolia* subsp. *teretifolia* south from the Macleay River valley and *Hakea actites* north from the Coffs Harbour district). Graminoid clay heathland also appears to function as a refuge for species that are rare or otherwise restricted in the wallum and related vegetation of north-eastern NSW. Examples include: *Isopogon mnoraifolius* in Bundjalung NP and Yuraygir NP: *Cryptandra scortechinii* and *Bossiaea stephensonii* in Crowdy Bay NP; *Thesium australe*, *Xanthosia tridentata*, *Gahnia radula* and *Comesperma sphaerocarpum* in Old Bar Park (Greater Taree City Council 1996); and *Xanthosia tridentata* on Charlotte Head in Booti Booti NP (Griffith et al. 2000).

Numerical analysis preserved the identity of the three API groups, although with further separation of graminoid clay heathlands on the far North Coast (API group 59021) into three geographically disjunct subgroups (Fig. 6). One subgroup is located at Evans Head, approximately 50 km north of the next subgroup in the vicinity of Brooms Head (Yuraygir NP), and the third subgroup is found in the Wooli area (Yuraygir NP), about 19 km further south. Homogeneity analysis supported this five-group separation into the following communities (Appendices 1, 2):

Community 16: *Themeda australis – Banksia oblongifolia – Aristida warburgii* low to mid-high closed heathland (API group 59041);

Community 17: *Ptilothrix deusta – Aristida warburgii – Hakea teretifolia* subsp. *teretifolia* low to tall closed heathland (API group 59031);

Community 18: *Ptilothrix deusta – Banksia oblongifolia – Mirbelia rubiifolia* low to mid-high closed heathland (part API group 59021);

Community 19: *Ptilothrix deusta – Aristida warburgii – Banksia oblongifolia – Allocasuarina littoralis – Epacris pulchella* low to mid-high closed heathland (part API group 59021);

Community 20: *Banksia oblongifolia – Ptilothrix deusta – Aristida warburgii – Allocasuarina littoralis* low to mid-high closed heathland (part API group 59021).

Each community supports a minimum of two indicator species (e.g. *Bossiaea stephensonii*, *Cryptandra scortechinii*, *Euphrasia collina* subsp. *paludosa*, *Isopogon mnoraifolius*), and this trend contrasts with a relative paucity of indicators for wet and dry heathland communities (discussed below). Ordination preserved the five-group classification (eigenvalues: axis 1 = 0.3170; axis 2 = 0.2028), and also indicated that three communities on the upper North Coast at Evans Head (18) and in Yuraygir NP (19 and 20) are more closely aligned to each other than to communities further south in Arakoon SRA (16) and Crowdy Bay NP (17) (Griffith 2002). Communities 18, 19 and 20 clustered about the sedimentary rock, hillslope, lower slope and simple slope centroids. Community 17 clustered about the centroids for hillcrest and upper slope, and samples for community 16 were closest to the adamellite centroid. Vectors for the numerical environmental variables were short, and therefore these are likely to be relatively unimportant. In summary, the ordination trends for substrate and topographic position were consistent with sampled field conditions.

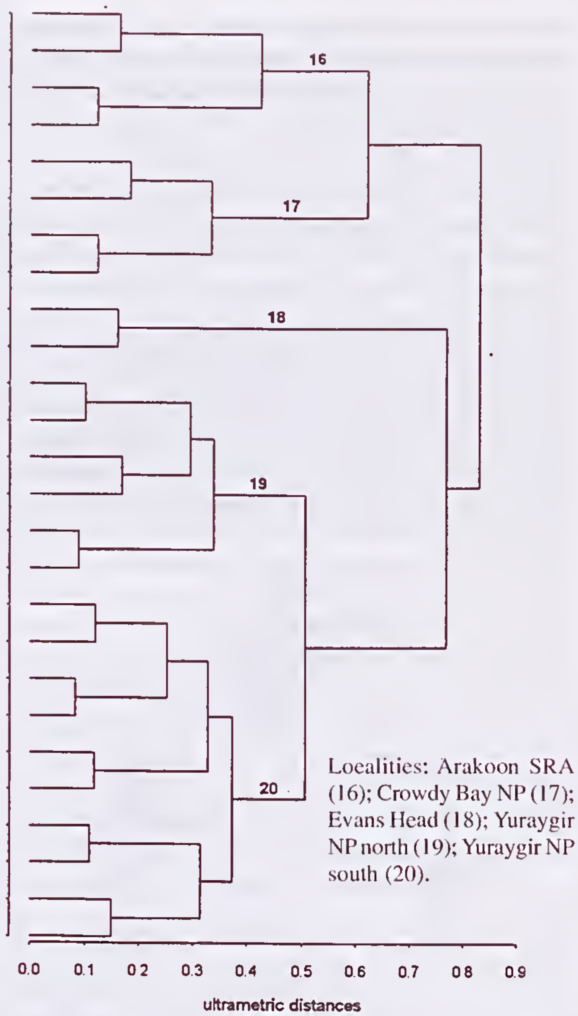


Fig. 6. Dendrogram for graminoid clay heathland samples. Communities (16–20) are labelled as they appear in the text.

Wet heathland

The wet heathland subformation is widespread and extensive along the coast of northern NSW, and four API groups are recognised on the basis of floristic composition and general habitat conditions (Table 1). As presently circumscribed, API group 60021 has a somewhat variable floristic composition, although three or more of *Banksia oblongifolia*, *Leptospermum liversidgei*, *Sporadanthus interruptus*, *Sprengelia sprengelioides* and *Xanthorrhoea fulva* are usually conspicuous (e.g. Griffith et al. 2000). Some of this variation may be attributed to fire, particularly where frequent burning limits recruitment in obligate seeders (e.g. *Sprengelia sprengelioides*). API group 60071 (*Banksia oblongifolia – Leptospermum polygalifolium* subsp. *cismontanum – Melaleuca nodosa*) has a widely disjunct and rather restricted distribution, and therefore also displays some floristic variation. On the other hand, API groups 60031 (*Leptospermum juniperinum*) and 60041 (*Xanthorrhoea fulva*) display more consistent floristic composition, at least for the dominant heath shrubs.

Numerical analysis preserved the four API groups as primary subdivisions (Griffith 2002; see also Figure 3). Nonetheless, homogeneity analysis suggested a nine-group separation, further dividing API group 60021 into five subgroups and API group 60071 into two subgroups, although without division of API groups 60031 and 60041.

Eight wet heathland communities are now recognised, and this level of distinction accords with the numerical and homogeneity analyses except that one and not two communities are distinguished for API group 60071. This relatively uncommon API group was only sampled at three widely separated locations, and it was considered undesirable at this stage to further separate such a small data set into two poorly defined communities. The five communities distinguished for API group 60021 share many species, and so are likely to form mosaic distribution patterns in the field across diffuse boundaries. This overlap in floristic composition is apparent for the five species after which the API group is named – *Leptospermum liversidgei*, *Sporadanthus interruptus*, *Sprengelia sprengelioides* and *Xanthorrhoea fulva* occured in more than 90% of quadrats, whereas *Banksia oblongifolia* occurred in 60%. Such a trend would support the utilitarian approach of mapping a single, floristically variable API group, particularly where fire further complicates patterns of distribution and abundance for obligate seeders. The eight communities are identified as follows (Appendices 1, 2):

Community 21: *Leptospermum juniperinum* mid-high to tall heathland and closed heathland (API group 60031);

Community 22: *Xanthorrhoea fulva – Ptilothrix densta* low to tall closed heathland (API group 60041);

Community 23: *Banksia oblongifolia – Leptospermum polygalifolium* subsp. *cismontanum – Melaleuca nodosa* low to tall heathland and closed heathland (API group 60071);

Community 24: *Sporadanthus interruptus – Xanthorrhoea fulva – Banksia ericifolia* subsp. *macrantha – Leptospermum liversidgei – Baeckea frutescens* mid-high to tall closed heathland (part API group 60021);

Community 25: *Sporadanthus interruptus – Xanthorrhoea fulva* low to tall closed heathland (part API group 60021);

Community 26: *Banksia oblongifolia – Xanthorrhoea fulva* low to tall closed heathland (part API group 60021);

Community 27: *Xanthorrhoea fulva – Schoenus paludosus – Banksia ericifolia* subsp. *macrantha* low to tall closed heathland (part API group 60021); and

Community 28: *Leptospermum liversidgei – Sporadanthus interruptus – Empodisma minus* low to tall closed heathland (part API group 60021).

Ordination (eigenvalues: axis 1 = 0.4710; axis 2 = 0.1610) once again indicated that the numerical variables are unlikely to play a major role in community variation (Griffith 2002). Communities 23 to 28 clustered around the swale and open depression centroids, whereas communities 21 and 22 clustered near the backplain, drainage depression and flat centroids. Ordination also reinforced the observation of considerable overlap in floristic composition and habitat for many examples of wet heathland. This was particularly so for communities 24, 25 and 28, as separated from the broader API group 60021. It was also apparent from the spread of samples that *Banksia oblongifolia – Leptospermum polygalifolium* subsp. *cismontanum – Melaleuca nodosa* wet heathland (23) may be internally heterogenous, and therefore worthy of further investigation.

Dry heathland

Dry heathland is a widespread and predominantly species-rich subformation on sand masses in northern NSW, and two API groups are distinguished. *Banksia aemula* (Wallum Banksia) is consistent and conspicuous in API group 54021 along with many other heath shrubs as associates. API group 54031 is distinguished by the presence of *B. aemula* in addition to a relatively high cover of *Allocasuarina littoralis*.

Casual field observations suggest that although dry heathland is floristically distinct from other heathland subformations, there is considerable floristic overlap from one dry heathland stand to the next. Numerical and homogeneity analyses appeared to support this generalisation (Griffith 2002), and three plant communities that nonetheless share many species in common are now recognised (Appendices 1, 2):

Community 29: *Banksia aemula – Leptospermum trinervium* low to tall closed heathland (part API groups 58021, 58031);

Community 30: *Banksia aemula – Allocasuarina littoralis* low to tall closed heathland (part API group 58031); and

Community 31: *Banksia aemula* low to tall closed heathland (part API groups 58021, 58031).

Samples for API group 58021 separated to dominate two of the three communities (29 and 31). Two of four sites in API group 58031 maintained their identity as the third community (30), whereas the remainder separated and merged into communities 29 and 31. Ordination maintained the identity of each community (eigenvalues: axis 1 = 0.2679; axis 2 = 0.1173), and a correlation with beach ridges and dunes was most apparent (Griffith 2002). Vectors for the numerical environmental variables were once again short and therefore relatively uninformative.

Vegetation with two or more strata

Sampling in mallee and shrubland provided data for 130 randomly paired quadrats. Walker and Hopkins (1984) distinguish between tree mallee and shrub mallee, and both formations are characterised by species of *Eucalyptus* and allied Myrtaceae. The tallest stratum of tree mallee is composed of multi-stemmed, lignotuberous individuals where each plant has fewer than five trunks, three or more of which exceed 100 mm in diameter at breast height. Shrub mallee is also composed of multi-stemmed, lignotuberous individuals, although each plant usually supports five or more trunks, with three or more of the largest not exceeding 100 mm in diameter at breast height. Both structural formations are present in the wallum, although stands may grade from tree mallee to shrub mallee over short distances. Fire influences the structure of mallee. This is evident where a severe crown fire kills all stems and the basal resprouts are smaller in diameter than the dead standing stems for many years. Less severe fires allow regeneration from epicormic buds without the death of mature stems. A small number of species characterise the tallest stratum of wallum mallee in northern NSW. *Eucalyptus pilularis*, *E. planchoniana* and *Corymbia gummifera* occupy extensive areas, whereas somewhat restricted species include *Eucalyptus robusta*, *E. signata* and *Lophostemon confertus* (Table 1).

Walker and Hopkins (1984) apply the shrub growth form to woody plants that are generally multi-stemmed at the base or within 20 cm of the ground surface. As opposed to heathland vegetation, the tallest stratum of wallum shrubland is generally much higher than two metres, hence the recognition of a lower stratum of shorter species. However, it needs to be appreciated that Walker and Hopkins (1984) set a minimum height of two metres for the tree growth form, and in wallum the distinction between shrubs and trees is not always clear-cut. As an example, some *Banksia* species may be multi-stemmed or heavily branched, although this branching can initiate higher than 20 cm above the ground surface. The development of a large woody lignotuber in *B. aemula* further complicates distinctions between mallee, shrub and tree growth forms. In the present study a consistent approach of distinguishing between the heath shrub (< 2 m) and shrub (>2 m) growth forms solely on the basis of height is adopted for species such as *B. aemula*. Some accounts of wallum in south-eastern Queensland using an alternative structural classification developed by R.L. Specht (Specht 1981, Specht et al. 1974) refer to taller stands dominated by *B. aemula* as low woodlands (e.g. Batianoff & Elsol 1989). Conspicuous shrub species in the wallum of northern NSW include *B. aemula* and *B. ericifolia* subsp. *macrantha*. *Leptospermum juniperinum*, *L. speciosum* and *Melaleuca sieberi* are examples of more restricted shrubs (Table 1).

Dry sclerophyll and swamp sclerophyll subformations are distinguished in tree mallee, shrub mallee and shrubland, and these can be linked to soil moisture and drainage conditions (Table 1). This distinction is analogous to that between dry heathland and wet heathland.

Comparative floristic relations of tallest stratum species

A simple test was devised to assess the efficacy of API for distinguishing tree mallee, shrub mallee and shrubland formations and subformations on the basis of floristic composition for the dominant growth form. Numerical analysis was performed as previously described; although after first excluding records for species restricted to lower strata, and adjusting foliage cover scores to preclude any unnecessary bias for tallest stratum species also represented in a lower stratum. Vines and hemiparasites associated with the tallest stratum were similarly excluded, for example *Cassytha* species and mistletoes. These generally achieved a foliage cover score of only 1 (<1% cover), or rarely 2 (1–5%).

Numerical analysis largely upheld the API classification, although without discrimination between tree mallee and shrub mallee (Fig. 7). *Banksia aemula – Allocasuarina littoralis* dry sclerophyll shrubland (54031/2) was the only API group not readily distinguished. This was sampled at two sites (HBR017.1/.2, HKA002.1/.2), and both clustered with samples for API group 54021/2, *B. aemula* dry sclerophyll shrubland (Group A, Fig. 7). As would be expected, the floristic composition of the tallest stratum was sufficient to discriminate between shrubland and mallee. Several other trends for the analysis are worthy of comment.

The *Banksia aemula* shrublands of API group 54021/2 separate into stands in which *B. aemula* is the sole dominant (Group N), and stands in which other species are minor or subsidiary associates of *B. aemula* in the tallest stratum (Group A). *Leptospermum trinervium* is the most common tallest stratum associate, and less common ones include *Allocasuarina littoralis*, *Leptospermum polygalifolium* subsp. *cismontanum*, *Xanthorrhoea glauca* subsp. *glauca* (south from Limeburners Creek NR), *Melaleuca nodosa*, *Monotoca elliptica* and *Callitris rhomboidea* (in Hat Head NP). Many of the associates are conspicuous in the lower stratum of *B. aemula* shrubland, and in the absence of fire for extended periods they appear to increase in height and so reach the tallest stratum (e.g. Griffith et al. 2000). It seems that *B. aemula – A. littoralis* dry sclerophyll shrubland (API group 54031/2) is also associated with long-unburnt wallum, where sufficient time has elapsed for *A. littoralis* to recruit and co-dominate. This API group has a scattered distribution on the North Coast of NSW (Table 1), and it extends into south-eastern Queensland (Batianoff & Elsol 1989). In practice, the application of API to further separate *B. aemula* shrublands on the basis of tallest stratum associates is problematic, for example where fire boundaries are not obvious on aerial photographs, or where burns vary in intensiy and spatial extent over small areas.

The dry sclerophyll mallee of well-drained, podzolised sands separates into API groups dominated by either *Eucalyptus pilularis* (Group C) or *E. planchoniana* (Group B). This separation also applies to the floristically variable tree mallee of API group 50071 (*E. pilularis*/*E. planchoniana*/*Corymbia gummifera*), which is found in Hat Head NP on the lower North Coast. For this API group shifts in dominance, often over distances measured in tens of metres, range from clear dominance of the tallest stratum by *E. pilularis* to varying combinations of *E. pilularis*, *E. planchoniana* and *Corymbia gummifera*, to clear dominance by *E. planchoniana*. Samples for API group 50071 dominated by *E. pilularis*

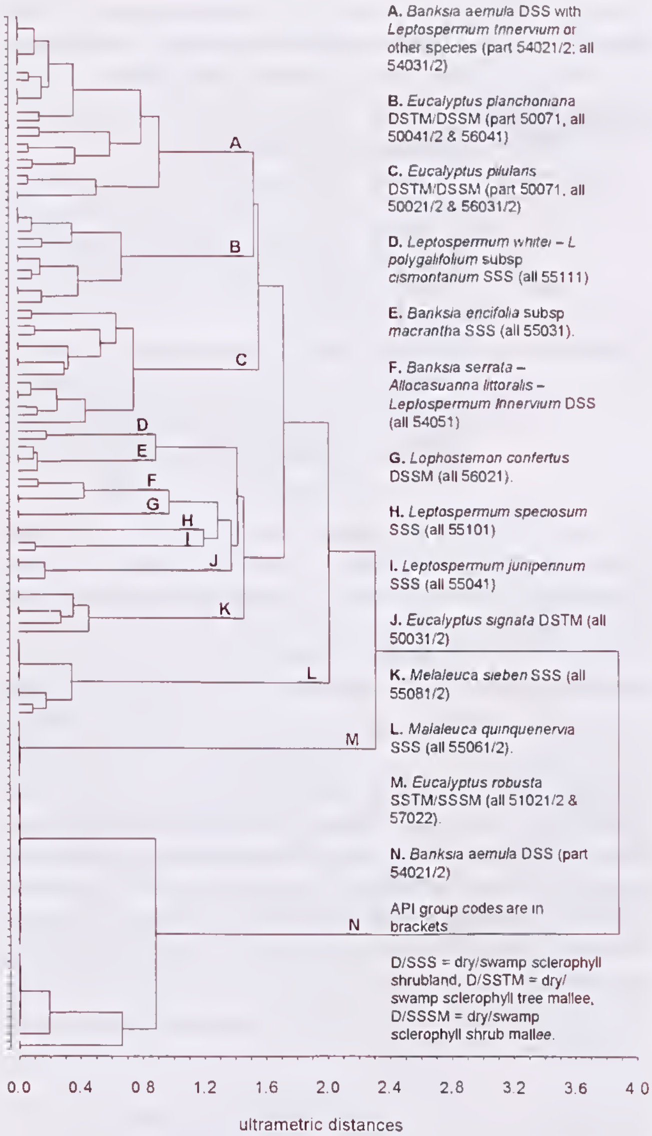


Fig. 7. Dendrogram for samples of the tallest stratum in tree mallee, shrub mallee and shrubland.

cluster with API groups 50021/2 (*E. pilularis* tree mallee) and 56031/2 (*E. pilularis* shrub mallee), whereas samples dominated by *E. planchoniana* cluster with API groups 50041/2 (*E. planchoniana* tree mallee) and 56041 (*E. planchoniana* shrub mallee).

Numerical analysis also separated mallee and shrubland API groups associated with relatively well-drained, podzolised sands (e.g. Groups A, B, C) from structurally equivalent API groups most commonly associated with either poorly drained podzolised sands (e.g. Groups H, I), or younger less podzolised sand masses (e.g. Groups F, G). This confirms the utility of API for distinguishing wallum subformations where floristic composition of the tallest stratum is also diagnostic for growth forms of lower strata (e.g. a prevalence of helophytes in waterlogged habitats).

Comparative floristic relations for all species

As previously demonstrated, a reasonable degree of discrimination can be expected for mallee and shrubland on the basis of air photo signature where a classification of floristic composition for the dominant growth form (tallest stratum) is desirable or adequate. Nonetheless, a thorough phytosociological treatment requires the simultaneous consideration of all species irrespective of vertical arrangement. For the purpose of community circumscription, shrubland samples were analysed as one subset, and shrub mallee and tree mallee samples together as a second subset. The mallee formations were combined because stands can be structurally gradational, especially in response to fire, and few samples are currently available for shrub mallee.

Shrublands

Numerical analysis revealed floristic overlap between several shrubland API groups, and this outcome suggests that species in lower strata strongly influence clustering patterns (Fig. 8). Nonetheless, the dry sclerophyll and swamp sclerophyll subformations remained distinct. All quadrat pairs re-united at lower ultrametric distances. Eight communities are now distinguished on the basis of trends for numerical and homogeneity analyses, and three of these support indicator species (Appendices 1, 2):

Community 32: *Banksia aemula – Phyllota phylicoides* tall to very tall (occasionally extremely tall), sparse to closed shrubland (90% of samples for API group 54021/2);

Community 33: *Banksia aemula – Allocasuarina littoralis +/- B. serrata* tall to extremely tall, sparse to closed shrubland (10% of samples for API group 54021/2, and all samples for 54031/2 and 54051;

Community 34: *Banksia ericifolia* subsp. *macrantha +/- Leptospermum whitei – L. polygalifolium* subsp. *cismontanum* tall to very tall shrubland and closed shrubland, or rarely open shrubland (part API group 55031, and all samples for 55111);

Community 35: *Melaleuca sieberi/Banksia ericifolia* subsp. *macrantha – M. thymifolia* tall to very tall, sparse to closed shrubland (part API group 55031, and all samples for 55081/2);

Community 36: *Melaleuca quinquenervia – Baumea teretifolia* tall to very tall, sparse to closed shrubland (part API group 55061/2);

Community 37: *Melaleuca quinquenervia – Baumea juncea* tall shrubland and closed shrubland (part API group 55061/2);

Community 38: *Leptospermum speciosum* tall to very tall closed shrubland (API group 55101);

Community 39: *Leptospermum juniperinum* tall to very tall shrubland and closed shrubland (API group 55041).

Seven communities remained relatively discrete in an ordination (eigenvalues: axis 1 = 0.7674; axis 2 = 0.5452). *Melaleuca quinquenervia – Baumea juncea* swamp sclerophyll shrubland (37) was an exception, and this outcome appeared to reflect the sampled habitat, which varied from drainage (open) depressions to swamps in closed

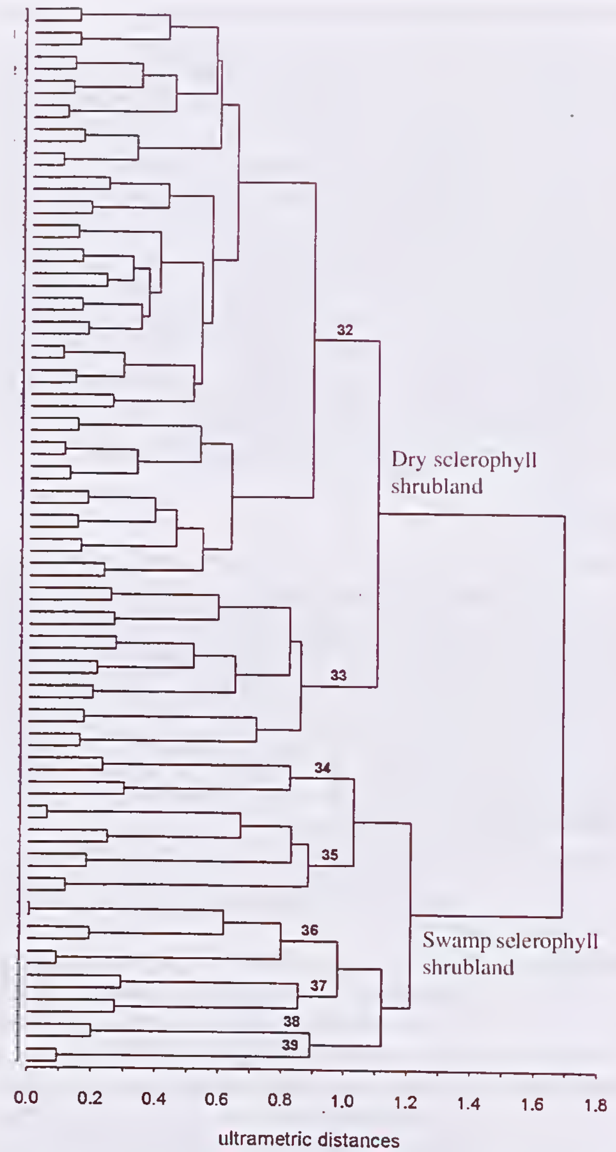


Fig. 8. Dendrogram for all shrubland quadrats. Community descriptions (32–39) and API group details are provided in the text.

depressions. Clustering patterns about centroids for the remaining communities were consistent with sampled field conditions, for example the association of 32 and 33 with beach ridges and dunes, 34 with swales, 35 predominantly with flats on plains or backplains and 39 with rhyolite. Vectors for the numerical variables were once again short (Griffith 2002), and these environmental factors probably have relatively little influence upon community distribution.

Mallee

Numerical analysis revealed floristic and structural overlap between the mallee API groups, although *Lophostemon confertus* dry sclerophyll mallee shrubland remained distinct. As for the shrublands, this outcome emphasises the significance of understorey species to floristic patterns in mallee. All quadrat pairs re-united at lower ultrametric distances. Three communities are now distinguished on the basis of trends for numerical and homogeneity analyses, and two of these support indicator species (Appendices 1, 2):

Community 40: *Lophostemon confertus* very tall closed mallee shrubland (API group 56021);

Community 41: *Eucalyptus robusta/E. signata – Baloskion tetraphyllum* subsp. *meiostachyum* very tall sparse to open mallee shrubland, and very tall to extremely tall, open mallee woodland to closed mallee forest (part API group 50031/2, and all samples for 51021/2 and 57022);

Community 42: *Eucalyptus pilularis/E. planchoniana/E. signata – Leptospermum trinervium* tall to very tall, sparse to closed mallee shrubland, and tall to extremely tall, open mallee woodland to closed mallee forest (part API group 50031/2, and all samples for 50021/2, 50041/2, 50071 and 56031/2).

The communities remained distinct in an ordination (eigenvalues: axis 1 = 0.7534; axis 2 = 0.2998), with most samples concentrated about centroids for topography in agreement with sampled field conditions. For example, *Lophostemon confertus* dry sclerophyll mallee shrubland (40) maintained its distinct association with foredunes (FOR centroid), whereas samples for community 42 in which *Eucalyptus pilularis* or *E. planchoniana* are often the dominant mallee coincided with the dune (DUN) and beach ridge (BRI) centroids representative of older dunefields and beach ridge plains respectively. Samples for *E. signata* tree mallee (API group 50031/2) separated in the numerical analysis and regrouped either with *E. robusta* swamp sclerophyll mallee (41) or *E. pilularis/E. planchoniana* dry sclerophyll mallee (42). This outcome suggests that *E. signata* mallee supports both dry and swamp facies in terms of understorey composition.

Comparative floristic relations of single stratum and multi-stratum vegetation

Floristic overlap between single stratum and multi-stratum vegetation would be consistent with the comparatively fine scale, mosaic patterning of different structural formations in wallum across seemingly slight environmental gradients (Batianoff & Elsol 1989, Griffith 1983, Griffith et al. 2000), the commonality of many species to two or more formations or subformations (Griffith & Williams 1997), and the potential for fire to alter structure. An exploratory ordination confirmed this overlap in structure, habitat and floristic composition (Fig. 9). The various formations and subformations of single stratum vegetation largely maintain their identity; and the primary axes of the biplot appear to reflect variations in drainage and substrate, most notably a perceived moisture gradient (linked to landform element and morphology) along axis 1 separating dry heathland, sod grassland and graminoid clay heathland (left of the origin) from tussock grassland, sedgeland, fernland, rushland, and the majority of the wet heathland quadrats (right of the origin). In contrast, samples for multi-stratum vegetation are widely dispersed and generally intermixed with those for single stratum vegetation. This ordination also displays a relatively strong correlation between vegetation and topography.

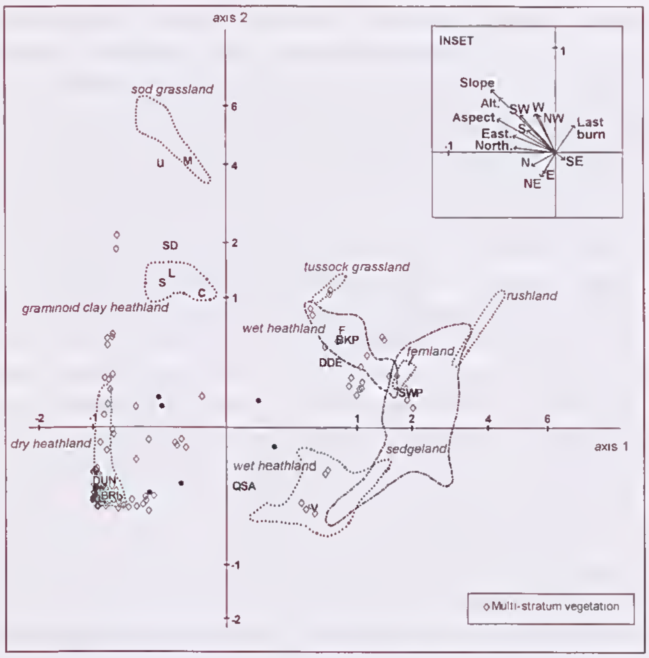
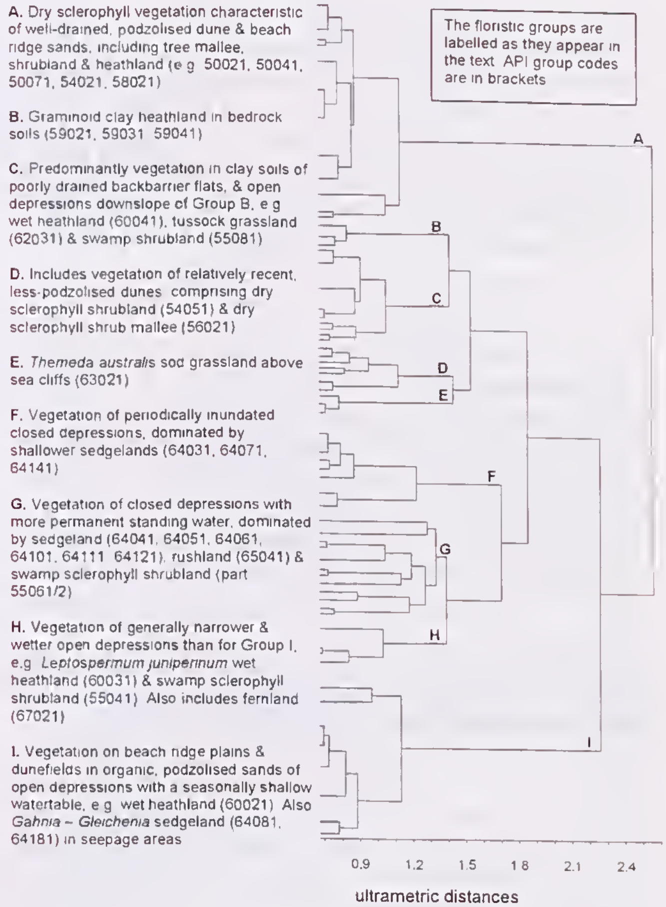


Fig. 9. Ordination for all samples of single stratum and multi-stratum vegetation.

Eigenvalues: axis 1 = 0.7157; axis 2 = 0.5170. Most (96%) wet heathland quadrats clustered either near the open depression (V) centroid, or the backplain (BKP), drainage depression (DDE) and flat (F) centroids. Polygons define quadrat distribution for single stratum vegetation (except outlying wet heathland quadrats of API group 60071, denoted '•'). To aid interpretation of the biplot, all values were square root transformed after the ordination. The dune and ridge (R) centroids coincided (latter not shown). See the Methods for details of other centroid and vector codes.



ultrametric distances

Fig. 10. Dendrogram for all samples of single stratum and multi-stratum vegetation

Floristic relations for single stratum and multi-stratum vegetation were examined simultaneously using numerical analysis, and for illustrative purposes this was constrained to nine groups (Groups A–I, Fig. 10). Homogeneity analysis supported this level of group recognition.

Several floristic groups exhibit considerable structural heterogeneity. For example, Group A is dominated by samples for dry sclerophyll tree mallee and shrub mallee supporting varying combinations of *Eucalyptus pilularis*, *E. planchoniana* and *Corymbia gummifera*, in addition to samples for *Banksia aemula* dry sclerophyll shrubland and dry heathland. Groups C, D, F, G, H and I also display varying amounts of structural heterogeneity, although this is not the case for Groups B and E. Group B is exclusive for samples of graminoid clay heathland on headlands and coastal hills, and therefore is both structurally and floristically robust. Likewise, Group E only comprises samples for *Themeda australis* sod grassland along sea cliffs. Although samples for multi-stratum vegetation are widely dispersed in the ordination (Fig. 9), they do not intermix with samples for graminoid clay heathland or *T. australis* sod grassland. Also note that graminoid clay heathland and *T. australis* sod grassland display a stronger (positive) correlation with slope and altitude than do, for example, wet heathland and sedgeland. Numerical analysis revealed that vegetation of relatively recent, less-podzolised dune sands (Group D, Fig. 10) is floristically more similar to *T. australis* sod grassland than to the vegetation of older, heavily podzolised dune and beach ridge deposits (e.g. Group A). Griffith et al. (2000) made a similar observation when comparing the vegetation of foredunes and older sand masses with *T. australis* sod grassland.

Patterns of species richness

Soil moisture relations are often used as the basis for separating wallum and similar vegetation into subformations (Beadle 1981, Griffith et al. 2000, Myerscough & Carolin 1986, Myerscough et al. 1995, Siddiqi et al. 1972, Specht 1979, Williams 1982), and the phytosociological analyses identified different floristic assemblages in wet and dry habitats. Vegetation patterns along known or perceived moisture gradients were further explored for trends in vascular species richness at the 25 m^2 scale.

Across all formations and subformations, mean species richness ranged from 4.0 in fernland to 34.5 in dry heathland (Fig. 11). Significant ($P < 0.05$) between-habitat differences in species richness were detected for sand mass vegetation

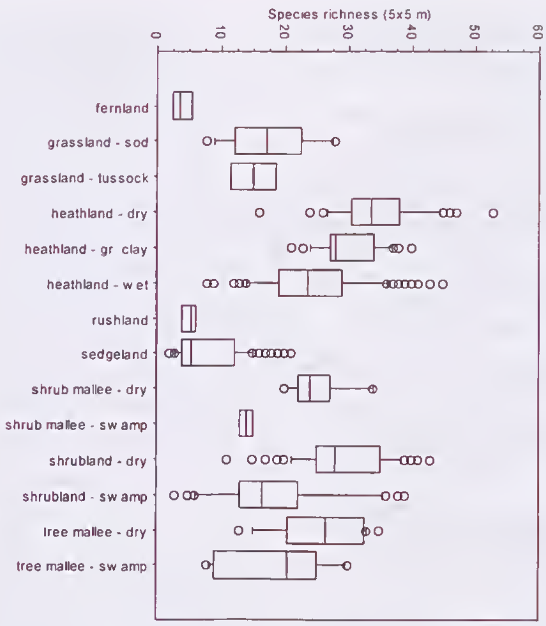


Fig. 11. Variation in species richness at the 25 m² scale. Median and quartiles shown as a box, 10th and 90th percentiles as whiskers, and outliers as open circles.

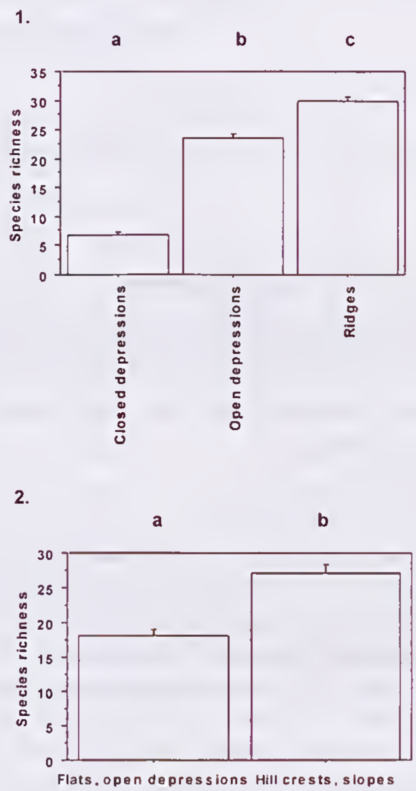


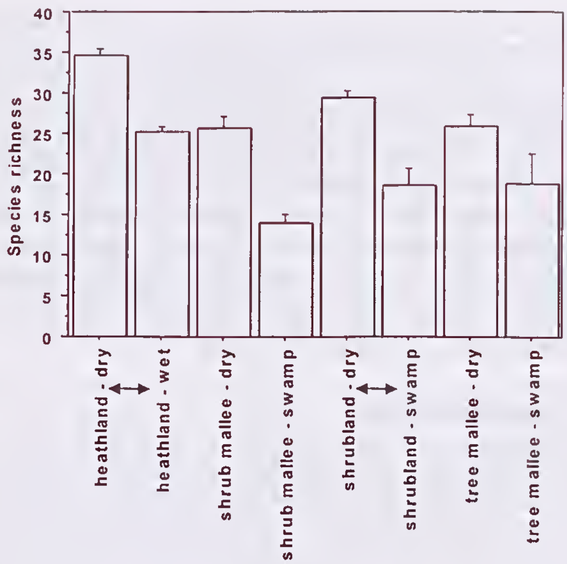
Fig. 12. Trends in mean (+/- SE) species richness (25 m²)along moisture gradients for: (1) sand mass (wallum) soils; (2) clayey soils associated with hills, flats and drainage depressions. Significant differences (ANOVA: P<0.0001; Tukey/Kramer: P<0.05) are denoted with different letters.

when samples (n = 432) were assigned by characteristic position along a hypothetical ridge – open depression – closed depression toposequence. Significant between-habitat differences were also detected when the vegetation on bedrock hills and headlands was compared with vegetation occupying clayey soils on flats or along drainage (open) depressions (n = 62). The consistent trend was significantly lower species richness in wetter habitats (Fig. 12), and this finding supports observations for other parts of Australia in habitats with impeded drainage (Hnatiuk & Hopkins 1981, Keith 1993, Rice & Westoby 1983). However, it has been suggested that various issues may complicate the interpretation of species richness trends, for example: plant size and growth form; species longevity, life history and recruitment mode; disturbance history; the spatial distribution of resources; and variations in phenology linked to temporal partitioning of resources (Adam et al. 1989, Austin et al. 1996. Le Brocque 1998, Lunt 1990). It was not possible to control for all potentially confounding variables, although the likely influence of plant size and growth form was minimised by restricting comparisons to structurally similar vegetation. Mean species richness was consistently lower for the wetter member in each pair of structural analogues (Fig. 13), although the differences were not universally significant (P <0.05). A trend of significantly higher species richness in dry heathland than in wet heathland is noteworthy, as this differs from an earlier finding of no significant difference for wallum on the lower North Coast of NSW (Myerscough et al. 1995). Overall, the values for mean species richness are within the general range for equivalent formations in other parts of Australia (Keith & Myerscough 1993; Le Brocque 1998).

Overview of findings

Utility of air photo interpretation

A potential limitation of API is the inability to identify spatial relationships for all species. Nonetheless, a high level of congruence between API groups and numerically derived phytosociological units was achieved for single stratum vegetation, thereby demonstrating that photo signatures equate with noda for the full complement of vascular species. Air photo interpretation is also a suitable technique for depicting the spatial distribution of dominant species in the tallest stratum of multi-stratum vegetation, as demonstrated for mallee and shrubland. Growth form alone allows discrimination of photo patterns in multi-stratum vegetation, as with differences in crown architecture that separate mallee from shrubland. Differences in floristic composition of the tallest stratum registering as distinct photo signatures can in turn facilitate the recognition of subformations. However, photo signatures for floristic composition and growth form of the tallest stratum are less satisfactory as surrogates to identify noda for the full complement of species regardless of their vertical arrangement.



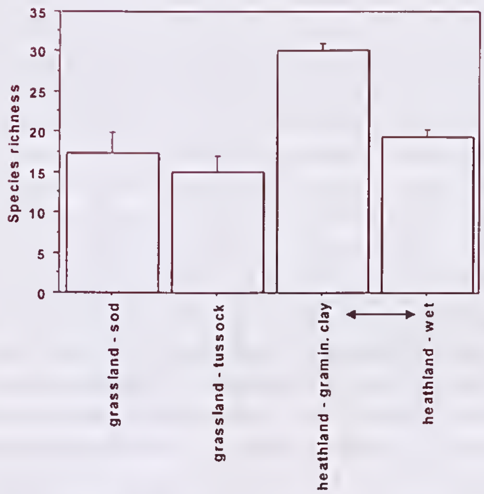


Fig. 13. Trends in mean (+/- SE) species richness of structural analogues for: (1) sand mass (wallum) vegetation; (2) vegetation of clayey soils associated with hills, flats and drainage depressions. For purposes of analysis, sod grassland and tussock grassland were considered sufficiently similar in terms of structure and growth-form size. Pairs for which differences were significant (Tukey/Kramer: $P < 0.05$) are identified with arrows.

It is likely that effective arguments could be constructed both for and against the segregation of data sets on the basis of vegetation structure prior to the circumscription of phytosociological units, and such decisions will influence the outcome of determinations for species descriptors such as fidelity. These issues do not arise to any extent in phytosociological treatments of vegetation with comparatively limited variation in structure and dominant growth form (Adam et al. 1988, Benson 1994, Webb et al. 1984). It is also apparent that decisions regarding the inclusivity of phytosociological treatments will impact upon the utility of vegetation classifications for nature conservation and land management. For example, it may be sufficient to implement fire management regimes in wallum at the level of formation and subformation without undue concern for floristic composition (NSW National Parks & Wildlife Service 1997, 1998a,b), and conventional API techniques can be applied to achieve the desired outcome. On the other hand, to model potential habitat for a rare species, detailed information about phytosociological and plant – environment relationships may prove more reliable. It would seem that there is value in classifying vegetation at various levels of structural and floristic detail, so that maximum end-use benefits are derived.

Plant – environment relationships

Although testing of additional environmental factors is required, categorical measures of topographic position appear to explain much of the floristic variation in the wallum and allied vegetation of northern NSW. Ironically, the likely overriding significance of topography in the wallum was first recognised almost half a century earlier (Coaldrake 1961), at a time when Australian ecologists were paying considerable attention to soil nutrient gradients as key determinants of vegetation pattern (Coaldrake & Haydock 1958).

Other Australian studies have demonstrated correlations between floristic composition and topography or micro-topography (Connor & Clifford 1972, Myerscough & Carolin 1986, Myerscough et al. 1995, Rayson 1957, Zammit 1981); and repetitive patterns of topography, soils and vegetation are apparent in north-eastern NSW and south-eastern Queensland (e.g. Atkinson 1999, Thompson & Moore 1984). The recognition of topography – vegetation relationships is also fundamental to the circumscription of soil landscapes in NSW (Eddie 2000; Matthei 1995; Milford 1999; Morand 1994, 1996; Murphy 1995). For coastal dunefields and beach ridge plains in eastern Australia generally, there are known or probable interactions between topographic position and rates of soil erosion and deposition, solum depth, the placement and morphology of B horizons, and in turn soil moisture characteristics with respect to seasonal and permanent watertables (e.g. Thompson 1992, Coaldrake 1961).

Species richness

Although mean vascular species richness in the wallum and associated vegetation of northern NSW is lower in wetter habitats at the 25 m^2 scale, differences were not always significant. This outcome suggests that soil moisture gradients alone may be insufficient to explain the species richness trends, and other variables such as fire should be explored. Whether or not the significantly lower species richness in some wet habitats is related to limiting environmental factors is unknown, and robust explanations of species richness in terms of resource availability would require detailed morphological and physiological studies of individual species with respect to resource utilisation.

Conservation

Some plant communities appear to be relatively uncommon in north-eastern NSW, and therefore require further assessment with respect to the adequacy of existing conservation reserves (e.g. 14 *Themeda australis* sod grassland, 38 *Leptospermum speciosum* swamp sclerophyll shrubland, and 40 *Lophostemon confertus* dry sclerophyll mallee shrubland; see Table 1, Appendix 1). For wallum dominated by species found in southern Queensland but only extending into the far north of NSW, for example *L. speciosum* shrubland, conservation strategies are best formulated in collaboration with Queensland environmental agencies.

The regularity with which paired quadrats reunited in numerical analyses suggests a high degree of spatial autocorrelation. This is particularly so for communities with a very disjunct distribution, for example *Themeda australis* sod grassland (14) and communities comprising graminoid clay heathland (16–20). In many instances this pattern of correlation probably demonstrates the influence of subordinate species rather than community dominants. Graminoid clay heathland is of particular interest, because the recognition of geographically discrete communities suggests that this subformation is likely to be in some way unique at each of its widely separated locations along the NSW North Coast. The component communities also support a relatively high number of high-fidelity species, and therefore function as refugia for rare or otherwise restricted species in the wallum. These observations support the listing of graminoid clay heathland at Byron Bay on the far North Coast (outside the study area) as an Endangered Ecological Community under the Threatened Species Conservation Act (1995). The conservation significance of other stands should also be considered, for example on the lower North Coast at Bonny Hills (Gardner Browne Planning Consultants 1989), Old Bar (Greater Taree City Council 1996), and Charlotte Head in Booti Booti NP (Griffith et al. 2000). For environmental agencies and consultants assessing the conservation status of coastal vegetation in northern NSW, it would be inappropriate to dismiss unreserved occurrences as superficially similar to reserved occurrences and therefore of diminished conservation value. Decisions as to the significance of stands currently lacking environmental protection should be based on thorough comparative assessments of floristic composition.

The sedgeland and rushland components of wallum occur in closed depressions, and they meet the inclusion criteria for protection under State Environmental Planning Policy (SEPP) No. 14 Coastal Wetlands (Adam et al. 1985). However, this policy specifically excludes wet heathland and the swamp facies of mallee and some shrublands found in open depressions. Dunefields and beach ridge plains have closely integrated catchment and drainage systems, often with watertables perched at many different elevations, and groundwater displays considerable lateral movement within sand masses. A comparatively strong relationship between vegetation and topography suggests that landscape processes are paramount to the long-term functioning of this ecosystem. Therefore, the objectives of SEPP 14 are likely to be better served if wallum wetlands are conserved as landform patterns rather than isolated landform elements, for example by protecting a beach ridge plain (landform pattern) rather than just a swamp (landform element) supporting sedgeland at the lowest part of the plain. In this respect the existing policy already takes a liberal approach with some designated wetlands (e.g. No. 484 in Limeburners Creek NR, Nos. 543 and 545 in Crowdy Bay NP, and No. 686 in Myall Lakes NP), where extensive beach ridge–swale–swamp and dune–swale–swamp toposequences supporting mosaics of forest, shrubland, heathland and sedgeland are protected. This approach would circumvent much of the ongoing debate about wetland definition and boundary delineation (e.g. Rogers & Saintilan 2002) as it relates to wallum.

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Appendix 1. Descriptions for 42 plant communities circumscribed using numerical and homogeneity analyses.

Species of highest constancy ('constant species') are listed in each community description as follows: plant name (constancy class), for example *Cladium procerum* (V). Species with the highest mean cover-abundance score ('cover-abundant species') are similarly listed: plant name (mean cover class score; constancy class), for example *Salvinia molesta* (4.00; III). Indicator species are identified: plant name (constancy class; mean cover class score), for example *Cladium procerum* (V; 5.00).

Each community description also provides details of: sites, where each represents one or both quadrats of a random pair (e.g. HBU007.1 and HBU007.2); API group (map unit) equivalence; structure, using the height and crown cover classes of Walker and Hopkins (1984); exotic species recorded in quadrats; species richness (total, and mean (+/- SE) in 25 m^2); general habitat using data gathered at each quadrat; distribution in northern NSW (primarily localities on the vegetation mapping used for sample stratification); and equivalent or related vegetation types as recognised by others.

Community No. 1: *Baumea rubiginosa* sedgeland

Sites: HBU035.1/.2, HYU022.1/.2, HYU027.1/.2, HHA017.1/.2, HLA005.1/.2, HCR004.1/.2.

API group: 64041 (*Baumea rubiginosa* sedgeland).

Structure: tall to very tall closed sedgeland.

Floristic composition:
- Constant species: *Baumea rubiginosa* (V), *Triglochin procerum* s. lat. (V).
- Cover-abundant species: *Baumea rubiginosa* (3.83; V).
- Indicator species: none.
- Exotic species: *Salvinia molesta*.
- Species richness: total = 12; mean (+/- SE) in 25 m^2 = 3.75 (0.31).

Habitat:
- Topographic position: closed depressions (swamps).
- Altitude: <10, to 20 m ASL.
- Aspect: nil. • Slope: 0°.
- Geology: Quaternary sediments.
- Comments: Often replaced by sedgeland communities No. 11, 12 or 13 upslope as average standing water depth decreases.

Map localities in northern NSW: Newrybar Swamp, Bundjalung NP, Yuraygir NP, Hat Head NP, Limeburners Creek NR, Lake Innes NR, Crowdy Bay NP.

Equivalent vegetation types: *Baumea rubiginosa* has a widespread distribution in eastern NSW, and it is found in all other Australian states (Harden 1993). There are scattered records for *B. rubiginosa* sedgeland elsewhere on the North Coast of NSW (Pressey & Griffith 1987), and the community would be included under the *Baumea* sedgelands described for eastern and southern Australia by Briggs (1981). The community is likely to form part of a *B. rubiginosa* – *Baloskion pallens* (syn. *Restio pallens*) – *Gahnia* spp. vegetation unit reported for south-eastern Queensland (McDonald & Elsol 1984).

Community No. 2: *Lepironia articulata* sedgeland

Sites: HBU017.1/.2, HYU021.1/.2, HHA006.1/.2, HCR007.1/.2.

API group: 64051 (*Lepironia articulata* sedgeland).

Structure: very tall closed sedgeland.

Floristic composition:
- Constant species: *Lepironia articulata* (V).
- Cover-abundant species: *Lepironia articulata* (3.75; V).
- Indicator species: *Lepironia articulata* (V; 3.75).
- Exotic species: none.
- Species richness: total = 7; mean (+/- SE) in 25 m^2 = 3.00 (0.42).

Habitat:
- Topographic position: closed depressions (swamps, lakes).
- Altitude: <10, to 30 m ASL.
- Aspect: nil. • Slope: 0°.
- Geology: Quaternary sediments (often sand).
- Comments: Occurs in perched swamps associated with interdunal depressions, and also along lake margins and on backbarriers. Often replaced by sedgeland communities No. 1, 11, 12 or 13 upslope as average standing water depth decreases.

Map localities in northern NSW: Broadwater NP, Bundjalung NP, Yuraygir NP, Hat Head NP, Limeburners Creek NR, Lake Innes NR, Crowdy Bay NP.

Equivalent vegetation types: *Lepironia articulata* has a coastal distribution in NSW, extending northwards from the Central Coast (Harden 1993). Others report *Lepironia articulata* sedgeland for the North Coast of NSW (Bell 1997, Myerscough & Carolin 1986, Pressey 1987a,b), and also for south-eastern Queensland (Batianoff & Elsol 1989, Dowling & McDonald 1976, Durrington 1977, Elsol & Dowling 1978). The community forms part of the 'coastal *Lepironia* swamp' wetland type of Goodrick (1970).

Community No. 3: *Baumea articulata* sedgeland

Sites: HBU006.1/.2, HYU028.1/.2, HHA018.1/.2, HLA007.1/.2.

API group: 64061 (*Baumea articulata* sedgeland).

Structure: very tall sedgeland and closed sedgeland.

Floristic composition:
- Constant species: *Baumea articulata* (V).
- Cover-abundant species: *Baumea articulata* (4.12; V).
- Indicator species: none.
- Exotic species: *Nymphaea caerulea* subsp. *zanzibarensis*.
- Species richness: total = 13; mean (+/- SE) in 25 m^2 = 4.38 (0.32).

Habitat:
- Topographic position: closed depressions (swamps).
- Altitude: <10 m ASL.
- Aspect: nil. • Slope: 0°.
- Geology: Quaternary sediments.

Map localities in northern NSW: Bundjalung NP, Yuraygir NP, Hat Head NP, Lake Innes NR, Frogalla Swamp.

Equivalent vegetation types: *Baumea articulata* has a widespread distribution in coastal NSW, and it is found in most Australian states (Harden 1993). Others report *Baumea articulata* sedgeland for the North Coast of NSW, although it is apparently of limited extent (Bell 1997, Pressey 1987a,b, Pressey & Griffith 1987). The community would be included under the *Baumea* sedgelands broadly defined by Briggs (1981) for eastern, southern and south-western Australia. The community is likely to form part of a *B. articulata* – *Cladium procerum* – *Lepironia articulata* vegetation unit reported for south-eastern Queensland (McDonald & Elsol 1984).

Community No. 4: *Eleocharis sphacelata* sedgeland

Sites: HBU034.1/.2, HHA019.1/.2.

API group: 64101 (*Eleocharis sphacelata* sedgeland).

Structure: tall to very tall closed sedgeland.

Floristic composition:
- Constant species: *Eleocharis sphacelata* (V).
- Cover-abundant species: *Eleocharis sphacelata* (3.75; V).
- Indicator species: none.
- Exotic species: *Nymphaea caerulea* subsp. *zanzibarensis*.
- Species richness: total = 9; mean (+/- SE) in 25 m^2 = 4.50 (0.29).

Habitat:
- Topographic position: closed depressions (swamps).
- Altitude: <10 m ASL.
- Aspect: nil. • Slope: 0°.
- Geology: Quaternary sediments.
- Comments: Often replaced by *Baumea rubiginosa* sedgeland (community No. 1) or *Lepironia articulata* sedgeland (community No. 2) as average standing water depth decreases.

Map localities in northern NSW: Bundjalung NP, Hat Head NP.

Equivalent vegetation types: *Eleocharis sphacelata* has a widespread distribution in NSW, and also throughout the remainder of Australia (Briggs 1981, Harden 1993). Others report sedgeland dominated by *Eleocharis sphacelata* for the North Coast of NSW (Pressey 1981, 1987a,b), and also for the Central Coast, South Coast and inland NSW (Benson 1989). The community would form part of the *Eleocharis* sedgelands broadly defined for Australia by Briggs (1981).

Community No. 5: *Baumea arthrophylla* sedgeland

Sites: HHA021.1/.2, HLA006.1/.2.

API group: 64121 (*Baumea arthrophylla* sedgeland).

Structure: tall to very tall closed sedgeland.

Floristic composition:
- Constant species: *Baumea arthrophylla* (V), *Triglochin procerum* s. lat. (IV).
- Cover-abundant species: *Baumea arthrophylla* (3.50; V).
- Indicator species: none.
- Exotic species: none.
- Species richness: total = 4; mean (+/- SE) in 25 m^2 = 2.50 (0.29).

Habitat:
- Topographic position: closed depressions (swamps).
- Altitude: <10 m ASL.
- Aspect: nil. • Slope: 0°.
- Geology: Quaternary sediments.

Map localities in northern NSW: Hat Head NP, Lake Innes NR.

Equivalent vegetation types: Although *Baumea arthrophylla* is found throughout Australia, it is confined to the Central Coast and North Coast in NSW where it is considered to have a sporadic distribution (Harden 1993). Equivalent vegetation types are not known.

Community No. 6: *Cladium procerum* sedgeland

Sites: HBU015.1/.2, HCR005.1/.2.

API group: 64111 (*Cladium procerum* sedgeland).

Structure: very tall closed sedgeland.

Floristic composition:
- Constant species: *Cladium procerum* (V).
- Cover-abundant species: *Cladium procerum* (5.00; V), *Salvinia molesta* (4.00; III).
- Indicator species: *Cladium procerum* (V; 5.00).
- Exotic species: *Salvinia molesta*.
- Species richness: total = 8; mean (+/- SE) in 25 m^2 = 4.75 (0.48).

Habitat:
- Topographic posititon: closed depressions (swamps, lakes).
- Altitude: <10 m ASL.
- Aspect: nil. • Slope: 0°.
- Geology: Quaternary sediments.
- Comments: Typically found bordering deep open water on floating mats of organic matter, the outer edge of which may break up to form rafts.

Map localities in northern NSW: Bundjalung NP, Hat Head NP, Lake Innes NR, Crowdy Bay NP.

Equivalent vegetation types: *Cladium procerum* has a sporadic distribution in coastal NSW (Harden 1993). Others report sedgeland dominated by *Cladium procerum* for the North Coast of NSW (Murphy 1995, Myerscough & Carolin 1986, Pressey 1987a,b). *Cladium procerum* is also likely to dominate sedgelands in south-eastern Queensland (Blake 1968, Dowling & McDonald 1976, Durrington 1977, Elsol & Dowling 1978).

Community No. 7: *Typha orientalis* rushland

Sites: HNE006.1/.2, HLA008.1/.2.

API group: 65041 (*Typha orientalis* rushland).

Structure: very tall rushland and closed rushland.

Floristic composition:
- Constant species: *Typha orientalis* (V).
- Cover-abundant species: *Typha orientalis* (3.75; V).
- Indicator species: *Typha orientalis* (V; 3.75), *Nymphoides indica* (III; 2.00).
- Exotic species: *Nymphaea caerulea* subsp. *zanzibarensis*, *Salvinia molesta*.
- Species richness: total = 11; mean (+/- SE) in 25 m^2 = 5.00 (0.71).

Habitat:
- Topographic position: closed depressions (swamps, lakes).
- Altitude: <10 m ASL.
- Aspect: nil. • Slope: 0°.
- Geology: Quaternary sediments.

Map localities in northern NSW: Newrybar Swamp, Evans Head, Lake Innes NR.

Equivalent vegetation types: *Typha orientalis* has a widespread distribution in NSW, and throughout Australia generally (Harden 1993). Rushlands dominated by this species are likely to occur on floodplains in northern NSW (Pressey 1987a). Briggs (1981) describes 'grassland' communities dominated by one or other of *Typha domingensis* and *T. orientalis*.

Community No. 8: *Blechnum indicum* fernland

Sites: HBU007.1/.2, HCR002.1/.2.

API group: 67021 (*Blechnum indicum* fernland).

Structure: tall to very tall closed fernland.

Floristic composition:
- Constant species: *Blechnum indicum* (V).
- Cover-abundant species: *Blechnum indicum* (5.00; V).
- Indicator species: none.
- Exotic species: none.
- Species richness: total = 10; mean (+/- SE) in 25 m^2 = 4.00 (1.08).

Habitat:
- Topographic position: closed depressions (swamps).
- Altitude: <10 m ASL.
- Aspect: nil. • Slope: 0°.
- Geology: Quaternary sand.
- Comments: Found in interbarrier swamps close to the sea where relatively high inputs of cyclic salt could be expected.

Map localities in northern NSW: Newrybar Swamp, Bundjalung NP, Crowdy Bay NP.

Equivalent vegetation types: *Blechnum indicum* has a coastal distribution, extending north from Jervis Bay on the NSW South Coast. This distribution continues disjunctly along the Queensland coastline into northern Australia (Chambers et al. 1998, Harden 1990). The community appears to have a scattered distribution on the North Coast of NSW (Murray 1989, Osborn & Robertson 1939 (as *B. serrulatum*), Pressey 1987a,b, Pressey & Griffith 1987), and possibly also on the Central Coast (see Hamilton 1919, as *B. serrulatum*).

Community No. 9: *Baloskion pallens – Melaleuca quinquenervia* sedgeland-heathland

Sites: HBR001.1/.2, HBR004.1/.2, HYU008.1/.2.

API group: 64071 (*Baloskion pallens – Baumea teretifolia – Melaleuca quinquenervia* sedgeland-heathland).

Structure: mid-high to tall closed sedgeland-heathland (or sedge-heath sensu Beadle 1981). *Melaleuca quinquenervia* is present as a heath shrub, although its crown cover varies and so the community is structurally heterogenous. Sedges are generally continuous in height with *M. quinquenervia*.

Floristic composition:

- Constant species: *Melaleuca quinquenervia* (V), *Baloskion pallens* (IV), *Melaleuca squamea* (IV).
- Cover-abundant species: *Melaleuca quinquenervia* (4.00; V), *Baloskion pallens* (4.00; IV), *Baumea juncea* (4.00; II).
- Indicator species: none.
- Exotic species: none.
- Species richness: total = 20; mean (+/- SE) in 25 m^2 = 6.67 (1.20).
- Comments: *Baloskion pallens* and *Baumea teretifolia* (III) are generally more constant in this community than the analyses would suggest. Site HYU008.1/.2 is considered to be somewhat atypical – at this location *B. pallens* and *B. teretifolia* were both locally absent in a relatively small stand of the community, whereas *Baumea juncea* was abundant. *Melaleuca squamea*, a fire-sensitive species, varies in constancy and cover-abundance with differences in the fire regime.

Habitat:

- Topographic position: closed depressions (swamps).
- Altitude: <10 m ASL.
- Aspect: nil. • Slope: 0°.
- Geology: Quaternary sand.
- Comments: Often associated with deflated, windswept beach ridge plains, although occasionally present in interdunal depressions. This community is often replaced by wet heathland upslope.

Map localities in northern NSW: Newrybar Swamp, Broadwater NP, Evans Head, Bundjalung NP, Yamba area, Yuraygir NP.

Equivalent vegetation types: Apparently best developed on the far North Coast of NSW, although identical or similar communities are reported for south-eastern Queensland (Batianoff & Elsol 1989 (see Photograph 45), Durrington 1977).

Community No. 10: *Gahnia sieberiana – Gleichenia* sedgeland

Sites: HBU026.1/.2, HBU031.1/.2, HYU026.1/.2, HHA004.1/.2.

API groups: 64081 (*Gahnia sieberiana – Gleichenia mendellii* sedgeland); 64181 (*Gahnia sieberiana – Gleichenia dicarpa* sedgeland).

Structure: tall to very tall closed sedgeland.

Floristic composition:

- Constant species: *Gahnia sieberiana* (V), *Empodisma minus* (V), *Sporadanthus interruptus* (V), *Leptospermum liversidgei* (V), *Adrastaea salicifolia* (V), *Epacris microphylla* var. *microphylla* (V), *Gleichenia mendellii* (IV).
- Cover-abundant species: *Gleichenia dicarpa* (5.50; II), *G. mendellii* (4.83; IV), *Gahnia sieberiana* (3.50; V), *Empodisma minus* (3.50; V), *Sporadanthus interruptus* (3.12; V).
- Indicator species: none.
- Exotic species: none.
- Species richness: total = 37; mean (+/- SE) in 25 m^2 = 15.63 (1.10).
- Comments: This community is floristically more similar to wet heathland (see community No. 28 below) than to other sedgelands. Two geographic variants of the community could be recognised based upon the distributions of *Gleichenia mendellii* and *G. dicarpa*. *Gleichenia mendellii* has a restricted distribution, extending from south-eastern Queensland to the Wooli area (east of Grafton) in northern NSW, whereas *G. dicarpa* is widespread in eastern Australia (Chinnock & Bell 1998). *Durringtonia paludosa* (Rubiaceae), a restricted species and monotypic genus, is found in the community.

Habitat:

- Topographic position: open depressions (swales, drainage depressions); ridges (dunes).
- Altitude: <10, to 15 m ASL.
- Aspect: nil, N, SSW. • Slope: 0–4°.
- Geology: Quaternary sand.
- Comments: Characteristically associated with dunefields, in deep Acid Peats kept moist by groundwater seepage.

Map localities in northern NSW: Broadwater NP, Evans Head, Bundjalung NP, Yuraygir NP, Hat Head NP, Crowdy Bay NP. At the latter two localities *Gleichenia dicarpa* replaces *G. mendellii*.

Equivalent vegetation types: *Gahnia sieberiana* and *Gleichenia dicarpa* are common in sedgelands described for the Central Coast of NSW (Buchanan 1980, Pidgeon 1938) as *Gahnia psittacorum*, presumably in error), and a *G. sieberiana – Gleichenia* sp. community occurs in south-eastern Queensland (W. McDonald, Queensland Herbarium pers. comm.). See also Blake (1968) regarding the apparent dominance by *G. sieberiana* in localised areas of wallum in south-eastern Queensland.

Plant community No. 11: *Leptocarpus tenax – Baloskion pallens* sedgeland in Crowdy Bay NP (HCR028.2).

Community No. 11: *Leptocarpus tenax – Baloskion pallens* sedgeland

Sites: HBU001.1/.2, HBU003.1/.2, HBU027.1/.2, HYU006.1/.2, HHA012.1/.2, HLI011.1/.2, HLI013.1/.2, HLI025.1/.2, HLA001.1/.2, HCR006.1/.2, HCR014.1/.2, HCR017.1/.2, HCR019.1/.2, HCR021.1/.2, HCR028.1/.2, HCR031.1/.2.

API group: 64031 in part (*Leptocarpus tenax – Baloskion pallens – Schoenus brevifolius* sedgeland).

Structure: tall to very tall closed sedgeland.

Floristic composition:

- Constant species: *Callistemon pachyphyllus* (V), *Baloskion pallens* (V), *Baumea teretifolia* (V), *Leptocarpus tenax* (V).

- Cover-abundant species: *Leptocarpus tenax* (2.65; V), *Balaskian pallens* (2.50; V), *Schoenus brevifolius* (2.37; III), *Callistemon pachyphyllus* (2.33; V), *Sporadanthus caudatus* (2.33; I), *Melaleuca thymifolia* (2.17; II), *Baumea teretifolia* (2.04; V).
- Indicator species: none.
- Exotic species: none.
- Species richness: total = 47; mean (+/- SE) in 25 m^2 = 11.94 (0.66).
- Comments: This community could be separated from the floristically variable API group 64031. Although named after the two constant species of highest mean cover-abundance (*Leptocarpus tenax* and *Baloskion pallens*), other species that may be locally abundant include *Baumea teretifolia*, *Callistemon pachyphyllus*, *Melaleuca thymifolia* and *Schoenus brevifolius*. *Baumea arthraphylla* was subsidiary to co-dominant at one site (HYU006.1/.2),displaying floristic affinities with community No. 5. The community supports *Durringtonia paludosa*, a restricted species and monotypic genus.

Habitat:

- Topographic position: closed depressions (swamps).
- Altitude: <10, to 20 m ASL
- Aspect: generally nil (N at 1 site). • Slope: generally 0° (to 1°).
- Geology: Quaternary sediments (typically sand).
- Comments: Found in shallower swamps than many other sedgeland communities, where the watertable periodically drops to ground level if not beneath the soil surface.

Map localities in northern NSW: Bundjalung NP, Yuraygir NP, Hat Head NP, Limeburners Creek NR, Lake Innes NR, Crowdy Bay NP.

Equivalent vegetation types: This community shares species in common with an *Empodisma minus* (syn. *Calorophus minor*) – *Leptocarpus tenax* alliance described by Beadle (1981) for south-eastern Queensland and NSW. *Leptocarpus tenax*, *Baloskion pallens*, *Schoenus brevifolius* and *Baumea teretifolia* are characteristic of a sedgeland community delineated for Tomaree NP on the lower North Coast of NSW (Bell 1997), and a related sedgeland of *L. tenax*, *S. brevifolius* and other species is described for the Gosford – Lake Macquarie area on the Central Coast (Benson 1986). Similar or related sedgelands occur in south-eastern Queensland (Batianoff & Elsol 1989, Dowling & McDonald 1976, Elsol & Dowling 1978).

Community No. 12: *Schoenus brevifolius – Baumea teretifolia* sedgeland

Sites: HBU009.1/.2, HLI020.1/.2, HLI026.1/.2.

API group: 64031 in part (*Leptocarpus tenax – Baloskion pallens – Schaenus brevifolius* sedgeland).

Structure: tall to very tall closed sedgeland.

Floristic composition:

- Constant species: *Schoenus brevifolius* (V), *Baumea teretifolia* (V), *Chorizandra sphaerocephala* (V), *Lepyrodia muelleri* (V).
- Cover-abundant species: *Schoenus brevifolius* (3.00; V), *Baumea teretifolia* (3.00; V), *Melaleuca thymifolia* (3.00; IV), *Chorizandra sphaerocephala* (2.67; V).
- Indicator species: none.
- Exotic species: none.
- Species richness: total = 20; mean (+/- SE) in 25 m^2 = 10.83 (1.66).
- Comments: This community could be separated from the floristically variable API group 64031. Although named after the two constant species of highest mean cover-abundance (*Schoenus brevifolius* and *Baumea teretifolia*), other species that may be locally abundant are *Callistemon pachyphyllus*, *Chorizandra sphaerocephala* and *Melaleuca thymifolia*.

Habitat:

- Topographic position: closed depressions (swamps).
- Altitude: <10 m ASL.
- Aspect: nil. • Slope: 0°.
- Geology: Quaternary sediments.
- Comments: Found in shallower swamps than many other sedgeland communities, where the watertable periodically drops to ground level if not beneath the soil surface.

Map localities in northern NSW: Bundjalung NP, Limeburners Creek NR.

Equivalent vegetation types: This community shares species in common with an *Empodisma minus* (syn. *Calorophus minor*) – *Leptocarpus tenax* alliance described by Beadle (1981) for south-eastern Queensland and NSW. *Leptocarpus tenax*, *Baloskian pallens*, *Schoenus brevifolius* and *Baumea teretifolia* are characteristic of a sedgeland community delineated for Tomaree NP on the lower North Coast of NSW (Bell 1997), and similar or related sedgelands occur in south-eastern Queensland (Batianoff & Elsol 1989, Dowling & McDonald 1976, Elsol & Dowling 1978).

Community No. 13: *Baloskion pallens – Baumea teretifolia* sedgeland

Sites: HNE001.1/.2, HNE003.1/.2, HBU021.1/.2, HBU030.1/.2, HBU047.1/.2, HYU023.1/.2, HHA007.1/.2, HLI008.1/.2.

API groups: 64031 in part (*Leptocarpus tenax – Baloskian pallens – Schoenus brevifolius* sedgeland); 64141 (*Baloskion pallens – Schoenus brevifolius* sedgeland).

Structure: tall to very tall closed sedgeland.

Floristic composition:

- Constant species: *Balaskion pallens* (V), *Baumea teretifolia* (V), *Schoenus brevifalius* (IV).
- Cover-abundant species: *Baloskion pallens* (3.06; V), *Sporadanthus caudatus* (2.78; III), *Baumea teretifolia* (2.44; V), *Schoenus brevifolius* (2.17; IV), *Callisteman pachyphyllus* (2.00; I), *Melaleuca squamea* (2.00; I).
- Indicator species: none.
- Exotic species: none.
- Species richness: total = 16; mean (+/- SE) in 25 m^2 = 4.63 (0.36).
- Comments: API groups 64031 and 64141 could be re-evaluated to accommodate this community as a distinct entity. Although named after the two constant species of highest mean cover-abundance (*Baloskion pallens* and *Baumea teretifolia*), other species that may be locally abundant are *Schoenus brevifolius* and *Sporadanthus caudatus*. *Melaleuca squamea* is an obligate seeder, and is therefore likely to vary in cover-abundance with differences in the fire regime.

Habitat:

- Topographic position: closed depressions (swamps).
- Altitude: <10, to 30 m ASL.
- Aspect: generally nil (S at 1 site). • Slope: generally 0° (to 1°).
- Geology: Quaternary sediments (typically sand).
- Comments: Found in shallower swamps than many other sedgeland communities, where the watertable periodically drops to ground level if not beneath the soil surface.

Map localities in northern NSW: Newrybar Swamp, Bundjalung NP, Yuraygir NP, Hat Head NP, Limeburners Creek NR.

Equivalent vegetation types: This community shares species in common with an *Empodisma minus* (syn. *Calorophus minor*) – *Leptocarpus tenax* alliance described by Beadle (1981) for south-eastern Queensland and NSW. *Leptocarpus tenax*, *Baloskion pallens*, *Schoenus brevifolius* and *Baumea teretifolia* are characteristic of a sedgeland community delineated for Tomaree NP on the lower North Coast of NSW (Bell 1997), and similar or related sedgelands occur in south-eastern Queensland (Batianoff & Elsol 1989, Dowling & McDonald 1976, Elsol & Dowling 1978).

Community No. 14: *Themeda australis* sod grassland

Sites: HEV003.1/.2, HMO002.1/.2, HHA009.1/.2, HL1010.1/.2.

API group: 63021 (*Themeda australis* sod grassland).

Structure: low to tall closed sod grassland.

Floristic composition:

- Constant species: *Themeda australis* (V), *Pimelea linifolia* (V), *Polymeria calycina* (IV), *Hydrocotyle peduncularis* (IV), *Centella asiatica* (IV), *Carex breviculmis* (IV), *Poranthera microphylla* (IV), *Bracteantha bracteata* (IV).
- Cover-abundant species: *Themeda australis* (5.75; V), *Pultenaea maritima* ms. (3.50; II).
- Indicator species: *Polymeria calycina* (IV; 2.33), *Bracteantha bracteata* (IV; 2.00), *Hydrocotyle peduncularis* (IV; 1.67), *Poranthera microphylla* (IV; 1.33), *Centella asiatica* (IV; 1.00), *Carex breviculmis* (IV; 1.00).
- Exotic species: *Baccharis halimifolia*, *Chrysanthemoides monilifera* subsp. *rotundata*, *Hypochaeris radicata*, *Pennisetum clandestinum*.
- Species richness: total = 56; mean (+/- SE) in 25 m^2 = 17.38 (2.46).
- Comments: The rare species *Thesium australe* is found in this community, and also a restricted prostrate *Pultenaea* (*P. maritima* ms., Harden 2002).

Habitat:

- Topographic position: hillslopes.
- Altitude: 20–50 m ASL.
- Aspect: NE, E, S, SW. • Slope: 10–25°.
- Geology: sedimentary lithologies.
- Comments: Occupies very exposed seaward slopes of headlands, in Black Headland Soils formed under high levels of cyclic salt accession. Replaced by a range of other headland vegetation types on less exposed aspects. Also found on other substrates such as adamellite (not sampled).

Map localities in northern NSW: Evans Head, Bundjalung NP, Yuraygir NP, Moonee Beach NR, Hat Head NP, Limeburners Creek NR, Kattang NR, Crowdy Bay NP, Booti Booti NP.

Equivalent vegetation types: *Themeda australis* sod grassland is widespread on the North Coast of NSW (Griffith 1992b, Quint 1982). It also extends further south along the NSW coast (Adam et al. 1989, Beadle 1981, Benson 1986, Benson & Howell 1990, McRae 1990), and into coastal southern Queensland (see Batianoff & Elsol (1989), Sattler & Williams (1999) as *T. triandra*). Beadle (1981) describes an equivalent *T. australis* littoral grassland.

Community No. 15: *Themeda australis – Ptilothrix deusta* tussock grassland

Sites: HBU008.1/.2, HYU002.1/.2.

API group: 62031 (*Ischaemum australe – Ptilothrix deusta – Schoenus brevifolius – Themeda australis* tussock grassland).

Structure: mid-high to tall closed tussock grassland.

Floristic composition:

- Constant species: *Themeda australis* (V), *Ptilothrix deusta* (V), *Schoenus brevifolius* (V), *Gonocarpus tetragynus* (IV).
- Cover-abundant species: *Themeda australis* (4.00; V), *Ischaemum australe* (4.00; III), *Ptilothrix deusta* (3.50; V), *Entolasia stricta* (3.00; III).
- Indicator species: *Rutidosis heterogama* (III; 1.00).
- Exotic species: none.
- Species richness: total = 31; mean (+/- SE) in 25 m^2 = 15.00 (2.04).
- Comments: The API group name could be amended to recognise *Themeda australis* and *Ptilothrix deusta* as constant (both 100% occurrence), cover-abundant species. Nonetheless, *Ischaemum australe* is also abundant in some stands, and *Schoenus brevifolius* is constant (100% occurrence). The rare species *Rutidosis heterogama* is found in this community.

Habitat:

- Topographic position: flats (backplains) and drainage (open) depressions.
- Altitude: <10, to 25 m ASL.
- Aspect: nil, or SSE. • Slope: 0–1°.
- Geology: Quaternary sediments (heavy-textured).
- Comments: Found in poorly drained, heavy clay soils derived from muddy estuarine deposits or alluvium. This community often adjoins graminoid clay heathland, or *Xanthorrhoea fulva – Ptilothrix deusta* wet heathland (community No. 22 below).

Map localities in northern NSW: Bundjalung NP, Yuraygir NP.

Equivalent vegetation types: The distribution of this community elsewhere in NSW is uncertain, although grasslands in which *Ischaemum australe* features are known for south-eastern Queensland (Batianoff & Elsol 1989). The community possibly forms part of the 'wet grasslands' described by Briggs (1981) for Australia generally.

Community No. 16: *Themeda australis – Banksia oblongifolia – Aristida warburgii* graminoid clay heathland

Sites: HAR001.1/.2, HAR002.1/.2.

API group: 59041 (*Banksia oblongifolia – Allocasuarina littoralis – Hakea teretifolia* subsp. *teretifolia – Aristida warburgii – Themeda australis* graminoid clay heathland).

Structure: (occasionally dwarf to) low to mid-high closed heathland.

Floristic composition:

- Constant species: *Banksia oblongifolia* (V), *Themeda australis* (V), *Patersonia sericea* (V), *Gompholobium pinnatum* (V), *Panicum simile* (V), *Lepidosperma laterale* (V), *Aristida warburgii* (V), *Patersonia glabrata* (V), *Lomandra multiflora* subsp. *multiflora* (V), *Gonocarpus tetragynus* (V), *Pimelea linifolia* (V), *Lepidosperma neesii* (V), *Phyllota phylicaides* (V), *Entolasia stricta* (V), *Mirbelia rubiifolia* (V), *Austrostipa pubescens* (V), *Boronia pinnata* (V), *Hibbertia empetrifolia* subsp. *empetrifolia* (V), *Lomandra longifolia* (V), *Bossiaea ensata* (V).
- Cover-abundant species: *Themeda australis* (4.00; V), *Banksia oblongifolia* (3.50; V), *Allocasuarina littoralis* (3.00; IV), *Aristida warburgii* (3.00; V), *Hibbertia empetrifolia* subsp. *empetrifolia* (2.50; V), *Platysace ericoides* (2.50; III).
- Indicator species: *Hibbertia empetrifolia* subsp. *empetrifolia* (V; 2.50), *Lomatia silaifolia* (IV; 1.00), *Acacia leiocalyx* (III; 1.00), *Jacksonia scaparia* (III; 1.00).
- Exotic species: none.
- Species richness: total = 52; mean (+/- SE) in 25 m^2 = 29.75 (2.32).
- Comments: *Ptilothrix deusta*, a characteristic species of other graminoid clay heathlands on the North Coast of NSW, is apparently absent from this community in Arakoon SRA. *Hakea teretifolia* subsp. *teretifolia* reaches its northern distribution limit in the vicinity of Arakoon SRA (Harden 2002). The cover-abundance of *H. teretifolia* subsp. *teretifolia* (generally an obligate seeder) and *Allocasuarina littoralis* is likely to vary with differences in the fire regime. The API group name could be amended to recognise *Themeda australis*, *Banksia oblongifolia* and *Aristida warburgii* as the more constant (all 100% occurrence), cover-abundant species.

Habitat:

- Topographic position: hillslopes.
- Altitude: 40–70 m ASL.
- Aspect: NNE, WNW. • Slope: 8–22°.
- Geology: adamellite.
- Comments: Found in periodically waterlogged, solodic sandy clay loam to sandy clay soils on relatively exposed coastal hills.

Map localities in northern NSW: Arakoon SRA.

Equivalent vegetation types: This community forms part of an *Allocasuarina littoralis – Banksia oblongifolia* (syn. *Casuarina littoralis – B. aspleniifolia*) 'headland heath' alliance delineated by Beadle (1981) for south-eastern Queensland and northern NSW. Related communities occur elsewhere on the lower North Coast (Benson 1981, Griffith et al. 2000), and also on the Central Coast (McRae 1990). Similar heathland vegetation is found on trachyte and rhyolite in south-eastern Queensland (Batianoff & Elsol 1989), for example on Mount Coolum (S. Griffith pers. observ. 1999).

Community No. 17: *Ptilothrix deusta – Aristida warburgii – Hakea teretifolia* subsp. *teretifolia* graminoid clay heathland

Sites: HCR001.1/.2, HCR003.1/.2.

API group: 59031 (*Banksia oblongifolia – Allocasuarina littoralis – Hakea teretifolia* subsp. *teretifolia – Aristida warburgii – Ptilothrix deusta* graminoid clay heathland).

Structure: low to tall closed heathland.

Floristic composition:

- Constant species: *Banksia oblongifolia* (V), *Themeda australis* (V), *Patersonia sericea* (V), *Gompholobium pinnatum* (V), *Panicum simile* (V), *Allocasuarina littoralis* (V), *Lepidosperma laterale* (V), *Aristida warburgii* (V), *Cassytha glabella* forma *glabella* (V), *Lomandra multiflora* subsp. *multiflora* (V), *Melichrus procumbens* (V), *Gonocarpus tetragynus* (V), *Pimelea linifolia* (V), *Lepidosperma neesii* (V), *Ptilothrix deusta* (V), *Hakea laevipes* subsp. *laevipes* (V), *Entolasia stricta* (V), *Mirbelia rubiifolia* (V), *Tricoryne elatior* (V), *Schoenus brevifolius* (V), *Austrostipa pubescens* (V), *Boronia pinnata* (V), *Isopogon anemonifolius* (V), *Hakea teretifolia* subsp. *teretifolia* (V), *Hibbertia riparia* (V), *Goodenia stelligera* (V), *Sowerbaea juncea* (V).
- Cover-abundant species: *Ptilothrix deusta* (4.50; V), *Aristida warburgii* (4.00; V), *Hakea teretifolia* subsp. *teretifolia* (3.00; V), *Isopogon anemonifolius* (2.50; V).
- Indicator species: *Cryptandra scortechinii* (III; 1.50), *Euphrasia collina* subsp. *paludosa* (III; 1.50), *Bossiaea stephensonii* (III; 1.00), *Brunoniella pumilio* (III; 1.00), *Caesia parviflora* (III; 1.00).
- Exotic species: none.
- Species richness: total = 66; mean (+/- SE) in 25 m^2 = 37.00 (1.29).
- Comments: *Hakea teretifolia* subsp. *teretifolia* reaches its northern distribution limit in the Macleay River valley on the mid North Coast of NSW (Harden 2002). The cover-abundance of *H. teretifolia* subsp. *teretifolia* (generally an obligate seeder) is likely to vary with differences in the fire regime, and at exceptionally high cover values this species may displace other heath shrubs such as *Banksia oblongifolia* and *Allocasuarina littoralis*. The API group name could be amended to recognise *Ptilothrix deusta*, *Aristida warburgii* and *Hakea teretifolia* subsp. *teretifolia* as the more constant (all 100% occurrence), cover-abundant species.

Habitat:
- Topographic position: hillslopes and hillcrests.
- Altitude: 10–50 m ASL.
- Aspect: NW. • Slope: 1–13°.
- Geology: sedimentary lithologies (rhyolite elsewhere).
- Comments: Found in periodically waterlogged, solodic clay loam to heavy clay soils on relatively exposed coastal and sub-coastal hills.

Map localities in northern NSW: Crowdy Bay NP.

Equivalent vegetation types: The community forms part of an *Allocasuarina littoralis – Banksia oblongifolia* (syn. *Casuarina littoralis – B. aspleniifolia*) 'headland heath' alliance delineated by Beadle (1981) for south-eastern Queensland and northern NSW. Related communities occur elsewhere on the lower North Coast (Benson 1981, Griffith et al. 2000), and also on the Central Coast (McRae 1990). Similar heathland vegetation is found on trachyte and rhyolite in south-eastern Queensland (Batianoff & Elsol 1989), for example on Mount Coolum (S. Griffith pers. observ. 1999).

Community No. 18: *Ptilothrix deusta – Banksia oblongifolia – Mirbelia rubiifolia* graminoid clay heathland

Sites: HEV001.1/.2.

API group: 59021, in part (*Banksia oblongifolia – Allocasuarina littoralis – Aristida warburgii – Ptilothrix deusta* graminoid clay heathland).

Structure: low to mid-high closed heathland.

Floristic composition:

- Constant species: *Banksia oblongifolia* (V), *Themeda australis* (V), *Patersonia sericea* (V), *Gompholobium pinnatum* (V), *Panicum simile* (V), *Allocasuarina littoralis* (V), *Lepidosperma laterale* (V), *Cassytha glabella* forma *glabella* (V), *Patersonia glabrata* (V), *Melichrus procumbens* (V), *Epacris pulchella* (V), *Ptilothrix deusta* (V), *Entolasia stricta* (V), *Mirbelia rubiifolia* (V), *Tricoryne elatior* (V), *Bossiaea ensata* (V), *Notelaea ovata* (V), *Hibbertia vestita* (V), *Phyllanthus hirtellus* (V), *Melaleuca nodosa* (V), *Leptospermum trinervium* (V), *Boronia safrolifera* (V), *Austromyrtus dulcis* (V), *Bossiaea rhombifolia* subsp. *rhombifolia* (V), *Xanthosia pilosa* (V), *Hibbertia diffusa* (V), *Ochrosperma citriodorum* (V), *Homoranthus virgatus* (V).
- Cover-abundant species: *Ptilothrix deusta* (5.00; V), *Banksia oblongifolia* (4.00; V), *Mirbelia rubiifolia* (4.00; V), *Epacris pulchella* (3.00; V), *Hibbertia vestita* (3.00; V), *Melaleuca nodosa* (3.00; V), *Boronia safrolifera* (3.00; V), *Bossiaea rhombifolia* subsp. *rhombifolia* (3.00; V).
- Indicator species: *Bossiaea rhombifolia* subsp. *rhombifolia* (V; 3.00), *Callitris columellaris* (III; 1.00).
- Exotic species: none.
- Species richness: total = 42; mean (+/- SE) in 25 m^2 = 31.50 (0.50).
- Comments: This community could be segregated from the broader API group 59021.

Habitat:
- Topographic position: hillslope.
- Altitude: 37 m ASL.
- Aspect: NE. • Slope: 7°.
- Geology: sedimentary lithology.
- Comments: Found in periodically waterlogged, solodic light sandy clay loam to sandy clay loam soil on a relatively exposed coastal hill.

Map localities in northern NSW: Evans Head.

Equivalent vegetation types: The community forms part of an *Allocasuarina littoralis – Banksia oblongifolia* (syn. *Casuarina littoralis – B. aspleniifolia*) 'headland heath' alliance delineated by Beadle (1981) for south-eastern Queensland and northern NSW. Related communities occur on the lower North Coast (Benson 1981, Griffith et al. 2000), and also on the Central Coast (McRae 1990, see also Adam et al. (1989) who report a *B. oblongifolia – Mirbelia rubiifolia* closed heathland). Similar heathland vegetation is found on trachyte and rhyolite in south-eastern Queensland (Batianoff & Elsol 1989), for example on Mount Coolum (S. Griffith pers. observ. 1999).

Community No. 19: *Ptilothrix deusta – Aristida warburgii – Banksia oblongifolia – Allocasuarina littoralis – Epacris pulchella* graminoid clay heathland

Sites: HYU001.1/.2, HYU004.1/.2, HYU005.1/.2.

API group: 59021, in part (*Banksia oblongifolia – Allocasuarina littoralis – Aristida warburgii – Ptilothrix deusta* graminoid clay heathland).

Structure: low to mid-high (occasionally dwarf or tall) closed heathland.

Floristic composition:

- Constant species: *Banksia oblongifolia* (V), *Themeda australis* (V), *Patersonia sericea* (V), *Gompholobium pinnatum* (V), *Panicum simile* (V), *Allocasuarina littoralis* (V), *Lepidosperma laterale* (V), *Aristida warburgii* (V), *Cassytha glabella* forma *glabella* (V), *Dampiera stricta* (V), *Pimelea linifolia* (V), *Goodenia bellidifolia* (V), *Epacris pulchella* (V), *Ptilothrix deusta* (V), *Hakea laevipes* subsp. *laevipes* (V), *Platysace ericoides* (V), *Hibbertia vestita* (V), *Phyllanthus hirtellus* (V), *Kunzea capitata* (V), *Dillwynia retorta* (V).
- Cover-abundant species: *Ptilothrix deusta* (4.67; V), *Aristida warburgii* (4.00; V), *Banksia oblongifolia* (3.50; V), *Allocasuarina littoralis* (3.17; V), *Epacris pulchella* (3.00; V).
- Indicator species: *Lambertia formosa* (IV; 2.00), *Lomandra obliqua* (IV; 2.00).
- Exotic species: none.
- Species richness: total = 52; mean (+/- SE) in 25 m^2 = 25.83 (1.14).
- Comments: This community could be segregated from the broader API group 59021.

Habitat:

- Topographic position: hillslopes.
- Altitude: 20–40 m ASL.
- Aspect: SE, S. • Slope: 2–3°.
- Geology: sedimentary lithologies.
- Comments: Found in periodically waterlogged, solodic sandy clay loam to heavy clay soils on relatively exposed coastal and sub-coastal hills.

Map localities in northern NSW: Yuraygir NP (and adjoining lands).

Equivalent vegetation types: The community forms part of an *Allocasuarina littoralis – Banksia oblongifolia* (syn. *Casuarina littoralis – B. aspleniifolia*) 'headland heath' alliance delineated by Beadle (1981) for south-eastern Queensland and northern NSW. Related communities occur on the lower North Coast (Benson 1981, Griffith et al. 2000), and also on the Central Coast (McRae 1990). Similar heathland vegetation is found on trachyte and rhyolite in south-eastern Queensland (Batianoff & Elsol 1989), for example on Mount Coolum (S. Griffith pers. observ. 1999).

Plant community No. 20: *Banksia oblongifolia – Ptilothrix deusta – Aristida warburgii – Allocasuarina littoralis* graminoid clay heathland in Yuraygir NP (HYU020.1). Lake Minnie Water in the background.

Community No. 20: *Banksia oblongifolia – Ptilothrix deusta – Aristida warburgii –Allocasuarina littoralis* graminoid clay heathland.

Sites: HYU016.1/.2, HYU017.1/.2, HYU018.1/.2, HYU019.1/.2, HYU020.1/.2.

API group: 59021, in part (*Banksia oblongifolia – Allocasuarina littoralis – Aristida warburgii – Ptilothrix deusta* graminoid clay heathland).

Structure: low to mid-high (occasionally dwarf or tall) closed heathland.

Floristic composition:

- Constant species: *Banksia oblongifolia* (V), *Themeda australis* (V), *Patersonia sericea* (V), *Gompholobium pinnatum* (V), *Panicum simile* (V), *Allocasuarina littoralis* (V), *Aristida warburgii* (V), *Lomandra multiflora* subsp. *multiflora* (V), *Dampiera stricta* (V), *Pimelea linifolia* (V), *Phyllota phylicoides* (V), *Goodenia bellidifolia* (V), *Ptilothrix deusta* (V), *Hibbertia vestita* (V), *Kunzea capitata* (V), *Eremochloa bimaculata* (V), *Lissanthe* sp. B (V).
- Cover-abundant species: *Banksia oblongifolia* (3.90; V), *Ptilothrix deusta* (3.60; V), *Aristida warburgii* (3.40; V), *Allocasuarina littoralis* (3.10; V).
- Indicator species: *Lissanthe* sp. B (V; 1.50), *Fimbristylis cinnamometorum* (III; 1.30), *Isopogon mnoraifolius* (IV; 1.00).
- Exotic species: none.
- Species richness: total = 62; mean (+/- SE) in 25 m^2 = 29.50 (1.54).
- Comments: This community could be segregated from the broader API group 59021, although without modification of the existing community name.

Habitat:

- Topographic position: hillslopes.
- Altitude: <10, to 20 m ASL.
- Aspect: S, SE, WSW. • Slope: 1–3°.
- Geology: sedimentary lithologies.
- Comments: Found in periodically waterlogged, solodic light sandy clay loam to heavy clay soils on relatively exposed sub-coastal hills.

Map localities in northern NSW: Yuraygir NP (and adjoining lands).

Equivalent vegetation types: The community forms part of an *Allocasuarina littoralis – Banksia oblongifolia* (syn. *Casuarina littoralis – B. aspleniifolia*) 'headland heath' alliance delineated by Beadle (1981) for south-eastern Queensland and northern NSW.

Related communities occur on the lower North Coast (Benson 1981, Griffith et al. 2000), and also on the Central Coast (McRae 1990). Similar heathland vegetation is found on trachyte and rhyolite in south-eastern Queensland (Batianoff & Elsol 1989), for example on Mount Coolum (S. Griffith pers. observ. 1999).

Community No. 21: *Leptospermum juniperinum* wet heathland

Sites: HBU025.1/.2, HYU029.1/.2, HHA008.1/.2, HCR023.1/.2.

API group: 60031 (*Leptospermum juniperinum* wet heathland).

Structure: mid-high to tall heathland and closed heathland.

Floristic composition:

- Constant species: *Leptospermum juniperinum* (V), *Baumea teretifolia* (V), *Entolasia stricta* (V), *Baumea rubiginosa* (V), *Blechnum indicum* (V).
- Cover-abundant species: *Leptospermum juniperinum* (5.00; V), *Sporadanthus caudatus* (3.00; IV).
- Indicator species: none.
- Exotic species: none.
- Species richness: total = 39; mean (+/- SE) in 25 m^2 = 12.38 (0.89).
- Comments: This community supports *Durringtonia paludosa*, a restricted species and monotypic genus.

Habitat:

- Topographic position: open depressions (swales, drainage depressions).
- Altitude: <10 m ASL.
- Aspect: nil. • Slope: 0°.
- Geology: Quaternary sand.
- Comments: Found in wetter situations than other wet heathland communities where groundwater remains at or just above the soil surface for extended periods.

Map localities in northern NSW: Newrybar Swamp, Evans Head, Bundjalung NP, Yuraygir NP, Moonee Beach NR, Hat Head NP, Lake Innes NR, Crowdy Bay NP.

Equivalent vegetation types: *Leptospermum juniperinum* is widespread on the coast and adjoining tablelands of NSW, and continues into Queensland (Harden 2002, Queensland Herbarium 1994). Nonetheless, the community appears to have a scattered distribution along the North Coast. For Brisbane Waters NP on the Central Coast, Benson and Fallding (1981) report *L. juniperinum* as a dominant in poorly drained situations. *Leptospermum juniperinum* is a common species of wet heathland in coastal south-western Victoria (Head 1988).

Community No. 22: *Xanthorrhoea fulva – Ptilothrix deusta* wet heathland

Sites: HBU010.1/.2, HBU011.1/.2, HYU003.1/.2, HLI001.1/.2, HLI002.1/.2, HLI003.1/.2, HLI004.1/.2, HLI009.1/.2, HLI027.1/.2, HLI033.1/.2, HLI034.1/.2.

API group: 60041 (*Xanthorrhoea fulva* wet heathland).

Structure: low to tall closed heathland.

Floristic composition:

- Constant species: *Xanthorrhoea fulva* (V), *Entolasia stricta* (V), *Schoenus brevifolius* (V), *Melaleuca thymifolia* (V), *Ptilothrix deusta* (V).
- Cover-abundant species: *Ptilothrix deusta* (4.14; V), *Xanthorrhoea fulva* (4.09; V), *Pultenaea myrtoides* (2.60; II).
- Indicator species: none.
- Exotic species: *Verbena bonariensis*.
- Species richness: total = 97; mean (+/- SE) in 25 m^2 = 19.27 (0.89).
- Comments: The API group name could be amended to recognise *Ptilothrix deusta* as a constant (100% occurrence), cover-abundant species. This community supports the rare species *Gonocarpus salsoloides* and *Rutidosis heterogama*.

Habitat:

- Topographic position: flats (backplains), or less commonly drainage (open) depressions.
- Altitude: generally <10 (to 20) m ASL.
- Aspect: nil. • Slope: 0°.
- Geology: Quaternary sediments.
- Comments: Typically found in sandy loam to heavy clay soils associated with muddy estuarine deposits or alluvium. The soils are periodically waterlogged by a rising watertable.

Map localities in northern NSW: Evans Head, Bundjalung NP, Yuraygir NP, Limeburners Creek NR, Lake Innes NR, Crowdy Bay NP.

Equivalent vegetation types: *Xanthorrhoea fulva* has a coastal distribution which extends north from Wyong on the Central Coast of NSW, and continues into Queensland (Harden 1993). Wet heathland dominated by *X. fulva* is reasonably widespread on the North Coast of NSW, and it also occurs in south-eastern Queensland (W. McDonald, Queensland Herbarium pers. comm.; see also Photograph 42 in Batianoff & Elsol 1989). For south-eastern Queensland and southwards, Beadle (1981) recognises a *Xanthorrhoea resinosa* s. lat. (= *X. fulva*/*X. concava*) association. Similarly, for the Central Coast and South Coast in NSW, Benson (1989) recognises a *X. resinosa* s. lat. +/- *Schoenus brevifolius* community.

Plant community No. 22: *Xanthorrhoea fulva – Ptilothrix deusta* wet heathland in Limeburners Creek NR (HLI003.1).

Plant community No. 23: *Banksia oblongifolia – Leptospermum polygalifolium* subsp. *cismontanum – Melaleuca nodosa* wet heathland in Yuraygir NP (HYU034.1/.2). Note also tree mallee and forest dominated by *Eucalyptus pilularis* in the background.

Community No. 23: *Banksia oblongifolia – Leptospermum polygalifolium* subsp. *cismontanum – Melaleuca nodosa* wet heathland

Sites: HBR025.1/.2, HYU034.1/.2, HLI031.1/.2.

API group: 60071 (*Banksia oblongifolia – Leptospermum polygalifolium* subsp. *cismontanum – Melaleuca nodosa* wet heathland).

Structure: low to tall heathland and closed heathland.

Floristic composition:

- Constant species: *Melaleuca nodosa* (V), *Banksia oblongifolia* (V), *Leptospermum polygalifolium* subsp. *cismontanum* (V), *Pseudanthus orientalis* (V).
- Cover-abundant species: *Pteridium esculentum* (4.00; II), *Banksia oblongifolia* (3.50; V), *Melaleuca nodosa* (3.17; V), *Leptospermum polygalifolium* subsp. *cismontanum* (3.00; V).
- Indicator species: none.
- Exotic species: *Lantana camara*.
- Species richness: total = 108; mean (+/- SE) in 25 m^2 = 30.00 (4.14).

Habitat:

- Topographic position: open depressions (swales).
- Altitude: <10, to 30 m ASL.
- Aspect: nil, or E. • Slope: 0–1°.
- Geology: Quaternary sand.
- Comments: This community appears to be associated with sandy podzolised soils in which a relatively shallow, weakly indurated or incipient pan retards, but doesn't prevent, vertical drainage.

Map localities in northern NSW: Broadwater NP, Bundjalung NP, Yuraygir NP, Limeburners Creek NR, Khappinghat NP.

Equivalent vegetation types: This community appears to have a scattered distribution on the North Coast of NSW, and it apparently extends to the Central Coast (see Benson 1989). A related *Melaleuca nodosa – Leptospermum polygalifolium* (syn. *L. flavescens*) 'shrub thicket' or 'closed scrub' is described for south-eastern Queensland (Coaldrake 1961, Specht et al. 1974), and also a *L. polygalifolium – L. semibaccatum – Banksia oblongifolia* heathland (Specht et al. 1974). Coaldrake (1961) further identifies a correlation between the occurrence of *L. polygalifolium* and soils with a soft organic pan. The community is probably best placed in the *L. polygalifolium – L. trinervium* (syn. *L. attenuatum*) alliance of Beadle (1981).

Community No. 24: *Sporadanthus interruptus – Xanthorrhoea fulva – Banksia ericifolia* subsp. *macrantha – Leptospermum liversidgei – Baeckea frutescens* wet heathland

Sites: HBR003.1/.2, HBR005.1/.2, HBR006.1/.2, HBR008.1/.2, HBR009.1/.2, HBR012.1/.2, HBR013.1/.2, HEV006.1/.2, HYU007.1/.2.

API group: 60021 in part (*Banksia oblongifolia – Leptospermum liversidgei – Sporadanthus interruptus – Sprengelia sprengelioides – Xanthorrhoea fulva* wet heathland).

Structure: (rarely low to) mid-high to tall closed heathland.

Floristic composition:

- Constant species: *Banksia ericifolia* subsp. *macrantha* (V), *Selaginella uliginosa* (V), *Leptocarpus tenax* (V), *Xanthorrhoea fulva* (V), *Cassytha glabella* forma *glabella* (V), *Sporadanthus interruptus* (V), *Epacris obtusifolia* (V), *Leptospermum liversidgei* (V), *Baeckea frutescens* (V), *Sprengelia sprengelioides* (V), *Aotus ericoides* (V).
- Cover-abundant species: *Sporadanthus interruptus* (4.00; V), *Xanthorrhoea fulva* (3.94; V), *Banksia ericifolia* subsp. *macrantha* (3.47; V), *Leptospermum liversidgei* (3.11; V), *Baeckea frutescens* (3.11; V), *Eurychorda complanata* (3.00; I).
- Indicator species: none.
- Exotic species: none.
- Species richness: total = 66; mean (+/- SE) in 25 m^2 = 20.78 (0.82).
- Comments: This community could be segregated from the broader API group 60021. *Banksia ericifolia* subsp. *macrantha* is a fire-sensitive obligate seeder, and therefore likely to vary in distribution and cover-abundance with differences in the fire regime.

Habitat:

- Topographic position: open depressions (swales).
- Altitude: <10 m ASL.
- Aspect: nil. • Slope: 0°.
- Geology: Quaternary sand.
- Comments: Grows in poorly drained podzolised sands where a watertable remains close to the ground surface for extended periods. Often replaced by dry heathland or dry sclerophyll shrubland upslope as soil drainage improves. Replaced by sedgeland downslope where standing water accumulates.

Map localities in northern NSW: Broadwater NP, Evans Head, Yuraygir NP.

Equivalent vegetation types: Four of the five species for which this community is named reach their southern distribution limit on the lower North Coast, whereas *Xanthorrhoea fulva* extends further south (Bean 1997, Greater Taree City Council 1996, Harden 1993, 2002, McNair 1992). As presently known, the community appears to be restricted to the upper North Coast of NSW, although related heathlands (without *Banksia ericifolia* subsp. *macrantha*) are likely to be present in south-eastern Queensland (Batianoff & Elsol 1989, Clifford & Specht 1979, Durrington 1977, Elsol & Dowling 1978). The community is probably best placed in the *Leptospermum liversidgei* alliance of Beadle (1981).

Plant community No. 25: *Sporadanthus interruptus – Xanthorrhoea fulva* wet heathland in Crowdy Bay NP (HCR010.1), with *Banksia oblongifolia* also frequent. Note dense shrubland dominated by *Banksia ericifolia* subsp. *macrantha* in the background.

Community No. 25: *Sporadanthus interruptus – Xanthorrhoea fulva* wet heathland

Sites: HNE002.1/.2, HBR010.1/.2, HBU028.1, HBU041.1/.2, HBU042.1/.2, HBU045.1/.2, HBU049.1/.2, HBU051.1/.2, HYU025.1/.2, HHA001.1/.2, HLI005.1/.2, HLI007.1/.2, HLI015.1/.2, HLI018.1/.2, HLI022.1/.2, HLI023.1/.2, HLI024.1/.2, HLI028.1/.2, HLI029.1/.2, HLI030.1/.2, HLA002.1/.2, HCR008.1/.2, HCR010.1/.2, HCR011.1/.2, HCR013.1/.2, HCR015.1/.2, HCR016.1/.2, HCR018.1/.2, HCR020.1/.2, HCR024.1/.2, HCR027.1/.2, HCR035.1/.2, HCR036.1/.2, HCR037.1/.2.

API group: 60021 in part (*Banksia oblongifolia – Leptospermum liversidgei – Sporadanthus interruptus – Sprengelia sprengelioides – Xanthorrhoea fulva* wet heathland).

Structure: low to tall closed heathland.

Floristic composition:

- Constant species: *Banksia ericifolia* subsp. *macrantha* (V), *Baeckea imbricata* (V), *Xantharrhaea fulva* (V), *Cassytha glabella* forma *glabella* (V), *Sporadanthus interruptus* (V), *Pimelea linifalia* (V), *Epacris obtusifolia* (V), *Leptospermum liversidgei* (V), *Dillwynia floribunda* (V), *Pseudanthus orientalis* (V), *Boronia falcifalia* (V), *Sprengelia sprengelioides* (V).
- Cover-abundant species: *Baeckea frutescens* (3.36; III), *Sporadanthus interruptus* (3.15; V), *Xanthorrhoea fulva* (3.07; V), *Baeckea linifolia* (3.00; I), *Leptospermum liversidgei* (2.94; V), *Banksia ablongifalia* (2.79; IV).
- Indicator species: none.
- Exotic species: none.
- Species richness: total = 154; mean (+/- SE) in 25 m^2 = 28.52 (0.79).
- Comments: This community could be segregated from the broader API group 60021. Although named after *Sparadanthus interruptus* and *Xanthorrhoea fulva*, the two constant species (both 100% occurrence) of highest mean cover-abundance, *Leptospermum liversidgei* is also constant as a subsidiary species. Some stands of the community in Hat Head NP support *Baeckea linifolia* as a subsidiary to co-dominant heath shrub, and this species is not known from wallum elsewhere in the study area. The community also supports the rare species *Allacasuarina defungens* and *Gonacarpus salsoloides*.

Habitat:

- Topographic position: open depressions (swales).
- Altitude: <10, to 20 m ASL.
- Aspect: nil, E, ESE, S, W, WNW, NW. • Slope: 0–4°.
- Geology: Quaternary sand.
- Comments: Grows in poorly drained podzolised sands where a watertable remains close to the ground surface for extended periods. Often replaced by dry heathland or dry sclerophyll shrubland upslope as soil drainage improves. Replaced by sedgeland downslope where standing water accumulates.

Map localities in northern NSW: Newrybar Swamp, Broadwater NP, Bundjalung NP, Yuraygir NP, Hat Head NP, Limeburners Creek NR, Lake Innes NR, Crowdy Bay NP.

Equivalent vegetation types: Two of the three species for which this community is named reach their southern distribution limit on the lower North Coast, whereas *Xantharrhoea fulva* extends further south (Harden 1993, McNair 1992). The community appears to be widespread on the North Coast of NSW, and similar communities are likely to be present in south-eastern Queensland (Batianoff & Elsol 1989, Clifford & Specht 1979, Elsol & Dowling 1978). The community is probably best placed in the *Leptospermum liversidgei* alliance of Beadle (1981).

Community No. 26: *Banksia oblongifolia – Xanthorrhoea fulva* wet heathland

Sites: HBU002.1/.2, HBU004.1/.2, HBU038.1/.2, HYU039.1/.2, HMO001.1/.2.

API group: 60021 in part (*Banksia oblangifalia – Leptaspermum liversidgei – Sporadanthus interruptus – Sprengelia sprengeliaides – Xanthorrhaea fulva* wet heathland).

Structure: low to tall closed heathland.

Floristic composition:

- Constant species: *Burchardia umbellata* (V), *Blandfordia grandiflora* (V), *Leptocarpus tenax* (V), *Xanthorrhoea fulva* (V), *Cassytha glabella* forma *glabella* (V), *Pimelea linifolia* (V), *Leptaspermum liversidgei* (V), *Banksia oblangifolia* (V), *Drosera auriculata* (V), *Pseudanthus orientalis* (V), *Sprengelia sprengelioides* (V), *Persoonia virgata* (V), *Hibbertia vestita* (V), *Entalasia stricta* (V).
- Cover-abundant species: *Banksia oblangifolia* (3.70; V), *Xanthorrhoea fulva* (3.40; V), *Aotus ericoides* (3.00; I), *Platysace* sp. A (3.00; IV), *Lepidosperma neesii* (3.00; I), *Leptaspermum liversidgei* (2.70; V), *Empodisma minus* (2.67; II), *Hibbertia vestita* (2.56; V).
- Indicator species: none.
- Exotic species: none.
- Species richness: total = 94; mean (+/- SE) in 25 m^2 = 32.20 (1.41).
- Comments: This community could be segregated from the broader API group 60021. Although named after *Banksia oblongifolia* and *Xanthorrhoea fulva*, the two constant species (both 100% occurrence) of highest mean cover-abundance, *Leptospermum liversidgei* (100% occurrence) and *Hibberita vestita* (90% occurrence) are frequent as subsidiary species. The community supports the rare species *Prostanthera palustris*.

Habitat:

- Topographic position: open depressions (swales).
- Altitude: generally <10 (to 10) m ASL.
- Aspect: nil. • Slope: 0°.
- Geology: Quaternary sand.
- Comments: Grows in poorly drained podzolised sands where a watertable remains close to the ground surface for extended periods.

Map localities in northern NSW: Bundjalung NP, Yuraygir NP, Moonee Beach NR.

Equivalent vegetation types: This community appears to have a scattered distribution along the NSW North Coast, although both species for which it is named extend further south (Harden 1993, 2002). Similar or related communities are likely to occur in south-eastern Queensland (Batianoff & Elsol 1989). The community has affinities with the *Banksia oblongifolia* (syn. *B. aspleniifolia*) alliance of Beadle (1981).

Community No. 27: *Xanthorrhoea fulva – Schoenus paludosus – Banksia ericifolia* subsp. *macrantha* wet heathland

Sites: HCR022.1/.2.

API group: 60021 in part (*Banksia ablangifalia – Leptospermum liversidgei – Sporadanthus interruptus – Sprengelia sprengelioides – Xanthorrhaea fulva* wet heathland).

Structure: low to tall closed heathland.

Floristic composition:

- Constant species: *Banksia ericifolia* subsp. *macrantha* (V), *Burchardia umbellata* (V), *Blandfordia grandiflora* (V), *Selaginella uliginosa* (V), *Leptocarpus tenax* (V), *Xanthorrhoea fulva* (V), *Cassytha glabella* forma *glabella* (V), *Sporadanthus interruptus* (V), *Pimelea linifolia* (V), *Epacris obtusifolia* (V), *Entolasia stricta* (V), *Schoenus brevifolius* (V), *Eurycharda complanata* (V), *Sawerbaea juncea* (V), *Chorizandra sphaeracephala* (V), *Persoonia lanceolata* (V), *Schoenus paludosus* (V), *Sprengelia incarnata* (V), *Kunzea capitata* (V), *Gymnoschoenus sphaerocephalus* (V), *Lepyrodia* sp. A (V).
- Cover-abundant species: *Xanthorrhoea fulva* (4.00; V), *Schaenus paludosus* (4.00; V), *Banksia ericifolia* subsp. *macrantha* (3.50; V), *Sporadanthus interruptus* (3.00; V).
- Indicator species: *Gymnoschoenus sphaerocephalus* (V; 2.00), *Plinthanthesis paradaxa* (III; 1.00).
- Exotic species: none.
- Species richness: total = 34; mean (+/- SE) in 25 m^2 = 21.50 (0.50).
- Comments: This community could be segregated from the broader API group 60021.

Habitat:

- Topographic position: open depression (swale).

- Altitude: <10 m ASL.
- Aspect: nil. • Slope: 0°.
- Geology: Quaternary sand.
- Comments: Grows in poorly drained podzolised sand where a watertable remains close to the ground surface for extended periods.

Map localities in northern NSW: Crowdy Bay NP.

Equivalent vegetation types: The high cover-abundance of *Schoenus paludosus* in this community seems unusual for wet heathlands along the North Coast of NSW. The community is probably most closely aligned with the *Banksia ericifolia* (subsp. *ericifolia* and subsp. *macrantha*) alliance of Beadle (1981).

Plant community No. 28: *Leptospermum liversidgei – Sporadanthus interruptus – Empodisma minus* wet heathland in Bundjalung NP (HBU022.1).

Community No. 28: *Leptospermum liversidgei – Sporadanthus interruptus – Empodisma minus* wet heathland

Sites: HBU013.1/.2, HBU020.1/.2, HBU022.1/.2, HBU028.2, HBU032.1/.2, HBU046.1/.2, HYU012.1/.2, HYU013.1/.2, HYU031.1/.2, HYU032.1/.2, HYU040.1/.2, HHA013.1/.2, HHA014.1/.2, HHA015.1/.2, HLI017.1/.2.

API group: 60021 in part (*Banksia oblongifolia – Leptospermum liversidgei – Sporadanthus interruptus – Sprengelia sprengelioides – Xanthorrhoea fulva* wet heathland).

Structure: low to tall closed heathland.

Floristic composition:

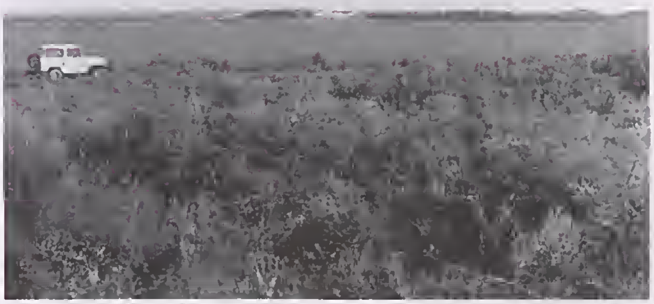
- Constant species: *Xanthorrhoea fulva* (V), *Cassytha glabella* forma *glabella* (V), *Sporadanthus interruptus* (V), *Pimelea linifolia* (V), *Leptospermum liversidgei* (V), *Baumea muelleri* (V), *Boronia falcifolia* (V), *Sprengelia sprengelioides* (V), *Adrastaea salicifolia* (V), *Empodisma minus* (V), *Epacris microphylla* var. *microphylla* (V).
- Cover-abundant species: *Leptospermum liversidgei* (3.69; V), *Sporadanthus interruptus* (3.24; V), *Empodisma minus* (3.10; V), *Baeckea frutescens* (3.06; IV), *Gleichenia mendellii* (3.00; I), *Baeckea linifolia* (3.00; I), *Xanthorrhoea fulva* (2.64; V).
- Indicator species: none.
- Exotic species: none.
- Species richness: total = 81; mean (+/- SE) in 25 m^2 = 19.90 (0.98).
- Comments: This community could be segregated from the broader API group 60021. Some stands of the community in Hat Head NP support *Baeckea linifolia* as a subsidiary heath shrub, and this species is not known from wallum elsewhere in the study area. The community supports a strong component of sedges (most notably *Empodisma minus* and *Sporadanthus interruptus*, but also *Schoenus scabripes* and others), and therefore may resemble a sedge-heath (sensu Beadle 1981) in appearance.

Habitat:

- Topographic position: open depressions (swales).
- Altitude: <10, to 20 m ASL.
- Aspect: nil, N, NE, ENE, E, SE, ESE, SSE, S, SSW, SW.
- Slope: 0–6°.
- Geology: Quaternary sand.
- Comments: Characteristic of soils with a well-developed layer of peat, and often associated with gentle slopes that appear to receive groundwater seepage.

Map localities in northern NSW: Bundjalung NP, Yuraygir NP, Hat Head NP, Limeburners Creek NR.

Equivalent vegetation types: This community has floristic affinities with *Gahnia sieberiana – Gleichenia* sedgeland (community No. 10 above). Two of the three species for which the community is named reach their southern distribution limit on the lower North Coast of NSW, whereas *Empodisma minus* extends further south (Harden 1993, McNair 1992). Similar or related communities are likely to occur in south-eastern Queensland (Batianoff & Elsol 1989, Clifford & Specht 1979, Durrington 1977). The community has affinities with the *Leptospermum liversidgei* alliance of Beadle (1981).



Plant community No. 29: *Banksia aemula – Leptospermum trinervium* dry heathland in Yuraygir NP (HYU024.2). Note also wet heathland (relatively smooth appearance) in the background.

Community No. 29: *Banksia aemula – Leptospermum trinervium* dry heathland

Sites: HNE005.1/.2, HBR011.1/.2, HBR014.1/.2, HEV002.1/.2, HBU005.1/.2, HBU012.1/.2, HBU014.1/.2, HBU029.1/.2, HBU053.1/.2, HYU011.1/.2, HYU014.1/.2, HYU024.1/.2, HYU030.1/.2, HHA010.1/.2, HHA011.1/.2, HLI014.1/.2.

API groups: 58021 in part (*Banksia aemula* dry heathland); 58031 in part (*Banksia aemula – Allocasuarina littoralis* dry heathland).

Structure: low to tall closed heathland.

Floristic composition:

- Constant species: *Banksia aemula* (V), *Leucopogon leptospermoides* (V), *Caustis recurvata* var. *recurvata* (V), *Monotoca scoparia* (V), *Dillwynia retorta* (V), *Acacia ulicifolia* (V), *Schoenus ericetorum* (V), *Brachyloma daphnoides* (V), *Leucopogon virgatus* (V), *Bossiaea ensata* (V), *Acacia suaveolens* (V), *Gompholobium virgatum* var. *virgatum* (V), *Persoonia virgata* (V), *Leptospermum trinervium* (V), *Coleocarya gracilis* (V).
- Cover-abundant species: *Banksia aemula* (3.53; V), *Leptospermum trinervium* (3.04; V), *Calytrix tetragona* (3.00; I), *Xanthorrhoea glauca* subsp. *glauca* (3.00; I), *Melaleuca nodosa* (2.90; IV), *Leptospermum semibaccatum* (2.57; II), *Xanthorrhoea johnsonii* (2.50; IV), *Monotoca scoparia* (2.41; V).

- Indicator species: none.
- Exotic species: none.
- Species richness: total = 110; mean (+/- SE) in 25 m² = 35.31 (1.42).
- Comments: This community could be segregated from API groups 58021 and 58031. It is typically distinguished from other dry heathland communities by relatively high constancy (88% occurrence) and mean cover-abundance for *Leptospermum trinervium*. Other locally abundant species include *Calytrix tetragona*, *Xanthorrhoea glauca* subsp. *glauca* and *Melaleuca nodosa*. The community supports the rare species *Olax angulata*.

Habitat:

- Topographic position: ridges (beach ridges and dunes).
- Altitude: <10, to 45 m ASL.
- Aspect: nil, N, ENE, E, ESE, SE, S, SSW, SW. • Slope: 0–12°.
- Geology: Quaternary sand.
- Comments: Found in deep, well-drained podzolised sands, typically where somewhat exposed to prevailing onshore winds. The community grades into dry sclerophyll shrubland (often API group 54021/2) on less exposed aspects.

Map localities in northern NSW: Newrybar Swamp, Broadwater NP, Evans Head, Bundjalung NP, Yuraygir NP, Hat Head NP, Limeburners Creek NR.

Equivalent vegetation types: *Banksia aemula* has a coastal distribution, and this extends north from the Central Coast of NSW into south-eastern Queensland. *Leptospermum trinervium* is more widespread (Harden 2002, Queensland Herbarium 1994). As presently circumscribed, the *B. aemula – L. trinervium* community appears to be widespread along the North Coast of NSW to the north of the Hastings River. However, throughout this range some congeneric species interchange across distribution boundaries, for example *Xanthorrhoea johnsonii* north from the Macleay River valley and *Xanthorrhoea glauca* subsp. *glauca* to the south. The community is likely to extend into south-eastern Queensland (Durrington 1977), and it forms part of a *Banksia aemula* (syn. *B. serratifolia*) alliance erected by Beadle (1981).

Community No. 30: *Banksia aemula – Allocasuarina littoralis* dry heathland

Sites: HBR018.1/.2, HYU038.1/.2.

API group: 58031 in part (*Banksia aemula – Allocasuarina littoralis* dry heathland).

Structure: low to tall closed heathland.

Floristic composition:

- Constant species: *Banksia aemula* (V), *Leucopogon leptospermoides* (V), *Caustis recurvata* var. *recurvata* (V), *Monotoca scoparia* (V), *Eriostemon australasius* (V), *Zieria laxiflora* (V), *Bossiaea ensata* (V), *Acacia suaveolens* (V), *Gompholobium virgatum* var. *virgatum* (V), *Allocasuarina littoralis* (V), *Tetratheca thymifolia* (V), *Pomax umbellata* (V), *Hibbertia vestita* (V).
- Cover-abundant species: *Banksia aemula* (3.50; V), *Allocasuarina littoralis* (3.50; V), *Hypolaena fastigiata* (3.00; III), *Platysace lanceolata* (3.00; III), *Leptospermum trinervium* (3.00; III), *Pteridium esculentum* (3.00; III), *Monotoca scoparia* (2.75; V).
- Indicator species: none.
- Exotic species: none.
- Species richness: total = 73; mean (+/- SE) in 25 m² = 33.25 (1.49).
- Comments: This community maintains the identity of API group 58031 for stands in which *Allocasuarina littoralis* clearly co-dominates with *Banksia aemula*. *Boronia rosmarinifolia*, an uncommon species of wallum on the North Coast of NSW, occurs in the community.

Habitat:

- Topographic position: ridges (dunes).
- Altitude: 20–35 m ASL.
- Aspect: E, SSW. • Slope: 9°.
- Geology: Quaternary sand.
- Comments: Found in deep, well-drained podzolised sands, typically where somewhat exposed to prevailing onshore winds. Anecdotal evidence suggests that *Allocasuarina littoralis* develops high cover values under a regime of long inter-fire intervals, for example in parts of Broadwater NP.

Map localities in northern NSW: Broadwater NP, Yuraygir NP.

Equivalent vegetation types: The respective distributions of *Banksia aemula* and *Allocasuarina littoralis* overlap from the Central Coast of NSW northwards into south-eastern Queensland (Harden 1990,1991, Queensland Herbarium 1994). The community appears to have a very scattered distribution along the North Coast of NSW, although it is likely to be present in south-eastern Queensland (Batianoff & Elsol 1989). A related heathland in which another *Allocasuarina*, *A. simulans*, associates with *Banksia aemula* occurs in Booti Booti NP on the lower North Coast of NSW (Griffith et al. 2000). Further south on the Central Coast, McRae (1990) reports *A. distyla* as common in *B. aemula* heathland of Bouddi Peninsula. The community forms part of a *B. aemula* (syn. *B. serratifolia*) alliance erected by Beadle (1981).

Community No. 31: *Banksia aemula* dry heathland

Sites: HKA001.1/.2, HCR025.1/.2, HCR029.1/.2, HCR030.1/.2, HCR034.1/.2, HCR038.1/.2.

API groups: 58021 in part (*Banksia aemula* dry heathland); 58031 in part (*Banksia aemula – Allocasuarina littoralis* dry heathland).

Structure: low to tall closed heathland.

Floristic composition:

- Constant species: *Banksia aemula* (V), *Leucopogon leptospermoides* (V), *Caustis recurvata* var. *recurvata* (V), *Monotoca scoparia* (V), *Phyllota phylicoides* (V), *Hypolaena fastigiata* (V), *Hibbertia fasciculata* (V), *Ricinocarpus pinifolius* (V), *Pimelea linifolia* (V), *Schoenus ericetorum* (V), *Brachyloma daphnoides* (V), *Leucopogon virgatus* (V), *Pseudanthus orientalis* (V), *Leptospermum semibaccatum* (V), *Platysace lanceolata* (V), *Boronia pinnata* (V), *Lomandra glauca* (V).
- Cover-abundant species: *Banksia aemula* (3.42; V), *Philotheca salsolifolia* (3.00; I), *Boronia pinnata* (2.70; V), *Leptospermum semibaccatum* (2.60; V), *Monotoca scoparia* (2.58; V), *Phyllota phylicoides* (2.55; V), *Dillwynia retorta* (2.50; III), *Eriostemon australasius* (2.50; IV), *Coleocarya gracilis* (2.50; I), *Xanthorrhoea glauca* subsp. *glauca* (2.50; III).
- Indicator species: none.
- Exotic species: none.
- Species richness: total = 88; mean (+/- SE) in 25 m² = 32.75 (0.87).
- Comments: This community could be segregated from API groups 58021 and 58031. *Banksia aemula* is present at relatively high mean cover-abundance. Other locally conspicuous species include *Philotheca salsolifolia*, *Boronia pinnata*, *Leptospermum semibaccatum* and *Monotoca scoparia*. The community supports restricted or otherwise uncommon species in the wallum of north-eastern NSW, for example *Acacia quadrilateralis* and *Persoonia katerae*.

Habitat:

- Topographic position: ridges (beach ridges and dunes).
- Altitude: <10, to 60 m ASL.
- Aspect: nil, SE, WNW. • Slope: 0–12°.
- Geology: Quaternary sand.

- Comments: Found in deep, well-drained podzolised sands, typically where somewhat exposed to prevailing onshore winds. The community may grade into wet heathland downslope as soil drainage deteriorates, and into dry sclerophyll shrubland on less exposed aspects.

Map localities in northern NSW: Kattang NR, Crowdy Bay NP.

Equivalent vegetation types: In contrast to *Banksia aemula – Leptospermum trinervium* dry heathland (community No. 29 above), this community represents those dry heathlands of the study area to the south of the Hastings River in which *L. trinervium* is conspicuous by its absence. Conversely, species such as *Boronia pinnata* feature in this community but not to any extent in *B. aemula – L. trinervium* dry heathland. *Hypolaena fastigiata* is constant, possibly linking this community to a *B. aemula – H. fastigiata* one described for the Central Coast of NSW by Adam et al. (1989). The community forms part of a *Banksia aemula* (syn. *B. serratifolia*) alliance erected by Beadle (1981).

Plant community No. 32: *Banksia aemula – Phyllota phylicoides* dry sclerophyll shrubland in Crowdy Bay NP (HCR033.2). *Banksia aemula* forms a tallest stratum to 4 m over lower heath shrubs and herbaceous species.

Community No. 32: *Banksia aemula – Phyllota phylicoides* dry sclerophyll shrubland

Sites: HNE004.1/.2, HBR021.1/.2, HBR023.1/.2, HBR024.1/.2, HBU019.1/.2, HBU033.1/.2, HBU037.1/.2, HBU039.1/.2, HBU040.1/.2, HBU043.1/.2, HBU044.1/.2, HBU048.1/.2, HBU050.1/.2, HBU052.1/.2, HBU054.1/.2, HYU036.1/.2, HYU037.1/.2, HHA002.1/.2, HLI006.1/.2, HLI019.1/.2, HLI021.1/.2, HLI032.1/.2, HCR032.1/.2, HCR033.1/.2.

API group: This community accounts for approximately 90% of samples for 54021/2 (*Banksia aemula* dry sclerophyll shrubland).

Structure: tall to very tall (occasionally extremely tall), sparse to closed shrubland.

Floristic composition:

- Constant species: *Banksia aemula* (V), *Leucopogon leptospermoides* (V), *Hibbertia fasciculata* (V), *Leptospermum polygalifolium* subsp. *cismontanum* (V), *Pseudanthus orientalis* (V), *Monotoca scoparia* (V), *Dillwynia retorta* (V), *Caustis recurvata* var. *recurvata* (V), *Schoenus ericetorum* (V), *Phyllota phylicoides* (V).
- Cover-abundant species: *Banksia aemula* (3.38; V), *Callitris rhomboidea* (3.00; I), *Xanthorrhoea glauca* subsp. *glauca* (2.80; II), *Leptospermum semibaccatum* (2.73; IV), *Leptospermum trinervium* (2.70; III), *Xanthorrhoea johnsonii* (2.64; IV), *Melaleuca nodosa* (2.54; III), *Boronia pinnata* (2.50; II), *Leucopogon leptospermoides* (2.47; V), *Phyllota phylicoides* (2.41; V).
- Indicator species: none.
- Exotic species: none.
- Species richness: total = 138; mean (+/- SE) in 25 m^2 = 30.10 (0.91).
- Comments: *Banksia aemula* is constant (100% occurrence) in the tallest stratum, and has the highest mean cover-abundance. Other relatively constant, cover-abundant species include the understorey heath shrubs *Phyllota phylicoides* (92% occurrence) and *Leucopogon leptospermoides* (98% occurrence). The community supports *Allocasuarina defungens* and *Leucopogon rodwayi*, which are rare in the wallum of northern NSW.

Habitat:

- Topographic position: ridges (dunes and beach ridges).
- Altitude: <10, to 30 m ASL.
- Aspect: nil, N, NE, E, SE, S, SW, WSW, NW. • Slope: 0–5°.
- Geology: Quaternary sand.
- Comments: This community is characteristic of well-drained, podzolised sands. It grades structurally into dry heathland with increasing exposure to onshore winds.

Map localities in northern NSW: Newrybar Swamp, Broadwater NP, Bundjalung NP, Yuraygir NP, Hat Head NP, Limeburners Creek NR, Crowdy Bay NP.

Equivalent vegetation types: *Banksia aemula* has a coastal distribution which extends north from the Central Coast of NSW into south-eastern Queensland, and *Phyllota phylicoides* is more widespread (Harden 2002, Queensland Herbarium 1994). The *B. aemula – P. phylicoides* community appears to be widespread along the North Coast of NSW, and throughout this range some congeneric species interchange across distribution boundaries, for example *Xanthorrhoea johnsonii* north from the Macleay River valley and *Xanthorrhoea glauca* subsp. *glauca* to the south. Similar or related communities are reported for the Central Coast (Benson & Howell 1990), and south-eastern Queensland (Batianoff & Elsol 1989, Dowling & McDonald 1976, Durrington 1977, Sattler & Williams 1999). The community would form part of a *B. aemula* (syn. *B. serratifolia*) alliance established by Beadle (1981).

Community No. 33: *Banksia aemula – Allocasuarina littoralis +/- B. serrata* dry sclerophyll shrubland

Sites: HBR015.1/.2, HBR016.1/.2, HBR017.1/.2, HEV007.1/.2, HYU010.1/.2, HMO003.1/.2, HKA002.1/.2.

API groups: This community accounts for approximately 10% of samples for 54021/2 (*Banksia aemula* dry sclerophyll shrubland), and all samples for 54031/2 (*B. aemula – Allocasuarina littoralis* dry sclerophyll shrubland) and 54051 (*B. serrata – A. littoralis – Leptospermum trinervium* dry sclerophyll shrubland).

Structure: tall to extremely tall, sparse to closed shrubland.

Floristic composition:

- Constant species: *Banksia aemula* (V), *Leucopogon leptospermoides* (V), *Allocasuarina littoralis* (V), *Monotoca elliptica* (IV), *Pteridium esculentum* (IV), *Acacia suaveolens* (IV), *Panicum simile* (IV), *Themeda australis* (IV), *Leptospermum trinervium* (IV), *Dillwynia retorta* (IV), *Caustis recurvata* var. *recurvata* (IV), *Patersonia glabrata* (IV), *Pomax umbellata* (IV).
- Cover-abundant species: *Melaleuca nodosa* (4.00; I), *Hibbertia acuminata* (3.50; I), *Banksia serrata* (3.25; II), *Leptospermum polygalifolium* subsp. *cismontanum* (3.17; III), *Banksia aemula* (3.14; V), *Boronia safrolifera* (3.00; I), *Xanthorrhoea fulva* (3.00; I), *Leptospermum trinervium* (2.91; IV), *Pteridium esculentum* (2.73; IV), *Aotus lanigera* (2.50; I), *Austromyrtus dulcis* (2.50; III), *Austrostipa pubescens* (2.50; I), *Banksia integrifolia* subsp. *integrifolia* (2.50; I), *Acronychia imperforata* (2.33; II), *Allocasuarina littoralis* (2.25; V), *Leptospermum semibaccatum* (2.25; II).
- Indicator species: none.

- Exotic species: *Andropogon virginicus*.
- Species richness: total = 129; mean (+/- SE) in 25 m^2 = 26.64 (2.20).
- Comments: *Banksia aemula* and *Allocasuarina littoralis* are comparatively constant and cover-abundant, generally in the tallest stratum. *Banksia serrata* and *Leptospermum trinervium* are also abundant in the tallest stratum of some stands. Conspicuous understorey species include *Austromyrtus dulcis* and *Pteridium esculentum*. The community supports *Acronychia imperforata* and *Cupaniopsis anacardioides*, tree species that are typical of littoral rainforest (see Floyd 1990). These and other rainforest taxa may recruit into the community in the absence of fire for extended periods. Infrequent fire probably also favours *A. littoralis* (discussed previously). Two taxa, *Abildgaardia vaginata* and *Persoonia katerae*, have restricted distributions in the wallum of northern NSW.

Habitat:

- Topographic position: ridges (dunes).
- Altitude: <10, to 40 m ASL.
- Aspect: nil, NE, S, SW, WSW, WNW. • Slope: 0–12°.
- Geology: Quaternary sand.
- Comments: Often found in well-drained sands close to the sea where the soils are likely to be younger and therefore less podzolised (cf. community No. 32).

Map localities in northern NSW: Broadwater NP, Evans Head, Yuraygir NP, Moonee Beach NR, Kattang NR.

Equivalent vegetation types: This community appears to be sporadic along the North Coast of NSW. A related *Banksia serrata – Allocasuarina littoralis* (syn. *Casuarina littoralis*) low open forest is reported for Newcastle Bight on the lower North Coast (National Parks Association of NSW 1976), and for coastal NSW south from Forster (lower North Coast) Adam et al. (1989) describe a *B. serrata – Allocasuarina distyla* community. Related woodlands and low forests are described for south-eastern Queensland in which *B. serrata* and *A. littoralis* feature with other species, sometimes with *L. trinervium* (syn. *L. stellatum*) common in a lower stratum (Durrington 1977). Batianoff and Elsol (1989) also describe a *B. aemula – A. littoralis* community for south-eastern Queensland.

Community No. 34: *Banksia ericifolia* subsp. *macrantha* +/- *Leptospermum whitei – L. polygalifolium* subsp. *cismontanum* swamp sclerophyll shrubland

Sites: HNE008.1/.2, HCR009.1/.2.

API groups: 55031 in part (*Banksia ericifolia* subsp. *macrantha* swamp sclerophyll shrubland), and all samples for 55111 (*Leptospermum whitei – L. polygalifolium* subsp. *cismontanum* swamp sclerophyll shrubland).

Structure: tall to very tall shrubland and closed shrubland (rarely open shrubland).

Floristic composition:

- Constant species: *Pimelea linifolia* (V), *Sporadanthus interruptus* (V), *Xanthorrhoea fulva* (V), *Banksia ericifolia* subsp. *macrantha* (V), *Dillwynia floribunda* (V), *Burchardia umbellata* (V), *Blandfordia grandiflora* (V), *Gahnia sieberiana* (V).
- Cover-abundant species: *Leptospermum whitei* (4.50; III), *Banksia ericifolia* subsp. *macrantha* (4.00; V), *Leptospermum polygalifolium* subsp. *cismontanum* (3.50; III), *Baeckea frutescens* (3.00; III), *Banksia oblongifolia* (3.00; III), *Empodisma minus* (3.00; III), *Platysace* sp. A (3.00; III).
- Indicator species: *Acacia maidenii* (III; 1.00).
- Exotic species: *Crassocephalum crepidioides*, *Erechtites valerianifolia*.
- Species richness: total = 63; mean (+/- SE) in 25 m^2 = 25.25 (3.59).
- Comments: *Banksia ericifolia* subsp. *macrantha* is constant (100% occurrence) with relatively high mean cover-abundance. The tallest stratum of some stands is clearly dominated by *B. ericifolia* subsp. *macrantha*. In other stands *Leptospermum whitei* and *L. polygalifolium* subsp. *cismontanum* dominate the tallest stratum with *B. ericifolia* subsp. *macrantha* also co-dominant or subsidiary. *Banksia ericifolia* subsp. *macrantha* is fire-sensitive, and therefore likely to vary in cover-abundance with differences in the fire regime.

Habitat:

- Topographic position: open depressions (swales).
- Altitude: <10 m ASL.
- Aspect: nil. • Slope: 0°.
- Geology: Quaternary sand.
- Comments: Found in poorly drained podzolised sands with a shallow watertable.

Map localities in northern NSW: Newrybar Swamp, Crowdy Bay NP.

Equivalent vegetation types: *Banksia ericifolia* subsp. *macrantha* is restricted to the North Coast in NSW, where it has a disjunct distribution north from the Forster area (Harden 2002). Stands of this community dominated by *B. ericifolia* subsp. *macrantha* form part of a *B. ericifolia* (subsp. *ericifolia* and subsp. *macrantha*) alliance for NSW (Beadle 1981). *Banksia ericifolia* subsp. *ericifolia* forms shrublands on the Central Coast of NSW (Benson & Fallding 1981). Stands of the community dominated by *Leptospermum whitei* and *L. polygalifolium* subsp. *cismontanum* possibly form part of a *L. polygalifolium – L. trinervium* (syn. *L. flavescens – L. attenuatum*) alliance (Beadle 1981).

Community No. 35: *Melaleuca sieberi/Banksia ericifolia* subsp. *macrantha – M. thymifolia* swamp sclerophyll shrubland

Sites: HBU036.1/.2, HYU015.1/.2, HLI012.1/.2, HCR039.1/.2.

API groups: 55031 in part (*Banksia ericifolia* subsp. *macrantha* swamp sclerophyll shrubland), and all samples for 55081/2 (*Melaleuca sieberi* swamp sclerophyll shrubland).

Structure: tall to very tall, sparse to closed shrubland.

Floristic composition:

- Constant species: *Entolasia stricta* (V), *Schoenus brevifolius* (V), *Ischaemum australe* (V), *Melaleuca thymifolia* (V), *Callistemon pachyphyllus* (V).
- Cover-abundant species: *Banksia ericifolia* subsp. *macrantha* (4.00; II), *Melaleuca sieberi* (3.67; IV), *Ptilothrix deusta* (3.50; III), *Aristida warburgii* (3.00; II), *Goodenia paniculata* (3.00; II), *Hibbertia vestita* (3.00; II), *Themeda australis* (3.00; II), *Hakea actites* (2.50; III), *Melaleuca thymifolia* (2.38; V).
- Indicator species: none.
- Exotic species: none.
- Species richness: total = 81; mean (+/- SE) in 25 m^2 = 24.38 (3.76).
- Comments: This community comprises shrublands in which the tallest stratum is dominated by either *Melaleuca sieberi* or *Banksia ericifolia* subsp. *macrantha*. Constant, but not necessarily cover-abundant, understorey species include *Entolasia stricta*, *Schoenus brevifolius*, *Callistemon pachyphyllus* and *Melaleuca thymifolia* (all with 100% occurrence). *Banksia ericifolia* subsp. *macrantha* is fire-sensitive, and therefore likely to vary in cover-abundance with differences in the fire regime. *Almaleea paludosa* occurs in the community, and is apparently rare in the wallum and associated vegetation of northern NSW.

Habitat:

- Topographic position: flats (plains and backplains), open depressions (swales).
- Altitude: <10, to 40 m ASL.

- Aspect: nil, ESE. • Slope: 0–1°.
- Geology: Quaternary sediments.
- Comments: Often associated with heavier-textured soils (at least in the profile surface) than community No. 34, and periodically water-logged or inundated.

Map localities in northern NSW: Bundjalung NP, Yuraygir NP, Limeburners Creek NR, Crowdy Bay NP.

Equivalent vegetation types: *Banksia ericifolia* subsp. *macrantha* is restricted to the North Coast in NSW, where it has a disjunct distribution north from the Forster area (Harden 2002). Stands of this community dominated by *B. ericifolia* subsp. *macrantha* form part of a *B. ericifolia* (subsp. *ericifolia* and subsp. *macrantha*) alliance for NSW (Beadle 1981). *Banksia ericifolia* subsp. *ericifolia* forms shrublands on the Central Coast of NSW (Benson & Fallding 1981). *Melaleuca sieberi* reaches its southern distribution limit in the Gosford area on the Central Coast of NSW (Harden 2002), and Benson (1986) reports the species as a dominant of some swamp forests and 'scrubs' in this region. A *M. sieberi* scrub is also reported for south-eastern Queensland (Dowling & McDonald 1976).

Community No. 36: *Melaleuca quinquenervia – Baumea teretifolia* swamp sclerophyll shrubland

Sites: HNE009.1/.2, HBR002.1/.2, HHA020.1/.2.

API group: 55061/2 in part (*Melaleuca quinquenervia* swamp sclerophyll shrubland).

Structure: tall to very tall, sparse to closed shrubland.

Floristic composition:

- Constant species: *Melaleuca quinquenervia* (V), *Baumea teretifolia* (V), *Blechnum indicum* (IV), *Baumea rubiginosa* (IV), *Baloskion pallens* (IV), *Leptospermum juniperinum* (IV).
- Cover-abundant species: *Blechnum indicum* (4.00; IV), *Baumea articulata* (3.00; II), *Gahnia sieberiana* (3.00; II), *Melaleuca quinquenervia* (3.00; V), *Baumea teretifolia* (2.83; V), *Baloskion pallens* (2.75; IV).
- Indicator species: none.
- Exotic species: none.
- Species richness: total = 25; mean (+/- SE) in 25 m^2 = 8.17 (1.92).
- Comments: *Baumea teretifolia* is conspicuous (100% occurrence) in the understorey of this *Melaleuca quinquenervia* shrubland. It supports *Durringtonia paludosa*, a restricted species and monotypic genus.
- Topographic position: closed depressions (swamps).
- Altitude: <10 m ASL.
- Aspect: nil. • Slope: 0°.
- Geology: Quaternary sand.
- Comments: Found in swamps where standing water is present for extended periods.

Map localities in northern NSW: Newrybar Swamp, Broadwater NP, Hat Head NP.

Equivalent vegetation types: *Melaleuca quinquenervia* has a coastal distribution which extends from the Central Coast of NSW into northern Queensland, and *Baumea teretifolia* is more widespread (Harden 1993, 2002, Queensland Herbarium 1994). Minor occurrences of *M. quinquenervia* shrubland are reported for south-eastern Queensland (McDonald & Elsol 1984), and also related heathlands in which *M. quinquenervia* is dominant or co-dominant (Batianoff & Elsol 1989, Dowling & McDonald 1976, Durrington 1977).

Community No. 37: *Melaleuca quinquenervia – Baumea juncea* swamp sclerophyll shrubland

Sites: HYU009.1/.2, HKA003.1/.2.

API group: 55061/2 in part (*Melaleuca quinquenervia* swamp sclerophyll shrubland).

Structure: tall shrubland and closed shrubland.

Floristic composition:

- Constant species: *Parsonsia straminea* (V), *Melaleuca quinquenervia* (V), *Baumea juncea* (V), *Dianella caerulea* (IV), *Blechnum indicum* (IV).
- Cover-abundant species: *Melaleuca quinquenervia* (4.50; V), *Baumea rubiginosa* (3.00; III), *Baumea arthrophylla* (2.50; III), *Baumea juncea* (2.50; V), *Histiopteris incisa* (2.50; III).
- Indicator species: *Hypolepis muelleri* (III; 2.00), *Utricularia uliginosa* (III; 2.00), *Entolasia marginata* (III; 1.00), *Oplismenus imbecillis* (III; 1.00).
- Exotic species: *Chrysanthemoides monilifera* subsp. *rotundata*, *Lantana camara*.
- Species richness: total = 46; mean (+/- SE) in 25 m^2 = 18.00 (1.41).
- Comments: *Baumea juncea* is conspicuous in the understorey of this *Melaleuca quinquenervia* shrubland. Both species are constant (100% occurrence).

Habitat:

- Topographic position: open (drainage) depressions, closed depressions (swamps).
- Altitude: <10, to 25 m ASL.
- Aspect: nil. • Slope: 0°.
- Geology: Quaternary sand (mantling bedrock at one location).
- Comments: Likely to be associated with more saline conditions than the previous community (No. 36), as indicated by the presence of *Baumea juncea*, a species also found in saltmarsh vegetation (Adam et al. 1988).

Map localities in northern NSW: Yuraygir NP, Kattang NR.

Equivalent vegetation types: *Melaleuca quinquenervia* has a coastal distribution which extends from the Central Coast of NSW into northern Queensland, and *Baumea juncea* is more widespread (Harden 1993, 2002, Queensland Herbarium 1994). Minor occurrences of *M. quinquenervia* shrubland are reported for south-eastern Queensland (McDonald & Elsol 1984), and also related heathlands in which *M. quinquenervia* is dominant or co-dominant (Batianoff & Elsol 1989, Dowling & McDonald 1976, Durrington 1977).

Community No. 38: *Leptospermum speciosum* swamp sclerophyll shrubland

Sites: HBR020.1/.2.

API group: 55101 (*Leptospermum speciosum* swamp sclerophyll shrubland).

Structure: tall to very tall closed shrubland.

Floristic composition:

- Constant species: *Leucopogon lanceolatus* var. *gracilis* (V), *Pteridium esculentum* (V), *Elaeocarpus reticulatus* (V), *Entolasia stricta* (V), *Leptospermum speciosum* (V), *Baloskion tetraphyllum* subsp. *meiostachyum* (V), *Blechnum indicum* (V), *Gahnia clarkei* (V), *Kennedia rubicunda* (V), *Acacia elongota* (V).
- Cover-abundant species: *Leptospermum speciosum* (5.00; V), *Baloskion tetraphyllum* subsp. *meiostachyum* (4.00; V), *Blechnum indicum* (3.50; V), *Entolasia stricta* (3.00; V), *Pteridium esculentum* (3.00; V), *Gahnia clarkei* (2.50; V).
- Indicator species: *Leptospermum speciosum* (V; 5.00), *Ageratum houstonianum* (III; 1.00), *Conyza albida* (III; 1.00), *Melastoma affine* (III; 1.00), *Oxylobium robustum* (III: 1.00).
- Exotic species: *Ageratum houstonianum*, *Conyza albida*.
- Species richness: total = 19; mean (+/- SE) in 25 m^2 = 15.00 (2.00).
- Comments: *Leptospermum speciosum* dominates the tallest stratum. Conspicuous understorey species include *Baloskion tetraphyllum* subsp. *meiostachyum* and *Blechnum indicum*.

Habitat:

- Topographic position: open (drainage) depression.
- Altitude: <10 m ASL.
- Aspect: nil. • Slope: 0°.
- Geology: Quaternary sand.
- Comments: Found in poorly drained podzolised sands with a shallow watertable.

Map localities in northern NSW: Broadwater NP.

Equivalent vegetation types: *Leptospermum speciosum* has a coastal distribution, and extends from the Clarence River district (far NSW North Coast) into south-eastern Queensland (Harden 2002, Queensland Herbarium 1994). A related *L. speciosum* closed heathland is known for Queensland (Elsol & Sattler 1979, in Batianoff & Elsol 1989).

Community No. 39: *Leptospermum juniperinum* swamp sclerophyll shrubland

Sites: HCR012.1/.2.

API group: 55041 (*Leptospermum juniperinum* swamp sclerophyll shrubland).

Structure: tall to very tall shrubland and closed shrubland.

Floristic composition:

- Constant species: *Entolasia stricta* (V), *Imperata cylindrica* var. *major* (V), *Baloskion tetraphyllum* subsp. *meiostachyum* (V), *Blechnum indicum* (V), *Baumea teretifolia* (V), *Hemarthria uncinata* (V), *Chorizandra sphaerocephala* (V), *Gonocarpus tetragynus* (V), *Sphaerolobium vimineum* (V), *Leptospermum juniperinum* (V), *Gleichenia dicarpa* (V), *Empodisma minus* (V).
- Cover-abundant species: *Leptospermum juniperinum* (4.50; V), *Baloskion tetraphyllum* subsp. *meiostachyum* (4.00; V), *Chorizandra sphaerocephala* (3.00; V), *Gleichenia dicarpa* (3.00; V).
- Indicator species: none.
- Exotic species: none.
- Species richness: total = 14; mean (+/- SE) in 25 m^2 = 13.00 (0.00).
- Comments: *Leptospermum juniperinum* dominates the tallest stratum, and *Baloskion tetraphyllum* subsp. *meiostachyum* is conspicuous in the understorey. Both species are constant (100% occurrence).

Habitat:

- Topographic position: open (drainage) depression.
- Altitude: 35 m ASL.
- Aspect: NNW. • Slope: 3°.
- Geology: rhyolite.
- Comments: As sampled, this community was restricted to a narrow drainage line on a coastal hill.

Map localities in northern NSW: Crowdy Bay NP, and possibly Newrybar Swamp (the latter location requires sampling).

Equivalent vegetation types: *Leptospermum juniperinum* is widespread on the coast and adjoining tablelands of NSW, and continues into Queensland (Harden 2002, Queensland Herbarium 1994). Nonetheless, the community appears to have a scattered distribution along the North Coast. For Brisbane Waters NP on the Central Coast, Benson and Fallding (1981) report *L. juniperinum* as a dominant in poorly drained situations. *Leptospermum juniperinum* is a common species of wet heathland in coastal south-western Victoria (Head 1988).

Community No. 40: *Lophostemon confertus* dry sclerophyll mallee shrubland

Sites: HBR026.1/.2.

API group: 56021 (*Lophostemon confertus* dry sclerophyll mallee shrubland).

Structure: very tall closed mallee shrubland.

Floristic composition:

- Constant species: *Lophostemon confertus* (V), *Imperata cylindrica* var. *major* (V), *Acronychia imperforata* (V), *Cupaniopsis anacardioides* (V), *Cyperus stradbrokensis* (V), *Paspalidium distans* (V), *Geitonoplesium cymosum* (V), *Banksia integrifolia* subsp. *integrifolia* (V), *Acacia disparrima* subsp. *disparrima* (V), *Lomandra laxa* (V), *Chrysanthemoides monilifera* subsp. *rotundata* (V), *Austromyrtus dulcis* (V), *Hibbertia scandens* (V), *Lomandra longifolia* (V), *Cassytha pubescens* (V), *Pteridium esculentum* (V), *Pomax umbellata* (V), *Pandorea pandorana* (V).
- Cover-abundant species: *Lophostemon confertus* (5.00; V), *Acronychia imperforata* (3.00; V), *Austromyrtus dulcis* (3.00; V), *Chrysanthemoides monilifera* subsp. *rotundata* (3.00; V), *Lomandra longifolia* (2.50; V).
- Indicator species: *Lophostemon confertus* (V; 5.00), *Acronychia imperforata* (V; 3.00), *Acacia disparrima* subsp. *disparrima* (V; 1.00), *Cupaniopsis anacardioides* (V; 1.00), *Cyperus stradbrokensis* (V; 1.00), *Lomandra laxa* (V; 1.50), *Cyperus enervis* (III; 1.00), *Pittosporum revolutum* (III; 1.00), *Rapanea variabilis* (III; 1.00).
- Exotic species: *Chrysanthemoides monilifera* subsp. *rotundata*.
- Species richness: total = 26; mean (+/- SE) in 25 m^2 = 22.00 (2.00).
- Comments: *Lophostemon confertus* dominates the tallest stratum, and conspicuous understorey species include *Austromyrtus dulcis*, *Chrysanthemoides monilifera* subsp. *rotundata* and *Lomandra longifolia*.

Habitat:

- Topographic position: ridge (foredune).
- Altitude: 10 m ASL.
- Aspect: nil. • Slope: 0°.
- Geology: Quaternary sand.
- Comments: Found in well-drained foredune sands where the soils are likely to be younger and therefore less podzolised than those of inland sand masses.

Map localities in northern NSW: Broadwater NP.

Equivalent vegetation types: The natural distribution of *Lophostemon confertus* extends north from the Hunter River district on the lower North Coast of NSW, and continues into Queensland (Harden 2002, Queensland Herbarium 1994). This community is apparently uncommon along the North Coast, although similar *L. confertus* mallee is likely to occur in south-eastern Queensland (Dowling & McDonald 1976, Durrington 1977, Elsol & Dowling 1978). A related *L. confertus* littoral rainforest occupies North Coast headlands in soils derived from bedrock, and this may be reduced to mallee (Floyd 1990).

Community No. 41: *Eucalyptus robusta/E. signata – Baloskion tetraphyllum* subsp. *meiostachyum* swamp sclerophyll mallee shrubland, mallee forest and mallee woodland

Sites: HNE007.1/.2, HBR007.1/.2, HMO004.1/.2, HLA003.1/.2, HLA004.1/.2.

API groups: 50031/2 in part (*Eucalyptus signata* dry sclerophyll mallee forest and woodland); and all samples for 51021/2 (*E. robusta* swamp sclerophyll mallee forest and woodland) and 57022 (*E. robusta* swamp sclerophyll mallee shrubland).

Structure: very tall sparse to open mallee shrubland; very tall to extremely tall, open mallee woodland to closed mallee forest.

Floristic composition:

- Constant species: *Leptospermum polygalifolium* subsp. *cismontanum* (V), *Leucopogon lanceolatus* var. *gracilis* (V), *Baloskion tetraphyllum* subsp. *meiostachyum* (IV), *Cassytha glabella* forma *glabella* (IV), *Elaeocarpus reticulatus* (IV), *Eucalyptus robusta* (IV), *Xanthorrhoea fulva* (IV).
- Cover-abundant species: *Eucalyptus robusta* (4.00; IV), *E. signata* (3.50; I), *Baloskion tetraphyllum* subsp. *meiostachyum* (3.25; IV), *Baeckea frutescens* (3.00; II), *Gleichenia mendellii* (3.00; I), *Melaleuca nodosa* (3.00, II), *Xanthorrhoea fulva* (2.71; IV), *Blechnum indicum* (2.60; III), *Leptospermum polygalifolium* subsp. *cismontanum* (2.60; V), *Acacia elongata* (2.50, I), *Gahnia clarkei* (2.50; I), *Pteridium esculentum* (2.50; III).
- Indicator species: none.
- Exotic species: *Chrysanthemoides monilifera* subsp. *rotundata*.
- Species richness: total = 78; mean (+/- SE) in 25 m^2 = 17.70 (2.21).
- Comments: *Eucalyptus robusta* commonly dominates the tallest stratum, or occasionally *E. signata*. Comparatively constant, cover-abundant understorey species are *Baloskion tetraphyllum* subsp. *meiostachyum* (80% occurrence), *Leptospermum polygalifolium* subsp. *cismontanum* (100% occurrence) and *Xanthorrhoea fulva* (70% occurrence). Samples of API group 50031/2 included in this community (cf. community No. 42) suggest that a swamp facies of *E. signata* mallee should be recognised on the basis of understorey composition.

Habitat:

- Topographic position: open (drainage) depressions in which *Eucalyptus robusta* dominates, or ridges (dunes) of minimal relief where *E. signata* dominates.
- Altitude: <10 m ASL.
- Aspect: nil.
- Slope: 0°.
- Geology: Quaternary sand.
- Comments: Characteristic of poorly drained, podzolised sands.

Map localities in northern NSW: Newrybar Swamp, Broadwater NP, Evans Head, Moonee Beach NR, Lake Innes NR, Crowdy Bay NP, Booti Booti NP.

Equivalent vegetation types: The distributions of *Eucalyptus robusta*, *E. signata* and *Baloskion tetraphyllum* subsp. *meiostachyum* overlap in coastal districts of NSW and Queensland to the north of the upper Central Coast (Harden 1993, 2002, Queensland Herbarium 1994). The community appears to have a scattered distribution along the North Coast, and for this region other studies also document mallee stands of *E. robusta* and *E. signata* (Murray 1989, Pressey & Griffith 1992). *Eucalyptus signata* mallee occurs in south-eastern Queensland (Durrington 1977).

Community No. 42: *Eucalyptus pilularis/E. planchoniana/E. signata – Leptospermum trinervium* dry sclerophyll mallee shrubland, mallee forest and mallee woodland.

Sites: HBR019.1/.2, HBR022.1/.2, HEV004.1/.2, HEV005.1/.2, HBU016.1/.2, HBU018.1/.2, HBU023.1/.2, HBU024.1/.2, HYU033.1/.2, HYU035.1/.2, HHA003.1/.2, HHA005.1/.2, HHA016.1/.2, HLI016.1/.2, HCR026.1/.2.

API groups: 50031/2 in part (*Eucalyptus signata* dry sclerophyll mallee forest and woodland); and all samples for 50021/2 (*E. pilularis* dry sclerophyll mallee forest and woodland), 50041/2 (*E. planchoniana* dry sclerophyll mallee forest and woodland), 50071 (*E. pilularis/E. planchoniana/Corymbia gummifera* dry sclerophyll mallee forest), 56031/2 (*E. pilularis* dry sclerophyll mallee shrubland) and 56041 (*E. planchoniana* dry sclerophyll mallee shrubland).

Structure: tall to very tall, sparse to closed mallee shrubland; tall to extremely tall, open mallee woodland to closed mallee forest.

Floristic composition:

- Constant species: *Banksia aemula* (V), *Pimelea linifolia* (V), *Leptospermum trinervium* (V), *Acacia ulicifolia* (V), *A. suaveolens* (V), *Caustis recurvata* var. *recurvata* (V), *Leucopogon leptospermoides* (V), *Xanthorrhoea johnsonii* (V).
- Cover-abundant species: *Eucalyptus signata* (3.50; I), *E. planchoniana* (3.43; III), *E. pilularis* (3.19; III), *Aotus ericoides* (3.00; I), *Xanthorrhoea glauca* subsp. *glauca* (3.00; I), *X. johnsonii* (2.92; V), *Banksia aemula* (2.80; V), *Phyllota phylicoides* (2.76; IV), *Corymbia gummifera* (2.50; I), *Monotoca scoparia* (2.50; IV), *Leptospermum trinervium* (2.48; V), *Boronia pinnata* (2.44; II), *Leucopogon leptospermoides* (2.43; V).
- Indicator species: *Eucalyptus pilularis* (III; 3.19).
- Exotic species: none.
- Species richness: total = 112; mean (+/- SE) in 25 m^2 = 26.57 (1.11).
- Comments: Comprises mallee vegetation with a tallest stratum dominated by varying combinations of *Eucalyptus pilularis* and *E. planchoniana* (+/- *Corymbia gummifera*), or rarely *E. signata*. Comparatively constant, cover-abundant understorey species include *Banksia aemula*, *Leptospermum trinervium*, *Monotoca scoparia*, *Phyllota phylicoides* and *Xanthorrhoea johnsonii* (north from the Macleay River district).

Habitat:

- Topographic position: ridges (dunes, or rarely beach ridges).
- Altitude: <10, to 50 m ASL.
- Aspect: N, NNE, NE, ENE, E, ESE, SE, S, SSW, W, WNW, NNW.
- Slope: 2–15°.
- Geology: Quaternary sand.
- Comments: Characteristic of well-drained, podzolised sands.

Map localities in northern NSW: Broadwater NP, Evans Head, Bundjalung NP, Yuraygir NP, Hat Head NP, Limeburners Creek NR, Lake Innes NR, Crowdy Bay NP, Booti Booti NP.

Equivalent vegetation types: The distributions of *Eucalyptus pilularis*, *E. planchoniana*, *E. signata* and *Leptospermum trinervium* overlap along much of the NSW North Coast and in southern Queensland (Harden 1993, 2002, Queensland Herbarium 1994). *Eucalyptus planchoniana* is common in some 'mallee-heaths' of south-eastern Queensland (Clifford & Specht 1979, Dowling & McDonald 1976, Elsol & Dowling 1978, McDonald & Elsol 1984), and in places becomes a community dominant (W. McDonald, Queensland Herbarium pers. comm., Sattler & Williams 1999). *Eucalyptus signata* mallee is also known for south-eastern Queensland (Durrington 1977).

Appendix 2. Synoptic constancy table for plant communities

This table complements plant community descriptions provided as Appendix 1, and the numbering (1–42) is identical:

1: *Baumea rubiginosa* tall to very tall closed sedgeland
2: *Lepironia articulata* very tall closed sedgeland
3: *Baumea articulata* very tall sedgeland and closed sedgeland
4: *Eleocharis sphacelata* tall to very tall closed sedgeland
5: *Baumea arthrophylla* tall to very tall closed sedgeland
6: *Cladium procerum* very tall closed sedgeland
7: *Typha orientalis* very tall rushland and closed rushland
8: *Blechnum indicum* tall to very tall closed fernland
9: *Baloskion pallens – Melaleuca quinquenervia* mid-high to tall closed sedgeland–heathland
10: *Gahnia sieberiana – Gleichenia* tall to very tall closed sedgeland
11: *Leptocarpus tenax – Baloskion pallens* tall to very tall closed sedgeland
12: *Schoenus brevifolius – Baumea teretifolia* tall to very tall closed sedgeland
13: *Baloskion pallens – Baumea teretifolia* tall to very tall closed sedgeland
14: *Themeda australis* low to tall closed sod grassland
15: *Themeda australis – Ptilothrix deusta* mid-high to tall closed tussock grassland
16: *Themeda australis – Banksia oblongifolia – Aristida warburgii* (occasionally dwarf to) low to mid-high closed heathland
17: *Ptilothrix deusta – Aristida warburgii – Hakea teretifolia* subsp. *teretifolia* low to tall closed heathland
18: *Ptilothrix deusta – Banksia oblongifolia – Mirbelia rubiifolia* low to mid-high closed heathland
19: *Ptilothrix deusta – Aristida warburgii – Banksia oblongifolia – Allocasuarina littoralis – Epacris pulchella* low to mid-high (occasionally dwarf or tall) closed heathland
20: *Banksia oblongifolia – Ptilothrix deusta – Aristida warburgii – Allocasuarina littoralis* low to mid-high (occasionally dwarf or tall)closed heathland
21: *Leptospermum juniperinum* mid-high to tall heathland and closed heathland
22: *Xanthorrhoea fulva – Ptilothrix deusta* low to tall closed heathland
23: *Banksia oblongifolia – Leptospermum polygalifolium* subsp. *cismontanum – Melaleuca nodosa* low to tall heathland and closed heathland
24: *Sporadanthus interruptus – Xanthorrhoea fulva – Banksia ericifolia* subsp. *macrantha – Leptospermum liversidgei – Baeckea frutescens* (rarely low to) mid-high to tall closed heathland
25: *Sporadanthus interruptus – Xanthorrhoea fulva* low to tall closed heathland
26: *Banksia oblongifolia – Xanthorrhoea fulva* low to tall closed heathland
27: *Xanthorrhoea fulva – Schoenus paludosus – Banksia ericifolia* subsp. *macrantha* low to tall closed heathland
28: *Leptospermum liversidgei – Sporadanthus interruptus – Empodisma minus* low to tall closed heathland
29: *Banksia aemula – Leptospermum trinervium* low to tall closed heathland
30: *Banksia aemula – Allocasuarina littoralis* low to tall closed heathland
31: *Banksia aemula* low to tall closed heathland
32: *Banksia aemula – Phyllota phylicoides* tall to very tall (occasionally extremely tall), sparse to closed shrubland
33: *Banksia aemula – Allocasuarina littoralis +/- B. serrata* tall to extremely tall, sparse to closed shrubland
34: *Banksia ericifolia* subsp. *macrantha +/- Leptospermum whitei – L. polygalifolium* subsp. *cismontanum* tall to very tall shrubland and closed shrubland, or rarely open shrubland
35: *Melaleuca sieberi/Banksia ericifolia* subsp. *macrantha – M. thymifolia* tall to very tall, sparse to closed shrubland
36: *Melaleuca quinquenervia – Baumea teretifolia* tall to very tall, sparse to closed shrubland
37: *Melaleuca quinquenervia – Baumea juncea* tall shrubland and closed shrubland
38: *Leptospermum speciosum* tall to very tall closed shrubland
39: *Leptospermum juniperinum* tall to very tall shrubland and closed shrubland
40: *Lophostemon confertus* very tall closed mallee shrubland
41: *Eucalyptus robusta/E. signata – Baloskion tetraphyllum* subsp. *meiostachyum* very tall sparse to open mallee shrubland, and very tall to extremely tall, open mallee woodland to closed mallee forest
42: *Eucalyptus pilularis/E. planchoniana/E. signata – Leptospermum trinervium* tall to very tall, sparse to closed mallee shrubland, and tall to extremely tall, open mallee woodland to closed mallee forest.

Constancy classes: I = 1–20% of quadrats; II = 21–40%; III = 41–60%; IV = 61–80%; and V = 81–100%. Note: for communities represented by fewer than 5 quadrats, some constancy classes are not applicable (e.g. community 18 was sampled in 2 quadrats, and classes V and III are the only alternatives).

Species exhibiting high fidelity to a particular community (fidelity index >/= 0.8, and occurring in >/= 50% of quadrats) are denoted with an asterisk (*).

An average cover class score is provided for all species in each community. These are mean rankings for six foliage cover classes: 1 (<1% cover); 2 (1–5%); 3 (6–25%); 4 (26–50%); 5 (51–75%); and 6 (76–100%).

	Community (constancy; average cover)
Class LYCOPSIDA	
LYCOPODIACEAE	
Lycopodiella lateralis	25(I;1.50) 28(II;1.67)
SELAGINELLACEAE	
Selaginella uliginosa	11(III;1.62) 15(III;1.00) 21(II;1.00) 22(I;1.00) 23(II;1.00) 24(V;1.44) 25(IV;1.12) 26(III;1.40) 27(V;2.00) 28(III;1.25) 31(II;1.00) 32(I;1.17) 35(II;1.00) 36(I;1.00) 41(II;1.25)
Class FILICOPSIDA	
ASPLENIACEAE	
Asplenium sp.	25(I;1.00)
AZOLLACEAE	
Azolla filiculoides	7(II;1.00)
Azolla pinnata	3(I;1.00)
BLECHNACEAE	
Blechnum indicum	1(I;1.00) 6(III;1.50) 8(V;5.00) 10(III;2.00) 11(II;1.88) 13(I;1.00) 21(V;1.57) 36(IV;4.00) 37(IV;1.33) 38(V;3.50) 39(V;2.00) 41(III;2.60)

DENNSTAEDTIACEAE

Histiopteris incisa 34(II;2.00) 37(III;2.50)

Hypolepis muelleri 37*(III;2.00)

Pteridium esculentum 23(II;4.00) 25(I;1.00) 26(I;1.00) 28(I;1.50) 29(I;1.00) 30(III;3.00) 32(I;1.33) 33(IV;2.73) 34(II;2.00) 38(V;3.00) 40(V;1.50) 41(III;2.50) 42(IV;1.79)

GLEICHENIACEAE

Gleichenia dicarpa 10(II;5.50) 21(II;1.00) 34(III;1.50) 39(V;3.00)

Gleichenia mendellii 10(IV;4.83) 21(I;1.00) 28(I;3.00) 41(I;3.00)

LINDSAEACEAE

Lindsaea linearis 16(III;1.00) 17(IV;1.00) 18(III;1.00) 35(II;1.00)

Lindsaea sp. 20(I;1.00)

SALVINIACEAE

Salvinia molesta 1(I;2.50) 6(III;4.00) 7(II;1.00)

SCHIZAEACEAE

Schizaea bifida 16(II;1.00) 18(III;1.00) 22(I;1.00) 25(I;1.00) 28(II;1.00) 29(I;1.00) 32(I;1.00) 37(II;1.00) 42(I;1.00)

Schizaea dichotoma 29(III;1.08) 30(III;2.00) 32(I;1.00) 33(II;1.00) 42(I;1.00)

Class CONIFEROPSIDA

CUPRESSACEAE

Callitris columellaris 18*(III;1.00)

Callitris rhomboidea 29(I;1.00) 32(I;3.00) 42(I;1.00)

Class MAGNOLIOPSIDA – LILIIDAE

ANTHERICACEAE

Caesia parviflora 17*(III;1.00) 29(I;1.00)

Laxmannia gracilis 23(IV;1.50) 25(I;1.00) 26(I;1.00) 29(II;1.29) 30(III;1.00) 32(II;1.00) 33(I;1.00) 42(II;1.00)

Sowerbaea juncea 14(I;1.00) 17(V;1.00) 20(I;1.00) 22(I;1.00) 23(II;1.00) 25(II;1.15) 26(I;1.00) 27(V;1.50) 28(I;1.20) 31(I;1.00) 32(I;1.00) 42(I;1.00)

Thysanotus juncifolius 17(II;1.00) 31(I;1.00)

Tricoryne elatior 14(II;1.00) 16(IV;1.00) 17(V;1.00) 18(V;1.00) 22(I;1.00) 23(I;1.00) 25(I;1.00) 29(II;1.43) 30(IV;1.00) 32(I;1.00) 33(II;1.00) 42(I;1.00)

Tricoryne simplex 17(II;1.00)

BLANDFORDIACEAE

Blandfordia grandiflora 10(I;1.00) 22(II;1.00) 23(II;1.00) 24(II;1.00) 25(III;1.06) 26(V;1.78) 27(V;2.00) 28(III;1.87) 32(I;1.00) 34(V;1.00) 35(II;1.00)

COLCHICACEAE

Burchardia umbellata 15(III;1.00) 16(II;1.00) 17(II;1.00) 19(IV;1.00) 20(IV;1.00) 22(IV;1.00) 24(III;1.00) 25(III;1.00) 26(V;1.00) 27(V;1.00) 28(II;1.00) 31(II;1.00) 32(I;1.00) 34(V;1.00) 35(II;1.00)

Wurmbea biglandulosa 22(I;1.00)

CYPERACEAE

Abildgaardia vaginata 33(I;1.50)

Baumea acuta 25(I;1.00)

Baumea arthrophylla 1(II;1.50) 3(II;1.00) 4(II;1.00) 5(V;3.5) 11(III;1.85) 12(III;1.33) 36(I;1.00) 37(III;2.50)

Baumea articulata 1(I;1.00) 2(III;1.25) 3(V;4.12) 4(III;1.00) 6(III;1.00) 7(III;1.00) 36(II;3.00) 37(III;2.00)

Baumea juncea 9(II;4.00) 22(I;1.00) 37(V;2.50)

Baumea muelleri 21(I;1.00) 24(IV;1.17) 25(IV;1.23) 26(II;1.00) 28(V;1.54) 41(I;1.00)

Baumea rubiginosa 1(V;3.83) 2(III;2.25) 3(II;1.33) 4(III;2.00) 5(II;1.00) 6(III;1.50) 7(III;2.00) 8(II;1.00) 10(I;1.00) 11(I;1.67) 13(I;1.00) 21(V;2.00) 36(IV;2.25) 37(III;3.00) 41(I;2.00)

Baumea teretifolia 1(II;1.50) 2(II;1.67) 4(III;2.00) 9(III;2.33) 10(III;1.50) 11(V;2.04) 12(V;3.00) 13(V;2.44) 15(II;1.00) 21(V;2.00) 22(I;1.00) 24(I;1.00) 25(I;1.00) 26(III;1.33) 27(III;1.00) 28(I;1.00) 35(III;2.00) 36(V;2.83) 39(V;1.00)

Carex breviculmis 14*(IV;1.00)

Caustis blakei subsp. *blakei* 42(I;2.33)

Caustis recurvata var. *recurvata* 23(III;1.67) 24(I;1.50) 25(II;1.96) 26(I;1.00) 28(I;1.00) 29(V;1.69) 30(V;2.25) 31(V;2.42) 32(V;2.04) 33(IV;1.90) 41(I;2.00) 42(V;1.28)

Chorizandra cymbaria 11(I;1.00) 12(II;1.00) 21(I;1.00) 22(I;1.00) 35(II;1.00)

Chorizandra sphaerocephala 1(I;1.00) 10(II;1.50) 11(II;1.91) 12(V;2.67) 15(III;1.00) 21(IV;1.60) 22(III;1.44) 24(I;1.00) 25(I;1.12) 27(V;1.00) 28(I;2.00) 35(III;1.50) 39(V;3.00)

Cladium procerum 6*(V;5.00)

Cyperus enervis 40*(III;1.00)

Cyperus stradbrokensis 40*(V;1.00)

Eleocharis sphacelata 3(III;1.00) 4(V;3.75) 5(III;1.00)

Fimbristylis cinnamometorum 20*(III;1.30)

Fimbristylis dichotoma 14(I;1.00)

Gahnia clarkei 37(II;1.00) 38(V;2.50) 41(I;2.50)

Gahnia sieberiana 10(V;3.50) 11(I;1.50) 21(IV;2.00) 22(I;1.50) 24(I;1.00) 25(II;1.22) 26(I;2.00) 28(IV;1.28) 32(I;1.00) 34(V;1.25) 36(II;3.00) 41(III;2.00)

Gymnoschoenus sphaerocephalus 25(I;2.17) 27*(V;2.00)

Isolepis nodosa 37(II;1.00) 40(III;1.00)

Lepidosperma concavum 29(II;1.62) 31(I;2.00) 32(I;1.00) 33(I;1.50) 42(I;1.00)

Lepidosperma filiforme 23(II;2.00) 25(II;1.62) 26(I;1.50)

Lepidosperma laterale 16(V;1.50) 17(V;1.00) 18(V;2.00) 19(V;1.00) 20(IV;1.00) 35(I;1.00)

Lepidosperma longitudinale 22(I;1.00)

Lepidosperma neesii 16(V;2.25) 17(V;1.75) 20(II;1.30) 22(II;1.25) 23(II;1.00) 25(I;1.33) 26(I;3.00) 35(II;1.50)

Lepidosperma quadrangulatum 22(I;1.50) 28(I;1.00)

Lepironia articulata 2*(V;3.75) 13(I;1.00)

Ptilothrix deusta 15(V;3.50) 17(V;4.50) 18(V;5.00) 19(V;4.67) 20(V;3.60) 22(V;4.14) 23(II;1.00) 25(I;2.00) 26(I;1.00) 35(III;3.50)

Schoenus apogon 14(II;1.33)

Schoenus brevifolius 1(I;1.50) 8(II;2.00) 9(II;1.00) 11(III;2.37) 12(V;3.00) 13(IV;2.17) 15(V;1.50) 16(IV;1.00) 17(V;1.50) 18(III;1.00) 20(I;1.00) 21(II;1.00) 22(V;1.48) 23(II;1.00) 24(I;1.00) 25(III;1.24) 26(III;1.33) 27(V;2.00) 28(I;1.00) 32(I;1.00) 35(V;2.00) 37(III;2.00) 39(III;1.00) 41(I;2.00)

Schoenus ericetorum 17(II;1.00) 23(I;1.00) 29(V;1.59) 30(III;2.00) 31(V;1.90) 32(V;1.50) 33(III;1.71) 42(IV;1.00)

Schoenus lepidosperma subsp. *pachylepis* 24(I;1.00) 25(IV;1.71) 26(III;1.00) 28(II;1.22) 32(I;1.00) 34(II;1.00)

Schoenus paludosus 11(I;1.00) 22(I;1.50) 25(I;1.17) 26(I;1.00) 27(V;4.00) 35(I;2.00)

Schoenus scabripes 10(IV;1.40) 25(I;1.25) 28(IV;1.62)

Schoenus turbinatus 29(I;1.00) 31(I;1.00) 32(I;1.00) 42(I;2.00)

Tricostularia pauciflora 23(II;2.00)

ERIOCAULACEAE

Eriocaulon australe 1(I;2.00) 11(I;1.33) 21(I;1.00)

Eriocaulon scariosum 12(I;1.00) 35(II;1.00)

GEITONOPLESIACEAE

Geitonoplesium cymosum 33(II;1.00) 37(II;1.00) 40(V;1.00)

HAEMODORACEAE

Haemodorum austroqueenslandicum 20(I;1.00) 26(I;1.00)

Haemodorum corymbosum 17(II;1.00)

Haemodorum planifolium 23(I;1.00)

Haemodorum tenuifolium 10(I;1.00) 25(I;1.00) 26(II;1.00) 28(I;1.00) 34(II;1.00)

IRIDACEAE

Patersonia fragilis 25(I;1.00) 32(I;1.00)

Patersonia glabrata 16(V;1.50) 17(III;1.50) 18(V;1.00) 19(IV;1.50) 20(II;1.00) 29(III;1.12) 30(III;1.00) 31(II;1.00) 32(I;1.00) 33(IV;1.44) 42(I;1.00)

Patersonia sericea 15(II;1.00) 16(V;2.25) 17(V;2.00) 18(V;1.00) 19(V;2.33) 20(V;2.00) 22(II;1.00) 23(III;1.33) 25(I;1.00) 29(III;1.00) 30(II;1.00) 31(I;1.00) 32(II;1.00) 33(II;1.00) 35(II;1.50) 42(I;1.00)

Patersonia sp. aff. *fragilis* 17(II;1.00) 22(I;1.00) 23(II;1.00) 24(I;1.00) 25(III;1.05) 26(I;1.00) 28(I;1.00) 29(I;1.00) 31(III;1.00) 32(I;1.00) 33(I;1.00) 34(II;1.00)

JUNCAGINACEAE

Triglochin procerum s. lat. 1(V;1.00) 2(II;1.00) 3(III;1.00) 4(III;1.00) 5(IV;1.00) 6(III;1.00) 7(III;1.50) 8(II;1.00) 11(II;1.00) 13(I;1.00) 21(III;1.00) 36(II;1.00) 37(II;1.00)

LEMNACEAE

Lemna disperma 7(II;1.00)

LOMANDRACEAE

Lomandra elongata 23(I;1.00) 25(I;1.00) 26(II;1.00) 29(IV;1.30) 30(II;1.00) 32(III;1.08) 33(III;1.33) 42(III;1.00)

Lomandra filiformis 20(II;2.00) 33(I;1.00) 35(I;1.00)

Lomandra glauca 17(III;1.00) 23(II;1.00) 25(I;1.10) 29(I;1.00) 31(V;1.30) 32(I;1.00) 33(I;1.50) 42(I;1.00)

Lomandra laxa 40*(V;1.50)

Lomandra longifolia 14(II;1.00) 16(V;1.00) 25(I;1.33) 26(I;1.00) 33(III;2.12) 37(II;1.00) 40(V;2.50) 41(III;1.83) 42(I;1.50)

Lomandra multiflora subsp. *multiflora* 16(V;1.50) 17(V;1.00) 18(III;1.00) 19(II;1.00) 20(V;1.20) 22(I;1.00) 35(I;1.00)

Lomandra obliqua 19*(IV;2.00)

ORCHIDACEAE

Acianthus sp. 23(I;1.00) 25(I;1.00)

Caleana major 31(I;1.00) 42(I;1.00)

Calochilus grandiflorus 25(I;1.00)

Calochilus sp. 25(I;1.00)

Corybas sp. 20(I;1.00) 28(I;1.00)

Cryptostylis sp. 22(I;1.00) 25(I;1.00) 26(I;1.00) 27(III;1.00) 28(I;1.00) 34(II;1.00) 35(I;1.00) 37(II;1.00) 38(V;1.00) 41(I;1.00)

Eriochilus sp. 22(I;1.00)

Genoplesium rufum 29(I;1.00)

Genoplesium sp. 42(I;1.00)

Microtis sp. 20(I;1.00)

Pterostylis sp. 28(I;1.00) 29(I;1.00) 32(I;1.00) 33(II;1.33) 41(I;1.00) 42(I;1.00)

Thelymitra pauciflora 23(I;1.00)

Thelymitra purpurata 22(I;1.00) 25(I;1.00)

Thelymitra sp. 25(I;1.00)

unidentified sp. 22(I;1.00) 25(I;1.00) 28(I;1.00) 32(I;1.00) 33(I;1.00) 42(I;1.00)

PHILYDRACEAE

Philydrum lanuginosum 3(I;1.00) 11(I;1.00) 37(II;1.00)

PHORMIACEAE

Dianella caerulea 16(III;1.00) 29(I;1.17) 30(III;2.50) 32(I;1.00) 33(III;1.00) 37(IV;1.00) 40(III;1.00) 41(II;1.00) 42(I;1.20)

Dianella crinoides 14(II;1.00)

Dianella revoluta 15(II;1.00) 22(I;1.00) 25(I;1.00) 32(I;1.00)

POACEAE

Andropogon virginicus 33(II;1.00)

Aristida warburgii 16(V;3.00) 17(V;4.00) 18(III;1.00) 19(V;4.00) 20(V;3.40) 22(I;1.00) 23(I;1.00) 35(II;3.00)

Austrostipa pubescens 16(V;1.50) 17(V;2.00) 22(I;1.00) 23(II;1.50) 25(I;1.00) 31(II;2.00) 33(I;2.50)

Cymbopogon refractus 42(I;1.00)

Digitaria parviflora 33(I;1.00) 42(I;1.00)

Entolasia marginata 37*(III;1.00)

Entolasia stricta 8(II;1.00) 9(I;1.00) 10(IV;1.00) 11(II;1.56) 15(III;3.00) 16(V;1.75) 17(V;1.25) 18(V;2.00) 20(I;1.00) 21(V;1.43) 22(V;1.40) 23(III;1.33) 24(II;1.00) 25(II;1.05) 26(V;1.67) 27(V;1.00) 28(I;1.00) 29(I;1.00) 31(I;1.00) 32(I;1.14) 33(II;1.00) 34(III;1.00) 35(V;1.38) 36(I;1.00) 37(II;1.00) 38(V;3.00) 39(V;1.00) 41(III;1.80)

Eragrostis brownii 15(III;1.50) 16(III;1.00) 22(I;1.67) 29(I;1.00) 30(III;2.00) 33(I;1.00)

Eragrostis sororia 15(II;1.00) 22(I;1.00) 33(I;1.00)

Eremochloa bimaculata 19(I;1.00) 20(V;1.60) 22(III;1.27) 23(II;2.00) 25(I;1.00) 35(II;2.00)

Hemarthria uncinata 8(II;1.00) 11(II;1.25) 15(II;1.00) 21(III;1.50) 22(I;1.00) 35(III;1.00) 36(II;1.00) 39(V;2.00)

Imperata cylindrica var. *major* 21(II;1.00) 33(I;1.00) 37(II;2.00) 39(V;1.50) 40(V;2.00)

Ischaemum australe 9(I;1.00) 11(III;1.00) 12(IV;1.50) 14(II;2.50) 15(III;4.00) 21(III;1.25) 22(II;1.29) 26(I;1.50) 27(III;1.00) 35(V;1.29) 36(I;1.00) 37(III;1.00)

Leersia hexandra 21(I;1.00)

Oplismenus imbecillis 33(I;1.00) 37*(III;1.00)

Panicum simile 15(III;2.00) 16(V;2.00) 17(V;1.50) 18(V;1.00) 19(V;1.67) 20(V;1.40) 22(IV;1.33) 23(IV;2.00) 24(I;1.00) 25(II;1.52) 26(IV;1.29) 29(IV;1.00) 30(III;1.00) 31(I;1.00) 32(I;1.00) 33(IV;1.22) 35(III;1.50) 42(I;1.00)

Paspalidium distans 15(III;1.00) 16(III;1.00) 17(IV;1.00) 19(I;1.00) 22(I;1.00) 23(I;1.00) 33(III;1.00) 35(II;1.00) 40(V;1.50)

Paspalum orbiculare 3(I;1.00) 9(I;1.00) 11(I;1.00) 15(III;1.50) 22(I;1.00) 37(III;1.00)

Pennisetum clandestinum 14(I;1.00)

Phragmites australis 3(II;1.00) 9(I;1.00) 36(II;1.00)

Plinthanthesis paradoxa 25(I;1.00) 27*(III;1.00)

Pseudoraphis spinescens 3(II;3.00)

Themeda australis 14(V;5.75) 15(V;4.00) 16(V;4.00) 17(V;2.00) 18(V;1.00) 19(V;2.67) 20(V;2.50) 22(III;1.36) 23(II;1.50) 25(I;1.00) 26(I;1.50) 29(III;1.94) 30(III;2.00) 31(II;1.50) 32(I;1.00) 33(IV;1.20) 35(II;3.00) 40(III;1.00) 42(II;1.12)

Zoysia macrantha 14(I;1.00)

RESTIONACEAE

Baloskion pallens 1(II;1.67) 2(I;1.00) 9(IV;4.00) 11(V;2.50) 12(IV;1.50) 13(V;3.06) 21(I;1.00) 22(I;1.00) 23(IV;2.00) 24(III;1.33) 25(IV;1.20) 28(I;1.00) 32(I;1.22) 35(III;1.75) 36(IV;2.75) 41(I;2.00)

Baloskion tenuiculme 24(I;1.50) 25(I;1.43) 31(I;1.00) 32(I;1.00)

Baloskion tetraphyllum subsp. *meiostachyum* 8(III;1.00) 10(I;100) 21(IV;2.20) 25(I;1.00) 32(I;1.00) 36(I;2.00) 38(V;4.00) 39(V;4.00) 41(IV;3.25)

Coleocarya gracilis 29(V;2.19) 31(I;2.50) 32(III;2.00) 33(I;1.00) 42(III;1.78)

Empodisma minus 10(V;3.50) 21(III;1.75) 23(II;2.00) 25(II;2.50) 26(II;2.67) 28(V;3.10) 34(III;3.00) 39(V;1.00)

Eurychorda complanata 11(I;1.33) 22(I;1.00) 24(I;3.00) 25(II;1.30) 26(IV;1.86) 27(V;1.00) 28(I;1.50) 34(III;1.00) 35(IV;1.00)

Hypolaena fastigiata 23(IV;1.75) 24(I;1.00) 25(II;1.40) 29(III;1.82) 30(III;3.00) 31(V;2.36) 32(IV;2.30) 33(III;1.57) 41(I;1.00) 42(I;2.00)

Leptocarpus tenax 9(I;1.00) 11(V;2.65) 12(II;1.50) 22(IV;1.65) 23(IV;2.00) 24(V;1.73) 25(IV;1.18) 26(V;1.40) 27(V;2.00) 28(I;1.67) 32(I;1.33) 34(II;1.00) 35(IV;1.33) 36(II;2.00) 37(II;1.00)

Lepyrodia muelleri 11(II;1.75) 12(V;1.67) 35(III;1.50)

Lepyrodia scariosa 22(III;1.62) 23(IV;2.00) 25(I;1.30) 26(I;2.00) 35(II;1.00)

Lepyrodia sp. *A* 22(III;1.30) 27(V;1.00)

Sporadanthus caudatus 9(I;1.00) 11(I;2.33) 13(III;2.78) 21(IV;3.00) 22(I;1.00) 36(I;1.00)

Sporadanthus interruptus 10(V;3.12) 20(I;1.00) 21(II;2.00) 24(V;4.00) 25(V;3.15) 26(IV;2.50) 27(V;3.00) 28(V;3.24) 31(I;1.00) 32(II;1.50) 33(I;1.00) 34(V;2.00) 41(II;1.50)

SMILACACEAE

Smilax australis 33(I;1.00) 34(II;1.00)

Smilax glyciphylla 33(II;1.00) 37(II;1.00) 41(I;1.00)

TYPHACEAE

Typha orientalis 7*(V;3.75)

XANTHORRHOEACEAE

Xanthorrhoea fulva 9(II;1.00) 10(III;1.50) 11(I;1.50) 17(II;1.00) 19(I;1.00) 20(I;1.00) 22(V;4.09) 24(V;3.91) 25(V;3.07) 26(V;3.40) 27(V;4.00) 28(V;2.64) 31(II;1.50) 32(I;1.71) 33(I;3.00) 34(V;2.00) 35(IV;2.00) 41(IV;2.71)

Xanthorrhoea glauca subsp. *glauca* 25(I;1.67) 29(I;3.00) 31(III;2.50) 32(II;2.80) 42(I;3.00)

Xanthorrhoea johnsonii 23(III;1.00) 26(I;1.00) 29(IV;2.50) 30(III;1.00) 32(IV;2.64) 33(II;2.20) 42(V;2.92)

Xanthorrhoea latifolia subsp. *latifolia* 19(I;1.00) 20(III;1.30) 33(I;2.00)

XYRIDACEAE

Xyris gracilis subsp. *gracilis* 22(I;1.00) 23(III;1.67) 24(I;1.00) 25(I;1.00) 31(I;1.00) 32(I;1.00)

Xyris juncea 25(II;1.00) 28(III;1.00) 34(II;1.00) 35(II;1.00)

Xyris operculata 10(II;1.00) 11(III;1.73) 12(II;1.00) 22(II;1.00) 25(II;1.32) 26(I;1.00) 27(III;1.00) 28(IV;1.55) 34(II;1.00) 35(II;1.67) 41(I;2.00)

Class MAGNOLIOPSIDA – MAGNOLIIDAE

ACANTHACEAE

Brunoniella australis 15(III;1.50) 19(I;1.00) 22(I;1.00) 35(I;1.00)

Brunoniella pumilio 17*(III;1.00)

Pseuderanthemum variabile 37(II;1.00)

AIZOACEAE

Macarthuria neo-cambrica 29(I;1.00) 32(I;1.00) 33(I;1.00) 42(I;1.00)

APIACEAE

Actinotus helianthi 29(II;2.14) 30(III;1.00) 31(I;1.00) 33(I;1.00) 42(I;1.33)

Centella asiatica 14*(IV;1.00)

Hydrocotyle peduncularis 14*(IV;1.67)

Platysace ericoides 16(III;2.50) 19(V;1.50) 20(II;1.80) 23(I;1.00) 25(I;1.80) 26(I;1.50) 29(III;1.25) 30(III;2.00) 31(I;1.00) 32(III;1.57) 33(III;1.71) 41(II;1.00) 42(III;1.50)

Platysace lanceolata 23(II;1.50) 29(I;2.25) 30(III;3.00) 31(V;1.60) 32(I;1.50) 42(I;1.67)

Platysace sp. *A* 10(I;1.00) 23(II;1.00) 24(I;1.50) 25(I;1.17) 26(IV;3.00) 28(II;1.75) 34(III;3.00) 35(II;2.00)

Trachymene incisa subsp. *incisa* 17(II;1.00) 20(III;1.00) 25(I;1.00) 26(I;1.00) 29(I;1.00) 32(I;1.00) 42(I;1.00)

Xanthosia pilosa 18(V;1.00) 23(I;1.00) 25(I;1.00) 29(II;1.18) 30(II;1.00) 31(III;1.60) 32(I;1.00) 33(II;1.40) 34(II;1.00) 41(II;1.25) 42(IV;1.21)

APOCYNACEAE

Parsonsia straminea 21(I;1.00) 22(I;1.00) 23(II;1.50) 30(II;1.00) 33(III;1.14) 34(III;1.00) 37(V;2.00) 38(III;1.00)

ARALIACEAE

Astrotricha longifolia 29(I;1.00)

Polyscias sambucifolia 33(I;1.00)

ASCLEPIADACEAE

Marsdenia fraseri 29(I;1.00) 33(I;1.00) 41(I;1.00)

Marsdenia rostrata 33(I;1.00) 37(II;1.00)

Marsdenia suaveolens 31(I;1.00) 33(I;1.00)

ASTERACEAE

Ageratum houstonianum 38(III;1.00)

Baccharis halimifolia 14(I;1.00)

Brachycome multifida var. *multifida* 14(II;1.00)

Bracteantha bracteata 14*(IV;2.00)

Chrysanthemoides monilifera subsp. *rotundata* 14(II;1.00) 37(III:2.00) 40(V:3.00) 41(I;1.00)

Conyza albida 38(III;1.00)

Craspedia variabilis 14(II;1.00)

Crassocephalum crepidioides 34(II;1.00)

Erechtites valerianifolia 34(II;1.00)

Helichrysum elatum 33(I;1.00)

Hypochaeris radicata 14(II;2.00)

Ozothamnus diosmifolius 26(I;1.00)

Picris angustifolia subsp. *carolorum-hericorum* 14(I;1.00)

Rutidosis heterogama 15*(III;1.00) 22(I;1.00)

Senecio lautus subsp. *maritimus* 14(II;2.00)

BAUERACEAE

Bauera capitata 17(III;1.00) 23(II;1.50) 24(II;2.00) 25(IV;2.15) 26(I;1.00) 28(III;2.08) 32(I;1.00) 34(II;1.00)

BIGNONIACEAE

Pandorea pandorana 23(I;1.00) 30(II;1.00) 33(II;1.00) 37(III;1.50) 40(V;1.00) 42(I;1.50)

CAMPANULACEAE

Wahlenbergia littoricola 14(II;1.00)

CASUARINACEAE

Allocasuarina defungens 25(I;1.00) 32(I;2.00)

Allocasuarina defungens × *littoralis* 32(I;2.00)

Allocasuarina littoralis 16(IV;3.00) 17(V;1.50) 18(V;2.00) 19(V;3.17) 20(V;3.10) 23(I;1.00) 29(II;1.57) 30(V;3.50) 31(III;2.33) 33(V;2.25) 42(I;1.00)

Allocasuarina torulosa 16(II;1.00)

Casuarina glauca 37(II;1.00)

CLUSIACEAE

Hypericum gramineum 19(II;1.00) 20(I;1.00) 22(II;1.00)

CONVOLVULACEAE

Dichondra repens 14(II;1.00)

Polymeria calycina 14*(IV;2.33)

DILLENIACEAE

Adrastaea salicifolia 10(V;1.43) 21(I;1.00) 24(II;1.25) 25(II;1.33) 26(I;1.50) 28(V;2.46)

Hibbertia acuminata 29(III;1.56) 32(I;1.25) 33(I;3.50) 42(II;1.50)

Hibbertia aspera 14(II;2.00) 33(I;1.00)

Hibbertia diffusa 18(V;1.00) 29(I;2.00) 32(I:1.00) 42(I;1.00)

Hibbertia empetrifolia subsp. *empetrifolia* 16*(V;2.50)

Hibbertia fasciculata 23(II;2.00) 25(III;1.00) 29(III;1.00) 30(III;1.00) 31(V;1.27) 32(V;1.14) 33(I;1.00) 34(II;1.00) 41(I;1.00) 42(III;1.15)

Hibbertia linearis 29(II;1.11) 30(IV;2.00) 31(II;1.50) 32(II;1.57) 33(I;1.00) 42(II;1.50)

Hibbertia riparia 17(V;1.50) 25(I;1.60) 31(II;1.00) 32(I;1.00)

Hibbertia rufa 23(I;1.00) 25(I;1.00) 29(IV;1.00) 30(II;1.00) 31(IV;1.11) 32(IV;1.06) 33(I:1.50) 42(II;1.00)

Hibbertia scandens 23(I;1.00) 33(III;1.00) 34(II;1.00) 40(V;1.50) 41(I;1.00)

Hibbertia vestita 14(II;2.00) 18(V;3.00) 19(V;2.67) 20(V;2.50) 22(II;1.71) 23(II;1.50) 24(I;1.00) 25(I;1.00) 26(V;2.56) 29(I;1.40) 30(V;1.50) 33(I;1.50) 35(II;3.00) 42(I;2.00)

DROSERACEAE

Drosera auriculata 15(II;1.00) 20(IV;1.00) 22(I;1.00) 23(II;1.00) 24(IV;1.00) 25(III;1.00) 26(V;1.00) 28(III;1.00) 29(I;1.00) 32(II;1.00) 34(IV;1.00) 41(II;1.00)

Drosera binata 8(III;1.00) 10(IV;1.00) 11(I;1.00) 21(I;1.00) 25(I;1.00) 28(III;1.08)

Drosera pygmaea 22(II;1.00) 25(I;1.00) 28(I;1.00)

Drosera spatulata 22(I;1.00) 23(I;1.00) 24(I;1.00) 25(II;1.05) 28(I;1.00) 35(II;1.00)

ELAEOCARPACEAE

Elaeocarpus reticulatus 23(I;1.00) 30(II;1.00) 33(II;1.40) 34(III;2.00) 38(V;1.00) 41(IV;2.14)

EPACRIDACEAE

Astroloma pinifolium 29(I;1.00) 30(IV;1.33) 32(I;1.00) 33(II;1.00) 42(I;1.00)

Brachyloma daphnoides 16(III;2.00) 29(V;1.46) 30(III;1.50) 31(V;2.42) 32(III;1.46) 33(II;1.00) 42(II;1.33)

Brachyloma scortechinii 25(I;1.00) 29(I;1.00) 32(I;1.00) 33(I;1.00)

Epacris microphylla var. *microphylla* 10(V;1.29) 11(I;1.25) 21(II;1.67) 22(II;1.60) 23(II;2.00) 24(I;1.00) 25(I;1.67) 28(V;1.62) 31(II;1.00) 32(I;1.50)

Epacris obtusifolia 10(I;1.00) 11(I;1.00) 22(I;1.67) 24(V;2.61) 25(V;1.84) 26(IV;1.50) 27(V;2.50) 28(IV;1.35) 34(III;1.00) 35(II;2.00) 36(I;1.00) 41(I;1.00)

Epacris pulchella 17(IV;2.33) 18(V;3.00) 19(V;3.00) 20(II;1.50) 24(I;2.00) 25(II;1.19) 26(II;1.00) 29(II;1.82) 31(I;1.00) 32(III;1.20) 33(I;2.00) 35(I;1.00) 41(II;1.50) 42(I;1.60)

Leucopogon deformis 23(I;1.00) 28(I;1.00) 29(IV;1.14) 30(II;1.00) 32(III;1.57) 33(I;1.00) 42(II;1.20)

Leucopogon ericoides 23(II;1.50) 25(I;1.00) 26(I;1.00) 29(III;1.37) 30(II;1.00) 31(II;1.67) 32(II;1.13) 33(III;1.17) 41(I;1.00) 42(IV;1.63)

Leucopogon esquamatus 17(II;1.00)

Leucopogon lanceolatus var. *gracilis* 23(II;2.00) 25(I;1.00) 29(I;1.00) 30(II;1.00) 32(I;1.00) 33(III;1.62) 34(IV;1.00) 38(V;1.50) 41(V;2.11) 42(II;1.50)

Leucopogon lanceolatus var. *lanceolatus* 19(I;1.00)

Leucopogon leptospermoides 23(II;1.00) 24(III;1.67) 25(II;1.33) 26(II;1.00) 28(I;1.00) 29(V;2.12) 30(V;2.50) 31(V;1.80) 32(V;2.47) 33(V;1.85) 34(III;1.00) 41(III;1.50) 42(V;2.43)

Leucopogon margarodes 33(II;1.50) 34(II;1.00) 41(III;1.20) 42(I;1.00)

Leucopogon redwayi 25(I;1.00) 26(I;1.00) 32(I;1.00)

Leucopogon virgatus 29(V;1.61) 30(IV;1.33) 31(V;1.67) 32(IV;1.40) 33(I;2.00) 42(III;1.86)

Lissanthe sp. *A* 18(III;1.00) 23(II;1.00) 24(II;1.29) 25(I;1.50) 26(III;1.00) 28(I;1.00) 32(I;1.33) 34(III;1.50)

Lissanthe sp. *B* 20*(V;1.50)

Melichrus procumbens 16(II;1.00) 17(V;1.00) 18(V;1.00) 19(II;1.00) 20(II;1.00)

Monotoca elliptica 25(I;1.14) 29(I;1.33) 30(II;1.00) 32(I;1.20) 33(IV;1.64) 34(II;1.00) 36(I;1.00) 41(II;1.25) 42(II;1.36)

Monotoca scoparia 16(III;2.00) 17(IV;1.33) 19(IV;1.50) 20(II;1.30) 24(I;1.00) 25(I;1.08) 29(V;2.41) 30(V;2.75) 31(V;2.58) 32(V;2.31) 33(II;1.40) 42(IV;2.50)

Sprengelia incarnata 10(II;1.00) 22(I;1.33) 25(I;1.75) 27(V;1.00) 35(I;1.00)

Sprengelia sprengelioides 10(III;1.00) 11(I;1.00) 24(V;2.50) 25(V;1.76) 26(V;2.00) 28(V;2.21) 35(II;1.00)

Styphelia viridis subsp. *breviflora* 18(III;1.00) 19(I;1.00) 23(III;1.00) 26(I;1.00) 29(III;1.56) 30(IV;1.00) 32(II;1.27) 33(I;1.00) 42(II;1.00)

Woollsia pungens 29(III;1.62) 30(III;2.00) 32(I;2.33) 33(II;1.50) 42(I;1.40)

EUPHORBIACEAE

Amperea xiphoclada 29(II;1.12) 30(III;1.00) 31(IV;1.11) 32(II;1.21) 33(II;1.00) 41(II;1.00) 42(II;1.10)

Phyllanthus hirtellus 18(V;1.00) 19(V;1.00) 20(IV;1.00) 29(I;1.00) 30(IV;1.33) 33(II;1.00) 42(I;1.00)

Poranthera microphylla 14*(IV;1.33) 42(I;1.00)

Pseudanthus orientalis 17(IV;1.00) 23(V;1.67) 24(III;1.10) 25(V;1.35) 26(V;1.11) 28(I;1.00) 29(IV;1.14) 31(V;1.73) 32(V;1.27) 33(II;1.25) 34(II;1.00) 35(II;1.00) 42(II;1.08)

Ricinocarpus pinifolius 17(II;1.00) 24(I;1.00) 25(II;1.26) 26(I;1.00) 29(IV;2.04) 30(III;1.00) 31(V;1.75) 32(IV;1.44) 33(II;1.00) 42(IV;1.62)

FABACEAE – FABOIDEAE

Almaleea paludosa 22(I;1.00) 35(II;1.00)

Aotus ericoides 10(II;1.00) 24(V;2.44) 25(II;1.56) 26(I;3.00) 28(III;1.92) 32(I;1.20) 34(III;1.50) 35(II;1.00) 41(II;2.00) 42(I;3.00)

Aotus lanigera 11(I;1.00) 23(I;2.00) 24(I;1.00) 25(I;1.00) 28(I;1.00) 29(I;1.60) 32(II;1.80) 33(I;2.50) 41(I;1.00) 42(I;2.00)

Bossiaea ensata 16(V;1.50) 18(V;2.50) 29(V;1.47) 30(V;1.50) 31(III;1.67) 32(II;1.00) 33(II;1.00) 42(III;1.00)

Bossiaea heterophylla 23(II;2.00) 25(I;1.00) 29(IV;1.75) 31(IV;1.88) 32(II;1.50) 33(I;1.00) 42(IV;1.70)

Bossiaea rhombifolia subsp. *rhombifolia* 18*(V;3.00)

Bossiaea stephensonii 17*(III;1.00)

Chorizema parviflorum 14(II;1.00)

Daviesia umbellulata 19(I;1.00) 20(II;1.50)

Dillwynia floribunda 17(IV;1.00) 23(II;2.00) 24(II;1.83) 25(V;1.89) 26(IV;2.50) 28(IV;2.06) 32(II;1.10) 34(V;1.00) 35(II;1.50)

Dillwynia glaberrima 25(I;1.00) 29(I;2.00) 30(III;1.00) 31(III;1.67) 32(II;1.69)

Dillwynia retorta 19(V;1.50) 23(II;1.00) 25(I;1.00) 29(V;1.88) 30(III;1.00) 31(III;2.50) 32(V;1.79) 33(IV;1.22) 42(IV;1.87)

Glycine microphylla 14(I;1.00) 33(I;1.00)

Glycine tomentella 14(II;1.00)

Gompholobium glabratum 23(I;1.00) 32(I;1.00)

Gompholobium pinnatum 16(V;1.50) 17(V;1.00) 18(V;1.00) 19(V;1.40) 20(V;1.00) 22(I;1.25) 23(II;1.00) 25(I;1.00) 26(III;1.00) 35(III;1.00)

Gompholobium virgatum var. *virgatum* 29(V;1.16) 30(V;1.25) 31(I;1.00) 32(IV;1.68) 33(II;1.40) 42(IV;1.33)

Hardenbergia violacea 14(I;1.00) 30(II;1.00) 42(I;1.50)

Hovea heterophylla 14(II;1.00) 19(II;1.00)

Jacksonia scoparia 14(I;2.00) 16*(III;1.00)

Jacksonia stackhousii 29(III;1.24) 32(I;1.14)

Kennedia rubicunda 37(II;1.00) 38(V;2.00) 41(II;1.00)

Mirbelia rubiifolia 16(V;2.00) 17(V;1.75) 18(V;4.00) 20(II;1.00) 25(I;1.00) 26(III;1.83) 35(II;1.00)

Oxylobium robustum 38*(III;1.00)

Phyllota phylicoides 14(II;2.50) 16(V;1.50) 17(III;1.00) 20(V;1.50) 23(IV;1.75) 29(IV;2.29) 30(II;1.00) 31(V;2.55) 32(V;2.41) 42(IV;2.76)

Pultenaea maritima ms. 14(II;3.50)

Pultenaea myrtoides 19(IV;2.75) 20(II;1.50) 22(II;2.60) 26(I;2.00) 28(I;1.00) 35(II;1.00)

Pultenaea retusa 14(II;1.50)

Sphaerolobium minus 17(II;1.00) 23(II;1.00)

Sphaerolobium vimineum 22(I;1.00) 35(II;1.00) 39(V;1.00)

Swainsona galegifolia 14(II;1.00)

Viminaria juncea 11(I;1.00) 21(I;1.00) 22(I;1.50)

Zornia dyctiocarpa var. *dyctiocarpa* 14(I;1.00)

FABACEAE – MIMOSOIDEAE

Acacia baueri subsp. *baueri* 25(I;1.00) 28(I;1.00) 29(II;1.00) 31(II;1.00) 32(II;1.00) 42(I;1.00)

Acacia brownii 19(II;1.00) 20(III;1.20)

Acacia disparrima subsp. *disparrima* 40*(V;1.00)

Acacia elongata 21(I;2.00) 34(III;1.00) 35(I;1.00) 38(V;1.00) 41(I;2.50)

Acacia leiocalyx 14(I;1.00) 16*(III;1.00)

Acacia longifolia subsp. *longifolia* 27(III;1.00) 37(II;1.00) 41(II;1.00) 42(I;1.00)

Acacia longifolia subsp. *sophorae* 15(II;1.00) 19(I;1.00) 31(I;1.00) 33(I;1.00) 34(II;1.00) 42(I;1.00)

Acacia maidenii 34*(III;1.00)

Acacia myrtifolia 14(II;1.00) 16(III;1.00)

Acacia quadrilateralis 31(I;1.00)

Acacia suaveolens 16(IV;1.00) 17(III;1.00) 23(II;1.00) 25(I;1.00) 28(I;1.00) 29(V;1.56) 30(V;1.00) 31(I;1.00) 32(II;1.08) 33(IV;1.00) 35(I;1.00) 41(I;1.00) 42(V;1.37)

Acacia ulicifolia 29(V;1.48) 30(III;2.00) 31(IV;1.12) 32(III;1.48) 33(I;1.00) 41(I;1.00) 42(V;1.73)

GOODENIACEAE

Dampiera stricta 10(I;1.00) 15(II;2.00) 16(III;2.00) 17(IV;1.33) 19(V;1.83) 20(V;1.80) 22(II;1.60) 23(III;1.00) 24(I;1.00) 25(II;1.17) 26(III;1.33) 28(I;1.00) 29(II;1.20) 30(III;1.00) 31(IV;1.00) 32(II;1.08) 33(III;1.12) 35(II;1.00) 37(II;1.00) 41(III;1.00) 42(I;1.00)

Goodenia bellidifolia 15(III;1.50) 17(III;1.00) 19(V;1.17) 20(V;1.80) 26(I;1.50) 35(II;1.00)

Goodenia hederacea subsp. *hederacea* 14(II;1.50) 22(I;1.00)

Goodenia heterophylla 19(II;1.00) 22(I;1.00)

Goodenia paniculata 12(II;2.00) 22(I;1.75) 35(II;3.00)

Goodenia rotundifolia 14(I;3.00)

Goodenia stelligera 10(II;1.00) 11(I;1.00) 12(II;1.00) 17(V;1.25) 22(II;1.29) 24(I;1.00) 25(II;1.00) 26(II;1.00) 28(II;1.00) 35(I;1.00)

Velleia spathulata 15(III;1.50) 20(II;1.00) 22(II;1.12)

HALORAGACEAE

Gonocarpus micranthus 8(II;1.00) 11(I;1.00) 22(III;1.09) 23(II;1.00) 24(II;1.00) 25(III;1.24) 26(III;1.20) 27(III;1.00) 34(II;1.00) 35(II;1.50) 38(III;2.00) 41(II;1.00)

Gonocarpus salsoloides 22(I;1.00) 25(I;1.00)

Gonocarpus tetragynus 15(IV;2.33) 16(V;2.00) 17(V;1.50) 19(IV;2.00) 20(III;1.00) 21(II;1.00) 22(II;1.40) 35(II;1.00) 39(V;1.00)

LAMIACEAE

Prostanthera palustris 26(I;1.50)

LAURACEAE

Cassytha filiformis 14(I;1.00) 18(III;1.00) 23(I;1.00) 24(I;1.67) 25(I;1.25) 29(II;1.36) 31(I;1.00) 32(I;1.17) 33(II;1.67) 34(III;1.00) 35(I;1.00) 39(III;2.00) 41(I;1.00) 42(I;1.00)

Cassytha glabella forma *glabella* 2(II;2.00) 9(II;1.50) 10(II;1.00) 11(I;1.00) 13(I;1.50) 14(II;1.00) 15(III;1.00) 16(III;1.50) 17(V;1.00) 18(V;1.50) 19(V;1.33) 20(III;1.00) 21(II;1.00) 22(II;1.25) 23(III;1.00) 24(V;1.47) 25(V;1.05) 26(V;1.00) 27(V;1.00) 28(V;1.19) 29(III;1.21) 30(III;1.00) 31(III;1.00) 32(III;1.12) 33(II;1.25) 35(III;1.00) 37(III;1.50) 41(IV;1.43)

Cassytha pubescens 24(I;1.00) 25(I;1.00) 29(II;1.36) 30(IV;1.33) 31(II;1.33) 32(I;1.57) 33(II;1.25) 37(II;1.00) 40(V;1.00) 41(I;1.50) 42(I;1.50)

Endiandra sieberi 41(I;1.00)

LENTIBULARIACEAE

Utricularia australis 3(II;2.00) 4(II;1.00) 6(III;1.00) 7(III;1.50)

Utricularia biloba 13(I;1.00)

Utricularia dichotoma 11(II;1.00) 12(II;2.00)

Utricularia gibba 3(II;1.00) 4(III;1.00)

Utricularia lateriflora 24(I;1.00) 25(I;1.00) 28(I;1.00)

Utricularia uliginosa 35(I;1.00) 37*(III;2.00)

LOBELIACEAE

Lobelia alata 11(I;1.00) 14(II;1.00)

LOGANIACEAE

Logania pusilla 14(II;1.00) 17(III;1.00) 19(I;1.00)

Mitrasacme alsinoides 22(I;1.00) 28(I;1.00)

Mitrasacme paludosa 26(II;1.25)

Mitrasacme polymorpha 17(III;1.00) 25(II;1.00) 26(II;1.00) 28(I;1.00) 29(I;1.00) 30(II;1.00) 32(I;1.00) 34(II;1.00)

LORANTHACEAE

Amyema congener subsp. *congener* 33(I;1.50)

Dendrophthoe vitellina 9(I;1.00) 20(I;1.00) 23(I;1.00) 33(I;1.00) 36(II;1.00) 37(II;1.00) 42(I;1.00)

Muellerina celastroides 33(I;1.00) 42(I;1.50)

MELASTOMATACEAE

Melastoma affine 38*(III;1.00)

MENYANTHACEAE

Nymphoides indica 7*(III;2.00)

Villarsia exaltata 8(III;1.00) 9(II;1.00) 11(IV;1.64) 12(II;1.00) 13(I;1.00) 21(III;1.25) 28(I;1.00) 35(II;1.00) 36(II;2.00) 41(I;1.00)

MORACEAE

Ficus superba var. *henneana* 34(II;1.00)

MYRSINACEAE

Rapanea howittiana 33(I;1.00)

Rapanea variabilis 33(I;1.00) 40*(III;1.00)

MYRTACEAE

Angophora costata 25(I;1.00) 35(I;1.00)

Angophora woodsiana 42(I;2.00)

Austromyrtus dulcis 18(V;2.50) 23(II;2.50) 29(I;2.00) 30(III;1.00) 32(I;1.00) 33(III;2.50) 40(V;3.00) 41(I;1.00)

Baeckea diosmifolia 23(II;2.00) 25(I;1.33) 31(III;2.40) 32(II;2.00)

Baeckea frutescens 9(I;2.00) 10(II;1.50) 23(IV;1.75) 24(V;3.11) 25(III;3.36) 26(I;1.00) 28(IV;3.06) 32(II;1.46) 34(III;3.00) 41(II;3.00)

Baeckea imbricata 22(II;1.17) 23(III;1.00) 24(IV;2.27) 25(V;1.70) 26(III;1.17) 27(III;1.00) 28(II;1.56) 32(I;1.00) 35(II;1.00)

Baeckea linifolia 25(I;3.00) 28(I;3.00)

Callistemon pachyphyllus 9(II;2.00) 10(II;1.00) 11(V;2.33) 12(IV;2.00) 13(I;2.00) 15(III;1.00) 21(II;1.67) 22(IV;1.36) 24(IV;1.36) 25(II;1.07) 26(IV;1.62) 28(I;1.00) 34(III;1.00) 35(V;1.38) 36(II;2.00)

Calytrix tetragona 29(I;3.00) 31(III;1.60) 32(II;1.50) 42(I;1.00)

Corymbia gummifera 22(I;1.00) 42(I;2.50)

Corymbia intermedia 20(I;1.00)

Darwinia leptantha 23(I;1.00) 25(III;1.69) 27(III;1.00) 31(I;1.00) 32(I;1.00) 34(III;1.00)

Eucalyptus globoidea 32(I;2.00)

Eucalyptus pilularis 33(I;1.00) 42*(III;3.19)

Eucalyptus planchoniana 42(III;3.43)

Eucalyptus resinifera 25(I;1.00)

Eucalyptus robusta 21(I;1.00) 24(I;1.00) 25(I;1.00) 33(I;1.50) 35(II;1.00) 38(III;1.00) 41(IV;4.00)

Eucalyptus signata 35(II;1.50) 41(I;3.50) 42(I;3.50)

Eucalyptus tereticornis 22(I;1.00)

Euryomyrtus ramosissima subsp. *ramosissima* 23(I;2.00) 25(I;1.00) 29(I;2.00) 31(IV;2.00) 32(II;2.00) 42(I;2.00)

Homoranthus virgatus 18(V;1.00) 23(II;1.00) 25(I;1.00) 29(IV;1.33) 30(IV;1.00) 31(II;1.50) 32(III;1.64) 33(III;2.12) 41(I;2.00) 42(IV;1.40)

Kunzea capitata 19(V;1.33) 20(V;2.20) 23(II;1.00) 25(I;1.67) 27(V;1.00) 31(I;1.00) 32(I;1.50)

Leptospermum arachnoides 23(II;2.00)

Leptospermum juniperinum 10(III;1.00) 11(I;1.40) 21(V;5.00) 22(I;1.00) 24(I;1.67) 25(III;1.24) 26(I;1.00) 27(III;1.00) 28(I;1.00) 34(III;2.00) 35(II;1.33) 36(IV;1.00) 39(V;4.50) 41(I;1.00)

Leptospermum laevigatum 31(I;1.00)

Leptospermum liversidgei 10(V;1.88) 11(I;1.00) 13(I;1.00) 21(I;1.00) 24(V;3.11) 25(V;2.94) 26(V;2.70) 27(III;2.00) 28(V;3.69) 34(III;1.00) 36(I;1.00) 41(I;2.00)

Leptospermum polygalifolium subsp. *cismontanum* 17(III;2.00) 18(III;1.00) 19(II;1.50) 20(IV;1.40) 23(V;3.00) 24(IV;1.69) 25(I;1.57) 26(III;1.40) 28(I;1.00) 29(II;2.20) 30(III;2.50) 31(IV;1.62) 32(V;2.38) 33(III;3.17) 34(III;3.50) 35(II;2.00) 37(III;2.00) 41(V;2.60) 42(III;1.92)

Leptospermum semibaccatum 23(II;2.50) 25(I;1.67) 29(II;2.57) 30(III;2.50) 31(V;2.60) 32(IV;2.73) 33(II;2.25)

Leptospermum speciosum 32(I;1.00) 38*(V;5.00)

Leptospermum trinervium 18(V;2.00) 20(IV;1.60) 29(V;3.04) 30(III;3.00) 32(III;2.70) 33(IV;2.91) 41(I;1.50) 42(V;2.48)

Leptospermum whitei 23(I;1.00) 24(I;1.33) 25(II;1.93) 26(II;2.25) 32(II;1.94) 34(III;4.50) 41(I;1.00) 42(I;1.00)

Lophostemon confertus 40*(V;5.00)

Lophostemon suaveolens 22(I;1.00)

Melaleuca alternifolia 15(III;2.00) 35(II;1.00)

Melaleuca linariifolia 12(I;1.00)

Melaleuca nodosa 18(V;3.00) 19(IV;1.25) 20(III;2.30) 22(I;1.00) 23(V;3.17) 24(III;1.89) 25(II;1.56) 26(IV;2.38) 28(I;1.00) 29(IV;2.90) 31(I;1.50) 32(III;2.54) 33(I;4.00) 35(II;2.00) 37(III;1.00) 41(II;3.00) 42(I;2.00)

Melaleuca quinquenervia 1(I;1.00) 6(IV;1.00) 9(V;4.00) 11(II;1.00) 13(I;1.00) 22(I;1.00) 24(II;1.00) 25(I;1.00) 26(II;1.00) 28(I;1.00) 33(I;1.00) 34(III;1.50) 36(V;3.00) 37(V;4.50) 41(II;1.33)

Melaleuca sieberi 15(III;1.00) 22(II;1.67) 23(III;1.33) 25(I;1.00) 26(I;1.00) 35(IV;3.67)

Melaleuca squamea 9(IV;1.75) 11(I;1.50) 13(I;2.00) 24(IV;1.92)

Melaleuca thymifolia 9(II;1.50) 11(II;2.17) 12(IV;3.00) 15(III;1.50) 22(V;1.94) 23(I;1.00) 25(I;1.00) 26(II;2.00) 35(V;2.38)

Ochrosperma citriodorum 18(V;1.00) 23(II;2.00) 25(I;1.44) 26(I;1.00) 29(I;1.00) 32(II;1.40)

Ochrosperma lineare 23(II;1.50) 25(I;1.00) 29(IV;2.10) 30(III;1.50) 31(IV;2.00) 32(IV;1.86) 33(II;1.40) 41(I;1.00) 42(III;1.57)

Syzygium oleosum 41(I;1.00)

NYMPHAEACEAE

Nymphaea caerulea subsp. *zanzibarensis* 3(II;1.00) 4(III;2.00) 7(III;1.50)

OLACACEAE

Olax angulata 29(I;1.50)

Olax retusa 24(I;1.00) 25(II;1.00) 26(I;1.00) 28(III;1.19) 29(I;1.00) 32(I;1.00)

Olax stricta 23(I;1.00) 25(I;1.00) 29(I;1.00) 30(II;1.00) 31(I;1.00) 32(II;1.08) 42(I;1.00)

OLEACEAE

Notelaea longifolia 33(II;1.00) 41(I;1.00)

Notelaea ovata 16(IV;1.00) 18(V;1.50) 19(III;1.00) 20(III;1.20)

OXALIDACEAE

Oxalis exilis 14(II;1.00)

Oxalis rubens 14(II;1.00)

PITTOSPORACEAE

Billardiera scandens 16(II;1.00) 17(III;1.00) 23(II;1.00) 26(I;1.00) 30(II;1.00) 33(III;1.17) 34(III;1.00) 41(I;1.00)

Pittosporum revolutum 40*(III;1.00)

POLYGALACEAE

Comesperma defoliatum 10(II;1.00) 24(II;1.00) 25(I;1.00) 28(II;1.00) 31(I;1.00) 32(I;1.00)

Comesperma ericinum 16(III;2.00) 20(I;1.00) 22(II;1.00) 25(II;1.25) 27(III;1.00) 28(I;1.00) 31(III;1.14) 32(I;1.50) 35(II;1.00) 42(I;1.00)

POLYGONACEAE

Persicaria attenuata 7(II;1.00)

PROTEACEAE

Banksia aemula 10(II;1.00) 23(I;1.00) 25(II;1.07) 28(I;1.00) 29(V;3.53) 30(V;3.50) 31(V;3.42) 32(V;3.38) 33(V;3.14) 34(II;1.00) 40(III;2.00) 41(II;1.50) 42(V;2.80)

Banksia ericifolia subsp. *macrantha* 11(I;1.50) 12(III;1.00) 13(I;1.00) 17(IV;1.00) 21(II;1.00) 22(II;1.00) 23(IV;1.75) 24(V;3.47) 25(V;2.37) 26(I;1.00) 27(V;3.50) 28(III;1.38) 29(I;2.00) 31(I;1.00) 32(II;1.08) 34(V;4.00) 35(II;4.00) 41(II;1.00)

Banksia integrifolia subsp. *integrifolia* 14(II;1.00) 33(I;2.50) 37(III;1.50) 40(V;2.00)

Banksia oblongifolia 11(I;1.00) 16(V;3.50) 17(V;2.25) 18(V;4.00) 19(V;3.50) 20(V;3.90) 22(III;1.85) 23(V;3.50) 24(IV;2.00) 25(IV;2.79) 26(V;3.70) 28(II;1.25) 29(I;1.00) 32(III;1.63) 33(I;1.00) 34(III;3.00) 35(IV;2.00) 41(I;1.00)

Banksia robur 11(I;2.00)

Banksia serrata 33(II;3.25)

Conospermum taxifolium 17(II;1.00) 23(IV;2.00) 25(II;1.74) 29(IV;1.08) 30(III;2.00) 31(II;1.33) 32(II;1.29) 42(III;1.21)

Grevillea humilis 22(II;1.00) 26(I;1.00)

Hakea actites 9(I;1.00) 19(I;1.00) 22(I;2.00) 26(I;1.00) 35(III;2.50)

Hakea laevipes subsp. *laevipes* 17(V;2.00) 18(III;1.00) 19(V;1.50) 20(IV;1.30) 23(II;2.00)

Hakea teretifolia subsp. *teretifolia* 12(III;1.00) 16(II;2.00) 17(V;3.00) 22(III;1.17) 23(II;1.00) 25(I;2.00) 35(II;1.67)

Isopogon anemonifolius 16(III;1.50) 17(V;2.50) 23(II;1.00) 25(I;1.40) 29(I;1.33) 31(IV;1.56) 32(I;1.33) 33(I;1.00) 42(I;1.00)

Isopogon mnoraifolius 19(I;1.00) 20*(IV;1.00)

Lambertia formosa 19*(IV;2.00)

Lomatia silaifolia 16*(IV;1.00)

Persoonia adenantha 32(I;1.00) 33(I;1.00)

Persoonia conjuncta 17(II;1.00) 29(I;1.00) 34(II;1.00) 35(I;1.00)

Persoonia katerae 31(I;1.00) 33(I;1.00)

Persoonia lanceolata 23(II;1.00) 25(II;1.20) 27(V;1.00) 28(I;1.00) 29(I;1.00) 31(I;1.00) 32(I;1.00)

Persoonia levis 26(I;1.00) 42(I;1.00)

Persoonia stradbrokensis 16(III;1.00) 18(III;1.00) 20(I;1.00) 26(II;1.00) 28(I;1.00) 29(I;1.00) 30(II;1.00) 32(I;1.00) 33(I;1.00) 41(II;1.00) 42(I;1.00)

Persoonia tenuifolia 18(III;1.00) 19(II;1.00) 20(II;1.00)

Persoonia virgata 10(II;1.00) 23(II;1.00) 24(I;1.00) 25(II;1.00) 26(V;1.10) 28(II;1.09) 29(V;1.14) 30(II;1.00) 31(I;1.50) 32(IV;1.15) 33(II;1.00) 41(I;1.00) 42(IV;1.13)

Petrophile canescens 16(III;1.50) 20(I;1.00) 23(II;1.50) 25(I;1.00) 29(IV;1.10) 32(II;1.00) 42(II;1.00)

Petrophile pulchella 23(II;1.00) 25(I;1.40) 32(I;1.00) 42(I;1.00)

Symphionema paludosum 25(I;1.00)

RANUNCULACEAE

Ranunculus lappaceus 14(II;1.00)

RHAMNACEAE

Cryptandra propinqua 16(II;1.00)

Cryptandra scortechinii 17*(III;1.50)

RUBIACEAE

Cyclophyllum longipetalum 41(I;1.00)

Durringtonia paludosa 10(II;1.00) 11(I;1.00) 21(II;1.33) 36(II;1.00)

Pomax umbellata 23(I;1.00) 29(I;1.00) 30(V;1.00) 33(IV;1.55) 38(III;2.00) 40(V;1.00) 42(III;1.00)

RUTACEAE

Acronychia imperforata 33(II;2.33) 40*(V;3.00)

Boronia falcifolia 23(II;1.00) 24(IV;2.08) 25(V;2.15) 26(IV;1.86) 28(V;1.73) 32(I;1.00) 34(II;1.00)

Boronia parviflora 11(I;1.00) 22(II;1.00) 25(I;1.00) 26(I;1.00) 27(III;1.00) 35(II;1.00)

Boronia pinnata 16(V;1.50) 17(V;1.50) 25(I;2.00) 29(I;1.83) 31(V;2.70) 32(II;2.50) 33(I;2.00) 34(II;1.00) 41(II;1.67) 42(II;2.44)

Boronia polygalifolia 14(II;1.00) 17(III;1.00) 19(IV;1.00)

Boronia rosmarinifolia 30(II;2.00)

Boronia safrolifera 18(V;3.00) 29(II;2.00) 32(II;1.89) 33(I;3.00) 41(I;2.00) 42(I;1.33)

Eriostemon australasius 29(III;1.06) 30(V;1.75) 31(IV;2.50) 32(I;1.14) 33(I;1.00) 42(III;1.29)

Nematolepis squamea subsp. *squamea* 23(II;1.50) 33(III;1.17) 37(II;1.00)

Philotheca salsolifolia 29(II;1.60) 31(I;3.00) 33(I;2.00)

Zieria arborescens subsp. *arborescens* 33(I;1.00)

Zieria laxiflora 16(III;1.00) 23(II;1.00) 29(IV;1.36) 30(V;2.00) 31(IV;1.33) 32(III;1.38) 33(II;1.40) 42(III;1.00)

SANTALACEAE

Leptomeria acida 22(I;1.00) 24(II;1.17) 25(I;1.14) 26(I;1.00) 28(I;1.00) 29(III;1.59) 30(II;1.00) 32(II;1.11) 33(III;1.33) 35(I;1.00) 41(III;1.20) 42(II;1.00)

Thesium australe 14(I;1.00)

SAPINDACEAE

Cupaniopsis anacardioides 33(I;1.00) 40*(V;1.00)

Dodonaea triquetra 33(I;1.00)

Guioa semiglauca 41(I;1.00)

SCROPHULARIACEAE

Euphrasia collina subsp. *paludosa* 17*(III;1.50) 22(I;1.00)

STACKHOUSIACEAE

Stackhousia nuda 10(I;1.00) 17(II;1.00) 20(II;1.00) 21(II;1.00) 22(I;1.00) 25(I;1.00) 26(II;1.00) 29(I;1.00) 30(II;1.00) 32(I;1.00) 34(II;1.00) 42(I;1.00)

STYLIDIACEAE

Stylidium graminifolium 16(II;1.00) 17(III;1.00) 20(I;1.00) 22(II;1.00) 23(II;1.00) 25(II;1.00) 26(I;1.00) 29(I;1.00) 31(IV;1.00) 32(II;1.00) 35(II;1.00)

Stylidium ornatum 24(I;1.00) 25(IV;1.43) 26(II;1.50) 28(II;1.40) 31(I;1.00) 32(I;1.17) 34(III;1.00)

THYMELAEACEAE

Pimelea linifolia 10(I;1.00) 14(V;2.12) 15(II;1.00) 16(V;1.75) 17(V;2.00) 19(V;1.50) 20(V;1.60) 22(IV;1.33) 23(IV;1.00) 24(IV;1.18) 25(V;1.27) 26(V;2.20) 27(V;1.50) 28(V;1.40) 29(IV;1.18) 30(IV;1.67) 31(V;1.36) 32(IV;1.11) 33(III;1.00) 34(V;1.25) 40(III;1.00) 42(V;1.24)

Wikstroemia indica 37(II;1.00)

TREMANDRACEAE

Tetratheca thymifolia 16(III;1.00) 18(III;1.00) 29(II;1.00) 30(V;1.25) 31(III;1.50) 32(I;1.25) 33(II;1.00) 42(II;1.25)

VERBENACEAE

Lantana camara 23(I;1.00) 37(III;1.00)

Verbena bonariensis 22(I;1.00)

VIOLACEAE

Hybanthus stellarioides 14(I;1.00) 19(I;1.00)

Hybanthus vernonii subsp. *scaber* 19(I;1.00)

Viola betonicifolia 14(II;1.00)

Viola hederacea 14(III;1.50) 37(III;2.00)

Natural Vegetation of the New South Wales Wheat-belt (Cobar–Nyngan–Gilgandra, Nymagee–Narromine–Dubbo 1:250 000 vegetation sheets)

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Abstract: The vegetation of the Central Division of New South Wales (lat. 31°–33° S, long. 146° 30'–149° E) was classified and mapped (Cobar–Nyngan–Gilgandra, Nymagee–Narromine–Dubbo 1:250 000 mapsheets) as part of the NSW National Parks & Wildlife Service wheat-belt mapping series. The vegetation classification was derived using traditional air photo interpretation and quantitative analysis of data from 428 field sites. Analyses included hierarchical classification in PATN to define floristic groups, then Fidel and ANOSIM to elucidate the characteristic species of the groups and explore the consistency of these relationships at various levels of similarity. Maps and descriptions show the floristic composition and structure, the geographic distribution of assemblages, the current extent, and shape and degree of connectivity of vegetation and changes in native woody vegetation cover over time.

22 vegetation units were defined, 19 were woodlands and forests dominated by eucalypts including *Eucalyptus populnea* subsp. *bimbil* — P4 Poplar Box Woodlands and P16 Simple Poplar Box Woodlands; *Eucalyptus largiflorens* — R3 Black Box Woodlands; *Eucalyptus microcarpa* — P12 Woodlands on Jurassic Sandstone and P13 Grey Box Woodlands; *Eucalyptus camaldulensis* — R1 River Red Gum Forests and Woodlands; *Eucalyptus intertexta* — P14 Red Box, Poplar Box and Pine Woodlands, U1 Red Box, Poplar Box, Pine and Green Mallee Woodlands and U2 Red Box, Poplar Box and Pine Woodlands on Granite Hillslopes; *Eucalyptus dwyeri* — U3 Dwyer's Red Gum Low Open Woodland on Granite Crests, H1 Dwyer's Red Gum, Ironbark and Green Mallee Woodlands and H9 Dwyer's Red Gum Open Woodlands on Granite Hills; *Eucalyptus viridis* — H2 Green Mallee Woodlands; *Eucalyptus morrisii* — H6 Grey Mallee Open Woodlands; Mallee — H7 Mallee Woodlands on Rolling Hills and P1 Mallee Woodlands on Plains; *Eucalyptus dealbata* — H8 Tumble-down Red Gum Woodlands on Basalt Hills; and *Eucalyptus chloroclada* — P15 Dirty Red Gum, Pine and Poplar Box Woodlands. These eucalypt woodlands exhibit diversity in structure and associated species composition. Two tall open shrublands of *Acacia pendula* — R5 Myall Woodlands and *Flindersia maculosa* — P11 Leopardwood Open Shrublands and a woodland dominated by *Callitris glaucophylla* — P6 White Cypress Pine Woodlands are included in the mapping.

The current extent of native woody vegetation is 1.2 million ha (29%) of the total 4.1 million ha study area. Over a period of 15 years approximately 130 000 ha or 10% of the extant vegetation was cleared. Only four of the 22 vegetation units are represented in conservation reserves. These reserves are not considered to adequately represent the diversity of the vegetation units they contain nor do they comprehensively represent the diversity of the vegetation. Threatening processes including; continued clearing, changing water regimes, habitat fragmentation, over-grazing by domestic, feral and native animals, nutrient enrichment, compaction of soil, firewood collection and weed invasion operate in this predominantly agricultural landscape, all of which have implications for the long-term persistence of the vegetation of the area.

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Introduction

Inventory of natural resources is a pre-requisite for land management and conservation (Brooker & Margules 1996, Pressey & Taffs 2001). A vegetation map can provide quantitative information including: the composition and structure of floristic assemblages; the total remaining area of vegetation types; the degree of connectivity between remnant vegetation and conservation reserves; proximity of vegetation to important natural or cultural features; and probable locations of rare, endangered or vulnerable species in the landscape. Information of this type allows management decisions to be discussed on a factual rather than speculative basis and provides a consistent base-line for monitoring further change. This mapping is the second in the NSW National Parks & Wildlife Service (NP&WS) wheat-belt study (Fig. 1) and follows the Forbes and Cargelligo 1:250 000 map sheets (Sivertsen & Metcalfe 1995).

Thematic mapping has always relied on a variety of techniques to depict and summarise the real world. Improvements in analysis of quantitative data, geographic information systems and remote sensing techniques has led to an increased ability to classify and use complex data to inform and quantify decisions about map categories. The maps presented here rely on qualitative patterns, recognised from

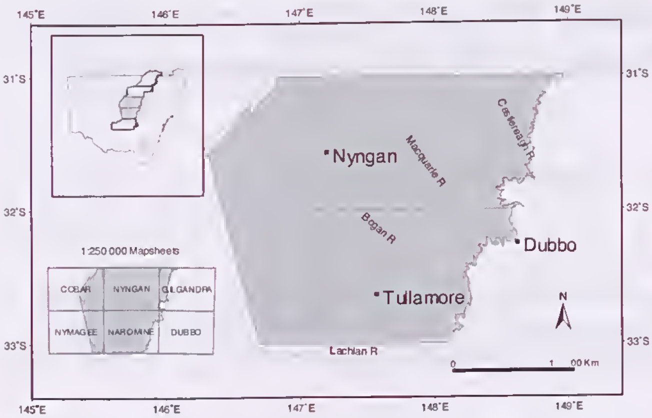

Fig. 1. Study area of NP&WS wheat-belt vegetation mapping showing Cobar–Nyngan–Gilgandra and Nymagee–Narromine–Dubbo 1:250 000 map sheets.

broad scale aerial photography interpretation (API), combined with analyses of quantitative information collected at spatially explicit site locations. Techniques such as: PATN analysis, an hierarchical classification of floristic site data; ANOSIM, comparison within and between groups from an hierarchical classification; and a technique to compare independent data to the hierarchical groups were all used to assess quantitative support for the qualitative interpretations of the vegetation. Systematic quantitative analyses allows an increased level of transparency in assigning and describing map categories, and the ability to repeat and revise such mapping in the light of additional data.

Quantitative information collected on structural diversity and species composition can also be used to reconstruct the original extent and distribution of vegetation types (Austin et al. 2000), determine potential sources of native seed and guide appropriate species selection for revegetation programmes to ameliorate the effects of salinity and excessive clearing (DLWC 2000).

This section of the NSW NP&WS wheat-belt study area covers the central west of NSW, west of Dubbo, and includes the towns of Nyngan, Girilambone, Warren, Gulargambone Gilgandra, Narromine, Nevertire, Tullamore, Tottenham, Trangie, Fifield, and Trundle (lat. 31°–33° S long. 146° 30'–149° E). The eastern edge is the beginning of the South Western slopes at approximately the 300 m contour line (~149°) and the western edge is the Western Division boundary (~146°30') (Fig. 1). The total study area is 4 177 500 ha and includes four of the Interim Biogeographic Regionalisation for Australia (IBRA) units (Laut et al. 1980, Thackway & Cresswell 1995, Fig. 2, Table 1) and ten Local Government Areas (Table 2).

Prior to European settlement the NSW wheat-belt area was predominantly vegetated by temperate eucalypt woodlands (Beadle 1981) which are some of the most poorly conserved ecosystems in Australia (Yates & Hobbs 1997). In this agricultural landscape of chiefly freehold title, eucalypt woodlands have been substantially cleared (MDBMC 1987, Benson 1991, Graetz 1992, Benson 1999, Barson 2000, Sivertsen & Clarke 2000) and are subject to many threatening processes such as: continued clearing (Cox et al. 2001, Bedward et al. 2001); changing water regimes (Kingsford & Thomas 1995); habitat fragmentation; over-grazing by domestic, feral and native animals; nutrient enrichment; compaction of soil; firewood collection and weed

Table 1. IBRA units in the NP&WS wheat-belt study area showing total area, area mapped with native woody vegetation cover on Cobar–Nyngan–Gilgandra, Nymagee–Narromine–Dubbo 1:250 000 mapsheets.

IBRA unit	Area mapped (this paper) (ha) (% total area)	Area vegetated (this paper) (ha) (% area mapped)	Total area (wheatbelt study, ha)
Brigalow Belt South	213 230 (4)	28 122 (13)	5 271 990
Cobar Peneplain	1 693 216 (23)	680 826 (40)	7 346 050
Darling Riverine Plains	1 861 183 (19)	433 463 (23)	9 704 600
NSW South Western Slopes	409 798 (5)	52 463 (13)	8 083 833

Table 2. Area of Local Government Areas (LGA) mapped in this paper

LGA	Extent of LGA in study area (ha)	%	Total area LGA (ha)
Bogan	1 178 021	96	1 230 447
Cobar	224	9	2 598
Coonabarabran	4 805	7	68 004
Coonamble	291 445	30	960 516
Dubbo	50 380	100	50 380
Gilgandra	233 156	100	233 156
Lachlan	805 125	54	1494 874
Narromine	481 403	100	481 403
Parkes	324 167	71	454 089
Warren	808 703	76	1 068 835

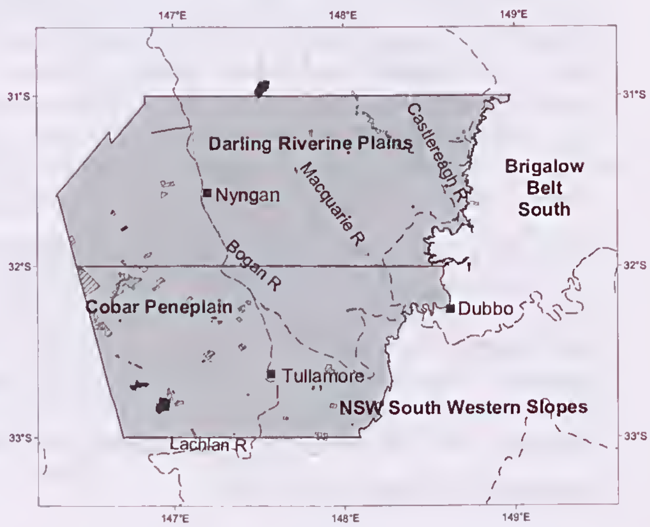

Fig. 2. IBRA areas represented in the NP&WS wheat-belt study area and the location of State Forest, hatched; National Parks &Wildlife Service estate, black; IBRA units, dashed line.

Table 3. Previous vegetation mapping within the study area: Cobar–Nyngan–Gilgandra, Nymagee–Narromine–Dubbo 1:250 000 mapsheets). Total area of NSW NP&WS wheat-belt study is 4 177 500 ha.

Reference	Scale	Area (ha) in study area	Mapping approach
Beadle 1981	1:360 000	2 992 830	Intuitive classification developed from extensive field reconnaissance. Mapping extrapolated to cleared areas using field observations and inferred relationships between vegetation, climate and soils.
Biddiscombe 1963	1:60 000	661 186	Intuitive classification developed from extensive field reconnaissance. Floristic alliances mapped using API. Mapping extrapolated to cleared areas using field observations and inferred relationships between vegetation, climate and soils.
Chinnick & Key 1971	1:127 000	1 849 985	Air photo interpretation (API), soils and density of timber.
Johnson et al. 1991	1:25 000	99 295	Quantitative classification from field sites reconciled with API
Pickard & Norris 1994	1:1 000 000	931 555	Intuitive classification developed from limited field reconnaissance and literature. Floristic alliances mapped using API (photomosaics) and geological mapping. Mapping extrapolated to cleared areas using geological and climatic maps.
Steenbeeke 1996	1:50 000	356 000	Quantitative classification from field sites reconciled with API
Hassle & Associates 1996	1:250 000	72 000	Interpretation of 1:250 000 Landsat TM
Porteners 1998	1:50 000	854	Quantitative classification from field sites reconciled with API
Austin et al. 2000	N/A	518 781	Distribution models developed for frequently occurring tree species from field samples and spatial data on soils, climate and terrain. Pixels classified into classes based on the predicted composition of modelled tree species.
Porteners 2001	1:100 000	9 797	Quantitative classification from field sites reconciled with API
Lewer et al. 1998	1:100 000	1 049 776	Quantitative classification from intensive field sampling across all tenure reconciled with API

invasion (Yates & Hobbs 1997, Hobbs &Yates 2000). The resources and time required to redress these problems are substantial (Prober et al. 2001). Despite the *Native Vegetation Conservation Act* (1997), extensive clearing has continued, particularly the already fragmented vegetation of the agricultural areas (EPA 1997, 2000, ERIC 1998, Cox et al. 2001). Clearing has been recognised as a major concern for the persistence of biodiversity and has been listed as a key threatening process under the NSW *Threatened Species Conservation Act* (1995). These legislative measures appear to have only had limited success in reducing clearing in the wheat-belt.

We have systematically mapped and described the remaining native woody vegetation at the 1:250 000 scale, across all tenures, occurring on the Cobar–Nyngan–Gilgandra and Nymagee–Narromine–Dubbo 1:250 000 map sheets (Fig. 1). The maps show composition and structure of floristic assemblages, extent, shape, and configuration of native woody vegetation. These allow land managers to assess the value and vulnerability of vegetation that occurs on various land tenures and determine the implications for management and sustainability of this natural resource. These maps have also been used successfully to provide a consistent base-line for monitoring further change in native woody vegetation cover (see Cox et al. 2001).

Previous mapping

Various maps and descriptions of the vegetation exist (Fig. 3, Table 3). Beadle (1948, 1981) described the general location of plant alliances; Biddiscombe (1963) mapped (at 1:60 000 scale) 22 floristic associations on the lower north-western slopes and on the plains in the east of the study area. Soils and timber density on the Bogan–Macquarie floodplain affected by an outbreak of the locust *Chortoicetes terminifera* were mapped by Chinnick & Key (1971). A small part of Macquarie Marshes Nature Reserve 1:25 000 mapping (Johnson et al. 1991) and the eastern margin of Pickard & Norris (1994) 1:1 000 000 map are in the study area. Steenbeeke's (unpub.) draft mapping identified 20 vegetation units, including five *Eucalyptus populnea* Poplar Box Woodland sub-alliances at 1:25 000 scale in the lower Macquarie floodplain. Macquarie Valley Landcare (Hassall & Associates 1996) investigated tree density, historical changes and current health of vegetation in the upper Macquarie River. A small amount of systematic data collection and mapping on an *ad hoc* basis has been done in conservation reserves (e.g. Porteners 1998, 2001). Distribution models for frequently occurring plant species developed by Austin et al. (2000) from field samples and spatial data on soils, climate and terrain are available for part of the south-eastern corner. Recent detailed mapping by Lewer et al. (unpub.) covers the Tottenham, Dandaloo, Boona Mount, Tullamore, Condobolin and Bogan Gate 1:100 000 map sheets.

A general overview of the predicted distribution and broad floristic associations of the vegetation was obtained from Biddiscombe (1963), Beadle (1948, 1981), Norris and Pickard (1994). As the data collection for this study was completed in 1988 and the digitising completed in 1999, some of the mapping since these dates has been informed by this work.

Porteners (1998 and 2001) used this mapping for a general overview of the vegetation for the area in and around the Woggoon and Tollingo Nature Reserves, then sampled more intensively within the Nature Reserves. Floristic data from this survey was provided to Austin et al. (2000) for inclusion in the floristic distribution models. Johnson et al. (1991) mapping is predominantly outside the study area and the mapping within the study area identifies non-woody floodplain vegetation not covered in this work. Similarly the focus of Steenbeeke's (unpub.) work is non-woody floodplain vegetation and was examined specifically in relation to the Eucalypt Box Woodland vegetation. The site data from Lewer (unpub.) is used in this mapping to examine the adequacy of sampling on public land and to determine if the sampling regime was comprehensive for the floristic diversity of a subset of the study area. While these mapping exercises contribute to the understanding of floristic diversity, they do not collectively provide a map of extant vegetation for the whole area. The maps presented here, across all tenure, address the needs of land managers on both public and private lands for management and conservation planning at a regional scale.

Fig. 3. Coverage of previous vegetation mapping: Beadle, 1948; Biddiscombe, 1963; Chinnick & Key, 1971; Johnson et al., 1991; Steenbeeke, unpub.; Pickard & Norris, 1994; and Lewer et al., unpub.

History of occupation and land use

Indigenous people occupied the area for thousands of years prior to European settlement (Pearson 1973). The Wiradjuri people are recognised as the main Aboriginal group with an affinity to the area, but little evidence of their occupation has been recorded (Pearson 1973). Some ceremonial grounds and burial mounds were documented around Dubbo (Garnsey 1946) and Dorothy McLelland photographed dendroglyphs marking burial sites in the Narromine area (Payne unpub.). Since the introduction of pastoralism and agriculture, land use has changed radically and rapidly. Permanent camps, borah rings, canoe scar trees, dendroglyphs, artefacts and significant natural sites are susceptible to clearing, ploughing and land disturbance (Pearson 1973, Pearson & Sullivan 1995). Many permanent camps, artefacts and sites were located along the most favourable routes and in the best locations for access to water and resources, and were displaced or destroyed by townships and rural settlement (Garnsey 1946, Pearson 1973). Many indigenous people were displaced by the advancing pastoralists (Garnsey 1946) and forcibly removed to missions or reserves (Payne unpub.). Aboriginal Land Councils represented in this area include Pilliga, Coonamble, Quambone, Nyngan, Coonabarabran, Weilwan, Cobar, Warren-Macquarie, Gilgandra, Condobolin, Dubbo, Trangie, Narromine and Peak Hill. These Land Councils have a limited role in the determination of land use and management in the area via Local Government and Regional Vegetation Management Committees (NVCA 1997).

Official European exploration of the area began with John Oxley, who travelled along the Macquarie and Castlereagh Rivers in 1818. Charles Sturt's observations on the landform, rivers, soils and vegetation (1828–29) encouraged pastoral leases west of Wellington from 1837 (Brennan 1972). Thomas Mitchell travelled through the area in 1846 and navigated to the western side of the Macquarie Marshes and on to the Bogan River. Rapid expansion of agricultural activities such as grazing of cattle and sheep followed. The first towns to be proclaimed include: Dubbo, in 1848; Warren, in 1860; and the village of Canonba, in 1866, which all but vanished by 1887, as the railhead at Nyngan was developed. Nevertire sprang up in 1883 as a railhead town transporting wool from the region and copper from Nymagee (Brennan 1972). The Narromine area is an historically important mining area. Tottenham and Albert were major copper producers and Fifield was the leading platinum producer in Australia in the late twentieth century. Currently, copper and gold are mined at Northparkes, 30 km north of Parkes, Peak Hill 1:100 000 (Sherwin 1996). Since 1993 the copper mining industry has been redeveloped west of Girilambone, where copper was first discovered in 1875 (Gilligan et al. 1995).

Management of river flows led to broad acre cropping of cereals and fodder close to the rivers. Irrigation has expanded since the 1940s and cropping now occurs across most of the study area. The intensity of production varies across the landscape. In the west, sheep grazing with occasional cereal or fodder cropping occurs. In the basin of the Bogan River, a mixture of grazing and cropping occurs, ground water is saline and stock are dependent upon dams filled by rainfall (Sherwin 1996). The intensity and frequency of cropping increases in the east, with large-scale irrigation along the Macquarie River. On the alluvial plains and deep soils, sheep grazing complements intense and frequent cereal cropping. Firewood collection for the domestic markets of Canberra and Sydney is widespread. Irrigated cropping of cotton is now an economically important activity in the Macquarie valley (ABS 1996). Increasing river regulation on the Macquarie River (Kingsford & Thomas 1995) has occurred since completion of the Burrendong Dam in 1965 and Windamere Dam in 1984.

Tenure

Freehold title accounts for 92% of the area. Land formally dedicated to nature conservation comprises four Nature Reserves: Macquarie Marshes; Quanda; Tollingo and Woggoon (14 860 ha or 0.35% of the study area). There are 56 small, often isolated State Forests (Table 5) occupying 1.4% of the study area. The remaining 248 000 ha or 6% is Public Land as Leasehold, Vacant Crown Land, Travelling Stock and Road Reserves (Table 4).

Table 4. Tenure of land in the study area (adapted from Pressey et al. 2000)

Tenure	Area (ha)	%
Freehold	3 857 600	92
Leasehold	182 600	4.4
Other Crownland	65 400	1.6
State Forest	58 550	1.4
Conservation Reserves	14 860	0.35
Total	4 174 700	

Table 5. Extent of State Forests that occur in the study area. Note the small size of most forests

State Forest	ha in study area	State Forest	ha in study area
Albert	1 062	Mellerstain	194
Balgay	1 091	Merri Merri	191
Barrow	1 224	Merrinele	536
Berida	73	Meryula	560
Blow Clear West	1 206	Miandetta	738
Bobadah	106	Mount Nobby	1 535
Bourbah	623	Mount Tilga	543
Boyben	44	Nangerybone	5 899
Bulbodney	2 390	Narraway	380
Carolina	479	Pangee	1 104
Carrabear	174	Peisley	1 274
Coradgery	784	Sandgate	780
Cowal	504	Strahorn	2 260
Cumbine	10 711	Tabratong	463
Curban	198	Tailby	911
Curra	274	Talgong	651
Derriwong	61	Tallegar	1 797
Eringanerin	88	Taratta	955
Euchabil	212	Tenandra	491
Eumungerie	135	Thorndale	1 761
Fifield	108	Tottenham	1 374
Gilgandra	192	Trundle	440
Gin Gin	38	Tullamore	124
Girilambone	972	Vermont Hill	426
Grahway	8 418	Warrie	295
Grayrigg	485	Wharfdale	599
Holybon	125	Wombin	405
Limestone	86	Yalgogrin	6
Total	58 550		

Climate

The climate is semi-arid with average annual rainfall usually less than 500 mm. Rainfall decreases from east to west, with a slight summer peak and a lesser winter peak (Table 6). Autumn and spring are usually drier but there is high variability (BOM 2002). Actual evapotranspiration rate varies between 400 to 600 mm, (BOM 2001) and exceeds annual average rainfall, leading to the potential for a moisture deficit in all but the most favourable rainfall years. Summers are mild to hot and winters are mild to cold (Watkins & Meakin 1996, BOM 2001).

Table 6. Climatic data for selected weather stations in the NSW NP&WS wheat-belt study area (BOM 2002)

Station	Average rainfall (mm)	Monthly av. annual rainfall (mm) Su	Wi	Temperature range °C Summer min	max	Winter min	max
Gilgandra	564	57	46	4	44	-6	31
Peak Hill	564	53	44	7	44	-3	26
Warren	512	56	30	7	44	-5	26
Tullamore	492	47	37	8	43	-4	26
Nyngan Airport	444	47	31	9	47	-3	29
Cobar	337	23	23	9	47	-3	29

Hydrology

The study area is part of the Murray Darling Basin. Three major rivers flow through from the south east to the north west (Fig. 1); the Castlereagh rises in the Warrumbungle Range and eventually joins the Macquarie Marshes; the Macquarie begins in the slopes of the Great Dividing Range and terminates in the Macquarie Marshes; and the Bogan begins in the plains north of Parkes; in full flood, it contributes to the flow of the Darling River via the Barwon.

The Macquarie River is of major agricultural and economic importance to the region, with Burrendong Dam providing regulated water flows (Kingsford & Thomas 1995). The Macquarie River channel terminates in the Macquarie Marshes, a wetland of international importance (Blackley et al. 1996). Of the extensive 131 000 ha Macquarie Marshes, only 18 150 ha are protected from clearing and irrigation development within the Nature Reserve, however, even the Nature Reserve is threatened by hydrological changes induced by upstream water use (Kingsford & Thomas 1995). The Castlereagh and Bogan rivers currently have limited regulation and water extraction. Important perennial and intermittent watercourses such as Merri Merri, Pangee, Bulbodney, Mulga and Gunningbar Creeks flow during local, irregular rainfall events.

Topography

Extensive level to gently sloping fluvial plains are associated with the Castlereagh, Macquarie and Bogan Rivers. These floodplains, channels and swamps are lower in the landscape than the low hill-lands to the east (up to approximately 300 m ASL) and the colluvial apron in the west (Watkins & Meakin 1996). The small rounded low hills of Mount Foster (266 m) and Mount Harris (242 m), north of Warren, and Mogometon Hill (282 m) north of Tenandra, contrast with the very low relief of the fluvial plains, as do the more extensive chain of hills of the Gobondry Mountains (429 m) east of Fifield in the south-east, and the Boona Mountains (461 m) east of Bobadah, in the south west. Associated with the colluvial apron is the gently rolling country of the eastern edge of the Cobar peneplain, where low gravelly slopes rise from the plain. Further west, on the colluvial apron on the Western Division boundary, are the more abrupt, high, steep slopes associated with granite intrusions.

Geology, geomorphology and soils

The landscape can be described in terms of three geomorphological subdivisions: (1) low hill-lands in the east; (2) riverine plains in the centre; (3) colluvial aprons of the Cobar Peneplain and the edge of the Central Western Slopes (Watkins & Meakin 1996). Within these subdivisions a range of geological variation is reflected in soil types, from heavy cracking clays to sandy and gravelly loams.

Low Hill-Lands of Jurassic Pilliga Sandstone and overlying Cretaceous Keelindi beds form the undulating low hill-lands that have well-defined drainage patterns to the south-east of Nyngan and north-east of Narromine respectively. Soils here are red-brown sandy loams over clay loams and are associated with the slight rises and the low hill-lands of the Jurassic Pilliga sedimentaries (Watkins & Meakin 1996). North-west striking ridges of mostly buried Devonian porphyritic intrusives give rise to the Boona Mountains west of Fifield, and isolated peaks of Mount Foster and Mount Harris, north of Warren (Watkins & Meakin 1996).

Riverine plains are dominated by the Castlereagh, Macquarie and Bogan rivers eroding through the sedimentary layers of relict Quaternary river systems. Four fluvial units are recognised by Watkins & Meakin (1996): Marra Creek; Bugwah, Carrabear and Trangie formations.

The Marra Creek formation is confined to the major channels of the Macquarie and Bogan Rivers and has heavy textured dark grey and brown cracking clayey soils. The soil profiles are poorly-developed, with clay content increasing with depth. The Bugwah formation is located between Macquarie and Bogan Rivers, associated with the Backplains of the Riverine plains, the soils here are similar to those of the Marra Creek formation with grey cracking clay soils dominating. Located between Castlereagh and Macquarie Rivers, the Carrabear formation exhibits orange sandy soils with well-defined profiles. The soils of the Trangie formation, associated with the Riverine plains south-east of Nyngan, are dark red to orange-brown sandy soils with weathering profiles up to tens of metres thick. Transitional soils occur within all these formations, on the slightly elevated meander plains, light textured red to red brown earths occur in close association with grey-brown heavy textured soils. Coarser material gives stability to these soils, but silt is readily dispersed by water and wind, making some meander plains soils susceptible to erosion and scalding (Watkins & Meakin 1996).

Colluvial aprons form the slightly elevated areas to the east (Central Tablelands) and to the west (Cobar peneplain). This narrow belt of colluvial material from Siluro-devonian sedimentary rock forms the base of the Central Tablelands. Soils on the low hills of these colluvial aprons are generally light textured, red to brown coloured, acidic, with poorly-developed profiles, commonly containing gravel and lacking in calcium carbonate (Watkins & Meakin 1996). The colluvial apron of the Cobar peneplain is characterised by an abundance of chert and fine grained quartz rich Quaternary sediments, that obscure Cambro-ordivician Girilambone Group sedimentary rock (Watkins & Meakin 1996, Sherwin 1996). The slightly undulating to level low hills in the west display shallow, gravelly, loamy soils and red earths (Watkins & Meakin 1996). A small area of late Ordovician siltstone and sandstone outcrops near Narromine (Sherwin 1996). A distinctive outcropping of late Ordovician hornblendite, recognised as the Honeybugle complex, occurs west of Nyngan and is associated with an extensive area of mallee (Gilligan et al. 1995).

Methods

The vegetation maps presented here are a synthesis of vegetation patterns identified subjectively by air photo interpretation (API) and analyses of quantitative survey data. These analyses were iterative, in that the initial analyses directed more detailed consideration of some vegetation patterns. A new quantitative technique was used to compare floristic classifications using dissimilarity matrices derived from the survey data.

Native woody vegetation was mapped at the 1:250 000 scale to ensure an accurate and comprehensive representation of the structural diversity of vegetation and in recognition of the resource limitations of the project. The following criteria were used to identify the remaining native woody vegetation; a minimum tree canopy cover of 5%, treating canopies as solid objects, as per the crown cover projection method outlined in McDonald et al. (1990). If an area was identified as reaching the minimum threshold then remnants down to approximately 10 ha in size were identified. Some remnants slightly smaller than 10 ha were included in this mapping to ensure a more accurate representation of the extent and fragmented nature of the vegetation. In the east where clearing has been more extensive, the number of remnants less than 10 ha is greatest. These small remnants are easily distinguished on air photos in the agricultural landscape. Remnants of less than 10 ha in size account for 20% of the polygons mapped but only 11 000 ha (1%) of the total area of native woody vegetation mapped. Vegetation remnants vary in structure and composition from having all layers dominated by native species to having only native canopy species with other layers in the understorey dominated by introduced species.

The native woody vegetation remnants were then allocated to a photo-pattern based on the structure, height, density, species composition, position in the landscape, and relation to other geological or geomorphological formations that could be determined on air photos. 30 vegetation patterns were recognised.

Certain categories of vegetation could not be mapped consistently using the criteria and API outlined above. Lignum, Myall, Chenopod Shrublands, wetlands, patches of native vegetation less than 10 ha in size, and naturally treeless plains (grasslands) are difficult to discern on photographs less than 1:50 000 scale, the smallest scale used for these maps (Table 7. Extensive grasslands are present in the study area, under Open Woodlands and in open pasture or cleared areas. These grasslands are mostly secondary or derived grasslands that may or may not be dominated by native species. Pure native grasslands have not been mapped because of the difficulty in distinguishing grassland from improved pasture and some chenopod shrublands. Grasslands ideally need to be mapped at a larger scale, with landuse information indicating the extent of pasture improvement and time since last tilling.

Table 7. 1:250 000 map-sheet, scale and dates of aerial photography.

Map-sheet	Scale	Date air photo
Cobar	1:80 000	1987
Nyngan	1:85 000	1985
Gilgandra	1:50 000	1981
Nymagee	1:83 900	1987
Narromine	1:50 000	1985
Dubbo	1:50 000	1985

Site selection and survey

Survey sites were selected across the range of API vegetation patterns and throughout their geographic extent. For ease of access and due to time limitations, sites were located on public land including State Forests, Nature Reserves, Vacant Crown Lands, Travelling Stock Reserves and Road Reserves. Sites were supplemented with opportunistic recording of remnants on both public and private land.

Data collection methods follow Sivertsen & Metcalfe (1995). At each site, usually 400 m^2 area, a description of the physical characteristics of the site, vegetation structure and relative abundance of each vascular plant species were recorded using a modified seven point Braun-Blanquet scale. Terminology for descriptions of the geology, landforms, soils, vegetation structure and growth form follow McDonald et al. (1990). A total of 428 sites were collected, 414 during fieldwork in April and May 1988 and an additional 14 sites were completed in November 1994. Botanical classification and nomenclature follow Harden (1990–1993, 2000, 2002).

Data analysis

Quantitative classification

Affinities between sites in terms of plant species composition were examined by constructing alternative classifications using the PATN package (Belbin 1994). The symmetric form of the Kulczynski coefficient was used to calculate dissimilarity between sites and the clustering algorithm UPGMA with beta parameter set to 0 was used to generate hierarchical classifications (Belbin 1991).

Three alternative classifications were generated using the following site data components: (1) all species; (2) exotic species excluded; (3) restricted (where exotic, annual and species recorded only once in the survey were excluded) (Table 8). From these alternative classifications a single classification that best explained the relationship between sites needed to be selected. To assess the contribution that exotics, annuals and infrequently occurring species made to the position of individual sites between classifications, each pair of classifications in turn had their association matrices subtracted from one another to generate matrices of dendrogram differences i.e. all species minus exotics excluded, all species minus restricted, restricted minus exotics excluded. The resulting dendrogram differences were used to identify site affinities that changed most between the classifications. A list was generated that contained absolute dendrogram differences greater than 0.25. Subsequently, the 10 sites most frequently represented in the list and the 10 sites with the largest absolute dendrogram differences were selected. These sites were examined to determine what trends in species composition influenced the dendrogram differences and the original classifications. From this comparison a final classification was selected.

The three classifications were examined using the homogeneity algorithm (Bedward et al. 1992) to determine an appropriate minimum number of groups in a classification based on the floristic site data and to assess the likelihood of adequately representing the heterogeneity within the data. To identify and eliminate potentially misclassified sites the classification was examined using nearest neighbour analyses (Keith & Bedward 1999). Misclassified sites were then reallocated to the group that contained their nearest neighbours.

Table 8. Number and percentage of species used in the three alternative classifications

Classification	1 All	(%)	2 Exotics excluded	3 Restricted
Native perennial	290	(56%)	290	290
Exotic	44	(8%)	–	–
Native annual	26	(4%)	26	–
Single occurrence	166	(32%)	166	–
Total species	526	(100%)	482	290

Reconciling quantitative and qualitative classifications

The qualitative classification of the vegetation was based on API. These photo-patterns or photo-types represent the structure of the vegetation, landscape variables and floristic associations. The 30 photo-types were reconciled with the quantitative analysis (classification groups), which are based on the floristic component of the site information only. Lineages within the dendrogram were explored at different levels of dissimilarity to distinguish between photo-types. Photo-types with distinctive floristic assemblages and narrow biophysiological tolerances were recognised at high levels of dissimilarity in the dendrogram. Where photo-types had similar floristic composition, overlapped in their position in the landscape or represented a mosaic of vegetation, the dendrogram was explored at lower levels of dissimilarity. The process of defining and reconciling quantitative and qualitative classification was iterative in that the initial analyses directed revision or more detailed consideration of some of the photo-types. The final classification groups were then matched to photo-types. Where there was a one to one relationship, characteristic species were used to build a description of the vegetation. In some cases photo-types did not correspond to single classification group and a description of the vegetation was derived from more than one classification group. In some cases photo-types were not clearly differentiated in classification groups and could not be separated using other quantitative techniques (see below), these photo-types were incorporated into the photo-type that dominated the classification group.

Photo-types may overlap in species composition, but usually have different structure or occupy different positions in the landscape. Where a single classification group represented more than one photo-type, the variation within the classification group was examined to identify any quantitative differences between the sites representing each photo-type compared to the variation in the entire classification group. Sites within a single classification group were assigned their photo-type and the relationship of the sites examined using the ranked association matrix values and the ANOSIM algorithm (Clarke 1993). A difference in the floristic data would demonstrate quantitative support for the floristic composition of the vegetation corroborating distinctions based on differences in structure and position in the landscape. The converse, where photo-types were subsumed into the dominant photo-type because of lack of quantitative support, also occurred.

The final photo-types have characteristic species from their corresponding classification group identified using the Fidel computer routine (Keith & Bedward 1999). Fidel examines each group in terms of the way species occur in the sites within a group compared to sites outside the group. The fidelity of a species to a group is expressed in terms of categories: positive and negative (diagnostic), constant (characteristic) and uninformative (Table 9). Positive species are more likely to occur within the group than outside the group. Negative species are unlikely to occur in the group but are abundant outside the group. Constant species are similar in abundance and frequency inside and outside the group; uninformative species are less frequent or abundant in the group but also likely to be less frequent or abundant outside the group (Table 9). Map unit descriptions were developed from the positive and constant species derived from the Fidel analysis, the structure of the vegetation and the physical characteristics recorded at the sites, (elevation, slope, geology, landform, soil surface texture and soil type). Map unit descriptions are given in Appendix 1. The map unit naming convention follows Sivertsen & Metcalfe (1995).

Table 9. Definition of Fidelity Classes from Fidel programme (comparing in-group with out-group). Adapted from Keith & Bedward (1999).

C/A = Braun-Blanquet cover abundance values.
F: Frequency is proportion of sites in which the species was recorded.
M: median

		Outside the group		
		F 0.5 & M C/A 2	**F < 0.5 or M C/A < 2**	**F = 0 (Species absent)**
Within group	**F 0.5 & M C/A 2**	Constant	Positive	Positive
	F < 0.5 or M C/A < 2	Negative	Uninformative	Positive
	F = 0 (Species absent)	Negative	Uninformative	–

Comparison of vegetation mapping with independent data

In recognition of our sampling limitations i.e. restricted to public land, limited numbers of sites per map sheet and data collection during autumn 1988, we examined if the mapping was floristically adequate. We examined a subset of the original survey area with independent site data from four 1:100 000 map sheets: Tottenham, Dandaloo, Boona Mount, and Tullamore (Lewer et al. unpub.) (Fig. 3). The independent site data was collected in 2000, after favourable growing conditions, across all tenures, with more intensive sampling (approximately 100 sites per 1:100 000 map sheet compared to approximately 35 sites per 1:100 000 map sheet for our data).

Due to the differences between these two data sets, seasons, time, sampling intensity, and tenure, a quantitative rather than qualitative approach was taken. The two data sets were standardised to reduce the effect of the 12 years between the sampling efforts, and the large seasonal differences in rainfall events leading up to the surveys — below average rainfall for our survey and above average for Lewer et al. (Table 10). Species that occurred twice or more in either data set were used; exotics, annuals and cryptic species such as orchids were eliminated, and nomenclatural inconsistencies resolved.

To take into account the dispersion of the sites within classification groups, independent sites were not compared to the centroid of the classification groups as in ALOC (Belbin 1994). Due to the large differences in species richness between the data sets, the average value of the classification group was also avoided (Clarke 1993). Instead, the independent sites were allocated to a classification group based on the nearest value in the group. To avoid imposing an arbitrary critical distance or cut-off, progressively lower levels of dissimilarity were used to identify which independent quadrats fell within the domain of the classification. This approach was a conservative use of the independent data, as successively more stringent levels were used to assess the dissimilarity between two data sets. At each level the unallocated independent sites were examined. This can best be described as using a numerical approach to guide expert assessment.

The independent sites were compared to each site in our classification using custom written routines in the statistical package R (Venables & Smith 2001). The dissimilarity between each independent site and the sites in our classification groups was calculated. Independent sites were allocated to a classification group at 0.8, 0.7, and 0.6 levels of dissimilarity. Where the dissimilarity value calculated for the independent site was less than or equal to the nominated value, the site was allocated to a classification group. Independent sites that did not allocate to a classification group were identified and their floristic composition and spatial location examined.

Table 10. Climatic records at selected weather stations prior to field work for this study in autumn 1988 and Lewer et al. in 2000.

	Highest rainfall day (mm)		Average rainfall (mm)	
Year	**Nyngan**	**Tullamore**	**Nyngan**	**Tullamore**
1985	53	35	455	440
1986	48	41	349	359
1987	61	77	450	531
1988[a]	69	49	630	523
1997	54	29	366	253
1998	80	46	695	709
1999	97	78	749	604
2000	97	48	741	579
Annual average rainfall			444	492

[a] Note in 1988 72% of rain fell after May for Tullamore and 60% for Nyngan.

Field checking

To check spatial accuracy and to validate the attribute consistency of the maps, extensive ground truthing was carried out during three field reconnaissance trips along public roads. Vegetation remnants adjacent to public roads were inspected and alterations annotated on field maps and corrected by referring to field observations, notes recorded during the original field-work and further API where necessary. Corrections were then made to the digital data.

Mapping of clearing

The original API used 1980s photos (Table 7). Marked changes in land cover were noted during subsequent field checking. To measure changes in native woody vegetation cover, the original mapping boundaries were compared to satellite imagery and areas of clearing recorded to produce an updated coverage of native woody vegetation. Clearing was defined as a change in average canopy cover from greater than 5% to less than 5%. Using satellite imagery, it was possible to detect in some instances the complete removal of the understorey while retaining a canopy of 5%, these situations occurred for a very small proportion of the areas defined as clearing. The extent of clearing of native woody vegetation was derived from visual interpretation of Landsat Thematic Mapper satellite imagery as described in Cox et al. (2001) and documented for this area in Bedward et al. (2001).

Results

Taxa recorded in the survey

For the quantitative analysis and classification of the map units, 395 (92%) of the 428 survey quadrats were used. 33 sites were eliminated from the analysis: ten of these fell outside the survey boundary; three sites had no species recorded; and 20 sites had inadequate cover abundance scores. From the sites used in the analysis, 526 plant taxa were recorded from 84 families, 40% of all recorded species were in the families Poaceae, Fabaceae, and Asteraceae (Table 11). None of the plants listed under ROTAP (Briggs & Leigh 1995), nor any of the 10 species listed under the *NSW Threatened Species Conservation Act* (1995) or *Environment Protection Biodiversity Act* (1999) were recorded in the survey quadrats. This may have been because of low rainfall prior to field-work (Table 10) or that these species may require targeted searches rather than the stratified random sampling used in this survey.

Table 11. The ten most commonly represented families in the quadrat data

Family	No. of taxa	%
Poaceae	90	17
Fabaceae Total	61	12
Asteraceae	57	11
Fabaceae Mimosoideae	37	7
Myrtaceae	31	6
Chenopodiaceae	28	5
Fabaceae Faboideae	20	4
Malvaceae	14	3
Cyperaceae	13	3
Solanaceae	13	3
Myoporaceae	12	2
Sapindaceae	12	2
Fabaceae Caesalpinioidae	4	2

Comparison of quantitative classifications

Based on the comparison of the dendrogram differences, classification 1 containing all species and classification 2, with only exotics removed, were the least different from each other (Table 8). The greatest difference in distance matrices was between classification 2 exotics removed and 3 restricted. The floristic composition of the 10 most frequently represented sites and the 10 sites with the largest absolute dendrogram differences were examined. The 10 sites with largest absolute dendrogram differences had low species diversity i.e. were depauperate and had a high proportion of exotic and annual species present. In these sites more than one species was excluded from the analysis in the restricted classification (Table 12). The 10 sites that most frequently had dendrogram differences with an absolute value greater than 0.25 also had low species diversity at the time of the survey. These sites usually had only perennial shrubs and canopy species recorded (Table 12). Sites that were species poor and sites with a high proportion of exotics were most affected by restricting the data (Table 12).

Table 12. A comparison of the total number of species and number of species masked in the 10 sites with the most frequent absolute dendrogram differences and highest absolute dendrogram differences. Exotic, annual and singly occurring species were masked

10 most-frequent absolute dendrogram difference										
Frequency	57	41	41	41	28	24	24	23	15	15
No. species in the site	6	10	12	15	8	4	5	7	11	12
No. species masked	0	0	0	0	1	0	0	0	0	0
Highest absolute dendrogram difference										
Frequency	1	2	2	4	1	1	1	1	1	1
No. species in the site	2	8	3	4	33	7	2	3	11	2
No. species masked	0	1	3	0	6	3	0	0	7	0

Exotic, ephemeral and singly occurring species exhibit a high degree of variability in distribution and abundance in relation to climatic conditions, particularly rainfall (Cunningham et al. 1992). Rainfall events in the central west are often patchy, and fieldwork for the survey was completed in late autumn 1988 after an extended dry period (Table 10). Such climatic conditions can account for variations in species composition, particularly among ephemeral and short-lived perennials (Fox 1990). Inclusion of such species in the final analysis and classification would introduce unwanted bias to the quantitative classification. Accordingly, the restricted classification (Table 8) considering only native, perennial (herbaceous and woody) species that occurred more than once in the data set, was selected as the final classification and used to quantitatively define the floristic attributes of the map units. Of the 526 species recorded in the quadrat data, 290 were used in the final quantitative analysis (Table 8).

Nearest neighbour analysis

Based on the results above, 20 classification groups were initially identified. Group size ranged from 1 to 166 sites. Nearest neighbour analysis (Keith & Bedward 1999) identified two sites, members of classification group 15 that were misclassified. These sites were moved to classification groups 1 and 2 respectively reducing the number of classification groups to 19 (Fig. 4).

Consideration of quantitative classification in relation to the definition of map units

The characteristic species from Fidel analysis (Keith & Bedward 1999) were examined for each of the classification groups. Most classification groups corresponded to a photo type except in two cases: group 19, which consisted of non-woody wetland species which were not identified consistently in the air photo interpretation and thus not represented in the mapping; and three classification groups with suspected misidentification of the dominant canopy species; Red Gum species identified as the dominant canopy species classification groups 12 (3 sites), 13 (1 site) and 14 (2 sites) (Fig. 4, Table 13). Groups 12 and 13 had *Eucalyptus chloroclada* recorded and group 14 had *Eucalyptus dealbata*. The accompanying information recorded for these sites such as associated species, structure, landform, soil surface texture, and geology suggest that the identification of the Red Gums was incorrect. Red Gums are known to hybridise in this area particularly *Eucalyptus dealbata* with *Eucalyptus dwyeri* and *Eucalyptus chloroclada* with *Eucalyptus camaldulensis* (Harden 2002), which makes their appearance in the field variable. Group 12, 13 and 14 had similarities in their species composition as indicated by their juxtaposition in the dendrogram but due to the uncertainty in the identification of the Red Gums they were eliminated from further consideration. The remaining 15 classification groups provided the quantitative basis for further exploration of the dendrogram lineages and ultimately the map unit descriptions.

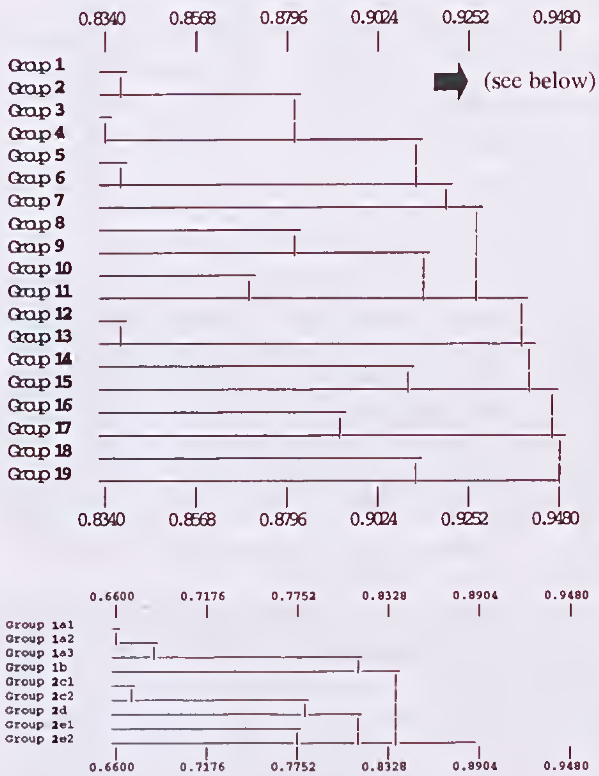

Fig. 4. Schematic dendrogram of classification 3, the final classification selected to define the floristic composition of the map units, representing the 20 original groups resulting from the quantitative PATN analysis.

Table 13. Classification groups from PATN matched to API photo-types

PCG: Primary cassification group; SCG: Secondary classification group; MU: Corresponding map unit; SMU: Secondary map unit.

PCG	SCG	MU/API	No. sites	SMU/API
1	1a1	P6	8	P15
1	1a2	P12	24	P6
1	1a3	H1	9	
1	1b	P13	24	H1
2	2c1	P4	52	P7
2	2c2	P4	75	P16
2	2d	P14	15	
2	2e1	P7	13	P4
2	2e2	P4	7	
3	3	R3	28	
4	4	R5	9	
5	5	H7	19	P1
6	6	P1	6	
7	7	P4	4	
8	8	H1	14	H2
9	9	P12	3	
10	10	H1	6	P12
11	11	H1	26	H2
12, 13, 14	12, 13, 14	No API unit uncertain identification	3,1, 2	
15	15	H8	1	
16	16	H9	3	
17	17	H6	1	
18	18	R1	33	
19	19	No API unit wetland	2	
–	No group	P11	–	
–	No group	U1	3	
–	No group	U2	3	
–	No group	U3	1	

Reconciling quantitative classification with qualitative photo-types

To produce map descriptions, the 30 qualitative photo-types were matched to the 15 primary quantitative classification groups. Some photo-types had very few survey sites due to either limited distribution or difficulty of access. Four photo-types had no corresponding classification group (Table 13). The map unit descriptions for these were derived from the site data that had not been used in the quantitative classification (Table 8) and from informal sites and field observations.

Eleven photo-types corresponded to a single classification group; the characteristic species defined by fidelity analysis were used to construct the floristic descriptions of these map units. Where a photo-type represented a mosaic of floristic assemblages, more than one classification group would be expected to correspond to this photo-type. This was the case for photo-types H1, H2, P4, P7, P12 (Table 13) and the map unit descriptions are based on a compilation of the fidelity analyses of the combined classification groups corresponding to the photo-type.

Classification group 5 (Fig. 4, Table 13) contained sites with mallee on two distinct landforms. Photo-types had been distinguished based on differences in structure of the canopy and the landform on which the mallee occurred. ANOSIM gave an R value of 0.45, using 10 000 random allocations compared to the observed R=0.391 which gives quantitative floristic support to the recognition of photo-types based on structural differences in Mallee vegetation. The floristic composition of these photo-types was described by separating the sites in group 5 based on photo-types, to maintain consistency in the map unit descriptions.

Heterogeneity within map units

An obvious separation in the classification groups was observed between distinctive floristic assemblages that occupy narrow ecological tolerances e.g. between River Red Gum and outcropping hills, or between Black Box woodlands and Mallee woodlands. Floristic assemblages that are associated with a narrow set of environmental conditions are easily identified as photo-types and are relatively homogeneous, and readily matched to a classification group. Where the subjective distinction between the photo-types was difficult (because of fine scale complexity, the fragmented nature of the vegetation, the variation in land management and the extremely subtle changes in the elevation, soils and other abiotic conditions) the quantitative definition of floristic composition was also difficult to achieve. Classification groups 1 and 2 (65 and 166 sites respectively) contained most of the Eucalypt Box Woodlands sites and represented nine photo-types. These groups required thorough interrogation at lower levels of dissimilarity in the dendrogram and resulted in 9 further secondary classification groups to ascertain quantitative support for subtle distinctions in vegetation assemblages, that were recognisable photo-types within the scope of this mapping project (Fig. 4, Table 13). Eight photo-types were subsumed into the photo-types and floristic groups that most closely reflected their composition. In summary, 30 photo-types identified from the API and 15 PATN classification groups were identified at the primary level of dissimilarity. Groups 1 and 2 of this classification were examined at a secondary level of dissimilarity which provided a further 9 classification groups, resulting in a total of 24 classification groups. The final dendrogram structure shows 24 classification groups corresponding to 22 photo-types (Fig. 4, Table 13).

Homogeneity

The homogeneity curve from Classification 3, the restricted classification, indicates the heterogeneity of the data set is most efficiently represented at about 24 groups. Further subdivision in the classification above the change in the curve (at about 24 groups) gives small increases in the homogeneity of the groups and below this level some improvement in the degree of group homogeneity in the data can be made. Further subdivisions of the floristic groups were considered unwarranted for the small gain in homogeneity.

Comparison of vegetation mapping with independent data

At the highest level of dissimilarity 420 (97%) of 433 independent sites were allocated to our classification. The 13 independent sites not allocated at this level were located outside the area designated as native woody vegetation in our mapping. The floristic composition of 11 out of the 13 independent sites was non-woody i.e. composed of grasses, forbs and some low chenopod shrubs. The focus of our mapping was on native woody vegetation; grasslands, chenopod shrublands and wetlands were not specifically sampled or represented separately in the maps. Independent sites in these associations were not allocated to our classification.

At the next level of dissimilarity, 91 independent quadrats were not allocated to a classification group. Eighty one percent, (64) of these sites were located on private property and the floristic composition for 70% was grasses, forbs and low chenopods and corresponded to 'Null — not mapped as woody vegetation' category for our mapping. Of the remaining sites, 26 out of the 27 occurred on private property and had woody components to their floristic composition. Examination of the floristic composition of these sites revealed 60% (16 of the 26) had an overstorey of *Eucalyptus populnea* with many grass and forb species and 3 sites had *Eucalyptus sideroxylon* with many species of *Acacia* and other peas. The species diversity of the independent sites was high (with an average of 53 (median 56) species per site, compared to an average of 23 (median 22) species per site in our data). The high species diversity in the unallocated independent sites affects the allocation of these sites. When the location of these sites were compared to our vegetation mapping, the independent sites occur in vegetation communities that reflect their overstorey species composition. The greater species diversity in the understorey of the independent sites suggests that some of the understorey associations identified in the independent data would not be reflected in our maps. Four of the unallocated independent quadrats contained *Eucalyptus vicina*, all of these quadrats occurred in H1 Dywer's Red Gum *Eucalyptus dwyeri*, *Eucalyptus sideroxylon* and *Eucalyptus viridis* Woodland remnants. At the time of our survey *Eucalyptus vicina* was synonymous with *Eucalyptus dwyeri*. At the lowest level of dissimilarity, 204 or just less than 50% of the independent quadrats were not allocated to a classification group.

The independent sites fit within the native woody floristic associations defined in our mapping, indicating that the floristic groups defined by the original data are comprehensive for native woody vegetation in this area at the 1:250 00 scale. There appear to be no unsampled native woody vegetation classes in the classification, supporting the notion that our sites on public land adequately sampled the floristic diversity of native woody vegetation. The sampling regime for the independent sites intentionally located on private land has provided valuable additional information, particularly in relation to grasslands, shrublands and understorey composition of shrubs and annuals in favourable growing seasons (Lewer et al. unpub.).

Floristic composition and extent of native vegetation

The final 22 map units, named using the dominant association and structural formation (McDonald et al. 1990), are described in Appendix 1. The maps depict the floristic assemblages, structure, spatial configuration and extent of the 22 units. The map units correspond to four broad landform types: riverine plains (R), floodplains (P), peneplains (U) and hills (H). Eucalypt species dominate 19 of the units. Associated with the riverine plains is R1 *Eucalyptus camaldulensis* (River Red Gum) confined to the channels of the major river systems of the Castlereagh, Macquarie and Bogan (Fig. 7). Adjacent to the channels are areas of R3 *Eucalyptus largiflorens* (Black Box, Fig. 8) and R5 *Acacia pendula* (Myall) Woodlands (Fig. 9). The floodplains units reflect the changes in soil and rainfall across the area. P4 *Eucalyptus populnea* (Poplar Box) Woodlands (Fig. 11) are widely distributed across the peneplain and floodplains. P7 *Casuarina cristata* (Belah) (Fig. 13) and Poplar Box Woodlands are associated with drainage lines and depressions. P15 *Eucalyptus chloroclada* (Dirty Red Gum), *Callitris glaucophylla* (Pine) and Poplar Box Woodlands (Fig. 18) most commonly occur on the sandy lenses of relict streams of the meander plains. P6 *Callitris glaucophylla* (White Cypress Pine) Woodlands (Fig. 12) and P13 *Eucalyptus microcarpa* (Grey Box), Poplar Box and Pine Woodlands (Fig. 16) occur on the inter-grade between the floodplain and the peneplain.

The peneplains in the east are dominated by P12 Woodlands on Jurassic Sandstone (Fig. 15) and in the west by P14 *Eucalyptus intertexta* (Red Box), Poplar Box and Pine Woodlands (Fig. 17) that grade into P16 Simple Poplar Box Woodlands (Fig. 19). U1 Red Box, Poplar Box Pine and *Eucalyptus viridis* (Green Mallee) Woodlands (Fig. 20) occupy the slopes of the hills in the west of the study area. P1 Mallee Woodlands on plains (Fig. 10) are restricted to the sandy soils on the rolling country of the Cobar Peneplain. U2 Red Box, Poplar Box and Pine woodlands and U3 *Eucalyptus dwyeri* (Dwyer's Red Gum) Low Open Woodlands occur on granite intrusions.

There are six vegetation units associated with the hills. H1 *Eucalyptus dwyeri*, *Eucalyptus sideroxylon* (Ironbark) and *Eucalyptus viridis* (Green Mallee) Woodlands (Fig. 21) are the most extensive hill unit and occur across the study area on the low rises and extensive chain of hills associated with the Gobondry and Boona Mountains. On the gravelly crest of these hills, pure stands of H2 *Eucalyptus viridis* (Green Mallee) Woodlands (Fig. 22) occur. H8 *Eucalyptus dealbata* (Tumble-down Red Gum) Woodlands (Fig. 25) are restricted to outcropping basalt hills and H9 Dwyer's Red Gum Open Woodland (Fig. 26) is restricted to out cropping granite hills. In the west of the study area on steep rocky hills are H6 *Eucalyptus morrisii* (Grey Mallee) Open Woodlands (Fig. 23).

Some vegetation units change gradually over subtle abiotic gradients and it was difficult to discern a distinct boundary between them e.g. *Eucalyptus microcarpa* (Grey Box) Woodlands and areas of *Eucalyptus populnea* (Poplar Box) Woodlands on the plains. Other vegetation units are more striking in their abrupt and definite boundaries usually related to distinct changes in soils, landform or landuse e.g. *Eucalyptus dealbata* (Tumble-down Red Gum) restricted to basalt hills and *Eucalyptus camaldulensis* (River Red Gum) Woodlands primarily associated with major rivers and streams, rarely extending beyond the confines of the river bank.

Across the entire range of *Eucalyptus populnea* (Poplar Box) distribution for Australia, Beeston et al. (1980) identify 8 broad groups subdivided into 31 communities based on structure and floristics. In NSW *Eucalyptus populnea* subsp. *bimbil* is the only subspecies. Four of these groups occur in the study area. *Eucalyptus populnea* with grassy lower layer and *Eucalyptus populnea* with shrubby lower layer equate to 3 map units; P4 Poplar Box Woodlands, P16 Simple Poplar Box Woodlands, and U2 Red Box, Poplar Box, Pine and Green Mallee Woodlands. *Eucalyptus populnea* with *Casuarina* species equates to map unit P7 *Casuarina cristata* (Belah) and Poplar Box Woodlands and *Eucalyptus populnea* with *Callitris glaucophylla* equates to map unit P6 *Callitris glaucophylla* (White Cypress Pine) Woodlands.

Due to the variety within the P4 Poplar Box Woodland and P16 Simple Poplar Box Woodland and their gradients across the study area, there was considerable overlap of sites between classification groups. Using the classification and additional biogeographic elements — sub-catchments, rainfall, and terrain, these Poplar Box woodlands were split into western P16 Simple Poplar Box Woodland and eastern P4 Poplar Box Woodland classes. The boundary between P16 Woodland and P4 Woodland loosely follows the Cobar Peneplain IBRA boundary, the Bogan River and then a string of ranges and hills (Quartz Ridge, Tottenham Hills, Albert Hills, East of the Boona Ranges and the Deriwong Mountains).

Only three units are not dominated by Eucalypt species, R5 *Acacia pendula* (Myall) Shrublands; P6 *Callitris glaucophylla* (White Cypress Pine) Woodlands; and P11 *Flindersia maculosa* (Leopardwood) Open Shrublands (Fig. 14).

Extent of remaining native vegetation and rate of clearing during the study

At the beginning of the survey in the 1980s 1 324 000 ha (32%) was mapped as native woody vegetation (the study area is approximately 4 177 500 ha). Considerable land cover change occurred during the course of the study. Bedward et al. (2001) documented 129 865 ha of clearing. Clearing from the 1980s to 2000 resulted in a reduction of nearly 10% of the total extent of vegetation originally mapped (Table 14). Only 32% of the total area mapped was considered to have native woody vegetation cover at the beginning of the study, by 2000 this had been reduced by 3% to 29% (Table 14). This is a conservative estimate of clearing, it does not include remnants of less than 10 ha, and scattered paddock trees or the decline in native woody vegetation cover resulting from selective thinning. It does not take into account 'natural' tree loss such as senescence of mature trees, windthrow and dieback.

The clearing is not evenly distributed geographically across the study area or floristically across the vegetation units (Fig. 5). Five map units (P16 Simple Box Woodlands, U2 Red Box, Poplar Box and Pine Woodlands, P13 Grey Box Woodlands, P14 Red Box Poplar Box and Pine Woodlands and P7 Belah and Poplar Box Woodlands) have been cleared above the average for native woody vegetation as a whole. Poplar Box dominates four of these units, with P16 Simple Poplar Box Woodlands in the west reduced by 17% since the beginning of the study (Table 14). Map units already greatly depleted have been further reduced during this time, for example R5 Myall Woodlands have been reduced by 10% and H7 Mallee On Rolling Hills reduced by 9%.

Table 14. Decrease of native woody vegetation cover (1980s and 2000)

Map Unit		1980s (ha)	2000 (ha)	Decreases (ha)	% of 1980s
R1	*Eucalyptus camaldulensis* Forests and Woodlands	92 483	88 319	4 164	5%
R3	*Eucalyptus largiflorens* Woodlands	74 569	69 379	5 190	7%
R5	*Acacia pendula* Woodlands	25 701	23 043	2 658	10%
P1	*Eucalyptus socialis* – *Eucalyptus dumosa* Mallee Woodlands on Plains	19 675	18 757	918	5%
P4	*Eucalyptus populnea* Woodlands	290 823	266 140	24 683	8%
P6	*Callitris glaucophylla* Woodlands	19 892	19 629	263	1%
P7	*Casuarina cristata* – *Eucalyptus populnea* Woodlands	39 335	34 568	4 767	12%
P11	*Flindersia maculosa* Open Shrublands	190	190	0	0%
P12	Woodlands on Jurassic Sandstone	21 331	20 418	913	4%
P13	*Eucalyptus microcarpa* Woodlands	69 165	59 963	9 202	13%
P14	*Eucalyptus intertexta* – *Eucalyptus populnea* – *Callitris glaucophylla* Woodlands	267 313	234 381	32 932	12%
P15	*Eucalyptus chloroclada* – *Callitris glaucophylla* – *Eucalyptus populnea* Woodlands	16 899	15 592	1 307	8%
P16	Simple *Eucalyptus populnea* Woodlands	163 283	134 428	28 855	18%
U1	*Eucalyptus intertexta* – *Eucalyptus populnea*, *Callitris glaucophylla* – *Eucalyptus viridis* Woodlands	33 838	30 994	2 844	8%
U2	*Eucalyptus intertexta* – *Eucalyptus populnea* – *Callitris glaucophylla* Woodlands on Granite Hillslopes	20 232	17 239	2 993	15%
U3	*Eucalyptus dwyeri* Low Open Woodland on Granite Crests	10 021	9 195	826	8%
H1	*Eucalyptus dwyeri* – *Eucalyptus sideroxylon* – *Eucalyptus viridis* Woodlands	89 774	87 005	2 769	3%
H2	*Eucalyptus viridis* Woodlands	21 891	20 893	998	5%
H6	*Eucalyptus morrisii* Open Woodlands	6 625	6 602	23	0%
H7	*Eucalyptus dumosa* – *Eucalyptus socialis* Mallee Woodlands on Rolling Hills	38 208	34 665	3 543	9%
H8	*Eucalyptus dealbata* Woodlands on Basalt Hills	282	282	0	0%
H9	*Eucalyptus dwyeri* Open Woodland on Granite Hills	432	415	17	4%
	Total	1 321 962	1 192 097	129 865	10%

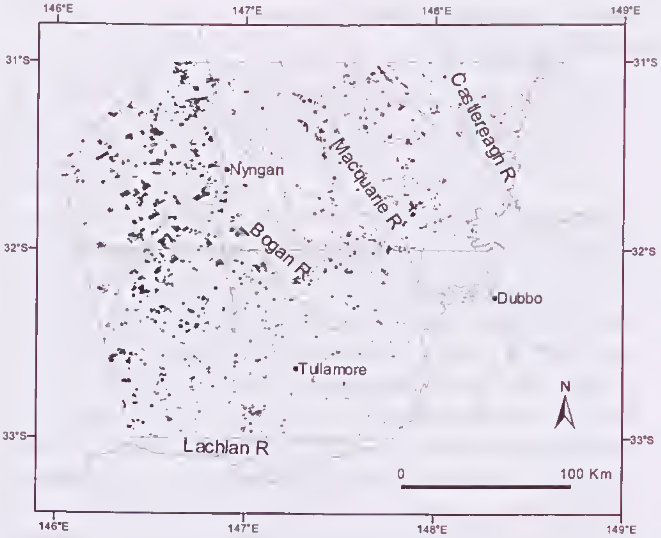

Fig. 5. Shaded areas represent the location of clearing events recorded from visual interpretation of Landsat TM imagery up to 2000.

Clearing events need to be considered in the context of the surrounding vegetation. Large sections of clearing occurred in the west of the study area (Fig. 5) and have a striking visual impact. The proportional loss of vegetation associated with smaller clearing events in the east can be demonstrated by an analysis of the proportion of clearing within a 10 kilometre radius. Where little vegetation remains, a clearing event of a small number of hectares causes a large proportional loss in the vegetation in the immediate vicinity (Fig. 6) (Bedward et al. 2001).

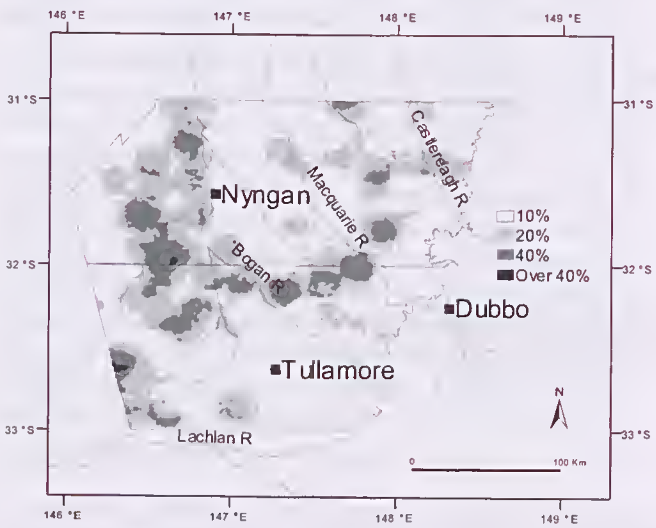

Fig. 6. Proportional loss of vegetation across the study area. Darker shade represents highest proportional loss. Note eastern section where clearing events are small but proportional loss is large.

Discussion

Quantitative techniques for mapping vegetation

The floristic assemblages have been derived using traditional mapping techniques and a number of quantitative techniques. Quantitative analyses were used to define the floristic classification, determine characteristic species for map units, select a classification from alternative classifications, explore consistency of classification groups where sites were distinguished in the photo patterns on non-floristic differences, and test the adequacy of sampling on public land compared to sampling across all tenure. The approach used to identify specific quantitative differences between alternative classifications allowed us to test assumptions that are frequently made about exotic and infrequently occurring species in floristic data sets.

The ANOSIM algorithm (Clarke 1993) was used to explore the consistency of sites within one classification group that had been separated on the differences in landform and vegetation structure in the aerial photographs. The technique provided quantitative support for qualitative patterns recognised within a classification group, in this case the qualitative patterns were landform and structure associated with mallee woodlands. These floristically very similar map units are cleared at strikingly different rates over time (Table 14). Initially (P1) Mallee Woodlands on Plains was cleared more rapidly than (H7) Mallee Woodlands on Rolling Hills, the trend in recent times has been reversed (Table 14).

The technique used to provide a quantitative comparison between two sampling regimes provided objective support that the original site data, sampled on public land only, was an adequate representation of the floristic diversity of the native woody vegetation within a subset of the study area.

Each of these techniques relies on quantitative site data and assists in explaining the relationships between the qualitative patterns recognised from API and the patterns based on quantitative floristic information. These techniques are useful in the part they play assisting to define the vegetation in the study area but more importantly offer insights into the way in which quantitative data may be explored to gain a more complete understanding of patterns in vegetation.

Map units within the landscape

The woodlands, forests and shrublands of the area are represented by 22 map units mapped at 1:250 000 scale, down to at least 10 ha in size, where canopy cover is greater than 5%. The remaining native woody vegetation within the highly modified agricultural landscape is a mosaic of isolated remnants sometimes linked by road, river, shelter-belt and wind-break corridors. As a result of agricultural activity some map units are greatly reduced from their original extent. The map units on the most fertile soils, with gentle relief and close to river systems have been preferentially cleared. R5 Myall Woodlands, R3 Black Box Woodlands and P4 Poplar Box Woodlands had all been highly depleted at the start of the study and have continued to decline.

is currently not viable to clear for cropping, such as steep slopes, poor soils, or restricted land use tenures. As changes in agricultural practices or demands for increased productivity are placed on the landscape, this remaining vegetation is vulnerable to clearing.

Vegetation and environmental associations

The distribution of the natural vegetation is related to landform, substrate, rainfall and position in the landscape. *Eucalyptus populnea* (Poplar Box) is the dominant woodland over a vast area between 300 mm to the 500 mm isohyet (Beadle 1981). The distribution of *Eucalyptus populnea* in these maps reflects trends previously noted (Biddiscombe 1963, Beadle 1948), dominating the plains in the west and north of the study area and declining in the east. As the rainfall gradient increases from west to east, *Eucalyptus largiflorens* (Black Box) is replaced by *Eucalyptus populnea*, which is in turn replaced by *Eucalyptus pilligaensis* (Pilliga Box) and *Eucalyptus microcarpa* (Grey Box).

A change in soil type also has a major effect on the distribution of vegetation. *Acacia pendula*, *Eucalyptus largiflorens* and *Casuarina cristata* are associated with clay soils, while *Eucalyptus microcarpa* is associated with duplex soils with high gravel content. Webb et al. (1980) linked the decline in *Eucalyptus populnea* abundance from west to east to the major soil groups. Our mapping supports the suggestion by Webb et al. (1980) that the distribution of *Eucalyptus populnea* is not based on a gradient of fertility levels between soils, but linked to the variation in the ability of different soils to hold water. This can be observed in the west of the study area, which has low rainfall and high evaporation potential. Here *Eucalyptus populnea* is associated with massive earths and is more likely to occur in a lower position in the landscape, where water availability is greater, than in the more elevated parts. Conversely in the east, where rainfall is higher, *Eucalyptus populnea* is associated with duplex and clay soils in a higher position in the landscape. It is also reflected by the change from P16 Simple Box Woodlands to P14 Red Box, Poplar Box and Pine Woodlands and U1 Red Box, Poplar Box, Pine and Green Mallee.

In some instances it has been argued that vegetation change over time is a direct reflection of land management practices and has little to do with environmental conditions. Harrington et al. (1981) suggested large Eucalypt trees are crucial to the distribution of shrubs and documented an increase in shrub distribution with a decrease in density of *Eucalyptus populnea*.

In *Eucalyptus populnea* woodlands where the density of *Eucalyptus populnea* has been reduced, Hodgkinson et al. (1980) found the soil seed banks showed low numbers of seed of formerly common grass species, but high numbers of shrub seeds. They found no species present in the soil seed-bank that were not present in the above ground floristic community. Lunt (1997) also found that the soil seed banks of anthropogenic native grasslands and grassy forest remnants reflected the above ground flora. These changes in the residual soil seed bank will limit attempts to restore woodland to a predominantly grassy understorey by change in management practices alone. It is likely that the re-introduction of many species, particularly palatable species, will be necessary for rehabilitation of remnants (Lunt 1997). The changes in structure and floristics of *Eucalyptus populnea* communities identified by Beeston et al. (1980) and Lunt (1997) are still being examined (Prober et al. 2001, Prober et al. 2002), particularly in relation to change in floristic composition, the simplification of vegetation structure and soil nutrient cycling.

The *Eucalyptus populnea* Woodlands can be described as a continuum, with species assemblages at the extremities of the distribution distinctly different in both an east-west and north-south direction. On the floodplain in the south *Eucalyptus populnea* is associated with *Eucalyptus largiflorens* while in the north *Eucalyptus populnea* is associated with *Eucalyptus coolibah*. In the east *Eucalyptus populnea* is associated with *Eucalyptus microcarpa – Eucalyptus pilligaensis* and in the west *Eucalyptus populnea* is associated with *Eucalyptus intertexta*. The site data separated some *Eucalyptus populnea* associations with well defined classification groups in the dendrogram but the differentiation between all *Eucalyptus populnea* associations is not definitive, and the perception that *Eucalyptus populnea* Woodlands are distinctly different in the east compared to the west (Beckers, Knop, Dykes pers. com.) was not strongly supported. Subtle differences in topography, soils and hydrology make it difficult to separate all the *Eucalyptus populnea* alliances at the 1:250 000 scale.

Change in vegetation cover

The reduction in the area occupied by temperate eucalypt woodlands is not a recent event. Compared with historical descriptions by Oxley (1818), Sturt (1828, 1829) and Mitchell (1846), Denny (1992) noted a large reduction in the amount of vegetation cover in the region. While present tree species composition is similar to the first European descriptions, there has been an obvious decrease in the density and area covered by the original vegetation associated with extensive land clearing for cropping and grazing activities. Wells et al. (1984) indicates up to 45 per cent of the forests and woodlands in this area have been severely modified since settlement and Walker et al. (1993) have estimated 14 billion trees have been removed from the Murray Darling Basin. Using extinct and threatened plant species data, Burgman (2002) reports that the primary cause for range contraction, population reduction and extinction in Australian vascular flora is due to land clearing for agriculture.

Recent legislative measures to constrain and manage clearing such as *State Environmental Planing Policy 46* 1996 and the *Native Vegetation Conservation Act*, 1997 and the listing of clearing as a threatening process at the national and state level (Environment Protection and Biodiversity Conservation Amendment (Wildlife Protection) Act 2001, NSW Scientific Committee 2002)) indicates the serious nature of the decline in native woody vegetation.

Land clearing rates have not slowed overall in Australia since the early 1990s (Burgman 2002). New clearing, progressive expansion of existing cropped areas into adjacent remnants, fragmentation of larger remnants, and vegetation permanently inundated by off-river storage (Sivertsen 1995) are all evident in the study area. Native woody vegetation occupied only 1 324 000 ha (32 %) of the study area examined in 1980s. Since that time, native woody vegetation cover has declined by 129 000 ha or10 %. In 2000 native woody vegetation occupied 1 194 000 ha (29 %) of the area mapped (Table 14). Thirty five percent (45 000 ha) of all clearing recorded in this study occurred between 1998 and 2000.

Beeston et al. (1980) indicate that development pressures are greatest along the eastern limit of the distribution of *Eucalyptus populnea* (Poplar Box) Woodlands. These assertions are supported by the limited distribution and fragmented or relictual (McIntyre & Hobbs 1999) nature of remnant vegetation in the eastern section of the study area, and by the high levels of clearing recorded in the P4 Poplar Box Woodlands, (24 683 ha) during the course of this study (Table 14).

P16 Simple Poplar Box Woodlands in the west of the study area are still relatively un-fragmented and could be described as variegated in their spatial pattern (McIntyre & Hobbs 1999). However, the largest proportion of clearing occurred within this unit and a distinct shift in land management practice can be observed where 18 % (28 855 ha) of the original extent have been removed since 1987. Similarly, the extensive and relatively un-fragmented P14 Red Box, Poplar Box and Pine Woodlands were cleared heavily, 32 932 ha or 12 % of the original extent since the 1980s, 2 % higher than the average for the entire study area (Table 14). Small, localised clearing events as allowed under the *Native Vegetation Conservation Act* exemptions, for example, may have major consequences for the persistence of native flora and fauna by reducing habitats to unsuitable size (van dee Rae & Bennett 2001) or preventing species movement by increasing distances to adjacent remnants (Law & Chidel 2002).

Although clearing is the most obvious cause for tree decline, other processes such as thinning for pasture improvement, dieback, windthrow, fire, salinity and rising water table, lack of regeneration due to feral and domestic grazers, inappropriate conditions for seedling establishment, and invasion by weeds all contribute to the underlying decline (Saunders et al. 1991). In this fragmented and degraded condition, with altered biotic and abiotic processes, medium to long term persistence of these woodlands in the landscape is uncertain (Prober & Thiele 1993, Prober et al. 2001).

The continuing reduction in native woody vegetation cover means that fewer options for conservation and sustainable agricultural practices are left, as the remaining options for vegetation management are used up in each clearing event. A review by Saunders et al. (1991) indicated that conservation of regional biotas depends entirely on the retention and management of remnants. The ecological implications resulting from the reduction of native woody vegetation cover include loss of habitat for flora and fauna species (which is considered the biggest current threat to biodiversity, WCMC 1992), increased runoff from rainfall, increased soil erosion, reduced extraction of groundwater (Walker et al. 1993) hence possible increase in groundwater levels, increased dryland salinity, decreased water quality, increased land degradation, uncertainty of persistence in the landscape of flora and fauna species, and decreased productivity in the major agricultural centre of NSW.

Despite national efforts such as One Billion Trees, Farming for the Future, 14 years of Landcare, and millions of dollars of Natural Heritage Trust Funding, *State Environmental Planning Policy Number 46* (1996) and *The Native Vegetation Conservation Act* (1997), common box woodland species are not adequately protected in dedicated conservation networks and continue to decline (Prober et al. 2001). The plight of temperate eucalypt woodlands of central NSW requires immediate attention.

Conservation status of the vegetation and implications for management

Four of the 22 vegetation units are represented in conservation reserves. These are: 9480 ha (50%) of P1 Mallee Woodlands on Plains; 345 ha (0.002%) of P16 Simple Poplar Box Woodlands; 290 ha (0.001%) of P14 Red Box, Poplar Box and White Cypress Pine Woodlands; and 70 ha (<0.001%) of H1 Dwyer's Red Gum, Ironbark and Green Mallee Woodlands. Although up to 50% of the current vegetation is in a conservation reserve for P1 Mallee Woodlands, mallee has been considerably reduced from its original extent. These reserves are not considered to adequately represent the diversity of these vegetation units and they clearly do not comprehensively represent the diversity of vegetation in the study area.

Acacia pendula (Myall) Woodlands R5, limited in distribution, fragmented, and threatened by clearing, grazing and altered water regime (Benson 1991, Specht et al. 1995), is not represented in the conservation network. Despite the increased clearing pressure on Box Woodlands no sites within the study area are protected under the Grassy Box Woodland Conservation Management Network and Grassy Poplar (Bimble) Box Woodlands have no representation in the Network at all (Prober et al. 2001). Beeston et al. stated in 1980 that the conservation of *Eucalyptus populnea* and allied communities was poor and that there was an urgent need for adequate sampling and conservation of the variation in both the species and communities. This action is even more important today, as the changes in community structure and the contraction of these communities is occurring at a higher rate than the contraction of native vegetation on the whole.

Existing conservation reserves in the study area are small and becoming more isolated as clearing continues. Quanda Nature Reserve (one of three small reserves in the area) is situated on an unusual geological intrusion with mainly mallee and some Poplar Box and Grey Box. It is not representative of the vegetation of the floodplains or the rolling hills surrounding this area. A large-scale clearing event in 2000 removed nearby vegetation corridors and effectively isolated the Nature Reserve from vegetation to the north. Similarly Tollingo and Woggoon Nature Reserves are of limited extent, represent mainly mallee vegetation associated with the plains and are surrounded by agricultural activity.

These small conservation reserves do not adequately represent the native vegetation of the study area. They exist as islands in a sea of agriculture, not as part of a matrix of compatible land use as is more common of reserves on the east coast of Australia. They are more susceptible to the degrading processes characteristic of fragmented ecosystems including changes in microclimate (influxes of radiation, wind, water and nutrients), degree of isolation (time since isolation, distance to other remnants, degree of connectivity, changes in the surrounding landscape), increased fertility from runoff, mobilisation of salts, changed fire regime, and lack of recruitment due to grazing pressure (Saunders et al. 1991). Their long-term persistence in the landscape is questionable (Landsberg & Wylie 1991).

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Appendix 1.

Map unit descriptions for the remnant vegetation of the Cobar–Nyngan–Gilgandra and Nymagee–Narromine–Dubbo 1:250 000 vegetation map sheets

22 Map Units have been identified, 18 occur on the Cobar–Nyngan–Gilgandra vegetation sheet and 16 on the Nymagee–Narromine–Dubbo 1:250 000 vegetation sheet. Each map unit is described as follows:

Name: Map Unit Code and Title

Area: The extent of the map unit in 2000

Sites: Number of formal sites used to derive the description

Landforms: Most frequently occurring Morphological Terrain Types

Soils: Main soil types based on field observations, not from formal profile descriptions

Geology: Geological formations interpreted from: Cobar 1:250 000 Metallogenic (1994) and Geological (1969) map sheet; Nyngan 1:250 000 Geological map sheet (1996); Gilgandra 1:250 000 Geological map sheet (1968); Nymagee 1:250 000 Geological map sheet (1968); Narromine 1:250 000 Geological map sheet (1972) and Dubbo 1:250 000 Geological map sheet (1971)

Structure: Main vegetation structural types following Walker & Hopkins (1990)

Species: Dominant and characteristic species listed by relevant stratum, trees, low trees, tall shrubs, shrubs, herbs and grasses

Comments: general descriptions and variation expected

Species table: Group C/A = the mean Cover/Abundance for the species in the sites within the classification group (50 percentile).
Group freq %: the percentage of the species in the sites within the classification group of the map unit.
Non-group C/A = the mean Cover/Abundance of the species in the sites outside the classification group (50 percentile).
Non-Group freq %: the percentage of the species in the sites outside the classification group.
Diagnostic (positive and negative) and characteristic (constant) species are listed (see Table 9).

Communities described as:

Riparian and floodplain remnants

R1 *Eucalyptus camaldulensis* (River Red Gum) Forests and Woodlands

R3 *Eucalyptus largiflorens* (Black Box) Woodlands

R5 *Acacia pendula* (Myall) Woodlands

Undulating Peneplain remnants

P1 *Eucalyptus socialis, Eucalyptus dumosa* Mallee Woodlands on Plains

P4 *Eucalyptus populnea* (Poplar Box) Woodlands

P6 *Callitris glaucophylla* (White Cypress Pine) Woodlands

P7 *Casuarina cristata* (Belah) – *Eucalyptus populnea* (Poplar Box) Woodlands

P11 *Flindersia maculosa* (Leopardwood) Open Shrublands

P12 Woodlands on Jurassic Sandstone

P13 *Eucalyptus microcarpa* (Grey Box) Woodlands

P14 *Eucalyptus intertexta* (Red Box), *Eucalyptus populnea* (Poplar Box) and *Callitris glaucophylla* (Pine) Woodlands

P15 *Eucalyptus chloroclada* (Dirty Red Gum), *Callitris glaucophylla* (Pine) and *Eucalyptus populnea* (Poplar Box) Woodlands

P16 Simple *Eucalyptus populnea* (Poplar Box) Woodlands

Remnants on undulating rises

U1 *Eucalyptus intertexta* (Red Box), *Eucalyptus populnea* (Poplar Box), *Callitris glaucophylla* (Pine) and *Eucalyptus viridis* (Green Mallee) Woodlands

U2 *Eucalyptus intertexta* (Red Box), *Eucalyptus populnea* (Poplar Box) and *Callitris glaucophylla* (Pine) Woodlands on Granite Hillslopes

U3 *Eucalyptus dwyeri* (Dwyer's Red Gum) Low Open Woodland on Granite Crests

Hill and ridge remnants

H2 *Eucalyptus viridis* (Green Mallee) Woodlands

H6 *Eucalyptus morrisii* (Grey Mallee) Open Woodlands

H7 *Eucalyptus dumosa – Eucalyptus socialis* Mallee Woodlands on Rolling Hills

H8 *Eucalyptus dealbata* (Tumbled Down Red Gum) Woodlands on basalt hills

H9 *Eucalyptus dwyeri* (Dwyer's Red Gum) Open Woodland on Granite Hills

Riparian and floodplain remnants (R)

R1 *Eucalyptus camaldulensis* (River Red Gum) Forests and Woodlands

Area: 88 319 ha **Sites:** 42

Landforms: Banks, channels, depressions, cowals and backplains of the Bogan, Macquarie and Castlereagh Rivers. Banks of major tributaries in the Cobar and Pilliga peneplains.

Soils: Grey cracking clays, polygenetic alluvial soils.

Geology: Unconsolidated Quaternary alluvials. Note that these alluvials overlay the Ordovician fine grained quartzose metasediments of the Girilambone geological group in the Cobar peneplain and the Jurassic Pilliga sandstone in the Pilliga peneplain region.

Structure: Tall to Very Tall Open Forests and Mid-high to Tall Open Woodlands.

Trees: *Eucalyptus camaldulensis*, occasionally *Eucalyptus largiflorens*. Low Trees: *Acacia salicina, Acacia stenophylla*. Shrubs: *Bursaria spinosa, Glycyrrhiza acanthocarpa, Muehlenbeckia florulenta*. Herbs and Rushes: *Carex appressa, Cyperus gymnocaulos, Eleocharis pallens, Eleocharis plana, Glycine tabacina, Juncus radula, Marsilea drummondii*. Grasses: *Austrodanthonia caespitosa, Eulalia aurea, Phragmites australis, Austrostipa ramosissima, Austrostipa verticillata*.

Comments: Typically dominated by *Eucalyptus camaldulensis* primarily confined to the banks and channels of the major river systems, on perennial streams, in depressions and around cowals and also on intermittent streams in the west of the area. Forests grade into Mid-high and Tall Open Woodlands on the marshes, cowals and open depressions of the Bogan and Macquarie River system. An example of an extensive area of Mid-high Open River Red Gum Woodland spreading from the confines of the river channel is found 25 kms north of Warren.

The low trees *Acacia stenophylla* (River Cooba) and *Acacia salicina* (Cooba) commonly occur in the upper strata. Along the Bogan River, Bulbodney and Crowie Creeks of the Narromine map sheet, *Eucalyptus largiflorens* commonly co-dominates. On sandier soils, particularly in the eastern part of study area (Narromine, Peak Hill, Dubbo, Gilgandra and Tenandra 1:100 000 sheets), along upper tributaries of the Castlereagh and Macquarie River and Coolbaggie Creek, *Eucalyptus conica* (Fuzzy Box), *Eucalyptus melliodora* (Yellow Box) and *Callitris glaucophylla* (White Cypress Pine) occasionally occur with River Red Gum.

The understorey is characterised by a patchy shrub layer, which is frequently absent, and a ground layer of herbs and grass species, often exotics, that vary considerably between sites.

Species	Fidelity class	Group C/A	Group freq %	Non-group C/A	Non-group freq %
Callitris glaucophylla	negative	4	9	4	5
Acacia salicina	positive	2	12	0	0
Bursaria spinosa	positive	1	3	0	0
Carex appressa	positive	4	9	0	0
Cyperus gymnocaulos	positive	6	6	0	0
Austrodanthonia caespitosa	positive	4	3	0	0
Eleocharis plana	positive	4	9	0	0
Eucalyptus camaldulensis	positive	6	97	4	4
Eulalia aurea	positive	4	3	0	0
Glycine tabacina	positive	1	6	0	0
Glycyrrhiza acanthocarpa	positive	5	6	0	0
Juncus radula	positive	4	6	0	0
Phragmites australis	positive	6	6	0	0
Austrostipa ramosissima	positive	4	3	0	0
Austrostipa verticillata	positive	4	3	0	0

Fig. 7. R1 *Eucalyptus camaldulensis* (River Red Gum) Forests and Woodlands, Gunning Bar Creek

Fig. 8. R3 *Eucalyptus largiflorens* (Black Box) Woodlands

R3 *Eucalyptus largiflorens* (Black Box) Woodlands

Area: 69 379 ha **Sites:** 26

Landforms: Floodplains, banks, depressions, cowals and flats of the Bogan-Macquarie floodplain.

Soils: Mainly grey cracking clays, minor red and red-brown earths.

Geology: Quaternary alluvium.

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

Trees: *Eucalyptus largiflorens*, occasionally *Eucalyptus camaldulensis*, *Eucalyptus populnea*, *Casuarina cristata*. Low Trees: *Acacia stenophylla*. Tall Shrubs: *Geijera parviflora*, *Apophyllum anomalum*. Shrubs: *Atriplex semibaccata*, *Einadia nutans* subsp. *nutans*, *Lysiana subfalcata* subsp. *subfalcata*, *Rhagodia spinescens*, *Sclerolaena tricuspis*, *Muehlenbeckia florulenta*, *Solanum esuriale*. Herbs and Rushes: *Calotis scapigera*, *Marsilea drummondii*, *Minuria integerrima*, *Modiola caroliniana*, *Oxalis chnoodes*, *Tribulus terrestris*, *Eleocharis pusilla*. Grasses: *Enteropogon acicularis*, *Leptochloa digitata*, *Thyridolepis mitchelliana*.

Comments: Characterised by Mid-high Open Woodlands of *Eucalyptus largiflorens* and most commonly found on grey cracking clays of the broad floodplain of the Bogan-Macquarie system and north of the Lachlan River (Narromine 1:250 000 map-sheet). Mid-high Woodlands and Mid-high Open Woodlands dominated by *Eucalyptus largiflorens* occur along the banks of the Bogan River and on the slow draining flats, depressions and seasonally flooded low-lying areas (Nyngan 1:250 000 map sheet). Black Box Woodlands are generally absent in the study area east of the Macquarie River except along Marthaguy and Back Creeks.

Along the Bogan River, R3 Black Box Woodlands integrades with R1 River Red Gum Forests. *Eucalyptus camaldulensis* and *Acacia stenophylla* occasionally occur in the overstorey. Away from the main river channels, and on slightly higher ground where the soils grade between grey cracking clays and red earths, a floodplain mosaic comprising minor areas of *Eucalyptus populnea* and *Casuarina cristata* occurs within this unit.

Typically the understorey is composed of scattered low trees and tall shrubs such as *Geijera parviflora* and *Apophyllum anomalum*. Generally a low shrub layer is lacking. Where it is present, chenopods usually dominate, however in those areas subject to periodic inundation, the shrub *Muehlenbeckia florulenta*, may occur. The ground layer may be sparse or absent and is often dependent on seasonal influences.

Species	Fidelity class	Group C/A	Group freq %	Non-group C/A	Non-group freq %
Callitris glaucophylla	negative	0	0	4	54
Atriplex semibaccata	positive	4	7	0	0
Calotis scapigera	positive	1	3	0	0
Einadia nutans subsp. *nutans*	positive	3	59	2	35
Eleocharis pusilla	positive	3	3	0	0
Eucalyptus largiflorens	positive	5	100	4	2
Lysiana subfalcata	positive	1	3	0	0
Minuria integerrima	positive	2	10	0	0
Modiola caroliniana	positive	4	3	0	0
Rhagodia spinescens	positive	3	52	2	14
Sclerolaena tricuspis	positive	1	7	0	0

Fig. 9. R5 *Acacia pendula* (Myall) Woodlands

R5 *Acacia pendula* (Myall) Woodlands

Area: 23 043 ha **Sites:** 14

Landforms: Flats of the alluvial plains subject to gilgai development and extending to the flats of the Pilliga peneplain.

Soils: Grey and brown clays, rarely on deeper red and brown earths

Geology: Quaternary alluvium.

Structure: Mid-high Woodland and Mid-high Open Woodland. Minor Low Open Woodlands.

Low Trees: *Acacia pendula*. Tall Shrubs: *Geijera parviflora*, *Apophyllum anomalum*. Shrubs: *Atriplex vesicaria*, *Lasiopetalum baueri*, *Maireana aphylla*, *Einadia nutans* subsp. *nutans*, *Rhagodia spinescens*, *Sclerolaena muricata*, *Amyema quandang*. Herbs: *Brachycome curvicarpa*. Grasses: *Austrodanthonia linkii* var. *linkii*, *Digitaria divaricatissima*, *Enteropogon acicularis*, *Paspalidium gracile*, *Austrostipa aristiglumis*.

Comments: Occurs as small stands scattered across the flats of the alluvial floodplain of the Bogan and Macquarie Rivers and Boggy Cowal, or isolated remnants in roadside reserves, or pockets amongst taller woodlands. Myall Woodlands most frequently occur on the heavy grey and brown clay gilgais, occasionally on the red and brown earths of the flats of the Pilliga peneplain. Canopy is characteristically monospecific though eucalypts and tall shrubs such as *Geijera parviflora* and *Apophyllum anomalum* may occur with *Acacia pendula* where it is adjacent to Poplar Box or Black Box Woodlands.

Understorey characterised by many species of low chenopod shrubs and grasses. *Amyema quandang* is a common stem parasite of *Acacia pendula*. [Myall Woodlands are difficult to distinguish from pasture and grasslands on API, and may be more common than is indicated by the mapping.]

Species	Fidelity class	Group C/A	Group freq %	Non-group C/A	Non-group freq %
Callitris glaucophylla	negative	0	0	4	51
Acacia pendula	positive	5	100	0	0
Amyema quandang	positive	2	56	0	0
Brachycome curvicarpa	positive	3	33	0	0
Einadia nutans subsp. *nutans*	positive	3	89	2	24
Lasiopetalum baueri	positive	1	11	0	0
Rhagodia spinescens	positive	3	67	3	14
Sclerolaena muricata	positive	2	78	2	9

Fig. 10. P1 *Eucalyptus socialis, Eucalyptus dumosa* (Mallee) Woodlands on Plains

Undulating Peneplain remnants (P)

P1 *Eucalyptus socialis, Eucalyptus dumosa* (Mallee) Woodlands on Plains

Area: 18 757 ha **Sites:** 13

Landforms: Flats very low hills in the east of the Cobar peneplain on Nymagee and Cobar map sheets. **Soils:** Red Earths

Geology: Mainly confined to Honeybugle Ordovician basic intrusion on Cobar map sheet, but also occurs on very low rises of the peneplain around Quanda Nature Reserve on Ordovician sediments.

Structure: Dense, generally even height Very Tall to Extremely Tall Closed Mallee Forest.

Trees: *Eucalyptus socialis* (Pointed Mallee), *Eucalyptus dumosa* (Congoo), *Eucalyptus leptophylla* (Narrow-leafed Red Mallee), *Eucalyptus sideroxylon* (Mugga Ironbark), *Eucalyptus microcarpa* (Mallee Grey Box) *Eucalyptus viridis, Brachychiton populneus, Callitris glaucophylla, Eucalyptus intertexta.* Tall Shrubs: *Acacia deanei* subsp. *paucijuga, Acacia buxifolia* subsp. *buxifolia, Acacia hakeoides, Acacia tetragonophylla, Eremophila deserti, Hakea leucoptera, Eremophila longifolia, Geijera parviflora.* Shrubs: *Pimelea microcephala, Bertya cunninghamii, Cassinia laevis, Choretrum glomeratum, Bossiaea walkeri, Senna artemisioides* subsp. *zygophylla, Eremophila glabra, Olearia pimeleoides, Sclerolaena bicornis* var. *horrida;* Herbs: *Solanum ellipticum, Solanum ferocissimum.* Grasses: *Dianella revoluta, Lomandra effusa, Austrostipa scabra, Triodia scariosa* subsp. *scariosa.*

Comments: *Eucalyptus viridis* (Green Mallee) is an occasional co-dominant on gravelly soils. *Brachychiton populneus* (Kurrajong), *Eucalyptus intertexta* (Red Box) and *Callitris glaucophylla* (White Cypress Pine) may also be found as isolated trees. Understorey typically composed of *Acacia* species, *Geijera parviflora* and *Eremophila longifolia* in the upper shrub layer with the grass *Triodia scariosa* subsp. *scariosa* and herbs being characteristic of the ground layer. [This map unit is similar to H7 Mallee Woodlands on Rolling Hills in floristic composition, but P1 Mallee Woodlands on Plains are more diverse and display a taller structure, and generally occur lower in the landscape.]

Occurrences within Tollingo, Woggoon and Quanda Nature Reserves represents the largest eastern-most remnants of this vegetation type (Porteners 1998, 2001). It has been extensively cleared and outside of Nature Reserves all that remains of this once extensive map unit are narrow fragmented remnants along the roadsides.

Species	Fidelity class	Group C/A	Group freq %	Non-group C/A	Non-group freq %
Acacia deanei subsp. *paucijuga*	positive	2	100	4	1
Acacia hakeoides	positive	1	50	1	6
Acacia buxifolia subsp. *buxifolia*	positive	1	33	0	0
Bertya cunninghamii	positive	4	66	4	3
Callitris glaucophylla	positive	4	83	2	27
Cassinia laevis	positive	1	83	1	1
Choretrum glomeratum	positive	1	16	0	0
Dianella revoluta	positive	3	50	3	2
Eremophila glabra	positive	2	66	1	4
Eucalyptus socialis	positive	5	50	4	10
Eucalyptus sideroxylon	positive	4	50	4	13
Lomandra effusa	positive	1	66	3	1
Phebalium glandulosum subsp. *glandulosum*	positive	4	33	0	0
Pimelea microcephala	positive	1	33	0	0
Sclerolaena bicornis var. *horrida*	positive	1	50	2	1
Senna artemisioides subsp. *zygophylla*	positive	1	50	3	1
Austrostipa scabra	positive	2	100	4	10

Fig. 11. P4 *Eucalyptus populnea* (Poplar Box) Woodlands

P4 *Eucalyptus populnea* (Poplar Box) Woodlands

Area: 266 140 ha **Sites:** 76

Landforms: Flats and some open depressions of the backplains, floodplains and low footslopes of the peneplain.

Soils: Red, red-brown and yellow earths and grey, brown and red clays.

Geology: Quaternary colluvial and alluvial derivation.

Structure: Mid-high to Tall Woodlands and Open Woodlands.

Trees: *Eucalyptus populnea, Callitris glaucophylla, Allocasuarina luehmannii.* Low Trees: *Alectryon oleifolius, Capparis mitchellii, Acacia colletioides, Acacia salicina.* Tall Shrubs: *Geijera parviflora, Eremophila mitchellii, Eucalyptus glabra, Apophyllum anomalum, Hakea leucoptera.* Shrubs: *Bertya cunninghamii, Einadia nutans* subsp. *nutans, Rhagodia spinescens, Sclerolaena* spp., *Maireana decalvans.* Herbs and Rushes: *Brunoniella australis, Calotis* spp., *Cheilanthes sieberi* subsp. *sieberi, Dichondra repens, Pelargonium australe, Eleocharis* spp., *Carex appressa;* Grasses: *Austrostipa scabra, Cymbopogon obtectus, Enteropogon acicularis, Aristida* spp.

Comments: *Eucalyptus populnea* (Poplar Box) Woodlands are the most commonly occurring and widespread remnant types in the study area. They have been categorised into P4 Poplar Box Woodland and P16 Simple Poplar Box Woodland map units and account for 30% of all vegetation mapped. The distinction between these units is based on a slight difference in floristic composition, examination of air photo patterns and field observations. Within the P4 Poplar Box Woodland map unit a number of different associations are recognised and described. Their subtle differences in structure and composition in the field made it impractical to classify them as separate map units given the scale of the aerial photography interpreted the amount of available site data, and the scale of the final map. P4 Poplar Box Woodland may occur as small isolated stands and narrow, linear corridors along road and property boundaries and as wind breaks. Where land use and management has had minimal impact, expansive Tall Woodlands and Tall Open Woodlands are found.

A typical Poplar Box Woodland remnant is dominated by *Eucalyptus populnea* (Poplar Box) with the relative dominance of associated overstorey and understorey species changing with the degree of impact of past and current land use practices and local variations in environmental conditions. The upper layer of the understorey is commonly composed of scattered low trees such as *Alectryon oleifolius* and *Capparis mitchellii* occurring with tall shrubs including *Geijera parviflora*, *Eremophila mitchellii* and *Apophyllum anomalum*. The lower shrub layer is typically dominated by chenopods and the ground layer is generally characterised by herbs and grasses.

From east to west of the range of associations can be noted at the local level, but are not represented in the maps. From the Pilliga Peneplain west to the Castlereagh River P4 Poplar Box Woodlands occur on the sandier, quartzose-dominated soils and grade into P12 Woodlands on Jurassic Sandstone. Here *Eucalyptus pilligaensis*, *Eucalyptus microcarpa*, *Eucalyptus conica*, and *Casuarina cristata* occur as associated overstorey species. On the yellow earths of the banks and raised flats of the Castlereagh River, *Eucalyptus populnea*, *Callitris glaucophylla*, and *Eucalyptus melanophlaia* can occur with *Eucalyptus camaldulensis*.

West of the Castlereagh where the Macquarie River floodplain rises gently, the red and yellow earths of Quaternary Carrabear formation support Tall Woodlands and Tall Open Woodlands of *Eucalyptus populnea* with *Callitris glaucophylla* and *Allocasuarina luehmannii*. Remnants adjacent to P15 *Eucalyptus chloroclada* (Dirty Gum), Pine and Poplar Box Woodlands, *Eucalyptus chloroclada* and *Callitris glaucophylla* may co-dominant with *Eucalyptus populnea*. P4 Poplar Box woodlands adjacent to and east of the Bogan river, on soils with higher fertility, *Eucalyptus microcarpa* (Grey Box) may dominate. In the zone of transition from the Macquarie River floodplain to the Bogan River floodplains and backplains, alluvial red and yellow earths and some grey clays support Tall Open Woodlands of *Eucalyptus populnea* with occasional *Casuarina cristata* and *Allocasuarina luehmannii* (Tullamore and Dandaloo 1:100 000 sheets). From the elevated flats of the Bogan River backplain west to the Cobar peneplaiin, P4 Poplar Box Woodlands grade into P16 Simple Poplar Box Woodland, where *Eucalyptus populnea* is associated with *Callitris glaucophylla*, *Casuarina cristata* and *Eucalyptus intertexta*.

Species	Fidelity class	Group C/A	Group freq %	Non-group C/A	Non-group freq %
Callitris glaucophylla	constant	4	88	4	51
Acacia colletioides	positive	4	13	0	0
Acacia salicina	positive	5	38	0	0
Alectryan oleifalius	positive	3	57	1	14
Aristida behriana	positive	1	26	0	0
Aristida jerichoensis	positive	3	19	0	0
Aristida leichhardtiana	positive	2	19	0	.0
Bertya cunninghamii	positive	4	26	0	0
Brunoniella australis	positive	2	25	0	0
Bursaria spinosa	positive	1	1	0	0
Calotis cuneata	positive	1	1	0	0
Calotis lappulacea	positive	2	50	3	4
Calotis scapigera	positive	3	2	0	0
Carex appressa	positive	3	2	0	0
Cheilanthes sieberi subsp. *sieberi*	positive	2	50	2	5
Cymbopogon abtectus	positive	1	2	0	0
Dichondra repens	positive	2	25	0	0
Einadia nutans subsp. *nutans*	positive	2	65	3	37
Eleacharis pallens	positive	3	2	0	0
Eleocharis plana	positive	3	6	0	0
Eleocharis pusilla	positive	3	2	0	0
Enneapagon polyphyllus	positive	2	26	0	0
Enteropogon acicularis	positive	3	55	3	34
Eragrostis megalosperma	positive	3	2	0	0
Eremaphila glabra	positive	3	2	0	0
Eremophila mitchellii	positive	3	51	2	26
Eriochloa pseudaacrotricha	positive	4	2	0	0
Eucalyptus populnea	constant	5	98	4	56
Eucalyptus melliodora	positive	6	2	4	1
Geijera parviflora	positive	3	67	3	42
Juncus radula	positive	1	2	0	0
Lysiana subfalcata	positive	4	2	0	0
Muehlenbeckia florulenta	positive	4	77	0	0
Pelargonium australe	positive	3	2	0	0
Rhagadia spinescens	positive	3	50	2	8
Rhynchosia minima	positive	1	2	0	0
Scleralaena tricuspis	positive	2	58	0	0
Vittadinia dissecta var. *hirta*	positive	4	14	0	0

Fig. 12. P6 *Callitris glaucophylla* (White Cypress Pine) Woodlands, adjacent to Meryula State Forest

P6 *Callitris glaucophylla* (White Cypress Pine) Woodlands

Area: 19 629 ha **Sites:** 17

Landforms: Flats, low rises and aeolian dunes of the alluvial plain. Low slopes and flats of the peneplains.

Soils: Sandy red and yellow earths

Geology: Quaternary alluvials and residuals.

Structure: Tall Open Woodland and Tall Woodland. Minor Mid-high Open Woodland.

Trees: *Callitris glaucophylla*. Tall Shrubs: *Dodonaea viscosa*. Shrubs: *Einadia nutans* subsp. *nutans*, *Rhagodia spinescens*. Herbs: *Calotis cuneifolia*, *Cheilanthes austrotenuifolia*. Grasses: *Enteropogon acicularis*, *Austrostipa scabra*.

Comments: Occurs on red earths of the Cobar peneplain, the alluvial plains of the major rivers and the sandy red and yellow earths of the Pilliga peneplain. Characterised by a predominance of mature *Callitris glaucophylla* (White Cypress Pine) in the tallest stratum, or by a dense, uniform, regrowth layer of *Callitris glaucophylla* in the mid stratum, with a sparse understorey. In State Forests typically occurs as large stands of Tall Open Woodlands or Tall Woodlands with eucalypt species as isolated emergent trees, having been thinned in the past. On the low slopes and flats of the Cobar peneplain, overstorey species *Eucalyptus populnea* and *Eucalyptus intertexta* are infrequently interspersed. The distinctive airphoto pattern of the canopy and lack of species recorded in the understorey and ground layer has influenced the classification of this map unit.

Species	Fidelity class	Group C/A	Group freq %	Non-group C/A	Non-group freq %
Callitris glaucophylla	constant	6	100	4	62
Eucalyptus populnea	negative	2	4	4	72
Geijera parviflora	negative	1	8	3	52
Einadia nutans subsp. *nutans*	positive	3	87	2	42
Enteropogon acicularis	positive	3	75	3	38

Fig. 13. P7 *Casuarina cristata* (Belah) and *Eucalyptus populnea* (Poplar Box) Open Woodlands

P7 *Casuarina cristata* (Belah) – *Eucalyptus populnea* (Poplar Box) Woodlands

Area: 34 568 ha **Sites:** 16

Landforms: Flats and depressions of the floodplains.

Soils: Red Earth, grey and brown clays.

Geology: Quaternary alluvium.

Structure: Mid-high Open Woodlands

Trees: *Casuarina cristata, Allocasuarina luehmannii, Eucalyptus populnea.* Low Trees: *Acacia salicina.* Tall shrubs: *Geijera parviflora, Eremophila mitchellii, Alectryon oleifolius, Apophyllum anomalum.* Shrubs: *Muehlenbeckia florulenta. Lysiana subfalcata. Rhagodia spinescens. Sclerolaena birchii, Sclerolaena muricata, Einadia nutans* subsp. *nutans.* Herbs: *Oxalis chnoodes. Calotis cuneata, Calotis scapigera, Calotis lappulacea. Marsilea drummondii, Pelargonium australe, Rhynchosia minima.* Grasses: *Aristida jerichoensis. Aristida leichhardtiana, Cymbopogon obtectus, Enteropogon acicularis, Eriochloa pseudoacrotricha, Austrostipa scabra, Carex appressa. Eleocharis pallens. Eleocharis pusilla. Eleocharis plana, Juncus radula.*

Comments: Occurs in the eastern third of the study area on a range of topographical sequences: on the banks of intermittent and perennial creeks, on the flats and depressions of the alluvial plains and backplains of the major river systems. In favourable situations these woodlands may occur beyond the backplains in the zone of transition between the floodplain and peneplain.

Typically a Tall Woodland to Tall Open Woodland with *Casuarina cristata (*Belah) commonly the dominant canopy species. *Eucalyptus populnea* frequently occurs with *Casuarina cristata* on the red and brown earths and sandy clays of the flats of the alluvial plains and in depressions that may be subject to periodic inundation. Away from the main channels towards the backplains where fine, sandy, yellow and red earths occur, *Casuarina cristata* declines in dominance and species such as *Allocasuarina luehmannii* (Bulloak), and *Eucalyptus populnea* become more common. The relative distribution and abundance of these species is related to local variations in environmental conditions, such as, soil type, soil moisture and microtopography.

Geijera parviflora is a common understorey species in remnants. Scattered *Alectryon oleifolius* also occurs, often as a result of having been left as fodder trees following thinning or clearing of the surrounding vegetation. The lower shrub layer and ground cover varies between remnants but usually consists of unpalatable chenopods and grasses. Lignum is common in the understorey on the Dandaloo and Tottenham 1:100 000 sheets (Nyngan 1:250 000). Surrounding the Bay of Biscay Swamp, between the Bogan River and Narromine, *Casuarina cristata* and *Eucalyptus microcarpa (*Grey Box) occur on Red Brown Earths. *Casuarina cristata* with both Poplar Box and Grey Box are less restricted, occurring throughout the flats of the Bogan River on Yellow, Red and Red Brown Earths, as well as the Grey and Brown Clays near Dandaloo. Localised pure stands of *Casuarina cristata* are usually associated with intermittent drainage lines.

Species	Fidelity class	Group C/A	Group freq %	Non-group C/A	Non-group freq %
Eucalyptus populnea	constant	5	98	4	56
Callitris glaucophylla	negative	0	0	4	67
Acacia salicina	positive	5	38	0	0
Aristida jerichoensis	positive	3	1	0	0
Aristida leichhardtiana	positive	2	1	0	0
Calotis cuneata	positive	1	1	0	0
Calotis scapigera	positive	3	1	0	0
Carex appressa	positive	3	1	0	0
Casuarina cristata	positive	5	69	2	06
Cymbopogon obtectus	positive	1	1	0	0
Eleocharis pallens	positive	3	1	0	0
Eleocharis plana	positive	3	6	0	0
Eleocharis pusilla	positive	3	1	0	0
Eriochloa pseudoacrotricha	positive	4	1	0	0
Geijera parviflora	positive	4	84	2	45
Juncus radula	positive	1	1	0	0
Lysiana subfalcata	positive	4	1	0	0
Muehlenbeckia florulenta	positive	4	7	0	0
Oxalis chnoodes	positive	2	53	2	24
Pelargonium australe	positive	3	1	0	0
Rhagodia spinesceus	positive	3	50	2	7
Rhynchosia minima	positive	1	1	0	0

Fig. 14. P11 *Flindersia maculosa* (Leopardwood) Open Shrublands

P11 *Flindersia maculosa* (Leopardwood) Open Shrublands

Area: 190 ha **Sites:** 1

Landforms: Flats on alluvial plains.

Soils: Red and grey clays

Geology: Quaternary alluvium.

Structure: Mid-high Sparse Shrublands to Low Open Woodlands.

Low Trees: *Flindersia maculosa*. Tall Shrubs: *Apophyllum anomalum, Atalaya hemiglauca, Geijera parviflora, Capparis mitchellii*. Shrubs: *Rhagodia spinescens, Sclerolaena muricata, Einadia nutans* subsp. *nutans, Lysiana subfalcata, Lasiopetalum baueri*.

Comments: Occurs in small areas on red and grey clays of the flats of the alluvial plains. A sparse shrub layer includes scattered tall shrubs *Geijera parviflora* and *Apophyllum anomalum*. The stem parasite *Lysiana subfalcata* may be found growing on the overstorey species. Beadle (1948) notes that on the red soils of slightly elevated areas, low scrub of the perennial saltbushes *Atriplex nummularia* and *Atriplex vesicaria* was once supported and surrounded by a zone of *Flindersia maculosa*. Given the present degraded nature of this remnant, it is possible that some of the larger trees have been removed in the past and grazing pressure on the palatable saltbush species has produced the current vegetation mapped today.

Remnants of this map unit are not common in the study area and are often difficult to distinguish on the high level aerial photography. More extensive areas of P11 *Flindersia maculosa* (Leopardwood) Open Shrublands occur further north on the Bourke and Walgett 1:250 000 sheets.

Fig. 15. P12 *Eucalyptus microcarpa, Eucalyptus sideroxylon* Woodlands on Jurassic Sandstone

P12 Woodlands on Jurassic Sandstone

Area: 20 418 ha **Sites:** 27

Landforms: Flats, broad drainage lines and gently undulating rises of the Pilliga Peneplain.

Soils: Yellow Earths, sandy Red and Red Brown Earths and Lithosols

Geology: Jurassic Pilliga Sandstone.

Structure: Mid-high to Tall Open Woodlands and Woodlands.

Trees: *Eucalyptus populnea* subsp. *bimbil, Eucalyptus crebra, Eucalyptus sideroxylon, Eucalyptus microcarpa, Eucalyptus pilligaensis, Eucalyptus viridis, Eucalyptus dwyeri, Eucalyptus chloroclada, Eucalyptus melliodora, Callitris glaucophylla*. Low Trees: *Allocasuarina luehmannii*. Tall Shrubs: *Acacia havilandiorum, Acacia hakeoides, Acacia tindaleae, Geijera parviflora*. Shrubs: *Acacia cardiophylla, Acacia triptera, Cassinia* species, *Dillwynia juniperina, Dodonaea viscosa, Melaleuca uncinata, Melichrus urceolatus*. Herbs: *Cheilanthes austrotenuifolia, Chrysocephalum apiculatum, Einadia nutans* subsp. *nutans, Hibbertia sericea, Lomandra collina*. Grasses: *Enteropogon acicularis, Eragrostis lacunaria*.

Comments: Occurs on low undulating hills and flats and broad drainage lines of the Pilliga peneplain in the east and south-east of the area, in some areas extending to the apron of colluvial material eroded from the Pilliga sandstone.

This map unit represents a diverse complex of vegetation varying spatially in structure and floristic composition. *Eucalyptus chloroclada, Eucalyptus pilligaensis, Eucalyptus sideroxylon, Callitris glaucophylla* and *Allocasuarina luehmannii* (Bulloak) are some of the more dominant canopy species with a dense shrub layer of *Acacias* occurring in some woodlands at the western limits of the outcropping Pilliga peneplain on the Bundemar 1:100 000 map sheet. On the main extent of the Pilliga peneplain, Grey Boxes, *Eucalyptus pilligaensis, Eucalyptus microcarpa* and *Eucalyptus conica*, Ironbarks *Eucalyptus crebra, Eucalyptus sideroxylon* and *Eucalyptus melanophloia*, Red Gums *Eucalyptus dwyeri, Eucalyptus chloroclada* and Pine *Callitris glaucophylla* predominate. The understorey is equally diverse, with a large *Acacia* component. Genera common to coastal and tableland communities are also a feature of the P12 Woodlands on Jurassic Sandstone; including *Dillwynia juniperina, Hibbertia sericea* and *Hibbertia obtusifolia, Melaleuca uncinata* and *Melaleuca densispicata* and *Melichrus urceolatus*. A wide range of grass species were recorded including: *Aristida calycina, Aristida jerichoensis* var. *jerichoensis, Aristida muricata, Aristida ramosa* var. *speciosa, Austrodanthonia linkii var. fulva, Austrostipa aristiglumis, Austrostipa scabra* var. *scabra, Paspalidium constrictum, Themeda australis, Thyridolepis mitchelliana*, however their frequency was too low to list them as characteristic species.

Of note is an area on the Bundemar 1:100 000 map sheet to the west of the peneplain near 'Ferndale Stud Park', where, on the raised flats surrounding a large cowal, there is vegetation that closely resembles that which commonly occurs to the east on the Jurassic peneplain sediments. Also of note was a small homogeneous stand of *Acacia harpophylla* (Brigalow) near the property 'Pine View'. The only other occurrence of this species in the study area is in the very north of the Gulargambone 1:100 000 map sheet near 'Fairfield', some distance from the Pilliga sediments. *Angophora floribunda* and *Eucalyptus conica* (Fuzzy Box), occur on banks of streams in the Coolbaggie creek system.

Species	Fidelity class	Group C/A	Group freq %	Non-group C/A	Non-group freq %
Eucalyptus populnea	constant	1	50	4	66
Acacia cardiophylla	positive	3	66	0	0
Acacia hakeoides	positive	4	50	1	6
Acacia havilandiorum	positive	1	100	3	2
Acacia lineata	positive	3	83	4	3
Acacia tindaleae	positive	4	100	0	0
Acacia triptera	positive	7	66	3	2
Allocasuarina luehmannii	positive	1	66	2	2
Amyema miquelii	positive	1	66	1	3
Callitris glaucophylla	positive	1	66	2	29
Cassinia quinquefaria	positive	1	17	0	0
Dillwynia juniperina	positive	2	66	0	0
Einadia nutans subsp. *nutans*	positive	3	87	2	42
Enteropogon acicularis	positive	4	50	3	22
Eragrostis lacunaria	positive	4	67	4	2
Eucalyptus crebra	positive	3	16	0	0
Eucalyptus dwyeri	positive	3	67	4	14
Eucalyptus microcarpa	positive	4	96	3	7
Eucalyptus sideroxylon	positive	5	100	4	11
Eucalyptus viridis	positive	4	67	5	9
Hibbertia sericea	positive	2	33	0	0
Melaleuca uncinata	positive	7	100	0	0

Fig. 16.
P13 *Eucalyptus microcarpa* (Grey Box) Woodlands

P13 *Eucalyptus microcarpa* (Grey Box) Woodlands

Area: 59 963 ha **Sites:** 21

Landforms: Slopes and low rises of the hills and the peneplains. Relief to 15 m

Soils: Red Earths.

Geology: Quaternary eluvial sediments that overlay many different geological substrates.

Structure: Mid-High to Tall Open Woodlands

Trees: *Eucalyptus microcarpa, Callitris glaucophylla, Eucalyptus populnea.* Tall shrubs: *Acacia lineata, Acacia pravifolia.* Shrubs: *Cassinia aculeata, Cassinia uncata, Eremophila debilis, Eremophila deserti, Dillwynia juniperina, Melichrus urceolatus, Dodonaea viscosa sens lat, Asperula conferta.* Grasses: *Amphipogon caricinus, Enteropogon acicularis, Austrostipa setacea, Dianella revoluta.*

Comments: Occur in the central and western part of the area on rolling country of the Nymagee 1:250 000 sheet; and on footslopes and rolling country of the Narromine 1:250 000 sheet (Boona Mount, Tottenham and Tullamore 1:100 000 sheets). *Eucalyptus microcarpa* (Grey Box) and occasionally *Eucalyptus populnea* are the dominant canopy species. The understorey has a diverse range of shrubs and a grassy ground layer is generally present, with *Enteropogon acicularis*, and *Austrostipa setacea* commonly occurring. The vine *Parsonsia eucalyptophylla* occurs scrambling through the ground layer. The understorey ranges from dense to sparse due to changes in local environmental factors, but may also have a localised and distinct 'patchwork' pattern resulting from land use. In these areas, White Cypress Pine regeneration is common. Grey Box also becomes a more frequent component of P4 Poplar Box Woodlands adjacent to and immediately to the east of the Bogan River.

Where the outcrops of substrates occur, *Eucalyptus microcarpa* Woodlands frequently give way to other plant communities. Common to the crests and shallow, gravelly soils are H2 Green Mallee Woodlands or H1 Dwyer's Red Gum, Ironbark and Green Mallee Woodlands. This pattern, of rolling plains of P13 Grey Box Woodlands interspersed with crests of H2 Green Mallee and hills with H1 Dwyer's Red Gum, Ironbark and Green Mallee Woodlands, is characteristic of the western half of the Narromine 1:250 000 sheet and parts of the northern half of the Nymagee 1:250 000 sheet.

Species	Fidelity class	Group C/A	Group freq %	Non-group C/A	Non-group freq %
Callitris glaucophylla	constant	4	54	4	65
Eucalyptus populnea	negative	1	17	4	71
Acacia lineata	positive	3	8	0	0
Acacia pravifolia	positive	2	4	0	0
Amphipogon caricinus	positive	4	4	0	0
Asperula conferta	positive	2	4	0	0
Austrostipa setacea	positive	5	4	0	0
Dianella revoluta	positive	2	4	0	0
Dodonaea viscosa subsp. *spatulata*	positive	1	4	0	0
Enteropogon acicularis	positive	4	63	3	37
Eremophila debilis	positive	3	8	0	0
Eremophila deserti	positive	1	4	0	0
Eucalyptus microcarpa	positive	4	96	3	7

Fig. 17.
P14 *Eucalyptus intertexta, Eucalyptus populnea* and *Callitris glaucophylla* (Red Box, Poplar Box and Pine) Woodlands

P14 *Eucalyptus intertexta* (Red Box), *Eucalyptus populnea* (Poplar Box) and *Callitris glaucophylla* (Pine) Woodlands

Area: 234 381 ha **Sites:** 33

Landforms: Undulating rises, slopes, flats and open depressions of the Cobar peneplain. Relief to 15 m.

Soils: Red earths and quartzose dominated coarse-grained quaternary colluvial and alluvial deposits overlying Ordovician sedimentary bedding and some Devonian volcanics.

Geology: Coarse-grained quaternary colluvial and alluvial deposits overlying Ordovician sedimentary bedding and some Devonian volcanics.

Structure: Tall Woodlands to Tall Open Woodlands. Minor Very Tall Mallee Woodlands.

Trees: *Eucalyptus intertexta, Callitris glaucophylla, Eucalyptus populnea.* Tall Shrubs: *Eremophila mitchellii, Geijera parviflora.* Shrubs: *Dodonaea lobulata, Dodonaea viscosa, Acacia decora, Lycium australe, Senna artemisioides* subsp. *filifolia, Sclerolaena muricata.* Herbs: *Cheilanthes austrotenuifolia, Solanum ellipticum, Solanum ferocissimum, Ptilotus obovatus.* Grasses: *Aristida jerichoensis* var. *jerichoensis, Enteropogon acicularis.*

Comments: P14 Woodlands characterise the slopes of the far north-west of the area extending west from the Bogan River to the undulating rises of the peneplain and occupy the flats in between. They occur on the deeper red earths of the flats and open depressions. Further up slope from the flats, on the more gravelly rises and low crests, *Eucalyptus intertexta* (Red Box) becomes a major component of these woodlands. On some of the coarser grained quartzose dominated soils at the crests of the undulations, may be localised stands of *Eucalyptus viridis* (Green mallee). *Geijera parviflora* and *Eremophila mitchellii* form an open understorey that is occasionally dense particularly where nutrients and moisture accumulate on the flats and in open depressions.

P14 Woodlands are similar to U1 Red Box, Poplar Box, Pine and Green Mallee Woodlands and P13 Grey Box Woodlands. P14 Red Box, Poplar Box, and Pine Woodlands differs from U1 in that it occurs slightly lower in the landscape and extends further east on the undulating rises and open depressions of the Cobar peneplain. P14 Woodlands are associated with the gentler more undulating landforms than the steeper more abrupt rises of P13 Grey Box Woodlands and differ from U1 and P13 in that *Eucalyptus intertexta* is one of the major canopy species especially on the more gravelly rises and rocky drainage lines.

Species	Fidelity class	Group C/A	Group freq %	Non-group C/A	Non-group freq %
Callitris glaucophylla	constant	4	73	4	63
Eucalyptus populnea	negative	4	40	4	67
Dodonaea lobulata	positive	6	13	0	0
Eremophila mitchellii	positive	2	53	3	31
Eucalyptus intertexta	positive	4	100	3	56
Geijera parviflora	positive	2	87	3	45
Hibbertia riparia	positive	1	67	0	0
Lycium australe	positive	2	13	0	0
Ptilotus obovatus	positive	2	13	0	0
Solanum ellipticum	positive	1	67	0	0

Fig. 18. P15 *Eucalyptus chloroclada* (Dirty Red Gum), Pine and Poplar Box Woodlands

P15 *Eucalyptus chloroclada* (Dirty Red Gum), *Callitris glaucophylla* (Pine) and *Eucalyptus populnea* (Poplar Box) Woodlands

Area: 15 592 ha **Sites:** 5

Landforms: Flats and gently undulating belts and sandy lenses of the meander plain and flats to low gentle rises of the western apron of the Pilliga peneplain.

Soils: Sandy Yellow Earths and Light Red Loams

Geology: Quaternary meander plain of the Carrabear Formation.

Structure: Mid-high to Tall Woodlands.

Trees: *Eucalyptus chloroclada*, *Callitris glaucophylla*, *Eucalyptus populnea* subsp. *bimbil*, *Allocasuarina luehmannii*. Low Trees: *Alectryon oleifolius*. Tall Shrubs: *Hakea leucoptera*, *Apophyllum anomalum*. Shrubs: *Dodonaea viscosa*, *Sclerolaena bicornis*, *Einadia nutans* subsp. *nutans*. Herbs: *Calotis lappulacea*, *Caloti cuneifolia*, *Cheilanthes austrotenuifolia;* Grasses *Enteropogon acicularis*, *Austrostipa aristiglumis*, *Paspalidium constrictum*, *Aristida jerichoensis* var. *jerichoensis*.

Comments: This map unit is associated with the lateral sandy lenses of The Monkey Scrub, the alluvial meander plain of the Carrabear Formation. A smaller occurrence can be found further south on the sandy red earths of the western apron of the Pilliga peneplain on the Bundemar 1:100 000 map sheet.

Eucalyptus chloroclada (Dirty Gum) and *Callitris glaucophylla* (White Cypress Pine) usually co-dominate, other species such as *Eucalyptus populnea* (Poplar Box), and *Allocasuarina luehmannii* (Buloke) occur frequently. Scattered *Brachychiton populneus* (Kurrajong) has been observed in Warrie State Forest at the south-eastern extent of The Monkey Scrub and *Eucalyptus sideroxylon* (Mugga Ironbark) has also been observed in this map unit situated within the Pilliga peneplain. The low trees *Alstonia constricta* and *Atalaya hemiglauca* are commonly scattered throughout this community with tall shrubs such as *Hakea leucoptera* and *Acacia* species forming the upper shrub layer of the understorey. In remnants on the Pilliga peneplain, *Acacia ixiophylla* is common in the understorey with dense monospecific stands of this species observed on the low slopes. The lower shrub layer is often absent and only scattered herbs and grasses were recorded in the ground layer at the time of the survey. The current extent of this map unit is restricted to a chain of State Forests, that at the time of survey were heavily grazed.

Characteristic species	Fidelity class	Group C/A	Group freq %	Non-group C/A	Non-group freq %
Callitris glaucophylla	constant	6	100	4	63
Eucalyptus populnea	constant	1	50	4	66
Einadia nutans subsp. *nutans*	positive	3	86	2	42
Enteropogon acicularis	positive	3	75	3	38
Eucalyptus chloroclada	positive	4	25	4	5

Fig. 19. P16 Simple *Eucalyptus populnea* (Poplar Box) Woodlands

P16 Simple *Eucalyptus populnea* (Poplar Box) Woodlands

Area: 134 428 ha **Sites:** 29

Landforms: Flats and drainage depressions of the plains and rises of the Cobar peneplain.

Soils: Red earths and occasional red clay soils

Geology: Quaternary colluvial and alluvial derivation over the Ordovician Girilambone Beds.

Structure: Mid-high to Tall Woodlands and Open Woodlands.

Trees: *Eucalyptus populnea*, *Callitris glaucophylla*. Low Trees: *Alectryon oleifolius*. Tall Shrubs: *Acacia aneura* var. *latifolia*, *Acacia colletioides*. Shrubs: *Bertya cunninghamii*, *Bursaria spinosa*, *Eremophila glabra*, *Eucalyptus mitchellii*, *Einadia nutans* subsp. *nutans*, *Maireana microphylla*. Herbs: *Solanum quadriloculatum*, *Stackhousia viminea*, *Wahlenbergia luteola*, *Oxalis chnoodes*, *Cheilanthes austrotenuifolia*. Grasses: *Aristida behriana*, *Enneapogon polyphyllus*, *Eragrostis megalosperma*, *Triodia scariosa* subsp. *scariosa*, *Enteropogon acicularis*.

Comments: Woodlands dominated by Poplar Box occur across the study area and have been separated into two units P16 Simple Poplar Box Woodlands and P4 Poplar Box Woodlands (see above). *Eucalyptus populnea* and *Callitris glaucophylla* with a grassy understorey and a patchy, open shrub layer characterise P16 Woodlands.

The distinction between the two Poplar Box units is based on slight differences in the floristic composition, structure, underlying geology and topographic location. It was difficult to determine the boundaries of this map unit from API consistently; the east-west boundary is not as abrupt as indicated on the maps but has an area of transition between the Cobar Peneplain colluvial apron and the Bogan River.

P16 Woodlands range from the low slopes, broad drainage lines and low undulations of the Cobar peneplain in the west, to the slightly elevated flats of the alluvial meander plains of the Bogan River in the east. The shape and size of the remnants have the same variation as P4 Poplar Box Woodland in the east but P16 Woodlands occupy a smaller area (134,428 ha in 530 remnants, median remnant size 37 ha) than the more extensive P4 Woodlands. The remnants can occur as small isolated stands and narrow, linear corridors along road and property boundaries or as expansive Tall Woodlands and Tall Open Woodlands where land use and management has left the vegetation relatively intact.

P16 Simple Poplar Box Woodlands exhibit variation in the landscape. On the flats and low gentle rises of the Cobar peneplain, Mid-high to Tall Open Woodlands of *Eucalyptus populnea* and *Callitris glaucophylla* occur on the Quaternary red earths. Associated overstorey species include *Eucalyptus intertexta* (Red Box) and *Brachychiton populneus* (Kurrajong), with the former infrequently occurring as a co-dominant on the slopes of the more gentle rises. The understorey varies with seasonal influences and the relative level of disturbance caused by grazing. On the lower flats and in drainage depressions, the remnants are denser Mid-high Woodlands of *Eucalyptus populnea* and *Callitris glaucophylla*. In the drainage lines *Casuarina cristata* (Belah) may co-dominate. In the south east of the Simple Poplar Box Woodlands distribution *Eucalyptus microcarpa* (Grey Box) may occur on the gentle, gravelier crests. *Eucalyptus largiflorens* (Black Box) occurs occasionally, particularly in the alluvial outwash areas near Fountain Dale on the Nymagee 1:250 000.

Species	Fidelity class	Group C/A	Group freq %	Non-group C/A	Non-group freq %
Callitris glaucophylla	constant	4	88	4	51
Acacia aneura var. *latifolia*	positive	6	1	0	0
Acacia colletioides	positive	4	1	0	0
Aristida behriana	positive	1	3	0	0
Bertya cunninghamii	positive	4	3	0	0
Bursaria spinosa	positive	1	1	0	0
Einadia nutans subsp. *nutans*	positive	1	1	0	0
Enneapogon polyphyllus	positive	2	3	0	0
Eragrostis megalosperma	positive	3	3	0	0
Eremophila glabra	positive	3	3	0	0
Eucalyptus populnea	positive	5	100	4	48
Solanum quadriloculatum	positive	3	3	0	0
Stackhousia viminea	positive	2	3	0	0
Triodia scariosa subsp. *scariosa*	positive	2	1	0	0
Wahlenbergia luteola	positive	1	1	0	0

Remnants on undulating rises (U)

U1 *Eucalyptus intertexta* (Red Box), *Eucalyptus populnea* (Poplar Box), *Callitris glaucophylla* (Pine) and *Eucalyptus viridis* (Green Mallee) Woodlands

Area: 30 994 ha **Sites:** 3

Landforms: Low crests and slopes of rounded ridges of the Cobar peneplain. Relief to 30 m.

Soils: Red to red-brown earths and gravelly quartzites.

Geology: Ordovician sedimentaries and Devonian sedimentary beds and volcanics.

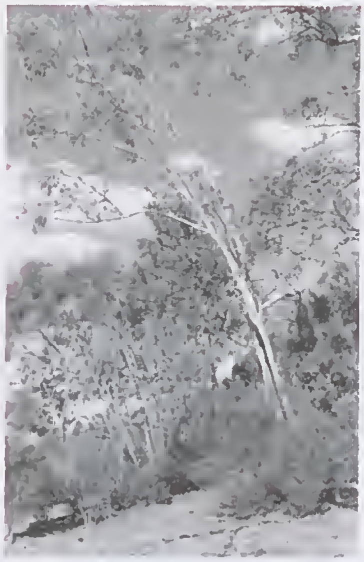

Fig. 20.
U1 *Eucalyptus intertexta*, *Eucalyptus populnea*, *Callitris glaucophylla* and *Eucalyptus viridis* (Red Box, Poplar Box, Pine and Green Mallee) Woodlands

Structure: Mid-high to Tall Open Woodlands and Very Tall to Extremely Tall Mallee Woodlands

Trees: *Eucalyptus intertexta*, *E. populnea*, *E. viridis*, *Callitris glaucophylla*. Tall Shrubs: *Eremophila mitchellii*, *Geijera parviflora*. Shrubs: *Dodonaea viscosa* subsp. *angustissima*, *Acacia decora*, *Capparis mitchellii*, *Senna* sp. Grasses: *Themeda australis*.

Comments: This map unit is predominantly associated with the rolling hills and lower crests of the Cobar peneplain west of Girilambone (Cobar 1:250 000) and extends into the Western Division. The mallee *Eucalyptus viridis* is most commonly found on low crests where shallow gravelly quartzites and light red earths occur. On the upper and mid-slopes where deeper red and red-brown earths occur, *Eucalyptus intertexta* dominates as Mid-high to Tall Open Woodlands. *Eucalyptus populnea* and *Callitris glaucophylla* are often scattered within these woodlands and may be co-dominant in some areas. *Eremophila mitchellii* and *Geijera parviflora* commonly form an open understorey with the lower shrub layer consisting of *Acacia decora*, *Capparis mitchellii* and *Senna* sp. *Themeda australis* forms good grass cover where grazing has been minimal and seasonal conditions have been favourable. On the mid and lower slopes, deep colluvial and eluvial red earths are Tall Woodlands of *Eucalyptus populnea* with occasional *Eucalyptus intertexta* and *Callitris glaucophylla*. The understorey is similar to that of the mid and upper slopes but may be locally dense in minor depressions where nutrients and moisture accumulate, and where thinning of the vegetation has been minimal. There is no table of characteristic species available for this map unit.

U2 *Eucalyptus intertexta* (Red Box), *Eucalyptus populnea* (Poplar Box) and *Callitris glaucophylla* (Pine) Woodlands on Granite Hillslopes

Area: 17 239 ha **Sites:** 3

Landforms: Slopes and swales of rolling granite country west of Black Range.

Soils: Red Earths on Quaternary eluvial sediments.

Geology: Silurian grey granite.

Structure: Low Open Woodlands

Trees: *Eucalyptus intertexta*, *Eucalyptus populnea*, *Callitris glaucophylla*, *Brachychiton populneus*. Tall shrubs: *Eremophila mitchellii*, *Acacia homalophylla*. Low shrubs: *Sclerolaena bicornis*. Grasses: *Enteropogon acicularis*.

Comments: Occurs on rolling granite country in the far west of the area (Nymagee 1:250 000), part of a much larger granite belt, extending into the Western Division. Found on the Bobadah and

Gindoono 1:100 000 map sheets west and south from the property of Balowra and Nangerybone State Forest, down to the Tarran Hills. The rolling country on granite is steeper than the rolling country of the nearby peneplain, with relief up to 30 m. These Low Open Woodlands of *Eucalyptus intertexta* with *Eucalyptus populnea* are characterised by a very sparse understorey. Scattered shrubs may include *Sclerolaena bicornis* and *Acacia homalophylla* (Yarran), while small trees of *Eremophila mitchellii* (Budda) also occur. Scattered patches of *Enteropogon acicularis* occur on the ground.

U2 Low Open Woodlands occur between patches of outcropping substrate, the level of outcropping is less than the adjacent U3 (Dwyer's Red Gum Low Open Woodlands on Granite Hill crests). There is no table of species available for this map unit.

U3 *Eucalyptus dwyeri* (Dwyer's Red Gum) Low Open Woodland on Granite Crests

Area: 9 195 ha **Sites:** 1

Landforms: Upper slopes and crests of the rolling granite country west of Black Range.

Soils: Lithosols

Geology: Silurian grey granite

Structure: Low Open Woodlands

Species: Trees *Eucalyptus dwyeri, Callitris glaucophylla, Brachychiton populneus;* Shrubs *Acacia decora*; Herbs *Cheilanthes austrotenuifolia, Goodenia cycloptera;* Grasses *Enteropogon acicularis.*

Comments: Occurs on the exposed granite outcrops in association with U2 Red Box, Poplar Box and Pine Woodlands (Nymagee 1:250 000). The vegetation of the granite crests has a barren character about it, accentuated by bare slabs of granite with lone *Eucalyptus dwyeri* growing in the crevices. The understorey is equally sparse, with isolated occurrences of species such as *Acacia decora, Goodenia cycloptera, Enteropogon acicularis* and *Cheilanthes austrotenuifolia*. The soils are fragile and prone to erosion.

Fig. 21. H1 *Eucalyptus dwyeri, Eucalyptus sideroxylon* and *Eucalyptus viridis* (Dwyer's Red Gum, Ironbark and Green Mallee) Woodlands, note *Eucalyptus sideroxylon* in foreground

Hill and ridge remnants (H)

H1 *Eucalyptus dwyeri* (Dwyer's Red Gum), *Eucalyptus sideroxylon* (Ironbark) and *Eucalyptus viridis* (Green Mallee) Woodlands

Area: 87 005 ha **Sites:** 54

Landforms: Slopes, ridges and crests of Hills and Low Rises.

Soils: Predominantly gravelly to sandy Red Earths, with Red-Brown Earths, Yellow Earths, and Lithosols.

Geology: Ordovician sediments, Silurian conglomerate, sandstone, chert. Devonian sediments, granite, limestone and a small patch of Tertiary basalt.

Structure: Mid High Woodlands to Open Woodlands

Trees: *Eucalyptus dwyeri, Eucalyptus sideroxylon, Eucalyptus viridis, Eucalyptus crebra, Callitris glaucophylla, Allocasuarina luehmannii.* Shrubs: *Acacia doratoxylon, Acacia hakeoides, Acacia lineata, Acacia difformis.* Low Shrubs: *Acacia triptera, Calytrix tetragona, Cassinia aculeata, Daviesia genistifolia, Dodonaea viscosa, Hibbertia sericea, Kunzea ambigua, Melichrus urceolatus, Olearia tenuifolia, Phyllanthus hirtellus.* Herbs: *Goodenia glabra, Goodenia ovata, Bracteantha bracteata, Bracteantha viscosa, Ptilotus atriplicifolius* var. *atriplicifolius. Cheilanthes austrotenuifolia, Cheilanthes lasiophylla.* Grasses: *Aristida leichhardtiana, Aristida ramosa var. scaberula, Cymbopogon refractus, Enneapogon nigricans, Eragrostis lacunaria, Eulalia aurea, Fimbristylis dichotoma, Scirpus fluviatilis, Lomandra glauca.*

Comments: Occurs high up off the plains on the hills, ridges and slopes (usually greater than 250 m ASL) on shallow gravelly soils and make up some of the largest remnants of the study area as these landforms are unfavourable for agriculture. In the west the woodlands of the hills are a simple association of *Eucalyptus dwyeri* and *Callitris glaucophylla*. Further east they become more diverse, with *Eucalyptus sideroxylon* on the slopes and *Eucalyptus viridis* occurring with *Eucalyptus dwyeri* and Callitris *glaucophylla* on the crests. Given the large geographic range, other tree species may be locally common. *Eucalyptus intertexta* is scattered over low, rocky and gravelly rises on the ridges and slopes of hills in the central-eastern part of the area (Tullamore 1:100 000 sheet), *Eucalyptus microcarpa* and *Eucalyptus populnea* may occur on the lower slopes where the soils are slightly loamier. In the east, *Allocasuarina luehmannii* sometimes occurs on the sandier soils. On an outcrop of Jurassic conglomerate and fine sandstone just east of the Boona Mountains, tall woodland of *Eucalyptus sideroxylon* occurs over a dense thicket of *Kunzea*. *Exocarpos cupressiformis* and *Callitris endlicheri* also occur here.

The understorey of the H1 woodlands has a strong representation of Acacias. *Acacia doratoxylon* is the most dominant species, although *Acacia hakeoides, Acacia lineata* and *Acacia triptera* are also common. The ground layer is generally open with a variety of grasses and herbs occurring.

Species	Fidelity class	Group C/A	Group freq %	Non-group C/A	Non-group freq %
Eucalyptus populnea	negative	1	11	4	68
Acacia difformis	positive	3	11	0	0
Acacia doratoxylon	positive	3	73	2	3
Acacia hakeoides	positive	4	50	1	7
Acacia lineata	positive	3	83	4	3
Acacia triptera	positive	4	11	0	0
Allocasuarina luehmannii	positive	1	67	2	2
Aristida leichhardtiana	positive	2	4	0	0
Aristida ramosa var. *scaberula*	positive	3	11	0	0
Bracteantha bracteata	positive	2	4	0	0
Bracteantha viscosa	positive	2	8	0	0
Callitris glaucophylla	positive	2	73	2	22
Calytrix tetragona	positive	3	15	0	0
Cassinia aculeata	positive	2	12	0	0
Chamaesyce drummondii	positive	1	11	0	0
Cheilanthes austrotenuifolia	positive	3	54	3	9
Cheilanthes lasiophylla	positive	3	22	0	0
Cymbopogon refractus	positive	2	4	0	0
Daviesia genistifolia	positive	2	11	0	0
Dodonaea viscosa	positive	1	8	0	0
Enneapogon nigricans	positive	2	11	0	0
Eragrostis lacunaria	positive	4	67	4	3

Eriachne mucronata	positive	2	11	0	0
Eucalyptus crebra	positive	3	17	0	0
Eucalyptus dwyeri	positive	4	81	4	3
Eucalyptus sideroxylon	positive	4	50	4	8
Eucalyptus viridis	positive	6	100	2	2
Eulalia aurea	positive	2	11	0	0
Fimbristylis dichotoma	positive	3	11	0	0
Goodenia glabra	positive	2	4	0	0
Goodenia ovata	positive	1	4	0	0
Hibbertia sericea	positive	1	11	0	0
Kunzea ambigua	positive	5	15	0	0
Lomandra glauca	positive	3	4	0	0
Olearia tenuifolia	positive	3	11	0	0
Panicum effusum	positive	2	4	0	0
Phyllanthus hirtellus	positive	3	8	0	0
Platysace lanceolata	positive	2	11	0	0
Ptilotus atriplicifolius var. *atriplicifolius*	positive	3	4	0	0
Scirpus fluviatilis	positive	1	11	0	0

Fig. 22. H2 *Eucalyptus viridis* (Green Mallee) Woodlands

H2 *Eucalyptus viridis* (Green Mallee) Woodlands

Area: 20 893 ha **Sites:** 7

Landforms: Crests and gentle hillslopes.

Soils: Gravelly Red and Yellow Earths and Lithosols.

Geology: Ordovician sediments, Silurian conglomerate and sandstone.

Structure: Mid High Open Mallee Woodlands.

Trees: *Eucalyptus viridis*, *Eucalyptus dwyeri*, *Eucalyptus sideroxylon*, *Callitris glaucophylla*. Tall Shrubs: *Acacia doratoxylon*. Shrubs: *Acacia difformis*, *Acacia amblygona*, *Cassinia aculeate*, *Dodonaea viscosa*, *Olearia tenuifolia*, *Melichrus erubescens*, *Calytrix tetragona*. Herbs: *Cheilanthes austrotenuifolia*. Grasses: *Aristida calycina*, *Thyridolepis mitchelliana*, *Enteropogon acicularis*.

Comments: H2 Woodlands are characteristic of crests and hilltops in the south western half of the area (on the Gindoono, Bobadah, Tottenham and Boona Mount 1:100 000 sheets). *Eucalyptus dwyeri* is commonly scattered throughout, becoming more frequent towards the eastern part of the distribution of this map unit (on the Tottenham & Boona Mount sheets). In the far south-west, *Eucalyptus intertexta* occurs on saddles between the crests. Dominant shrubs in the understorey include *Acacia doratoxylon*, *Acacia difformis*, *Acacia amblygona*, *Cassinia* and *Dodonaea* species. The ground layer is sparse and dominated by grasses.

A mosaic of H2 Woodlands on the shallow, gravelly soils on the crests and P13 Grey Box Woodlands on Red Earths of the slopes and flats of the rolling country is characteristic.

Species	Fidelity class	Group C/A	Group freq %	Non-group C/A	Non-group freq %
Acacia amblygona	positive	3	14	0	0
Acacia difformis	positive	2	7	0	0
Acacia doratoxylon	positive	3	73	2	30
Aristida calycina	positive	2	7	0	0
Callitris glaucophylla	positive	3	50	2	28
Calytrix tetragona	positive	3	15	0	0
Cassinia aculeata	positive	2	11	0	0
Cheilanthes austrotenuifolia	positive	3	54	3	9
Dodonaea viscosa	positive	1	7	0	0
Eucalyptus dwyeri	positive	4	80	4	3
Eucalyptus sideroxylon	positive	4	50	4	8
Eucalyptus viridis	positive	6	100	2	2
Olearia tenuifolia	positive	3	14	0	0

Fig. 23. H6 *Eucalyptus morrisii* (Grey Mallee) Open Woodlands

H6 *Eucalyptus morrisii* (Grey Mallee) Open Woodlands

Area: 6 602 ha **Sites:** 4

Landforms: High steep hills and outcropping linear ridges of the Cobar peneplain. Relief to 100 m.

Soils: Shallow stony and sandy lithosols becoming deeper, better developed gravelly red earths down slope.

Geology: Whinfell Chert and massive white quartzites of the Ordovician Girilambone Group and the early Devonian volcanics of the Kopyje Group.

Structure: Tall to Very Tall Open Mallee Woodland and Mid-high Open Woodland.

Trees: *Eucalyptus morrisii*, occasionally *Eucalyptus viridis*, *Eucalyptus intertexta*, *Eucalyptus socialis*, *Callitris glaucophylla*. Low Trees: *Acacia aneura*, *Acacia burrowii*, *Acacia doratoxylon*, *Alectryon oleifolius*. Tall Shrubs: *Eremophila mitchellii*. Shrubs: *Acacia deanei*, *Acacia decora*, *Acacia hakeoides*, *Beyeria viscosa*, *Cassinia laevis*, *Prostanthera ringens*. Herbs: *Cheilanthes sieberi* subsp. *sieberi*. Grasses: *Themeda australis*. Vines: *Pandorea pandorana*.

Comments: Grow on the lithosols and skeletal soils on the crests of the high, steep, hills and ridgelines of the Cobar peneplain. *Eucalyptus morrisii* (Grey Mallee) is common in the overstorey in these areas with *Eucalyptus viridis* an occasional co-dominant. Scattered low trees and a patchy shrub layer with a variety of *Acacia* species are characteristic of the understorey.

Downslope from the high hill crests and ridgelines, the lithosols and skeletal soils grade into the more developed gravelly eluvial red earths. The vegetation here changes from the being dominated by H6 Grey Mallee Woodlands to Mid-high Open Woodlands of *Eucalyptus intertexta* (Red Box), *Eucalyptus populnea* (Poplar Box) and *Callitris* *glaucophylla* (Pine) with mallee species occasionally interspersed. The understorey of this map unit is generally open with scattered *Alectryon oleifolius* and *Eremophila mitchellii* in the upper layer and shrubs such as *Einadia nutans* subsp. *nutans*, *Dodonaea viscosa* and *Cassinia laevis* in the lower layer. The ground layer is patchy, with few herbaceous or grass species recorded in the sites.

H6 Grey Mallee Open Woodlands are confined to the Coolabah and Canbelago 1:100 000 map sheets (Cobar 1:250 000). Small occurrences occur on the outcrops known as 'Trig Hill' and 'The Brothers' just west of Girilambone.

Species	Fidelity class	Group C/A	Group freq %	Non-group C/A	Non-group freq %
Cheilanthes sieberi subsp. *sieberi*	positive	4	100	2	5
Eucalyptus morrisii	positive	4	100	0	0
Pandorea pandorana	positive	2	100	2	3

Fig. 24. H 7 Mallee Woodlands on rolling hills

H7 *Eucalyptus dumosa – Eucalyptus socialis* Mallee Woodlands on rolling hills

Area: 34 665 ha **Sites:** 14

Landforms: Rolling hills, ridges and crests of the Cobar peneplain. Relief to 50 m.

Soils: Red Earths, Red-Brown Earths and minor gravelly Red Earths

Geology: Ordovician metasediments and some Devonian volcanics. Including the Whinfell cherts along ridges in the west of the study area.

Structure: Very Tall to Extremely Tall Open to Closed Mallee Forest.

Trees: *Eucalyptus dumosa*, *Eucalyptus socialis*, *Eucalyptus viridis*. Low Trees: *Callitris verrucosa*. Tall Shrubs: *Acacia aneura* var. *latifolia*, *Acacia tetragonophylla*, *Eremophila mitchellii*, *Geijera parviflora*. Shrubs: *Bertya cunninghamii*, *Bossiaea walkeri*, *Dodonaea viscosa* subsp. *cuneata*, *Dodonaea boroniifolia*, *Eutaxia microphylla*, *Einadia nutans* subsp. *nutans*, *Eremophila glabra*, *Olearia pimeleoides*, *Senna artemisioides* subsp. *filifolia*. Herbs: *Calotis cuneata*, *Marsdenia australis*, *Solanum parvifolium*, Grasses *Digitaria hystrichoides*.

Comments: Occur mainly on slopes, ridges and hill crests of the Cobar peneplain. *Eucalyptus socialis* (Pointed Mallee) and *Eucalyptus dumosa* (Congoo) dominate on the deeper red earths with *Eucalyptus viridis* (Green Mallee) becoming more prevalent as the soils become increasingly gravelly at the crests of the hills. It is typically dense Mallee Forest; generally more variable in height than P1 Mallee Woodlands further east on the flats of the peneplain. The understorey is variable and often reflects the density of the overstorey and past management practices. *Triodia scariosa* subsp. *scariosa* is noticeably absent from the understorey.

Species	Fidelity class	Group C/A	Group freq %	Non-group C/A	Non-group freq %
Callitris glaucophylla	negative	2	26	4	51
Acacia amblygona	positive	3	14	0	0
Acacia aneura var. *latifolia*	positive	1	5	0	0
Acacia difformis	positive	2	7	0	0
Acacia tetragonophylla	positive	3	11	0	0
Aristida calycina	positive	2	7	0	0
Callitris verrucosa	positive	5	5	0	0
Calotis cuneata	positive	1	5	0	0
Digitaria hystrichoides	positive	2	5	0	0
Dodonaea boroniifalia	positive	2	5	0	0
Eremophila mitchellii	positive	2	79	2	6
Eucalyptus dumosa	positive	4	94	3	2
Eucalyptus socialis	positive	4	84	5	3
Eucalyptus viridis	positive	6	100	2	2
Eutaxia microphylla	positive	2	11	0	0
Geijera parviflora	positive	2	68	2	2
Halgania cyanea	positive	2	16	0	0
Marsdenia australis	positive	3	11	0	0
Olearia tenuifolia	positive	3	14	0	0
Solanum parvifolium	positive	2	5	0	0

Fig. 25. H8 *Eucalyptus dealbata* (Tumble-down Red Gum) Woodlands on Basalt Hills

H8 *Eucalyptus dealbata* (Tumbled Down Red Gum) Woodlands on basalt hills

Area: 282 ha **Sites:** 2

Landforms: Outcropping hills in the east of the study area. Relief to approximately 100 m.

Soils: Basaltic Clay Lithosols with some outcropping

Geology: Tertiary Basalt.

Structure: Low to Mid-high Open Woodland.

Trees: *Eucalyptus dealbata*, *Casuarina cristata*. Low Trees: *Atalaya hemiglauca*, *Alectryon oleifolius*, *Alstonia constricta*, *Owenia acidula*. Tall Shrubs: *Geijera parviflora*. Shrubs: *Canthium oleifolium*, *Lycium ferocissimum*. Herbs: *Malva parviflora*, *Medicago truncatula*, *Oxalis chnoodes*, *Rumex brownii*. Grasses: *Eleusine indica*.

Comments: Occurs on the outcropping basaltic hills in the east of the area. Structure varies with aspect, landuse and grazing pressure. The low trees *Atalaya hemiglauca*, *Alectryon oleifolius*, *Alstonia constricta* and *Owenia acidula* commonly occur on the upper and lower slopes. *Eucalyptus dealbata* occurs on on the north-east facing slopes of Tenandra Hill, while mature *Casuarina cristata* occurs on Magometon Hill. As with H9 Woodland on Granite Hills further west, the lower shrub and ground layers contains a mix of woody shrubs, grasses and herbs, influenced by grazing, herbicide spraying and the degree of outcropping.

Species	Fidelity class	Group C/A	Group freq %	Non-group C/A	Non-group freq %
Alectryon oleifolius	positive	5	100	1	3
Alstonia constricta	positive	2	100	3	3
Atalaya hemiglauca	positive	4	100	2	1
Canthium oleifolium	positive	2	100	1	1
Geijera parviflora	positive	2	100	2	3
Oxalis chnoodes	positive	2	100	2	2
Rumex brownii	positive	1	100	3	1

Fig. 26. H9 *Eucalyptus dwyeri* (Dwyer's Red Gum) Open Woodlands on Granite Hills. Note outcropping.

H9 *Eucalyptus dwyeri* (Dwyer's Red Gum) Open Woodland on granite hills

Area: 415 ha

Landforms: Rounded outcropping hills on the Macquarie River floodplain. Relief to approximately 80 m.

Soils: Lithosols with some outcropping

Geology: Mount Foster Monzonite, part of the early Devonian intrusives of the Lachlan Fold Belt.

Structure: Low to Mid-high Open Woodland.

Trees: *Eucalyptus dwyeri*, occasional *Eucalyptus populnea*, and *Brachychiton populneus*. Low Trees: *Alstonia constricta, Alectryon oleifolius*. Shrubs: *Sclerolaena birchii*. Herbs: *Cheilanthes sieberi* subsp. *sieberi, Cheilanthes distans, Chamaesyce drummondii, Calostemma purpureum, Calotis lappulacea, Chrysocephalum apiculatum, Fimbristylis dichotoma, Glycine canescens, Goodenia fascicularis, Isotoma axillaris, Lepidium pseudohyssopifolium, Mimulus prostratus, Mimulus repens, Oxalis chnoodes, Pelargonium australe, Rhynchosia minima, Rostellularia adscendens* subsp. *adscendens* var. *adscendens, Sida corrugata, Solanum esuriale, Trachymene incisa* subsp. *corrugata, Wahlenbergia communis*. Vines: *Pandorea pandorana, Jasminum lineare;* Grasses *Cymbopogon obtectus, Digitaria brownii, Enneapogon nigricans, Eriachne mucronata, Austrostipa scabra, Themeda australis*.

Comments: Occurs on the granitic intrusives of Mt Foster and Mt Harris on the Mt Harris 1:100 000 map sheet (Nyngan 1:250 000). Typically very open, low woodland with scattered occurrences of *Eucalyptus dwyeri* (in both tree and mallee form). *Eucalyptus populnea, Brachychiton populneus* and the low trees *Alstonia constricta, Atalaya hemiglauca* and *Alectryon oleifolius*. Shrubs are generally scattered with the ground layer a diverse array of herbs and grasses. A limited number of formal sites were collected from this map unit due to its restricted distribution and lack of access from public land. The lower shrub and ground layers may be dominated by a diverse mix of woody shrubs, grasses and herbs, influenced by grazing, herbicide spraying and the degree of outcropping.

Species	Fidelity class	Group C/A	Group freq %	Non-group C/A	Non-group freq %
Callitris glaucophylla	negative	0	0	4	50
Alstonia constricta	positive	3	100	4	13
Calostemma purpureum	positive	3	67	3	25
Calotis lappulacea	positive	2	67	3	4
Chamaesyce drummondii	positive	1	67	2	3
Cheilanthes distans	positive	3	67	0	0
Cheilanthes sieberi subsp. *sieberi*	positive	2	100	2	4
Chrysocephalum apiculatum	positive	1	67	2	1
Cymbopogon obtectus	positive	1	67	0	0
Digitaria brownii	positive	1	33	0	0
Enneapogon nigricans	positive	1	33	0	0
Eriachne mucronata	positive	5	67	0	0
Eucalyptus dwyeri	positive	4	67	4	15
Fimbristylis dichotoma	positive	1	33	0	0
Glycine canescens	positive	2	33	0	0
Goodenia fascicularis	positive	4	67	1	2
Isotoma axillaris	positive	1	67	0	0
Jasminum lineare	positive	1	33	0	0
Lepidium pseudohyssopifolium	positive	1	67	2	1
Mimulus prostratus	positive	1	100	0	0
Mimulus repens	positive	1	33	0	0
Oxalis chnoodes	positive	3	100	2	14
Pandorea pandorana	positive	4	67	2	2
Pelargonium australe	positive	2	67	0	0
Rhynchosia minima	positive	1	33	0	0
Rostellularia adscendens subsp. *adscendens* var. *adscendens*	positive	1	33	0	0
Sclerolaena birchii	positive	1	67	4	2
Sida corrugata	positive	2	33	0	0
Solanum esuriale	positive	3	100	2	6
Austrostipa scabra	positive	4	67	2	13
Themeda australis	positive	1	33	0	0
Trachymene incisa subsp. *corrugata*	positive	2	67	0	0

Null, not mapped as native woody vegetation

Areas identified on the maps as not native woody vegetation consist of four categories; **exotic vegetation, highly modified native vegetation, no vegetation and native vegetation difficult to be accurately identified on high level API.** Exotic vegetation is land that is highly modified, under crop production and areas where current land management activity will not allow vegetation to revert to a natural state, for example plantations, crops, orchards. Highly modified native vegetation occurs where native species composition and density is low. The area is usually dominated by exotic species, this is often as a result of intensive thinning, tilling and grazing. The area was not under cultivation at the time of the survey or ground truthing. Areas where no vegetation is present due to natural or management induced physical conditions include barrens, scars, scalds, tilled or ploughed earth and off river storage. Native vegetation difficult to accurately identify on high level air photos comprise patches of native vegetation less than 10 hectares in size and vegetation types such as Lignum, Myall, Chenopod Shrublands, wetlands and naturally treeless plains (grasslands) that are difficult to discern on photographs of a scale less than 1:50 000.

Map Code	Map Unit *	Common Overstorey Species	Landform and Soils
Riparian and Floodplains (R)			
R1	River Red Gum Forests and Woodlands	*Eucalyptus camaldulensis, E. largiflorens Acacia stenophylla, A. salicina.*	Banks, channels, depressions, cowals & backplains; grey cracking clays, polygenetic alluvial soils.
R3	Black Box Woodlands	*Eucalyptus largiflorens, E. camaldulensis, E. populnea, Casuarina cristata, Acacia stenophylla.*	Floodplains, banks, depressions, cowals & flats; grey cracking clays, minor red & red brown earths.
R5	Myall Woodlands	*Acacia pendula, Geijera parviflora, Apophyllum anomalum.*	Flats subject to gilgai development; grey & brown clays.
Undulating Peneplains (P)			
P1	Mallee Woodlands on Plains	*Eucalyptus dumosa, E. socialis, E. sideroxylon, E. viridis, Brachychiton populneus, Callitris glaucophylla.*	Flats; red earths.
P4	Poplar Box Woodlands	*Eucalyptus populnea, Callitris glaucophylla, Allocasuarina luehmannii, Alectryon oleifolius, Acacia colletioides, A. salicina.*	Flats & some open depressions; red, red brown & yellow earths, grey, brown & red clays.
P6	White Cypress Pine Woodlands	*Callitris glaucophylla, Dodonaea viscosa, Einadia nutans, Rhagodia spinescens,* minor, *Eucalyptus populnea.*	Flats, low rises & low aeolian dunes; sandy red & yellow earths.
P7	Belah and Poplar Box Woodlands	*Casuarina cristata, Allocasuarina luehmannii, Eucalyptus populnea, Acacia salicina.*	Flats & depressions; red earths, grey & brown clays.
P11	Leopardwood Open Shrublands	*Flindersia maculosa, Apophyllum anomalum, Atalaya hemiglauca, Capparis mitchellii, Geijera parviflora.*	Flats; red & grey clays.
P12	Woodlands on Jurassic Sandstone	*Eucalyptus populnea, E. crebra, E. sideroxylon, E. microcarpa, E. pilligaensis, E. viridis, E. dwyeri, E. chloroclada, E. melliodora, Callitris glaucophylla, Allocasuarina luehmannii.*	Flats, broad drainage lines, gently undulating rises; yellow earths, sandy red & red brown earths & lithosols.
P14	Red Box, Poplar Box and Pine Woodlands	*Eucalyptus intertexta, E. populnea, Callitris glaucophylla.*	Undulating rises, slopes, flats & open depressions; red earths & quartzose alluvial & colluvial deposits.
P15	Dirty Red Gum, Pine and Poplar Box Woodlands	*Eucalyptus chloroclada, E. populnea, Callitris glaucophylla, Allocasuarina luehmannii.*	Flats, gently undulating, sandy lenses & low gentle rises; sandy yellow earths & light red sandy loams.
P16	Simple Poplar Box Woodlands	*Eucalyptus populnea, Callitris glaucophylla, Alectryon oleifolius, Acacia aneura.*	Flats & drainage depressions; red earths & occasionally red clay soils.
Undulating Rises (U)			
U1	Red Box, Poplar Box, Pine and Green Mallee Woodlands	*Eucalyptus intertexta, E. populnea, E. viridis, Callitris glaucophylla, Eremophila mitchellii, Geijera parviflora.*	Low crests & slopes of rounded ridges; red to red brown earths & gravelly quartzites.
Hills and Ridges (H)			
H1	Dwyer's Red Gum, Ironbark & Green Mallee Woodlands	*Eucalyptus dwyeri, E. sideroxylon, E. viridis, E. crebra, Callitris glaucophylla, Allocasuarina luehmannii.*	Slopes, ridges & crests of hills & low rises; gravelly to sandy red earths, red brown & yellow earths & lithosols.
H6	Grey Mallee Open Woodlands	*Eucalyptus morrisii* occasionally *E. viridis, E. intertexta, E. socialis, Callitris glaucophylla.*	High steep hills & outcropping linear ridges; shallow stony & sandy lithosols, gravelly red earths.
H7	Mallee Woodlands on Rolling Hills	*Eucalyptus dumosa, E. socialis, E. viridis Callitris verrucosa, Acacia aneura.*	Rolling hills, ridges & crests; red earths, red brown earths & minor gravelly red earths.
H8	Tumble down Red Gum Woodlands on Basalt Hills	*Eucalyptus dealbata, Casuarina cristata, Atalaya hemiglauca, Alectryon oleifolius, Alstonia contricta, Owenia acidula.*	Outcropping hills; basaltic clay lithosols.
H9	Dwyer's Red Gum Open Woodland on Granite Hills	*Eucalyptus dwyeri, E. populnea, Brachychiton populneus, Alstonia constricta, Alectryon oleifolius.*	Rounded outcropping hills; lithosols.
	Not mapped as woody vegetation.	This unit includes; exotic vegetation, highly modified native vegetation, crops, bare ground & native vegetation difficult to accurately detect on high level aerial photography.	
Clearing			
	Cleared	Areas of native woody vegetation mapped from 1980's aerial photography identified as cleared by subsequent satelite image analysis from Landsat TM false colour (bands 2, 4, 5). 1998 clearing data compiled from visually interpreted hardcopy 1:250000 scenes 92/82 22/03/98, 93/82 17/06/98 & 91/82 3/6/98. 2000 clearing data compiled from visually interpreted on screen 1:250000 scenes 92/82.5 14/12/99, 92/81.5 14/12/99, 93/81.5 28/04/00 & 93/82.5 28/04/00.	

* For full explanations of these map units see report.

NATURAL VEGETATION OF THE NEW SOUTH WALES WHEATBELT

Cobar, Nyngan and Gilgandra

1:250 000

Vegetation Sheets

L. Metcalfe, D.P. Sivertsen, D. Tindall & K.M. Ryan.
NSW National Parks and Wildlife Service
to accompany CUNNINGHAMIA VOLUME 8 NUMBER 2 2003.
Published by Royal Botanic Gardens Sydney

Map Code	Map Unit *	Common Overstorey Species	Landform and Soils
Riparian and Floodplains (R)			
R1	River Red Gum Forests and Woodlands	*Eucalyptus camaldulensis, E. largiflorens Acacia stenophylla, A. salicina.*	Banks, channels, depressions, cowals & backplains; grey cracking clays, polygenetic alluvial soils.
R3	Black Box Woodlands	*Eucalyptus largiflorens, E. camaldulensis, E. populnea, Casuarina cristata, Acacia stenophylla.*	Floodplains, banks, depressions & flats; grey cracking clays, minor red & red brown earths.
R5	Myall Woodlands	*Acacia pendula, Geijera parviflora, Apophyllum anomalum.*	Flats of the alluvial plain subject to gilgai development; grey & brown clays.
Undulating Peneplains (P)			
P1	Mallee Woodlands on Plains	*Eucalyptus socialis, E. dumosa, E. sideroxylon, E. viridis, Brachychiton populneus, Callitris glaucophylla.*	Flats; red earths.
P4	Poplar Box Woodlands	*Eucalyptus populnea, Callitris glaucophylla, Allocasuarina luehmannii, Alectryon oleifolius, Acacia colletioides, A. salicina.*	Flats & open depressions; red, red brown & yellow earths, grey, brown & red clays.
P6	White Cypress Pine Woodlands	*Callitris glaucophylla, Eucalyptus populnea, Dodonaea viscosa.*	Flats, low rises & aeolian dunes; sandy red & yellow earths.
P7	Belah and Poplar Box Woodlands	*Casuarina cristata, Allocasuarina luehmannii, Eucalyptus populnea, Acacia salicina.*	Flats & depressions; red earths, grey & brown clays.
P12	Woodlands on Jurassic Sandstone	*Eucalyptus populnea, E. crebra, E. sideroxylon, E. microcarpa, E. pilligaensis, E. viridis, E. dwyeri, E. chloroclada, E. melliodora, Callitris glaucophylla, Allocasuarina luehmannii.*	Flats, broad drainage lines, gently undulating rises; yellow earths, sandy red & red brown earths & lithosols.
P13	Grey Box Woodlands	*Eucalyptus microcarpa, E. populnea, Callitris glaucophylla.*	Slopes & low rises; red earths.
P14	Red Box, Poplar Box and Pine Woodlands	*Eucalyptus intertexta, Callitris glaucophylla E. populnea.*	Undulating rises, slopes, flats & open depressions; red earths & quartzose alluvial & colluvial deposits.
P16	Simple Poplar Box Woodlands	*Eucalyptus populnea, Callitris glaucophylla, E. intertexta, Alectryon oleifolius.*	Flats & drainage depressions; red earths & occasionally red clay soils.
Undulating Rises (U)			
U1	Red Box, Poplar Box, and Pine Woodlands on Granite Hillslopes	*Eucalyptus intertexta, E. populnea, Callitris glaucophylla.*	Low slopes and swales of the rolling granite country; red earths.
U3	Dwyer's Red Gum, Low Open Woodland on Granite Crests	*Eucalyptus dwyeri, Callitris glaucophylla, Brachychiton populneus, Acacia decora.*	Upper slopes and crests of the rolling granite country, lithosols.
Hills and Ridges (H)			
H1	Dwyer's Red Gum, Ironbark and Green Mallee Woodlands	*Eucalyptus dwyeri, E. sideroxylon, E. viridis, E. crebra, Callitris glaucophylla, Allocasuarina luehmannii.*	Slopes, ridges & crests of hills & low rises; gravelly to sandy red earths, red brown & yellow earths & lithosols.
H2	Green Mallee Woodlands	*Eucalyptus viridis, E. dwyeri, E. sideroxylon, Callitris glaucophylla, Acacia doratoxylon.*	Crests & gentle hillslopes; gravelly red & yellow earths & lithosols.
H7	Mallee Woodlands on Rolling Hills	*Eucalyptus dumosa, E. socialis, E. viridis, Callitris verrucosa.*	Rolling hills, ridges & crests; red earths, red brown earths & minor gravelly red earths.

(no code)	Not mapped as woody vegetation.	This unit includes; exotic vegetation, highly modified native vegetation, crops, bare ground & native vegetation difficult to accurately detect on high level aerial photography.
(hatched)	Cleared	Areas of native woody vegetation mapped from 1980's aerial photography identified as cleared by subsequent satelite image analysis from Landsat TM false colour (bands 2, 4, 5). 1998 clearing data compiled from visually interpreted hardcopy 1:250000 scenes 92/82 22/03/98, 92/83 22/03/98 & 91/82 3/6/98. 2000 clearing data compiled from visually interpreted on screen 1:250000 scenes 92/82.5 14/12/99, 93/82.5 28/04/99, 91/83 20/10/99 & 91/82 20/10/99.

* For full explanations of these map units see report.

 Map compiled from field data. Pattern recognition is via interpretation of uncontrolled aerial photography: Nymagee 1987 1:83900, Narromine 1983 1:50000, Dubbo 1980 1:50000. Interpreted by Kate Ryan. 1998 Satellite image interpretation by Justin Downie. 2000 satellite image interpretation by Christopher Simpson. Stable base layer (C) Commonwealth, AUSLIG, Australia's National mapping agency. It has been reproduced with permission of Australian Surveying and Land Information Group, Dept. of Administrative Services, Canberra, ACT.

NATURAL VEGETATION OF THE NEW SOUTH WALES WHEATBELT

Nymagee, Narromine and Dubbo

1:250 000

Vegetation Sheets

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