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Floristic community diversity in derived native grasslands: a case study from the upper Hunter Valley of New South Wales

Stephen A. J. Bell

School of Environmental and Life Sciences, University of Newcastle,
University Drive, Callaghan, NSW 2308, AUSTRALIA. stephen.bell@newcastle.edu.au

***Abstract*:** Little research has been undertaken on the conservation value of natural and derived native grasslands within the Hunter Valley region of New South Wales. In part, this is due to a lack of rigorous survey and classification of grassland habitats, but also because of the ease with which past studies have deferred to the concept of 'derived grasslands' to describe grassland areas. Given the extent of European occupation of the Hunter Valley over the past 200 years, all grasslands have been impacted upon in one way or another by agricultural activities, and hence all can be considered 'derived'.

For one site in the upper Hunter Valley, classification and mapping of grasslands was undertaken using data collected over three Spring seasons from 2009 to 2011, encompassing over 1,000 ha of derived grassland habitat within a wider mosaic of forest and woodland. Numerical classification of 168 sampling plots (each 0.01ha in size) delineated 17 floristic groups (16 communities, one with two sub-communities). Based on the composition of component taxa, 8 of these can be considered primarily of exotic origin, while the remaining 9 are predominantly native. All grasslands have been shaped by past agricultural activities, and all have been collectively referred to previously as derived grasslands.

Plant species of significance within the grasslands include the threatened terrestrial orchids *Diuris tricolor* and *Prasophyllum petilum*, the threatened forbs *Swainsona recta* and *Thesium australe*, and the rare but localised grass *Bothriochloa biloba*. An additional 19 taxa occur at or extend known distributional limits.

The lack of an appropriate existing framework with which to assign conservation value to grasslands in the Hunter complicates any assessment of significance. However, considerable diversity is present within grasslands collectively referred to as 'derived', and effort should be applied in future studies to elucidate community patterns more satisfactorily. Within State and Federal threatened species legislation, there are 30 grassland or derived grassland communities, but only one of these (*White Box - Yellow Box – Blakely's Red Gum Grassy Woodland and Derived Native Grassland*: EPBC Act) potentially include the grasslands under study here.

Key words: derived native grasslands, numerical classification, Hunter Valley

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Introduction

Many parts of New South Wales and Australia have been subjected to extensive landscape modification since European settlement (Benson 1991; Griffiths 2002). Those landscapes considered the best for agricultural enterprises have undergone the most widespread modification, with woody vegetation removed or thinned to allow better growth of grasslands. In many places, this level of modification is so great that it is difficult to recreate how they would have looked prior to settlement, although several studies have worked towards this (e.g. Benson & Redpath 1997; Van der Ree & Bennett 2001; Lang 2008; Spooner *et al*. 2010). it is believed that, prior to European settlement, Aboriginal burning across grasslands to provide habitat for huntable fauna and harvestable food plants also promoted diversity (Griffiths 2002; Butzer & Helgren 2005; Gott 2005). This disturbance-driven concept of maintaining biodiversity in native grasslands has dominated much of the research undertaken in temperate Australian grasslands, with the influence of rainfall in combination with disturbance history seen as the primary driver of productivity, although other *in-situ* factors may also be important (Price *et al*. 2019). Not surprisingly, native grasslands are considered one of the most studied ecosystems in Australia (Williams *et al*. 2015).

Forests and woodlands that have been fully or partially cleared for agriculture often result in the development of grassland habitats that formerly did not occur in those locations. Such areas are referred to as 'derived grasslands' in recognition of this fact and are typically comprised of those more resilient plant species that thrive in open sunlight and that can withstand varying levels of grazing by domestic and native stock. Benson (1996) defined derived grasslands as "*native grasslands remaining after the removal or dieback of previous woody canopy vegetation (shrubs or trees), to a point where woody vegetation has less than 10% cover*". A similar stipulation limiting woody cover has been proposed by Dixon *et al*. (2014) for standardizing all grasslands across the world, and they also include guidelines on acceptable proportions of graminoids, herbs and shrubs. As influenced by the floristic composition of those original habitats that are replaced (the *landscape context* of Schmucki *et al*. 2012), derived grasslands can be particularly diverse, and respond differently to differing grazing pressures (Story 1963a; Lunt 1997b; Leonard & Kirkpatrick 2004; McIntyre & Tongway 2005; Schultz *et al*. 2014). Lightly grazed areas may retain a full complement of species, but under moderate levels of grazing the most palatable and least resilient species may become rare or locally extinct. Under heavy grazing, many of the palatable perennial species may be lost, while unpalatable perennials, ephemerals or introduced species proliferate. Derived grasslands are different but clearly related to naturally occurring native grasslands in south-eastern Australia (e.g. the Monaro grasslands, Benson 1994; the Gippsland grasslands, Lunt 1997a; the Liverpool grasslands, Bean & Whalley 2001).

'Derived grasslands' as a term has been used repeatedly in the literature over many years (e.g. Eldridge *et al*. 2000; Prober *et al*. 2008; Good *et al*. 2011) and in legislation (e.g. EPBC Act 1999) to refer to grasslands dominated by native grass species, but whose existence can be attributed to land-clearing and modification since European settlement. Lunt (1997) refered to these as 'anthropogenic grasslands', which is perhaps a more meaningful phrase and one more reflective of the influence of the European culture in their development. Within the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act), derived grasslands are specified in the title of only two threatened ecological communities (White Box - Yellow Box - Blakely's Red Gum Grassy Woodland and Derived Native Grassland; Grey Box *Eucalyptus microcarpa* Grassy Woodlands and Derived Native Grasslands of South-eastern Australia), although their protection is implied in several others (e.g. Grassy Eucalypt Woodland of the Victorian Volcanic Plain, Lowland Grassy Woodland in the South East Corner Bioregion, Lowland Native Grasslands of Tasmania, Gippsland Red Gum *Eucalyptus tereticornis* subsp. *mediana* Grassy Woodland and Associated Native Grassland). In New South Wales legislation, the extent to which derived grasslands are protected in threatened ecological community listings is less clear: only one includes the term in its title (White Box - Yellow Box - Blakely's Red Gum Grassy Woodland and Derived Native Grassland) but several others specifically mention derived grasslands as forming part of those communities. Never-the-less, vegetation classifications which recognise derived grasslands are becoming increasingly evident in the literature, and efforts to better understand their compositions are desirable and can only assist ongoing management.

Irrespective of disturbance history, the timing of vegetation surveys used to describe grassland environments can have a marked impact on the diversity of species observed and the communities delineated, and ill-timed surveys can mask their potential conservation value. Many species of grass, forbs and herbs flower only after sufficient rains have fallen, and identification at times other than this can be extremely difficult or impossible. For example, working in the South Western Slopes region of New South Wales Burrows (2004) found that surveys undertaken in mid to late Spring recorded the highest percentage of plant species present. In addition, he found that a single, optimally-timed survey conducted after near- or above-average rainfall in the two or three months preceding the survey will record 65-75% of the total species diversity. In comparison, a single or multiple survey over much of Summer, Autumn and early Winter will record fewer than 50% of the total species present (Burrows 2004). Allen and Benson (2012) demonstrated that the repeated sampling of sixty permanent plots on the Liverpool Plains revealed important seasonal differences in grassland flora detection. They concluded that single-season surveys fail to produce a comprehensive picture of species diversity, and that vegetation community definition and description should include seasonal phases. Further, sampling in 'wet' and 'dry' years can result in distinctly different community diagnoses, and classifications describing grassland communities should acknowledge the likely influence of temporal changes. The influence of grazing pressures by domestic animals can also be strong and long-lasting (Schultz *et al*. 2014; Sims *et al*. 2019). Other grassland studies promote a range of optimum survey periods, but additional factors (such as the timing of recent rains irrespective of season, project logistics, etc)

often govern when many studies are conducted. Ultimately, surveys in the Spring or Summer-Autumn seasons are the most informative (e.g. Benson 1994; Benson *et al*. 1997; Hunter & Earl 1999; Bean & Whalley 2001).

To date, surveys and mapping undertaken on behalf of the development industry, and for conservation and land management, have applied the term 'derived grassland' to any area that has undergone full or partial clearing of woody vegetation, and which now supports grasslands dominated by native or exotic species. Collectively, these areas are often assessed and managed as a single unit without examination of any conservation benefits or significance within. This over-simplifies their importance, as some derived grasslands provide essential and important habitat for threatened flora and fauna (e.g. Dorrough & Ash 2009; Turner 2012; Baker-Gabb *et al*. 2016), and perhaps more importantly contain the propagules, soil microbes and genetic material necessary for rebuilding natural landscapes following disturbances (Prober *et al*. 2005; Nussbaumer *et al*. 2012). On the other hand, grasslands branded as derived can also include areas supporting little native biodiversity content, but within management and legislation these are often considered of equal value to those dominated by native species.

Prior to gaining development approval, biodiversity surveys and assessments undertaken at the Glencore Coal Pty Ltd (Glencore)-owned Mangoola Coal Mine ('Mangoola') in the Hunter Valley of New South Wales categorised all non-forested lands as 'derived grasslands' (Umwelt 2008). This simplification of these landscapes was acknowledged at the time but was consistent with the practice commonly employed in environmental assessments throughout New South Wales and was acceptable for assessment purposes. Under current assessment practices, derived grasslands are now allocated to their presumed Plant Community Type (NSW Department of Planning, Industry and Environment 2020) to better recognise these landscapes; however, this process only partly surrogates for grassland diversity. Recognising the value of grassland habitats, Mangoola proposed further research on native and derived grasslands which was adopted by determining authorities as a condition of consent. Using Mangoola as a case study, this paper examines the diversity of its derived grasslands to illustrate how more detailed documentation of these landscapes can reveal overlooked and potentially significant biodiversity.

Study Area

The Hunter Valley is a botanically diverse region within central eastern New South Wales, a reflection of the habitats provided by the range in soil, geology, topography and climate (Peake 2006). Following the phytogeographic classification of Anderson (1961), the region encompasses parts of five botanical subregions (North Coast, Central Coast, Northern Tablelands, Southern Tablelands & Central Western Slopes), and elements of all five are represented to varying extents. The upper Hunter Valley was first opened up to European settlers by the surveyor Henry Dangar in 1824, and soon after several large agricultural estates became established in the area (Perry 1955; Umwelt 2006). Livestock grazing was the principal enterprise during the early decades, and from the mid 1900's other industries (e.g. timber clearing for mining props and sale) were prevalent at times in the area. Collectively, these past uses of the land resulted in a heavily cleared landscape, as visible in aerial photographs between c. 1930 and 1967. In the context of native grasslands, it is evident that most if not all the original vegetation prior to European settlement comprised open forests and woodlands, and that the grasslands evident today have been derived from these past clearing and grazing activities.

Examination of the diversity in present-day grasslands has been undertaken at a site near the regional town of Muswellbrook, in the upper Hunter Valley. Mangoola Coal Mine, situated in the Central Western Slopes subregion, is an open cut coal mine located approximately 180 kilometres NNW of Sydney. Commencing operations in 2010, Mangoola plans to extract, process and transport up to 150 million tonnes of coal over a 21 year period. One condition of consent for coal extraction was to undertake research into the grasslands of the area, and consequently 2950 ha of proposed development and offset lands was made available to investigate grassland diversity. Approximately 64% of this 2950 ha comprises forest and woodland vegetation, the balance (c. 1070 ha) being derived grassland (Figure 1).

Methods

Survey Timing

Sampling of grasslands at Mangoola was systematically undertaken over three consecutive Spring seasons from 2009 to 2011. Survey timing was programmed to coincide with flowering of the majority of grassland and herb species on the Western Slopes to assist identification and diagnosis of floristic communities (Burrows 2004), and was guided by rainfall received prior to and during each Spring season (Figure 2). Floristic data was collected in October and November 2009 (at or above average rainfall, following mostly lower-than-average falls for the preceeding nine months; Figure 2), October to December 2010 (well-above average rainfall following a mostly wet preceeding nine-month period; Figure 2) and November and December 2011 (well-above average rainfall in November, following a mostly wet preceeding 10 months; Figure 2).

Plot sampling

Selection of sample sites was preferential in nature and was governed by the need to be fully representative of the total study landscape. Knowledge of the area gleaned as part of targeted terrestrial orchid surveys conducted concurrently with grassland survey over the three-year study period provided a broad appreciation of the diversity of grassland types requiring sampling. During those orchid surveys (>330 km of walked transects), notes were made on grassland diversity and potential plot sampling locations identified. Proposed sampling locations were reviewed against photo-patterns evident on aerial photographs prior to sampling, to ensure that sample locations were representative of the wider landscape.

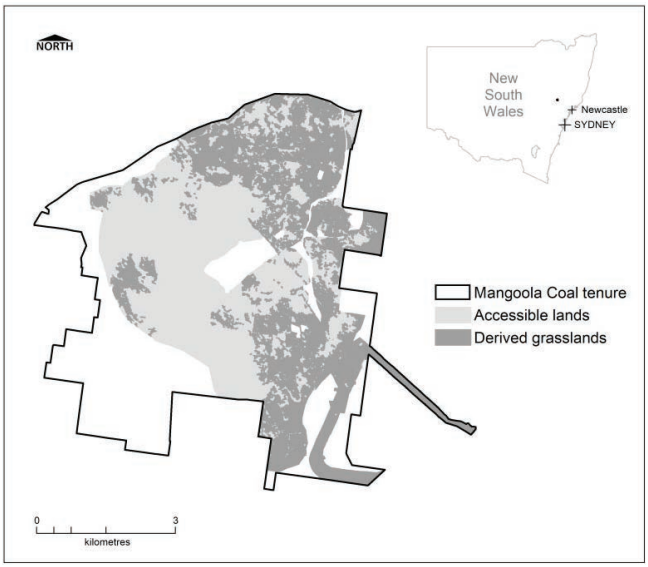

Figure 1. Location of derived grasslands within accessible lands and the wider Mangoola tenure. Note that grasslands occupy approximately 36% of this total extent.

Sampling involved establishing 10 m x 10 m (0.01 ha) plots in grassland areas, recording all vascular plant species (native and exotic). Sampling plots of this size have been shown to be appropriate for temperate grassland environments (e.g. Benson 1994; Allen & Benson 2012), although smaller or larger plots are often employed in Europe (Chytry & Otypkova 2013) and in some other Australian grassland studies (e.g. Lunt 1997; Neldner *et al*. 1997; Fensham 1998, 1999; Hunter & Earl 1999; Hunter 2020). Within each sample plot at Mangoola, cover abundance codes (modified Braun-Blanquet 1-6 scale: 1 = few individuals, <5% cover; 2 = many individuals, <5% cover; 3 = 5-25% cover; 4 = 26-50% cover; 5 = 51-75% cover; 6 = 76-100% cover) were applied to all species, and structural information (height range and % cover for each strata present) was also recorded. Photographs of each sample plot were taken, and other biophysical information relating to soil and disturbance recorded.

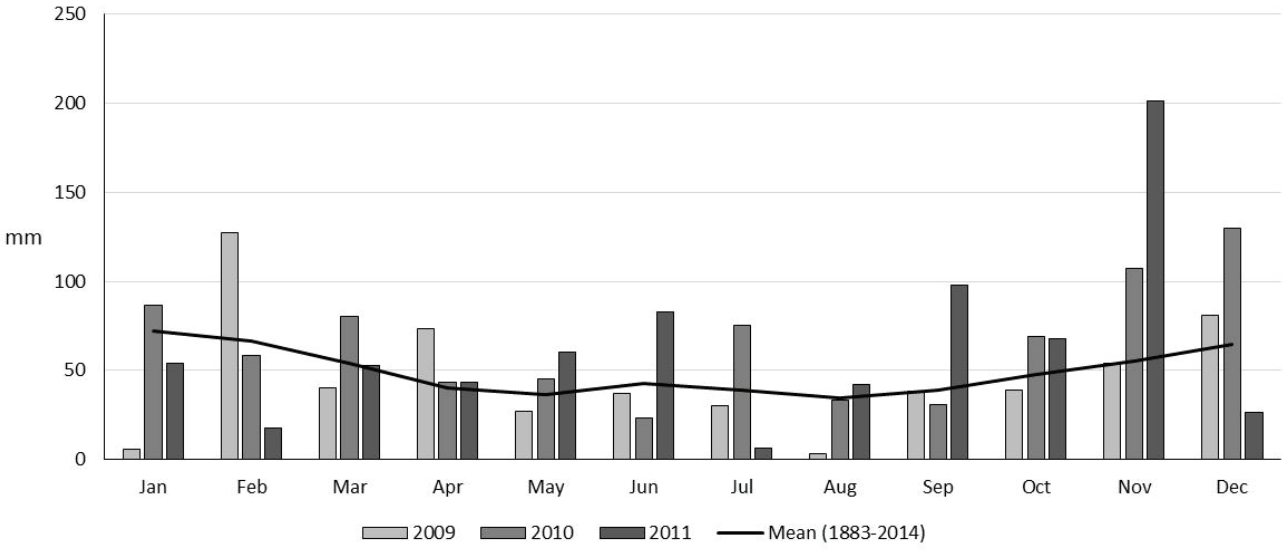

Figure 2. Rainfall data for Denman, 10 km south of Mangoola, over the study period (2009 to 2011), showing the 130 year average (weather station closed in 2014). Source: Bureau of Meteorology 2014.

Data Analysis

Floristic plot data was analysed using multivariate techniques with the *Primer* software package (Clarke & Gorley 2006). Agglomerative hierarchical cluster analysis and non-metric multidimensional scaling (nMDS) were performed on the dataset using the group averaging strategy, the Bray-Curtis similarity measure and a Beta value of – 0.1. SIMPROF was used to guide the delineation of groups in the data, supported by field observations. Ordinations were performed in two and three dimensions with 25 random starts and a minimum stress of 0.01. While both analysis methods were utilised, nMDS ordinations have been presented rather than cluster diagrams, as the former have been shown to be more robust and to provide more informative summaries in ecological studies (e.g. Kim *et al*. 2000; Quinn & Keough 2002; Cheng 2004). Cluster analyses are, however, informative in a supportive role in situations involving closely related groups. During all analyses, weed species were retained in the dataset as they form an important component of derived grasslands in the region. The SIMPER routine in *Primer* was used to generate diagnostic species lists for each defined floristic group, identifying the top 90% of floristic variation present in each group. This routine, which compares 'similarity percentages', decomposes average Bray-Curtis similarities among samples within a group into percentage contributions from each species, listing the species in decreasing order of contribution (Clarke & Gorley 2006). The proportion of native and exotic species, and annual or perennial species were examined with univariate statistics, after categorizing each taxon into growth form classes based on descriptions in Plantnet (http://plantnet.rbgsyd.nsw.gov.au/).

Community Mapping

Mapping of grassland communities was conducted initially through on-screen interpretation of high resolution digital colour aerial photographs supplied by Mangoola Coal. During this process, observable photo-patterns were circumscribed and applied a preliminary draft unit code. Following field investigations and data analysis, delineated grassland community groups were rationalised with the preliminary mapping to produce a final map layer of distribution.

Results

Sampling Effort

In total, 168 sample plots were surveyed between 2009 and 2011 across the study area (Figure 3). Sixty of these were sampled in 2009, 88 in 2010 and 20 in 2011, and all accessible grassland areas were represented. Taken across all grasslands, a sampling density of one plot per 6.4 ha was achieved.

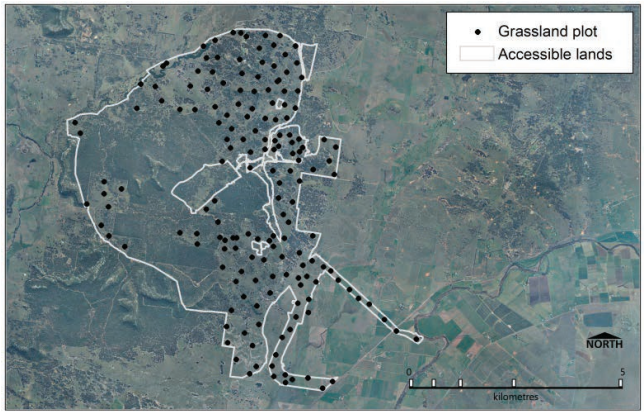

Figure 3. Location of 168 grassland sample plots surveyed over three seasons, Spring 2009 to 2011 (aerial image courtesy of Mangoola Coal).

Species Richness, Origin & Growth Form

Total floristic richness was 305 plant taxa, comprising 184 native and 121 exotic taxa (Appendix 1). Grasses, herbs and forbs were the most well represented growth form, with shrubs such as *Allocasuarina luehmannii, Acacia paradoxa* and *Notelaea microcarpa* also occurring, and the trees *Eucalyptus crebra, Angophora floribunda* and *Eucalyptus moluccana* present as saplings in a sparse shrub layer at some occasions. Significant species recorded include *Diuris tricolor* (Vulnerable BC Act 2016, EPBC Act 1999; Endangered Population BC Act 2016) and *Prasophyllum petilum* (critically endangered, as *Prasophyllum* sp. Wybong (C. Phelps ORG5269), EPBC Act 1999). Several other taxa of interest were also present within plots (see Appendix 2), their significance principally related to distributional limits and the presumed role the Hunter Valley plays in the dispersal of plants from the western districts of NSW (Crisp *et al*. 1999; Peake 2005). Included in this group are three small trees, three shrubs, ten forbs and six grasses. Several other species, particularly grasses and herbs (e.g. *Eriochloa pseudoacrotricha*), may also represent eastern limits of distribution within the Hunter Valley, however herbarium collections show disjunct records for the Cumberland Plain near Sydney, and these species may in fact have been introduced there through stock movements during the 1800s. Similar dispersal mechanisms may also have operated into the Hunter Valley from western districts, however this is more difficult to ascertain.

None of the 168 sample plots were wholly comprised of native plant species, and none were entirely exotic. The number of native species within each plot ranged from one (8.3% of taxa for that plot) to 35 (70%), with an overall average of 19.6 taxa per plot (Figure 4). Exotic species ranged from two (22.2% of taxa for that plot) to 24 (75%), with an overall average of 12.8 taxa per plot. Annual species occurrence (native & exotic collectively) ranged from none (0% of that plot) to 19 taxa (35%), while perennials ranged from 3 (25%) to 41 taxa (82%). The overall average for annuals was 9.8 taxa per plot, and for perennials 22.6 taxa per plot.

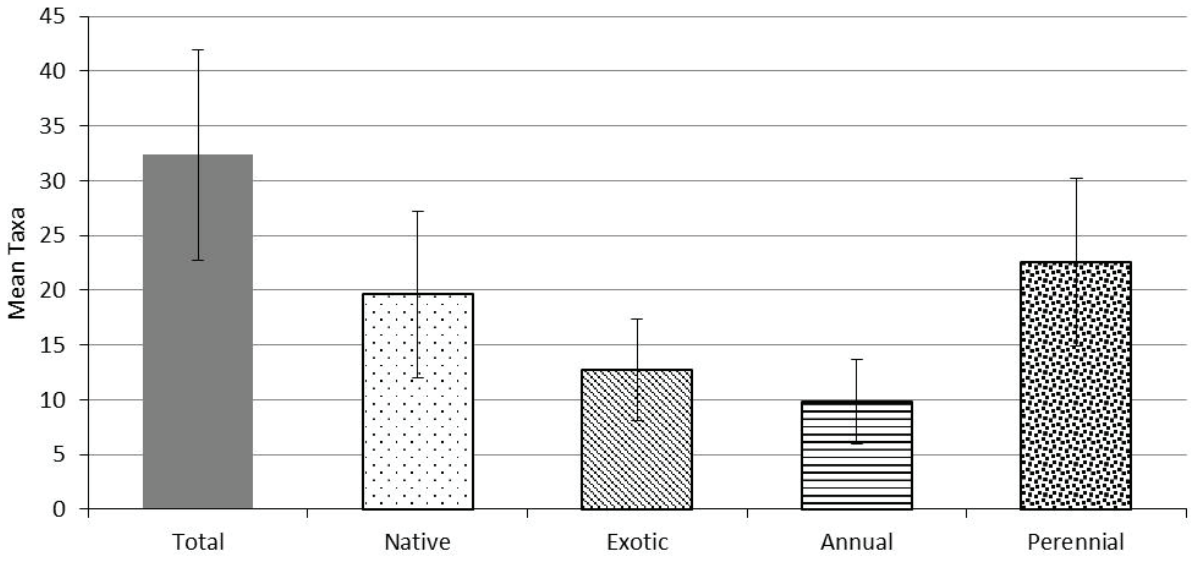

Figure 4. Summary statistics of 168 grassland sample plots, showing mean number of taxa per plot and standard deviations (n=168).

Of the 184 native plant taxa recorded, only 24 (13%) were annuals, while 160 (87%) were perennial (Figure 5). Conversely, of the 121 exotic taxa, 78 (65%) were annuals and 43 (35%) were perennials (Figure 6). These differences between origin (native vs exotic) and life expectancy (annual vs perennial) can have important implications on the classification of grassland communities, particularly in relation to the timing of field surveys. Evidently, within the grassland dataset examined here, annual and perennial plant taxa fulfil opposite roles in their respective exotic and native taxa datasets: annuals are far more important within the exotic flora than they are within the native flora.

Classification

Cluster analysis of the 168 sample plots delineated seventeen floristic groups at 36% similarity, highlighting the diversity of vegetation present within lands previously considered collectively as 'derived grasslands'. All but two of these have been defined at community level, as they occupy distinct geospatial positions in the landscape; the single sample representing *Calocephalus*/ *Eulalia* Herbland (Unit 1b) was considered a sub-unit of the more heavily sampled *Dichanthium/ Sporobolus/ Chloris* Grassland (Unit 1a). The possibility remains that some defined communities may be the result of differing compositions over different sampling years; however, a review of plot allocations by community and year of sampling showed that most (16 of 17 units) are based on data from plots sampled in 2009 and 2010. The majority of defined units (12 of 17) stem from data collected in 2009 (with replicates in 2010 and 2011), while 3 units were defined only from 2010 data (1-2 plots), one from 2011 data (2 plots), and one from 2010 and 2011 data (10 plots). These latter 5 units were largely dominated by perennial weed species.

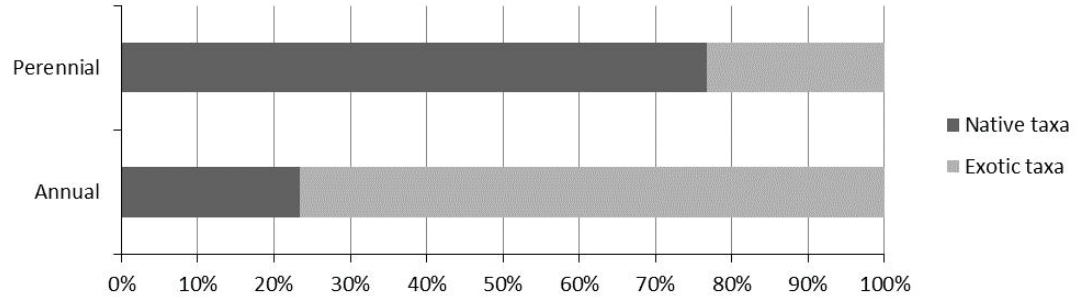

Figure 5. Origin (native vs exotic) in perennial and annual plant taxa (168 samples, combined).

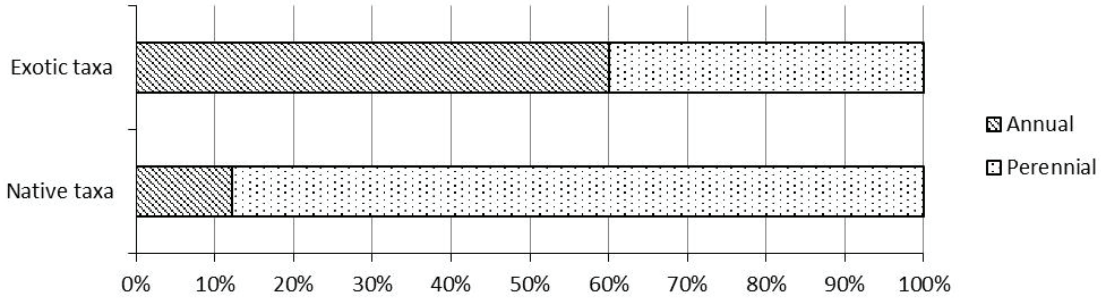

Figure 6. Life expectancy (annual vs perennial) in exotic and native plant taxa (168 samples, combined).

The nMDS ordination performed on the same dataset reinforced patterns shown in the cluster analysis, displaying the distribution of groups in 2-dimensional space (Figure 7). Not all of these groups support vegetation dominated by native taxa (those characterised by exotic species are shown with open symbols), however they are distinct and observable entities within the landscape. The ellipses shown on Figure 7, representative of cut-points in the cluster analysis at 36% similarity, depict the close relationships existing between many of the defined units. Some units, such as *Cynodon*/ *Hordeum*/ *Lolium* Grassland (Unit 11) and *Lolium*/ *Sisymbrium*/ *Avena* Grassland (Unit 9) form distinct groups of samples. Others, however, share several taxa with related units, ensuring considerable overlapping of component plots groups. In landscapes with a common disturbance history, this is not entirely unexpected.

Table 2 summarises all units defined in the grassland classification. Of the seventeen floristic groups (16 communities, 1 with two sub-communities), nine may be considered of natural origin (dominated by native taxa), and eight may be considered of exotic origin (dominated by exotic taxa). Both threatened terrestrial orchids (*Diuris tricolor, Prasophyllum petilum*) occurred predominantly within the *Dichanthium/ Sporobolus/ Chloris* Grassland (Unit 1a) and *Aristida/ Cymbopogon* Grassland (Unit 2). The rare grass *Bothriochloa biloba* dominated stands of the *Bothriochloa biloba/ Carthamnus/ Rytidosperma* Grassland (Unit 4) and the *Bothriochloa biloba/ Verbena/ Dichanthium* Grassland (Unit 5).

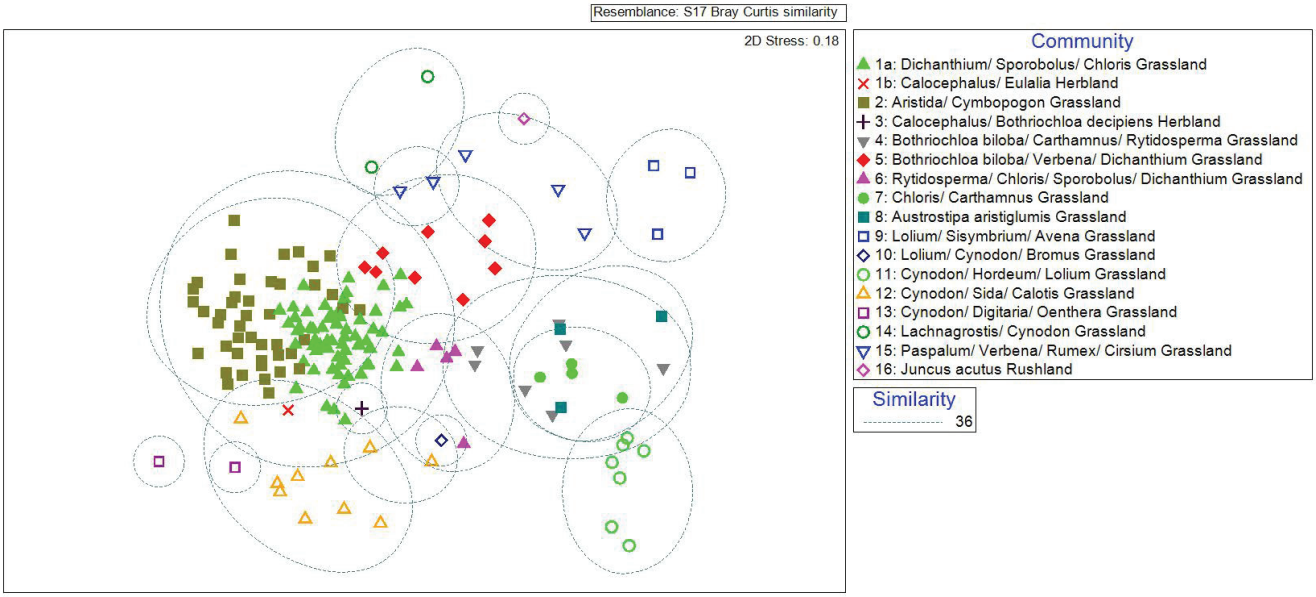

Figure 7. Non-metric Multi Dimensional Scaling ordination of plot samples, showing spatial arrangement within 2-dimensional space. Solid symbols represent communities dominated by native taxa, open symbols those dominated by exotic taxa; herblands shown by character symbols. Stress = 0.18.

Table 2. Floristic groups, extent and observed variations (* = exotic in origin).

Floristic Group (ha)	Extent, Comments & Variations
1a: *Dichanthium/ Sporobolus/ Chloris* Grassland	559 ha; *Hyparrhenia hirta* is locally dominant
1b: *Calocephalus/ Eulalia* Herbland	2 ha; bare areas within *Dichanthium* grassland
2: *Aristida/ Cymbopogon* Grassland	276 ha; clay soils in *Eucalyptus crebra* landscapes
3: *Calocephalus/ Bothriochloa decipiens* Herbland	0.5 ha; bare patches within *Aristida* grassland
4: *Bothriochloa biloba/ Carthamnus/ Rytidosperma* Grassland	66 ha; edges of major floodplain in heavy soils
5: *Bothriochloa biloba/ Verbena/ Dichanthium* Grassland	33 ha; in heavy loam soils
6: *Rytidosperma / Chloris/ Sporobolus/ Dichanthium* Grassland	45 ha; edges of major floodplain in lighter soils
7: *Chloris/ Carthamnus* Grassland	28 ha; intensively grazed but good condition areas
8: *Austrostipa aristiglumis* Grassland	8 ha; deep cracking clays on floodplains
9: *Lolium/ Sisymbrium/ Avena* Grassland *	16 ha; intensively grazed and cropped lands
10: *Lolium/ Cynodon/ Bromus* Grassland *	2 ha; heavily used stockyards around homesteads
11: *Cynodon/ Hordeum/ Lolium* Grassland *	22 ha; in more intensively grazed areas
12: *Cynodon/ Sida/ Calotis* Grassland *	2 ha; in old stock camps under paddock trees
13: *Cynodon/ Digitaria/ Oenthera* Grassland *	1 ha; heavily grazed and improved pastures
14: *Lachnagrostis/ Cynodon* Grassland *	1 ha; temporarily moist culverts & dam over-flows
15: *Paspalum/ Verbena/ Rumex/ Cirsium* Grassland *	6 ha; along drainage lines and moist depressions
16: *Juncus acutus* Rushland *	2 ha; along drainage lines with higher salinity

SIMPER analysis undertaken on the data identified plant taxa defining each of the seventeen floristic groups. An upper limit of 90% was set for this analysis, returning only those species contributing to the upper 90% of diversity for each group. Brief profiles of each of these floristic groups are presented in Appendix 3.

Community Mapping

Mapping of the seventeen floristic groups across the study area revealed specific patterns in geographical distribution, presumably related to land use history and 'parent' woodland community type (Figure 8). Excluding treed vegetation and disturbed areas, *Aristida/ Cymbopogon* Grassland (Unit 2) predominates in the higher lands, while *Dichanthium/ Sporobolus/ Chloris* Grassland (Unit 1a) dominates the lower areas. Vegetation characterised by the rare *Bothriochloa biloba* (Unit 4: *Bothriochloa biloba/ Carthamnus/ Rytidosperma* Grassland & Unit 5: *Bothriochloa biloba/ Verbena/ Dichanthium* Grassland) is localised to specific areas. All other floristic groups are highly restricted or occur only in more intensely grazed areas in the south-east of the study area.

Discussion

Mangoola and other Grasslands Studies

Relative to other regions in New South Wales, few studies of the grasslands in the Hunter Valley have been undertaken, possibly due to their derived rather than native origins. Story (1963a,b) broadly classified all vegetation of the Hunter, and briefly discussed grassland dominance and species composition within the more widespread woodlands, however no detailed typology was presented. Similarly, Tame (1984) intuitively described the rainforests, forests, woodlands and heaths of the region in some detail, but overlooked the grasslands in his treatise. More recent numerical-based classifications of the Hunter have also simplified or overlooked the diversity of grasslands to be found here, in favour of the perhaps more pressing need to identify and manage woody vegetation (e.g. NPWS 1999; Peake 2006; Somerville 2009). Although the Hunter Remnant Vegetation Project of Peake (2006) focused on the mapping and description of only woody vegetation in its 3,150 km^2 study area, extensive grasslands were recognised as occurring there. Only two grassland communities were described by Somerville (2009) for the entire Hunter-Central Rivers catchment area (encompassing 40,300 km^2); a *Plainsgrass Grassland* (MU163) on basalt soils on the Merriwa Plateau, and *Kangaroo Grass/ Westringia fruticosa on Coastal Headlands* (MU162) for parts of the immediate coastline. The most recent classification of vegetation in the Hunter Valley is that of Sivertsen *et al*. (2012), who expanded on Somerville (2009) to include just four grassland units (*Themeda australis*/ *Westringia fruticosa* grassland on coastal headlands; *Austrostipa aristiglumis*/ *Aristida ramosa*/ *Austrodanthonia bipartita* grassland on basalt soils of the Merriwa plateau; *Austrostipa aristiglumis* grassland of the Liverpool Plains; and Derived Grasslands of the Greater Hunter mapping area). The last of these (Derived Grasslands) in this classification is characterized by the genera *Rytidosperma, Austrostipa, Chloris, Panicum* and *Enteropogon*. At a more local scale, Bell and Carty (2012) defined thirteen grassland types for the Singleton Military Area (across an area of 145 km^2), all of which were categorised as derived.

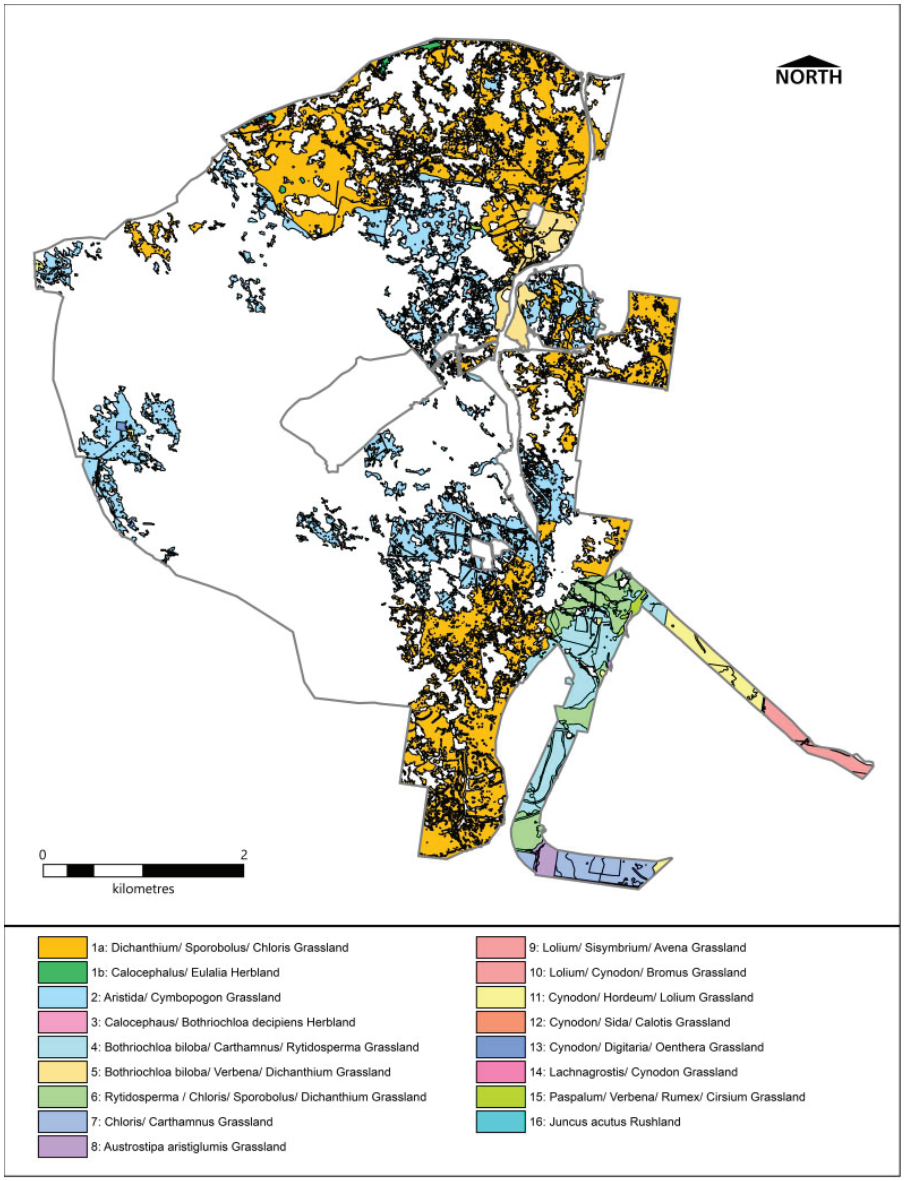

Figure 8. Distribution of grassland communities across the study area.

Seventeen floristic grassland groups (16 communities, one with two sub-communities) have been delineated for Mangoola, eight of which are characterised by exotic taxa but nine are predominantly native. Aligning these grassland types with the few existing Hunter Valley classifications is difficult, primarily due to differences in scale of classification between the current and recent works. The two grassland communities described by Somerville (2009) for the Hunter Valley, and the four delineated by Sivertsen *et al*. (2012), are broad and do not adequately capture the grassland diversity present throughout the region. The more localised study of Bell and Carty (2012) at Singleton (c. 100 km south-east of Mangoola) provides some correlation, but only three of the thirteen grassland communities defined in that study draw some similarities to the Mangoola grasslands. Such observations support the recommendation first raised by Peake (2006) for a more thorough grassland typology of the entire Hunter Valley.

Grassland studies elsewhere in New South Wales are also difficult to rationalise against the Mangoola grasslands. The work of Bean and Whalley (2001) on the Liverpool Plains appears floristically closest to Mangoola, perhaps as may be expected given its geographical position adjacent to the Hunter Valley, yet others align poorly. It may be expected that grasslands in the upper Hunter Valley would show affinities to the *Western Slopes Grasslands* class of Keith (2004), and broadly speaking this is true. Grasslands within this class, according to Keith (2004), are distinguished by the dominance of *Austrostipa aristiglumis* in dense swards to 1.5m high, often growing to the exclusion of other grass species. Other indicative grass species present include *Aristida leptopoda, Rytidosperma bipartitum, Chloris truncata, Dichanthium sericeum, Enteropogon acicularis, Paspalidium constrictum, Sporobolus carolii* and *Sporobolus elongatus*. Some, but not all, of these species are present within the Mangoola grasslands, but there are clear floristic similarities in the shared genera. Grasslands defined for the elevated New England Tableland are dominated by a range of different taxa with few similarities to Mangoola (Hunter & Hunter 2016).

Conservation Significance of Grasslands

Within the mid to upper Hunter Valley, there are few areas where Sub-humid Temperate Grassland (native or derived) dominated by *Themeda, Poa* and/or *Austrostipa* remain. Although there is little documented quantitative evidence, historical observations suggest that a long history of grazing has modified the once extensive *Themeda*-dominated grasslands to one where other less palatable species predominate. Benson and Redpath (1997) cite a letter from the explorer Ludwig Leichhardt in 1844, where he discusses species diversity in south-eastern Australia and states "*The ground under the trees, which would be covered with blueberry and whortleberry bushes in our oak forests, is mostly covered with kangaroo grass* [Themeda triandra] *here…. This grass ripens in October and November, when the ground under the trees looks like an even, sweeping field of oats*." Lang (2008) argues that *Themeda* and other grazing sensitive species (*Eulalia, Astrebla*) may once have dominated those grasslands on the Liverpool Plains now occupied by *Austrostipa aristiglumis*. Stol and Prober (2015) identify 'very high conservation value ground-layers' in the nationally threatened Box-Gum grassy woodlands by the dominance of *Themeda triandra* and/or *Poa sieberiana*, with the implication that these species formed a prominent component of grassy woodlands prior to European modification.

In parts of the Hunter Valley where stock grazing has been reduced or removed, some restricted areas of grassland within woodland landscapes are still dominated by *Themeda triandra* and the similarly grazing-sensitive *Sorghum leoicladum* (e.g. near Singleton, Bell 2018) and *Themeda avenacea* (e.g. Merriwa, T. Peake pers. comm.). During wet years, a surprising number of rarely seen herbs and grasses appear (Bell 2020a), many of these grazing-sensitive species which may always be present but rarely seen. Where grazing exclusion fencing has been installed in areas dominated by *Aristida* and *Cymbopogon*, *Themeda* and *Sorghum* return to dominance after a few years (unpubl. data). At other locations on elevated basalt east of Mururrundi, *Themeda*, *Sorghum* and *Poa* dominate little-grazed woodlands of *Eucalyptus albens* and *Eucalyptus goniocalyx* (unpubl. data), and roadside verges in these districts also often support these grasses. Such circumstantial evidence from several widely separated localities suggests a formerly more widespread dominance by these palatable grasses across the Hunter. None of these grasses have been observed at Mangoola, although historically they may have once formed an important component of the communities present there. Promotion of fire across these landscapes in combination with grazing exclusion may see them return to the grassland flora, given evidence of fire-induced breaking of dormancy reported in the literature (Baxter *et al*. 1994; Cole & Lunt 2005) and the response of other areas where fire has been introduced (Lunt & Morgan 1999; Morgan 1999; Prober *et al*. 2007).

Groves (1979) predicted that by the year 2079 Sub-humid Temperate Grasslands would be of higher conservation significance at that time in history than it was in 1979. His reasoning for this was that this once formerly widespread grassland formation was confined to small pockets in ungrazed lands close to urban areas, typically along railway lines and roadsides, and in cemeteries. Forty years on, and the prediction by Groves is alarmingly accurate. In south-eastern Australia, the *Natural Temperate Grasslands of the Victorian Volcanic Plain, Natural Grasslands of the Murray Valley Plains* and *Natural Temperate Grasslands of the South Eastern Highlands* are all listed as critically endangered on the Commonwealth *EPBC Act 1999*. In New South Wales, *Native vegetation on cracking clay soils of the Liverpool Plains* and *Themeda Grassland on Seacliffs and Coastal Headlands* are endangered ecological communities on the *BC Act 2016*. Additionally, derived or secondary temperate grasslands are also specifically encompassed in several Commonwealth and NSW threatened woodland communities (Table 3). The Hunter Valley is encapsulated in two main State-listed threatened communities (*Central Hunter Ironbark - Spotted Gum - Grey Box Forest EEC* and *Central Hunter Grey Box - Ironbark Woodland EEC*), and one Commonwealth-listed

community (*Central Hunter Valley Eucalypt Forest and Woodland CEEC*), yet only the last implicitly includes derived native grasslands within their definitions (and this only in very restricted situations near wooded vegetation).

To date, there has been no research undertaken on the conservation significance of grasslands within the Hunter Valley. In part, this is due to the lack of rigorous survey and classification of grassland habitats, and the ease with which past studies have deferred to the concept of 'derived grasslands' to describe grassland diversity. Given the extent of European occupation of the Hunter Valley over the past 200 years, all grasslands have been impacted upon in one way or another by agricultural activities (Butzer & Helgren 2005), and hence all can be described as derived. Along with Bell and Carty (2012), the classification of the Mangoola grasslands presented here represents the first serious attempt at numerically-based classifications of the derived grasslands of the Hunter Valley. With this comes the opportunity to consider the relative importance of each grassland unit, albeit without an over-riding regional framework in which to place them. Only one of the thirty State and Commonwealth-listed grassland threatened ecological communities potentially include some of the grasslands at Mangoola, but there are also certain floristic similarities to the NSW-listed *Native vegetation on cracking clay soils of the Liverpool Plains*:

White Box - Yellow Box – Blakely's Red Gum Grassy Woodland and Derived Native Grassland – this Commonwealth-listed CEEC specifically includes derived grasslands within White Box (*Eucalyptus albens*), Yellow Box (*Eucalyptus melliodora*) and Blakely's Red Gum (*Eucalyptus blakelyi*) landscapes. Such derived grasslands have been created following long periods of agricultural activities including tree thinning and land clearing, however remain of conservation significance. At Mangoola, Unit 7 (*Chloris/ Carthamnus* Grassland), Unit 4 (*Bothriochloa biloba/ Carthamnus/ Rytidosperma* Grassland), and Unit 1a (*Dichanthium/ Sporobolus/ Chloris* Grassland) all potentially fall within this CEEC, as all occur in the vicinity of Box or Redgum eucalypts and support many of the component ground species.

Native Vegetation on Cracking Clay Soils of the Liverpool Plains – this State-listed EEC occurs within the Liverpool Plains catchment on the North West Slopes and Plains of NSW. It is characterised by grasslands dominated by the grasses *Austrostipa aristiglumis, Dichanthium sericeum* or *Panicum queenslandicum*, and occurs in the Liverpool Plains, Quirindi, Coonabarabran, Gunnedah, Narrabri, and Parry local government areas (NSW Scientific Committee 2001). Lang (2008) argues that the dominance of *Austrostipa aristiglumis* in these areas is a consequence of heavy and continuous grazing by domestic stock and rabbits, and that other species such as *Themeda avenacea, Eulalia aurea* and *Astrebla lappacea* were probably more abundant and characteristic. At Mangoola, Unit 8 (*Austrostipa aristiglumis* Grassland) is floristically similar to this EEC through the dominance of *Austrostipa aristiglumis* and its occurrence on the clay soils of a broad plain, while Unit 1a (*Dichanthium/ Sporobolus/ Chloris* Grassland) also shares many species. Both, however, are excluded from this EEC through their geographical location being outside of the Liverpool Plains catchment.

Table 3. Threatened grassland and derived grassland communities within NSW (*BC Act 2016*) and Commonwealth (*EPBC Act 1999*) legislation (* = potentially applicable to Mangoola). EEC = Endangered Ecological Community; CEEC = Critically Endangered Ecological Community.

Level	Threatened Community
State (NSW)	Araluen Scarp Grassy Forest EEC (includes derived grassland)
	Cumberland Plain Woodland CEEC (includes derived grassland)
	Lowland Grassy Woodland EEC (includes derived grassland)
	Monaro Tableland Cool Temperate Grassy Woodland CEEC (includes derived grassland)
	Myall Woodland EEC (includes derived grassland)
	Native vegetation on cracking clay soils of the Liverpool Plains EEC *
	Porcupine Grass-Red Mallee-Gum Coolabah Hummock Grassland/Low Sparse Woodland CEEC
	Ribbon Gum-Mountain Gum-Snow Gum Grassy Forest/Woodland EEC (includes derived grassland)
	Tableland Basalt Forest EEC (includes derived grassland)
	Themeda grassland on seacliffs and coastal headlands EEC
	Werriwa Tablelands Cool Temperate Grassy Woodland CEEC (includes derived grassland)
Commonwealth	Castlereagh Scribbly Gum and Agnes Banks Woodlands of the Sydney Basin EEC (includes derived grasslands)
	Gippsland Red Gum (*E. tereticornis* subsp. *mediana*) Grassy Woodland and Associated Native Grassland CEEC
	Grassy Eucalypt Woodland of the Victorian Volcanic Plain CEEC (includes derived grassland)
	Grey Box (*E. microcarpa*) grassy woodlands and derived native grasslands of south-eastern Australia EEC
	Hunter Valley Weeping Myall (*Acacia pendula*) Woodland CEEC (includes derived grassland)
	Illawarra and south coast lowland forest and woodland CEEC (includes some derived grassland)
	Iron-grass natural temperate grassland of South Australia CEEC
	Lowland Grassy Woodland in the South East Corner CEEC (includes derived grassland)
	Lowland native grasslands of Tasmania CEEC
	Natural Damp Grassland of the Victorian Coastal Plains CEEC
	Natural Grasslands of the Murray Valley Plains CEEC
	Natural Grasslands of the Queensland Central Highlands and the northern Fitzroy Basin EEC
	Natural Grasslands on basalt and fine-textured alluvial plains of northern NSW and southern QLD CEEC
	Natural Temperate Grasslands of the South Eastern Highlands CEEC
	Natural Temperate Grassland of the Victorian Volcanic Plain CEEC

Level	Threatened Community
	Poplar Box Grassy Woodland on Alluvial Plains EEC (includes some derived grassland)
	Shale Sandstone Transition Forest of the Sydney Basin CEEC (includes derived grassland)
	Southern Highlands Shale Forest and Woodland of the Sydney Basin CEEC (includes some derived grassland)
	White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland CEEC *

At the taxon level, several plant species of National or State significance occur within the Mangoola grasslands. The NSW-listed threatened terrestrial orchids *Diuris tricolor* (Vulnerable) and the Commonwealth and NSW-listed *Prasophyllum petilum* (Endangered) are common across a range of grassland types, but mostly within the *Dichanthium/ Sporobolus/ Chloris* and *Aristida/ Cymbopogon* Grasslands (Units 1a & 2). Both species have been the subject of a large and successful translocation program at Mangoola, re-establishing plants into grassland areas to mitigate their loss through mining (Bell 2020b). Single records of the seasonal and cryptic NSW- and Commonwealth-listed endangered *Swainsona recta* and vulnerable *Thesium australe* also reportedly occur in grassland at Mangoola (Glencore 2018), and both species potentially occur across a wider area. A NSW-listed endangered population of *Acacia pendula* occurs within the Hunter catchment, and clonal groups of these are present within several grassland areas. Additionally, over twenty species occur at or extend their known geographical distributions within the Mangoola area (Appendix 2).

A New Appreciation of 'Derived Grasslands'?

Contemporay grasslands throughout much of New South Wales, including the Hunter Valley, are largely secondary associations that have developed following sustained disturbance regimes (Benson 1996; Griffiths 2002; Reed 2014). These derived grasslands comprise varying compositions of native and exotic species, including a range of introduced pasture species. Reed (2014) has reviewed the introduction, use and development of perennial pasture grasses in southern Australia, detailing the promotion of many exotic grass species (e.g. *Lolium perenne, Phalaris aquatic, Dactylis glomerata*) in support of the agricultural industry. He outlined how the original native grasslands progressively became depleted of diversity and fertility through overexploitation by cloven-hooved ruminants, leading to the experimental introduction of a range of exotic grass species. Over time, many of these species persisted and adapted to new environments and now comprise a tenacious presence in most derived grasslands. In the modern era, incorporation of native ground cover species into mining rehabilitation, where traditionally exotic species such as *Chloris gayana, Panicum maximum, Medicago sativa* and *Medicago truncatula* have been used extensively, ensured that over time these species would also volunteer into derived grasslands. Huxtable (1995, 2000) and Huxtable *et al*. (2005) have experimented with replacing these with native species, and adoption of such a practice is gaining momentum. Mangoola mine itself has experimentally established grasslands dominated by native species into its rehabilitation areas, which are now providing habitat for translocated orchids (Bell 2021).

In this context, derived grasslands which retain a high proportion of local native species should be seen as contributing positively to regional biodiversity. To date, this has not been overly recognized by government or legislation, perhaps due to perceptions of unknown floristic complexity within the region and how to adequately address this. However, as evidenced by this study of the Mangoola grasslands, it is possible to differentiate several definable grassland associations from areas considered simply as 'derived grassland'. While a number of currently listed threatened plant species inhabit areas of derived grassland, it is those increasingly rare forbs and grasses that are not presently protected by legislation that may decline in the long term. Some of these are disturbance-dependent species but suffer under continual stock grazing (Kirkpatrick 2007), and their ongoing persistence will require knowledge and application of specific disturbance regimes (e.g. fire). Peake (2006) wrote of the need for a comprehensive grassland typology of the entire Hunter Valley so that areas of significant or high biodiversity could be identified in these otherwise overlooked landscapes. Such a typology is still lacking nearly fifteen years later, and perhaps this should now be addressed more comprehensively to monitor and prevent unnecessary loss of biodiversity.

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Appendix 1 Plant Species list for Mangoola grasslands, Upper Hunter Valley

Family	Scientific Name	Common Name
Acanthaceae	*Brunoniella australis*	Blue Trumpet
	Rostellularia adscendens var. *adscendens*	
Adiantaceae	*Cheilanthes distans*	Bristly Cloak Fern
	Cheilanthes sieberi subsp. *sieberi*	Rock Fern
Aizoaceae	*Galenia pubescens* *	Galenia
Amaranthaceae	*Alternanthera pungens* *	Khaki Weed
	Alternanthera sp. A	
	Gomphrena celosioides *	Gomphrena Weed
	Ptilotus semilanatus	Lambs tails
Anthericaceae	*Arthropodium minus*	Small Vanilla Lily
	Arthropodium sp. B	
	Dichopogon fimbriatus	Nodding Chocolate Lily
	Laxmannia gracilis	Slender Wire Lily
	Thysanotus tuberosus subsp. *tuberosus*	
	Tricoryne elatior	Yellow Autumn-lily
Apiaceae	*Centella asiatica*	Indian Pennywort
	Cyclospermum leptophyllum *	Slender Celery
	Daucus glochidiatus	Native Carrot
	Foeniculum vulgare *	Fennel
	Hydrocotyle laxiflora	Stinking Pennywort
Apocynaceae	*Gomphocarpus fruticosus* *	Narrow-leaved Cotton Bush
Asteraceae	*Arctotheca calendula* *	Capeweed
	Aster subulatus *	Wild Aster
	Brachyscome ciliaris	Variable Daisy
	Brachyscome curvicarpa	
	Calocephalus citreus	Lemon Beauty-heads
	Calotis lappulacea	Yellow Burr-daisy
	Carthamus lanatus *	Saffron Thistle
	Cassinia arcuata	Sifton Bush
	Centaurea melitensis *	Maltese Cockspur
	Chrysocephalum apiculatum	Common Everlasting
	Chrysocephalum semipapposum	Clustered Everlasting
	Cichorium intybus *	Chicory
	Cirsium vulgare *	Spear Thistle
	Conyza bonariensis *	Flaxleaf Fleabane
	Conyza spp. *	A Fleabane
	Cotula australis	Common Cotula
	Cotula coronopifolia *	Water Buttons
	Cyanthillium cinereum var. *cinereum*	
	Cymbonotus lawsonianus	Bear's Ear
	Eclipta platyglossa	Yellow Twin-heads
	Epaltes australis	Spreading Nut-heads
	Euchiton sphaericus	Star Cudweed
	Facelis retusa *	

Family	Scientific Name	Common Name
	Gamochaeta americana *	Cudweed
	Gamochaeta coarctata *	Cudweed
	Glossocardia bidens	Cobbler's Tack
	Hypochaeris albiflora *	White Flatweed
	Hypochaeris radicata *	Catsear
	Lagenophora stipitata	Common Lagenophora
	Leiocarpa panaetioides	Wooly Buttons
	Leontodon rhagadioloides *	Cretan Weed
	Minuria leptophylla	
	Senecio madagascariensis *	Fireweed
	Senecio quadridentatus	Cotton Fireweed
	Soliva sessilis *	Bindyi
	Sonchus asper *	Prickly Sowthistle
	Sonchus oleraceus *	Common Sowthistle
	Taraxacum officinale *	Dandelion
	Tolpis barbata *	Yellow Hawkweed
	Triptilodiscus pygmaeus	Common Sunray
	Vittadinia cervicularis var. *subcervicularis*	
	Vittadinia cuneata var. *cuneata*	A Fuzzweed
	Vittadinia muelleri	A Fuzzweed
	Vittadinia sulcata	
	Xanthium spinosum *	Bathurst Burr
Boraginaceae	*Echium plantagineum* *	Patterson's Curse
	Heliotropium amplexicaule *	Blue Heliotrope
Brassicaceae	*Lepidium africanum* *	Common Peppercress
	Lepidium bonariense *	Argentine Peppercress
	Lepidium didymum *	Lesser Swinecress
	Rapistrum rugosum *	Turnip Weed
	Sisymbrium irio *	London Rocket
	Sisymbrium officinale *	Hedge Mustard
Cactaceae	*Opuntia aurantiaca* *	Tiger Pear
	Opuntia stricta var. *stricta* *	Common Prickly Pear
Campanulaceae	*Wahlenbergia communis*	Tufted Bluebell
	Wahlenbergia gracilis	Sprawling Bluebell
	Wahlenbergia luteola	Bluebell
	Wahlenbergia stricta subsp. *stricta*	Tall Bluebell
Caryophyllaceae	*Paronychia brasiliana* *	Chilean Whitlow Wort, Brazilian Whitlow
	Petrorhagia dubia *	
	Petrorhagia nanteuilii *	Proliferous Pink
	Polycarpon tetraphyllum *	Four-leaved Allseed
	Silene gallica var. *gallica* *	French Catchfly
	Spergularia marina	Lesser Sea-spurrey
	Spergularia rubra *	Sandspurry
Casuarinaceae	*Allocasuarina luehmannii*	Bulloak
Chenopodiaceae	*Atriplex semibaccata*	Creeping Saltbush

Family	Scientific Name	Common Name
	Einadia hastata	Berry Saltbush
	Einadia nutans subsp. *linifolia*	Climbing Saltbush
	Enchylaena tomentosa	Ruby Saltbush
	Maireana enchylaenoides	Wingless Fissure-weed
	Maireana microphylla	Small-leaf Bluebush
	Sclerolaena birchii	Galvinized Burr
	Sclerolaena muricata	Black Rolypoly
Clusiaceae	*Hypericum gramineum*	Small St John's Wort
	Hypericum perforatum *	St. Johns Wort
Colchicaceae	*Wurmbea dioica* subsp. *dioica*	Early Nancy
Commelinaceae	*Commelina cyanea*	Native Wandering Jew
	Murdannia graminea	
Convolvulaceae	*Convolvulus erubescens*	Pink Bindweed
	Dichondra repens	Kidney Weed
	Dichondra sp. Inglewood (J.M. Dalby 86/93)	Kidney Weed
	Evolvulus alsinoides var. *decumbens*	
Crassulaceae	*Crassula sieberiana*	Australian Stonecrop
Cyperaceae	*Carex appressa*	Tall Sedge
	Carex inversa	Knob Sedge
	Cyperus aggregatus *	
	Cyperus eragrostis *	Umbrella Sedge
	Cyperus gracilis	Slender Flat-sedge
	Fimbristylis dichotoma	Common Fringe-sedge
	Gahnia aspera	Rough Saw-sedge
	Schoenus apogon	Fluke Bogrush
Droseraceae	*Drosera peltata*	A Sundew
Euphorbiaceae	*Euphorbia drummondii*	Caustic Weed
Fabaceae (Faboideae)	*Bossiaea prostrata*	
	Chorizema parviflorum	Eastern Flame Pea
	Daviesia ulicifolia subsp. *ulicifolia*	
	Desmodium varians	Slender Tick-trefoil
	Glycine clandestina	Twining glycine
	Glycine microphylla	Small-leaf Glycine
	Glycine stenophita	
	Glycine tabacina	Variable Glycine
	Medicago minima *	Woolly Burr Medic
	Medicago polymorpha *	Burr Medic
	Medicago sativa *	Lucerne
	Medicago truncatula *	Barrel Medic
	Oxytes brachypoda	Large Tick-trefoil
	Templetonia stenophylla	Leafy Templetonia
	Trifolium angustifolium *	Narrow-leaved Clover
	Trifolium arvense *	Haresfoot Clover

Family	Scientific Name	Common Name
	Trifolium campestre *	Hop Clover
	Trifolium pretense *	Red Clover
	Trifolium repens *	White Clover
	Trifolium scabrum *	Rough Clover
	Trifolium vesiculosum *	
	Vicia sativa subsp. *nigra* *	Narrow-leaved Vetch
	Zornia dyctiocarpa var. *dyctiocarpa*	Zornia
Fabaceae (Mimosoideae)	*Acacia decora*	Western Silver Wattle
	Acacia falcata	
	Acacia homalophylla	Yarran
	Acacia paradoxa	Kangaroo Thorn
	Neptunia gracilis f. *gracilis*	Sensitive Plant
Gentianaceae	*Centaurium erythraea* *	Common Centaury
	Centaurium tenuiflorum *	Branched Centaury, Slender centaury
Geraniaceae	*Erodium cicutarium* *	Common Crowfoot
	Geranium molle subsp. *molle* *	Cranesbill Geranium
	Geranium solanderi var. *solanderi*	
Goodeniaceae	*Goodenia hederacea* subsp. *hederacea*	
	Goodenia macbarronii	Narrow Goodenia
	Goodenia pinnatifida	Scrambles Eggs
Haloragaceae	*Haloragis heterophylla*	Variable Raspwort
Hypoxidaceae	*Hypoxis hygrometrica* var. *hygrometrica*	
	Hypoxis hygrometrica var. *villosisepala*	
Iridaceae	*Romulea rosea* var. *australis* *	Onion Grass
	Sisyrinchium rosulatum	Scourweed
Juncaceae	*Juncus acutus* subsp. *acutus* *	Sharp Rush
	Juncus continuus	
	Juncus subsecundus	Finger Rush
	Juncus usitatus	
Lamiaceae	*Lamium amplexicaule* *	Dead Nettle
	Mentha satureioides	Native Pennyroyal
	Salvia reflexa *	Mintweed
	Salvia verbenaca *	Vervain
	Stachys arvensis *	Stagger Weed
Linaceae	*Linum marginale*	Native Flax
	Linum trigynum *	French Flax
Lobeliaceae	*Pratia concolor*	Poison Pratia
Loganiaceae	*Orianthera pusilla*	
Lomandraceae	*Lomandra confertifolia* subsp. *pallida*	Matrush
	Lomandra filiformis subsp. *coriacea*	Wattle Matt-rush

Family	Scientific Name	Common Name
	Lomandra longifolia	Spiny-headed Mat-rush
	Lomandra multiflora subsp. *multiflora*	Many-flowered Mat-rush
Lythraceae	*Lythrum hyssopifolia* *	Hyssop Loosestrife
Malvaceae	*Malva parviflora* *	Small-flowered Mallow
	Modiola caroliniana *	Red-flowered Mallow
	Sida corrugata	Corrugated Sida
	Sida filiformis	
	Sida hackettiana	
	Sida rhombifolia *	Paddy's Lucerne
	Sida trichopoda	High Sida
Marsileaceae	*Marsilea drummondii*	Common Nardoo
Myoporaceae	*Eremophila debilis*	Amulla
Myrsinaceae	*Lysimachia arvensis* *	Scarlet Pimpernel
Myrtaceae	*Angophora floribunda*	Rough-barked Apple
	Eucalyptus crebra	Narrow-leaved Ironbark
	Eucalyptus moluccana	Grey Box
	Melaleuca decora	
Nyctaginaceae	*Boerhavia dominii*	Tarvine
Oleaceae	*Notelaea microcarpa* var. *microcarpa*	
Onagraceae	*Oenothera longiflora* *	
	Oenothera stricta subsp. *stricta* *	
Orchidaceae	*Diuris tricolor*	Pine Donkey Orchid
	Microtis parviflora	Slender Onion Orchid
	Microtis unifolia	Common Onion Orchid
	Prasophyllum petilum	Tarengo Leek Orchid
	Pterostylis bicolor	Black-tip Greenhood
	Thelymitra pauciflora	Slender Sun Orchid
Oxalidaceae	*Oxalis perennans*	
Phormiaceae	*Dianella longifolia* var. *longifolia*	A Blue Flax Lily
	Dianella revoluta var. *revoluta*	A Blue Flax Lily
Phyllanthaceae	*Phyllanthus virgatus*	Wiry Spurge
	Poranthera microphylla	Small Poranthera
Pittosporaceae	*Bursaria spinosa*	Native Blackthorn
Plantaginaceae	*Plantago debilis*	Shade Plantain
	Plantago lanceolata *	Lamb's Tongues
	Plantago myosuros subsp. *myosuros* *	
	Veronica plebeia	Trailing Speedwell

Family	Scientific Name	Common Name
Poaceae	*Aira caryophyllea* *	Silvery Hairgrass
	Anthosachne scabra	Common Wheatgrass
	Aristida ramosa	Purple Wiregrass
	Aristida vagans	Threeawn Speargrass
	Aristida warburgii	
	Austrostipa aristiglumis	Plains Grass
	Austrostipa ramosissima	Stout Bamboo Grass
	Austrostipa scabra subsp. *falcata*	Rough Speargrass
	Austrostipa scabra subsp. *scabra*	Rough Speargrass
	Austrostipa verticillata	Slender Bamboo Grass
	Avena sativa *	Oats
	Axonopus fissifolius *	Narrow-leafed Carpet Grass
	Bothriochloa biloba	Lobed Bluegrass
	Bothriochloa decipiens var. *decipiens*	Pitted Bluegrass
	Bothriochloa macra	Red Grass
	Briza minor *	Shivery Grass
	Briza subaristata *	
	Bromus brevis *	
	Bromus catharticus *	Praire Grass
	Bromus hordeaceus *	Soft Brome
	Bromus molliformis *	Soft Brome
	Chloris truncata	Windmill Grass
	Chloris ventricosa	
	Cymbopogon refractus	Barbed Wire Grass
	Cynodon dactylon	Common Couch
	Cynodon incompletus *	
	Dactylis glomerata *	Cocksfoot
	Dichanthium sericeum subsp. *sericeum*	Queensland Bluegrass
	Dichelachne micrantha	Shorthair Plumegrass
	Digitaria coenicola	Finger Panic Grass
	Digitaria diffusa	Open Summer-grass
	Digitaria sanguinalis *	Crab Grass
	Echinopogon intermedius	Erect Hedgehog Grass
	Eleusine tristachya *	Goose Grass
	Enneapogon gracilis	Slender Nineawn
	Enteropogon acicularis	Curly Windmill Grass
	Eragrostis brownii	Brown's Lovegrass
	Eragrostis elongata	Clustered Lovegrass
	Eragrostis lacunaria	Purple Lovegrass
	Eragrostis leptostachya	Paddock Lovegrass
	Eriochloa pseudoacrotricha	Early Spring Grass
	Eulalia aurea	Silky Browntop
	Hordeum leporinum *	Barley Grass
	Hyparrhenia hirta *	Coolatai Grass
	Lachnagrostis aemula	Blowngrass
	Lachnagrostis filiformis	
	Lolium loliaceum *	Stiff Ryegrass
	Lolium multiflorum *	Italian Ryegrass
	Lolium perenne *	Perennial Ryegrass
	Microlaena stipoides var. *stipoides*	Weeping Grass
	Panicum capillare var. *capillare* *	Witchgrass
	Panicum effusum	Hairy Panic

Family	Scientific Name	Common Name
	Panicum queenslandicum var. *queenslandicum*	Yabila Grass
	Panicum simile	Two-colour Panic
	Paspalidium constrictum	Knottybutt Grass
	Paspalidium distans	
	Paspalum dilatatum *	Paspalum
	Paspalum distichum	Water Couch
	Phalaris aquatic *	Phalaris
	Polypogon monspeliensis *	Annual Beardgrass
	Rostraria cristata *	Annual Cat's Tail
	Rostraria pumila *	Roughtail
	Rytidosperma caespitosum	Ringed Wallaby Grass
	Rytidosperma racemosum var. *obtusatum*	A Wallaby Grass
	Rytidosperma racemosum var. *racemosum*	A Wallaby Grass
	Rytidosperma setaceum	Smallflower Wallaby Grass
	Rytidosperma tenuius	A Wallaby Grass
	Setaria parviflora *	
	Sporobolus africanus *	Parramatta Grass
	Sporobolus caroli	Fairy Grass
	Sporobolus creber	Slender Rat's Tail Grass
	Tripogon loliiformis	Fiveminute Grass
	Urochloa panicoides *	Urochloa Grass
	Vulpia muralis *	Wall Fescue
Polygonaceae	*Polygonum bellardii* *	Tree Hogweed
	Rumex brownii	Swamp Dock
	Rumex crispus *	Curled Dock
Portulacaceae	*Portulaca oleracea*	Pigweed
Rubiaceae	*Asperula conferta*	Common Woodruff
	Richardia humistrata *	
	Richardia stellaris *	
Scrophulariaceae	*Euphrasia collina*	
	Linaria pelisseriana *	Pelisser's Toadflax
	Parentucellia latifolia *	Red Bartsia
	Verbascum spp. *	
Solanaceae	*Lycium ferocissimum* *	African Boxthorn
	Solanum cinereum	Narrawa Burr
	Solanum nigrum *	Black-berry Nightshade
	Solanum prinophyllum	Forest Nightshade
Stackhousiaceae	*Stackhousia muricata*	Stackhousia
Typhaceae	*Typha domingensis*	Narrow-leaved Cumbungi
Verbenaceae	*Verbena bonariensis* *	Purple Top
	Verbena officinalis *	Common Verbena
	Verbena rigida var. *rigida* *	Veined Verbena

Appendix 2 Significant grassland taxa, Mangoola

Family	Taxon	Notes on Significance
Asteraceae	*Brachyscome curvicarpa*	eastern limit in the upper Hunter Valley; known only from the study area but likely to be more widespread
	Leiocarpa panaetioides	eastern limit in the upper Hunter Valley, extending to the Muswellbrook district
	Minuria leptophylla	eastern limit in the upper Hunter Valley, extending to the Singleton district
Casuarinaceae	*Allocasuarina luehmannii*	eastern limit in the upper Hunter Valley, extending to the Singleton district
Chenopodiaceae	*Maireana enchylaenoides*	eastern limit in the upper Hunter Valley, extending to the Singleton district
	Maireana microphylla	near eastern limit in the mid Hunter Valley, extending to the Cessnock district (also present on Cumberland Plain, where it is possibly introduced)
	Sclerolaena birchii	eastern limit in the upper Hunter Valley, extending to the Ravensworth district
Fabaceae	*Acacia homalophylla*	disjunct eastern occurrences in the upper Hunter Valley, extending to the Jerrys Plains district; probably introduced
	Glycine stenophita	eastern limit in the upper Hunter Valley, extending to the Muswellbrook district
	Neptunia gracilis f. *gracilis*	eastern and southern limit in the upper Hunter Valley, extending to the Singleton district
	Templetonia stenophylla	eastern limit in the mid Hunter Valley, extending to the Cessnock district
Malvaceae	*Sida trichopoda*	eastern limit in the upper Hunter Valley, extending to the Singleton district
Myrtaceae	*Melaleuca decora*	westerly limit in the upper Hunter Valley, extending to the Muswellbrook district from coastal populations
Oleaceae	*Notelaea microcarpa* var. *microcarpa*	eastern and southern limit in the upper Hunter Valley, extending to the Broke district
Orchidaceae	*Diuris tricolor*	threatened species; eastern limit in the central Hunter Valley, extending to the Branxton district
	Prasophyllum petilum	threatened species; disjunct population in the upper Hunter Valley in the Muswellbrook district
Poaceae	*Bothriochloa biloba*	eastern limit in the upper Hunter Valley, extending to the Singleton district
	Digitaria coenicola	eastern limit in the upper Hunter Valley, extending to the Singleton district
	Enteropogon acicularis	eastern limit in the upper Hunter Valley, extending to the Singleton district; possibly extinct on Cumberland Plain, and may have been introduced there
	Eragrostis lacunaria	eastern limit in the upper Hunter Valley, extending to the Muswellbrook district
	Eulalia aurea	eastern limit in the upper Hunter Valley, extending to the Singleton district
	Panicum queenslandicum var. *queenslandicum*	eastern limit in the central Hunter Valley, extending to the Branxton district

Appendix 3 Community profiles, Mangoola

The derivation of diagnostic species included in each community profile have been defined using the SIMPER routine in *Primer*. SIMPER analysis calculates the relative contributions of each species to the Bray-Curtis similarity within each of the defined vegetation communities. Only those species contributing to a total cumulative contribution of 90% of the average similarity (i.e. the value shown at the top of each table) for each community are listed. These species can be described of as *typical* of that community, and have a consistently large presence within the data as reflected in the ratio of their contribution to the standard deviation (the Sim/SD field in each table) across the within-group similarities (the average similarity). Community groups with less than two samples (e.g. *Calocephalus/ Bothriochloa decipiens* Herbland, *Juncus acutus* Rushland) cannot be analysed in this way. Instead, the full species list from the single plot in each community is shown, in alphabetic order.

In the *Key Diagnostic Species* tables in each profile:

- Average similarity — is the within-group similarity for all pairs of sample plots comprising the community. Higher average similarity indicates a better defined community.
- Av.Abund — is the average cover abundance of that species within sample plots comprising the community
- Av.Sim — is the average similarity (contribution) made by each species to the within-group similarity (the overall average similarity).
- Sim/SD — is the ratio of average similarity to standard deviation for each species across all pairs of samples. A high ratio represents a good discriminating species. At least three samples are required for this ratio to be calculated.
- Contrib % — is the percentage contribution of each species to the overall average similarity for the community.
- Cum. % — is the cumulative percentage contribution of all species, up to 90% of the total.

Dichanthium/ Sporobolus/ Chloris Grassland — Unit 1a

General Description:

Grasslands dominated by Queensland Blue-grass (*Dichanthium sericeum*), Rat-tail Grass (*Sporobolus creber*) and Windmill Grass (*Chloris truncata*) are reasonably common across the study area, most frequently within a Grey Box (*Eucalyptus moluccana*)/ Dawsons Box (*Eucalyptus dawsonii*) landscape. Other grass species can be locally important, such as Wallaby Grass (*Rytidosperma tenuius*). Of the top 90% of species comprising this community, 63% (24 of 38) taxa are native.

Characteristic Features:

- Low grassland co-dominated by Queensland blue-grass, Rat-tail Grass, Windmill Grass and (in some areas) Wallaby Grass
- Occurs within a Grey Box-Dawsons Box landscape

Relationship to Other Communities:

The combination of *Dichanthium sericeum, Sporobolus creber* and *Chloris truncata* is not found in other defined communities, although each species does occur in other communities.

Community Conservation Status:

EPBC Act (1999) Status	has affinities to *White Box – Yellow Box – Blakely's Redgum Grassy Woodlands and Derived Grasslands* TEC.
BC Act (2016) Status	has affinities to *Native Vegetation on Cracking Clay Soils of the Liverpool Plains* TEC.

Significant Species:

• Threatened (EPBC Act)	*Diuris tricolor, Prasophyllum petilum*
• Threatened (BC Act)	*Diuris tricolor*
• Rare	*Bothriochloa biloba*

Species Richness:

Number of plots:	63
Total species:	199
Mean species / plot (+/- SD):	39.51 (+/- 5.47)

Key Diagnostic Species [based on 63 plots]:

Group 1a: Dichanthium/ Sporobolus/ Chloris **Average similarity: 45.72**					
Species	**Av.Abund**	**Av.Sim**	**Sim/SD**	**Contrib%**	**Cum.%**
Linum trigynum	2.56	3.23	3.25	7.06	7.06
Dichanthium sericeum subsp. sericeum	2.92	2.68	1.09	5.87	12.92
Senecio madagascariensis *	1.89	2.58	3.58	5.64	18.56
Sporobulus creber	2.02	2.22	1.79	4.87	23.42
Lysimachia arvensis *	1.75	2.13	1.86	4.66	28.09
Chrysocephalum semipapposum	1.71	1.92	1.48	4.20	32.29
Centaurium tenuiflorum *	1.67	1.88	1.40	4.10	36.39
Bothriochloa decipiens var. decipiens	2.02	1.82	1.06	3.98	40.37
Glycine tabacina	1.56	1.78	1.47	3.90	44.27
Chloris truncata	1.79	1.41	0.93	3.09	47.36
Gamochaeta americana *	1.38	1.38	1.04	3.02	50.39
Cyclospermum leptophyllum *	1.35	1.22	1.19	2.67	53.05
Fimbristylis dichotoma	1.30	1.21	0.88	2.66	55.71
Aristida ramosa var. ramosa	1.52	1.21	0.89	2.64	58.35
Vittadinia muelleri	1.41	1.20	0.84	2.63	60.99
Cheilanthes sieberi subsp. sieberi	1.27	1.12	0.86	2.44	63.43
Dichelachne micrantha	1.59	1.09	0.76	2.38	65.80
Vulpia muralis *	1.38	1.05	0.77	2.30	68.10
Hypochaeris radicata *	1.21	0.90	0.73	1.97	70.08
Trifolium arvense *	0.97	0.83	0.93	1.81	71.88
Petrorhagia dubia *	1.08	0.81	0.73	1.78	73.66
Asperula conferta	1.06	0.78	0.68	1.70	75.36
Plantago debilis	1.03	0.77	0.67	1.69	77.05
Hypochaeris albiflora *	1.00	0.74	0.62	1.61	78.66
Dichondra repens	0.94	0.61	0.64	1.33	80.00
Oxalis perenans	0.94	0.61	0.61	1.33	81.33
Carthamnus lanatus *	0.81	0.39	0.50	0.86	82.19
Briza minor *	0.76	0.38	0.46	0.84	83.02
Eulalia aurea	0.92	0.37	0.36	0.81	83.83
Wahlenbergia communis	0.62	0.35	0.54	0.77	84.61
Convolvulus erubescens	0.62	0.35	0.49	0.76	85.36
Cymbopogon refractus	0.63	0.31	0.46	0.68	86.04
Daucus glochidiatus	0.65	0.31	0.40	0.67	86.71
Sida corrugata	0.65	0.31	0.39	0.67	87.38
Rytidosperma tenuius	0.65	0.30	0.36	0.65	88.03
Polycarpon tetraphyllum *	0.62	0.28	0.39	0.62	88.65
Triptilodiscus pygmaeus	0.62	0.28	0.33	0.62	89.27
Calocephalus citreus	0.78	0.27	0.33	0.58	89.85
Brunoniella australis	0.57	0.23	0.31	0.51	90.36

Calocephalus/ Eulalia Herbland Unit 1b

General Description:

Considered a component of the *Dichanthium/ Sporobolus/ Chloris* Grassland (Unit 1a), *Calocephalus/ Eulalia* Herbland is present in a few locations in areas with shallow, gravelly soils. Lemon Beauty-heads (*Calocephalus citreus*) and Silky Brown-top Grass (*Eulalia aurea*) characterise this community. Of all species comprising this community, 78% (28 of 36) taxa are native.

Characteristic Features:

- Low herbland dominated by Lemon Beauty-heads and Silky Brown-top grass
- Within a Grey Box/ Dawsons Box landscape

Relationship to Other Communities:

The dominance of *Calocephalus citreus* and *Eulalia aurea* distinguish this community from all others defined, although both species are present in several other communities at low abundance. A similar Herbland, dominated by *Calocephalus citreus* and *Bothriochloa decipiens*, occurs within *Eucalyptus crebra* landscapes elsewhere on the Mangoola property.

Community Conservation Status:

EPBC Act (1999) Status	not currently listed.
BC Act (2016) Status	not currently listed.

Significant Species:

• Threatened (EPBC Act)	none recorded
• Threatened (BC Act)	none recorded
• Rare	none recorded

Species Richness:

Number of plots:	1
Total species:	28
Mean species / plot (+/- SD):	28 (+/- n/a)

Key Diagnostic Species [based on 1 plot]:

Group 1b: Calocephalus/ Eulalia **Less than 2 samples in group**					
Species	**Av.Abund**	**Av.Sim**	**Sim/SD**	**Contrib%**	**Cum.%**
Acacia homalophylla	-	-	-	-	-
Allocasuarina luehmannii	-	-	-	-	-
Lysimachia arvensis *	-	-	-	-	-
Aristida vagans	-	-	-	-	-
Atriplex semibaccata	-	-	-	-	-
Bothriochloa decipiens var. decipiens	-	-	-	-	-
Calocephalus citreus	-	-	-	-	-
Cassinia arcuata	-	-	-	-	-
Centaurium tenuiflorum *	-	-	-	-	-
Cheilanthes sieberi subsp. sieberi	-	-	-	-	-
Chrysocephalum semipapposum	-	-	-	-	-
Convolvulus erubescens	-	-	-	-	-
Daucus glochidiatus	-	-	-	-	-
Dichanthium sericeum subsp. sericeum	-	-	-	-	-
Enteropogon acicularis	-	-	-	-	-
Eragrostis brownii	-	-	-	-	-
Eulalia aurea	-	-	-	-	-
Fimbristylis dichotoma	-	-	-	-	-
Gamochaeta americana *	-	-	-	-	-
Glossocardia bidens	-	-	-	-	-
Glycine tabacina	-	-	-	-	-
Hypochaeris radicata *	-	-	-	-	-
Linum marginale	-	-	-	-	-
Linum trigynum *	-	-	-	-	-
Minuria leptophylla	-	-	-	-	-
Phyllanthus virgatus	-	-	-	-	-
Plantago lanceolata *	-	-	-	-	-
Rytidosperma caespitosum	-	-	-	-	-
Rytidosperma setaceum	-	-	-	-	-
Senecio madagascariensis *	-	-	-	-	-
Sisyrinchium rosulatum *	-	-	-	-	-
Sporobolus creber	-	-	-	-	-
Stackhousia muricata	-	-	-	-	-
Vittadinia cuneata var. cuneata	-	-	-	-	-
Vittadinia muelleri	-	-	-	-	-
Wahlenbergia communis	-	-	-	-	-

Aristida/ Cymbopogon Grassland **Unit 2**

General Description:

Widespread across the study area, and characterised by the dominance of Wire-grasses (*Aristida ramosa, Aristida vagans*) and Barb-wire Grass (*Cymbopogon refractus*). In general, lands supporting this grassland type have been lightly to moderately grazed, and typically result from the clearing of woodlands dominated by Narrow-leaved Ironbark (*Eucalyptus crebra*). Of the top 90% of species comprising this community, 69% (25 of 36) taxa are native.

Characteristic Features:

- Medium-height grassland dominated by Wire-grasses and Barb-wire grass
- Within a Narrow-leaved Ironbark-Bulloak landscape

Relationship to Other Communities:

The dominance of *Aristida vagans* and/ or *Aristida ramosa* distinguishes this community from all others defined.

Community Conservation Status:

EPBC Act (1999) Status	not currently listed.
BC Act (2016) Status	not currently listed.

Significant Species:

• Threatened (EPBC Act)	*Diuris tricolor, Prasophyllum petilum*
• Threatened (BC Act)	*Diuris tricolor*
• Rare	none recorded

Species Richness:

Number of plots:	44
Total species:	186
Mean species / plot (+/- SD):	33.57 (+/- 5.16)

Key Diagnostic Species [based on 44 plots]:

Group 2: Aristida/ Cymbopogon **Average similarity: 39.82**					
Species	**Av.Abund**	**Av.Sim**	**Sim/SD**	**Contrib%**	**Cum.%**
Aristida ramosa var. ramosa	3.43	4.60	2.17	11.55	11.55
Linum trigynum *	2.18	3.01	2.04	7.56	19.11
Cheilanthes sieberi subsp. sieberi	2.07	2.84	2.01	7.14	26.25
Lysimachia arvensis *	1.70	2.42	1.73	6.09	32.34
Senecio madagascariensis *	1.66	2.32	1.65	5.84	38.18
Aristida vagans	1.95	1.83	0.90	4.60	42.78
Hypochaeris radicata *	1.75	1.77	1.00	4.44	47.22
Cymbopogon refractus	1.48	1.73	1.19	4.35	51.58
Glycine tabacina	1.14	1.32	1.25	3.32	54.90
Bothriochloa decipiens var. decipiens	1.43	1.23	0.69	3.08	57.98
Vulpia muralis *	1.27	1.20	0.97	3.02	61.00
Sporobulus creber	1.14	0.99	0.68	2.48	63.48
Briza minor *	1.07	0.96	0.79	2.41	65.89
Chrysocephalum apiculatum	1.02	0.81	0.54	2.03	67.92
Triptilodiscus pygmaeus	0.84	0.58	0.50	1.47	69.39
Vittadinia muelleri	0.93	0.58	0.44	1.45	70.83
Dichondra repens	0.77	0.54	0.53	1.35	72.18
Gamochaeta americana *	0.80	0.53	0.52	1.34	73.52
Dichelachne micrantha	0.82	0.52	0.49	1.31	74.83
Taraxacum officionale *	0.80	0.50	0.43	1.26	76.08
Lomandra confertifolia subsp. pallida	0.75	0.48	0.53	1.21	77.30
Tolpis barbata *	0.77	0.46	0.44	1.16	78.46
Lachnagrostis filiformis	0.75	0.44	0.39	1.10	79.56
Centaurium tenuiflorum *	0.70	0.41	0.41	1.03	80.59
Oxalis perenans	0.68	0.39	0.41	0.97	81.56
Richardia stellaris *	0.66	0.38	0.41	0.94	82.51
Chrysocephalum semipapposum	0.77	0.37	0.38	0.94	83.44
Fimbristylis dichotoma	0.68	0.37	0.37	0.93	84.38
Cyclospermum leptophyllum *	0.66	0.36	0.44	0.90	85.27
Petrorhagia dubia *	0.68	0.35	0.37	0.88	86.15
Asperula conferta	0.59	0.31	0.35	0.77	86.93
Sida corrugata	0.57	0.30	0.39	0.75	87.67
Linaria pelisseriana *	0.57	0.25	0.33	0.64	88.31
Glycine clandestina	0.41	0.23	0.41	0.58	88.89
Murdannia graminea	0.50	0.21	0.31	0.53	89.42
Centaurium erythraea *	0.50	0.20	0.25	0.50	89.92

Calocephalus/ Bothriochloa decipiens Herbland Unit 3

General Description:

Considered a component of the *Aristida/ Cymbopogon* Grassland (Unit 2a), *Calocephalus/ Bothriochloa decipiens* Herbland generally occurs on slight rises with shallow, gravelly soils. These area appear to coincide with old stock camps under or adjacent to remnant trees where cattle have taken rest. Lemon Beauty-heads (*Calocephalus citreus*) and Red-leg Grass (*Borthriochloa decipiens*) characterise this community. Of the top 90% of species comprising this community, 77% (24 of 31) taxa are native.

Characteristic Features:

- Low herbland dominated by Lemon Beauty-heads and Red-leg grass
- Within a Narrow-leaved Ironbark-Bulloak landscape

Relationship to Other Communities:

The dominance of *Calocephalus citreus* and *Bothriochloa decipiens* distinguish this community from all others defined. A similar Herbland, dominated by *Calocephalus citreus* and *Eulalia aurea*, occurs elsewhere on the Mangoola property.

Community Conservation Status:

EPBC Act (1999) Status	not currently listed.
BC Act (2016) Status	not currently listed.

Significant Species:

• Threatened (EPBC Act)	none recorded
• Threatened (BC Act)	none recorded
• Rare	none recorded

Species Richness:

Number of plots:	1
Total species:	25
Mean species / plot (+/- SD):	25 (+/- n/a)

Key Diagnostic Species [based on 1 plot]:

Group 3: Calocephalus/Bothriochloa decipiens **Less than 2 samples in group**					
Species	**Av.Abund**	**Av.Sim**	**Sim/SD**	**Contrib%**	**Cum.%**
Aristida ramosa	-	-	-	-	-
Asperula conferta	-	-	-	-	-
Bothriochloa decipiens var. decipiens	-	-	-	-	-
Brachyscome curvicarpa	-	-	-	-	-
Calocephalus citreus	-	-	-	-	-
Calotis lappulacea	-	-	-	-	-
Centaurium tenuiflorum *	-	-	-	-	-
Cheilanthes sieberi subsp. sieberi	-	-	-	-	-
Chloris truncata	-	-	-	-	-
Cirsium vulgare *	-	-	-	-	-
Convolvulus erubescens	-	-	-	-	-
Conyza bonariensis *	-	-	-	-	-
Cyclospermum leptophyllum *	-	-	-	-	-
Cymbopogon refractus	-	-	-	-	-
Dichelachne micrantha	-	-	-	-	-
Enchylaena tomentosa	-	-	-	-	-
Glycine stenophita	-	-	-	-	-
Glycine tabacina	-	-	-	-	-
Goodenia pinnatifida	-	-	-	-	-
Lagenophora stipitata	-	-	-	-	-
Linum trigynum *	-	-	-	-	-
Ptilotus semilanatus	-	-	-	-	-
Rytidosperma tenuius	-	-	-	-	-
Senecio madagascariensis *	-	-	-	-	-
Sida corrugata	-	-	-	-	-
Sida filiformis	-	-	-	-	-
Sporobolus creber	-	-	-	-	-
Tripogon loliiformis	-	-	-	-	-
Vittadinia cuneata var. cuneata	-	-	-	-	-
Vittadinia muelleri	-	-	-	-	-
Wahlenbergia gracilis	-	-	-	-	-

Bothriochloa biloba/ Carthamnus/ Rytidosperma Grassland Unit 4

General Description:

Grasslands dominated or co-dominated by Lobed Blue-grass (*Bothriochloa biloba*) are present in several areas across the study area. In some locations, this species clearly dominates the grass layer, while in others it occurs equally with Wallaby Grass (*Rytidosperma tenuius*), Windmill Grass (*Chloris truncata*) or in more heavily grazed areas *Urochloa panicoides*. Of the top 90% of species comprising this community, 69% (9 of 13) taxa are native.

Characteristic Features:

- Medium-height grassland dominated by Lobed Blue-grass, Safron Thistle and Wallaby Grass
- Often comprised of monospecific stands of Lobed Blue-grass

Relationship to Other Communities:

Although present occasionally in other communities, the dominance or co-dominance of *Bothriochloa biloba* distinguishes this community from most others. *Bothriochloa biloba/ Verbena/ Dichanthium* Grassland (Unit 4) shares the characteristic *Bothriochloa biloba*, but that community also supports *Dichanthium sericeum* and *Verbena bonariensis* is much higher abundance.

Community Conservation Status:

EPBC Act (1999) Status	has affinities to *White Box – Yellow Box – Blakely's Redgum Grassy Woodlands and Derived Grasslands* TEC.
BC Act (2016) Status	not currently listed.

Significant Species:

• Threatened (EPBC Act)	none recorded
• Threatened (BC Act)	none recorded
• Rare	*Bothriochloa biloba*

Species Richness:

Number of plots:	7
Total species:	55
Mean species / plot (+/- SD):	19.57 (+/- 5.99)

Key Diagnostic Species [based on 7 plots]:

Group 4: Bothriochloa biloba/ Carthamnus/ Rytidosperma **Average similarity: 50.03**					
Species	**Av.Abund**	**Av.Sim**	**Sim/SD**	**Contrib%**	**Cum.%**
Bothriochloa biloba	5.14	13.03	5.61	26.04	26.04
Carthamnus lanatus *	2.57	6.41	2.45	12.82	38.86
Chloris truncata	1.86	4.86	4.58	9.72	48.57
Rytidosperma tenuius	2.14	4.54	1.32	9.08	57.65
Einadia nutans subsp. linifolia	1.71	4.16	3.83	8.31	65.97
Lolium perenne *	1.57	3.31	1.35	6.61	72.58
Austrostipa aristiglumis	1.57	2.20	0.74	4.40	76.97
Vittadinia cuneata var. cuneata	0.86	1.55	0.90	3.11	80.08
Oxalis perenans	1.14	1.34	0.62	2.68	82.76
Senecio madagascariensis *	0.86	1.22	0.92	2.43	85.19
Sporobulus creber	1.00	1.07	0.59	2.13	87.32
Medicago truncatula *	0.86	0.95	0.60	1.90	89.22
Carex inversa	0.86	0.92	0.58	1.84	91.05

Bothriochloa biloba/ Verbena/ Dichanthium Grassland Unit 5

General Description:

Grasslands dominated by Lobed Blue-grass (*Bothriochloa biloba*) are easily recognisable, and co-occur with Purple Top (*Verbena bonariensis*) and Queensland Blue Grass (*Dichanthium sericeum*). The best stand has been bisected by an access road and occurs on rich brown soils. The herbs Common Woodruff (*Asperula conferta*), Creeping Mint (*Mentha satureioides*) and *Oxalis perenans* are characteristic, and occur with a number of weed species. Of the top 90% of species comprising this community, 52% (14 of 27) taxa are native.

Characteristic Features:

- Medium-height grassland dominated by Lobed Blue-grass and Purple Top
- Characterised by nearly monospecific stands of Lobed Blue-grass
- Occurs on rich brown soils

Relationship to Other Communities:

Although present occasionally in other communities, the dominance of *Bothriochloa biloba* in combination with *Verbena bonariensis, Dichanthium sericeum, Asperula conferta* and *Mentha satureioides* distinguishes this community from all others.

Community Conservation Status:

EPBC Act (1999) Status	has affinities to *White Box – Yellow Box – Blakely's Redgum Grassy Woodlands and Derived Grasslands* TEC.
BC Act (2016) Status	not currently listed.

Significant Species:

• Threatened (EPBC Act)	none recorded
• Threatened (BC Act)	none recorded
• Rare	*Bothriochloa biloba*

Species Richness:

Number of plots:	9
Total species:	93
Mean species / plot (+/- SD):	31.78 (+/- 8.74)

Key Diagnostic Species [based on 9 plots]:

Group 5: Bothriochloa biloba/ Verbena/ Dichanthium **Average similarity: 44.60**					
Species	**Av.Abund**	**Av.Sim**	**Sim/SD**	**Contrib%**	**Cum.%**
Bothriochloa biloba	3.78	5.13	0.79	11.51	11.51
Linum trigynum *	1.89	3.08	3.62	6.90	18.41
Oxalis perenans	1.67	2.78	1.60	6.24	24.65
Dichanthium sericeum subsp. sericeum	2.33	2.42	0.99	5.44	30.08
Asperula conferta	1.78	2.33	1.12	5.22	35.30
Mentha satureioides	1.56	2.32	1.47	5.19	40.50
Verbena bonariensis *	2.11	2.31	1.50	5.18	45.68
Sonchus oleaceus *	1.44	2.19	1.37	4.92	50.60
Cirsium vulgare *	1.56	2.15	1.49	4.83	55.43
Hypochaeris radicata *	1.33	1.54	1.05	3.45	58.88
Lysimachia arvensis *	1.33	1.53	1.10	3.43	62.31
Dichelachne micrantha	1.78	1.34	0.75	3.01	65.32
Stachys arvensis *	1.11	1.31	1.00	2.95	68.27
Senecio quadridentatus	1.11	1.27	1.10	2.86	71.12
Plantago debilis	1.11	1.03	0.80	2.32	73.44
Senecio madagascariensis *	1.00	0.88	0.55	1.96	75.41
Cymbonotus lawsonianus	0.89	0.84	0.79	1.88	77.29
Plantago lanceolata *	0.78	0.78	0.81	1.74	79.03
Centella asiatica	0.89	0.76	0.81	1.69	80.72
Convolvulus erubescens	0.67	0.72	0.82	1.63	82.35
Hypochaeris albiflora *	0.89	0.58	0.55	1.31	83.66
Carthamnus lanatus *	0.67	0.55	0.60	1.24	84.90
Centaurium tenuiflorum *	0.67	0.54	0.60	1.20	86.10
Paspalum dilatatum *	0.78	0.53	0.59	1.19	87.29
Einadia nutans subsp. linifolia	0.67	0.53	0.41	1.18	88.47
Geranium solanderi var. solanderi	0.67	0.52	0.42	1.17	89.64
Wahlenbergia communis	0.56	0.44	0.61	0.99	90.64

Rytidosperma / Chloris/ Sporobolus/ Dichanthium Grassland — Unit 6

General Description:

Localised areas in the east of the study area support grasslands where the dominant species include Wallaby Grass (*Rytidosperma tenuius*), Windmill Grass (*Chloris truncata*), Rat-tail Grass (*Sporobolus creber*) and Queensland Blue Grass (*Dichanthium sericeum*). These areas are most prevalent along the edges of major floodplains and drainage areas, above areas supporting *Austrostipa aristiglumis* Grassland (Unit 7). Of the top 90% of species comprising this community, 58% (11 of 19) taxa are native.

Characteristic Features:

- Low grassland dominated by Wallaby Grass, Windmill Grass, Rat-tail Grass and Queensland Blue Grass
- Occurs in areas above floodplains and drainage areas

Relationship to Other Communities:

Related to several other grassland types, particularly *Dichanthium/ Sporobolus/ Chloris* Grassland (Unit 1a), but differs in the combination of the four dominant grasses, which together comprise over 40% of the overall diversity in this community.

Community Conservation Status:

EPBC Act (1999) Status	has affinities to *White Box – Yellow Box – Blakely's Redgum Grassy Woodlands and Derived Grasslands* TEC.
BC Act (2016) Status	not currently listed.

Significant Species:

• Threatened (EPBC Act)	none recorded
• Threatened (BC Act)	none recorded
• Rare	*Bothriochloa biloba* may be present as scattered individuals

Species Richness:

Number of plots:	5
Total species:	70
Mean species / plot (+/- SD):	29.60 (+/- 5.59)

Key Diagnostic Species [based on 5 plots]:

Group 6: Rytidosperma /Chloris/Sporobolus/Dichanthium **Average similarity: 49.88**					
Species	**Av.Abund**	**Av.Sim**	**Sim/SD**	**Contrib%**	**Cum.%**
Chloris truncata	4.40	7.13	2.71	14.29	14.29
Dichanthium sericeum subsp. sericeum	3.00	4.95	10.21	9.92	24.20
Sporobulus creber	3.00	4.95	10.21	9.92	34.12
Rytidosperma tenuius	2.80	3.35	1.13	6.71	40.83
Einadia nutans subsp. linifolia	1.80	3.14	2.70	6.29	47.12
Senecio madagascariensis *	1.80	3.14	2.70	6.29	53.41
Hypochaeris albiflora *	1.80	3.00	4.41	6.02	59.42
Vittadinia muelleri	2.00	3.00	4.41	6.02	65.44
Carthamnus lanatus *	1.60	2.47	3.31	4.95	70.39
Oxalis perenans	1.60	2.11	1.16	4.23	74.62
Euphorbia drummondii	1.20	1.22	1.06	2.45	77.07
Petrorhagia nanteuilii *	1.20	1.22	1.06	2.45	79.52
Linum trigynum *	1.20	1.05	0.62	2.10	81.62
Medicago truncatula *	1.00	0.82	0.55	1.65	83.27
Trifolium arvense *	1.00	0.76	0.60	1.53	84.80
Chrysocephalum apiculatum	1.00	0.73	0.57	1.47	86.27
Asperula conferta	1.00	0.69	0.58	1.39	87.66
Bothriochloa biloba	1.00	0.69	0.58	1.39	89.04
Spergularia rubra *	0.80	0.63	0.62	1.26	90.30

Chloris/ Carthamnus Grassland Unit 7

General Description:

On moderately to heavily grazed lands, grasslands dominated by Windmill Grass (*Chloris truncata*) occur, generally with a compliment of exotic herbs and grasses. Safron Thistle (*Carthamnus lanatus*) in particular is common in this community, and these two species combined contribute over 50% of the floristic diversity present. Of the top 90% of species comprising this community, 18% (2 of 11) taxa are native.

Characteristic Features:

- Low grassland dominated by Windmill Grass and Saffron Thistle

Relationship to Other Communities:

The dominance of *Chloris truncata* in this community is not repeated in any other defined community.

Community Conservation Status:

EPBC Act (1999) Status	has affinities to *White Box – Yellow Box – Blakely's Redgum Grassy Woodlands and Derived Grasslands* TEC.
BC Act (2016) Status	not currently listed.

Significant Species:

• Threatened (EPBC Act)	none recorded
• Threatened (BC Act)	none recorded
• Rare	none recorded

Species Richness:

Number of plots:	4
Total species:	37
Mean species / plot (+/- SD):	17.25 (+/- 3.69)

Key Diagnostic Species [based on 4 plots]:

Group 7: Chloris/ Carthamnus **Average similarity: 46.92**					
Species	**Av.Abund**	**Av.Sim**	**Sim/SD**	**Contrib%**	**Cum.%**
Chloris truncata	5.75	18.69	6.29	39.84	39.84
Carthamnus lanatus *	2.00	5.06	2.76	10.78	50.62
Einadia nutans subsp. linifolia	1.75	3.88	3.80	8.28	58.90
Sonchus oleaceus *	1.25	2.23	0.85	4.76	63.66
Bromus bevis *	1.25	2.13	0.79	4.55	68.21
Malva parviflora *	1.25	2.13	0.79	4.55	72.75
Cirsium vulgare *	0.75	1.84	0.91	3.91	76.67
Cyclospermum leptophyllum *	1.00	1.72	0.90	3.67	80.34
Lepidium bonariense *	0.75	1.72	0.90	3.67	84.01
Senecio madagascariensis *	1.00	1.72	0.90	3.67	87.68
Hordeum leporinum *	1.00	1.13	0.41	2.41	90.08

Austrostipa aristiglumis Grassland — Unit 8

General Description:

Tall grasslands dominated by often monospecific stands of Plains grass (*Austrostipa aristiglumis*) occur in low-lying depressions and plains. Although present in areas subjected to moderate to high grazing levels, these grasslands do not appear to be a favourable fodder for cattle when well established, and evidence elsewhere suggests that current-day monospecific stands of Plains grass may be a consequence of heavy grazing (Lang 2008). Of the top 90% of species comprising this community, 54% (7 of 13) taxa are native.

Characteristic Features:

- Tall grassland dominated by Plains grass
- Occurs in broad plains on level to gently undulating ground around drainage lines.

Relationship to Other Communities:

The dominance of *Austrostipa aristiglumis* distinguish this community from all others defined.

Community Conservation Status:

EPBC Act (1999) Status	not currently listed.
BC Act (2016) Status	has affinities to *Native Vegetation on Cracking Clay Soils of the Liverpool Plains* TEC.

Significant Species:

• Threatened (EPBC Act)	none recorded
• Threatened (BC Act)	none recorded
• Rare	none recorded

Species Richness:

Number of plots:	3
Total species:	31
Mean species / plot (+/- SD):	17.67 (+/- 4.04)

Key Diagnostic Species [based on 3 plots]:

Group 8: Austrostipa aristiglumis **Average similarity: 52.75**					
Species	**Av.Abund**	**Av.Sim**	**Sim/SD**	**Contrib%**	**Cum.%**
Austrostipa aristiglumis	6.00	19.46	11.36	36.88	36.88
Einadia nutans subsp. linifolia	1.67	4.41	1.95	8.36	45.25
Geranium solanderi var. solanderi	1.67	4.34	2.23	8.22	53.47
Atriplex semibaccata	1.67	4.22	2.93	8.01	61.47
Rytidosperma tenuius	2.00	2.94	0.58	5.58	67.05
Plantago lanceolata *	1.33	2.19	0.58	4.14	71.19
Chloris truncata	1.33	1.96	0.58	3.72	74.91
Conyza bonariensis *	1.33	1.96	0.58	3.72	78.63
Oxalis perenans	1.33	1.96	0.58	3.72	82.34
Malva parviflora *	0.67	1.17	0.58	2.22	84.56
Rapistrum rugosum *	1.00	1.17	0.58	2.22	86.78
Sonchus oleaceus *	1.00	1.09	0.58	2.07	88.85
Cirsium vulgare *	0.67	0.98	0.58	1.86	90.71

Lolium/ Sisymbrium/ Avena Grassland Unit 9

General Description:

Lolium/ Sisymbrium/ Avena Grassland is common on heavily grazed or cultivated lands in the east of the study area, particularly on alluvial soils. It is dominated by Stiff Rye-grass (*Lolium loliaceum*), Wild Oats (*Avena sativa*), Hedge Mustard (*Sisymbrium officionale*), and Lucerne (*Medicago sativa*). Very few native species are present within this community. Some areas support denser stands of Hedge Mustard effectively constituting a shrub layer. Of the top 90% of species comprising this community, 25% (2 of 8) taxa are native.

Characteristic Features:

- Low to Medium-height grassland dominated by Stiff Rye-grass, Wild Oats, Hedge Mustard and Lucerne
- Generally in very heavily grazed or cultivated lands on alluvial soils

Relationship to Other Communities:

The dominance of weed species such as *Lolium loliaceum, Avena sativa*, *Sisymbrium officionale*, and *Medicago sativa* is not repeated in other communities.

Community Conservation Status:

EPBC Act (1999) Status	not currently listed.
BC Act (2016) Status	not currently listed.

Significant Species:

• Threatened (EPBC Act)	none recorded
• Threatened (BC Act)	none recorded
• Rare	none recorded

Species Richness:

Number of plots:	3
Total species:	21
Mean species / plot (+/- SD):	12.67 (+/- 3.06)

Key Diagnostic Species [based on 3 plots]:

Group 9: Lolium/ Sisymbrium/ Avena **Average similarity: 50.95**					
Species	**Av.Abund**	**Av.Sim**	**Sim/SD**	**Contrib%**	**Cum.%**
Lolium loliaceum *	3.33	10.74	2.50	21.08	21.08
Avena sativa *	3.33	8.13	16.51	15.95	37.03
Sisymbrium officinale *	2.33	8.13	16.51	15.95	52.98
Medicago sativa *	1.67	5.37	2.50	10.54	63.52
Oxalis perenans	1.33	4.06	16.51	7.98	71.50
Sonchus oleaceus *	1.33	4.06	16.51	7.98	79.48
Paspalidium distans	2.33	3.92	0.58	7.70	87.17
Bromus bevis *	2.00	2.61	0.58	5.13	92.30

Lolium/ Cynodon/ Bromus Grassland Unit 10

General Description:

Related to Unit 8 (*Lolium/ Sisymbrium/ Avena* Grassland) this community occurs in heavily used grazing lands adjacent to farm homesteads, probably where livestock were held for short periods of time. These areas have now been recolonised with mostly exotic grasses and herbs, where Perennial Ryegrass (*Lolium perenne*), *Cynodon incompletus*, and Soft Brome (*Bromus molliformis*) are characteristic. Of the top 90% of species comprising this community, 25% (8 of 32) taxa are native.

Characteristic Features:

- Low to Medium-height grassland dominated by Stiff Rye-grass, Couch Grass, and Brome
- Generally in very heavily grazed lands close to homesteads

Relationship to Other Communities:

The dominance of exotic grasses and weed species in this community is similar to that within Unit 8 (*Lolium/ Sisymbrium/ Avena* Grassland). However, the combination of *Lolium perenne, Cynodon incompletus* and *Bromus* spp. is not repeated elsewhere.

Community Conservation Status:

EPBC Act (1999) Status	not currently listed.
BC Act (2016) Status	not currently listed.

Significant Species:

• Threatened (EPBC Act)	none recorded
• Threatened (BC Act)	none recorded
• Rare	none recorded

Species Richness:

Number of plots:	1
Total species:	21
Mean species / plot (+/- SD):	12.7 (+/- 3.06)

Key Diagnostic Species [based on 1 plot]:

Group 10: Lolium/ Cynodon/ Bromus **Less than 2 samples in group**					
Species	**Av.Abund**	**Av.Sim**	**Sim/SD**	**Contrib%**	**Cum.%**
Lysimachia arvensis *	-	-	-	-	-
Austrostipa ramosissima	-	-	-	-	-
Bromus catharticus *	-	-	-	-	-
Bromus molliformis *	-	-	-	-	-
Carthamus lanatus *	-	-	-	-	-
Conyza bonariensis *	-	-	-	-	-
Cyclospermum leptophyllum *	-	-	-	-	-
Cynodon incompletus *	-	-	-	-	-
Cyperus aggregates *	-	-	-	-	-
Einadia hastata	-	-	-	-	-
Eragrostis leptostachya	-	-	-	-	-
Eriochloa pseudoacrotricha	-	-	-	-	-
Facelis retusa *	-	-	-	-	-
Galenia pubescens *	-	-	-	-	-
Gamochaeta Americana *	-	-	-	-	-
Hypochaeris radicata *	-	-	-	-	-
Lamium amplexicaule *	-	-	-	-	-
Lepidium africanum *	-	-	-	-	-
Lolium perenne *	-	-	-	-	-
Modiola caroliniana *	-	-	-	-	-
Oxalis perennans	-	-	-	-	-
Plantago lanceolata *	-	-	-	-	-
Rostraria cristata *	-	-	-	-	-
Rumex brownii	-	-	-	-	-
Senecio madagascariensis *	-	-	-	-	-
Setaria parviflora *	-	-	-	-	-
Sida rhombifolia *	-	-	-	-	-
Sonchus oleraceus *	-	-	-	-	-
Sporobolus creber	-	-	-	-	-
Trifolium arvense *	-	-	-	-	-
Vulpia muralis *	-	-	-	-	-
Wahlenbergia gracilis	-	-	-	-	-

Cynodon/ Hordeum/ Lolium Grassland Unit 11

General Description:

Present on the more heavily grazed lands on gentle slopes, generally where pastures have been improved. Common in the vicinity of old stockyards and buildings, where *Cynodon incompletus* forms large monospecific grasslands and few native species occur. Of the top 90% of species comprising this community, 22% (2 of 9) taxa are native.

Characteristic Features:

- Low grassland dominated by Couch grass
- Often forms monospecific stands with few other species present

Relationship to Other Communities:

No other community supports *Cynodon incompletus* as the dominant ground cover.

Community Conservation Status:

EPBC Act (1999) Status	not currently listed.
BC Act (2016) Status	not currently listed.

Significant Species:

• Threatened (EPBC Act)	none recorded
• Threatened (BC Act)	none recorded
• Rare	none recorded

Species Richness:

Number of plots:	7
Total species:	33
Mean species / plot (+/- SD):	13.71 (+/- 3.45)

Key Diagnostic Species [based on 7 plots]:

Group 11: Cynodon/ Hordeum/ Lolium **Average similarity: 54.20**					
Species	**Av.Abund**	**Av.Sim**	**Sim/SD**	**Contrib%**	**Cum.%**
Cynodon incompletus *	4.71	14.84	2.80	27.38	27.38
Hordeum leporinum *	2.43	6.72	2.97	12.41	39.78
Einadia nutans subsp. linifolia	2.00	6.11	4.36	11.27	51.06
Atriplex semibaccata	2.71	5.06	1.18	9.33	60.39
Malva parviflora *	1.71	4.92	1.52	9.07	69.46
Lepidium bonariense *	1.29	3.24	1.17	5.98	75.44
Lolium perenne *	1.57	3.08	0.93	5.68	81.12
Bromus bevis *	1.43	2.57	0.89	4.75	85.87
Lolium loliaceum *	1.86	2.52	0.60	4.65	90.52

Cynodon/ Sida/ Calotis Grassland Unit 12

General Description:

Cynodon/ Sida/ Calotis Grassland is present typically along the edges of remnant stands of Narrow-leaved Ironbark (*Eucalyptus crebra*) forest and woodland, and appears to have established on previously bare areas after removal of cattle. This community is characterised by *Cynodon incompletus,* Golden Rod (*Sida hackettiana*) and Yellow Burr-daisy (*Calotis lappulacea*), often occurring within *Aristida/ Cymbopogon* Grassland (Unit 2a). Of the top 90% of species comprising this community, 79% (22 of 28) taxa are native.

Characteristic Features:

- Low grassland dominated by Couch grass, Calotis and Sida
- Often interspersed with bare areas not yet recolonised by vegetation

Relationship to Other Communities:

No other community supports *Cynodon incompletus, Sida hackettiana* and *Calotis lappulacea* as the dominant ground cover.

Community Conservation Status:

EPBC Act (1999) Status	not currently listed.
BC Act (2016) Status	not currently listed.

Significant Species:

• Threatened (EPBC Act)	none recorded
• Threatened (BC Act)	none recorded
• Rare	none recorded

Species Richness:

Number of plots:	10
Total species:	105
Mean species / plot (+/- SD):	33.30 (+/- 4.52)

Key Diagnostic Species [based on 10 plots]:

Group 12: Cynodon/ Sida/ Calotis **Average similarity: 42.33**					
Species	**Av.Abund**	**Av.Sim**	**Sim/SD**	**Contrib%**	**Cum.%**
Sida hackettiana	3.00	4.18	2.19	9.87	9.87
Calotis lappulacea	3.00	4.16	3.24	9.83	19.70
Cheilanthes sieberi subsp. sieberi	1.70	2.52	1.73	5.95	25.65
Senecio madagascariensis *	1.60	2.01	1.53	4.74	30.39
Cyperus gracilis	1.60	2.00	1.54	4.73	35.13
Wahlenbergia gracilis	1.30	1.61	1.61	3.80	38.92
Einadia nutans subsp. linifolia	1.40	1.59	0.92	3.77	42.69
Eragrostis leptostachya	1.30	1.50	1.09	3.55	46.25
Fimbristylis dichotoma	1.30	1.50	1.08	3.55	49.80
Einadia hastata	1.30	1.44	0.86	3.41	53.21
Aristida ramosa var. ramosa	1.30	1.43	0.86	3.37	56.58
Oxalis perenans	1.40	1.38	0.86	3.27	59.86
Sida corrugata	1.20	1.34	1.13	3.18	63.03
Phyllanthus virgatus	1.20	1.26	0.83	2.98	66.01
Euphorbia drummondii	1.20	1.26	0.85	2.97	68.97
Austrostipa verticillata	1.40	1.03	0.65	2.44	71.41
Glycine tabacina	1.10	0.97	0.66	2.29	73.70
Cynodon incompletus *	1.70	0.93	0.49	2.19	75.89
Lysimachia arvensis *	1.00	0.79	0.64	1.86	77.75
Paronychia brasiliana *	1.10	0.78	0.66	1.85	79.61
Boerhavia dominii	0.90	0.73	0.65	1.73	81.33
Bothriochloa decipiens var. decipiens	0.90	0.68	0.65	1.60	82.93
Austrostipa scabra var. falcata	1.10	0.55	0.38	1.30	84.23
Digitaria diffusa	0.90	0.50	0.39	1.17	85.41
Opuntia aurantiaca *	0.60	0.41	0.53	0.97	86.38
Trifolium arvense *	0.70	0.41	0.51	0.97	87.35
Zornia dyctiocarpa var. dyctiocarpa	0.70	0.35	0.37	0.83	88.18
Crassula sieberiana	0.70	0.33	0.37	0.78	88.96

Cynodon/ Digitaria/ Oenthera Grassland Unit 13

General Description:

Cynodon/ Digitaria/ Oenthera Grassland occurs at two locations in lands that have been heavily grazed and improved with exotic species. At one of these, relatively recent scouring of the ground surface has likely led to colonisation by Common Couch (*Cynodon dactylon*), Witchgrass (*Panicum capillare*) and Summer Grass (*Digitaria sanguinalis*). Of the top 90% of species comprising this community, 33% (2 of 6) taxa are native.

Characteristic Features:

- Low grassland dominated by Couch grass, Witchgrass and Crabgrass
- Can be interspersed with bare areas not yet recolonised by vegetation

Relationship to Other Communities:

Similar to other communities that support *Cynodon dactlyon,* but *Panicum capillare* and *Digitaria sanguinalis* are not present in those.

Community Conservation Status:

EPBC Act (1999) Status	not currently listed.
BC Act (2016) Status	not currently listed.

Significant Species:

• Threatened (EPBC Act)	none recorded
• Threatened (BC Act)	none recorded
• Rare	none recorded

Species Richness:

Number of plots:	2
Total species:	36
Mean species / plot (+/- SD):	21.50 (+/- 4.95)

Key Diagnostic Species [based on 2 plots]:

Group 13: Cynodon/ Digitaria/ Oenthera **Average similarity: 30.14**					
Species	**Av.Abund**	**Av.Sim**	**Sim/SD**	**Contrib%**	**Cum.%**
Cynodon dactylon	4.50	10.96	-	36.36	36.36
Conyza sp. *	2.50	5.48	-	18.18	54.55
Centaurium erythraea *	1.50	2.74	-	9.09	63.64
Cheilanthes sieberi subsp. sieberi	1.50	2.74	-	9.09	72.73
Hypochaeris radicata *	1.50	2.74	-	9.09	81.82
Petrorhagia dubia *	1.50	2.74	-	9.09	90.91

Lachnagrostis/ Cynodon Grassland Unit 14

General Description:

Grasslands occurring within drainage channels, culverts or associated with farm dams support *Lachnagrostis/ Cynodon* Grassland. *Lachnagrostis filiformis* in particular is characteristic in this community when at peak flowering, and when dominant this community is unlikely to be confused with any other. Of the top 90% of species comprising this community, 67% (4 of 6) taxa are native.

Characteristic Features:

- Low to medium-height grassland dominated by Blown Grass, with Couch Grass and some wetland species
- Occurs in moist areas of grassland, such as along drainage channels, culverts etc

Relationship to Other Communities:

No other community supports *Lachnagrostis filiformis* as the dominant ground cover.

Community Conservation Status:

EPBC Act (1999) Status	not currently listed.
BC Act (2016) Status	not currently listed.

Significant Species:

• Threatened (EPBC Act)	none recorded
• Threatened (BC Act)	none recorded
• Rare	none recorded

Species Richness:

Number of plots:	2
Total species:	31
Mean species / plot (+/- SD):	19.00 (+/- 4.24)

Key Diagnostic Species [based on 2 plots]:

Group 14: Lachnagrostis/ Cynodon **Average similarity: 40.54**					
Species	**Av.Abund**	**Av.Sim**	**Sim/SD**	**Contrib%**	**Cum.%**
Lachnagrostis filiformis	5.50	13.51	-	33.33	33.33
Carex inversa	2.00	5.41	-	13.33	46.67
Cynodon dactylon	2.00	5.41	-	13.33	60.00
Lythrum hyssopifolia	2.00	5.41	-	13.33	73.33
Paspalum dilatatum *	3.00	5.41	-	13.33	86.67
Briza minor *	1.00	2.70	-	6.67	93.33

Paspalum/ Verbena/ Rumex/ Cirsium Grassland — Unit 15

General Description:

Grasslands where Paspalum Grass (*Paspalum dilatatum*) dominates tend to occur in more heavily grazed lands where native pastures have been improved, and often along drainage lines. A range of other exotic species, including Purple Top (*Verbena bonariensis*), occur in varying densities. In shallow depressions, the structure of this community changes to a shrubland, where *Verbena bonariensis* forms dense thickets. Of the top 90% of species comprising this community, 33% (6 of 18) taxa are native.

Characteristic Features:

- Low to Medium-height grassland dominated by Paspalum (*Paspalum dilatatum*) and Purple Top (*Verbena bonariensis*)
- Generally on more heavily grazed lands with high weed presence

Relationship to Other Communities:

Although Paspalum is present in some other grasslands, the dominance of this species in this community is not replicated elsewhere. *Verbena bonariensis*, too, does not occur as dense stands in any other community in association with Paspalum.

Community Conservation Status:

EPBC Act (1999) Status	not currently listed.
BC Act (2016) Status	not currently listed.

Significant Species:

• Threatened (EPBC Act)	none recorded
• Threatened (BC Act)	none recorded
• Rare	none recorded

Species Richness:

Number of plots:	5
Total species:	60
Mean species / plot (+/- SD):	23.80 (+/- 4.09)

Key Diagnostic Species [based on 5 plots]:

Group 15: Paspalum/ Verbena/ Rumex/ Cirsium **Average similarity: 40.98**					
Species	**Av.Abund**	**Av.Sim**	**Sim/SD**	**Contrib%**	**Cum.%**
Paspalum dilatatum *	4.60	8.47	3.11	20.68	20.68
Plantago lanceolata *	2.60	4.99	6.70	12.17	32.85
Cirsium vulgare *	2.00	4.40	8.61	10.74	43.59
Verbena bonariensis *	3.00	3.79	2.46	9.25	52.83
Cyclospermum leptophyllum *	1.60	2.71	1.14	6.62	59.46
Trifolium repens *	1.40	2.42	3.27	5.90	65.36
Oxalis perenans	1.00	1.31	1.14	3.21	68.57
Hypochaeris radicata *	1.20	1.31	0.62	3.20	71.76
Carex inversa	1.40	1.23	0.62	3.00	74.76
Rumex crispus *	1.20	0.96	0.59	2.33	77.09
Juncus continuus	1.20	0.94	0.54	2.31	79.40
Bromus bevis *	1.20	0.83	0.56	2.03	81.43
Rumex brownii	1.00	0.80	0.56	1.94	83.37
Sonchus oleaceus *	1.00	0.78	0.58	1.89	85.27
Cynodon incompletus *	1.40	0.66	0.32	1.61	86.88
Geranium solanderi var. solanderi	0.80	0.61	0.62	1.50	88.37
Cynodon dactylon	0.80	0.45	0.32	1.11	89.48
Medicago polymorpha *	0.80	0.44	0.32	1.07	90.56

Juncus acutus Rushland — Unit 16

General Description:

A few locations within the study area support rushlands of the invasive Spiny Rush (*Juncus acutus*). These areas are the result of heavy disturbance along drainage lines and low-lying country, particularly where salinity is high. Worst infestations occur where former Fuzzy Box (*Eucalyptus conica*) woodlands once occurred. Minor infestations are also evident elsewhere. Of all species comprising this community, 29% (5 of 17) taxa are native.

Characteristic Features:

- Tall rushland dominated by Spiny Rush
- Occur in moist depressions and creeklines following past clearing

Relationship to Other Communities:

The dominance of *Juncus acutus* distinguish this community from all others defined.

Community Conservation Status:

EPBC Act (1999) Status	not currently listed.
BC Act (2016) Status	not currently listed.

Significant Species:

• Threatened (EPBC Act)	none recorded
• Threatened (BC Act)	none recorded
• Rare	none recorded

Species Richness:

Number of plots:	1
Total species:	17
Mean species / plot (+/- SD):	17 (+/- n/a)

Key Diagnostic Species [based on 1 plot]:

Group 16: Juncus acutus **Less than 2 samples in group**					
Species	**Av.Abund**	**Av.Sim**	**Sim/SD**	**Contrib%**	**Cum.%**
Aster subulatus *	-	-	-	-	-
Bromus catharticus *	-	-	-	-	-
Cicliospermum leptophyllum *	-	-	-	-	-
Cirsium vulgare *	-	-	-	-	-
Conyza spp *	-	-	-	-	-
Cotula coronopifolia *	-	-	-	-	-
Cynodon dactlyon	-	-	-	-	-
Einadia hastata	-	-	-	-	-
Galenia pubescens *	-	-	-	-	-
Juncus acutus ssp acutus *	-	-	-	-	-
Oxalis perennans	-	-	-	-	-
Polypogon monspeliensis *	-	-	-	-	-
Senecio madagascariensis *	-	-	-	-	-
Sonchus oleraceus *	-	-	-	-	-
Spergularia marina	-	-	-	-	-
Typha domingensis	-	-	-	-	-
Verbena bonariensis *	-	-	-	-	-