Natural Temperate Grassland

May 2003

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Acknowledgments

This project was funded by *Environment Australia*.

The authors would like to thank the following people who provided much assistance, information and advice during the course of this project: Patrick Armstrong, Tim Barlow, John Benson, Brett Beecham, Karl Bossard, Arthur Chapman, Vanessa Craigie, Bob Denholm, Shirley Diez, Josh Dorrough, Mark Dunford, Mike Dunn, David Eddy, Russell Fairfax, Felicity Faulkner, Rod Fensham, Fiona Ferwerda, Paul Foreman, Neil Gibson, Louise Gilfedder, Alison Goodland, Eric Greenwood, Lee Heard, Richard Hobbs, Colin Hocking, Ryan Incoll, Greg Keith, Anne Kitchener, Ian Lunt, Keith McDougall, Simon Nazaretian, Alison Oates, Damon Oliver, David Rankin, Rainer Rehwinkel, James Ross, Sarah Sharp, James Todd, Allen Trumble-Ward, Felicity Smith, Ben Turner, Rick Webster, Matt White, Nick Williams and Naomi Withers and numerous others.

Caveat

The views expressed in this report are those of the authors and do not necessarily reflect the opinions of the Commonwealth Government, the Threatened Species Scientific Committee or individuals and bodies that assisted with this project. This report or sections of this report do not constitute a nomination or nominations under the *Environment Protection and Biodiversity Conservation Act 1999*. The Commonwealth does not guarantee, and accepts no legal liability whatsoever arising from or connected to, the accuracy, reliability, currency or completeness of any material contained in this report.

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Preface

The *Environment Protection and Biodiversity Conservation Act 1999* (*EPBC* Act), is the Commonwealth Government's new national environmental legislation. The *EPBC* Act provides for the listing of nationally threatened species and ecological communities. The Threatened Species Scientific Committee advises the Minister for the Environment and Heritage on proposed amendments to the lists in accordance with the criteria, as stated in the *EPBC* Act Regulations and listing Guidelines.

Several nominations for threatened grassland communities in south-eastern Australia have been submitted to the Minister including Central Gippsland Plains Grassland, Western Basalt Plains Grassland, Northern Plains Grassland and the *Austrostipa aristiglumis* Grasslands of the Liverpool Plains NSW. The Threatened Species Scientific Committee wants to determine how many distinctive ecological communities comprise Natural Temperate Grasslands in south-eastern Australia, what defines their boundaries and which communities can be lumped together for the purposes of nomination under the *EPBC* Act and which should be nominated separately.

'Grasslands' is a broad term that could be taken to mean any and all vegetation communities dominated by members of the vascular plant family Poaceae – the grasses. In this case, this definition is qualified by consideration of the descriptors 'Natural' and 'Temperate'. A principal task of the work being undertaken at the Arthur Rylah Institute is to provide a practical and working definition of 'Natural Temperate Grassland' which takes account of the social and legislative context in which such a definition will be applied.

Many natural (or 'native') grassy vegetation communities, although formerly widespread in temperate Australia, have become depleted in their extent, and may be considered rare and threatened under some definitions (eg. McDougall & Kirkpatrick 1993). Elsewhere, their condition has greatly changed through altered grazing or burning régimes or weed invasion and establishment. The principal processes that have driven this depletion have been land clearance, principally for agriculture (including horticulture), but also clearance for urban development, invasion by non-indigenous plant species and inappropriate management.

Aims

A starting point for this report is the provision of an objective definition of Natural Temperate Grassland. The definition here offered is based on a set of rules extracted from the academic literature, and utilises opinions of various grassland experts. This definition provides a basis for recognising and delimiting a coherent grassland vegetation community – as evidenced by its consistent physiognomy and functional relationships. After all, the term 'Natural Temperate Grassland' is itself merely a label or, at best, an imperfect summary of the vegetation community. The individual components of the label, ie. 'natural', 'temperate' and 'grassland', are each imprecise and open to individual interpretation (eg. see McDougall 1992; Benson 1996; Angermeier 1999). If the term 'Natural Temperate Grassland' were an adequate definition *per se* then there would be little need for this whole project!

Following on from the definition, the report provides a key for the identification of Natural Temperate Grassland. The intention for the key is that a person with basic botanical/ecological knowledge can distinguish Natural Temperate Grassland from non-Natural Temperate Grassland whilst standing at a site, without maps, historical records or externally-sourced environmental data.

Natural Temperate Grasslands are grouped into geographic components using the Interim Biogeographic Regionalisation of Australia (IBRA) (Thackway & Cresswell 1995). Distinct components of the community Natural Temperate Grasslands can be defined within those IBRA Bioregions and the definitions and boundaries for these components are given in section 2, where data are adequate to enable definition (semantically or geographically). The status of each component is described in section 2, in terms of a brief environmental description, geographic distribution (pre-1750 and extant), floristic description, driving processes, threats, condition, viability and conservation status. Gaps for future study are also identified.

Taxonomy

Scientific nomenclature follows the most recently published state flora, ie. the *Flora of Victoria* series (Walsh & Entwisle 1994, 1996, 1999). English names are taken from other authoritative field guides or Floras.

1. Definition of 'Natural Temperate Grassland'

1.1. Criteria for identifying Natural Temperate Grassland

Natural Temperate Grassland is a broad vegetation type usually reduced to relatively small, fragmented remnants (<10 ha) on public land, with most large patches (>100 ha) occurring on private land. For the purposes of this report, the smallest measurable size of a patch of Natural Temperate Grassland is 0.5 ha. This size was based on a synthesis of expert opinion and is partially justified by the need to distinguish between grassland and woodland or shrubland. In most patches of woodland or grassy shrubland, it is possible to find small patches of grassy field layer, lacking an upper stratum of trees or shrubs. Hence this vegetation mapping unit could be described as a mosaic of grassland and woodland interspersed - a major problem in mapping, definition and management if the grassland and non-grassland communities are managed or considered separately. A minimum patch size must be chosen and the smaller this size then the greater the problem becomes of finding patches of 'grassland' within other vegetation communities. It is recognised that many grassland remnants, formerly part of larger continuous grassland stands, are now less than 0.5 ha and would be overlooked by the minimal size here chosen. But a smaller minimal size would exponentially increase the number of sites of 'grassland' and include many sites better considered as merely a 'less-treed' site within other grassy communities. '0.5 ha' is a compromise.

Natural Temperate Grassland occurs in lowland south-eastern Australia, as far north as northern NSW (around 28^{o} latitude south). Sub-tropical and tropical grasslands occur north of this parallel. This northern limit is somewhat arbitrary and a scattering of grassland patches north of this limit may be best considered as Natural Temperate Grassland (notably a few grasslands in the Bunya Mountains dominated by *Poa labillardierei*). Nevertheless, 28^{o} south is the most useful limit - north of this parallel grass species with sub-tropical and tropical affinities usually dominate. The western limit of Natural Temperate Grasslands is the western extent of the Flinders Ranges, in South Australia (although scattered patches may occur further west in the Eyre Yorke Block – see section 2.10.1). Data from farther west in South Australia are equivocal. There are no Natural Temperate Grasslands in Western Australia (probably because the soil types that usually support Natural Temperate Grasslands are largely absent) (Beard 1990, Beard *et al.* 2000).

Natural Temperate Grassland is a vegetation community that is likely to contain a number of different grassland associations or communities[1] that may be floristically distinct, but nonetheless share many common attributes. The definition used in this report is based on a set of broad physiological attributes. Most Natural Temperate Grassland sites lie within the range of all attributes. Any outliers are noted as exceptions.

The definitional attributes used here are adapted mainly from McDougall & Kirkpatrick (1993). Aspects were discussed with various grassland experts. It is important to recognise that the definition of Natural Temperate Grassland used in this report does not necessarily encompass all grasslands that can be described as "natural" and "temperate". 'Natural Temperate Grassland' is merely a label applied to a range of vegetation communities that have certain ecological, structural and floristic attributes in common. Table 1 presents the criteria used to define Natural Temperate Grassland in this report. Table 2 discusses some 'grasslands' that are excluded from this definition. The section following Table 2 describes and justifies each criterion in turn.

[1] 'Community' is an ecological term used for a group of species that consistently occur together and indicate similar reliance on biotic and abiotic features of a particular environment (Allaby 1985, Knox *et al* 1994). It is a term of intentionally imprecise hierarchical status in any ecological classification (unlike terms such as 'association', 'formation' or 'alliance' all of which have specific meanings and hierarchical statuses; Bridgewater 1981, Rieley and Page 1990). Hence, a community may also contain a number of other communities, just as a group of people may be further subdivided into other constituent groups.

Table 1. Attributes of Natural Temperate Grassland

A (substantially) homogeneous vegetation stand of at least 0.5 ha, which has the following characteristics:

1. Tussock-forming species from any of the following genera dominate (ie. constitute the greatest proportional biomass) the native graminoid component of the field layer: A*ustrodanthonia, Austrostipa, Bothriochloa, Chloris, Enteropogon, Lomandra, Poa* or *Themeda;*

2. Trees and/or shrubs absent or very sparse (ie. less than 1 tree or shrub per hectare, or less than 10% projective foliage cover of emergent[2] trees or shrubs, or the inter-crown distance is more than three times the mean crown diameter) and the site has not been cleared of naturally-occurring trees within the last 20 years (evidence of former tree presence may include remnant stumps);

3. Introduced plant species comprise less than 70% of the total vegetation cover in spring or less than 50% of the total vegetation cover at other times;

4. The area is not inundated (ie. ground surface under water greater than 1 cm depth) for more than one month per year [3] or does not contain a high proportion of wetland taxa, notably Cyperaceae, Juncaceae, *Marsilea, Mimulus, Pratia* or *Lobelia*, and is not dominated by wetland grasses, notably *Amphibromus*, *Eragrostis australasica, Eragrostis infecunda, Glyceria*, *Phragmites*, *Pseudoraphis* or *Sporobolus mitchellii;*

5. The site is below 1 000 m above sea level on the mainland or below 600 m above sea level in Tasmania and the grassy component is not dominated by any of the following: *Chionochloa*, *Deschampsia*, *Trisetum* or *Poa costiniana, Poa fawcettiae, Poa hiemata, Poa petrophila, Poa phillipsiana* or *Poa saxicola*, nor contains *Celmisia, Drapetes, Oreobolus* nor *Trachymene humilis;*

6. The site receives a mean annual rainfall greater than 350 mm, and the mean annual rainfall is not summer-dominated (ie. with the wettest month three times the rainfall of the driest [winter] month) or (if the rainfall statistics are unknown) the following grasses do not occur commonly in the field layer - *Aristida*, *Astrebla, Chrysopogon, Cymbopogon, Eragrostis, Eulalia, Triodia*, *Zygochloa* and the grassy field layer is not dominated by *Dichanthium;*

7. The area is not noticeably saline.

[2] 'emergent' from the graminoid field layer
[3] excluding exceptional flooding events

Table 2. Some vegetation communities excluded from the definition of Natural Temperate Grassland

Although dominated by grasses, all the following vegetation communities are best considered as integral components of larger (non-grassland) ecosystems or biomes. It makes little management or conservation sense to distinguish them as 'grasslands', separate from the surrounding vegetation communities. Dominance by grasses is a taxonomic attribute and may have little ecological significance.

1. Reedbeds - Large stands of swampy soils dominated by the grass *Phragmites australis* can be found scattered throughout south-eastern Australia. These were excluded on the basis of them having more ecophysiological relationships with the associated swamps and wetlands, dominated by non-grasses, such as sedges or Cumbungi. Their occurrences are determined primarily by the intensity and persistence of soil waterlogging or flooding.
2. Coastal Tussock Grasslands - Many of the Bass Strait islands and nearby coastal areas of Tasmania and Victoria support dense stands of tussock grassland dominated by *Poa poiformis* and other littoral grasses (such as *Austrostipa flavescens* and *Austrostipa stipoides*). These were excluded on the basis of clear and dominating marine influences, notably the continuing deposition of wind-borne salt and its accumulation in the soil. Nevertheless, not all grasslands near the coast are primarily marine or littoral in ecophysiological relationship. Small patches of basalt grasslands occur along the coast in New South Wales, often (usually) dominated by *Themeda triandra* (a tussock grass commonly found inland and only rarely near the coast). Other typical grassland species (such as *Thesium australe*) in these patches indicate that their occurrence on the coast is not determinative. These are best considered as Natural Temperate Grassland that is coincidentally coastal.
3. Cane Grass Swamps - Inland swamps, often associated with inland-flowing rivers or endorheic drainage systems, may be dominated by either of the grasses *Eragrostis infecunda* or *Eragrostis australasica*. These are clearly best-considered as parts of these wetland systems and managed consistent with them. They are structurally very similar, almost indistinguishable, from nearby Lignum swamps dominated by shrubs such as *Muehlenbeckia* spp.
4. Riverine lawns - Extensive 'lawns' along inland flowing rivers may be dominated by rhizomatous grasses, notably *Sporobolus mitchellii*, but also including *Cynodon dactylon* var. *pulchellus* and *Pseudoraphis spinescens*. Their occurrences and persistence are inextricably determined by the rivers' flooding régimes, which deliver both the water and silt on which these grasses depend. It makes little sense to consider these (non-tussock) grasslands along with the tussock grasslands of the more distant plains and in isolation from the rest of the riparian system.

1. Is dominated (ie. constitute the greatest proportional biomass) by tussock-forming grasses in the graminoid component of the field layer

Natural Temperate Grasslands are characterised by perennial tussock grasses that are often closely spaced to form an upper stratum of loosely-interlacing leafy canopies. The characteristic dominant genera of Natural Temperate Grassland in Australia include *Austrodanthonia, Austrostipa, Bothriochloa, Chloris, Enteropogon, Lomandra, Poa* and/or *Themeda* (Groves & Williams 1981; Barlow 1998). Note that the Lomandra 'Irongrass' communities of the southern Flinders Ranges in South Australia are here included as 'Natural Temperate Grassland', although dominated by the non-grasses *Lomandra multiflora* subsp. *dura* and *Lomandra effusa* (Hyde 1995). These communities are subject to similar threats and occur in similar ecological situations as (other) Natural Temperate Grassland (on similar soil types, with similar rainfall patterns, identical physiognomy and similar fire régimes) (Specht 1972; Davies 1983). To exclude *Lomandra* from the definition because it is not a 'grass' (Poaceae) is taxonomic determinism. 'Grasslands' are an ecological group, not a taxonomic one. Some grasslands were excluded because their ecophysiological relationships are not primarily with other (tussock) grasslands, see Table 2. In the case of 'Irongrass' communities, although not solely dominated by a grass, they were included because their ecophysiological relationships are primarily with (other) grasslands.

A range of grassland communities occurs in lowland temperate Australia and these may be identified by particular 'character species'. The precise composition of these communities derives from interactions between soil, climate, fire régime and other physical site aspects, and between the plant and animal inhabitants (Barlow 1998).

Some grasslands have been described as 'herblands'. Grasses are themselves herbs and there is a rich variety of other annual and perennial herbaceous plants found between the grassy tussocks (Marriott & Marriott 1998). However, the term 'grassland' refers to the dominant, if not most frequent, species. The term herbland incorporates grassland (including tussock and hummock), sedgeland and herbfield and may exclude species of aquatic environments (Leigh *et al.* 1984).

"A native grassland is a vegetation type with few or no trees, in which the dominant species are native grasses" (Department of Conservation and Environment 1992). Dominance has been defined as: "*the ability of the species with the greatest foliage cover in the uppermost*

stratum of the ecosystem to intercept solar radiation; this species will therefore exert the greatest influence on the ecosystem via energy-fixation and transpiration" (Specht 1972). As in other communities, this definition presents practical and conceptual difficulties in grasslands, where very scattered trees may have little impact on ecosystem processes and yet are the 'uppermost' stratum. More satisfying definitions focus on the species or growth form(s) that have greatest influence on community processes. Allaby (1985, p. 208) offers the more useful and defensible definition of 'dominant' as *" In ecology, the species having the most influence on community composition and form*". This definition is accepted for this report, Hence 'grasslands' may still be classified as grasslands (ie. dominated by grasses) when they also include scattered trees or shrubs, but only as long as those trees or shrubs have trivial or subordinate impact on ecosystem processes and composition.

In many natural grasslands the ground surface is not totally covered with vegetation. Leigh *et al*. (1984) state that "*Tussock grassland or tussock sedgeland consist of discrete tussocks of perennial grasses, rushes or sedges which cover up to 70 per cent of the surface.*" Lunt *et al*. (1998) also point out that grasses may only cover 30-50% of the ground in grasslands, with a greater percentage in high-fertility areas such as the southern parts of the Victorian Western Plains. Inter-tussock spaces may be filled with other monocotyledonous plants, forbs, cryptogams, or bare ground. Bare ground in grassland may be an indicator of extremely low soil nutrient content; available nitrogen and phosphorus may have been taken up by the dominant grasses, excluding other species, but empirical studies are lacking. Given the potentially high proportion of ground unoccupied by higher plants, it makes sense to consider proportions of total *vegetation* cover rather than proportions of *ground* cover. For the purposes of this definition, at least 10% of the total ground surface should be covered by vegetation. Below this figure the plant species exert little impact on microclimate and hence it's reasonable to presume that any plant species present, including grasses, will not dominate.

Grass dominance in any stratum would not be a suitable indicator for grasslands because such a broad definition would incorporate many vegetation types which are best recognised as components of other ecosystems (Department of Conservation and Environment 1992). For example, the field layers of some Tall Open-forests and Dry Sclerophyll Forests such as in the Box-ironbark belt on the inland slopes of the Ranges, and the field layers of many Mallee communities, are dominated by grasses (Department of Conservation and Environment 1992).

This criterion excludes communities sometimes referred to as 'grasslands' but not dominated by grasses, such as the Button-grass (*Gymnoschoenus sphaerocephalus*, Cyperaceae) plains, which are common in western Tasmania, or Cutting Grass (*Gahnia* spp., Cyperaceae) swamps of south-eastern South Australia and south-western Victoria. Such communities are dominated by ecological processes different from those that determine grassland occurrence, composition and structure. Button-grass Plains occur on acid peaty soils (often organic) in very high rainfall zones and are dependent on frequent fire. Cutting-grass Swamps occur on somewhat peaty soils, with very high water tables, are frequently waterlogged and hence are best-considered as wetlands or swamps.

As with all vegetation communities, the structure and composition of grasslands, and the environments in which the different (sub-)communities occur, are a continuum (Barlow 1998), both within grassland and between grassland and the surrounding vegetation (Moore & O'Sullivan 1978; Elisseou *et al*. 1995; Reynolds *et al*. 1997; Turner *et al*. 1997; Morgan 1998; Stohlgren *et al*. 1998). Short, open grasslands tend to occur on free-draining, less fertile soils, and also tend to be relatively species-rich. There is a biomass accumulation towards tall, closed grasslands occurring on wetter, poor draining sites, with fertile soils. Tall, closed grasslands tend to be species poor (Turner *et al*. *op. cit.*; Barlow 1998).

2. Supports less than 1 tree or shrub per hectare, or less than 10% crown cover of trees or shrubs

The degree of tree cover remains a contentious attribute in defining the range of natural or native grasslands. An obvious question that arises is: "How many trees or shrubs are tolerable until a site can no longer be considered grassland?" It is generally accepted that a native grassland typically either does not contain trees, or only contains trees that are widely spaced and do not dominate the ecological processes (Marriott & Marriott 1998). The term grassy vegetation describes communities in which the herbaceous field layer is dominated by grasses (Tremont & McIntyre 1994) and thus may include communities with a major tree presence. In grasslands, shrubs tend to be uncommon and native grasses, lilies, orchids, peas and daisies are the main herbs (Marriott & Marriott 1998). However, the relationship between the trees and shrubs and the distinct grass stratum is less clear. Dense shrubs and/or trees and a fully-developed grass stratum rarely occur together at a site. Although there have been some studies addressing the effects of tree cover on Natural Temperate Grasslands in Australia, and even less research on the influence of the grassy swards on

seedling woody plants, further research is needed. Further discussion of the causes of treelessness is made in the 'Driving processes' sections under each Bioregion in section 2.

Various studies have considered the effects of increased tree or shrub cover on grassland structure and function (Fensham & Kirkpatrick 1992; Rolland 1995; Walker *et al.* 1997; Gibbs *et al.* 1999), although much of the literature has focussed on African savanna ecosystems (Belsky *et al.* 1993; Scholes & Archer 1997; Barnes & Archer 1999). It appears that increased shading by trees affects light availability to the ground layer and there may be increased resource demand by trees or shrubs (ie. water, space and nutrients). This woody component also provides a recalcitrant, low nitrogen litter (in contrast with the readily biodegradable herbaceous litter) and thus greatly changes the community's nutrient dynamics and supply (Boerner 1982; Read and Mitchell 1983). These may influence floristic composition to favour shade-tolerant species or those which tolerate 'lower than usual' resource levels. Conversely, Fensham & Kirkpatrick (1992), in a study in central Tasmania, concluded that the primary cause of a relative lack of trees in the open areas at all altitudes was the competition for moisture and root space provided by a dense grass sward.

Two ways of describing tree spacing are crown cover and projective foliage cover. Crown cover is the percentage of the sample site within the vertical projection of the periphery of the crowns (McDonald *et al.* 1998). In this case, crowns are treated as opaque. Projective foliage cover is a more relevant measure because it gives an indication of the amount of light passing through the canopy. Grassy woodlands have been described as having up to 30% projective foliage cover of trees (Specht 1970). The problem that arises in grassland mapping is that a projective foliage cover of 10% would allow a higher cover of trees (~20-30%) if crown cover is measured, as is usually the case. As canopy cover increases, so does the intensity of shading and the litter drop, leading to a discontinuous herbaceous layer and lack of grass dominance (Tremont & McIntyre 1994).

The floristic composition of the herbaceous strata of grasslands and grassy woodlands may be so similar to that of nearby grasslands lacking the tree canopy as to make the woodlands and grasslands virtually inseparable for the purposes of grassland conservation (Department of Conservation and Environment 1992). It makes little sense to distinguish a grassland with few or no shrubs or trees, from a nearby open-shrubland or open-woodland with scattered shrubs or trees (Department of Conservation and Environment 1992). Nevertheless, grassland mapping often distinguishes those sites that are clearly all grassland (eg. Plains Grassland) from other grassy vegetation that has some tree or shrub layer (eg. Grassy Woodland or Plains Grassland/Grassy Forest complex). Mapping is greatly facilitated if

grasslands and woodlands are distinguished. Given that projective foliage cover is difficult to measure accurately, then 'trees per hectare' is an appropriate unit if a primary consideration is that non-experts should be able to use the definition. Lunt *et al*. (1998, p11) suggest a density of 1 tree per hectare as a useful break point and that figure will be used for the definition developed in this project. Care must be taken to use broad spatial scales when determining tree density, as it could be easily over-estimated where a few trees occur in a small patch. For the purposes of the definition proposed in this report, a 0.5 ha patch of Natural Temperate Grassland must have fewer than 2 trees or 4 shrubs.

Natural Temperate Grasslands must also not be derived from tree or shrub clearing that has occurred in the last 20 years (ie. post-1982 inclusive). Those sites that are obviously recently derived from some other known vegetation type should not be classified as Natural Temperate Grassland but as a degraded or altered form of the previous vegetation community. The 20 year cut-off is particularly relevant to certain grassland regions, notably the Monaro Tablelands where obvious and intentional tree removal by humans has occurred in the last 20 years. Evidence of tree or shrub removal may be stumps on the ground, small scale topography, persistence of characteristic woodland (or non-grassland) species, photos, reliable historical or botanical records. Although some experts can read the landscape beyond the 20 year cut-off, it is often difficult to distinguish derived grasslands from 'pre-1750' or 'natural' grasslands if the clearing took place more than 20 years previously (Lunt, 1993). Sites with well-supported evidence to indicate derivation from some other vegetation community prior to 1982, are included as Natural Temperate Grassland, unless the sites occur in an IBRA Bioregion that was not likely to contain native grassland prior to European settlement.

3. Contains less than 70% total vegetation cover of introduced perennial plants in Spring or less than 50% at other times of the year

Weeds are almost always present in Natural Temperate Grasslands, and their observable presence may vary throughout the year due to changes in their visibility throughout their growing seasons. This criterion serves to distinguish sites with mostly introduced species that also support a minor presence of native species (eg. agricultural paddocks or urban wastelands) from sites that are clearly native-dominated. The point at which weeds so dominate a Native Grassland that it is no longer reasonable to consider the community as a native grassland is somewhat arbitrary, as few studies have made quantitative measures of the impacts of weeds on any of Australia's natural systems, let alone grasslands (for a

discussion see Williams & West (2000)). Nevertheless, some decision point must be set and it has here been set at introduced perennial plant species comprising 70% or more of the total vegetation cover in spring, or 50% or more of the total vegetation cover at other times of the year.

Weed invasion in Native Grassland has been attributed to higher available nutrient levels in disturbed soil (Wijesuriya & Hocking 1999; Watkinson & Ormerod 2001). As weed cover increases, so do the severity of impacts on Natural Temperate Grasslands. These impacts include: (1) competition with indigenous plants for light, nutrients and other resources, (2) replacement of indigenous plants, (3) prevention of natural regeneration, (4) changes in fire behaviour due to altered fuel quantity and distribution, and (5) alteration of disturbance régimes (Williams, 2000). However, there is some evidence that a moderate cover of weeds does not significantly alter conservation values of grassy ecosystems (Kirkpatrick, 1986).

4. Is not usually subject to regular inundation lasting longer than one month

Grasslands frequently inundated for more than a month tend to form wetlands (swamps, marshes etc.) and contain a different suite of species that includes a greater proportion of sedges, rushes and other typically wetland plants. In these situations, extended and relatively frequent inundation (at least in comparison with adjacent higher country) drives the ecological processes, and hence the species complement. On this consideration, wetlands dominated by grass species are excluded from the definition of 'Natural Temperate Grassland'. Hence, reedbeds dominated by *Phragmites australis*, riverine lawns dominated by *Sporobolus* spp., *Pseudoraphis spinescens* and other grasses, and Cane Grass Swamps dominated by *Eragrostis infecunda* or *Eragrostis australasica* are all excluded.

Riverine grasslands, associated with the Murray-Darling system, occur sporadically along the length of rivers and drainage systems. 'Lawns' of *Sporobolus* spp. (Rat-tail or Couch Grasses) and *Cynodon dactylon* (Couch Grass) can be found on heavy clay soils and mats of *Pseudoraphis spinescens* (Mud Grass) extend across drying billabongs, lakes and around their margins (Bren 1992). Cane grass swamps (dominated by large, rounded mounds of *Eragrostis* spp.) are scattered along the drainage lines and elsewhere in depressions on the plains (McIntyre *et al.* 1988). In moister climates, dense stands of either *Amphibromus* (Swamp Wallaby Grasses) or *Glyceria* spp. (Sweet Grass) may dominate the margins of

drying billabongs and other landscape depressions (Smith *et al.* 1996). All of these communities are excluded from the definition of Natural Temperate Grasslands.

Dense stands dominated by the grass *Phragmites australis* (Common Reed) are scattered throughout southern Australia in frequently-waterlogged riparian and paludal (eg. swamp or marsh) sites (eg. Roberts & Ludwig 1991) and are excluded from the definition of Natural Temperate Grasslands.

In all such sites, the water régime (its periodicity, predictability, extent and intensity) dominates the ecological conditions and hence determines that these grassy communities have greater ecological affinities with the associated woody riverine or paludal vegetation than with nearby grasslands in more elevated locations (Roberts & Ludwig 1991). They have been excluded from the definition of 'Natural Temperate Grassland'.

In depressions on the basalt plains of western Victoria, and elsewhere in heavy (often self-mulching) loams and clays of temperate climates, water may lie for a month or more each year. *Amphibromus* spp. dominate such scattered Grassy Wetlands (eg. Derrimut Grassland Reserve, see Lunt 1990). These may be usefully considered as wet Natural Temperate Grasslands or as ephemeral wetlands. They have been (somewhat arbitrarily) excluded from the definition of Natural Temperate Grasslands. Species characteristic of ephemeral wetlands are listed in couplet 4 of the key in section 1.3.

5. Must be below 1 000 m above sea level on the mainland or below 600 m above sea level in Tasmania

The grassland literature often describes native grasslands as occurring in 'lowlands' (eg. Lunt 1991; Kirkpatrick 1993; McDougall & Kirkpatrick 1993; Sharp 1994; Kirkpatrick *et al.* 1995; Lunt 1995, 1997a; Lunt & Morgan 2001). However, the term 'lowland' may not be useful to apply to all Natural Temperate Grasslands. Many of Australia's Natural Temperate Grasslands do not occur in lowlands; eg. grasslands of the New England Tablelands in NSW are often on high points in relation to the surrounds (McIntyre *et al.* 1993). Montane grasslands in the Monaro Region of NSW and Lake Omeo area of Victoria are generally not regarded as lowland, as they show clear high altitude affinities (Department of Natural Resources and Environment 1999). By some definitions, lowland describes "land low with respect to neighbouring country" (Delbridge *et al.* 1982). However, many grasslands are

confined to ridge tops and hill sides such as grasslands dominated by *Themeda triandra* on coastal cliffs at Bouddi in NSW (Benson & Howell 1994).

In general, with increasing altitude, different climatic and other environmental factors come to drive the composition and occurrences of grasslands when compared with lower altitudes. Alpine grasslands are clearly subject to radically different environmental régimes when compared with lowland grasslands (as evidenced by the few species shared in common between lowland and alpine grasslands). Nevertheless, the change from 'lowland' to 'alpine' is gradual and clinal as altitude increases and any line of distinction must, of necessity, be somewhat arbitrary. Alpine species may occur at lower altitudes in atypical protected situations (eg. *Poa costiniana* at Bidwell near Bendoc around 900 m ASL and *Austrofestuca hookeriana* at near sea level at Walkerville and Portland in southern Victoria) and typically lowland species may creep into the alps in atypical protected situations (eg. *Agrostis avenacea* at or above the tree line on the Cobberas). The altitudinal line separating 'high altitude lowland grassland' from 'low altitude alpine to subalpine grassland' varies not only with local topography but also with latitude. The definition relies on both the absolute altitude and the ecological relationships of the dominant grasses and associated flora. Ideally, the dividing altitude for Natural Temperate Grasslands would use a mathematical formula that accounted for latitudinal influence, however the definition described in this report is intended to be more user-friendly. For this reason, we have generalised the mainland altitudinal limit to 1000 m and the Tasmanian limit to 600 m ASL.

High altitude soils are usually distinctly different to those of lowland sites (Prescott 1952; Costin 1962; Adams & Attiwill 1986). For example, Alpine sod tussock grasslands occur mainly on alpine humus soils (Costin 1962). The rainfall and temperature regimes are also distinctly different when compared with lowland localities (Conn 1993). *Poa*-dominated alpine and subalpine grasslands (dominated by a variety of species, but notably *Poa costiniana, Poa fawcettiae, Poa hiemata* and *Poa hothamensis*) are excluded under this criterion, and are best considered with other alpine and subalpine vegetation communities (Lawrence 1998).

Poa-dominated sub-alpine and alpine tussock grasslands are found on the Bogong High Plains, the Dargo High Plains, the Kosciuszko region and elsewhere in the high country of the ACT, Victoria and New South Wales and in the highlands of Tasmania and are here excluded from the definition of Natural Temperate Grasslands (Wearne & Morgan 2001). In Australia, sub-alpine grasslands occur below the treeline at approximately 1 000 m to 1 680 m above sea level, and alpine grasslands occur above the treeline, usually between 1 700

and 1 950 m above sea level (Moore & Williams 1976; Walsh *et al.* 1986). The sub-alpine zone generally occurs at lower altitudes as latitude increases, thus in Tasmania the sub-alpine zone begins at around 600 m above sea level (Kirkpatrick 1999).

Approximately 21 000 hectares of naturally treeless sub-alpine or alpine vegetation occurs in Victoria (Walsh *et al.* 1986). Walsh *et al*. (1986) identified a Victorian sub-alpine grassland community at 1 200 - 1 680 m above sea level that was dominated by grasses including *Poa costiniana, Poa fawcettiae* and *Poa hiemata* and containing many inter-tussock herbs.

Some grass species have a wide distributional range that includes occurrences above and below the altitudinal limits of Natural Temperate Grassland distribution. For example, *Poa labillardierei* dominated grasslands are widespread on the wetter and poorer soil parts of the Southern Tablelands of New South Wales from 600 m to over 1 500m ASL. The majority are derived from removal of the tree layer in woodlands and forests (Benson 1994). Those *P. labillardierei* grasslands that occur above 1 000 m tend to contain species with more alpine affinities and are thus excluded from the definition. *P. labillardierei* grasslands also occur in the sub-alpine zone of the Mt Hotham region, on basalt, at altitudes ranging from 1 320 - 1 350 m and are also excluded (Wearne & Morgan 2001). *Poa sieberiana*-dominated grasslands occur in the sub-alpine zone between 1 340 - 1 470 m and are excluded (Wearne & Morgan 2001), although *Poa sieberiana* is typically a lowland species of grassy woodlands and forests. The alpine grasslands of the Snowy Mountains of New South Wales are dominated by *Poa* spp. or *Austrodanthonia frigida* and are also excluded (McVean 1969).

Sub-alpine *Themeda triandra* grasslands have been identified from the extensive cold-air plains of the Snowy Mountains in the Kosciuszko region (Wimbush & Costin 1979) and in the Mt Hotham region (Wearne & Morgan 2001). Although many grasslands dominated by *Themeda triandra, Poa labillardierei* and *Poa sieberiana* are included in this definition of Natural Temperate Grasslands, those that occur above 1 000 m on the mainland (or above 600 m in Tasmania) tend to have more alpine affinities and are here excluded.

In Tasmania, the largest areas of high altitude grasslands (ie. generally >600 m ASL, where *Themeda* and *Austrostipa* are largely absent) occur on the Tertiary basalt plains of the North West and Central Plateau (Kirkpatrick & Duncan 1987). Many high altitude grasslands are likely to have been present at the time of European occupancy (such as those on the Central Plateau), while others may be derived or enlarged by tree removal or senescence (such as areas of the North West) (Kirkpatrick & Duncan 1987). Sub-alpine tussock grasslands are dominated by the grasses *Poa labillardierei* and/or *Poa gunnii*, and are characterised by

inter-tussock herbs, notably *Trachymene humilis, Drapetes tasmanica, Celmisia saxifraga, Oreobolus distichus* and *Trisetum spicatum* (Kirkpatrick & Duncan 1987). It is on the basis of its characteristic assemblage of alpine species that this *Poa* community is excluded from Natural Temperate Grassland.

6. Receives greater than 350 mm mean annual rainfall with seasonal rainfall distribution not distinctly skewed to summer

Areas that receive less than 350 mm mean annual rainfall tend to form grasslands with arid affinities. Arid grasslands dominated by *Triodia* spp. or other grasses, such as *Aristida* spp. are excluded. *Triodia* sens. lat. is a dominant grass throughout much of central Australia and is rare and ecologically restricted in more temperate climates (Lazarides 1997). Other grasslands of arid climates are often dominated by genera that are either absent from, or of minor occurrence in, temperate parts of Australia. *Astrebla*, *Eragrostis*, *Yakirra* and *Zygochloa* are some of the genera typical of arid grasslands, but largely absent from, or rare in, temperate grasslands (eg. Wilson *et al.* 1990).

Semi-arid and arid grasslands occur where mean annual rainfall is less than 350 mm. These grasslands often define the inland boundary of Australia's Natural Temperate Grasslands and form a variety of communities that are briefly mentioned here. Most problematic are semi-arid grasslands usually co-dominated by *Austrodanthonia* and *Austrostipa* species, often in association with *Aristida* spp., which commonly 'straddle' this isohyet boundary. Grasslands on the slopes of the Flinders Ranges in South Australia are particularly difficult to categorise as either 'semi-arid' or 'temperate'. Nevertheless, a distinction must be made and grasslands experiencing a mean annual rainfall less than 350 mm are (somewhat arbitrarily) excluded from the definition of Natural Temperate Grasslands.

Astrebla lappacea (Curly Mitchell Grass) forms grassland in the northern part of NSW, which experiences a summer-dominant rainfall pattern and is thus excluded (Beadle 1948). *A. lappacea* is only found on heavy self-mulching soils which are not subject to flooding (Beadle 1948). Under summer rainfall conditions *A. lappacea* comprises by far the bulk of the biomass. Many herbs appear in winter. *A. lappacea* dominated-communities in the Queensland have been described elsewhere (eg. Orr & Holmes 1984; Fensham 1999).

Grassland communities dominated by *Triodia mitchellii* (Buck Spinifex) are restricted to the deep sands of the sandplains in the north and north-east of western New South Wales below an open cover of trees and shrubs. Their arid affinities and the abundance of trees and shrubs exclude them from this definition of Natural Temperate Grasslands.

Nevertheless, there is notable overlap and it is not always easy to make a distinction between arid and temperate grasslands based solely on dominant genera. Grasslands dominated by *Austrodanthonia* sens. lat. and *Austrostipa* sens. lat. often occur at this arid-temperate boundary (eg. at Eureka Flora and Fauna Reserve near Sea Lake in north-western Victoria). In such situations, *Themeda triandra* is absent, or restricted to mesic niches, and grasses with more arid distributions co-dominate, such as the eponymous *Austrostipa eremophila* and species of *Aristida.* Other genera may be useful in distinguishing arid from temperate grasslands, eg. *Zygophyllum* is often associated with arid grasslands and largely absent from temperate grasslands, whereas *Caesia* and *Hypericum* are frequent in, and often characteristic of, temperate grasslands, but absent in drier climates.

To a certain extent, using any isohyet as an ecological boundary for temperate versus arid grasslands is somewhat arbitrary. Some typically arid species may occur in restricted situations in regions considered largely temperate (such as *Triodia scariosa* at Lower Glenelg in far south-western Victoria with a mean annual rainfall over 700 mm) and, conversely, typically temperate species may occur in protected niches in largely arid regions (such as *Themeda triandra* along seasonal drainage lines throughout the Northern Flinders Ranges and elsewhere in Central Australia, with mean annual rainfalls well below 250 mm). Nevertheless, as all stands cannot be mapped at this (national) scale, a climatic boundary is useful and the 350 mm isohyet usefully separates the bulk of temperate grasslands from the bulk of arid grasslands.

“The Temperate Zone [of Australia] has a cool to warm temperate subtropical climate and precipitation is mainly winter in its incidence except in the eastern and south-eastern sections where it may be fairly evenly distributed throughout the year or may show both winter and summer maxima” (Burbidge 1960). The boundary between temperate and semi-arid is a precipitation threshold of approximately 350 mm. The boundary between temperate and sub-tropical is based on seasonality of rainfall (summer dominant) and absence of a pronounced summer drought period; there are also no cold extremes in sub-tropical climates (Burbidge 1960). However, regional maps of climate classification show ‘optimal’ climate

conditions and may not directly relate to local vegetation distribution. Altitude, aspect and proximity to the coast are all factors that can determine local climate.

In Australia temperate climates occur over much of Tasmania (except at high altitudes), Victoria (except the sub-alpine zone in the Alpine National Park and the semi-arid north west), NSW in much of the eastern half of the state, South Australia in the south-east within the 350 mm isohyet, Queensland in the far south-east, and Western Australia in the south-west (Lamp *et al.* 2001).

Sizeable areas of natural tropical grasslands occur in northern Australia and are excluded (Neldner *et al.* 1997). In these grasslands about 80% or more of the annual precipitation falls during a summer wet season extending from December to March (Neldner *et al.* 1997). Natural grasslands may be dominated by *Aristida*, *Eragrostis*, *Eriachne*, *Germania*, *Heteropogon, Imperata cylindrica, Ischaemum, Oryza*, *Mnesithea rottboellioides*, *Panicum, Sorghum, Sporobolus virginicus* and/or *Themeda* (Neldner *et al.* 1997).

Sub-tropical grasslands also occur in the Darling Downs (Darling Riverine Plains Bioregion) in Queensland and are dominated by *Dichanthium sericeum* (Queensland Bluegrass), although these grasslands have been severely reduced to about 1% of the pre-settlement area (Fensham 1997; Fensham 1998). Temperate species (including *Elymus scaber*, *Austrodanthonia* spp., *Stemmacantha australis* and *Thesium australe*) occur with subtropical species in these grasslands, which represent the northern range limit for many temperate species (Goodland 2000). The Darling Downs experiences greatest rainfall in summer with mean values for the driest month being about 30% of those for the wettest (Fensham 1998). These grasslands are therefore excluded from this definition of Natural Temperate Grasslands.

Montane grassy balds occur in isolated sites in the high country of south-eastern Australia, such as the Bunya Mountains of south-eastern Queensland (Fensham & Fairfax 1996a), north-east Tasmania (Ellis 1985), at Wollemi National Park, Barrington Tops and Dorrigo in New South Wales (Fensham & Fairfax 1996b) and the Hume Range in Victoria (Ashton 2000). The grassy balds in New South Wales have not been described (Fensham & Fairfax 1996b).

Grassy balds exist as a result of frost hollows, which relates to topographic accumulation of cold air and water (Fensham & Fairfax 1996a, Ashton 2000). The Bunya Mountains balds may be relics of formerly more widespread grasslands from colder, drier glacial periods,

maintained by either Aboriginal burning which prevented tree establishment, or by wind storms and subsequent droughts or frost, followed by a hot fire that created openings in the rainforest (Fensham & Fairfax 1996a). They occur at elevations between 600 and 1 146 m and on the second highest peak on the Bunya Mountains (Mount Mowbullan). January is the wettest month with mean monthly rainfall three times that of the driest month, August (Fensham & Fairfax 1996b, a). With rainfall distinctly skewed to summer the Bunya Mountains balds are excluded from this definition of Natural Temperate Grasslands.

The dominant grass species in the Bunya Mountains balds are *Poa labillardierei*, *Sorghum leiocladum* and *Themeda triandra*. Five floristic groups have been identified by Fensham & Fairfax (1996a), with "Group 3" showing greatest floristic affinity with Natural Temperate Grasslands, containing *Bracteantha bracteata*, *Chrysocephalum apiculatum* and *Picris angustifolius* (Fensham & Fairfax 1996b). Further study of local climatic differences in relation to floristic composition on the Bunya Mountains balds may distinguish 'temperate' sites that could be regarded as Natural Temperate Grasslands.

7. The area is not saline or notably sub-saline

Saline and sub-saline soils promote growth of salt-tolerant species. Soil salinity, the presence of a high concentration of free sodium and chloride ions in the soil, has a dramatic impact on the growing conditions for all plants - so much so that the soil salinity becomes a dominant and determinant growing condition (Matters & Bozon 1989). The other climatic and site processes that would otherwise determine local growing conditions, such as soil type, nutrient levels and rainfall, become secondary and halophytic plants dominate (Scarlett & Parsons 1993).

Coastal grasslands are generally excluded from the definition of Natural Temperate Grasslands because their occurrences are mainly determined by their coastal locality – coastal influences (such as the salt-spray effect and high wind régimes) primarily determine their floristic and structural composition (Beadle 1981). Salt, picked up as spray from the ocean, although containing nutrients essential for plant growth, also contains high concentrations of sodium and chloride ions, and is deposited on land as rain (and referred to as cyclic salt) (Beadle 1981).

In southern Australia, loose, primary dunes are often first colonised by **Ammophila arenaria* (Marram Grass) and/or *Spinifex* spp (Beadle 1981) and these grasslands are excluded from

the definition of Natural Temperate Grassland. *Spinifex sericeus* is a specialist grass for conditions of low nutrient status and high incident wind-borne salt (Beadle 1981). Following stabilisation of dunes, grasslands progress into dune scrub communities and in some areas may eventually form *Eucalyptus*-dominated woodlands. *Poa poiformis*-dominated grasslands tend to occur on richer, heavier, older profile soils, but are always littoral in occurrence and are thus excluded. For example, *P. poiformis*-dominated grasslands have been described for sites on the south coast of Phillip Island in Victoria (Oates 2001). *P. poiformis* is generally more salt tolerant than most other *Poa* species. Other coastal grasses such as *Zoysia* and *Imperata* occur in coastal ecosystems behind the primary dunes in similar ecological situations to *P. poiformis* grasslands and are thus excluded. The species composition of plant communities near the coast is a function of specifically coastal environmental conditions, such as high wind-borne salt, the duration and degree of any inundation and the availability of fresh water. Many coastal species are rhizomatous, ie. they produce horizontal shoots that can grip and stabilise the sandy soil in which they grow (Beadle 1981).

Characteristic species of the coastal grasslands that are excluded from the definition include:

Actites megalocarpa (Dune Thistle)
Apium prostratum subsp. *prostratum* (Sea Celery)
Austrostipa stipoides (Prickly Spear-grass)
Isolepis nodosa (Knobby Club-sedge)
Lachnagrostis billardierei (Coast Blown-grass)
Myoporum insulare (Boobialla*)*
Olearia axillaris (Coast Daisy-bush)
Ozothamnus turbinatus (Coast Everlasting)
Poa poiformis (Coast Tussock Grass)
Rhagodia candolleana (Seaberry Saltbush)
Samolus repens (Creeping Brookweed)
Spinifex spp. (Spinifex)
Swainsona lessertiifolia (Coast Swainson-pea)
Tetragonia implexicoma (Bower Spinach)

Hence, the narrow coastal bands dominated by *Spinifex* spp*.* and coastal islands and near-islands dominated by grasses, notably *Poa poiformis* and/or *Austrostipa stipoides*, and often supporting dense seabird colonies, are also excluded from this definition of 'Natural Temperate Grassland' (see Frood 1986).

Occasionally, Natural Temperate Grassland occurs in coastal locations such as coastal cliffs at Bouddi in New South Wales and on clayey headlands in the south-east of NSW (Benson & Howell 1994) and in Tasmania (Kirkpatrick 1999). In these instances, floristic and structural composition is apparently determined by environmental factors other than exposure to salt spray and strong winds, and these may legitimately be considered Natural Temperate Grasslands. For example, grasslands dominated by *Themeda triandra* occur in Tasmania on fertile coastal sites, exposed to high salt spray incidence and frequent fire (Kirkpatrick, 1993). These sites tend to occur inland of vegetation dominated by coastal species, notably *A. stipoides* and *P. poiformis* (Kirkpatrick 1993) and may also be included within the definition.

1.2. The inclusion of derived grasslands within Natural Temperate Grassland

Sometimes grasslands develop after tree and shrub clearing in a mature community, followed by grazing of the herbaceous stratum (Moore 1953b). These grasslands have been termed 'disclimax', 'derived' or 'induced' communities (Beadle 1981). Clearing of woodlands and forests and subsequent grazing has produced grassland (*Austrostipa falcata, Austrodanthonia* spp., *Themeda triandra* and/or *Aristida behriana*-dominated) disclimax or derived communities in the south-eastern Riverina of NSW (Moore 1953b) and also in Gippsland (Lunt 1997a). Such communities, obviously anthropogenic in origin, lead to a discussion of the suitability of inclusion of disclimax grassland communities in the definition of Natural Temperate Grasslands.

Disclimax or derived communities are derived from other vegetation types, usually as a result of human impact, and may be considered 'un-natural'. Derived grasslands are often quite rich in native species as a result of a very sparse tree layer, allowing proliferation of herbs that generally do not tolerate sub-canopy conditions. It should not be assumed that derived grasslands look any less like pre-1750 grasslands than those whose history is not known and are considered 'natural' or 'original' (ie. not derived). It could be argued that *all* remaining Natural Temperate Grasslands are derived, if longer timeframes are considered. Some grasslands are obviously recently derived (eg. by tree clearing or livestock grazing), however many seemingly "natural" or "relictual" grasslands may result from human burning over the last 40 000 years (Bowman *et al*. 1990, Crowley and Garnett 1997), or from some more historic climactic event, such as wildfire (Ashton 2000).

In many situations, it is impossible to determine which grasslands have developed as a result of land management practices after European settlement and which pre-date European

settlement. They are currently indistinguishable, and historical records are usually scanty and unhelpful. For the purposes of mapping, derived grasslands are often very difficult to distinguish from pre-1750 grasslands.

Exceptionally, historical records are adequate to enable confident statements that certain grasslands have been produced by clearing of former woodlands or forests, such as in Gippsland in Victoria (Lunt 1997a). Grasslands formed by agricultural practices include many (but possibly not all) in the NSW Riverina, where grasslands may be derived from chenopod shrublands and woodlands. In the south-eastern Riverina, *Aristida*-dominated grasslands are frequently associated with marginal or ecotonal communities, and the soils have a deep, sandy A horizon of low fertility (Moore 1953b).

Some apparently natural Temperate Grasslands may contain very few species (eg. Derrimut Grassland Reserve on the western basalt plains of Victoria, which is [over-]dominated by *Themeda triandra,* Lunt 1990). Relative monocultures, although lacking in species richness and diversity, may still provide ecological services, such as suitable habitat for native fauna.

Further to those grasslands derived following European settlement, are those that may be derived from Koori land management practices prior to European settlement. There has been considerable debate as to the frequency of burning of native vegetation by Kooris in pre-European times (eg. Benson & Redpath 1997). There is some suggestion that many of the largest stands of pre-European grassland owed their existence to relatively intense land management, often incorporating fire and grazing management, by Kooris. This is certainly the case where aboriginal burning practices have been maintained well into historical times (Bowman *et al.* 1990, Crowley and Garnett 1997). Hence it is very difficult to distinguish anthropogenic grasslands from 'natural' grasslands.

For the purposes of a useful definition that is not biased against significant (and threatened) sites, demarcation has been set at 20 years since derivation. Further justification of this cut-off has been previously discussed in section 1.1 under criterion 2.

1.3. Key to the identification of Natural Temperate Grassland (NTG)

This key is intended to:

(1) define the limits of a range of appropriate, observable attributes that describe Natural Temperate Grassland,

(2) present attributes that are unambiguous, measurable and consistently applicable across all sites,

(3) enable identification and exclusion of sites from Natural Temperate Grassland that otherwise might be confused with Natural Temperate Grassland and may have been included in similar ecological units, such as 'grassland' or 'native pasture',

(4) be independent of the conservation value of a site (species-poor and species-rich sites will be included, as will sites of high conservation value and sites of little to no conservation value).

(5) be useable by field workers with limited botanical or ecological expertise, and

(6) enable identification and classification of Natural Temperate Grassland while in the field (ie. recourse to external data bases or historical or other data are unnecessary)

With these intentions in mind, we have avoided a definition that is based on hard-to-measure attributes such as soil nutrient concentrations, water holding capacity and drainage, even though these may be more reliable attributes for assessment. Also, there has been some simplification of figures to make the key more user-friendly (eg. 1000 m altitudinal limit for mainland Australia, rather than use of a complex mathematical equation that recognises that the altitudinal upper limit varies with latitude, local topography and other environmental features).

Floristic "substitutes" have been incorporated in the key for situations where rainfall, inundation or other biophysical data are not available (or are likely to be unavailable to a field worker). To retain wide utility, and on the assumption that different genera are probably more reliably recognisable than individual species, we have tried to limit floristic attributes to genera and families. Specific determinations are required only rarely. The occasional emphasis on floristic attributes is not intended as a taxonomic bias - merely recognition that perennial species are usually present at a site regardless of season of inspection and regardless of local seasonal conditions. Hence they are a useful summary of site conditions throughout the year. Flooded sites support species indicative of those occasional floods, even if that particular site has not been flooded for a decade or more. Alpine sites are dominated by alpine species, even in high summer on days of 35 ^{o}C or more.

When using this key the observer should be standing in at least 0.5 ha of relatively homogeneous vegetation dominated by native grass(es) at a latitude near to, or greater than, 28^{o} south. Sites smaller than 0.5 ha cannot be reliably assigned to be a particular vegetation community. Dominant species are those that, by their size, abundance or growth form, have the greatest influence on the growing conditions throughout the community. Dominant species often produce the greatest biomass and usually appear to cover the most ground area.

KEY TO NATURAL TEMPERATE GRASSLAND

1 Tussock-forming species from any of the following genera dominate the native graminoid component of the field layer: A*ustrodanthonia, Austrostipa, Bothriochloa, Chloris, Enteropogon, Lomandra, Poa* or *Themeda* 2

1a The native graminoid component of the field layer is not dominated by any of the above genera ..... not NTG
(eg. pasture or grassland derived by clearing forest or woodland)

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2 Trees and/or shrubs absent or very sparse (ie. less than 1 tree or shrub per hectare, or less than 10% projective foliage cover of emergent[4] trees or shrubs, or the inter-crown distance is more than three times the mean crown diameter) and the site has not been cleared of naturally-occurring trees within the last 20 years (evidence of former tree presence may include remnant stumps) 3

2a Tree cover greater than above or tree cover has been less than above for less than 20 years ..... not NTG
(eg. woodland or recently-derived grassland)

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3 Introduced plant species comprise less than 70% of the total vegetation cover in spring or less than 50% of the total vegetation cover at other times 4

3a Introduced plant cover not as above and dominating the native component.... not NTG

(degraded)

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4 The area is not inundated (ie. ground surface under water greater than 1 cm depth) for more than one month per year [5] or does not contain a high proportion of wetland taxa, notably Cyperaceae, Juncaceae, *Marsilea, Mimulus, Pratia*, or *Lobelia*, and is not dominated by wetland grasses, notably *Amphibromus*, *Eragrostis australasica, Eragrostis infecunda, Glyceria*, *Phragmites*, *Pseudoraphis* or *Sporobolus mitchellii* 5

4a The area is subject to prolonged inundation annually (lasting more than 1 month) or supports a high proportion of the taxa listed in **4** (above) ..... not NTG
(wetland)

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5 The site is below 1 000 m above sea level on the mainland or below 600 m above sea level in Tasmania and the grassy component is not dominated by any of the following: *Chionochloa*, *Deschampsia*, *Trisetum* or *Poa costiniana, Poa fawcettiae, Poa*

[4] 'emergent' from the graminoid field layer
[5] excluding exceptional flooding events

hiemata, Poa petrophila, Poa phillipsiana or *Poa saxicola*, nor contains *Celmisia, Drapetes, Oreobolus* nor *Trachymene humilis* 6

5a The site is either above 1 000 m above sea level on the mainland or above 600 m above sea level in Tasmania or the grassy component is dominated by any of the following - *Chionochloa*, *Deschampsia*, *Trisetum*, *Poa costiniana, Poa fawcettiae, Poa hiemata, Poa petrophila, Poa phillipsiana* or *Poa saxicola* or includes *Celmisia, Drapetes, Oreobolus* or *Trachymene humilis* ..... not NTG (sub-alpine, alpine)

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6 The site receives a mean annual rainfall greater than 350 mm and the mean annual rainfall is not summer-dominated (ie. with the wettest month three times the rainfall of the driest [winter] month) or (if the rainfall statistics are unknown) the following grasses do not occur commonly in the field layer - *Aristida*, *Astrebla, Chrysopogon, Cymbopogon, Eragrostis, Eulalia, Triodia*, *Zygochloa* or the grassy field layer is not dominated by *Dichanthium* 7

6a The site receives a mean annual rainfall less than 350 mm or the rainfall pattern is strongly summer-dominated (ie. with the wettest month three times the rainfall of the driest [winter] month) or (if the rainfall statistics are unknown) the following grasses occur commonly in the field layer - *Aristida*, *Astrebla, Chrysopogon, Cymbopogon, Eragrostis, Eulalia, Triodia, Zygochloa* or the grassy field layer is dominated by *Dichanthium* ..... not NTG (semi-arid, arid, sub-tropical)

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7 The area is noticeably saline, as is indicated by a variety of species largely restricted to saline and sub-saline habitats, notably any of *Austrostipa stipoides, Distichlis*, *Gahnia filum, Poa poiformis, Poa sallacustris, Puccinellia, Spinifex, Sporobolus virginicus, Zoysia macrantha* or Aizoaceae ..... not NTG (coastal saltmarsh, inland samphire)

7a The area is not noticeably saline ..... **Natural Temperate Grassland**

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2. Natural Temperate Grassland Ecological Communities as defined by the Interim Biogeographic Regionalisation of Australia (IBRA)

2.1. Introduction

Discussion of Natural Temperate Grasslands has been grouped geographically, using the Interim Biogeographic Regionalisation of Australia (IBRA) (Thackway & Cresswell 1995), as this classification most suits the structure of previous grassland literature and the geographic distribution of Natural Temperate Grasslands. Management issues are often IBRA Bioregion specific and each region supports a certain internal consistency of climate and soils, and hence floristic composition. Furthermore, structuring grasslands by state, although convenient from a state legislative point of view, is not always relevant to the natural distributions of grassland communities (eg. the grasslands of the Western Basalt Plains of Victoria are quite different to grasslands of Victoria's Gippsland Plain and thus should be considered separately; the grasslands of the Victorian Riverina are most similar to more extensive stands north of the Murray River in NSW and share much less affinity with grasslands in southern Victoria). The grasslands are described using the following components:

Distribution

A description of the geographic extent (if known) of Natural Temperate Grassland in its current and pre-1750.

Description

The climate, rainfall, and soils are described for grasslands within each Bioregion. These factors may be basic determinants for the distributions of Natural Temperate Grasslands. Previously described grassland communities or assemblages that occur in each region, and fit the definition of Natural Temperate Grassland, are also noted.

Floristic Description

'Dominant' species refers only to those 'grasses' that are often most abundant in a vegetation community. In a grassland, these are most likely to be grasses that also dominate the community. 'Common herbs' are those non-grass species which are usually abundant (at least during their growing season) or conspicuous in the inter-tussock spaces of a grassland. 'Character' species are species that are largely restricted to a particular

vegetation community and also relatively common. 'Differential' species are those that are useful for distinguishing vegetation communities based on their presence, absence, growth form or abundance.

Plant species listed may not all occur in the same floristic assemblage (as usually described in the 'Description' section) but are representative species from Natural Temperate Grasslands in each Bioregion.

Nationally Significant Fauna

Within each bioregion, a list of nationally significant grassland fauna, that are listed as vulnerable, endangered or extinct under the *EPBC* Act, is provided.

Driving processes

Describes the main cause of treelessness (where known or postulated) and disturbances that maintain grassland. This section is, necessarily, somewhat speculative. It may provide a useful provocation to generate further research.

Threats

Lists threats identified in the literature as particularly relevant to the region. It is likely that all Natural Temperate Grasslands face a similar suite of threats (eg. inappropriate fire régimes, neglect, and weed invasion) but some will be peculiar to certain areas (eg. rice cropping on private land in the Riverina).

All Natural Temperate Grassland is under some threat to its long-term viability (Kirkpatrick *et al.* 1995). Degrading disturbances even occur in permanent reserves (Kirkpatrick *et al.* 1995). Many grassy remnants are also under severe and immediate threat due to their isolation and continuing changes in land use and land management practices (Tremont & McIntyre 1994). As a result of discontinuation of Aboriginal and faunal impacts, structural and floristic changes may have already occurred in many remnants (Tremont & McIntyre 1994). Alteration of species composition and community structure also occurs via heedless management practices and invasion by weeds. Other threatening processes include continuing urban expansion and clearance for agricultural purposes (Sharp & Shorthouse 1996; Williams *et al.* 2001). The impacts of these threats have often been exacerbated by a general (although now largely historical) lack of interest, while others are threatened by 'over-interest' where inappropriate tree-planting in native grasslands reduces the richness of the grassy layer (Kirkpatrick *et al.* 1995).

All Natural Temperate Grasslands are threatened, although the extent to which individual grassland remnants are threatened may be a function of their size and suitability for development, and their proximity to urban land. Broadly, the threats facing grasslands are depletion, fragmentation, modification, and degradation through inappropriate land management practices. Lunt (1991) and Kirkpatrick *et al*. (1995) discuss a comprehensive list of threats in detail and the resultant management implications.

Ecological condition

Literature that specifically measures or describes the condition and/or viability of Natural Temperate Grasslands is noted. The condition of a site is inextricably linked to its ecological viability (ie. viability is a measure of the anticipated change in condition over time, sometimes incorporating an assessment of the desirability of that change). There is a lack of recent data on the condition of grasslands and a virtual absence of studies pertaining to ecological viability.

Ecological viability is a complex concept and there are no set guidelines with which to measure it. Ecological viability could be based on any number of attributes of a site depending on the available resources (Carter 1998). An obvious difficulty is that viability implies maintenance over time and few long-term studies exist for grasslands (except perhaps Lunt & Morgan 1999). However, information on several ecological characteristics of a site, along with current ecological knowledge, can be used to form a qualitative assessment of the likelihood of vegetation community persistence. Examples of useful characteristics are the extant vegetation structure, patch size and threats. It is important to recognise that a viable site is not necessarily one that is in excellent condition but one that can persist into the future in either the current condition or some improvement of it.

Distinctive characteristics that define this component

All Natural Temperate Grasslands that are included within the definitions given in section 1 are structurally, and environmentally similar enough to be described as a broad ecological community. However, this broad ecological community[6] can be subdivided into a number of distinct components, or other communities, that share a narrow range of attributes such as local rainfall and temperate régime, soils, floristic composition, threats and/or driving processes. This section highlights the characteristics of each component (ie. bioregion) that make it ecologically distinct from other components, and refers to Natural Temperate

[6] As previously discussed, 'community' is an intentionally imprecise term that is not included in any ecological hierarchy or taxonomy, unlike terms such as 'alliance', 'association' or 'formation', all of which have precise definitions.

Grassland components with which it has the most ecological affinities. In many bioregional components this field remains empty, due to a lack of research or published discussion.

Conservation status

This is described using the criteria established by the Threatened Species Scientific Committee. The conservation status is assessed and a justification provided. All estimations of pre-1750 and extant area of Natural Temperate Grasslands should be treated with caution, as figures are usually derived from incomplete survey information. In addition, estimations are usually based on a different interpretation of what constitutes native grassland vegetation, and those interpretations are only rarely directly transferable to Natural Temperate Grassland as defined in this report. However, until further comprehensive studies have been completed, the estimated extent of Natural Temperate Grassland within each Bioregion is based on the best available figures describing the most similar vegetation types with comments as to accuracy of figures in relation to Natural Temperate Grasslands.

Conservation status is not solely determinable from the land tenure of a site. For example, many sites within Flora Reserves or National Parks may be inappropriately managed for their grassland values and thus the grassland conservation status is not ensured and may be degraded (Kirkpatrick & Gilfedder 1995).

Mapping available

This outlines digital mapping that has been completed, or is being completed, for the distribution of pre-1750 and extant Natural Temperate Grasslands.

Gap analysis for research

This section highlights research gaps pertaining to grassland mapping or grassland ecology, derived from literature sources and personal communication with grassland experts.

Although considerable research has been conducted on Australia's temperate grasslands in the last 30 years or so, there is still much to be done, particularly relating to the process and function aspects of grasslands, as well as more applied studies relating to management and distribution. The level of knowledge and quantity of information varies between the states and territories, and for this reason research priorities should be considered on a jurisdictional basis. Some documents suggest priority areas for future research (Tremont & McIntyre 1994; Wellington 1996), however these are already somewhat out of date and do not consider projects completed or instituted in recent years. In addition to literature surveys for

the latest reports and papers describing research gaps, personal communication with grassland experts has identified current research needs.

2.2. Brigalow Belt South

The name of this regional component of Natural Temperate Grassland
Grasslands of the Liverpool and Moree Plains in NSW

This name follows the TSSC's guidelines for naming national ecological communities. It incorporates the major vegetation type and indicates the geographic location.

2.2.1. Distribution

The Liverpool Plains are centred on the town of Gunnedah, in northern New South Wales, and stretch from Boggabri in the north to Quirindi in the south-east (Sim & Urwin 1984). Prior to European settlement the Liverpool Plains contained Australia's largest occurrence of *Austrostipa aristiglumis*-dominated Grassland, however most of this has been destroyed by agricultural development.

"The natural range of *A. aristiglumis* extends from the northern part of the Darling Downs in south-eastern Queensland, through the western slopes and plains of New South Wales and the north-eastern quarter of Victoria, to Yorke Peninsula in South Australia." (Sim & Urwin 1985, p25). It is difficult to accept this statement without critical evaluation. Whilst the species *A. aristiglumis* has a wide distribution, from south-eastern Queensland to South Australia, there is no extensive grassland community in Victoria or South Australia dominated by *A. aristiglumis.* *A. aristiglumis* is merely a component of other Natural Temperate Grasslands in those states. In addition, *A. aristiglumis* is rare in north-eastern Victoria. The distribution of *A. aristiglumis* and the grassland community it dominates are clearly not synonymous. Nevertheless, this assessment is made all the more difficult because the community '*A. aristiglumis* Grassland' is nowhere well, or even adequately, defined. Grasslands dominated by *A. aristiglumis* do not occur anywhere in arid Australia.

The pre European extent of Liverpool Plains Grassland is estimated to be 270 000 ha, or approximately 39% of the Liverpool Plains region. This is based on Sim and Urwin's (1984) 260 000 ha estimate of native grassland extent plus 10 000 ha added to include the northern outlier in the Moree Plains Shire. The current extent is estimated to be 25 000 ha (9.25% of pre-European extent). Most of the remnants of grassland mapped by Sim and Urwin (1984) have since been ploughed. It is not yet certain whether the Moree Plains grasslands are reasonably considered 'temperate' (*sensu* the definition presented in the current document) as the rainfall régime is summer-dominated and the floristic composition of remnant stands

includes many taxa with subtropical affinities, such as *Homopholis* and *Dichanthium*. Description and precise definition are required.

2.2.2. Description

Natural Temperate Grassland in the Brigalow Belt South Bioregion is restricted to the Liverpool Plains Province, which occur on the north-western slopes of New South Wales (Sim & Urwin 1984). The Liverpool Plains cover around 700 000 ha and occur on flat plains and low slopes on unconsolidated Quaternary alluvium (Sim & Urwin 1984). Natural Temperate Grasslands occur on deep, self-mulching, brown-black alluvial cracking clay soils (vertisols) on Tertiary basalt (Sim & Urwin 1984). Annual median rainfall is 500 – 650 mm (Sim & Urwin 1984).

Very little published information exists on the Natural Temperate Grasslands of the Brigalow Belt South Bioregion (except see Sim & Urwin 1984). As a result, much of the information in this section is based on unpublished research being conducted by John Benson (Royal Botanic Gardens, Sydney).

2.2.3. Floristic Description

The following grass dominates Natural Temperate Grasslands in the Brigalow Belt South Bioregion:

- *Austrostipa aristiglumis* (on the Liverpool Plains this species can form stands in which it is the sole dominant, hence the common name Liverpool Plains Grass).

Sub-dominant grasses include:

- *Austrodanthonia bipartita*
- *Dichanthium sericeum*
- *Themeda avenacea*

Characteristic forbs include:

- *Asperula conferta*
- *Haloragis heterophylla*
- *Leptorhynchos panaetioides*
- *Vittadinia cuneata*
- *Wahlenbergia communis*

2.2.4. Nationally Significant Fauna

Information regarding nationally significant grassland fauna has not yet been collated.

2.2.5. Driving processes

As at 1984, there was little known about the ecology of *Austrostipa aristiglumis*-dominated grassland or the dominant species itself (Sim & Urwin 1984). Species richness in Natural Temperate Grasslands tends to depend on grazing and/or ploughing history. Grassland sites are now rarely burnt, although it is likely that grassland was previously burnt by Aboriginals.

2.2.6. Threats

The main threats to Natural Temperate Grassland in the Brigalow Belt South Bioregion are:

- Clearing and ploughing for crops (particularly wheat and cotton) on previously grazed Natural Temperate Grassland
- Lack of reservation
- Dryland salinity
- Weed invasion (notably *Ammi majus, Aster subulatus, Lycium ferocissimum* and *Phalaris paradoxa*)
- Soil erosion
- Open cut coal mining in the Gunnedah Basin Region
- Grazing
- Fragmentation

2.2.7. Ecological condition

No published information exists on the condition or viability of Natural Temperate Grassland in the Brigalow Belt South. However, field checking by J. Benson in 2001 suggested that many sites are in poor health as structure and/or composition have been severely altered. Natural regeneration is likely for many sites if secondary impacts are removed and dynamic processes reinstated.

2.2.8. Conservation status proposed under the *EPBC* Act

Endangered

Note: The *Stipa aristiglumis* (syn. *Austrostipa aristiglumis*)-dominated grasslands of the Liverpool Plains in NSW have already been nominated as an endangered ecological community under the EPBC Act, by the NSW Scientific Committee.

Criterion 1 – Decline in geographic distribution

It is estimated that only 9.25% of the pre-European extent of Liverpool Plains Grassland remain (ie. 25 000 ha remaining of 270 000 pre-1750). The pre-1750 estimate is based on the extent of land units described in Sim & Urwin (1984) that contain native grassland (260 000 ha), plus 10 000 ha of native grassland in the Moree Plains (Hunter & Earle 2001). The figure for extant Natural Temperate Grassland is based on expert estimate and further mapping is required to produce a more accurate figure.

"*The almost pure stand association in which the species characteristically occurred on the Plains is seriously threatened and faces reduction to small isolated patches. This form of* Austrostipa aristiglumis *Grassland has a very limited distribution and is mainly confined to the Liverpool Plains, with lesser and widely scattered occurrences in the Macquarie region and in districts to the north and west of the state*" (Beadle (1948) cited in Sim & Urwin (1984), p29). *A. aristiglumis* grassland, which comprise most Natural Temperate Grassland in this Bioregion, was already threatened in 1984, and those sites surveyed by Sim and Urwin (1984) have since been ploughed and very few sites remain.

Criterion 2 – Small geographic distribution coupled with demonstrable threat

A. aristiglumis grassland is seriously threatened and reduced to small isolated patches (Sim, 1984). According to the conservation risk code assigned by Benson (1989), the *A. aristiglumis*-dominated community of the Liverpool Plains is endangered and likely to become extinct within the next few decades is remaining sites are not conserved and appropriately managed. Livestock grazing and cropping have largely contributed to the reduction in this vegetation community (Benson, 1989) and the lack of strict clearing controls is likely to have permitted more recent clearing.

2.2.9. Mapping available

The grasslands of the Liverpool Plains are scheduled to be mapped at 1:25 000 or 1:50 000 scale (topographic maps change over scale in middle of region) between 2002 and 2004 by John Benson and Chris Allen, Royal Botanic Gardens, Sydney.

2.2.10. Gap analysis for research

The community dominated by *A. aristiglumis* is largely undefined and inadequately described. It should be characterised and its distribution mapped (including condition assessment of remnant stands). There has been no targeted research into the ecology of Natural Temperate Grasslands on the Liverpool Plains. However, there are plans to establish long-term vegetation monitoring sites in Liverpool Plains grasslands.

2.3. Flinders Lofty Block

The name of this regional component of Natural Temperate Grassland

Temperate *Lomandra* / *Austrostipa* / *Austrodanthonia*-dominated grasslands of the Flinders Lofty and Kanmantoo Bioregions

This name follows the TSSC's guidelines for naming national ecological communities. It incorporates the major vegetation type, the co-dominant herbs, *Lomandra, Austrostipa* and *Austrodanthonia*, and the geographic location.

2.3.1. Distribution

Lomandra-dominated grasslands are very widespread in the temperate region of South Australia, occurring throughout the southern portion of the Flinders Ranges and stretching further south into the Mt Lofty Ranges (Hyde 1995). Examples are present along the Hummocks, in the Mallala district and on the northern Adelaide Plains. Prior to European settlement, these grasslands also occurred along the western foothills of the Mount Lofty Ranges onto the central and southern Adelaide Plains, occasionally as subordinate stratums in very open woodlands.

Natural Temperate Grasslands dominated by *Lomandra effusa* also occur at the eastern edge of the Kanmantoo Bioregion, extending south towards Strathalbyn (Hyde 1995). Outliers of *Lomandra effusa* grasslands also occur near Murray Bridge and Tailem Bend in the Murray Darling Depression Bioregion (Hyde 1995). Although not within the Flinders Lofty Bioregion, these grasslands form an apparently natural southerly continuation of Natural Temperate Grassland and may best be described in this section.

2.3.2. Description

The *Lomandra effusa* grasslands and the *Lomandra multiflora* / tussock grass complex that have been identified by Hyde (1995) form Natural Temperate Grasslands in the Flinders Lofty Block Bioregion. Natural Temperate Grassland vegetation is mostly restricted to areas where annual rainfall is between around 300 mm and 600 mm and grows in the more fertile clays and loams to sandy loams (Robertson 1998). The *Lomandra multiflora* / Tussock Grass Complex occurs throughout the Mount Lofty Block, in the southern portion of the Flinders Ranges and the Upper South-East. The *Lomandra effusa* grasslands are distributed at least as far north as Robertstown, and then follow the eastern edge of the Mount Lofty Ranges south as a narrow band (Hyde 1995). They occur scattered around Callington,

south to Lake Alexandrina, and on the eastern bank of the Murray River between Mannum and just south of Tailem Bend (Hyde 1995) and on the floor of the Bremer River Valley and west at a mine site at Kanmantoo (Hyde 1995).

At the southern end of the region, a vegetation community described as the Murray Lakes Grasslands previously occurred. This community is now extinct and was probably dominated by *Austrodanthonia semiannularis* and *Austrostipa setacea* (Hyde 1995).

Some 'grassy' communities identified by Hyde (1995) were not considered Natural Temperate Grassland because they did not fit the definition provided in the current report. For example, the *Austrostipa nitida* / *Gahnia lanigera* 'Grasslands' are generally excluded because of a very high sedge component and clear affinities with semi-arid mallee vegetation, and the Nardoo Herbfields are not Natural Temperate Grassland because they are frequently inundated. However, these and other excluded grassland floristic assemblages can be variable in their species composition and some sites may be reasonably considered as Natural Temperate Grasslands. For example, degraded *Allocasuarina*-dominated Woodlands are generally not Natural Temperate Grassland because the most common grass, *Themeda triandra*, does not occur as frequently as other species of trees and shrubs such as *Allocasuarina verticillata* and *Acacia continua*. However in some areas, tree and shrub cover may be low enough to consider the site to be Natural Temperate Grassland. Grasslands in 'temperate' South Australia that are not dominated by *Lomandra* spp. should be surveyed to determine their inclusion in, or exclusion from, the definition of Natural Temperate Grassland.

2.3.3. Floristic Description

The following grasses (plus *Lomandra*) can co-dominate Natural Temperate Grasslands in the Flinders Lofty Block:

- *Aristida behriana*
- *Austrodanthonia caespitosa*
- *Austrostipa nitida*
- *Lomandra effusa*
- *Lomandra multiflora* subsp. *dura*
- *Themeda triandra*

Common herbs include:

- *Arthropodium strictum*
- *Chrysocephalum apiculatum*

- *Convolvulus erubescens*
- *Crassula sieberiana* subsp. *tetramera*
- *Dianella revoluta* sens. lat.
- *Goodenia pusilliflora*
- *Oxalis perennans*
- *Podolepis tepperi*
- *Ptilotus spathulatus*

2.3.4. Nationally Significant Fauna

Pedionomus torquatus (Plains-wanderer) - vulnerable

Tiliqua adelaidensis (Adelaide Pygmy Bluetongue Lizard) - endangered

2.3.5. Driving processes

There are no published studies of the ecology of South Australian temperate grasslands, however there is a few biological surveys of grassland vegetation that could provide a suitable basis for studies of specific ecological processes (Hyde 1995; Robertson 1998; Hyde 1999; Hyde & Mathison 2001). The methodological framework used to study process and function in Australian rangelands (especially in South Australia) could also be applied to studies of Natural Temperate Grassland in South Australia (Ludwig *et al.* 1997).

2.3.6. Threats

Threats to Natural Temperate Grassland in the Flinders Lofty Block include:

- Lack of reservation in secure reserves with appropriate management
- Damage from prescribed fire (so-called 'fuel reduction' *sic*) and road-work activities along road or rail corridors
- Heavy grazing
- Invasion by introduced species such as *Avena barbata*, *Echium plantagineum*, *Salvia verbenaca*, *Gynandriris setifolia* and *Vulpia myuros*.

2.3.7. Ecological condition

There are no published studies that describe the ecological viability of Natural Temperate Grassland in South Australia. However, indications are that, unless urgent conservation action is taken, many examples of *Lomandra effusa* grassland will disappear (Hyde 1995). The remnants of *Lomandra effusa* grassland between Eudunda and Palmer are discontinuous, as much of this former community has been destroyed by cultivation (Hyde 1995). The remnants are badly degraded as a result of livestock grazing. Likewise, the

Lomandra multiflora / tussock grass complex requires reservation before species losses from the few remaining examples are irreversible (Hyde 1995).

2.3.8. Conservation status proposed under the *EPBC* Act

Critically endangered

Criterion 1 – Decline in geographic distribution

It has been estimated that over 1 500 000 hectares of temperate open grassland or very open grassy woodland existed in South Australia prior to European settlement (Hyde 1995). As of 1995, less than 5 000 hectares (<0.33%) of these communities remain (Hyde 1995). There are no firm estimations of the decline of the two vegetation communities identified by Hyde (1995) (or the proportion of the extant 5 000 ha of grassland that is made up by them) that are included in this definition of Natural Temperate Grasslands. However, much of the *Lomandra multiflora* / tussock grass complex has been cultivated and the community is now largely confined to narrow road and rail corridors (Hyde 1995). The *Lomandra effusa* grasslands have been eliminated from most sites suitable for cultivation for crops (Hyde 1995), and have been considered to be one of South Australia's top five plant communities most requiring conservation action (Davies 1983).

2.3.9. Mapping available

Pre-European mapping in of Natural Temperate Grassland in the Flinders Lofty Block Bioregion has been conducted for the Mid North region at 1:40 000. Further pre-1750s mapping is scheduled for the Southern Mount Lofty region (expected completion: 2003) by the Department for Environment and Heritage with field work to be done by Biodiversity Survey and Research, Department for Environment and Heritage, South Australia. Digital work will be conducted by the Environmental Analysis and Research Unit, within the Department for Environment and Heritage, South Australia.

To date, no funding exists for the mapping of Western Murray Flats region between South Mount Lofty and Murray River) nor for the area south and north of existing Mid North mapping. However, based on changes in priorities, separately funded projects could be undertaken to perform this mapping. Until this pre-European mapping is finished for the agricultural districts, no overall estimate of the area of original grassland extent can be accurately determined.

Extant mapping of areas containing Natural Temperate Grasslands in South Australia has been completed by the Department of Environment and Heritage, South Australia at 1:40 000.

Michael Hyde has also mapped areas of Natural Temperate Grassland in the Flinders Lofty Block (including the Bremer-Barmah Catchment) and the results are discussed in a report (Hyde 1999).

2.3.10. Gap analysis for research

Further research is needed to establish the relationship between the 'true' grasslands, and the very similar grassy field layers which intergrade throughout temperate South Australia (Hyde 1995). South Australia's Natural Temperate Grasslands are poorly known and all require further ecological research (Hyde 1995). Some relevant work is being conducted by a community group based in the Mid North of South Australia (Mid North Grasslands Working Group), who are undertaking an extensive study of appropriate grazing régimes for the conservation of native grasslands. This project began in 2000 and includes data collection and grazing manipulations at 8 sites across the Mid North. The study addresses a number of the key research priorities for South Australia. Further research and monitoring is occurring at Mokota Conservation Park to investigate appropriate grassland management within protected areas. The existence, composition end ecological relationships of purported Natural Temperate Grassland on Eyre Peninsula require characterisation.

2.4. Murray-Darling Depression

The name of this regional component of Natural Temperate Grassland
Wimmera Plains Grassland

This name follows the TSSC's guidelines for naming national ecological communities. It incorporates the major vegetation type and the geographic location.

2.4.1. Distribution

The fertile soils of the Western and Central Wimmera Plains of Victoria formerly supported grasslands (an *Austrostipa-Austrodanthonia* association) and grassy woodlands (Connor 1966; Morcom & Westbrooke 1998). It has also been suggested that *Themeda triandra* may have been a structural dominant in Wimmera grasslands (Connor 1966).

McDougall and Kirkpatrick (1993) recorded 10.35 ha of native grassland in the Southern Wimmera, mostly forming parts of Creswick Swamp. A 12 ha road reserve in Birchip was identified in the Northern Wimmera (McDougall & Kirkpatrick 1993). Early maps show extensive treeless plains north of Horsham and in the Avon–Richardson River system (McDougall & Kirkpatrick 1993).

The distribution of Natural Temperate Grassland in the Murray-Darling Depression outside the Wimmera is not well described. Grasslands north of the Wimmera in Victoria become semi-arid as mean annual rainfall drops below 350 mm and are excluded from the definition of Natural Temperate Grasslands. Scattered Natural Temperate Grasslands may occur as outliers to the west of the Riverina Bioregion or to the east of the Lofty Block Bioregion. A small area of Grassy Woodlands, and possibly Natural Temperate Grassland, occurred west of the Victoria – South Australia border near Bordertown, but this has all been cleared for agriculture. Further studies are required to determine occurrences, if any, in these areas.

2.4.2. Description

Few studies have described the Natural Temperate Grasslands of the Murray-Darling Depression, except for (except see Connor 1966; McDougall & Kirkpatrick 1993; Marriott & Marriott 1996, 1997; Morcom & Westbrooke 1998), which describe grasslands (not necessarily Natural Temperate Grasslands *sensu* the current report) in the Wimmera Region of Victoria. In the Wimmera mean annual rainfall ranges from about 375 mm near Birchip to 450 mm at Horsham (Connor 1966; McDougall *et al.* 1993). Soils tend to be grey, red-brown

and brown clays (gleys) of heavy texture and a highly self-mulching surface (Connor 1966). Natural Temperate Grassland may also exist in the Southern Wimmera between Horsham and Donald, on light to medium, red to red-brown alkaline clays with gilgai relief (McDougall *et al.* 1993).

2.4.3. Floristic Description

The following grasses dominate Natural Temperate Grasslands in the Wimmera:

- *Austrodanthonia caespitosa*
- *Austrodanthonia setacea* var. *setacea*
- *Austrostipa scabra*
- *Austrostipa nodosa*
- *Enteropogon acicularis*

Other common herbs include:

- *Arthropodium minus*
- *Calocephalus citreus*
- *Chrysocephalum apiculatum*
- *Goodenia pinnatifida*
- *Leptorhynchos squamatus*
- *Pelargonium rodneyanum*
- *Ptilotus macrocephalus*
- *Rhodanthe corymbiflora*
- *Sida corrugata*
- *Swainsona murrayana*

2.4.4. Nationally Significant Fauna

Delma impar (Striped Legless Lizard) - vulnerable

2.4.5. Driving processes

There is no literature description of the processes that maintain the Natural Temperate Grasslands of the Murray Darling Depression. Natural Temperate Grasslands were probably maintained by regular burning by Koori Aboriginals before European settlement, however there is only anecdotal information to support this supposition (Coutts 1977; Calder 1997). Most of the landscape has been converted to cropping, with the attendant destruction of native grassland communities (or stratums within woodlands). Exceptionally, small areas were not cleared and ploughed, and infrequent and light grazing by sheep or cattle maintained the most native-species-rich sites, particularly where fire has been excluded.

The extent of existing grasslands that are derived from woodland, shrubland or forest clearing, and then maintained by livestock grazing, is not clear.

2.4.6. Threats

- weed invasion
- inappropriate management
- lack of adequate reservation and protection
- Tree-planting
- Lack of local knowledge of the importance of grassland
- Disturbances associated with roadworks
- Cropping

2.4.7. Ecological condition

Two reports on 41 private properties containing 'grasslands' (ie. not necessarily consistent with Natural Temperate Grassland *sensu* the present report) in the Wimmera portion of the Murray-Darling Depression describe site conditions and provide recommendations for management to maintain viability (Marriott & Marriott 1996, 1997). Sites vary greatly in condition from poor to excellent. Sites surveyed in these reports were biased towards properties whose owners were forthcoming in permitting flora surveys.

The few surveyed by McDougall *et al.* (1993) identified threats and reservation status but did not specifically describe condition or viability.

2.4.8. Conservation status proposed under the *EPBC* Act

Critically Endangered

Criterion 1 – Decline in geographic distribution

Only 0.2% of the original cover of Grassland Broad Vegetation Type (a mapping unit that describes vegetation at 1:250 000 scale and is not consistent with Natural Temperate Grassland *sensu* the current report) remains in the Murray Mallee region within the Murray-Darling Depression Bioregion in Victoria. The (Victorian) Department of Natural Resources and Environment mapping determined that only 1 244 ha remained of the 440 460 ha that occurred prior to European settlement. Without more detailed survey and mapping it is difficult to provide a more reliable estimate. Although there are obvious overlaps, it is unclear as to what proportion of Grasslands Broad Vegetation Type is Natural Temperate Grassland.

2.4.9. Mapping available

Pre-1750 vegetation reconstructions and extant mapping of the Victorian portion of the Murray-Darling Depression have not been completed at a scale greater than 1:250 000. However, a mapping project has commenced (in 2002) that will survey and map vegetation in the Murray-Darling Depression at 1:100 000 scale. That project will be conducted by the Arthur Rylah Institute for Environmental Research, Ecology Australia and Spatial Vision.

2.4.10. Gap analysis for research

There is a lack of information on the nature and extent of remnant grasslands in the Wimmera including very little published material on the subject, whether of the flora or the fauna (Marriott & Marriott 1996). Further research is also required to deal with the control of weeds that threaten the integrity of many grassland remnants (Marriott & Marriott 1997).

2.5. Riverina

The name of this regional component of Natural Temperate Grassland
Murray Valley Grassland

This name follows the TSSC's guidelines for naming national ecological communities. It incorporates the major vegetation type and the geographic location.

2.5.1. Distribution

The native grasslands of New South Wales are bounded by: Urana in the south-east, Deniliquin in the south-west, Hay in the north-west, and Narrandera in the north-east (Benson *et al.* 1997). Outlying patches may be present on low-lying plains, such as Bullendbong Plain east of Lockhart (Benson *et al.* 1997). A plant community dominated by *Chloris truncata* and *Austrodanthonia semiannularis* occurs on level country in the southern portion of New South Wales on heavy soils, after late winter or spring rains (Beadle 1948). This community may be derived from chenopod shrublands (eg. dominated by *Atriplex vesicaria*; (Beadle 1948) and very few sites remain.

In Victoria, native vegetation no longer exists in irrigation areas and is confined to small public land reserves and private property outside irrigation areas. The *Austrodanthonia setacea*-dominated community described by McDougall *et al*. (1993) stretches from the western Northern Plains of Victoria to Moama, just over the New South Wales border (McDougall *et al.* 1993).

2.5.2. Description

Natural temperate grasslands occur in the Riverina Bioregion on the Northern Plains of Victoria and on the south-western Plains of New South Wales (the New South Wales and Victorian sections are together termed the Riverine Plain). The two areas are often described separately (except see Todd 1998). Therefore, the two sub-components; Victorian Northern Plains and New South Wales Riverine Plains, will be generally described separately. These two sub-components are geographically isolated, although they are essentially part of the same ecosystem (Foreman 1996). Hence any floristic differences are likely to have arisen from different land use histories rather than environmental differences.

It has been suggested that the grasslands of the Riverine Plains of New South Wales are derived from chenopod shrublands and Myall (*Acacia pendula*) open woodland (Moore 1953a). However, consideration of Plains-wanderer habitat preferences (see Baker-Gabb

1990) has lead to suggestions that original chenopod shrubland vegetation must have been patchy, with the birds occupying the open areas of sparse grassland between shrub-dominated patches (Benson *et al.* 1997). Until there has been a thorough study of vegetation processes in the New South Wales Riverine grasslands, their categorisation as disclimax should be abandoned (McDougall *et al.* 1993). The region of New South Wales where Natural Temperate Grasslands are now confined experiences hot summers and cool winters with the mean summer maximum reaching over 30^{o} C and mean winter minimum down to 5^{o} C (Benson *et al.* 1997). The mean annual rainfall is about 400 mm in the region and receives a slight winter to spring maximum, with occasional and unpredictable summer rainfall (Benson *et al.* 1997). New South Wales Riverine Plain grasslands are mainly restricted to red-brown clays and grey-brown clays (Moore 1953a).

Natural Temperate Grassland was originally present south of Echuca on the Victorian section of the Riverine Plain, but only patches remain in the 400 to 450 mm annual rainfall zone (McDougall & Kirkpatrick 1993). The Natural Temperate Grasslands in Victoria's Northern Plains occur in areas presumed to be treeless and largely lacking tall shrubs at the time of European settlement, and for this reason they are considered different from the New South Wales Riverina grasslands (Lunt *et al.* 1998). The main assemblage in the Victorian Northern Plain may be that described by McDougall *et al*. (1993) as community R1.1, which is frequently dominated by *Austrodanthonia setacea*. The recently declared Terrick Terrick National Park, which lies about 40 km west of Echuca in Victoria, probably contains the largest area of Natural Temperate Grassland on the Victorian Northern Plains (1 200 ha), dominated by *Austrodanthonia* spp. and *Austrostipa* spp. (Parks Victoria 2001).

2.5.3. Floristic Description

The New South Wales and Victorian Natural Temperate Grasslands in the Riverina Bioregion share strong floristic similarities, although they may have been quite different before European settlement (McDougall *et al.* 1993). Before European settlement, New South Wales Riverine Plains grasslands were possibly dominated by *Themeda triandra* but many areas likely had a more substantial cover of *Acacia pendula* and *Atriplex nummularia* (McDougall *et al.* 1993). Both of these species are now uncommon in the Riverina.

The following grasses now dominate Natural Temperate Grasslands in the Riverina Bioregion:

- *Austrodanthonia caespitosa*
- *Austrodanthonia duttoniana*
- *Austrodanthonia eriantha*

- *Austrostipa aristiglumis*
- *Austrostipa nodosa*
- *Chloris truncata*
- *Enteropogon ramosus*
- *Themeda triandra*

Other common herbs in the Riverina Bioregion include:

- *Arthropodium minus*
- *Bulbine bulbosa*
- *Calotis anthemoides*
- *Crassula decumbens*
- *Convolvulus erubescens*
- *Hypoxis glabella*
- *Isoetopsis graminifolia*
- *Leucochrysum molle*
- *Pycnosorus globosus*
- *Stackhousia monogyna*
- *Rhodanthe corymbiflora*
- *Rumex dumosus*
- *Sida corrugata*
- *Swainsona plagiotropis*
- *Wahlenbergia gracilenta*

2.5.4. Nationally Significant Fauna

Delma impar (Striped Legless Lizard) - vulnerable

Pedionomus torquatus (Plains-wanderer) – vulnerable

Areas of Natural Temperate Grassland in the New South Wales Riverine Plain also provide suitable habitat for the Plains-wanderer (*Pedionomus torquatus*) (Baker-Gabb 1998). Suitable grassland habitat tends to be those having:

- around 50% bare ground, with no more than 10% leaf litter,
- two layers of vegetation with most (94%) in the lower layer,
- the lower layer less than 5 cm in height, and
- the upper layer rarely exceeding 5 cm in height with tussocks spaced between 10-20 cm (Baker-Gabb (1990) cited in Benson *et al.* 1997).

2.5.5. Driving processes

The common consensus (Moore 1953a, b; Portners 1993; Benson *et al.* 1997) is that the combination of increased total grazing pressure since European invasion, drought, clearing and wildfire has resulted in a range of 'disclimax communities' in the New South Wales Riverina. However, this view is supported by little quantitative or anecdotal evidence (see Beadle 1948; Moore 1953a; Portners 1993). An alternate view is that natural events such as drought, flood and fire (perhaps in sequence or combination) may have triggered periodic changes from woodland and/or shrubland to grassland and that these disturbance promoted grasslands (McDougall *et al.* 1993; White in prep.).

Although fire is known to play an important role in maintaining species diversity in some grasslands (Lunt & Morgan 2001), fire is relatively infrequent on the Riverine Plain and its impacts largely unknown (Benson *et al.* 1997). Fire may be a useful management tool with further study of its role in biomass reduction and seed germination (Benson *et al.* 1997).

2.5.6. Threats

- Local ignorance of the values of Natural Temperate Grassland, which may lead to unintentional destruction of site values
- Tree-planting projects, sometimes as part of salinisation amelioration schemes. Although it may alter areas currently dominated by grasses, planting of *Acacia pendula* on the cracking clays on the New South Wales Riverine Plain where it was once common may be appropriate.
- Further extension of cultivation for either pasture improvement or crops such as rice
- Increased salinisation due to a rising saline water table caused by increased irrigation and the clearing of deep-rooted perennial vegetation. Since many of the native grasses are biannual or short-lived perennials and deep-rooted, their maintenance may help minimise future salinisation.
- Over-grazing

2.5.7. Ecological condition

The most native-species-rich Natural Temperate Grasslands on the New South Wales Riverine Plain tend to be those that are less disturbed (ie. not ploughed) (Benson *et al.* 1997). Sites containing rare species are more or less restricted to travelling stock routes and road reserves that have not been continuously heavily grazed or cultivated (Benson *et al.* 1997).

2.5.8. Conservation status proposed under the *EPBC* Act

Critically Endangered

Criterion 1 – Decline in geographic distribution

In the Victorian portion of the Riverina Bioregion, grassland complexes have been reduced to 0.7% of their pre-European extent and are considered endangered. This estimate is based on an assessment of the extent of Broad Vegetation Types (a vegetation unit mapped at 1:250 000) in the Victorian Riverina.

The Northern Plains Grassland Community, which is generally synonymous with Natural Temperate Grassland in this report, has already been listed as a threatened community under the Flora and Fauna Guarantee Act 1988 and less than 0.25% remain (Foreman 1997). According to McDougall *et al.* (1993), the *Austrodanthonia setacea*-dominated grassland assemblage (community R1.1), which covers much of the Victorian Northern Plains area of Natural Temperate Grassland, is reduced to approximately 0.75% of likely pre-1750 distribution (based on 1 871 of 250 000 ha at the time of European settlement). This estimate does not account for sites that may occur on unsurveyed private land or roadsides; their inclusion may press the total as high as 10 000 ha (4.0%) (Foreman 1997).

Community R1.2 (in McDougall *et al.* 1993) is a herb-dominated assemblage with the most dominant native grasses being *Austrodanthonia setacea, Enteropogon acicularis* or *Homopholis proluta* (the latter being a C_4 species of more northern (sub-tropical) affinities). This floristic assemblage has been reduced to less than 20% of its original distribution and the species-rich sites amount to an even smaller proportion (McDougall *et al.* 1993). Only 402.1 ha of this community were identified by McDougall *et al.* (1993).

Maps of the extent of Natural Temperate Grassland in the NSW Riverina before European settlement do not exist. There is considerable doubt as to the extent of grasslands in the NSW Riverina pre-settlement and doubt as to the proportion of the landscape that was formerly, or is currently, occupied by derived (c/f. 'original') grassland (as discussed above). Nevertheless, there is little doubt that substantial reductions in grassland extent have occurred and are likely in the near future (Moore 1953a, b; McDougall *et al.* 1993; Portners 1993; Benson *et al.* 1997).

2.5.9. Mapping available

The Northern Plains section of the Riverina Bioregion has not been adequately mapped. Paul Foreman surveyed grassland on private property in the Northern Plains and these data

have been digitised (Foreman 1996). It is likely that considerable areas of private land remain to be mapped. Much of the north-western region of Victoria is to be mapped to EVC level (1:100 000 scale) by the Arthur Rylah Institute for Environmental Research (ARI), Ecology Australia and Spatial Vision. The north-west mapping project will take in large tracts of Natural Temperate Grassland that occur(red) in the Wimmera and on the western parts of the Northern Plains and will incorporate pre-1750 and extant vegetation.

The New South Wales portion of the Riverina Bioregion has been mapped at 1:250 000, however this scale does not pick up many smaller patches (ie. around 4 ha or less) of Natural Temperate Grassland. Mapping of the Western Riverina in New South Wales is currently being conducted by a Department of Land and Water Conservation Mapping Team at 1:100 000 scale, but digital data were not available for inclusion on the attached map of Natural Temperate Grassland at the time of this report.

2.5.10. Gap analysis for research

Benson *et al*. (1997) outline some areas of future research in the New South Wales Riverine Plain. For example, mapping of grasslands is required for management (Benson *et al.* 1997). That mapping is now being completed (see 'mapping available' section above) and should be available around 2003.

Benson *et al*. (1997) also highlighted that future long-term monitoring of species changes in relation to climatic and disturbance factors would assist in management. Surveys of reptiles, mammals and invertebrates in the region are required to help refine conservation priorities (Benson *et al.* 1997).

2.6. South East Coastal Plain

The name of this regional component of Natural Temperate Grassland
Central Gippsland Plains Grassland

This name follows the TSSC's guidelines for naming national ecological communities. It incorporates the major vegetation type and the geographic location.

2.6.1. Distribution

The South East Coastal Plain Bioregion, which stretches from Melbourne in the west to Lakes Entrance in the East contained about 120 000 ha of savanna woodland and 60 000 ha of treeless grassland prior to European settlement (Lunt 1993). It is believed that pre-1750 treeless grasslands are now extinct and the derived Natural Temperate Grasslands (from grassy forests or woodlands) total between 13.5 ha (McDougall & Kirkpatrick 1993) and 25 ha. These can be found on the South East Coastal Plain between Seaspray and Welshpool and the head of Westernport Bay. Although probably derived from woodlands, these sites are considered Natural Temperate Grassland for the following reasons:

1. They are very similar to, and essentially indistinguishable from, otherwise putatively natural grasslands elsewhere in south-eastern Australia, and
2. the sites have been managed (intentionally or otherwise) as grasslands for a long time (certainly longer than the 20 years utilised in the key and definition presented in the current report).

The present areas of open, herb-rich grasslands occur almost exclusively on small areas of public land that have a history of frequent burning for fuel reduction *sic*. Small patches occur on rail lines and in local cemeteries and roadsides. Small patches have also been identified east of Lakes Entrance and in the south-eastern suburbs of Melbourne. There is a single patch of Natural Temperate Grassland dominated by *Themeda triandra* and *Austrodanthonia laevis* on French Island in Westernport Bay (Oates & Taranto 2001).

2.6.2. Description

The original pre-1750 ‘treeless’ grasslands are thought to be extinct (Lunt 1997a). The Natural Temperate Grasslands of the South East Coastal Plain are mainly dominated by *Themeda triandra* and are likely to be derived by tree clearance in woodlands, as a result of European settlement. The current grasslands occur on grey soils that are often seasonally waterlogged (Lunt 1997a) and derive from Upper Pleistocene alluvium of poorly drained,

heavy clays (Department of Natural Resources and Environment 1999). Mean annual rainfall is less than 650 mm (Department of Natural Resources and Environment 1999).

2.6.3. Floristic Description

Before European settlement, Natural Temperate Grasslands in Gippsland were probably dominated by *Themeda triandra* and/or *Poa labillardierei* (Lunt 1993).

The following grasses dominate Natural Temperate Grasslands in the South East Coastal Plain:

- *Austrodanthonia laevis*
- *Austrodanthonia semiannularis*
- *Poa labillardierei*
- *Themeda triandra*

Other common herbs include:

- *Chrysocephalum apiculatum*
- *Caesia calliantha*
- *Carex breviculmis*
- *Diuris punctata* sens. lat.
- *Hemarthria uncinata*
- *Hypoxis hygrometrica*
- *Juncus subsecundus*
- *Oxalis exilis*
- *Pentapogon quadrifidus*
- *Poa clelandii*
- *Schoenus apogon*

2.6.4. Nationally Significant Fauna

No nationally significant fauna are presently listed under the *EPBC* Act for the South East Coastal Plain.

2.6.5. Driving processes

Grazing by herbivores and Koori burning practices are likely to have maintained Natural Temperate Grasslands before European settlement. Following European settlement, different land-use histories, notably changes in grazing and burning régimes (Lunt 1997a), two grassland assemblages that now comprise Natural Temperate Grassland could be recognised; Forest Red Gum Grassy Woodland (a portion may have supported too many

trees to be Natural Temperate Grassland) and Central Gippsland Plains Grassland. These two assemblages have many species in common, but also contain different threatened species that have different management requirements.

2.6.6. Threats

- Isolation
- Weed invasion – by pasture species, cemetery garden waste, and invasion by native shrubs (eg. *Kunzea* spp. or *Melaleuca ericifolia*) on long-unburnt sites. Weed invasion by native shrubs can be attributed to the cessation of herbivore grazing ore browsing, and to a lack of burning.
- Inappropriate fuel reduction techniques (eg. slashing and mowing), particularly as part of railway maintenance works
- Lack of burning
- Overgrazing, particularly on disused rail lines and roadsides
- Roadside tree planting

2.6.7. Ecological condition

There is only one published study that describes the condition and viability of Natural Temperate Grassland sites in the South East Coastal Plain (Owen 1997). In that report, only one Natural Temperate Grassland site is described (site 2), which contains less than one hectare of 'disclimax' grassland, probably derived from dry sclerophyll forest. Other sites in the report are woodlands.

2.6.8. Distinctive characteristics that define this component

Natural Temperate Grasslands on the South East Coastal Plain are floristically distinguished from other Natural Temperate Grasslands in Victoria by an absence of *Swainsona* and *Ptilotus* spp.

2.6.9. Conservation status proposed under the *EPBC* Act

Critically endangered

Criterion 1 – Decline in geographic distribution

Pre-European Natural Temperate Grasslands on the Gippsland Plain are extinct (Lunt 1993). Current grassland remnants are derived from non-grassland vegetation and occur as isolated patches on roadsides, cemeteries and some private properties (Lunt 1993; Owen 1997). Due to the paucity of sites, each one makes important contributions to regional diversity

(Lunt 1997b). Only between 13.5 and 25 ha of Natural Temperate Grassland remain, which amounts to between 0.0002 and 0.0004% of the 60 000 ha of treeless plains that existed on the Gippsland Plains prior to European settlement (Lunt 1993; McDougall & Kirkpatrick 1993).

2.6.10. Mapping available

Pre-1750 and extant Natural Temperate Grassland was mapped at 1:100 000 on the South East Coastal Plain by the Department of Natural Resources and Environment (Department of Natural Resources and Environment 1999). Some unmapped private land sites may yet reveal Natural Temperate Grasslands, and further survey work is recommended.

2.6.11. Gap analysis for research

Although a number of studies has described Natural Temperate Grasslands in the South East Coastal Plain (Lunt 1993, 1997a; Owen 1997; Department of Conservation and Environment 1999; Department of Natural Resources and Environment 1999), and there is some understanding of processes that maintain them (particularly Lunt 1993, 1997a), there is a need for further studies to identify best-management practice of Natural Temperate Grasslands in this bioregion, so that the few sites remaining become ecologically viable.

2.7. South Eastern Highlands

The name of this regional component of Natural Temperate Grassland
Southern Tablelands Temperate Grassland

This name follows the TSSC's guidelines for naming national ecological communities. It incorporates the major vegetation type and the geographic location.

2.7.1. Distribution

The Monaro contains some of the few grasslands that comprise the 'upland' Natural Temperate Grasslands that occur between 700 and 1 000m above sea level. The Snowy Mountains cast a rain-shadow over the region resulting in a significant area receiving less than 500 mm mean annual rainfall. Above the 1 000 m threshold, heavier snowfalls occur and sites become much wetter. As a result, the grasslands have greater floristic affinities with alpine vegetation, such as a stronger component of *Poa* spp. (excluding *Poa labillardierei*).

In addition to the Monaro grasslands, similar vegetation may have occurred around Lake Omeo (near Benambra) in the Victorian High Country, within the South Eastern Highlands Bioregion. However, all these stands have been cleared for agriculture and only hints of their former occurrence remain.

It is estimated that 450 000 ha of native grassland occurred on the Southern Tablelands prior to European settlement (Benson 1994). This includes around 250 000 ha of native grassland on the Monaro Tablelands (Costin 1954), a further 20 000 ha in the ACT (ACT Government 1997), and a few hundred hectares in the Victorian section of the South Eastern Highlands (McDougall *et al.* 1993).

There are currently no reliable estimates of the current extent of Natural Temperate Grassland on the Southern Tablelands and estimates of extent on the Monaro are qualitative, however it is clear that only a small proportion of pre-European native grassland remains. Estimating the distribution of Natural Temperate Grasslands on the Monaro is particularly difficult because there is a very diffuse boundary between grasslands and grassy woodlands. Natural Temperate Grassland intergrades with grassy woodland on the slopes of the Southern Tablelands. Furthermore, ten thousand years ago all of the Monaro may have been grassland, with a slow natural increase in tree cover to the present (Hope 1989),

indicating an on-going gradual process of tree establishment that was interrupted by European settlement. A decline in *Eucalyptus pauciflora* cover in recent years has led to more (derived) grassland developing. As a result, a significant proportion of the savanna woodland mapped by Costin (1954) could now be considered Natural Temperate Grassland.

Estimates of Natural Temperate Grassland may not be extrapolated from estimates of "native grassland" extent, because studies of grassland in the Southern Tablelands have not separately identified grasslands produced by tree clearing (eg. Benson & Jackson 1993; McDougall *et al.* 1993; Benson 1994; ACT Government 1997) from pre-European Natural Temperate Grasslands. The inclusion of some of these 'native grasslands or pastures' under the definition of Natural Temperate Grassland in this report may therefore portray the community as less threatened. Estimates of the extent of Natural Temperate Grasslands that are rich in forbs and low in weeds (a possible reflection of livestock grazing history and/or topographic position), may be much lower. For example, excluding the large area of *Poa sieberiana*-dominated, semi-natural tussock grasslands on the basalt south of Cooma (often regarded as native pasture, and containing few inter-tussock forbs, except on rocky up-slopes (Dorrough 2001)), it is estimated that less than 1% of native grassland remains in good condition on the Monaro Tablelands (Benson & Jackson 1993). With the inclusion of the secondary *Poa sieberiana*-dominated grasslands the estimate would be much higher.

An important consideration on the Monaro is whether to include the 'native pastures'. A large proportion of the grasslands of the Monaro has been substantially modified and is dominated by only a few species of perennial grass (Benson 1994). When considering the threatened status of Natural Temperate Grassland in the South Eastern Highlands Bioregion, one should be wary of estimates of grassland extent that include these vast tracts of generally species-poor 'native pasture', as this may devalue the significance of the pre-European native grasslands. On the other hand, the ecological (or other) values of 'native pasture' in terms of habitat provision for fauna, corridors for species dispersal, soil stabilisation and retention of genetic diversity of some species, is not well documented on the Monaro. Thus, whilst they should be considered when conservation decisions and land management are being framed and implemented, they nevertheless may not be Natural Temperate Grassland *sensu* the definition in the current report. According to this definition, *some* 'native pastures' (ie. those that are not too weedy or recently derived from some other vegetation-type) will be included as Natural Temperate Grasslands. As we have not included conservation significance as part of the definition of Natural Temperate Grassland in the current report, it is reasonable/practicable to include some 'native pastures'.

A small area of (greatly disturbed) Natural Temperate Grassland occurs within the Victorian part of the South Eastern Highlands Bioregion, in the Lake Omeo / Benambra districts (classified as Montane Grassland Ecological Vegetation Class) (McDougall *et al.* 1993; Department of Natural Resources and Environment 1999). Also, an unmapped, species-rich Natural Temperate Grassland occurs at Bendoc Grassland in East Gippsland, which might best be described as Montane Grassland and Montane Grassy Woodland Ecological Vegetation Classes, dominated by *Poa labillardierei*. A 224 ha patch is located 7 km north-east of Bendoc, on the Victorian–New South Wales border.

2.7.2. Description

The South Eastern Highlands Bioregion extends north/south along the Great Dividing Range from Bathurst, New South Wales in the north, to near Melbourne, Victoria (Benson 1999). Natural Temperate Grasslands occur within the geographical region of the Southern Tablelands, which cover much of the South Eastern Highlands Bioregion, and extend southwards from the Abercrombie River to the Victorian Border, from Boorowa and Jindabyne to the west and Goulburn to Braidwood and Bombala in the east. Natural Temperate Grasslands occur at altitudes between approximately 550 and 1 000 m above sea level in valleys influenced by cold air drainage and in broad plains (Pryor 1954; Benson 1994). The Monaro Tablelands form a large, but ill-defined, part of the Southern Tablelands, extending from Canberra and Queanbeyan in the north to just south of the Victorian border in the south, bounded in the east by the Kybean Range and in the west by the Snowy Mountains and the Fiery Range of New South Wales and the Australian Capital Territory (Benson & Jackson 1993; Litchfield 2000). The Monaro experiences winter-dominated rainfall and mean annual rainfall of 450 to 600 mm (Benson & Jackson 1993). The relatively low rainfall of the tableland section of the Monaro is due to a rainshadow effect (Benson & Jackson 1993).

Natural Temperate Grasslands in the ACT include at least five floristic associations, identified by ACT Government (1997) and Benson (1994). These include 'Wet *Themeda* Grassland' (73.6 ha at 9 sites), '*Poa labillardierei* Grassland' (3 ha at 2 sites), '*Austrodanthonia* Grassland' (691.4 ha at 25 sites), 'Dry *Themeda* Grassland' (73.6 ha at 14 sites) and '*Austrostipa* Grassland' (637.3 ha at 17 sites). These grasslands often occur on gentle to moderate slopes, with poorly drained loamy or clay-loam soils (ACT Government 1997). The Wet Themeda association tends to occur along drainage lines and is often highly degraded with a high weed content (ACT Government 1997). Frequently inundated, or highly weedy sites, are excluded, according to the definition in the current report.

2.7.3. Floristic Description

The following grasses dominate Natural Temperate Grasslands in the South Eastern Highlands Bioregion:

- *Austrostipa* spp. (eg. *Austrostipa scabra* subsp. *falcata, Austrostipa bigeniculata*)
- *Austrodanthonia* spp. (eg. *Austrodanthonia carphoides, Austrodanthonia caespitosa, Austrodanthonia laevis*)
- *Poa* spp. (eg. *Poa labillardierei, Poa sieberiana*)
- *Themeda triandra*

Other common herbs include:

- *Acaena ovina*
- *Ajuga australis*
- *Asperula conferta*
- *Carex inversa*
- *Chrysocephalum apiculatum*
- *Convolvulus erubescens*
- *Elymus scaber*
- *Epilobium billardierianum*
- *Eryngium ovinum*
- *Geranium solanderi*
- *Goodenia pinnatifida*
- *Haloragis heterophylla*
- *Hydrocotyle laxiflora*
- *Leptorhynchos squamatus*
- *Plantago varia*
- *Schoenus apogon*
- *Wahlenbergia communis*

A useful differential species is *Joycea pallida* (Silvertop Wallaby Grass), which is almost always restricted to woodlands and forests (or ex-woodlands and forests) and occurs up to the drip line of trees at the boundary of grassland, but not into the grassland itself.

The Monaro grasslands were likely to have been *Poa, Austrostipa* and/or *Themeda* dominated pre-1750, but long-term grazing has altered their floristic composition and structure (Benson 1994). Moderate grazing pressure by livestock since European settlement on the Southern Tablelands has tended to favour grasses such as *Austrodanthonia,*

Austrostipa, Bothriochloa, Elymus, Enneapogon, Eragrostis, Microlaena, and *Panicum* (Moore 1970; Eddy *et al.* 1998).

2.7.4. Nationally Significant Fauna

Aprasia parapulchella (Pink tailed Worm lizard) - vulnerable
Delma impar (Striped Legless Lizard) – vulnerable
Perunga ochacea (Perunga Grasshopper) - vulnerable
Synemon plana (Golden Sun Moth) – endangered
Tympanocryptis pinguicolla (Grassland Earless Dragon) - endangered

2.7.5. Driving processes

The dry climate, and presence of heavy textured soils may explain the 'naturally' sparse tree layer of the Monaro grasslands (Benson & Jackson 1993), with moisture being the limiting factor for tree growth, particularly soon after establishment (Costin 1954). The weak rootlets of tree seedlings find it hard to reach available water on heavy textured, cracking clays where there is relatively low rainfall, desiccating winds, occasional frosts, rapid percolation and poor aeration (Costin 1954). In addition, the fragile rootlets may be repeatedly broken by contraction and expansion of these heavy loams as the soil profile is subject to repeated bouts of expansion and contraction on being wetted and subsequent desiccation.

Grassland vegetation on parts of the Monaro is likely to have been a response to some form of Aboriginal burning, although occupation in some areas may only date back to around 3 000 years (Flood *et al*. 1987). This former burning régime is likely to have changed following European settlement, possibly to the detriment of some species (Benson & Jackson 1993). Many Natural Temperate Grasslands in the Monaro are currently maintained by grazing. Ninety-five percent of the gross value of agricultural production on the Monaro comes from sheep and cattle (Litchfield 2000).

2.7.6. Threats

The main threats to Natural Temperate Grassland in the South Eastern Highlands Bioregion are:

- Excessive livestock grazing, particularly during seed production
- Rabbit grazing
- Weeds are perceived by many to be the biggest threat to grassland degradation, however weeds may be only a symptom of grassland degradation as a result of some other (primary) disturbance (Eddy 2000).
- Vegetation clearing for crops or pasture (including direct drilling)

- Unsympathetic grazing management
- Soil erosion

In cemeteries the main threats are:
- mowing too short, too frequently and during seed production
- weed invasion
- stockpiling of grave spoil
- ground disturbance
- vehicular traffic
- fencing breached by livestock and traffic

2.7.7. Ecological condition

Less than 5% of Natural Temperate Grassland on the Monaro is in a condition resembling its pre-1750 state (Eddy 2000). In a recent survey of 76 Travelling Stock Reserves, 16 sites were considered to be of high conservation value, 38 of medium conservation value and 22 of low conservation value (Eddy 2000). This conservation assessment was made on the basis of the dominant grass species, the diversity and abundance of other herbs, the presence of uncommon and threatened species and the abundance and species of weeds (Eddy 2000). In general, larger sites tended to have a higher conservation value. The condition of sites surveyed varied enormously from pristine to heavily degraded where topsoil had been removed. It is estimated that there are many thousands of hectares of grassland on private land on the Monaro that are in relatively good ecological condition, although it is not clear what proportion of these is derived from more wooded vegetation.

There are no published studies that document ecological condition or viability within the Victorian portion of the South Eastern Highlands Bioregion.

2.7.8. Conservation status proposed under the *EPBC* Act

Critically Endangered

Criterion 1 – Decline in geographic distribution

On the Monaro (which makes up, by far, the largest proportion of the area of Natural Temperate Grasslands in the South Eastern Highlands) over 95% of native grasslands (ie. those present before European settlement) have been destroyed or highly modified, leaving few sites in a condition resembling their pre-1750 state (Benson 1999; Eddy 2000). Excluding the large area of *Poa sieberiana*-dominated, semi-natural tussock grasslands on

the basalt south of Cooma (often regarded as native pasture and containing few inter-tussock forbs), less than 1% of native grassland remains in good condition on the Monaro Tablelands (Benson & Jackson 1993). An unknown proportion of the secondary *Poa sieberiana*-dominated grasslands, notably those that are in sheep camps, or on cultivated or improved land, on the Monaro are excluded from the definition of Natural Temperate Grassland because they support a high weed presence.

Around 7% of Natural Temperate Grassland remain in the ACT. This is based on the extant 1 480 ha (ACT Government 1997) as a proportion of the 20 000 ha thought to exist before European settlement (Benson & Jackson 1993).

3.4% of Natural Temperate Grassland remains in the Victorian portion of the South Eastern Highlands (Department of Natural Resources and Environment 1999). This estimate is based on 69 ha remaining of the pre-1750 area estimated area of Montane Grassland EVC (2 013 ha) (Department of Natural Resources and Environment 1999).

2.7.9. Mapping available

Costin (1954) estimated pre-European settlement vegetation distribution on the Monaro and Pryor (1939) estimated vegetation distribution for the ACT. The Victorian portion has been mapped (pre-settlement and extant) at 1:100 000 (Department of Natural Resources and Environment 1999). However, extant vegetation on most of the private land in this Bioregion has not been mapped (Benson 1999). The NSW National Parks and Wildlife Service is mapping pre-1750 and extant vegetation on the Southern Tablelands at 1:100 000 scale and completion is expected in 2002. This project uses multi-image analysis of satellite images, down to 18m pixels. Hence it is possible to distinguish between *Themeda triandra* grassland and *Phalaris* pasture. However it is impossible to distinguish between monocultures of *Themeda triandra* and diverse *Themeda triandra*-dominated grassland.

Many areas of the Monaro that have been mapped as Grassy Woodland may be Natural Temperate Grassland (*sensu* this report). The only consistent floristic differences between grassland and grassy woodland is the presence of 2 tree species in the woodland and perhaps some herbs (eg. *Joycea pallida*). Similar processes act on both 'native grassland' and 'grassy woodland', although there is an increase in above-ground primary productivity as you move from the former to the latter.

2.7.10. Gap analysis for research

Further mapping is needed for Natural Temperate Grassland on private land in the South Eastern Highlands, particularly on the Monaro, the Riverina Highlands and Lake Omeo/Benambra districts. In the ACT there is a need for more management-oriented research, particularly the dynamic response of the ecological community to management activities (ACT Government 1997). Further research is also needed on the basic ecological requirements of selected grassland species, including those that are threatened (ACT Government 1997).

2.8. Tasmania

Note: Individual Bioregions known to contain Natural Temperate Grasslands in Tasmania (ie. Ben Lomond, Flinders Island, Tasmanian Northern Midlands, Tasmanian Northern Slopes and Tasmanian South East) have been treated as a group because there are no published studies that separate the status of the grasslands in each of the relevant Tasmanian IBRA regions.

The name of this regional component of Natural Temperate Grassland

Lowland Temperate Grasslands of Tasmania

This name follows the TSSC's guidelines for naming national ecological communities. It includes the major vegetation type and the geographic location.

2.8.1. Distribution

Grassland covered around 850 km^2 of Tasmania prior to European settlement, with a large proportion occurring in subalpine and alpine areas above approximately 900 m above sea level (Kirkpatrick 1999). Below the alpine/lowland divide, the distribution of native grassy ecosystems seems to be confined to the driest niches on siliceous rocks, such as sandstone, or on more mesic sites on mudstones, and is extensive over the moisture gradient on basalt, dolerite, carbonate rocks and fertile alluvium (Kirkpatrick 1999).

The majority of *Poa labillardierei* (Silver Tussock-grass) Lowland Grassland remnants are found on river flats throughout the Northern Midlands Bioregion (Kirkpatrick 1999). *Themeda triandra* (Kangaroo Grass) Tussock Grasslands are scattered throughout the Ben Lomond, Flinders Island, Tasmanian Northern Midlands, Tasmanian Northern Slopes and Tasmanian South East Bioregions (Kirkpatrick 1999). The treeless nature of many *Themeda* grasslands is believed to be a post-European phenomenon relating to grazing and tree removal (Kirkpatrick 1999). Only those *Themeda* grasslands on fertile coastal headlands, and on the western foothills of the Eastern Tiers and Ben Lomond, are considered to have survived since European settlement (Kirkpatrick 1999). Aboriginal burning is likely to have extended the range of grassy ecosystems in Tasmania, but it is debatable as to what degree (Kirkpatrick 1999). In this sense, many of the grasslands that were present at the time of European settlement were already secondary or derived.

2.8.2. Description

At least two described grassland assemblages occur in Tasmania. These are:

- *Poa labillardierei* (Silver Tussock-grass) lowland grassland (Kirkpatrick 1999). Most of the examples of this heavily depleted community occur in the Tasmanian Midlands (Kirkpatrick 1999). It is found on alluvial river flats below 700 m above sea level. It usually occurs adjacent to, or intermixed with, *Eucalyptus ovata*-dominated grassy woodland. Lowland *Poa* grasslands are characterised by large dense tussocks of *Poa labillardierei* with herbs and small grasses in the inter-tussock space. Species richness is relatively low (<20 species per $10m^2$) (Kirkpatrick 1999).
- *Themeda triandra* (Kangaroo Grass) tussock grassland occurs in the western foothills of the Eastern Tiers and Ben Lomond and on some fertile coastal headlands (Kirkpatrick 1999). Treeless valley flats and well-drained slopes on basalt, dolerite and deep sands are dominated by *Themeda triandra*. It is used for pasture in agricultural land, and also occurs as small remnants on roadsides, country cemeteries and rail reserves. *Themeda triandra* (Kangaroo Grass) tussock grasslands are often characterised by a rich variety of lilies, orchids, daisies and other herbs in the patches between the grass tussocks. Species richness is generally high (>30 species per $10m^2$) (Kirkpatrick 1999). Other common grasses include species of *Austrodanthonia*, *Austrostipa* and *Poa.*

2.8.3. Floristic Description

The following grasses dominate Natural Temperate Grasslands in Tasmania:

- *Austrodanthonia* spp.
- *Poa labillardierei*
- *Themeda triandra*

Characteristic species include:

- *Acaena echinata*
- *Acaena novae-zelandiae*
- *Chrysocephalum apiculatum*
- *Dichondra repens*
- *Geranium* spp.
- *Lissanthe strigosa*
- *Oxalis perennans*
- *Solenogyne dominii*
- *Veronica gracilis*

2.8.4. Nationally Significant Fauna

Aquila audax fleayi (Tasmanian Wedge-tailed eagle) – endangered

Dasyurus maculatus maculatus (Tiger Quoll (southeast mainland and Tasmanian subspecies) – vulnerable

Dromaius novaehollandiae diemensis (Tasmanian Emu) – extinct

Perameles gunnii gunnii (Eastern Barred Bandicoot – Tasmania) – vulnerable

Thylacinus cynocephalus (Thylacine) – extinct

2.8.5. Driving processes

Fire is a major agent in the maintenance of much of Tasmania's Natural Temperate Grassland (Kirkpatrick 1999). Fire restricts shrub and tree invasion in lowland grasslands. Most Natural Temperate Grasslands in Tasmania are able to support trees and/or shrubs, and seedlings or stunted individuals occur on most sites (Kirkpatrick *et al.* 1988). However, factors such as seasonal drought and shading by the grass sward generally lead to reduced shrub and tree establishment (Kirkpatrick 1999).

2.8.6. Threats

- Inappropriate fire régimes
- Conversion to improved pasture
- Weed invasion
- Inappropriate road verge management
- Urban development (particularly on coastal headland *Themeda* grasslands)

2.8.7. Ecological condition

There are no recent published records of the condition or viability of Natural Temperate Grasslands in Tasmania. It is clear that the *Poa labillardierei* (Silver Tussock-grass) Lowland Grassland is the Tasmanian vegetation type most diminished since European settlement, with remnants often heavily weed infested (Kirkpatrick 1999). This indicates a floristic assemblage that may not be viable without further protective measures.

2.8.8. Conservation status proposed under the *EPBC* Act

Vulnerable

Criterion 1 – Decline in geographic distribution

There has been an 83% reduction in the extent of Natural Temperate Grassland in Tasmania (which includes *Poa labillardierei* (Silver Tussock-grass) lowland grassland and *Themeda triandra* (Kangaroo Grass) Tussock Grassland) (unpublished data from CARSAG pre-1750 vegetation reconstruction. *Poa labillardierei* (Silver Tussock-grass) lowland grassland may

be the Tasmanian vegetation type most diminished since European settlement (Kirkpatrick 1991).

2.8.9. Mapping available

Fensham (1989) reconstructed pre-settlement grassland distribution in the Tasmanian Midlands. These reconstructions were based on descriptive accounts of surveyors and travellers, survey plans, paintings and standing paddock trees (Fensham 1989). The Tasmanian Department of Primary Industries Water and Environment is currently modelling pre-1750 vegetation distribution for all of Tasmania.

Extant vegetation has been mapped (in 1993) at 1:25 000 (TasVeg) largely using remote sensing from aerial photographs and produced by the GIS section of the Tasmanian Department of Primary Industries, Water and Environment. As there has been little ground-truthing and 'grassland' vegetation was recognised predominantly from air photos, this mapping includes many non-native grasslands and pasture as well as Natural Temperate Grassland. The Tasmanian Department of Primary Industries, Water and Environment is currently carrying out up-to-date mapping, also at 1:25 000 scale.

2.8.10. Gap analysis for research

Further studies are required to determine the most appropriate management régimes for Natural Temperate Grasslands in Tasmania. Further survey of Natural Temperate Grassland on private land is also required and determination of the best methods for their protection and continued survival. Research that describes the status of Natural Temperate Grasslands within each Bioregion in Tasmania will also assist conservation management.

2.9. Victorian Volcanic Plain

The name of this regional component of Natural Temperate Grassland

Western (Basalt) Plains Grassland

This name follows the TSSC's guidelines for naming national ecological communities. It incorporates the major vegetation type and the geographic location.

2.9.1. Distribution

The Victorian Volcanic Plains stretch from Melbourne to Portland, Colac in the south, Beaufort in the north and Hamilton in the west and are flat to undulating basalt plains (Muir 1992). This Bioregion contains the main occurrence of Western Plains Grassland, also referred to as Western Basalt Plains Grassland and Volcanic Plains grassland.

Plains Grassland, an included component of Natural Temperate Grassland, originally occupied 220 073 ha of the Victorian Volcanic Plain (Natural Resources and Environment 1997), but currently occupies between 1 671 ha (0.2 % of its former extent) and 2 291 ha (1.0%) (Natural Resources and Environment 1997).

Further inclusion of the Ecological Vegetation Classes (EVCs) Plains Grassy Woodland and Plains Grassland/Plains Grassy Woodland Mosaic as Natural Temperate Grassland, increases the pre-1750 estimate of natural open grassland across the Victorian Volcanic Plain to approximately 800 000 – 1 000 000 ha (Barlow & Ross in prep.). Estimates of extant vegetation comprising these three EVCs total 5 000 – 6 000 ha (approximately 1 000 ha of these remnants are species rich and contain only a small weed component) (Barlow & Ross in prep.). An unknown proportion of the vegetation in the Plains Grassy Woodland and Plains Grassland/Plains Grassy Woodland Mosaic supports too many trees to be considered Natural Temperate Grassland.

2.9.2. Description

The Victorian Volcanic Plain Bioregion covers approximately 21 000 km^2 (Stuwe 1986). The Victorian Volcanic Plain receives between 500 mm and 700 mm of rain per annum (Stuwe 1986). Mean annual rainfall decreases from south-west to north-east across the plain and, in most areas, this rainfall is fairly evenly distributed throughout the year (Lunt *et al.* 1998). Summers are hot and dry with mean maximum temperatures ranging from 20^o to 27^o C.

Winters are cold and often frosty with the mean maximum of the coldest month of 10° C and a corresponding mean minimum of 3° or 4° C.

Most of the Victorian Volcanic Plain is characterised by an extensive Upper Cainozoic (Quaternary) basalt plain but does include some areas of Devonian granite and sediments ranging from Recent alluvial to Cambrian marine (Stuwe 1986). Soils are fertile and high in available phosphorus and are generally shallow reddish-brown or sometimes black loams and clays (Conn 1993).

2.9.3. Floristic Description

The following grasses dominate remnants of Natural Temperate Grasslands in the Victorian Volcanic Plain:

- *Austrodanthonia* spp. (notably *Austrodanthonia setacea*)
- *Austrostipa* spp. (including *Austrostipa aristiglumis* and *Austrostipa scabra*)
- *Poa sieberiana*
- *Themeda triandra*

Other common herbs include:

- *Acaena echinata*
- *Chrysocephalum apiculatum*
- *Convolvulus erubescens*
- *Eryngium ovinum*
- *Leptorhynchos squamatus*
- *Schoenus apogon*

2.9.4. Nationally Significant Fauna

Delma impar (Striped Legless Lizard) – vulnerable
Pedionomus torquatus (Plains-wanderer) – vulnerable
Perameles gunnii (Eastern Barred Bandicoot) – vulnerable
Synemon plana (Golden Sun Moth) – endangered
Tympanocryptis pinguicolla (Grassland Earless Dragon) - endangered

2.9.5. Driving processes

The primary drivers of treelessness on the Victorian Volcanic Plains are the 'heavy' clay soils that are poorly drained, readily becoming water-logged in winter or exceedingly dry in summer (Barlow & Ross in prep.). Water-logged soils tend to favour fibrous rooting plants

(ie. many grassland species) rather than tap-rooting plants (eg. trees). Low rainfall and periodic burning may compound the influence of soil drainage.

Fire may be a contributing factor to grassland presence/absence as post-fire competition may maintain a fairly closed ground cover preventing tree emergence (Ross 1994). Fire may also destroy tree seedlings that emerge beyond the grassy layer (Ross 1994). But some trees occur on nearly all temperate grasslands as tree seedlings may not die in the fast and low intensity fires that characterise these grasslands if the seedlings live to be about 3 or 4 years old. In open grasslands, tree presence depends on the inter-tussock opportunity for tree seedling recruitment (Patton 1935). The vegetation dynamics of these grasslands can be considered in terms of pressures and responses. Some factors can be manipulated (eg. disturbance régime, nutrient input) but others can not (eg. soils, topography, rainfall, temperature) (Barlow 1998).

2.9.6. Threats

Victorian Volcanic Plains grasslands have dramatically declined since pastoral settlement in the 1830s. They were heavily targeted for early pastoral settlement because of the suitability of the western plains for grazing sheep, without the need for extensive clearing of woody vegetation (Muir 1992). Nevertheless, some native grasslands persisted for over 100 years due to locally-low stocking rates (Stuwe 1986). After World War 2 the increased use of fertilisers and an increase in ploughing disturbed and dissected the remaining areas of native grassland (Muir 1992). Since then, the decline and destruction of these grasslands has been occurring at a great rate. The main threats to the grassland remnants are sub-division for residential and industrial development, poor management practices and weed invasion (Muir 1992). A few small examples of high quality Volcanic Plains Grassland have persisted in rail and road reserves and cemeteries, all of which are subject to similar pressures.

Most of the basalt plains are now in private ownership (Jackson 1998). The threats faced by grassland remnants differ between rural private land and land on the fringes of Melbourne. Rural grassland remnants persist where stock grazing has been light, particularly in areas where access for stock is difficult (Muir 1992). Grasslands on private land on the northern and western fringes of Melbourne are under threat of development for industry and housing.

Railway reserves once provided a refuge for some of the highest quality remnants of Western Plains Grassland (Stuwe 1986). However, since 1984, prescribed burning (which once maintained these remnants) has been replaced with the use of herbicides, slashing and bare earth breaks along boundary lines (Stuwe 1986). This has largely destroyed the

important biological values of these linear reserves. Lack of training and awareness of rail crews, and the use of rail reserves as utility corridors, are also a threat to these reserves.

Few disused railway lines support high quality native grasslands. However, disused railway line reserves have a better chance of survival than reserves along active railways because there is a wider strip of vegetation remaining and less intense fire prevention is carried out (Muir 1992). Tree-planting is a threat where linear reserves are developed into walking or cycling tracks (Muir 1992).

As with railway reserves, methods for fuel reduction on roadsides have become more destructive since the early 1980s. The use of herbicides, ploughing and crop sowing have contributed to the degradation of grasslands on roadsides. Roadsides are also vulnerable to soil disturbance due to the destructive nature of road-works in general. Tree planting is another threat to some grassland sites. Weed invasion is everywhere a major threat.

Within cemeteries, both weed invasion and destructive fuel reduction techniques (grazing and slashing) degrade native grasslands in these already small, grassland remnants.

2.9.7. Ecological condition

There are few published studies relating to the condition and viability of Natural Temperate Grassland in the Victorian Volcanic Plains Bioregion. Stuwe's 1986 report is increasingly out of date. However, some significant grassland sites of the Western Plains have been more recently rated, based on various criteria including ecological integrity and viability, with the intention of prioritising these sites to form a representative conservation network (Muir 1996). Only sites that were high quality (ie. one or more rare or threatened species of flora or fauna and weed cover less than 30 %) were included in Muir's (1996) study.

Lunt & Morgan (1999) examined vegetation changes over ten years in one grassland site (Derrimut Grassland Reserve), and the main floristic change observed was an increase in the richness of 'weedy' ruderal colonisers (ie. species not typical or common components of species-rich, temperate grassland remnants in southern Victoria). That study indicated that Derrimut Grassland Reserve (or at least the native species within it) may not be ecologically viable under current *laissez-faire* management. If current disturbance régimes continue, and threats are not controlled, then degradation towards a weed-dominated grassland poor in native species, is likely.

Only approximately 1 000 ha of extant native grassland remnants (most of which would be considered Natural Temperate Grassland) are species rich and contain a small weed component (Barlow & Ross in prep.). Around 4 000 to 5 000 ha of degraded or simplified native grassland, or disclimax grassy woodland communities, occur across the whole of the Victorian Volcanic Plain (Barlow & Ross in prep.).

2.9.8. Conservation status proposed under the *EPBC* Act

Critically endangered

Criterion 1 – Decline in geographic distribution

Western Basalt Plains Grassland:

- is in a demonstrable state of decline which is likely to result in extinction;
- is significantly prone to future threats which are likely to result in extinction;
- and is very rare in terms of the total area that it covers (Muir 1996).

Furthermore, Plains Grassland originally occupied 220 073 ha of the Victorian Volcanic Plain, but currently occupies between 1 671 ha (0.2 %) and 2 291 ha (1.0%) (Natural Resources and Environment 1997).

2.9.9. Mapping available

Pre-1750 and extant distribution of Natural Temperate Grasslands in the Victorian Volcanic Plains Bioregion has been mapped at 1:100 000 by the Department of Natural Resources and Environment (Department of Natural Resources and Environment 2000). John Morgan (La Trobe University) and Nick Williams (Australian Research Centre for Urban Ecology) are resurveying sites described by Stuwe (1986), and the results are likely to be digitally mapped in the near future.

Natural Temperate Grassland on the Victorian Volcanic Plain is likely to include most of what has been described as the Ecological Vegetation Class 'Plains Grassland' (Department of Natural Resources and Environment 2000). Maps of this vegetation unit provide a reliable distribution of Natural Temperate Grassland in the Victorian Volcanic Plain.

Plains Grassland Ecological Vegetation Class (EVC) frequently intergrades with Plains Grassy Woodland EVC and the boundaries are difficult to define and often reliant on some arbitrary change in tree density (a change that appears to have little impact on the floristic composition of the rest of the vegetation). However, many areas of Plains Grassy Woodland

EVC in Victoria contain a density greater than 1 tree per hectare or 10% crown cover and thus are excluded from the attached map of Natural Temperate Grassland. Some of both Plains Grassy Woodland and Plains Grassland/Plains Grassy Woodland Mosaic EVCs contain Natural Temperate Grasslands in this Bioregion but further research is needed to identify the proportions of each.

2.9.10. Gap analysis for research

The most comprehensive study completed for grassland sites on the Victorian Volcanic Plain is that of Stuwe (1986). Some of the sites identified in that report have recently been re-visited and a report from this latter work is in progress. However, the Action Statement for Western (Basalt) Plains Grassland Community (1994) discusses, in detail, the actions to be taken to ensure the long-term survival of the community. This Action Statement was completed in 1994 and was due for review in 1999. As yet, a reviewed Action Statement has not been published but is in preparation. The subsequent review has combined Northern, Southern and Gippsland Plains Grassland. It is not known how many of the intended or desirable management actions outlined in the original Action Statement were effected.

2.10. Other Bioregions that may contain Natural Temperate Grassland

Further survey and mapping is needed in the following Bioregions to determine the extent, if any, of Natural Temperate Grasslands. There is currently a lack of published data to accurately determine whether Natural Temperate Grasslands occur in the following Bioregions:

2.10.1. Eyre Yorke Block

Grasslands have been recorded in the Eyre Yorke Block in South Australia, although it is unclear whether there is a continued presence of native grasslands in this Bioregion (Boomsma & Lewis 1980) and whether such grasslands would be classified as Natural Temperate Grassland *sensu* the current report. The map of Natural Temperate Grasslands provided with this report shows some small extent of grassland continuous with the south-western extent of grassland in the Flinders Lofty Block (Boomsma & Lewis 1980). The *Lomandra multiflora* / Tussock Grass Complex identified by Hyde (1995) is probably present in the Cleve and Koppio Hills on Eyre Peninsula, but reliable data are scanty.

2.10.2. New England Tableland

Grassy vegetation occurs in the temperate climate New England Tablelands of NSW, and grassland field layers have been described for grassy woodlands and forests in the region (McIntyre *et al.* 1993). The area has been extensively exploited for agriculture since European settlement and the native vegetation is often highly modified (McIntyre *et al.* 1993). Originally, most of the New England Tablelands would have been grassy woodland, with grassy plains and swamps in valley floors and denser forest on the ridges (Norton 1971; Lodge *et al.* 1984). Any pre-1750 grasslands would presumably have been dominated by *Themeda triandra, Poa labillardierei, Poa sieberiana, Sorghum leiocladum* and/or *Poa labillardierei* (McIntyre *et al.* 1993).

Any existing Natural Temperate Grassland may be derived from tree removal or dieback in grassy woodlands and forests and would be described as native pasture. Grassy vegetation surveyed by McIntyre *et al.* (1993) contained tree densities that varied from absent or widely scattered to woodland or forest. Mapping of the New England Tableland Bioregion at 1:25 000 did not identify distinct grassland vegetation, although open forests and woodlands often contained a grassy subordinate stratum (Benson & Ashby 2000). In addition, native grasslands were not mapped due to the difficulty of reliably interpreting them from colour aerial photographs. Benson and Ashby (2000) implied that derived grasslands (produced

after removal of woody canopy species) occur in the Bioregion. Some of these may be considered Natural Temperate Grassland and further investigation is warranted.

2.10.3. NSW South West Slopes

Approximately 85% of native vegetation in the NSW South Western Slopes Bioregion has been cleared (Benson 1999). A small patch of Natural Temperate Grassland has been identified at Monteagle Cemetery, but it is not clear whether this is derived from woodland, a 'natural' occurrence, or an outlier of the Riverina or South Eastern Highlands grasslands. The pre-1750 extent of Natural Temperate Grassland in the NSW South West Slopes is unknown.

2.10.4. South East Corner

Grasslands on coastal clay headlands, on basalt, in the NSW portion of South East Corner Bioregion may be considered Natural Temperate Grassland but further floristic survey is required to determine their inclusion. These grasslands are presently conserved in reserves.

2.10.5. Sydney Basin

Themeda triandra-dominated grasslands occur on exposed sites below coastal cliffs at Bouddi and on the Warringah Peninsula (Benson & Howell 1994). Grassland tends to be restricted to the most fertile headland soils possibly reflecting a long history of land use (eg. Koori burning) and regular disturbance (Benson & Howell 1994). Some of these grassland sites may be considered Natural Temperate Grassland, however indications of a moderate cover of "…severely windswept shrubs such as *Westringia fruticosa, Banksia integrifolia* and *Baeckea imbricata*…"(Benson & Howell 1994/ p706) indicate that the coastal location is a significant influence on the local floristic composition. These sites may thus be excluded from the definition.

3. Conclusion – the Conservation Status of Natural Temperate Grassland Ecological Community

Prior to European settlement, native grasslands were located in many biogeographic regions of temperate south-eastern Australia. In New South Wales they occurred on the Southern Tablelands (including parts of the ACT and Victoria), Riverina and Liverpool plains. In Victoria they occurred on the Western Basalt, Gippsland, Northern and Wimmera plains. In South Australia they occurred in the Flinders Lofty and Kanmantoo Bioregions. In Tasmania they were concentrated in the Midlands region, but were also scattered across the eastern half of the state. The current area of 'Natural Temperate Grasslands' is severely reduced in all of these regions and few or no sites remain that are large, species-rich and floristically similar to purported pre-European condition.

There is sufficient information to assess components of the Natural Temperate Grasslands and justify nomination under the *EPBC* ACT within the following bioregions: Brigalow Belt South, Flinders Lofty Block (including Kanmantoo), Murray-Darling Depression, Riverina, South East Coastal Plain, South Eastern Highlands, Tasmania (including Ben Lomond, Flinders Island, Tasmanian Northern Midlands, Tasmanian Northern Slopes and Tasmanian South East) and the Victorian Volcanic Plain. Bioregions where Natural Temperate Grasslands may occur, but where there is insufficient information to assess their status or justify their nomination under the *EPBC* Act include: Eyre Yorke Block, New England Tableland, South East Corner, NSW South West Slopes and the Sydney Basin.

Summary statements of the pre-1750 and extant area of Natural Temperate Grassland within each IBRA Bioregion are presented.

Table 3. Area of pre-1750 and extant Natural Temperate Grasslands, by IBRA

Bioregion	Pre-1750 (ha)	Extant (ha)	% remaining [1]	Source [2]
Brigalow Belt South	270,000	25,000	9.26	
Flinders Lofty Block	1,500,000	5,000	0.33	Hyde (1995)
Murray-Darling Depression	440,460	1,244	0.28	
Riverina	2,750,000	26,871	0.98	Barlow & Thorburn (1999); McDougall *et al*. (1993b)
South East Coastal Plain	60,000	25	0.04	Lunt (1993)
South Eastern Highlands	450,000	<22,500	<5.00	ACT Government (1997); Benson (1994); Benson & Jackson (1993); NRE (1999)
Tasmania	80,098	13,617	17.00	CARSAG data set
Victorian Volcanic Plain	220,073	2,291	1.04	NRE (1997)
TOTAL	**5770631**	**96548**	**1.67**	

[1] The percent decline is not to be taken as an estimate of remnants that are left in good condition. In most cases only a small proportion of remaining remnants are in good condition.

[2] Interpretation of the quality and accuracy of figures is given is section 2. Information also was sourced from personal communications with grassland experts, particularly for bioregions where recent published sources were unavailable.

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