South Australian Perennial Grass Weeds Workshop

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Perennial grass weeds in Australia: impacts, conflicts of interest and management issues

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Introduction

Australia has around 27 000 introduced plant species, about 2700 of which have naturalized (Hosking *et al.* in press), that is, they have established self-replacing populations (Richardson *et al.* 2000). About 30% of the plants naturalized in Australia (798 species) have been classified as being major weeds of natural or agricultural ecosystems somewhere on the continent (Groves *et al.* 2003).

Grasses (Poaceae) are prominent amongst Australia's naturalized plants. There are 375 grass species in Hosking's database (Hosking *et al.* in press), representing about 14% of the naturalized flora. Of these 375 species, 141 (37.6%) have been classified as major weeds (Groves *et al.* 2003) suggesting that grasses have shown a somewhat greater tendency than naturalized plants as a whole to become major weeds. Seventeen grass species have been declared 'noxious' in one or more states or territories of Australia (Parsons and Cuthbertson 2001) (Table 1). Three grass species are amongst the twenty Weeds of National Significance declared under Australia's National Weed Strategy (Anon. 1997). They are serrated tussock (*Nassella trichotoma* (Nees) Hack. ex Arechav.), Chilean needlegrass (*Nassella neesiana* (Trin. & Rupr.) Barkworth) and olive hymenachne (*Hymenachne amplexicaulis* (Rudge) Nees).

Many naturalized plants were deliberately introduced to Australia. Of 290 species detected as naturalized in Australia in the period 1971–1995, at least 70% were deliberately introduced (Groves 1997). At least some of the relatively high proportion (approximately 20%) of species for which the purpose or means of introduction are not known, were probably also deliberately introduced. Of the 17 grass species reported by Groves (1997) as introduced to Australia between 1971 and 1995, two were introduced as ornamental plants, five as pasture grasses and ten either accidentally or for unknown purposes. Some species have been introduced for use in erosion control. Amongst Randall's (2001) 958 'garden thugs', there are 46 Poaceae that are either invasive or potentially invasive, and 26 that are classified as significant environmental weeds in Australia.

The deliberate introduction of grasses to Australia has been strongly driven by a demand for pasture grasses. The search for productive pasture grasses has been the basis of a major research and extension effort in Australia for several decades (Eyles and Cameron 1985, Jones 2001). This work introduced many thousands of accessions of both grasses and legumes, evaluated a proportion of these, and commercially released many forms, most of which were not selectively bred cultivars. The *Register of Australian Herbage Plant Cultivars* (Oram 1990) lists 43 temperate grasses and 67 tropical grasses (Jones 2001). Most of the grass species represented in the *Register* are also listed in Hosking's database of naturalized plants. Since the 1980s, there has been a reduced effort devoted to introducing, evaluating and releasing new pasture grasses (Jones 2001).

Grasses are prominent components of many natural ecosystems in Australia. They dominate the understoreys of many forests, woodlands and savannas that occupy much of the continent. Extensive grasslands are dominated by members of the genera *Astrebla*, *Plectrachne* and *Triodia* (Groves 1981). Why, then, are introduced grasses a problem? This paper discusses the impacts of introduced perennial grasses and the conflicts of interest and management issues associated with them.

Impacts of perennial grasses

Perennial grasses often dominate the herbaceous layer of the vegetation, making up the bulk of the ground cover. In doing so, they influence ecosystems and communities in at least four major ways. They:

i. regulate water and nutrient cycling;
ii. provide fuel for fires;
iii. provide resources for numerous organisms;
iv. compete with other components of the herbaceous layer.

In relation to perennial grass weeds, it is necessary to consider whether and how weedy perennial grasses differ from their non-weedy counterparts. What makes them weeds?

Water and nutrient cycling

Grasses, as dominants in the understorey, play key roles in the regulation of infiltration and the overland movement of water, and the nutrients, minerals and soil particles it contains (Tongway and Ludwig 1997). The species composition of the perennial grass layer may influence these processes via interspecific variation in plant density, biomass, sward continuity and rooting depth. However, there is little firm quantitative evidence that exotic grasses as a whole function differently from native grasses in these regards. Some, for example buffel grass (*Cenchrus ciliaris* L.) and Guinea grass (*Panicum maximum* Jacq.) may require higher levels of nutrients than many native grasses but this may only dictate in which soil types and landscape positions the species do well. Exotic grasses such as *C. ciliaris* have been used in rehabilitation projects (Griffin 1993) to help restore landscape function, that is, to reduce the flow of water, nutrients and soil material across the landscape (Noble *et al.* 1997). One common and widespread exotic

Table 1. Weedy perennial grasses of Australia, their legislative status and means/purpose of introduction. D, species declared as noxious in one or more states or territories of Australia (Parsons and Cuthbertson 2001); W, Weed of National Significance (Anon. 1997).

Scientific name	Common name	Status	Means/purpose of introduction
Achnatherum caudatum (Trin.) S.W.L.Jacobs & J.Everett = *Stipa caudata*	Broad-kernel espartillo	D	accidental
Achnatherum brachychaetum (Godr.) Barkworth = *Stipa brachychaetum*	Espartillo	D	accidental
Andropogon gayanus Kunth	Gamba grass	–	forage
Andropogon virginicus. L.	Whisky grass	D	?
Bothriochloa pertusa (L.) A.Camus	Indian couch	–	accidental
Brachiaria mutica (Forssk.) Stapf	Para grass	–	forage
Cenchrus ciliaris L.	Buffel grass	–	forage
Cenchrus echinatus L.	Mossman River grass	D	?
Cenchrus incertus M.A.Curtis	Spiny burr grass	D	?
Cortaderia jubata Stapf	Common pampas grass	D	ornamental
Cortaderia richardii (Endl.) Zotov	Cortaderia	D	ornamental
Cortaderia selloana (Schult. & Schult.f.) Asch. & Graebn.	Cortaderia	D	ornamental
Eragrostis curvula (Schrad.) Nees	African lovegrass	D	accidental, forage
Glyceria maxima (Hartm.) Holmb.	Glyceria	D	?
Hymenachne amplexicaulis (Rudge) Nees	Hymenachne	W	forage
Hyparrhenia hirta (L.) Stapf	Coolatai grass	–	?
Nassella charruana (Arechav.) Barkworth	Lobed needle grass	–	?
Nassella neesiana (Trin. & Rupr.) Barkworth	Chilean needle grass	–	?
Nassella tenuissima (Trin.) Barkworth	Mexican feather grass	W	?
Nassella trichotoma (Nees) Hack. ex Arechav.	Serrated tussock	D, W	accidental
Panicum maximum Jacq.	Guinea grass	–	forage
Pennisetum macrourum Trin.	African feather grass	D	accidental
Pennisetum polystachion (L.) Schult.	Mission grass	D	accidental
Pennisetum setaceum (Forssk.) Chiov.		–	ornamental
Pennisetum villosum. R.Br. ex Fresen.	Feathertop	D	?
Sorghum halepense (L.) Pers.	Johnson grass	D	forage
Sorghum × *almum* Parodi	Columbus grass	D	Forage
Sporobolus africanus (Poir.) Robyns & Tournay	Parramatta grass	–	?
Sporobolus fertilis (Steud.) Clayton	Giant Parramatta grass	–	?
Sporobolus jacquemontii Kunth	American rat's tail grass	–	?
Sporobolus natalensis (Steud.) T.Durand & Schinz	Giant rat's tail grass	–	?
Sporobolus pyramidalis P.Beauv.	Giant rat's tail grass	–	accidental
Themeda quadrivalvis (L.) Kuntze	Grader grass	D	accidental
Urochloa mosambicensis (Hack.) Dandy	Sabi grass	–	forage

perennial grass species in north-eastern Australia, Indian couch (*Bothriochloa pertusa* (L.) A.Camus), is morphologically quite distinct from most native perennial grasses, in that it is stoloniferous. Most native community dominants are tussock grasses. It has rapidly colonized overgrazed pastures in north-east Queensland and it is argued that it has been important in stabilizing such landscapes (Jones and Kerr 1993).

Fire

The characteristics of individual fires and of a fire regime will be strongly influenced by the nature of the fuel that is available. In particular, the characteristics of grasses can influence fire dynamics via the amount of fuel that they produce, the time or rate of curing of that fuel, its vertical profile, and distribution across the landscape. Several weedy exotic grasses have been associated with altered fire regimes. A prominent example is gamba grass (*Andropogon gayanus* Kunth) in northern Australia. This species produces fuel loads up to seven times higher than those derived from the native grasses of the region. Fires fuelled by *A. gayanus* are consequently much more intense than those dependent on native grasses and, given the fire-tolerant nature of the species, a 'grass-fire cycle' results (D'Antonio and Vitousek 1992, Rossiter *et al.* 2003). A similar process has been associated with mission grass (*Pennisetum polystachion* (L.) Schult.) in the Northern Territory (Williams *et al.* 2002) and *C. ciliaris* in acacia woodlands in central Queensland (Butler and Fairfax 2003). More intense or more frequent burning can alter recruitment and survival patterns of woody species.

Grasses for forage and other resources

Grasses are important sources of forage for both livestock and wildlife. Many granivorous species depend largely on seed produced by grasses. Grasses also provide shelter for ground-dwelling organisms. The quality and quantity of resources available in the herbaceous layer will be strongly influenced by the characteristics of the dominant grasses. Exotic grasses vary greatly in their palatability to livestock and other herbivores. Some species that were deliberately introduced as forage plants are highly palatable. Examples of highly palatable exotic grasses include *P. maximum* and sabi grass (*Urochloa mosambicensis* (Hack.) Dandy). Some forage species, however, are less palatable, particularly when tussocks become rank. This is the case, for example, with *A. gayanus* in northern Australia and at least some forms of African lovegrass (*Eragrostis curvula* (Schrad.) Nees) in south-eastern Australia (Johnston 1988). Exotic pasture grasses have been chosen not simply for high palatability but also for their tolerance to grazing, persistence under more extreme climatic conditions, or particular soils and, in some circumstances, ability to spread. These are characteristics that increase the likelihood of the species becoming weedy. Among the most serious weedy perennial grasses is a group of species that are highly unpalatable. These species were generally accidentally introduced and include the weedy *Sporobolus* spp. (*S. africanus* (Poir.) Robyns & Tournay, *S. fertilis* (Steud.) Clayton, *S. natalensis* T.Durand & Schinz, *S. pyramidalis* P.Beauv.) and *Nassella* spp.

Exotic grasses may differ from native species in their capacity to provide resources to wildlife. These resources could be in the form of shelter, forage for herbivores or seeds for granivores. There have, however, been few quantitative studies of the availability of resources from exotic grasses for wildlife. One example is of *C. ciliaris* that is invading the range of the last known population of the endangered northern hairy-nosed wombat (*Lasiorhinus krefftii* Owen) in central Queensland (Low 1997). It has not been established, however, that this invasion threatens the wombat population (Department of Environment and Heritage 1999). Certainly, the grass contributes significantly to the animal's diet (Woolnough 1998).

The role of grasses in providing seeds for granivores is very important in many Australian ecosystems, where key granivorous groups include ants and birds. Both these groups utilize the seed of certain exotic grasses (e.g. *U. mosambicensis*) but the seed of other species may not be useful to some granivores, especially birds. For example, seeds of species such as *C. ciliaris* that have prominent awns may be inaccessible to granivorous birds. Again, however, there are few data to support this view.

Plant competition

The interstices between perennial grass tussocks are generally occupied by forbs, annual grasses and, at least intermittently, by seedlings of the woody species that create the overstorey. The more strongly the understorey is dominated by perennial grasses, the less space and the fewer resources are available for other herbaceous species. These general relationships appear to occur for both native and exotic grasses. However, at least at the finest scales, the effect is greater for some exotic grasses than for certain native analogues (Jackson personal communication).

Other impacts

Some perennial grasses are regarded as weedy because of the characteristics of the seeds and their appendages. Several species have diaspores that enable them to attach to the hair or wool of livestock and other animals. Some grass diaspores have hygroscopic awns and sharp points so that they penetrate not only the hair but also the skin. These kinds of diaspores contaminate wool (vegetable fault) and degrade meat and so impose significant economic costs. They also cause serious animal health problems, especially in sheep. Annual and perennial, native and introduced species exhibit these traits. The introduced perennial grasses Mossman River grass (*Cenchrus echinatus* L.) and spiny burrgrass (*Cenchrus incertus* M.A.Curtis) and the annual *Hordeum* spp. are problems because of diaspore characteristics. Native grasses that have penetrating diaspores with hygroscopic awns are *Stipa* spp. (e.g. variable speargrass (*Austrostipa variabilis* (Hughes) S.W.L.Jacobs & J.Everett)) of southern Australia and black speargrass (*Heteropogon contortus* (L.) Roem. & Schult.) in northern Australia. The latter is also a valued forage species and is not generally regarded as a weed given that *H. contortus* pastures are generally grazed with cattle and not sheep (Grice and McIntyre 1995).

Conflicts of interest

The term 'weed' is as much or more a socio-economic term as a scientific term. The weed status of a particular plant species depends upon the perspective of the person(s) making the judgement (Grice and Campbell 2000). This means that different socio-economic perspectives can lead to conflicts of interest in relation to perennial grasses. The conflicts of interest relate to different land uses and five categories of weeds can be identified on this basis (Table 2):

1. Species introduced as forage grasses that become weeds of grazed areas;
2. Species introduced as forage grasses that become crop weeds;
3. Species introduced as forage grasses that become environmental weeds;
4. Species introduced as ornamental grasses that become weeds of grazed areas;
5. Species introduced as ornamental grasses that become environmental weeds.

These categories do not cover species that were accidentally introduced, in which case conflicts of interest generally do not arise. Particular species may fall into more than one category because they were introduced for more than one purpose or because they are weeds in more than one situation.

Lonsdale (1994) has drawn attention to the problems associated with plants introduced as forage species for tropical northern Australia, though this should not been interpreted as meaning that these are more serious than those associated with temperate pasture introductions. In Lonsdale's (1994) analysis, 13% of 186 introduced grass species were weedy in some situations, whereas only 5% were classified as useful to pastoralism. Of the eleven species classified as useful, only three have not become weedy in one situation or another. The remaining 151 species had not, at the time of the analyses, proved either useful or weedy. Lonsdale (1994) argued for an approach to forage plant introduction that recognizes the high probability of an introduced species becoming a weed and incorporates both analysis of economic and environmental costs and benefits, and development of control techniques prior to release. This would increase the cost of conducting research on new forage species. The fact that there has been declining research effort to introduce more forage grasses (Jones 2001) should reduce the risk of additional species becoming weeds, but it is also true that many past introductions that are not already weedy in Australia could yet become so.

The case for forage plant introduction is largely based on the major economic benefits to pastoral enterprises of a small number of valued forage species. 'The reality is that, of the [63 grass] cultivars released for tropical Australia, relatively few are traded on a large scale' (Jones 2001). Twenty-nine grasses 'developed for northern Australia' were available in commercial quantities in the late 1990s though over 90% of seed sown is from half a dozen taxa (Walker *et al.* 1997). *C. ciliaris* accounts for 75% of the area sown to tropical grasses (Walker *et al.* 1997). These species do contribute substantially to animal production in northern Australia but the large production gains associated with species such as *C. ciliaris*, compared with native pasture, are usually associated with additions of N-fertilizer or legumes as well as pasture establishment *per se* (t'Mannetje and Jones 1990).

Where a perennial grass is introduced as a forage species, it is desirable from the pastoralist's perspective that it becomes a prominent component of the vegetation. Valuable perennial pasture grasses are typically fast-growing, competitive and grazing-tolerant, with high above-ground biomass. These are traits that, along with drought-tolerance and prolific seeding, increase the species' propensity to become environmental weeds. Ornamental grasses, on the other hand, exhibit a broad range of traits. Lawn grasses, like pasture grasses, can be strongly competitive, palatable and grazing tolerant. Other species have been introduced as ornamentals because of their unusual foliage or showy inflloresences. Species that fall into this category (e.g. *Cortaderia* spp., fountain grass (*Pennisetum setaceum* (Forssk.) Chiov.)) have become significant environmental weeds in Australia (Table 2). Palatable lawn grasses are unlikely to be weeds of

Table 2. The purpose or means of introduction of some common weedy perennial grasses in Australia relative to the sectors to which they pose a threat.

Scientific name	Purpose/means of introduction	Weed threat					
		Agric	Forestry	Pastoral	Fire	Amenity	Environ
Andropogon virginicus	?			P	P		
Cenchrus echinatus	?	**P**		P		P	
Cenchrus incertus	?	**P**		P		P	
Glyceria maxima	?	P					
Hyparrhenia hirta	?			P			P
Nassella charruana	?			P			
Nassella neesiana	?			P			P
Nassella tenuissima	?			P			
Pennisetum villosum	?						?
Sporobolus africanus	?		P	P			
Sporobolus fertilis	?		P	P			
Sporobolus jacquemontii	?		P	P			
Sporobolus natalensis	?		P	P			
Achnatherum brachychaetum	accidental	**P**		P			
Achnatherum caudatum	accidental	P		P			
Bothriochloa pertusa	accidental						?
Eragrostis curvula	accidental			P			
Nassella trichotoma	accidental			P			
Pennisetum macrourum	accidental			P			
Pennisetum polystachion	accidental		P				P
Sporobolus pyramidalis	accidental		P	P			
Themeda quadrivalvis	accidental	**P**		P			
Andropogon gayanus	forage				P		P
Brachiaria mutica	forage						P
Cenchrus ciliaris	forage				P		P
Hymenachne amplexicaule	forage						P
Panicum maximum	forage				P		P
Sorghum halepense	forage	**P**	**P**				
Sorghum × almum	forage	**?**					
Urochloa mosambicensis	forage						?
Cortaderia jubata	ornamental				P		P
Cortaderia richardii	ornamental						P
Cortaderia selloana	ornamental				P	P	P
Pennisetum setaceum	ornamental						P

grazing lands, but Randall (2001) identifies a number of 'garden grasses' that are weeds of crops. Thus the benefits of ornamental grasses accrue to the nursery and turf industries and their customers, while the costs are borne by agricultural industries and the environment.

Conflicts of interests could also arise in relation to species introduced to help rehabilitate degraded areas. Grasses are often used in soil stabilization and also to help manage soil salinity or at least to increase the productivity of salt-affected landscapes (Virtue and Melland 2003). In these cases, the conflicts may be between pastoral interests that seek to maintain or improve production on degraded lands and the integrity of natural vegetation that is invaded by the plant. Conflict could also arise on the basis of competing environmental interests, for example, landscape stability versus composition of natural plant communities.

Managing the conflicts

There are two generic practical challenges in relation to perennial grass weeds. The first challenge is to develop and implement control techniques and management practices that are effective against perennial grass weeds in various situations. The second is to resolve conflicts of interest between stakeholders.

Control techniques and management practices

Potentially at least, the five general control techniques used for other types of weeds can be considered for perennial grass weeds. These are the use of herbicides, mechanical control, grazing, fire and biological control (Grice 2000). Each involves limitations. Herbicides face economic and regulatory limitations. Their use on extensive infestations may be precluded on land of low productivity. For example, the cost of flupropanate, the main herbicide used to control *N. trichotoma*, limits the circumstances in which it can be applied to that species (Campbell and Vere 1998) and helps explain the presence of large, dense infestations in the least productive areas. No herbicides are registered for use against the declared *H. amplexicaulis* in Queensland though there are three permits for 'off-label use' of herbicides in particular situations (Queensland Natural Resources and Mines 2003).

The use of mechanical techniques can also be restricted on economic grounds as well as by the nature of the terrain. Moreover, mechanical disturbance can facilitate seedling recruitment and the use of machinery without adequate hygiene can spread seeds to previously weed-free areas. The spread of giant rat's tail grass (*Sporobolus pyramidalis*) has been facilitated in this way (Bray *et al.* 1999).

Grazing could conceivably be used to control weedy grasses that are palatable though only in situations where the benefits of the control outweigh any side-effects of grazing. Many of our most serious perennial grass weeds are of low palatability. There are few prospects for controlling them with grazing. The more useful pasture grasses (e.g. *P. maximum*, *C. ciliaris*, *U. mosambicensis*) are not only relatively palatable but also grazing tolerant. Where they occur as environmental weeds, it may be difficult to control them using grazing because the native species are often less tolerant of grazing even if they are less palatable. Similar difficulties often apply to the use of fire for control of grass weeds.

Biological control of grasses is poorly developed. There are several programs currently underway to explore the possibilities of biological control of several grass species. Surveys have been conducted for potential biological control agents on three *Sporobolus* spp. (*S. pyramidalis*, *S. natalensis*, *S. africanus*). A large insect fauna has been documented but, at this stage, only one species shows promise as a prospective biological control agent. Twenty pathogens were also found during the survey, of which one was seen as a potential biological control agent. Given the large number of native *Sporobolus* spp. present in Australia, host-specificity will be a major issue for a biological control program addressing weedy members of the genus (Palmer 2003). There are also efforts underway in Australia to develop biological control for *N. trichotoma* and *N. neesiana*.

Conflicts of interest

This challenge can be considered in terms of three questions. The answers to them can be informed by science but resolution of conflicts of interest relies upon economic considerations and societal values, which is why there are conflicts of interest in the first place.

Is it possible to receive the benefits of a perennial grass without paying the costs of its impacts as a weed?

To maximize benefits and minimize costs, one would need to be able to contain a grass within specified areas. At least for some species, there are protocols and practices for containing grassy weeds such as the weedy *Sporobolus* spp. (Bray *et al.* 1999). These protocols and practices, however, can at best only be partially effective even when there are no conflicts of interest. In a situation where, for example, a valued pasture grass is an environmental weed, as is argued for *C. ciliaris*, not only must there be a technological means of containment, but there must also be the socio-economic means of containment. Socio-economic means could take the form of some combination of community agreements and/or regulations. It seems likely, however, that it will not be practical to efficiently contain naturalized perennial grasses that have desirable traits for pastoralism. The challenge to doing so will be especially great in extensively grazed areas (rangelands).

The alternative to containing perennial pasture grasses to grazing lands is to attempt to prevent their incursion into areas of high environmental value that would be threatened by invasion by the grass, or other areas subject to non-pastoral land uses. A protection strategy does not acknowledge the importance of off-reserve conservation.

One of the important considerations for both containment and protection strategies concerns who would be responsible for managing it and who would bear the cost. The cost of implementing a containment or protection strategy would have to be less than the value of the impacts avoided. There may be a tendency for the cost of a containment strategy to accrue to the user who is in favour of the grass but for the cost of a protection strategy to accrue to the user who is opposed to the grass. Of course, the costs could be divided between the two sides of the conflict. Part of the challenge would be to develop and implement a system for allocating costs.

It may be possible to receive some of the benefits of introduced pasture grasses without bearing the full cost of the introduction but the technical and regulatory systems for doing so would, themselves, be demanding and it would be difficult to maintain the commitment to the system by all relevant parties.

The prospects of reaping benefits from ornamental exotic grasses without incurring environmental or other costs are no more likely than they are for forage grasses. It may be possible to regulate so that exotic ornamental grasses can be cultivated in regions where the chances of them naturalizing or becoming weedy are small. This is equivalent to regional weed declarations. However, considerable risks would remain and one could question the cost-benefit ratio of such an approach.

In what situations should we accept the costs, that is, where are they outweighed by the benefits?

This question must be answered in reference to the relative costs and benefits of exploiting a particular grass. The benefits to pastoral industries of having exotic forage grasses are considerable. Most animal production in Australia is based on them. On the other hand, the marginal benefits of further introductions may not be sufficient to justify those introductions. As regards exotic forage grasses that are already in use, the prospects for avoiding further costs to agriculture, forestry, other industries or the environment must rely principally on containment and protective strategies.

It is far more difficult to justify continued use of ornamental grasses that pose environmental, agricultural or pastoral risks. Economic benefits presumably accrue to the nursery industry. However, unlike with pastoral enterprises exploiting exotic grasses, the issue as regards ornamental grasses is about the economic advantage of one nursery relative to another. If a prospective ornamental grass is not available within the industry, no enterprise is disadvantaged relative to others. The enterprise can rely on alternative products. The same argument can be applied in regard to any ornamental plant that is prohibited because it has weed potential.

How do we minimize conflicts of interest?

A comprehensive approach to the threats from invasive species should place emphasis on both preventive measures (Grice 2000) and overcoming current problems. Prevention should cover both spread of current weeds and new incursions. Effective and comprehensive weed risk assessment should be applied to all new prospective imports of grasses and other plants. Improving quarantine and weed risk assessment procedures will greatly assist here as will the apparently declining demand for new forage species (Jones 2001). Given the difficulty of controlling perennial grasses that naturalize, Australia must be very cautious of further introductions. The diversity of introduced perennial forage grasses already in the country, and the very weak case in favour of introduction of grasses for ornamental uses, provides the basis for a convincing argument against any further introductions of perennial grasses. Demand for ornamental grasses should be met by development and promotion of native species. Finally, development of containment and protection technologies and strategies appropriate to perennial grass weeds are urgently required. This should include development of systems for allocating costs to implement the strategies.

References

Anon. (1997). The National Weeds Strategy: a strategic approach to weed problems of national significance. (Commonwealth of Australia, Canberra).

Bray, S., Yee, M., Paton, C., Silcock, R. and Bahnisch, L. (1999). The role of humans in the invasion of pastures by giant rat's tail grass (*Sporobolus pyramidalis*). Proceedings of the VI International Rangeland Congress, eds D. Eldridge and D. Freudenberger, pp. 593-4 (VI International Rangeland Congress Inc., Townsville).

Butler, D.W. and Fairfax, R.J. (2003). Buffel grass and fire in a gidgee and brigalow woodland: a case study from Central Queensland. *Ecological Management and Restoration* 4, 120-5.

Campbell, M.H. and Vere, D.T. (1998). *Nassella trichotoma*. *In* 'The biology of Australian weeds' eds R.H. Groves, R.C.H. Shepherd and R.G. Richardson, pp. 189-202. (R.G. and F.J. Richardson, Melbourne).

D'Antonio, C.M. and Vitousek, P.M. (1992). Biological invasions by exotic grasses, the grass/fire cycle, and global change. *Annual Review of Ecology and Systematics* 23, 63-87.

Department of Environment and Heritage (1999). 'Northern hairy-nosed wombat (*Lasiorhinus krefftii*) recovery plan 1998–2002'. Available at: http://www.deh.gov.au/biodiversity/threatened/recovery/hairy-nosed-wombat/#14.

Eyles, A.G. and Cameron, D.G. (1985). Pasture research in Northern Australia – its history, achievements and future emphasis, ed J.B. Hacker, CSIRO Division of Tropical Crops and Pastures. Research Report No 4.

Grice, A.C. (2000). Weed management in Australian rangelands. *In* Australian weed management systems, ed. B.M. Sindel, pp. 429-58. (R.G. and F.J. Richardson, Melbourne).

Grice, A.C. and McIntyre, S. (1995). Speargrass (*Heteropogon contortus*) in Australia: dynamics of species and community. *The Rangeland Journal* 17, 3-25.

Grice, A.C. and Campbell, S.D. (2000). Weeds in pasture ecosystems – symptom or disease? *Tropical Grasslands* 34, 264-70.

Griffin, G.F. (1993). The spread of buffel grass in inland Australia: land use conflicts. Proceedings of the 10th Australian Weeds Conference and the 14th Asian Pacific Weed Science Society Conference, pp. 501-4. (Weed Society of Queensland, Brisbane).

Groves, R.H. (1981). 'Australian vegetation'. (Cambridge University Press, Cambridge).

Groves, R.H. (1997). 'Recent incursions of weeds to Australia 1971–1995'. (CRC for Weed Management Systems, Adelaide).

Groves, R.H., Hosking, J.R., Batianoff, G.N., Cooke, D.A., Cowie, I.D., Johnson, R.W., Keighery, G.J., Lepschi, B.J., Mitchell, A.A., Moerkerk, M., Randall, R.J., Rozefelds, A.C., Walsh, N.G. and Waterhouse, B.M. (2003). The naturalized non-native flora of Australia: its categorization, the threats it poses to natural and agricultural ecosystems, and some candidates for eradication.

Hosking, J. *et al.* (In press). The naturalized flora of Australia.

Johnston, W.H. (1988). Palatability to sheep of the *Eragrostis curvula* complex. 3. A comparison of naturalized and selected taxa. *Australian Journal of Experimental Agriculture* 28, 53-6.

Jones, R.J. (2001). Current developments from tropical forage research in Australia. Tropical forage plants: development and use, eds A. Sotomayor-Rios and W.D. Pitman, pp. 295-329. (CRC Press LLC, Boca Raton, Florida, USA).

Jones, R.J. and Kerr, A. (1993). *Bothriochloa pertusa* – a useful grazing-tolerant grass for the seasonally dry tropics? Proceedings of the XVII International Grassland Congress, pp. 1897-8. (New Zealand Grassland Association and Tropical Grassland Society of Australia, Rockhampton).

Lonsdale, W.M. (1994). Inviting trouble: introduced pasture species in northern Australia. *Australian Journal of Ecology* 19, 345-54.

Low, T. (1997). Tropical pasture plants as weeds. *Tropical Grasslands* 31, 337-43.

Noble, J.C., MacLeod, N. and Griffin, G. (1997). The rehabilitation of landscape function in the rangelands. *In* Landscape ecology, function and management: principles from Australia's rangelands, eds J. Ludwig, D. Tongway, D. Freudenberger, J. Noble and K. Hodgkinson, pp. 107-20. (CSIRO, Collingwood, Australia).

Oram, R.N. (1990). 'Register of Australian herbage plant cultivars', 2nd edition. (CSIRO, Australia).

Palmer, W.A. (2003). 'African survey for weedy *Sporobolus* biological control agents'. Progress Report to Meat and Livestock Australia. Project Number NPB.304.

Parsons, W. T. and Cuthbertson, E. G. (2001). 'Noxious Weeds of Australia', 2nd edition (CSIRO Publishing, Melbourne).

Queensland Natural Resources and Mines (2003). 'Hymenachne *Hymenachne amplexicaulis*'. NRM Facts Pest Series PP54 QNRM01271.

Randall, R. (2001). Garden thugs, a national list of invasive and potentially invasive garden plants. *Plant Protection Quarterly* 16, 138-71.

Richardson, D.M., Pysek, P., Rejmanek, M., Barbour, M.G., Panetta, F.D. and West, C.J. (2000). Naturalization and invasion of alien plants: concepts and definitions. *Diversity and Distributions* 6, 93-107.

Rossiter, N.A., Setterfield, S.A., Douglas, M.M. and Hutley, L.B. (2003). Testing the grass-fire cycle: alien grass invasion in the tropical savannas of northern Australia. *Diversity and Distributions* 9, 169-76.

t'Mannetje, L. and Jones, R.M. (1990). Pasture and animal productivity of buffel grass with Siratro, lucerne or nitrogen fertilizer. *Tropical Grasslands* 24, 269-81.

Tongway, D. and Ludwig, J. (1997). The conservation of water and nutrients within landscapes. *In* Landscape ecology: function and management, eds J. Ludwig, D. Tongway, D. Freudenberger, J. Noble and K. Hodgkinson, pp. 13-22. (CSIRO, Collingwood, Australia).

Virtue, J.G. and Melland, R.L. (2003). The environmental weed risk of revegetation and forestry plants. Technical Report DWLBC 2003/02. (Department of Water, Land and Biodiversity Conservation, SA).

Walker, B., Baker, J., Becker, M., Brunckhorst, R., Heatley, D., Simms, J., Skerman, D.S. and Walsh, S. (1997). Sown pasture priorities for the subtropical and tropical beef industry. *Tropical Grasslands* 31, 266-72.

Williams, R.J., Griffiths, A.D. and Allan, G.E. (2002). Fire regimes and biodiversity in the savannas of northern Australia. *In* Flammable Australia: the fire regimes and biodiversity of a continent', eds R.A. Bradstock, J.E. Williams and A.M. Gill, pp. 281-304. (Cambridge University Press, Cambridge).

Woolnough, A.P. (1998). The feeding ecology of the northern hairy-nosed wombat, *Lasiorhinus krefftii* (Marsupialia: Vombatidae). Ph.D. thesis, James Cook University of North Queensland, Townsville.