ness of the species. This process, in combination with field surveys and further consultation, are essential to improving knowledge of *P. pallida* distribution and invasiveness.

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Future directions for managing perennial grass weeds in South Australia

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Introduction

Perennial grass weeds have historically received less attention compared to other weed types in South Australia (SA). There are many reasons for this, but two common reasons are the general lack of recognition of various grass weed species and their impacts by land managers, and the fact that many species are useful pasture grasses. The preceding papers in this workshop have illustrated the wide range of perennial grass weeds threatening a range of landuses in SA. Here we highlight the significant issues raised in these papers and by participants at the SA Perennial Grass Weeds Workshop (hereafter known as the Workshop), which need to be addressed in order to improve management of perennial grass weeds in SA. We then propose the basic framework of a strategic approach to managing perennial grass weeds.

Issues

A wide range of issues regarding the use and management of perennial grass weeds in SA were raised by speakers and/or the participants at the Workshop. These need to be addressed in the preparation of a strategic plan to minimize the current and future impacts of perennial grass weeds in SA.

What is the current status of perennial grass weeds in SA?

There is currently no central list of exotic grass species present in SA, whether it is species that are currently recorded as naturalized in SA (e.g., Jessop 1993 lists 167 naturalized species amongst the Gramineae), or species being grown for agricultural use (see Prance 2004), landscaping use (see Nottle 2004) and turfgrasses. There are also new species being considered for pastures (see Prance 2004) and specimens being grown in the Adelaide Botanic Gardens, some which are known to be weedy overseas (Randall 2002) such as *Stipa ichu* (Ruiz & Pav.) Kunth and *Bromus brizaeformis* Fisch. & Mey. Lastly, there may be Australian perennial grass species being grown in SA that are not native to the State. Non-indigenous natives can sometimes become environmental weeds (Groves 2001, Bennett and Virtue in submission). There is a need to collate the grass species that fit into the above categories into a central list so that the full range of existing and potential weed threats can be considered in developing a strategic management plan.

A new handbook on all native and naturalized grass species in SA is currently being drafted (John Jessop personal communication), and this would be a key reference for the central list.

Speakers and participants at the Workshop questioned why annual grass weeds had been ignored on the day. There were three reasons for this. Firstly, the organizers were seeking a tight focus for the workshop. Secondly, the conflicts of interest surrounding grasses are generally related to perennial species. Finally, much concern about the impacts of perennial grass weeds has been demonstrated in recent years via considerable research and Natural Heritage Trust funds being spent on the issue. Indeed, NSW National Parks and Wildlife Service has listed perennial grass weeds as a key threatening process and a strategic management plan is to be developed (Paul Downey personal communication). Nonetheless, the impacts of exotic annual grasses (e.g. Lenz *et al.* 2003) should not be neglected.

Table 1. Perennial grass species of weed concern in SA, mentioned at the Workshop.

Species	Common name
Ammophila arenaria (L.) Link	marram grass
Cenchrus ciliaris L.	buffel grass
Chloris gayana Kunth	Rhodes grass
Cortaderia spp.	pampas grasses
Cynodon dactylon (L.) Pers.	couch
Dactylis glomerata L.	cocksfoot
Distichlis spicata (L.) Greene	saltgrass
Ehrharta calycina Sm.	perennial veldgrass
E. villosa (L.f.) J.H.Schult. var. *maxima* Stapf	pyp grass
Eragrostis curvula (Schrad.) Nees	African lovegrass
Holcus lanatus L.	Yorkshire fog
Hyparrhenia hirta (L.) Stapf	Coolatai grass
Jarava plumosa (Spreng.) S.W.L.Jacobs & J.Everett	plumerillo
Lophopyrum ponticum (Podp.) Á.Löve	tall wheatgrass
Nassella leucotricha Trin. & Rupr.	Texas needlegrass
N. neesiana (Trin. & Rupr.) Barkworth	Chilean needlegrass
N. trichotoma (Nees) Hack. ex Arechav.	serrated tussock
Pennisetum alopecuroides (L.) Spreng.	swamp foxtial grass
P. clandestinum Hochst. ex Chiov.	kikuyu
P. macrourum Trin.	African feather grass
P. setaceum (Forssk.) Chiov.	fountaingrass
P. villosum R.Br. ex. Fresen.	feathertop
Pentaschistis pallida (Thunb.) H.P.Linder	pussytail grass
Phalaris aquatica L.	phalaris
Piptatherum miliaceum (L.) Coss.	rice millet
Sorghum halepense (L.) Pers.	Johnson grass
Sporobolus africanus (Poir.) Robyns & Tournay	Parramatta grass
Thinopyrum junceiforme (Á. & D.Löve) Á.Löve	sea wheatgrass

What perennial grass species are weed threats to SA?

The species on the central list that are significant weed threats to SA need to be identified and prioritized for control. Formal weed risk assessment (WRA) needs to be undertaken, as was done for four grass species in Virtue and Melland 2003. Table 1 lists perennial grass species mentioned at the workshop that require a WRA. In undertaking such assessments, participants at the Workshop stressed the need to utilize the observations and experience of non-professionals working in the field, in addition to any available scientific information. The accuracy of WRAs, at national, state and regional levels, was also questioned at the Workshop.

Identification and motivation

One of the key difficulties with managing grass weeds is identification. Grasses are notoriously difficult to recognize, especially when not in flower. Most landholders and indeed many weed managers would not know key grass genera and species, both native and exotic. There are various grass identification resources (e.g. Gibbs and Gibbs 2001, Sharp and Simon 2002) and training courses available (e.g. provided by Trees for Life Inc. and Native Grasses Resource Group Inc.), yet are these reaching a wide enough audience? How can we increase general landholder recognition of the various grasses weeds?

The Workshop called for a standard process to enable regional people to report, identify and act upon suspect new grasses. Various formal and informal reporting systems currently exist within organizations such as the South Australian Animal and Plant Control Commission and the State Herbarium, but there is no formal, cross-government process in place. An internet-based identification and reporting system was suggested to enable quicker intervention against new grass weed problems.

Considerable concern was expressed at the Workshop about grasses being sold under the wrong common or scientific name at nurseries and markets. For example, there have been instances in SA of *Pennisetum setaceum* being sold as *Pennisetum alopecuroides*. Likewise *Hyparrhenia hirta* has been sold as kangaroo grass (*Themeda triandra* Forssk.). Whether accidental or deliberate, misnaming in nurseries is unacceptable and the Workshop suggested that consumer laws should be invoked to stop the practice. Related to this issue is what is truly a 'native grass'. Should there be clearer definitions of what is native to a region or SA, rather than just Australia? In addition, are some native grasses truly native? *P. alopecuroides* has been widely sold as a 'native' in recent years, but there is considerable doubt that it is (e.g., Sharp and Simon 2002, Walsh 2004).

Identification is not going to happen without a motivated public. There needs to be more regional awareness of the impacts of grass weeds on biodiversity and pastures. The relatively unnoticed spread of low-palatability grasses such as *Nassella* spp., *H. hirta* and *Eragrostis curvula* across SA is a sleeping giant which the livestock grazing industries should be much more concerned about. The gardening public and industry should also be targeted to raise awareness of the threats posed by the main weedy ornamental grasses.

Understanding grass impacts

Whilst WRA seeks to compare the threats posed by various weeds in a consistent manner, it is often limited by the availability of scientific information. In addition, assessments are rankings rather than absolute, quantitative measures of how much a weed will cost the region or state. We need more scientific measurements of the impacts of perennial grass weeds

in natural and agricultural ecosystems, including effects on biodiversity, feed availability, revegetation success, fire regimes and landscapes (e.g., Puckey and Albrecht 2004, Taylor 2004). This information is vital if the general community is to become concerned and motivated about grass weeds, and to justify government investment in eradication, containment and control programs. It is also vital for comparison with the economic and environmental benefits of pasture grass species.

Better control of perennial grass weeds in SA

A major concern raised at the Workshop was the need to achieve better control of perennial grass weeds in SA. This included better control techniques and more prompt and consistent government-led control programs.

Apart from within intensive cropping systems, there are generally limited techniques to control perennial grass weeds with minimal off-target effects on desirable plants (i.e. pasture, native vegetation). In general, herbicides are the main broadscale technique for perennial grass weeds. The two main herbicide options for large, established plants are glyphosate and flupropanate (Cook 2003). However, herbicide rate, application method, timing and effectiveness vary between species and landuses. Herbicide research and subsequent registrations/permits for their use are needed for key grass weed/landuse combinations in SA. Some Animal and Plant Control Boards are loath to enforce proclamation without being able to give a legal control recommendation to landholders. Past research outcomes with fluazifop-butyl in SA (Davies 1997) should be capitalized upon and new grass-selective herbicides should be investigated (Myers 2004). Workshop participants felt that greater information exchange between agronomists and farmers who manage pasture grasses (Prance 2004, Strugnell 2004) and those who manage environmental weeds would deliver better control outcomes.

Natural ecosystems and the arid Rangelands/Aboriginal Lands were singled out at the Workshop as landuses where broadscale control of perennial grass weeds with herbicides is usually cost-prohibitive. This is a familiar problem with weed control in general in these areas. Sites need to be prioritized for control based on conservation/production values and feasibility of controlling perennial grass weeds. It is clear that *Cenchrus ciliaris* is a major threat to biodiversity in central and northern SA (Pitt 2004, Puckey and Albrecht 2004), and strategic actions are urgently needed to minimize its impact in regionally significant sites. Better understanding of which sites are at-risk of invasion in the landscape (i.e., dispersal pathways, suitable habitats, the role of disturbance) will enable better strategic planning. Geographic information systems techniques to achieve this are currently being investigated at the Cooperative Research Centre for Australian Weed Management (Shaun Kolomeitz personal communication).

Roadsides were also singled out at the Workshop as a major concern with regards to facilitating spread of perennial grass weeds (through mowing, grading, vehicles and wind), competition from perennial grass weeds within remnant roadside native vegetation, and being a safety hazard (i.e., reduced visibility for driving and increased fire risk). We need to ensure that control techniques favour desirable species and do not create disturbances that facilitate further grass invasions. Roadside weed control is complicated by the various responsibilities and legal roles of state government agencies, local governments and adjacent landholders. The system needs to be simplified to enable more effective and efficient weed management.

The effectiveness of the proclamation of perennial grass weeds under *Animal and Plant Control (Agricultural Protection and Other Purposes) Act, 1986* was questioned at the Workshop. There were concerns over inconsistencies with regard to which grasses had been proclaimed. Proclamation leads to a legal responsibility of landholders to control a weed and/or prevent its sale and movement. Proclamation does not provide for government funds to landholders for on-ground control works of proclaimed plants. Hence, proclamation on its own will not lead to rapid regional control of a weed. The Workshop called for a quick response mechanism in SA for new weed incursions, including funding for control works, as is occurring with lobed needlegrass (*Nassella charruana* (Arechav.) Barkworth) in Victoria (McLaren *et al.* 2004). The need for a specific environmental weed class in SA legislation, similar to that in Queensland legislation, was raised. A national approach to proclamation for sale was also supported. This would remove the current inconsistencies in declarations between States and Territories that arise as wholesale nursery plants are moved across the country. Lastly, better hygiene measures to limit movement of contaminated machinery and fodder in SA are needed.

Resolving conflicts of interest

The significant uses of exotic perennial grasses in agricultural landuses need to be given due recognition in managing perennial grass weeds. Perennial grasses form the basis of sustainable pasture systems, supporting livestock industries producing several billion dollars worth of products nationally per year. They can provide the significant environmental benefit of increased soil water use that subsequently reduces dryland salinity and soil acidification (Strugnell 2004). They can stabilize soils to reduce erosion and nutrient runoff. Perennial grasses are also important socially, being the predominant vegetation in urban areas. They have functional and aesthetic uses for lawns, parks and sporting fields. They are revered as a significant class of ornamentals in gardens and landscaping (Nottle 2004).

Conflicts of interest arise where the above benefits of some perennial grasses go to some sectors of the community (e.g., graziers, gardeners) whilst the grasses spread away from cultivation to cause unwanted impacts and subsequent control costs for other sectors of the community (e.g. conservationists). The most frequent conflict of interest arising at the Workshop was pasture grasses invading native vegetation. Strugnell (2004) and Prance (2004) demonstrated that maximizing productivity of perennial grasses through heavy grazing at appropriate times also limited seed production and hence off-site spread. The technical feasibility of containing grasses such as tall wheatgrass (*Lophopyrum ponticum* (Podp.) Á.Löve) by appropriate management was appreciated by Workshop participants, but concerns were raised about financial and social feasibility. Grice (2004) questioned whether farmers have the resources to contain grasses to plantings. Would a requirement to manage useful but invasive grasses be accepted by the farming community through education, or would enforcement be required? Farmer containment of plantings may have limited value in locations where such grasses are already widely planted and naturalized. The focus would then shift to ongoing protection of high value conservation sites. Grice (2004) also questioned whether we have enough resources to focus on protecting such sites.

The Workshop sought a better preventative approach to minimize future conflicts of interest. The number of new grasses (new species and varieties) passing through Australia's quarantine system was questioned. The adoption of a formal weed risk assessment system by AQIS in 1998 should have reduced new grass weeds entering Australia. However, under international trade regulations weedy grass species already present in Australia can continue to be imported unless they are declared noxious weeds (Bennett and Virtue in submission). Permitted genera such as *Stipa* and *Sporobolus*, which are known to contain invasive species (Spafford Jacob *et al.* 2004), and undeclared internet mail orders of grass seeds remains a difficult problem.

At the State level, Grice (2004) stressed the importance of weighing up weed risk

and potential utility at the point of introduction. Prance (2004) called for a formal assessment process for new grass introductions in SA. New grass introductions should also include registered herbicides for their control.

Grice (2004) and Myers (2004) questioned whether we need more grass introductions at all. There may be an economic argument for further agricultural introductions, but the benefits to the wider community of further ornamental grass introductions is minimal. Grice (2004) suggested development of native grasses as ornamentals, but Nottle (2004) raised practical difficulties of current landscape plantings of native grasses. The most immediate action suggested at the workshop was to engage and educate the horticultural media and garden industry on invasive grasses and safe alternatives. Frequent appearances of the prohibited import white tussock (*Nassella tenuissima* (Trin.) Barkworth) in magazines such as Gardening Australia demonstrates that the message is still not getting through (Kate Blood personal communication). There is a general need to shift social norms of the gardening public to favour non-invasive alternatives.

Funding

The issue of adequate funding for research, eradication, containment, control and awareness of perennial grass weeds was raised at the Workshop. There was concern that the new regional funding arrangements for natural resource management (NRM) in Australia will cause difficulties for weed projects, which are often cross-region and long-term in nature. Weeds have recently been estimated to cost the Australian economy approximately $4 billion annually, with additional, still unquantifiable costs to biodiversity (Sinden *et al.* 2004). There needs to be greater political will to take on weeds as a significant NRM issue.

A strategic approach to perennial grass weeds in SA

The issues raised in this paper need to be part of a formal strategy to manage perennial grass weeds in SA. The basic framework of such a plan is suggested below. The further development of this plan will require collaboration between government, agricultural, conservation and gardening stakeholders in SA. A steering committee should be formed to advance the strategy and secure funding for its actions.

Vision

Perennial grass weeds do not threaten the biodiversity of natural ecosystems, the productivity of primary industries and the safety and welfare of people in South Australia.

WEED RISK	FEASIBILITY OF CONTROL		
	Low	***Medium***	***High***
Low	No action	No action	Monitor
Medium	Improve general weed management	Improve general weed management and local containment	Prevent entry and regional containment
High	Targeted management incl. biocontrol and local containment	Targeted management and regional containment and local eradication	Prevent entry and regional eradication

Figure 1. A decision matrix of management options based on weed risk and feasibility of control (Virtue *et al.* 2004).

Goals

1. To prevent the establishment and spread of new perennial grass weeds in SA
2. To minimize the economic, environmental and social impacts of established perennial grass weeds in SA

Grasses species considered in the strategy

Collation of a central list of perennial grass weeds present in SA was suggested above. Table 1 provides a starting point. The committee would need to undertake a preliminary screening of the list to remove species that have shown minimal weed impacts despite a long presence in the State.

Assessing strategic management options

The weed risk and feasibility of control of the various grass species would need to be assessed, so that they can be categorized into the most appropriate management actions (Figure 1). A national standard and assessment system has been developed to provide guidance for this process (Virtue *et al.* 2004). This categorization of the grass species should be done at the NRM region level. However, some actions may best be coordinated between regions, states or at a national level.

Prevention, eradication and containment

Perennial grass weeds of high to medium weed risk and feasibility of control will be priorities for Goal 1 (prevent establishment and spread). Actions to be considered for the strategy include:

- Raising awareness of the identification and potential impacts of the grass species, to foster reporting and early control;
- Searching likely infestation sites and mapping current distribution;
- Legal restrictions on sale and distribution;
- Legal requirements for control;
- Understanding the means of dispersal and how further spread can be prevented; and
- Controlling infestations.

Achieving effective, long-term control of infestations is crucial. For each species there will need to be consideration of whether control techniques are available or need research and whether there are legal herbicide registrations/permits in force. There will also need to be the right mix of education and enforcement, the selection of priority sites (for containment) and the measurement of control technique success.

Managing established perennial grass weeds

Perennial grass weeds of high weed risk but low to medium feasibility of control will be priorities for Goal 2 (reduce impacts of established grasses). Actions will be similar to the controlling infestations component of Goal 1, but with greater investment in integrated weed management research and the subsequent extension of these techniques to landholders (e.g.,

combining herbicides, grazing, competition, biocontrol).

Dealing with conflicts of interest

The SA perennial grass weeds strategy needs to develop effective means to maximize the benefits but minimize the risks of perennial grass pastures. For new pasture grasses the strategy should require only the use of species of low weed risk and that they be managed for production (i.e. not left to go rank and seed) and contained on farms using registered herbicides for their control. For widely planted pasture grasses the strategy should consider local containment programs for priority environmental sites. The strategy will need to consider the balance between and opportunities for enforcement and education. For invasive ornamentals the strategy should devise actions to educate the gardening industry and public on the weed risks of certain grasses, remove priority invasives and promote safe alternatives.

Funding

Adequate resourcing/funding is crucial to achieve all of the above. Countless strategies come and go, but unless there is funding to match, they are worth little more than the paper they are written on.

Conclusion

The SA Perennial Grass Weeds Workshop has demonstrated that these weeds are a significant current and future concern to agricultural, natural and urban landuses in the State. There are many technical, social and economic issues to deal with in tackling perennial grass weeds, but ignoring them is simply not an option. Perennial grass weeds, like all weeds, spread and continue to increase in abundance and impacts. Strategic intervention is needed now in SA.

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The research directions proposed here should improve pasture grass resilience and forage crop sustainability in Mediterranean and temperate summer-dry environments under the future drier and warmer conditions associated with climate change. Contents. 1. Introduction.Â In southern Australia, located between latitudes 30Â° and 43Â° S, depending on the greenhouse gas emission scenario chosen, the climate is expected to experience between 2 and 8 % more evapotranspiration, temperatures will increase by between 1.5 and 3 Â°C, and annual rainfall will decline by between 2 and 5 %. Moreover, the more northerly part of this region is likely.Â Perennial grasses dominate in most natural grasslands and provide the principal nutrition for ruminant livestock. They are used primarily against broadleaf weeds, perennial grasses, and sedges. The chemicals 2,4-D, dicamba, mecoprop (MCPP), carfentrazone, and sulfentrazone are very common broadleaf herbicides for use in warm-season turfgrass lawns. They have been combined in many products that control most broadleaf weeds.Â Most crabgrass preventers will stop most annual grass weeds from coming up in the lawn, including annual bluegrass (Poa annua). However, these preemergence herbicides may need to be reapplied again in the fall for season-long control, so check the product label (see Table 1). Postemergence: Continue to treat grassy and broadleaf weeds.Â Use pesticides only according to the directions on the label. Perennial ryegrass pastures have been the mainstay of pasture-based dairy farming in southern Australia and will likely continue to be into the foreseeable future. The 3030 Project has explored forage alternatives but has also examined perennial ryegrass to gain a better understanding of why it is the cornerstone of pasture-based systems in southern Australia.Â Perennial ryegrass thrives under good grazing management. Its nutritional qualities are also more forgiving of temporary changes in grazing practices, such as delayed grazing, than other perennial species. Recommended soil fertility and fertiliser programs induce few animal health issues with perennial ryegrass.Â Grass weeds such as barley grass or winter grass. More information.