Weedy Pasture Plants for Salinity Control

Sowing the Seeds of Destruction

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The Invasive Species Council is a national conservation group formed in 2002 to campaign for better laws and policies to protect Australia's natural environment from invasive plants, animals and micro-organisms.

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Contents

Summary

In Victoria one environmental problem – salinity – is being used to justify the exacerbation of another much worse environmental problem – weed invasion. Victorian farmers have been encouraged and subsidised to plant Tall Wheat Grass (*Lophopyrum ponticum*) as a salt-tolerant pasture. It has already escaped cultivation at hundreds of sites, and according to a Victorian Government assessment, it could invade more than 10 million hectares of Victoria. Despite the government's risk assessment recommending that the invasion of Tall Wheat Grass into saltmarshes be declared a threatening process, the government has continued to promote its planting. The department that developed and released the most commonly planted cultivar of Tall Wheat Grass is the same department that manages weed declarations.

Other weedy pasture plants are also being promoted for saline areas or to help control salinity across southern Australia, and agronomists are developing new pasture varieties for this purpose that are likely to be invasive. Although the Future Farm Industries Cooperative Research Centre now conducts weed risk assessments on proposed new releases, standards are so low that 'high risk' plants can be released.

In this report we examine the weed risks associated with salinity programs promoting exotic perennial pasture plants for salinity mitigation, and identify the institutional failings that have led to the promotion of serious weeds. Our focus is Victoria, but many of the problems are common to other southern states as well.

Salinity and perennial pastures

Dryland salinity is a well-recognised environmental and agricultural problem, attributed to the extensive replacement of native vegetation with crops and pastures that have shallower roots and shorter growing cycles, and use less of the soil water. In Victoria 1-2% of agricultural land is reported to be affected by salinity.

Governments, Catchment Management Authorities and agronomists have strongly promoted the cultivation of perennial pasture species as a solution for salinity problems. Perennial plants use more water than annual species, limiting the leakage of water into groundwater and reducing mobilisation of salts in the soil. Some perennial pasture species such as Tall Wheat Grass are salt-tolerant, so can be cultivated on salinised sites.

However, Victoria's dryland salinity problems have proved to be more localised and smaller in extent than previously estimated. Drier conditions since the mid 1990s have stabilised and reduced the salinity threat, and the drier climate predicted under climate change will further reduce the risk of salinity.

Perennial pasture systems are in any event failing to solve salinity problems. They have little effect in many areas (such as wetter catchments), graziers are not planting them on the scale required to reduce salinity, and in many catchments the extent of planting required to address salinity (up to 50%) is unrealistic.

The extent of salinity and its costs to Victoria are far outweighed by the threat and costs of weeds. The area threatened by just one of the weedy pasture plants promoted for salinity mitigation, Tall Wheat Grass, is more than an order of magnitude greater than the area threatened by salinity. Yet the weed risks are mostly ignored or downplayed.

Tall Wheat Grass

Lophopyrum ponticum is a productive exotic grass palatable to sheep and cattle. The Victorian Department of Primary Industries, which developed and released in 1999 the Dundas cultivar, considers that it has "the potential to reclaim most of the salt affected unproductive areas on farms within Victoria and other states".

Tall Wheat Grass is invasive in many countries, including in Australia's southern states. It has extraordinary ecological amplitude, invading saltmarsh, wetlands, grasslands, estuaries, coastal cliffs, waterways, roadsides and some woodlands and tolerating drought, frost, salinity, alkalinity and waterlogging.

Saltmarshes and wetlands are under particular threat. Tall Wheat Grass is a threat or potential threat to several rare and threatened species, and can substantially increase fuel loads in some invaded habitats.

The weed risk of Tall Wheat Grass has mostly been ignored. When it is acknowledged, governments and Catchment Management Authorities have recommended that Tall Wheat Grass be grazed by stock to prevent it setting seed. But even with the best intentions, some plants set seed. One study found that it had spread along creeks from about one-quarter of the study sites located near a creek and along roadsides from almost half the sites located near a road.

A state government weed risk assessment found that Tall Wheat Grass has the potential to invade 10.4 million ha of Victoria, that it is a very serious threat to saltmarshes in western Victoria and that threatened species are at risk. The assessors recommended that it be listed as a threatening processes for saltmarshes under state legislation, and acknowledged that it would not have passed a risk assessment had it been assessed prior to its use for salinity mitigation. But because of the grass's pastoral values for salt-affected areas, the assessors recommended against declaring it a noxious weed.

Other weedy pasture plants

The Future Farm Industries Cooperative Research Centre (CRC) is aiming for a tripling of the area in Australia sown with perennial pastures to more than 10 million hectares, to treat or prevent salinity and better withstand dry conditions. But this plan is likely to exacerbate existing weed problems and introduce new weeds.

Of 23 pasture species promoted by the CRC for use on saltlands (on their *Saltland Genie website*) more than half are environmental weeds in Australia. The CRC proposes to domesticate new pasture species and develop new cultivars of existing weedy pasture plants to tolerate harsher conditions (salinity and acidity) and grow in lower rainfall areas. Of 190 prospective pasture species identified by agronomists in three recent reviews, about half are already weeds in Australia and two-thirds are weeds elsewhere.

There are high weed risks with exotic pasture plants because many of the attributes sought – such as persistence, productivity, tolerance of difficult climatic and soil conditions, and grazing tolerance – are the same attributes that many weeds have.

Because state weed regulations and declaration processes are deficient, most weedy pasture plants can be freely traded and planted in Victoria (and in most other states and territories). There are almost no impediments to agronomists releasing new weed species and cultivars into Victoria's already severely weed-degraded environment. There are no requirements for graziers to prevent the spread of non-declared weeds beyond their boundaries.

The Future Farm Industries CRC conducts weed risk assessments, but under its protocol only plants assessed as 'very high' risk are rejected. 'Medium risk' and 'high risk' species, including plants that are already serious weeds in Australia, can be released and promoted with voluntary management guidelines. Under this protocol very few weeds will be rejected, and based on the failure of other voluntary approaches, it is unlikely that management guidelines will prevent escapes from cultivation.

Institutional failings

Many of Australia's most costly and damaging weeds are plants that were introduced for pasture under schemes mostly funded by taxpayers. The salinity program suggests that the lessons of the past have not yet been learned. Government promotion and funding of serious environmental weeds illustrate failures of governance, law and policy.

Abrogating responsibility: Governments are abrogating their responsibilities by allowing research institutes and companies to decide whether to release weedy species and individual landholders whether to plant them. The federal government could regulate the trade and use of invasive species but leaves this to the states. The Victorian Government could ban the planting of these weeds, but seldom imposes restrictions on plants considered useful to any sector, no matter how serious the consequences. Just one of the weedy species currently promoted for saltlands is restricted in Victoria.

Ignoring conflicts of interest: The Victorian Department of Primary Industries is compromised in its role of weed assessment because it is the same department that is promoting Tall Wheat Grass and other weedy pasture species. Its official purpose is “to sustainably maximise the wealth and wellbeing” generated from primary industries. Catchment Management Authorities that manage salinity programs and nominate weeds for declaration, and some of whose stakeholders include graziers who grow weedy pasture plants, may also face conflicts of interest over invasive pasture plants. Agronomy research institutions and graziers have obvious commercial conflicts of interest when making decisions about weedy pasture species.

Paying lip service to risk assessment: Assessments of weed risk have been non-existent or flawed. Only a small proportion of species promoted by or of interest to researchers for salinity mitigation have undergone weed risk assessment. A recent update of Victoria’s weed list did not result in risk assessment of any of the weedy pasture species promoted for salinity, and the Victorian Government’s risk assessment of Tall Wheat Grass was flawed. The risk assessment protocols of the Future Farm Industries CRC set a very low standard and permit release of weeds assessed as high risk.

Relying on voluntary restraint: The Victorian Government, Catchment Management Authorities and the Future Farm Industries CRC promote voluntary management guidelines as a way to manage weed risk, although CRC-associated researchers acknowledge there is no evidence that guidelines work. Even agronomists have difficulties controlling the spread of some species grown experimentally. There is evidence from other situations that voluntary guidelines are mostly ineffective in regulating behavior under comparable circumstances.

Ignoring biodiversity: The problems identified are symptomatic of sectoral approaches to natural resource management and the failure to embrace the ‘ecology’ aspect of sustainability. This perpetuates conflicts between resource use and conservation management, and promotes waste when one government program is funded to repair what another program has promoted. The threats of weedy pasture species for biodiversity are poorly recognised and there is virtually no management of invasive pasture species where they are invading natural ecosystems. Weeds are receiving far less attention than is warranted by the seriousness of their impacts. There is no equivalent of the $1.4 billion National Action Plan for Salinity for weeds, despite their greater harm.

Recommendations

Investigate threats and protect ecosystems at risk:

- Place a moratorium on further plantings of Tall Wheat Grass until its environmental risks are assessed.
- Conduct a comprehensive survey of Tall Wheat Grass in Victoria, investigating its means of dispersal and impacts on the environment, concluding in a peer-reviewed report.
- Conduct an inventory of areas, species and values at risk from Tall Wheat Grass and other invasive pasture plants, including the poorly known flora and fauna of primary salinity areas.
- Conduct weed risk assessments of invasive pasture species, including Tall Wheat Grass and Puccinellia, and declare them in appropriate noxious weed categories to prevent further introductions and spread threatening to biodiversity.
- Take immediate action to prevent Tall Wheat Grass and other invasive weeds spreading into natural ecosystems from plantings or infestations in adjacent areas. Manage existing infestations on both public and private lands.

Prevent further harm:

- Require that all species and cultivars proposed for introduction into new areas be assessed for their weed risk, and permit only low-risk taxa for release.
- Promote and develop low-risk pasture options, such as retention of native pastures, native species for sowing, and volunteer reclamation of saline areas.
- Assess invasive perennial pasture plants as a potential threatening process under both Victorian and federal legislation.
- Require landholders to prevent spread of sown pasture species that threaten biodiversity, by strengthening duty-of-care provisions and developing enforceable codes of conduct.

Address systemic problems:

- Conduct an independent review of the institutional failings that have led to promotion of, and subsidies for, planting of Tall Wheat Grass and other harmful invasive species for salinity control.
- Address conflicts of interest in the Victorian regulation of weed listings by shifting responsibility for assessments and declarations to the environment department and allowing nominations from the public.
- Adopt a precautionary 'permitted list' approach to regulation of invasive species similar to that adopted by the federal government for import assessments and by Western Australia.
- Develop federal regulations to restrict the trade and use of invasive species that potentially harm matters of national environmental significance.
- As a condition of government funding for agronomy research, require that research institutes such as those in the Future Farm Industries CRC only promote and release low-risk plant species as assessed by best-practice weed risk assessment.

STOP PRESS!

Since this report was completed, there have been two changes worth noting.

(1) The Victorian Government is conducting another weed risk assessment of Tall Wheat Grass. No result has been reported.

(2) The Future Farm Industries CRC has determined that Tall Wheat Grass represents a 'very high' weed risk in Victoria (but not in other states) and will no longer promote it in Victoria.

These developments, which were made in response to recent criticisms, are welcome, but will make little difference unless they lead to a ban on future plantings. They do not address the weed risks of Tall Wheat Grass outside Victoria.

1 Chapter

Introduction

Introduction

The saltland pasture industry has the potential to release a new wave of exotic weeds into Australia.
– Pasture researchers Bill Semple and colleagues, 2004[1]

1.1 A cautionary tale

Large areas of southwestern Western Australia have been devastated by salinity. The 'salt cancer' caused by extensive land clearing threatens millions of hectares of agricultural land and bushland, the health of wetlands, and the future of hundreds of endemic plant species and the wildlife that depends on them.

In 1990 a plant from eastern Europe and western Asia, Kochia (*Bassia scoparia*), was introduced into Western Australia for pasture and to rehabilitate salt-affected agricultural land. Unfortunately, Kochia proved only too hardy and successful. From 52 of the 68 sites where it was planted it spread into the wild, moving onto roadsides, pastures and areas not affected by salt.[2] Already well-known in the United States, Europe and elsewhere as a weed, it was quickly recognised as a serious threat to crops and the environment. Kochia forms dense infestations that eliminate native plants, assisted by chemicals it produces that reduce the growth and germination of nearby plants.[3]

Two years after its introduction, the Western Australian government prohibited Kochia and an eradication program was started (motivated primarily by its threat to wheat crops), which cost more than half a million dollars.[4]

The Kochia disaster provided impetus for reforming Australia's quarantine approach to prevent other high-risk imports of new exotic plant species. It also highlighted the potential for plant-based salinity programs to introduce new weeds to Australia.

This example of Kochia is not unique. Most of the plants promoted for salinity prevention and treatment in Australia are exotic (non-indigenous) and, as this report reveals, many are unacceptably weedy. With a focus on Victoria, we show that pasture plants for rehabilitation of saline lands are causing more problems than they are solving. We examine the systemic failings that have led to this weedy state of affairs.

1.2 Australia's salinity problems

Causes of salinity

Australia is a salty place with naturally saline ecosystems such as former marine plains around the coast and inland salt pans and lakes. Most of the salt has blown in from the oceans and fallen with rain or dust. Some has come from weathered rocks of marine origin.[5] Areas that are naturally saline, known as *primary salinity* sites, have evolved a distinctive salt-tolerant flora.

Secondary salinity is caused by changes in land use that alter hydrological dynamics. Since European settlement, native vegetation has been extensively cleared and replaced with crop and pasture species that have shallower root systems and shorter growing cycles (annuals rather than perennials). They use less of the soil water, allowing more rainwater to enter the groundwater. Rising watertables mobilise salts in the subsoils, bringing them to the surface in low-lying areas or where a slope breaks.[6] Salinisation also occurs when large volumes of irrigation water cause a rise in local groundwater levels (but irrigation salinity is not the focus in this report).

Where there is salinity there is often also waterlogging, both resulting from shallow watertables. Waterlogging in susceptible plant species causes oxygen deficiencies, rendering them more vulnerable to salt damage by reducing their capacity to screen out salt at the root surface.[7] Waterlogging can exacerbate salinity because it may reduce plant productivity and thereby reduce water transpiration.

Extent and costs of salinity

Salinity has not been comprehensively mapped, and estimates of areas affected vary widely. The most commonly cited estimates, by the National Land and Water Resources Audit conducted in 2000, found that Australia had 5.7 million hectares of land with a high potential of developing dryland salinity due to shallow watertables, estimated to increase to more than 17 million hectares by 2050.[8] However, the audit used methods that are now acknowledged to overestimate the salinity risk:

TABLE 1.1 Extent of mapped salt-affected land in Victoria[20]

Region	Mapped dryland salt-affected area[a] (ha)
Mallee	105,000
Glenelg Hopkins	27,435
North Central	27,114
Corangamite	25,162
West Gippsland	24,160
Wimmera	21,789
Goulburn Broken	4778
Port Phillip	2890
North East	1311
East Gippsland	273
Total	**239,912**

[a]Note: These areas include both primary and secondary salinity sites. In the Mallee region there may be up to 90,000 hectares of primary salinity sites.

> *It is ... generally understood that the techniques applied in the analysis had severe limitations. The approach used a monotonically rising groundwater trend, which was then converted to salinity risk. …the risk and hazard assessment was never explicitly linked to our understanding of individual groundwater systems.*[9]

The Australian Bureau of Statistics' most recent survey of farmers found that about 2.4 million hectares of agricultural land are affected by salinity (but no distinction was made between natural and secondary salinity).[10] This amounts to less than 0.6% of Australia's agricultural land.

Western Australia is by far the worst affected state. The audit estimated that 4.3 million hectares had a high potential to develop salinity (80% of Australia's total area at risk), and that this would rise to 8.8 million hectares in 2050.[11] The Bureau of Statistics reported that about 1 million hectares of agricultural land were affected.[12]

According to the audit, Victoria has the second largest area at risk from dryland salinity, with 670,000 hectares having a high potential to develop salinity, which is predicted to increase to 3.1 million hectares by 2050. The Bureau of Statistics reported in 2008 that 268,000 hectares of farmland were affected by dryland salinity (but this included both primary and secondary salinity), amounting to about 2% of agricultural land and about 11% of the total reported for Australia.[13] According to Victoria's 2008 State of the Environment report about 1% of agricultural land is affected.[14] Dryland salinity is most prevalent in the western half of Victoria, where land clearing has been particularly extensive, the terrain is lower, drainage is poorer, and there are naturally high salt levels[15] (see Table 1.1 for a breakdown of the regions mapped as being affected

1 Semple et al. (2004).
2 Weeds CRC (2003).
3 Navie and Adkins (2008).
4 Dodd (2004); Panetta and Lawes (2005). Dodd (2004) notes with concern that Kochia is still promoted as a beneficial plant for biosalinity projects, and that its seeds can still be obtained easily via the internet (although it is illegal to import seed to Australia).
5 NLWRA (2001). Dahlhaus et al. (2000) suggest that large salt loads in the soils of the Victorian Dundas Tablelands (an estimated 500 t/ha) came from a variety of sources: blown from the ocean and from saltpans in the Murray Basin, and acquired during marine submersion and dissolution of minerals by groundwater during weathering.
6 NLWRA (2001). However, this explanation of dryland salinisation may not apply in all cases. According to Dahlaus et al. (2000), secondary salinity on the Dundas Tablelands in Victoria, where shallow watertables pre-existed land clearing, may be caused by the lateral spread of existing primary salinity due to vegetation removal causing longer periods of seasonal waterlogging. Processes of dryland salinity are undoubtedly highly variable, and often take a century or more to develop.
7 Barrett-Lennard (1986).
8 NLWRA (2000).
9 Walker et al. (2008). Also see Keogh (2005). The Audit was based on the known incidence of salinity, soil characteristics, topography and groundwater (mapped at a scale of 1:250,000). Areas with mapped groundwater within 2 metres of the soil surface or within 2 to 5m and with demonstrated rising water tables were classed as having a high risk of salinity. But only a proportion of this area will develop secondary salinity. The predictions for 2050 were based on an assumption that groundwater would continue to rise, but this has not occurred.
10 Australian Bureau of Statistics (2008).
11 NLWRA (2001).
12 Australian Bureau of Statistics (2008).
13 Australian Bureau of Statistics (2008). The Bureau advises that the estimate should be used with caution as the relative standard error was 10-25%.
14 Commissioner for Environmental Sustainability (2008).
15 Victorian Catchment Management Council (2007).

by mapped dryland salinity – note that this does not distinguish between primary and secondary salinity).

Despite the alarming predictions, recent work suggests that the salinity risk in eastern Australia is more localised and smaller in extent than previously estimated.[16] In recent drier times (since the mid-1990s) Victorian watertables and the extent of observed salinity have dropped, and this trend is likely to continue with the drier climate predicted under climate change.[17] Annual average rainfall in Victoria is predicted to decrease, which in combination with higher rates of evaporation, will reduce runoff by a predicted 5-45% in western Victoria.[18] According to the Victorian *State of the Environment 2008 Report*, the extent of salinity is unlikely to expand.[19]

The salinity audit reported that salinity reduces agricultural profits in Australia by $187 million a year, which is estimated to increase to $288 million a year by 2020.[21] The value of lost agricultural profits in Victoria was estimated to be $27 million by the Audit and $50 million by the Victorian Government (the latter included both irrigated and dryland salinity).[22]

While losses in some agricultural areas are high, the overall impacts of salinity on agricultural profits are not substantial. According to a Land and Water Australia analysis:

> *… the reality is the economic impacts of salinity on dryland agriculture are estimated to be relatively small when viewed in the context of total agricultural profits. The NLWRA estimates that the present value of agricultural profits will decline by 1.5% over the next 20 years due to salinity — and this is not allowing for farmers' adaptive behaviour.*[23]

Effects on biodiversity

Australia's salinity programs have neglected biodiversity, not only by promoting the use of weedy pasture species that threaten biodiversity, but by largely ignoring the impacts of salinity on biodiversity, particularly in south-eastern Australia.[24] Until recently, native vegetation was not included in most salinity surveys,[25] and there have been few comprehensive studies of the impacts of salinity on biodiversity.[26] The neglect has been attributed to the domination of salinity programs by disciplines and agencies primarily interested in agriculture, as ecologists Briggs and Taw explain:

> *As members of different agencies with interests in gaining resources and status for their own discipline and agency, these groups manoeuvre to control the salinity agenda. Impacts of salinity on biodiversity have been ignored, as powerful, entrenched groups with little interest in biodiversity competed for dominance of the salinity agenda, and for the associated resources, funding and status.*[27]

The greatest salinity threats to biodiversity are in southwest Western Australia, where most wetland, dampland and woodland communities in the lower parts of catchments, and more than 450 endemic plant species, are thought to be at risk.[28]

In Victoria, a preliminary assessment found that the distribution of 4-8% of threatened plant species and 9-17% of threatened fauna species were in areas assessed by the Audit as high salinity risk by 2050 (although distributional overlaps are not a reliable measure of threat).[29] According to the Audit, about 6000 hectares of remnant vegetation and plantation forests in Victoria are at high risk of salinity, and this was predicted to increase to 24,300 hectares by 2050.[30]

Salinity can cause dieback in forests and woodlands, which in turn fosters further salinisation.[31] In one study of remnant woodlands in central southern NSW, 85% of trees at salinised sites showed symptoms of dieback compared to 34% at non-salinised sites.[32] A study in the Boorowa Shire, NSW, found that about 3% of native woody vegetation was affected, including 14% of riparian communities and 6% of an endangered ecological community.[33]

Salinisation of the Murray River is a major problem. With flow at the river mouth reduced by about three-quarters of the natural level, salt (due to natural salinity, clearing and irrigation) accumulates in the river, its floodplains and wetlands rather than being flushed to the sea.[34]

Plant-based pastoral approaches to salinity

Most of the native vegetation cleared for agriculture comprised perennial plants (with a life-cycle lasting more than two years), which are relatively deep-rooted, attributes that minimise the leakage of water past the root zone into groundwater. One of the obvious ways to address salinity is to revegetate areas with deep-rooted perennials, so as to "increase the proportion of rainfall that is returned to the atmosphere through evaporation and transpiration, and reduce the proportion that ends up as deep drainage ... and runoff."[35] This has been a primary focus of government-supported programs to address salinity, such as the $1.4 billion National Action Plan for Salinity and Water Quality running from 2000 to 2008. As discussed later, the prospects of achieving this goal were never entirely realistic.

As much of the area threatened by salinity in Victoria and elsewhere is used for grazing, the primary focus has been on developing and promoting pasture species that (a) prevent or limit salinity by reducing water leakage into groundwater, thereby lowering salt-mobilising watertables, or (b) make productive use of saline areas that may otherwise be bare or poorly vegetated. The premise of salinity programs has been that "profit will be the primary driver of land use change" and that providing and promoting profitable perennial pasture species is the only way to "influence salinity management without imposing a major economic and social burden on the wider community."[36] Australia-wide, 3.2 million hectares have reportedly been planted with crops, pastures and fodder plants partially or wholly for salinity management and 776,000 hectares have been planted with trees.[37] In Victoria, the areas planted partially or wholly for salinity management on non-irrigated farms include:[38]

Salt-tolerant crops	44,000 ha
Lucerne	83,000 ha
Other deep-rooted perennials	349,000 ha
Salt-tolerant pastures	585,000 ha
Saltbush, bluebush	3000 ha
Other fodder plants	542,000 ha
Trees	32,000 ha

Most of the pasture species planted for salinity management are exotic (introduced from overseas or elsewhere in Australia), and many are known to behave as weeds.[39] In high-rainfall areas in southern Australia, perennial grasses such as Phalaris (*Phalaris aquatica*), Perennial Ryegrass (*Lolium perenne*), Tall Fescue (*Festuca arundinacea*) and Cocksfoot (*Dactylis glomerata*), which all originated in temperate northern hemisphere environments,

16 Eg. Senate Committee (2006), quoting Mike Lee from the Department of Agriculture, Fisheries and Forestry: "…we are seeing that the hazard in eastern Australia is more specific and perhaps more manageable, so the picture is more optimistic than we thought."
17 Victorian Government (2008).
18 According to DSE (2008), rainfall is predicted to decrease by about 4% by 2030, and by 6 to 11% by 2070. The modal uncertainty for the 2030 prediction ranges from -9% to +1% and for the 2070 predictions from -14% to +2% and -25% to +3% respectively.
19 Commissioner for Environmental Sustainability (2008).
20 Commissioner for Environmental Sustainability (2008).
21 NLWRA (2001).
22 Victorian Auditor-General's Office (2001).
23 van Bueren and Price (2004).
24 According to the Australian and New Zealand Environment and Conservation Council (ANZECC 2002), salinity has been treated as a problem primarily for "agricultural production, water quality and infrastructure maintenance" and that most government policies deal separately with salinity and biodiversity. Briggs and Taws (2003) note that during the "rather sudden awakening of dryland salinity as an officially recognised land degradation issue in eastern Australia, biodiversity was largely a silent partner."
25 Briggs and Taws (2003), citing Please et al. (2002).
26 ANZECC (2002).
27 Briggs and Taws (2003).
28 ANZECC (2002), citing George et al. (1999) and Keighery et al. (2000).
29 ANZECC (2002).
30 NLWRA (2001).
31 Briggs and Taws (2003); ANZECC (2002).
32 Briggs and Taws (2003). However, Bann and Field (2006) dispute that the dieback was caused primarily by salinity.
33 Seddon et al. (2007) found more than 6000 patches of salt outbreak in woody vegetation, 6% of which were at least 1 ha. About 2000ha of woody vegetation were affected (3%), including 6% of yellow box-Blakely's red gum woodland (an endangered ecological community).
34 Commissioner for Environmental Sustainability (2008).
35 Lefroy et al. (2005).
36 Lefroy et al. (2005).
37 ABS (2002).
38 ABS (2002). These figures are for all land planted with crops, pastures and fodder plants for salinity management, irrespective of whether the farm has land showing signs of salinity.
39 Carr et al. (1992).

1

Chapter

Introduction

are widely planted in recharge areas.[40] More recently, exotic subtropical species that grow in summer and therefore more effectively reduce recharge, such as Kikuyu (*Pennisetum clandestinum*) and Rhodes Grass (*Chloris gayana*), are also being planted for this purpose.[41] All of these grasses behave as weeds under some situations, invading croplands and/or native ecosystems.[42] Native grasses are rarely sown, although there are interventions to enhance their growth in remnant areas.[43]

Lucerne (*Medicago sativa*) is the major herbaceous perennial legume planted, but its use is limited in areas of high acidity, waterlogging or low rainfall.[44] Other perennial legumes such as Birdsfoot Trefoil (*Lotus corniculatus*), an environmental weed, are suitable only for high-rainfall areas.[45] Shrubs are not widely used because of high establishment costs.

A growing emphasis on profitable use of saline sites[46] has generated strong interest in the plants known as halophytes. Most plant species are highly sensitive to salt; some can maintain growth at low salt concentrations but at higher concentrations suffer reduced growth or die. What distinguishes halophytes, such as saltbushes, is that their growth increases at low salt concentrations, and only tapers off at higher levels.[47] Many halophytes can also withstand waterlogging and/or submersion in water.

Among the halophytes, two grasses – Puccinellia (*Puccinellia ciliata*) and Tall Wheat Grass (*Lophopyrum ponticum*) – have been widely sown for grazing in southern Australia.[48] Legumes are also needed, to provide nitrogen in the diet of livestock, but legumes generally have low tolerances to salinity and waterlogging. Balansa Clover (*Trifolium michelianum*), Persian Clover (*T. resupinatum*) and Strawberry Clover (*T. fragiferum*) are used in mildly saline areas. Halophytic shrubs such as saltbush (*Atriplex* spp.) and Blue Bush (*Maireana brevifolia*) have been used in saline areas, but their establishment costs are quite high.[49] Some of the clovers and the two grasses behave as environmental weeds under some circumstances.

Agronomists claim that there are major gaps in the suite of pasture species available; in particular perennial grass options for stressful environments – low rainfall, acid soils and waterlogged soils – and legumes tolerant of a range of saline conditions.[50]

The failure of plant-based approaches to salinity

There is increasing evidence that pasture plant-based approaches are failing to solve the salinity problem, except sometimes at a local scale,[51] as indicated in the quotes below by various salinity-focused researchers:

> *...the current scientific knowledge of salinity indicates that we have made relatively little progress towards changing practices on the scale that would be effective in preventing groundwater rise, and thereby dryland salinity…*
>
> *The adoption of perennial pasture species, particularly in low- to medium-rainfall areas, has been too low to comprehensively lower saline watertables, and recent work indicates that in many catchments the extent of planting required to reduce the salinity hazard is too high to be economically feasible.*[52]
>
> *The results of this study indicate that the existing policy approach of providing encouragement, information and persuasion to farmers and relying mainly on their voluntary action is not succeeding.*[53]
>
> *It is now understood that perennial-based farming systems are only commercially viable in a narrow range of circumstances...*
>
> *The notion that salinity will be comprehensively fixed with targeted revegetation treatments or discharge management should be dispelled. There is no 'silver bullet'*[54]
>
> *Expectations of farm based change leading to salinity control need to be tempered.*[55]

Living with salinity is increasingly regarded as the most realistic option for many catchments.

In Western Australia more than 60% of the 2.4 million hectares affected by salinity are in areas of deeply weathered Precambrian rocks, whose high salt content and low hydraulic connectivity limit the capacity to manage salinity.[56] In eastern Australia, the worst affected areas are within Palaeozoic rocks of the Dividing Ranges that also often feature "low conductivity", limiting management options.

CSIRO modelling of the Wanilla catchment in South Australia found that salinity would continue to increase even with a 50% reduction in recharge. To achieve a 50% reduction would require replanting the upper 40% of the catchment with trees (abandoning current agricultural uses) and replacing annual species with perennial pasture species in the rest of the catchment.[57] It was thus concluded that there were "no viable technical options" to achieve substantial salinity control.

The Wanilla catchment is considered typical of many catchments,[58] and modeling elsewhere has similarly found that up to 50% or more of catchment areas need to be replanted with perennial vegetation to prevent or reduce salinity.[59] This is considered impractical in many places.[60] A report for the salinity audit featuring case-studies of four catchments concluded that "It will be not be economically sensible to control most dryland salinity and hence the community will have to 'live with' much of the existing (and looming) dryland salinity across Australia."[61]

Even where it may be feasible to manage salinity through large-scale planting of perennial pastures, it is mostly not profitable, or only marginally profitable, for graziers to do so with existing plant options, according to Ridley and Pannell from the former Dryland Salinity Cooperative Research Centre (CRC):

> *The crucial importance of farm-level economics in adoption behaviour is underscored by studies showing that existing perennial plant-based options in most regions of southern Australia are either unprofitable or lack profitability on a scale that would generate more than localised benefits.*[62]

There are also management, social and perception barriers to the widescale adoption of perennial pastures. They are often more demanding to manage, and require more intensive inputs,[63] which means they are mostly of no interest to managers of small-scale farming enterprises. Many Australian farms generate only small returns – those considered subcommercial (with an estimated value of operations less than $22,500) cover more than 16 million hectares.[64] More than a quarter of agricultural land in Victoria is on small farms.[65] In some cases the motivation to change practices is also limited by either the reality or the perception that salinity is not a major problem on the farm concerned.[66]
Where recharge sites are not on the same property as saline discharge sites, there is little motivation to invest in measures

40 Pannell and Ewing (2006).
41 Pannell and Ewing (2006).
42 Navie and Adkins (2008).
43 Pannell and Ewing (2006).
44 Pannell and Ewing (2006).
45 Pannell and Ewing (2006).
46 Barrett-Lennard et al. (2003); Pannell and Ewing (2006).
47 Barrett-Lennard et al. (2003). They can typically accumulate salt in their tissues to high concentrations; for example the leaf ash concentrations in some saltbushes can reach 39%.
48 Pannell and Ewing (2006).
49 Pannell and Ewing (2006).
50 Pannell and Ewing (2006).
51 Walker et al. (2008) classify salinisation processes in terms of local, intermediate and regional groundwater flow systems, which vary temporally and geographically. Local systems may be amenable to treatment by reducing recharge, whereas treatment of regional systems would require vegetation management over extremely large areas.
52 Pannell and Ewing (2006).
53 Kington and Pannell (2003).
54 van Bueren and Price (2004).
55 Read Sturgess and Associates (2001).
56 Walker et al. (2008).
57 Read Sturgess and Associates (2001), citing modeling by Stauffacher et al. (2000). The modelling found that if current land-use was maintained, in 20 years the area of shallow watertables would expand from 8% to 15% of the catchment and not increase significantly beyond that. With a 50% reduction in recharge the affected area would increase to about 12% of the catchment within 20 years, but not expand much beyond that. A 50-90% reduction would prevent further salinisation.
58 Read Sturgess and Associates (2001).
59 Pannell and Ewing (2006), citing George et al. (2001, 1999); Herron et al. (2003); Read Sturgess and Associates (2001).
60 For example, Lefroy et al. (2005) comment that in high rainfall areas (>800mm), including the western slopes of the Great Dividing Range in Victoria, it "appears that wholesale land use change, such as trees replacing grazing, rather than modifying farming systems ..., will be necessary to modify water flows where they intercept salt stores..."
61 Read Sturgess and Associates (2001).
62 Ridley and Pannell (2005).
63 Kington and Pannell (2003); Bathgate and Pannell (2002); Read Sturgess and Associates (2001).
64 Hooper et al. (2002).
65 Ridley and Pannell (2005) citing Barr (2004).
66 Kington and Pannell (2003) found that farmers in WA generally under-rated the extent of salinity on their property. van Bueren and Price (2004) reported that grain farmers targeted for participation in The Million Hectares for the Future project were unconvinced about the validity of salinity risk information and the benefits of management options.

that have no direct benefits.

The various problems have led some researchers to advocate a more diverse approach to salinity, including (a) acceptance that some areas will go saline, (b) productive use of saline areas and (c) the development of more economically attractive perennial pasture species.[67] The latter two are primary goals of the Future Farm Industries Cooperative Research Centre. Unfortunately, the development of new and better pasture species increases the risk of new weed species.

1.3 Australia's weed problems

Some Australians think of invasive species as having been introduced in a more ignorant past when there were few regulations governing their importation and use. Now, there are quarantine processes to protect Australia from new invasive species and every state and territory has laws to regulate weeds and pests. Governments have also adopted numerous policies and strategies with laudable goals of preventing further introductions and limiting the harm caused by existing invasive species.[68]

However, despite these laws and policies most invasive species are not regulated and the problems are worsening.[69] Numerous species escape into the wild (naturalise) each year[70] – on average 7.3 in Victoria alone[71] – and weed-driven transformations of ecosystems are gathering pace. Weeds are increasingly interacting with other degrading processes such as habitat loss, climate change, feral herbivores and fire.

Federally, there have been major reforms in regulations for imports of exotic species, with the 1997 introduction of a system that requires weed risk assessment of new species. But most weeds already in Australia, including new genetic variants of existing weeds, can be freely imported under this system. Most of the more than 26,000 exotic plant species already in Australia (outnumbering native plant species)[72] are not regulated and have not been assessed for their weed risk. Just over 10% (2739 species) are already weeds, and close to 6000 more are weeds overseas, indicating a high potential for weediness in Australia.[73] Of those already weedy in Australia, more than 1000 are environmental weeds,[74] and about 800 are considered a "major problem to managers of natural ecosystems".[75]

Most of Australia's weed species were imported as garden or agricultural plants.[76] Pasture plants have a particularly high invasive risk, as they are selected for qualities (such as vigour and persistence under grazing) that increase weed risk, and are planted over large areas, often close to bushland. More than 8200 potential pasture species were imported under the Commonwealth Plant Introductions program.[77]

Victoria can ill-afford more weeds. Invasive species have already wreaked havoc on biodiversity and caused extensive environmental degradation. At least two-thirds of the state is mostly or predominantly covered in exotic vegetation[78] and currently more than 1546 naturalised exotic taxa are known, or about 30% of the total Victorian flora.[79] The direct cost of weeds to Victorian agriculture is more than $360 million per year.[80] Victorian farmers reported spending $2070/hectare managing weeds n 2006-07, the highest level for any state/territory in Australia.[81]

About two-thirds of plants naturalised in Victoria were deliberately introduced.[82] The grasses (most introduced for pasture) are the dominating category of exotic plants in Victoria – by 2007 there were 197 exotic taxa (species and subspecies), 41% of the grass flora, compared to 277 taxa of indigenous grasses.[83] Despite the plethora of weeds in Victoria, and the great harm they cause, fewer than 10% of naturalised species are regulated by the government (see Appendix 2 for an outline of Victorian legislation and policies on weeds.) Virtually all invasive pasture plants can be freely planted.

1.4 Weeds versus salinity

Pasture-based approaches to salinity are often promoted as 'win-win' solutions for agriculture and the environment that increase productivity while reducing salinity. But this perspective ignores the serious damage caused by planting weeds for salinity mitigation.

In 1998, the Victorian parliament through its Environment and Natural Resources Committee held an inquiry into weed problems, which in part considered the threats associated with the proposed large-scale conversion to perennial pastures for salinity mitigation.[84] In its report the committee recognised that exotic pasture species promoted for this purpose present a high risk of invasion because the attributes selected for "can make such species invasive". The committee recognised that salinity programs were likely to conflict with nature conservation objectives and other agricultural or public land uses. They referred in particular to a 1994 report by ecologists McMahon and colleagues, commissioned by the state government to assess the likely impacts of large-scale conversion to perennial pastures.[85] This report warned of serious weed threats, loss of native vegetation, increased fertiliser use, rural tree decline and altered fire regimes and hydrology. In part, the committee considered that:

> *[W]here it has been established that introduced exotic species ... are posing significant economic or ecological threats, their ongoing use and promotion should be reviewed and it may be appropriate to list the weedy pasture plants as noxious in the `Restricted Weeds' category.*
>
> *To avoid the conflicts of different land management objectives it would be best "to prevent the introduction, development and promotion of species that are likely to become weeds." The usefulness of exotic species, their potential weediness, and the long-term consequences of their use should be investigated.*
>
> *The Victorian Weeds Advisory Committee should "have an important role in ensuring that appropriate screening measures are undertaken to ensure that the species chosen are those that will bring substantial benefits to Victoria, while minimising conflict between conservation and agricultural interests."*

Finally, the committee stated that:

> *Economic considerations must not override conservation objectives where it is likely that native flora and fauna will be seriously threatened as a result of the introduction or promotion of an exotic species for the purposes of agriculture and/or utility.*

But these concerns and findings were ignored. Weed risks have rarely rated a mention in the assessment or development of salinity policy in Australia. Neither the 2004 House of Representatives report *Science Overcoming Salinity*[86] nor the 2006 Australian Senate report *Living with Salinity – a Report on Progress*[87] mentioned weed risk as an issue in their support for a perennial pastures-based approach to salinity. The 10-year report on

67 Senate Committee (2006); CSIRO (2005); Ridley and Pannell (2005); van Bueren and Price (2004); Kington and Pannell (2003). The development of new perennial pasture options has been described as "crucial" by Ridley and Pannell (2005) and "imperative" by CSIRO (2005). The Senate Committee (2006) review of salinity concluded that "there is a greater need for R & D into profitable salinity management methods."

68 ARMCANZ and ANZECC (1999). This national weed strategy (adopted in 1997, and revised in 1999) contains a target that by 2001, no new non-native species are deliberately introduced into Australia unless assessed as being of low risk to the environment.

69 Low (1999).

70 Groves et al. (2003) report that on average 10 naturalisations have occurred each year since European settlement. The rate is increasing in Victoria and probably other states as well.

71 Commissioner for Environmental Sustainability (2008), citing Weiss (2007).

72 Randall (2007). About 97% are in cultivation. In total, including about 11,000 Australian species, there are 36,630 species in cultivation in Australia.

73 Randall (2007).

74 Navie and Adkins (2008).

75 Groves et al. (2003).

76 Groves et al. (2003); Low (1999); Carr (1993).

77 Cook and Dias (2006) documented the history of government-sponsored introductions: "For most of the 20th century, these and other introductions supported research into continental-scale transformation of Australian landscapes to support greatly increased pastoral productivity in order to achieve policy goals of maximum density of human population."

78 Carr (1993).

79 Walsh and Stajsic (2007).

80 Department of Natural Resources and Environment (2002).

81 Australian Bureau of Statistics (2008).

82 Carr (1993) notes that just as weeds are now being used for salinity mitigation, many of Victoria's weeds have been introduced for apparent environmental repair: "Soil stabilisation and revegetation activities are ironically amongst the most devastating practices, and in Victoria government agencies take the dubious lead. Of the 153 species advocated by Zallar (1980) for soil stabilisation, at least 51 are serious or very serious environmental weeds; many are less important weed species. For coastal erosion control Hill, Fitzsomons and Thomas (1985) recommended ten species, of which nine are likewise serious or very serious environmental weeds."

83 Walsh and Stajsic (2007).

84 Environment and Natural Resources Committee (1998).

85 McMahon et al. (1994).

86 House of Representatives Standing Committee on Science and Innovation (2004).

87 Senate Environment Communication Information Technology and the Arts References Committee (2006).

the National Dryland Salinity Program did not mention it.[88] Although Victoria's 2008 *State of Environment Report* had a section documenting the serious impacts of weeds, it failed to mention them in its coverage of salinity.[89] Apart from papers devoted specifically to the weed risk of exotic pasture grasses used in salinity programs, research papers also rarely mention weed problems or do so only cursorily. If considered at all, the weed risk is typically portrayed as something to be managed (by voluntary guidelines) rather than avoided. The implicit or explicit assumption running through the salinity literature is that the benefits provided by pasture species outweigh any weed costs (whatever they might be).

One environmental problem should not be solved by creating another (although the environment is so complex that conflicts inevitably arise in many situations). However, when it comes to a choice between salinity and weeds, there are strong reasons for a highly precautionary approach to weed risk. This is particularly justified given the limited potential of the pasture-based programs to redress Australia's salinity problems.

Weeds are a greater problem in Australia than salinity, except perhaps in a large part of southwestern Western Australia where salinity is especially severe. Weeds cost $4 billion a year in lost agricultural production and control, an order of magnitude more than the approximate $200 million lost due to dryland salinity.[90] In Victoria, the estimated cost of weeds to agriculture is 7-13 times that attributed to salinity.[91] Three-quarters of Victorian farmers reported that weed problems reduced the value of their production. About four times as many reported weed problems as salinity problems.[92] Table 1.2 shows that salinity is ranked lower than many other natural resource management problems reported by Victorian farmers in 2006-07.

TABLE 1.2 Natural resource management problems on Victorian farms (Australian Bureau of Statistics survey, 2006-07)[93]

Natural Resource Management problem for Victorian farms	Area reported affected, million ha (%)	Proportion reporting problem	Expenditure, $million ($/1000 ha)
Weeds	-	62.5%	$253m ($20,701)
Pests	-	65.1%	$144m ($12,198)
Soil compaction	1.65 (12.5%)	43.2%	$171m ($17,356)
Soil acidity	2.2 (16.6%)	48.0%	
Erosion	0.61 (4.6%)	37.4%	
Soil sodicity	0.61 (4.6%)	17.3%	
Dryland salinity	0.27 (2.0%)	16.8%	
Surface waterlogging	0.39 (2.9%)	24.9%	
Irrigation salinity	0.06 (0.5%)	9.7%	
Other land and soil related problems	0.41 (3.1%)	8.6%	

Weeds also have a worse impact on biodiversity than salinity. Overall, invasive species (including pest animals, weeds and pathogens) collectively rank as one of the top three threats to biodiversity in Australia.[94] Weeds have been ranked as one of the top three threats to threatened ecosystems, riparian zones and nationally important wetlands, and also as a major threat to threatened species.[95] Considered nationally and in Victoria, salinity ranks much lower as a threat to the environment.[96]

However, pasture species planted for salinity mitigation constitute only a small proportion of weeds, so a comparison of environmental harm should be limited to the subset of weeds that can be linked to salinity. In Victoria, just one weed could do far more harm to the natural environment – both in terms of area and asset value affected – than salinity in its entirety is predicted to do. The national salinity audit estimated that 6000 hectares of Victoria's remnant vegetation and plantation forest were affected by, or at high risk of, salinity, and 24,300 hectares would be at risk by 2050.[97] Tall Wheat Grass (*Lophopyrum ponticum*), promoted for salinity mitigation and the topic of the next chapter, has already naturalised unassisted (i.e. 'escaped' from deliberate plantings) in hundreds of sites in Victoria and has the potential to invade numerous habitats across more than 10 million hectares, far more than the largest salinity predictions for both agricultural and natural areas. This weed is invading very high-value conservation areas: drylands, wetlands (including Ramsar wetlands), saltmarshes and the habitat of numerous threatened species, and may cause ecological transformation by altering fire regimes and hydrology. This and other examples of species used to mitigate salinity show that pasture plants used to vegetate saline sites pose a far greater threat to the environment than the salinity they are being used to treat.

1.5 Aims and approaches of this study

This report documents some of the environmental threats posed by the perennial pastures program for salinity mitigation. Our focus is Victoria, although many of the conclusions apply more broadly to southern Australia and to other categories of pasture species.

In Chapter 2 we examine the very serious weed threats posed by Tall Wheat Grass, a plant heavily promoted by governments and Catchment Management Authorities for use on saline areas, which has been planted with financial incentives. In Chapter 3 we broaden the focus to consider the weed risks of pasture plants in use or recommended for development for recharge or discharge areas by the Future Farm Industries Cooperative Research Centre. In Chapter 4 we consider the institutional, policy and legislative failings that have led to the promotion of serious weeds for salinity mitigation, and recommend reforms. Further background information about relevant institutions, laws and policies, and a glossary, are provided in appendices.

Our aim in this report is to convince policy-makers to adequately investigate the weed threats of the salinity mitigation programs, to enact reforms to prevent the worsening of weed problems in Victoria and elsewhere, and to manage the invading weeds to prevent biodiversity loss.

88 van Bueren and Price (2004).
89 Commissioner for Environmental Sustainability (2008).
90 Agtrans Research and Dawson (2005); Australian Biosecurity Group (2005).
91 Department of Natural Resources and Environment (2002); Victorian Auditor-General's Office (2001). Department of Natural Resources and Environment (2002).
92 Australian Bureau of Statistics (2008).
93 Australian Bureau of Statistics (2008).
94 Invasive Species Council (2009); Australian Biosecurity Group (2005); National Land and Water Resources Audit (2002). Australian Biosecurity Group (2005).
95 Cork et al. (2006), citing Tait (unpublished).
96 The assessment referred to mostly used the extent of areas affected or the number of regions reporting the problem as the basis for ranking. But on other criteria as well, such as numbers of threatened species affected and the extent of degradation caused, weeds outrank salinity as a threat.
97 NLWRA (2002).

2

Chapter

TALL WHEAT GRASS

Tall Wheat Grass

On the balance of available qualitative evidence Tall Wheat Grass would alone destroy most upper saltmarsh in western Victoria.
– Botanist Geoff Carr, cited in a government assessment of the weed risk of Tall Wheat Grass[98]

2.1 Introduction

Instead of controlling weeds, some Victorian Catchment Management Authorities have been promoting them, and using public funds to do so. Graziers have been encouraged and funded to plant known weeds for salinity mitigation and productive use of saltlands (secondary saline sites).

In particular, Tall Wheat Grass (*Lophopyrum ponticum*) is strongly promoted in Victoria as a deep-rooted, salt-tolerant pasture plant for saltlands. But Tall Wheat Grass is highly invasive, spreading into a wide range of habitats, and with the potential to spread across more than half of Victoria.

The promotion of a dangerous weed as a salinity solution is using one environmental problem to justify causing another, in this case a much worse environmental problem. To make matters worse, the planting of Tall Wheat Grass is unlikely to do much to solve salinity problems.

This case study demonstrates many systemic problems with approaches to land management, research practices and government policy. In particular, it demonstrates failures to appreciate weed risk or take the issue seriously, and reveals conflicts of interest in agencies meant to assess and regulate environmental weeds.

BOX 2.1 Description of Tall Wheat Grass[101]

Robust densely caespitose perennial to 2.2m high. Culms erect, to 1 m high or more.

Leaves prominently veined, glabrous or with scattered hairs; blades flat or loosely inrolled, sharp-pointed, to 50cm long, 2-6mm wide, scabrous toward the tip, otherwise smooth; ligule truncate, minutely ciliate, c . 0.5mm long; auricles hardly developed.

Inflorescence a distichous spike, 10-40cm long. Spikelets 10-25mm long, often curving away from the rachis in the upper part; glumes truncate, 7-11mm long, the upper longer than the lower by up to 3mm, both prominently 5-11-nerved, sometimes weakly scabrous along midrib; lemma obtuse or notched at apex, 9-13mm long, c. 5-nerved, only the midrib prominent, glabrous except for finely ciliate margins; palea slightly shorter than lemma ; anthers 5-8mm long. Flowers in December.

Tall Wheat Grass (*Lophoryrum ponticum*), scale in mm.

Tall Wheat Grass (*Lophopyrum ponticum*)

Lophopyrum ponticum is a very robust, densely tufted perennial tussock grass, 1.5-2.2 m tall, with a root system extending up to 3.5 m.[99] A botanical description, modified from the *Flora of Victoria*,[100] is provided in Box 2.1.

Synonyms: Tall Wheat Grass has been variously known as *Thinopyrum ponticum*, *Thinopyrum elongatum, Lophopyrum elongatum*, *Elytrigia pontica*, *Elytrigia elongata*, *Agropyron elongatum*, *Elymus elongatus*, and *Triticum elongatum*.

Origin: Native to the Balkans, Black Sea, Asia Minor and southern Russia, where it grows in saline meadows, marshes, and on coasts.[102]

Commercial varieties: Two varieties are available in Australia: ‘Tyrrell’, which was developed in Australia in the 1950s from seed originating from the USA, and 'Dundas', a newer cultivar released by the Victorian Department of Primary Industries in 1999.[103]

Naturalised populations: Very widely naturalised in Victoria (see map p30, Figure 2.1) and South Australia, also in New South Wales, Tasmania and Western Australia.

Agricultural use of Tall Wheat Grass for saltlands

Tall Wheat Grass was first introduced to Australia in 1935 from Russia by CSIRO for reclamation of saline soils.[104] It is a productive grass that tolerates salty and alkaline soils and is palatable to sheep and cattle. It is now the mostly commonly used species for reclamation and grazing use of saline lands in many areas of Victoria.[105] Tall Wheat Grass has been planted in all southern Australian states, but most in Victoria in the Mallee, Wimmera, North Central, South Western and Western Districts.[106] According to the publication *Saltland Prospects*, it can be grown under conditions of low to moderate salinity and some waterlogging in all southern states.[108]

In the 1990s, 30-70 tonnes of certified Tyrrell seed were being produced each year in Australia, mainly for Victoria.[109] Current sales figures are unknown, but according to a 2006 report recent demand for the seed has been "well beyond the current capacity of the seed industry."[109]

The Victorian Department of Primary Industries (DPI) strongly promotes Tall Wheat Grass. It is regarded as "an important salt tolerant pasture species that has the potential to reclaim most of the salt affected unproductive areas on farms within Victoria and other states."[110] In the experience of DPI researchers, Tall Wheat Grass "is the most successful perennial grass species that can be grown in high salty (up to 14 ds/m) unproductive areas on the farm." The Victorian DPI Agricultural Note on Tall Wheat Grass says that it can increase stocking rates and is "one of the most productive species."[111]

Tall Wheat Grass has also been strongly promoted through the Cooperative Research Centre for Plant-based Management of Dryland Salinity (Dryland Salinity CRC) and its recent replacement, the Future Farm Industries CRC (see Appendix 1 for information about these CRCs and other institutions). The Future Farm Industries CRC publication *Saltland Prospects 2007: Prospects for Profit and Pride from Saltland* devotes considerable attention to Tall Wheat Grass.[112] It features in four of 15 pasture systems listed for sheep production in southern Australia. For Victoria, *Saltland Prospects* reports that whole-farm analysis (of one property) shows that Tall Wheat Grass-based pasture "is profitable on mildly and moderately saline land, in south-west Victoria." The study found that "profit could be increased by more than $200 a hectare on mildly saline land, by increasing the stocking rate across the whole farm by one sheep per hectare and

98 Weiss and Iaconis (2001).
99 Bleby et al. (1997).
100 Walsh and Entwisle (1994).
101 Walsh and Entwisle (1994).
102 Weiss and Iaconis (2001), citing others.
103 Smith and Kelman (2000).
104 Weiss and Iaconis (2001), citing Lamp et al. (1990).
105 For example, as Nicholson et al. (2006) note for the Corangamite region.
106 Weiss and Iaconis (2001).
107 Bennett and Price (2007).
108 Smith (1996), citing Reed et al. (1995).
109 McCaskill (2006).
110 Borg and Fairbairn (2003).
111 Nichols (2002) reports that the stocking rate can increase from 0.5 to 8 DSE/ha (DSE stands for Dry Sheep Equivalent).
112 Bennett and Price (2007). The four recommended systems are (1) Tall Wheat Grass, (2) Tall Wheat Grass / Sea Barleygrass, (3) Tall Wheat Grass / Tall Fescue / Phalaris / Perennial Ryegrass / annual legumes and (4) Sweet Clover / Tall Wheat Grass.

reducing the rate of supplementary feeding through Autumn." Tall Wheat Grass is also promoted on the Future Farm Industries CRC's *Saltland Genie* website.[113]

Tall Wheat Grass is also regarded as a promising pasture plant for non-saline, low-rainfall environments.[114] It has occasionally been used to stabilise the banks of waterways.[115]

2.2 Spread and impacts of Tall Wheat Grass

Extent of spread

Tall Wheat Grass has become invasive in many parts of the world – in the United States, Canada, Europe, Argentina and southern states in Australia, particularly Victoria.[116] But because it is valued as a fodder plant, it is not declared noxious anywhere in Australia, including under the *Victorian Catchment and Land Protection Act 1994*.

In Victoria Tall Wheat Grass has invaded a wide range of habitats, including dry saltmarsh (such as samphire or glasswort communities), wetlands, native grasslands, estuaries, coastal cliffs, waterways, roadsides, and some woodlands.[117] It is also likely to establish on coastal dunes.[118] It spreads by seed, with dispersal by water (along drainage lines and watercourses, and with floods),[119] by animals such as grazing macropods, and by mowers

Tall Wheat Grass (Lophopyrum ponticum). Photo: Geoff Carr

and vehicles along roadways.[120]

Tall Wheat Grass has not been systematically surveyed, so the sites of naturalisation and extent of spread are inadequately known. More than a decade ago it was reported as rapidly invading upper saltmarsh at Lake Connewarre near Geelong.[121] It was reported to have invaded pastures, roadsides and native grasslands in the Mallee, South West, Central and Gippsland regions.[122] A review for the Corangamite Catchment Management Authority reported that Tall Wheat Grass is widespread throughout the catchment, including in many wetlands.[123] Areas invaded include the Ramsar-listed and nationally significant wetlands Beeac Swamp, Lake Corangamite and areas around Leslie Manor.

More recent data indicate a much wider distribution and abundance of Tall Wheat Grass in Victoria than formerly appreciated. However, no systematic surveys have been undertaken to document its distribution, size of naturalised populations, and the types of environments invaded. More data are urgently required. Preliminary data on its Victorian distribution have been collated from various sources and the locations are shown in Figure 2.1. Sources of data are given in the footnote.[124]

Tall Wheat Grass has also naturalised in South Australia, New South Wales and Tasmania, to a lesser and apparently undocumented extent. In South Australia it is invading wetlands: along the Tod River, the Fleurieu Peninsula, Kangaroo Island, and in the Upper South-east region, including Coorong National Park, a Ramsar wetland.[125] Infestations greater than 1km in extent have been observed.

Potential for spread

Tall Wheat Grass has many weedy qualities. It produces large numbers of seeds (an estimated 1600 per plant);[126] is dispersed by water, vehicles and animals; can grow in a wide range of habitats; and tolerates extreme conditions – drought, frost, salinity, alkalinity and waterlogging.[127] In short, Tall Wheat Grass has an extraordinary ecological amplitude.

Recent observations by Geoff Sainty (Sainty and Associates, Sydney) indicate an ecological amplitude more extreme than so far revealed by our observations of the species as a naturalised plant in Victoria and South Australia:

> I confirm your fears – Tall Wheat Grass is amongst the toughest plants on the planet. It was thriving at 3000 m [altitude] in rock in central Turkey, and on the edge of Lake Van (4000 square km, at altitude 1644m) in far eastern Turkey where the water is so alkaline there are no waterplants or edge vegetation except for wheat grass, some battling *Phragmites* and a couple of chenopods.[128]

Illustrating its wide ecological amplitude, we have observed Tall Wheat Grass invading the following range of environments (in Victoria, unless otherwise specified):

- Coastal and non-coastal upper and mid-level saltmarshes
- Plains Grasslands on basalt-derived soils
- Coastal cliffs (Brighton and Bellarine Peninsula) and coastal calcareous sands (Freshwater Lake near Point Lonsdale)
- Salt Paperbark (*Melaleuca halmaturorum*) Swamp Scrub, Wimmera and Coorong, South Australia
- Grey Box (*Eucalyptus microcarpa*) Grassy Forest on stony clay loam
- River Red Gum (*E. camaldulensis*) Grassy Forest on clay loam and on deep siliceous sands (the latter with Porcupine Grass *Triodia scariosa*)
- Seasonal and permanent wetlands, brackish wetlands, estuaries and non-saline wetlands (including Brackish Sedgeland and Brackish Wetland)
- Mallee Chenopod Woodland on calcareous sandy loam, Kangaroo Island
- Riparian woodlands
- Exotic vegetation of road reserves from coastal western Victoria to Mildura in a very wide range of saline, brackish and non-saline environments

It has been recommended that Tall Wheat Grass be managed by stock grazing to prevent it setting seed.[129] But even with the best intentions, inevitably some plants escape grazing to set seed. If Tall Wheat Grass is not grazed for a while – for example, because of changed ownership of a property,[130] changed circumstances or because other, more palatable plants are available – it quickly

113 See www.saltlandgenie.org.au/solutions/ss5-tall-wheatgrass/tall-wheatgrass-in-a-nutshell.htm
114 Smith (1996).
115 Virtue and Melland (2003).
116 Verloove and Sanchez Gullon (2008); Randall (2007); Murray (2005); Darbyshire (2003); Virtue and Melland (2003); Ibid, citing Borrajo et al. (1997); Muyt (2001); Weiss and Iaconis (2001); Campbell (1998); Kartesz and Biota of North America Program (1998); Sedivec and Barket (1998); Carr et al. (1992); Calflora (nd).
117 Murray (2005); Virtue and Melland (2003); Elias (2002); Lazarides (2002); Weiss and Iaconis (2001); G. Carr (pers. obs.).
118 G. Carr (pers. obs.).
119 Murray (2005); Virtue and Melland (2003).
120 G. Carr (pers. obs.). It has spread along roadsides that are not mown, which suggests that vehicles are causing spread.
121 McMahon et al. (1994); Trengrove (1994).
122 Weiss and Iaconis (2001), citing Carr.
123 Murray (2005).
124 National Herbarium Victoria collections; DSE Flora Information System; Victorian Saltmarsh Study Group (2009); Walsh (2008); Roberts and Carr (2007); Crowfoot et al. (2006); Robertson (2005); McMahon et al. (1994); G. Carr (unpubl. data); A. Pritchard (pers. comm.); D. Pitts (pers. comm.); A. Governstone (pers. comm.); M. Trengove (pers. comm.); S. Talbot (pers. comm.); V. Stajsic (pers. comm.).
125 Virtue and Melland (2003); G. Carr (pers. obs.).
126 Weiss and Iaconis (2001).
127 Murray (2005); Virtue and Melland (2003); Weiss and Iaconis (2001); Sykes (2000); Smith (1996); G. Carr (pers. obs.).
128 G. Sainty (pers. comm. to G. Carr, 30 September 2009).
129 Borg and Fairbairn (2003).
130 Murray (2005) cites Greening Australia Victoria's concern about the risks associated with frequent changeover of property management: "New landholders and managers may not be aware of the management requirements of Tall Wheat Grass to prevent its spread."

becomes rank and unpalatable, which greatly increases the risk of spread. According to one agronomist who promoted Tall Wheat Grass, much of it "is poorly managed after sowing. It is undergrazed and quickly develops into coarse, unpalatable swards which provide very poor quality feed to grazing animals."[131] A 2003 study by DPI researchers Little and Kearney found that at 60 sites sown with Tall Wheat Grass it had spread along a creek from 26% of the 39 sites near a creek and along a roadside on 46% of the 24 sites near a road (see Box 2.2).[132] They commented that a large proportion of the landholders had allowed the grass to set seed over the first summer to improve its density.

On the basis of its current (and imperfectly known) distribution, its ready dispersal by a number of vectors, the age structure of populations and the rapid rate of recruitment, Tall Wheat Grass will spread much further. According to climate modeling by Weiss and Iaconis its potential range in Victoria is vast, covering more than 10 million hectares.[133] More than 3 million hectares of the vulnerable area is public land, mostly riverine grassy woodlands, heathy woodlands and inland slopes woodlands. Numerous wetlands (including Ramsar wetlands), all upper saltmarshes, many estuaries and riparian environments are at risk.[134] An assessment by weed scientists Virtue and Melland found that much of the native vegetation of the southern agricultural zone of South Australia was at risk of invasion, including 25% in the South-east, 10% in the Northern Agricultural Districts, 4% in the Eyre Peninsula, and 8% of Kangaroo Island.[135]

Impacts of Tall Wheat Grass

Saltmarshes, wetlands & other native vegetation communities

One ecosystem under particular threat is saltmarsh. The 2001 risk assessment of Tall Wheat Grass by Weiss and Iaconis noted that it poses a "particular threat to coastal saltmarsh vegetation" and that "on the balance of available qualitative evidence [it] would alone destroy most upper saltmarsh in western Victoria."[136] They recommended that invasion of saltmarshes be listed as a threatening process under the *Victorian Flora and Fauna Guarantee Act 1988*. Almost half the total flora of saltmarshes is comprised of exotic weeds. Weeds have had catastrophic impacts on upper saltmarshes, causing "major shifts in floristic composition, plant species extinctions, degradation of faunal habitat and changes in ecosystem function".[137] Of the weeds, Tall Wheat Grass "is unquestionably the most serious invader because of its very broad ecological amplitude and robust life form."

Wetlands also face particular risk from Tall Wheat Grass invasion. Victoria's wetlands are under threat – by 1994, when the last wetland inventory was undertaken, 37% had been destroyed mainly due to drainage.[138] Tall Wheat Grass was assessed as a "serious" threat to saline and subsaline wetlands in 1992.[139] With spread into numerous wetlands since then, including several that are Ramsar-listed, the threat has escalated.[140] An assessment for the Corangamite catchment found that the Ramsar-listed wetlands of the Western District Lakes under invasion from Tall Wheat Grass included Lakes Beeac, Bookar, Cundare, Milangil, Murdeduke, Terangpom, Colongulac, Corangamite and Gnarpurt.[141] It noted of the wetlands that:

> *They provide important feeding and roosting habitat for a large number and diversity of waterbirds including Eurasian coots, ducks, banded stilts, grebes, ibis and cormorants. Periodically, the Western District Lakes hold tens of thousands of ducks, swans and coots (The Ramsar Convention on Wetlands nd). These species rely on the present indigenous plant communities for their survival.*

The wetlands provide habitat for many rare and threatened species of flora and fauna. For example, within the Colac-Eurack area there are 76 saline wetlands known to provide habitat for 28 threatened species, as well as eight migratory species, and eight marine protected species.[142]

Tall Wheat Grass is listed as a high threat weed species in two Victorian Ecological Vegetation Classes (EVC): Brackish Sedgeland (scattered in near-coastal and western inland areas) and Brackish Wetland (mainly western and northern areas, but also scattered sites on coastal plains).[143] It threatens many other EVCs, and is the most seriously invasive weed of Victorian coastal saltmarsh.[144]

Tall Wheat Grass is a threat to natural vegetation communities not only where it has spread from planted sites, but also where it has been sown on naturally saline sites. Primary saline sites constitute a large proportion of Victoria's saltlands – more than half of the approximate 17,000 hectares of saline areas in the Corangamite catchment area[145] and up to 90,000 hectares in the Mallee bioregion.[146] However, it can be very difficult to distinguish primary and secondary saline sites, and the boundaries between them are often not clear. Whether deliberately or in ignorance, some primary salinity sites have been planted with Tall Wheat Grass, destroying their ecological values.[147]

Fire and hydrology

Because it grows tall and dense when not grazed or slashed, Tall Wheat Grass substantially increases the fuel loads in many infested areas, and may alter fire behavior and long-term fire regimes. Some vegetation types not subject to natural burning, such as shrublands dominated by *Tecticornia*, are becoming vulnerable to fire as a consequence of invasion by Tall Wheat Grass.[148]

The spread of Tall Wheat Grass may have detrimental impacts on hydrology. One of the objectives of planting it is to lower the water table to reduce the extent of salinity. However, under long-term drought conditions in south-eastern Australia and under changes predicted for climate change, the establishment of exotic deep-rooted perennial pastures may be detrimental to wetlands and river flows in some areas. (Hydrological impacts are further discussed in Chapter 3.)

Threatened species

Tall Wheat Grass is already a threat or a potential threat to rare and threatened plant and animal species, including the following listed under federal law – the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) – and / or under state law – the *Flora and Fauna Guarantee Act 1988* (FFG Act) or otherwise known to be threatened.

Orange-bellied Parrot (*Neophema chrysogaster*): Endangered (EPBC Act), Endangered (FFG Act). In Victoria, it mainly feeds in saltmarshes dominated by Beaded Glasswort (*Sarcocornia quinqeflora* ssp. *quinqueflora*), Southern Sea-heath (*Frankenia pauciflora*) and Shrubby Glasswort (*Tecticornia arbuscula*), as well as associated pastures. The saltmarsh and saline vegetation communities where it feeds, and some of its food plants, are threatened by Tall Wheat Grass. There is extensive invasion of saltmarsh adjoining parrot

131 Smith (1996).
132 Little and Kearney (2003).
133 Weiss and Iaconis (2001). This is about half Victoria's total land area.
134 Weiss and Iaconis (2001); G. Carr (pers. obs.).
135 Virtue and Melland (2003).
136 Weiss and Iaconis (2001), citing Carr.
137 Victorian Saltmarsh Study Group (2009).
138 Commissioner for Environmental Sustainability (2008).
139 Carr et al. (1992).
140 Murray (2005).
141 Murray (2005).
142 Nicholson et al. (2006).
143 DSE (2000).
144 Boon et al (in press).
145 Nicholson et al. (2006).
146 Commissioner for Environmental Sustainability (2008).
147 G. Carr (pers. obs.).
148 G. Carr (pers. obs.).

feeding areas near Barwon Heads. The Black-seeded Glasswort (*Tecticornia pergranulata*) saltmarsh in the Lake Connewarre system, which adjoins Orange-bellied Parrot feeding areas near Barwon Heads, is extensively invaded by Tall Wheat Grass.[149]

Spiny Peppercress (*Lepidium aschersonii*): Vulnerable (EPBC Act), Endangered (FFG Act). Weeds planted as pasture grasses suppress Spiny Peppercress and inhibit seed regeneration. Tall Wheat Grass is now invading this species' habitat in Victoria where it was formerly widespread in and around swamps and saltmarshes, particularly in Western Victoria.[150]

Salt-lake Tussock-grass (*Poa sallacustris*): Vulnerable (EPBC Act), Vulnerable (FFG Act). Endemic to south-western Victoria, occurring around the margins of salt lakes. There are nine populations covering about 0.6 ha. Major threats include stock grazing and weed invasion: "Continued expansion of (Tall Wheat Grass) at the current rate would see it becoming a major threat to Poa sallacustris."[151] It is already a major threat in some locations.[152]

Spiny Rice-flower (*Pimelea spinescens* ssp. *spinescens*): Critically endangered (EPBC Act), Endangered (FFG Act). Endemic to western Victoria. Known from about 20 wild populations containing up to 12,000 plants. Major threats include weed invasion, road works and stock grazing. Weeds are the "major threat facing all populations" with Phalaris and Tall Wheat Grass the most severe.[153]

Curly Sedge (*Carex tasmanica*): Vulnerable (EPBC Act), Vulnerable (FFG Act). Occurs in 52-59 sites in south-western Victoria, one north of Melbourne and several in Tasmania. In Victoria this species is generally confined to the upper margin of vegetation around slightly saline drainage lines or freshwater swamps. Weed invasion is a major problem in these habitats, and rated as a moderate threat to the sedge. Tall Wheat Grass invasion is noted as a potential threat.[154]

Tussock Grass (*Poa physoclina*): A critically endangered Victorian endemic only described in 2008. Known from five sites near the margins of salt lakes or seasonal wetlands. The major threat is encroachment by Tall Wheat Grass and Phalaris.[155]

Tall Wheat Grass poses a threat to many other plant species, especially those found in saltmarshes. Because these communities are poorly known, some of the species are undescribed and the conservation status of other species has not been assessed.

A preliminary evaluation of direct current or immanent threats to a subset of rare, vulnerable and endangered plant species of Victorian saltmarsh, lakes, swamps, floodplains and some grasslands is given in Table 2.1; the sources of data are also provided.

2.3 Responses to weed risk of Tall Wheat Grass

Limited acknowledgement of weed risk

Despite the harm it is causing, Tall Wheat Grass has been developed, researched, and promoted using public funds by publicly funded agricultural institutions, including the Victorian Department of Primary Industries, Victorian Catchment Management Authorities and salinity research institutes.

In 1999 the Victorian Department of Primary Industries developed and commercially released a new variety of Tall Wheat Grass called 'Dundas' without undertaking a weed risk assessment despite the existing cultivar ('Tyrell') behaving as a weed. In the paper describing 'Dundas' there was no mention of weed risk. It was described as "a productive, summer-active perennial pasture species" for saline and non-saline environments in southern Australia and ascribed an important role "in the reclamation of land affected by high watertables and salinity".[156] Since then, the Department has heavily promoted Tall Wheat Grass, particularly for saline areas, mostly without mention of its weed threat. The DPI Agricultural Note on Tall Wheat Grass claims that it is "one of the most productive species" for improved pastures and makes no mention of weed issues.[157] A recent Victorian DPI research paper is forthright in its commitment to Tall Wheat Grass with its title "Dundas tall wheat grass, our number one saline agronomy species for the high rainfall zone (550mm+)".[158] It acknowledges weed risk by noting that Tall Wheat Grass "should not be sown in areas were [sic] it can't be grazed or controlled by other means such as slashing or burning."

Some Victorian Catchment Management Authorities have also promoted Tall Wheat Grass as a salinity solution, and have provided incentives to graziers to plant it.[159]

Salinity and pasture researchers have focused attention on Tall Wheat Grass, promoting it as a pasture grass for a wide range of situations. In the Dryland Salinity CRC's 2003 publication *Saltland Pastures in Australia*, Tall Wheat Grass is described as "highly economic on moderately saline and waterlogged land in southern Australia", without mention of its weed threat.[160] Through its Land, Water & Wool Sustainable Grazing on Saline Lands (SGSL) Initiative the CRC ran a project (from 2002-2006) on 'Productive and Sustainable Salt-tolerant Pastures for South Australia and Victoria', which had a strong focus on Tall Wheat Grass.[161] Australian taxpayers, through the federally funded Land and Water Australia, were major funders of this work.[162] The final project report claims that "The Victorian component of SGSL made significant progress in developing best practices for establishing and maintaining tall wheat grass-based pastures for saline land." The report also noted that the research, combined with incentives from Catchment Management Authorities, had "stimulated demand for Tall Wheat Grass seed well beyond the current capacity of the seed industry".[163] Agricultural research papers also typically make no mention of the weed risk of Tall Wheat Grass.

State government risk assessment

For many years Tall Wheat Grass was promoted in Victoria and elsewhere without its weed risk having been assessed. In 2001 a Weed Risk Assessment was undertaken on behalf of the Parks, Flora and Fauna Division of the Department of Natural Resources and Environment.[164] The authors of that assessment, Weiss and Iaconis, commented that:

> *The Department of Natural Resources and Environment at present generally does not undertake risk assessment of pasture plant species that it promotes. Usually little thought is given to the utility of proposed imports and unwise introductions have been made.*

Their assessment acknowledged that Tall Wheat Grass would not have passed a risk assessment had it been assessed prior to use for salinity mitigation, that it has the potential to invade 10.4 million hectares of Victoria, that it is a very serious threat to saltmarshes in western Victoria and that threatened species

149 Commonwealth of Australia (2005); Trengrove (1994); McMahon et al. (1994).
150 Harris and Smith (2004).
151 Carter and Walsh (2006b).
152 McRobert and Carr (2008); G. Carr (unpubl. data); A. Pritchard (pers. comm.).
153 Carter and Walsh (2006a).
154 DSE (1999). Tall Wheat Grass was noted as a potential threat in the draft revision of the Flora and Fauna Guarantee Action Statement No. 88.
155 Walsh (2008); G. Carr (pers. obs.).
156 Smith and Kelman (2000).
157 Nichols (2002). The South Australian equivalent by Dooley (2003) acknowledges that Tall Wheat Grass is a weed, advising that "management strategies to minimise seed set and/or seed dispersion can be put in place where appropriate." *A Western Australian Farmnote* by Robinson (2000) makes no mention of weed risks.
158 Borg and Fairbairn (2003).
159 McCaskill (2006); Victorian Auditor-General's Office (2001).
160 Barrett-Lennard et al. (2003).
161 McCaskill (2006); Liddicoat and McFarlane (2007) explain the SGSL as "a five-year nationwide research and development program designed to provide wool growers and meat producers who are living with salt-affected land the most up-to-date, best bet information to enable sustainable, profitable production from saltland pastures."
162 See <http://www.landwaterwool.gov.au/land-water-and-wool/sustainable-grazing-saline-lands/projects/productive-and-sustainable-salt-tolera>. Land, Water and Wool is a partnership between Australian Wool Innovation Pty. Ltd. and Land & Water Australia, with additional funding from Meat & Livestock Australia.
163 McCaskill (2006).
164 Weiss and Iaconis (2001).

BOX 2.2 Misleading conclusions about spread of Tall Wheat Grass

A study of Tall Wheat Grass spread by the Victorian Department of Primary Industries researchers Little and Kearney published in 2003 has been cited as evidence that Tall Wheat Grass is not a significant weed risk (see footnote 170). The study is typically summed up in the quote from the conclusion that: “Little or no spread was detected for most of the 60 sites.”

The researchers investigated the spread of Tall Wheat Grass from 60 sites in the Glenelg Hopkins Catchment Management Authority region where it had been sown at least three years previously. They recorded spread from 26% of sites with a creek or other waterway, and from 46% of sites next to a road. They concluded that “spread from the original sown area only occurs when sites are allowed to set seed”, which is to be expected.

The researchers stressed that in most cases spread was less than 20 m, and that this could be attributed in many sites to seed displaced during sowing. Nonetheless, spread of greater than 20 m was recorded for 15% of sites with a waterway or next to a road. In three sites (two with a creek and one next to a road, 5% of total sites) plants were recorded hundreds of metres from plantings. The researchers said these sites had been

Potential for spread via/into	Number of sites	Proportion of sites with spread	Proportion of sites with spread >20m
Farmland	58	19%	5%
Roadside	24	46%	15%
Waterway	39	26%	15%
Plantation	20	25%	10%

Once outside the boundaries of the grazed area, even if it takes many years, Tall Wheat Grass plants are free to set seed and continue to spread.

poorly maintained. It is questionable whether the survey could have located all instances of spread given the potential for seeds to be washed hundreds of metres away or transported on mowers/vehicles along roadsides.

The distance spread within a few years after planting is not necessarily indicative of weed risk over longer timescales. Once outside the boundaries of the grazed area, even if it takes many years, Tall Wheat Grass plants are free to set seed and continue to spread.

There are numerous examples of weeds that did not exhibit invasive behavior until decades after their introduction to a new environment, and a 2009 European study by Williamson and colleagues found it took on average at least 150 years for naturalised plants to fill their range. That such a large proportion of sites planted with Tall Wheat Grass showed spread within a short time-frame (most sites had been sown less than 10 years previously; virtually all less than 20 years) suggests considerable potential for spread within the next few decades.

The reassuring conclusion that there was “little or no spread” is misleading and a flawed basis from which to infer that Tall Wheat Grass has little weed risk.

The critical finding of the report that was not adequately conveyed was that Tall Wheat Grass reliably spread within a short time span beyond sown sites, and that there was long-distance dispersal in some cases.

are at risk. They even recommended that invasion of saltmarshes by Tall Wheat Grass be listed as a threatening process under the *Flora and Fauna Guarantee Act 1988*. Despite this, they concluded that Tall Wheat Grass is a "lowly invasive weed", and relatively low in a list of weed rankings, and that it should not be declared a weed because this "would prevent the beneficial use of the plant".[165] They recommended that the weed risk be managed by "policy, guidelines or recommendations on where Tall Wheat Grass can be used and where it can not." [166]

The purpose of a weed assessment is to decide whether a plant is safe to use. An assessment serves no purpose if evidence of weediness is dismissed out of a belief that a plant should nonetheless be used.

Other assessments and recommendations

Both Glenelg Hopkins and Corangamite Catchment Management Authorities have recently responded to concerns about the weediness of Tall Wheat Grass with a study of its spread in the case of the former[167] and a review of weed risks in the case of the latter.[168] However, these assessments led only to revised management guidelines, and potentially some restrictions on where graziers are advised or assisted to plant Tall Wheat Grass.

The 2003 study conducted in the Glenelg Hopkins catchment area by DPI researchers Little and Kearney concluded that there was little or no spread of Tall Wheat Grass from 60 sites assessed and recommended that sites be managed by grazing to prevent spread.[169] However, the reassuring tone of their conclusions is belied by the data itself, which shows spread of Tall Wheat Grass from a significant proportion of sites, particularly along waterways (26% of sites with a waterway) and roadsides (45% of sites near a road). This study is discussed in Box 2.2. Unfortunately, the highly misleading conclusions of the study are quoted as evidence that Tall Wheat Grass is not a major weed threat.[170]

The 2005 review by Murray for the Corangamite Catchment Management Authority raised many concerns about Tall Wheat Grass and included comments from Greening Australia that it should not be planted, but the review recommended only management guidelines as a response to the weed risk.[171]

There is recent evidence of some caution about promoting Tall Wheat Grass. For example, the 2005-2008 Corangamite Salinity Action Plan acknowledges that Tall Wheat Grass is a weed, saying that "use of salt-tolerant pastures such as Tall Wheat Grass would be inappropriate next to Ramsar-listed or significant wetlands, where this pasture grass can become an environmental weed."[172]

165 There were other flaws with the assessment as well. (1) It underplayed the potential for dispersal, giving a low score for this criterion of risk by concluding that most seeds will fall "less than 200 m from parent plants, most within 20 m" because the "seeds have no special adaptations for dispersal". But there is acknowledgement that seeds could be transported by grazing mammals and the birds and mammals that eat seeds and use the grass for cover, and by water flows in drainage areas and natural waterways. These methods of dispersal offer significant potential for long distance dispersal. The evidence for this is the numerous sites where the grass has spread far beyond plantings. (2) The assessment acknowledges to some extent that Tall Wheat Grass invades intact natural habitats by saying that it establishes in "less disturbed situations", but then gives it a low score on this aspect by specifying that it invades only "highly disturbed" natural ecosystems. (3) It provides contradictory information about the spread of Tall Wheat Grass. Contrast (a) "Invasion by this species has occurred without planting or deliberate introduction for agricultural purposes, i.e. It is capable of wide dispersal without direct human agency and its range is expanding rapidly" with (b) "Most spread of Tall Wheat Grass would be a result of deliberate plantings." (4) There are inadequacies also in the method used to assess risk. The assessment failed to consider the most reliable indicator of weed risk: previous evidence of weediness in Australia or overseas. (5) The assessment also failed to consider the potential impacts of Tall Wheat Grass on natural environments, such as its threat to Ramsar wetlands and threatened species.

166 A reviewer of the present report pointed out that risk assessment and weed ranking for management effort/urgency should not be conflated. Decisions regarding listing a taxon as prohibited or otherwise should be based on invasiveness, expense of control, degree of environmental impact etc. The rate of spread is not ecologically relevant; however it could inform some process by which funds are allocated for management/control.

167 Little and Kearney (2003).

168 Murray (2005).

169 Little and Kearney (2003).

170 Eg. Land Water & Wool Program and Future Farm Industries CRC (2008); McCaskill (2006); Victorian Department of Primary Industries (2005).

171 Murray (2005).

172 Nicholson et al. (2006).

STOP PRESS!

The Victorian Government has decided to undertake a new weed risk assessment of Tall Wheat Grass (letter 5 November to G. Carr). The result is not yet known.

2 Chapter

Tall wheat grass

Tall What Grass invading margins of saltmarsh in the estuary of the Barwon River at Ocean Grove in Victoria. This site is adjacent to Port Phillip Bay and the Bellarine Peninsula Ramsar site. It has probably been planted here (December 2007). Photo: Geoff Carr

It advocates guidelines to accompany future sales of Tall Wheat Grass. The plan also moved away from recommending the planting of perennial pasture plants as a funded project initiative because of doubts about the effectiveness of this approach for salinity mitigation, although this was subject to review because of contestation by agricultural stakeholders.[173]

One intended project of the Land, Water & Wool Sustainable Grazing on Saline Lands Initiative was an assessment of the weed potential of Tall Wheat Grass and other species, but this was not implemented due to the failure to attract a research student.[174] Instead, it was claimed that the intent of the project was fulfilled by the Little and Kearney study of spread, and that their study found "there was little spread except by water, and that what spread occurred was believed to have been immediately after sowing." In fact, as noted above, the study found spread from a large proportion of the 60 assessed sites, particularly along roadsides and waterways (see Box 2.2).

2.4 Conclusion

There is abundant evidence that Tall Wheat Grass is invasive, and that it has already invaded and seriously threatens many important environmental assets, including saltmarshes, wetlands and threatened flora and fauna species. But because it is regarded

Above, Tall Wheat Grass invading upper saltmarsh, Lake Connewarre, Port Phillip Bay (western shoreline) and Bellarine Peninsula Ramsar site. Photo: Geoff Carr

as a valuable pasture grass, particularly for saline areas, the environmental risks have been ignored or downplayed. This is evident in the recommendation of the state government's risk assessment that the species not be declared a weed because of its pasture value for salt-affected areas. Yet the areas potentially affected by invasion of Tall Wheat Grass far exceed the areas potentially affected by salinity. Its potential environmental costs as a weed far outweigh its benefits for treating salinity.

The same government department that released 'Dundas', the major cultivar of Tall Wheat Grass, and promotes it as a salinity solution is also in charge of weed declarations. This conflict of interest and other systemic failings that have led to the widespread propagation of Tall Wheat Grass are discussed in Chapter 4.

173 Nicholson et al. (2006).
174 McCaskill (2006). The report refers to a publication resulting from a similar project in South Australia (Liddicoat & MacFarlane 2007). In the pasture manual funded under that project Tall Wheat Grass is strongly recommended for planting where rainfall is >425mm and for low to moderately high saline areas, despite the warning that it "is an aggressive coloniser and will establish easily in non-saline areas." McCAskill (2006) also reports that "*Puccinellia ciliata* has already become endemic [sic] in salt-affected areas of the Upper South-East of South Australia through widespread sowing. Since it has already spread into these salt-affected areas, a weediness study by SGSL would be too late to limit its spread within this region."

2 Chapter

TALL WHEAT GRASS

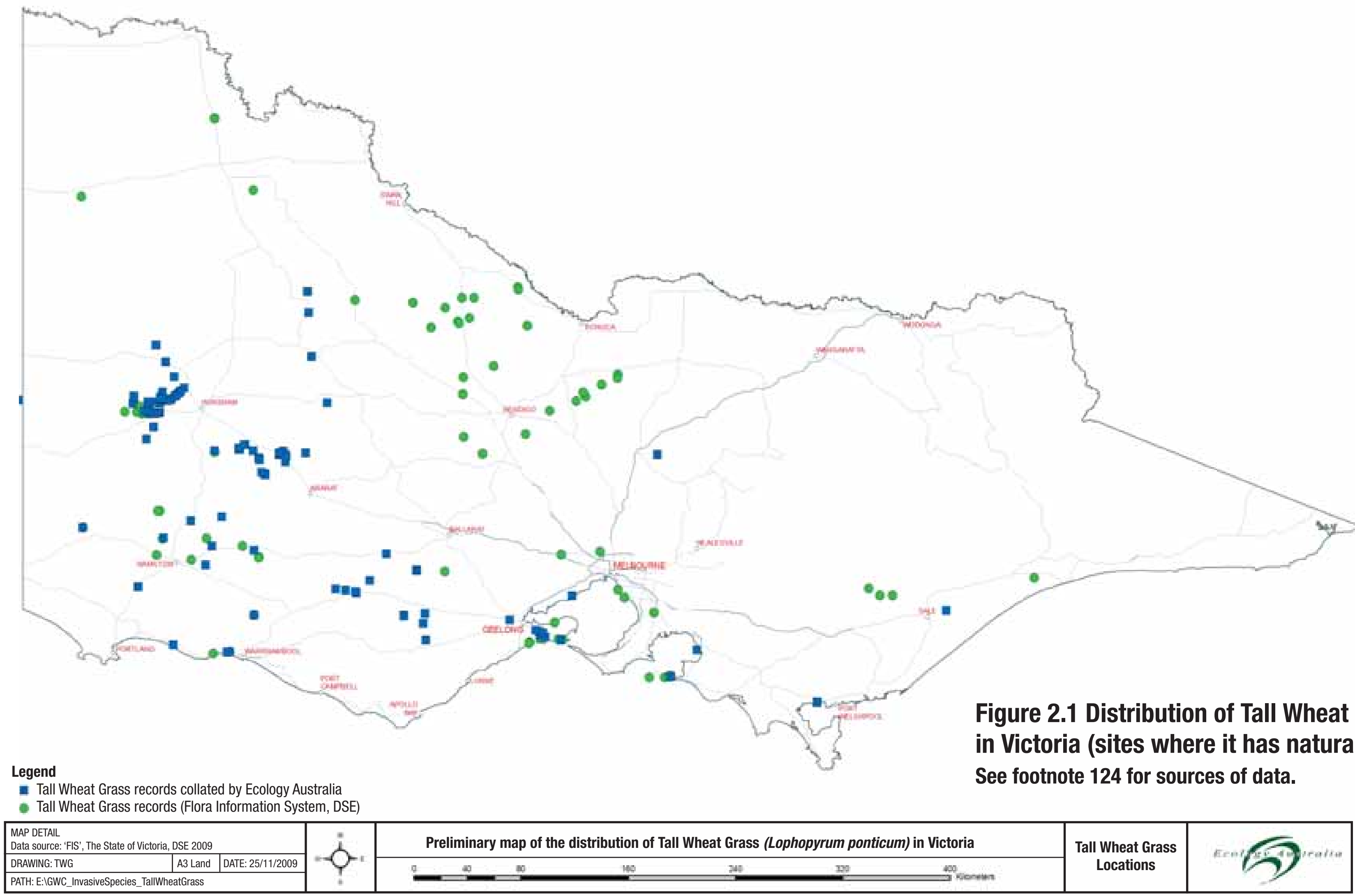

Figure 2.1 Distribution of Tall Wheat Grass in Victoria (sites where it has naturalised).
See footnote 124 for sources of data.

TABLE 2.1 Rare, vulnerable and endangered Victorian plant species of saltmarsh, lake, swamp and floodplain environments threatened by invading Tall Wheat Grass (*Lophopyrum ponticum*)

The grasslands of the Victorian Volcanic Plain, listed as critically endangered under federal environmental legislation, are overrun by exotic weeds, including escaped pasture species. Photo: Sarah Bekessy

Life form

A	annual
B	biennial
Gt	tuberous geophyte
Pr	perennial herb (rhizomatous or stolonferous)
Pt	perennial herb (tufted or tussock-forming)
Pa	herbaceous parasite
S	small to medium shrub
Ss	subshrub
T	tree
X	succulent herb, subshrub or shrub

Conservation status in Victoria (after Walsh and Stajsic 2007)

DSE	Department of Sustainability & Environment (2005)
EPBC	Listed under *Commonwealth Environment Protection and Biodiversity Conservation Act 1999*
FFG	Victorian *Flora and Fauna Guarantee Act 1988*
E	endangered in Australia
e	endangered in Victoria
K	poorly known in Australia (suspected to be rare, vulnerable or endangered)
k	poorly known in Victoria (suspected to be rare, vulnerable or endangered)
L	listed under the Victorian *Flora and Fauna Guarantee Act 1988*
nl	not listed (in Walsh & Stajsic 2007)
R	rare in Australia
r	rare in Victoria
V	vulnerable in Australia
v	vulnerable in Victoria

IUCN (2001) conservation status (determined by D. Cameron and G. Carr unpubl. data)

CR	Critically Endangered
EN	Endangered
NA	Not Assessed
VU	Vulnerable

Bioregion (where known to be threatened)

CVU	Central Victorian Uplands
DT	Dundas Tablelands
GG	Greater Grampians
GLP	Glenelg Plain
GP	Gippsland Plain
MF	Murray Fans
MM	Murray Mallee
OP	Otway Plain
VR	Victorian Riverina
VVP	Victorian Volcanic Plain
W	Wimmera

TABLE 2.1 Rare, vulnerable and endangered Victorian plant species of saltmarsh, lake, swamp and floodplain environments threatened by invading Tall Wheat Grass (*Lophopyrum ponticum*)

Species name	Common name	Family	Life form	Victorian endemic species	Conservation status in Victoria				Bioregion	References
					DSE	EPBC	FFG	IUCN (2001)		
Carex tasmanica	Curly Sedge	Cyperaceae	Pr	-	Vv	VU	L	NA	VVP	Carr (unpubl.), D. Pitts (pers. comm.)
Casuarina obesa	Swamp Sheoak	Casuarinaceae	T	-	e	-	L	CR	W	Carr (unpubl.)
Convolvulus angustissimus ssp. *omnigracilis*	Slender Bindweed	Convolvu-laceae	Pt	-	k	-	-	NA	WP,VVP	Carr (unpubl.)
Cullen parvum	Small Scurf-pea	Fabaceae	Pt	-	Ee	EN	L	CR	VVP, VR, MF	Muir (2003)
Cullen tenax	Tough Scurf-pea	Fabaceae	Pt	-	e	-	L	CR	VVP, MF, VR	Carr (unpubl.)
Cuscuta tasmanica	Golden Dodder	Cuscutaceae	Pa	-	nl	-	-	EN	VVP	Victorian Saltmarsh Study Group (2009)
Dianella sp. aff. *longifolia (Benambra)*	Arching Flax-lily	Hemerocal-lidaceae	Pt	-	Kv	-	-	NA	OP, GLP, DT, VVP, W	Carr (unpubl.), D. Pitts (pers. comm.)
Glycine latrobeana	Clover Glycine	Fabaceae	Pt	-	Vv	VU	L	NA	VVP	D. Pitts (pers. comm.)
Helichrysum sp. aff. *rutidolepis (Lowland Swamps)*	Pale Swamp Everlasting	Asteraceae	Pr	-	v	-	-	NA	VVP	Carr (unpubl.)
Juncus revolutus	Creeping Rush	Juncaceae	Pr	-	r	-	-	NA	GP, OP, VVP, WP	Victorian Saltmarsh Study Group (2009), Crowfoot et al. (2006), Carr (unpubl.)
Lachnagrostis adamsonii	Adamson's Blown-grass	Poaceae	Pt	✓	Vv	EN	L	NA	VVP	A.Brown (pers. comm.), Y. Ingeme (pers. comm.)

TABLE 2.1 Rare, vulnerable and endangered Victorian plant species of saltmarsh, lake, swamp and floodplain environments threatened by invading Tall Wheat Grass (*Lophopyrum ponticum*)										
Species name	**Common name**	**Family**	**Life form**	**Victorian endemic species**	**Conservation status in Victoria**				**Bioregion**	**References**
					DSE	**EPBC**	**FFG**	**IUCN (2001)**		
Lachnagrostis billardierei ssp. *billardierei*	Coast Blown-grass	Poaceae	Pt	-	nl	-	-	EN	OP, VVP	Carr (unpubl.)
Lachnagrostis deflexa	Blown-grass	Poaceae	Pt	✓	nl	-	-	NA	VVP	Brown (2008, pers. comm.)
Lachnagrostis leviseta	Blown-grass	Poaceae	Pt	✓	nl	-	-	NA	GG	A. Brown (pers. comm.)
Lachnagrostis palustris	Swamp Blown-grass	Poaceae	Pt	-	nl	-	-	NA	GP, DT	Brown (2008, pers. comm.), N. Walsh (pers. comm.)
Lachnagrostis punicea ssp. *filifolia*	Purple Blown-grass	Poaceae	Pt	-	Rr	-	L	NA	VVP	Pitts (in prep.)
Lachnagrostis punicea ssp. punicea	Purple Blown-grass	Poaceae	Pt	-	Rr	-	-	NA	VVP	A. Brown (pers. comm.)
Lachnagrostis robusta	Salt Blown-grass	Poaceae	Pt	-	Rr	-	-	NA	VVP	A. Brown (pers. comm.), N. Walsh (pers. comm.)
Lawrencia spicata	Salt Lawrencia	Malvaceae	B	-	r	-	-	CE	GP, OP, VVP	Victorian Saltmarsh Study Group (2009), Crowfoot et al. (2006). Carr (unpubl.)
Lepidium aschersonii	Spiny Peppercress	Brassicaceae	Pt	-	Ve	VU	L	NA	VVP	Carr (unpubl.), Harris & Smith (2004)
Lepidium hyssopifolium	Basalt Peppercress	Brassicaceae	Pt	-	Ee	EN	L	NA	CVU, VVP, W	N.Reiger (pers. comm.)

TABLE 2.1 Rare, vulnerable and endangered Victorian plant species of saltmarsh, lake, swamp and floodplain environments threatened by invading Tall Wheat Grass (*Lophopyrum ponticum*)

Species name	Common name	Family	Life form	Victorian endemic species	Conservation status in Victoria				Bioregion	References
					DSE	EPBC	FFG	IUCN (2001)		
Leptorhynchos waitzia	Button Immortelle	Asteraceae	A	-	v	-	-	NA	VVP	Carr (unpubl.), Harris & Smith (2004)
Limonium australe	Yellow Sea-lavender	Plumbagi-naceae	Pt	-	r	-	-	CE	GP, OP	Victorian Saltmarsh Study Group (2009), Crowfoot et al. (2006)
Melaleuca halmaturorum	Salt Paperbark	Myrtaceae	T	-	v	-	L	CE	WP, W	Carr (unpubl.)
Muehlenbeckia horrida ssp. horrida	Spiny Lignum	Polygonaceae	S	-	r	-	-	EN	W	Carr (unpubl.)
Pimelea spinescens ssp. spinescens	Spiny Rice-flower	Thymelae-aceae	S	✓	Ee	CR	L	CR	VVP	Carter & Walsh (2006a)
Poa physoclina	Tussock-grass	Poaceae	Pt	✓	Vv	-	-	CE	VVP	Walsh (2008)
Poa sallacustris	Salt-lake Tussock-grass	Poaceae	Pr	✓	Vv	VU	L	CE	VVP	Carter and Walsh (2006b), McRobert and Carr (2007)
Prasophyllum anticum	Pretty Hill Leek-orchid	Orchidaceae	Gt	✓	Ee	-	-	NA	VVP	D. Pitts (pers. comm.)
Prasophyllum diversiflorum	Gorae Leek-orchid	Orchidaceae	Gt	✓	Ee	EN	L	NA	VVP, DT	Carr (unpubl.), D. Pitts (pers. comm.)
Prasophyllum viretrum	Orford Leek-orchid	Orchidaceae	Gt	✓	Ee	-	-	NA	VVP	D. Pitts (pers. comm.)
Ranunculus diminutus	Brackish Plains Buttercup	Ranuncu-laceae	Pr	-	r	-	-	NA	VVP	Carr (unpubl.)

TABLE 2.1 Rare, vulnerable and endangered Victorian plant species of saltmarsh, lake, swamp and floodplain environments threatened by invading Tall Wheat Grass (*Lophopyrum ponticum*)										
Species name	**Common name**	**Family**	**Life form**	**Victorian endemic species**	**Conservation status in Victoria**				**Bioregion**	**References**
					DSE	**EPBC**	**FFG**	**IUCN (2001)**		
Senecio psilocarpus	Swamp Fireweed	Asteraceae	Pt	-	Vv	VU	-	NA	VVP	Carr (unpubl.)
Tecticornia syncarpa	Fused Glasswort	Chenopo-diaceae	X-S	-	Vv	-	-	NA	MM	N.Reiger (pers. comm.)
Teucrium albicaule	Scurfy Germander	Lamiaceae	Pr	-	k	-	-	CE	W	Carr (unpubl.)
Teucrium racemosum	Grey Germander	Lamiaceae	Pr	-	nl	-	-	CE	W	Carr (unpubl.)
Trichanthodium baracchianum	Dwarf Yellow-head	Asteraceae	A	✓	Vv	VU	L	NA	MM	N.Reiger (pers. comm.)
Triglochin minutissima	Tiny Arrowgrass	Juncaginaceae	A	-	r	-	-	CE	OP	Carr (unpubl.), Victorian Salt-marsh Study Group (2009),
Triglochin mucronata	Prickly Arrowgrass	Juncaginaceae	A	-	r	-	-	CE	OP, VVP	Victorian Saltmarsh Study Group (2009), Carr (unpubl.)
Xerochrysum palustre	Swamp Everlasting	Asteraceae	Pr	-	Vv	V	L	NA	GG	N.Walsh (pers. comm.)

3

Chapter

More Salinity Weed Risks

More Salinity Weed Risks

Unfortunately, persistent pastures have the same characteristics as weeds…

– Media release, Future Farm Industries CRC, 2007[175]

3.1 Introduction

Besides Tall Wheat Grass, several other known weeds are promoted as pasture plants for their capacity to grow in saline soils or reduce recharge of groundwater for salinity prevention. Dozens more known or potential weeds are being investigated or recommended for investigation for salinity mitigation. Much of this work is conducted by the Future Farm Industries Cooperative Research Centre (CRC), whose members include commercial agricultural companies, six state agricultural and environmental government agencies, four universities and the CSIRO. Its predecessor was the CRC for Plant Based Management of Dryland Salinity. In this case study we examine the weed risks of the two CRCs' perennial pastures programs to address salinity problems. The Future Farm Industries CRC advocates the planting of perennial pastures, which will undoubtedly include weedy species, over millions of hectares in southern Australia. Our main focus here is Victoria, but the problems and conclusions generally apply more broadly to south-eastern Australia.

Salinity poses an ostensible dilemma for environmental managers. As discussed in Chapter 1, the latest evidence suggests that sown perennial pastures will help redress salinity problems only if planted on a very large scale, in some catchments only, and that the salinity problem in south-eastern Australia is far less serious than formerly predicted.

Thus far, salinity programs to promote the planting of perennial pasture species have not been very successful – adoption rates by graziers have been low because of marginal economic returns, as well as more demanding management requirements. What is required, researchers say, is the development of better pasture options – economically attractive enough to motivate graziers to plant them over very large areas.[176] Agronomists have been seeking new plant options both here and overseas, and there have been calls for greater investment in plant-based R&D to develop new pasture options.[177]

However, the better the performance of a pasture plant to produce fodder and reproduce, the more likely it is to become a weed in non-pasture contexts. The qualities that make a good pasture plant are typically also those that make a make a plant highly invasive. In this report, we question whether the collateral environmental damage of weed invasion is justified, especially when there is no guarantee that these plants will solve salinity problems. The continued focus on pasture plants to counter salinity, despite the limited success over the past decade and despite evidence that the salinity problem in south-eastern Australia is less serious than predicted, raises suspicions that salinity is being used as an excuse to continue the long-established practice of introducing weeds for limited commercial benefit to the detriment of the public good.

The CRC's perennial intentions

The principal aim (and trademark) of the Future Farm Industries CRC is Profitable Perennials™ for Australian landscapes (see Appendix 1 for a description of the CRC). Box 3.1 describes the CRC programs and 'deliverables' that are most relevant to the weed risks of concern here. The CRC intends to develop, improve and promote salt-tolerant and drought-tolerant perennial pasture species (grasses, legumes and saltbushes) for salinity mitigation, to extend growing seasons and to extend uptake into lower rainfall areas. The focus is on perennials because "deep-root systems are more adaptable to climate variation and can lower water tables in low-lying, saline areas."[178] The intended users of perennial plant products and information are the 72,000 broadacre primary producers managing 60 million hectares of Australia's land area. The CRC's goal is the adoption of perennial cultivars on a further 7.4 million hectares,[179] which would more than triple the current 3 million hectares sown with perennial species.[180]

The CRC claims to have developed policies and protocols to minimise the weed risk, to "ensure that farming systems developed to solve one environmental problem do not cause another."[181]

3.2 Weed risks of the CRC program

The Victorian environment is under severe pressure from weeds. Almost all remnant vegetation in the agricultural zone is highly fragmented and vulnerable to invasion. For example, the grasslands of the Victorian Volcanic Plain, recently listed as critically endangered under federal environmental law, survive in small, highly degraded patches on 8% of their original extent. About one-third of the plant species (and a much higher proportion of their biomass) in these remnant grasslands are exotic weeds, including escaped pasture species. The federal listing advice notes that of particular concern are perennial exotic grasses "because their adverse impacts are potentially long-term and they are difficult to manage".[182] Agricultural enterprises in Victoria also suffer from extensive weed problems that will be worsened by the introduction of more weedy pasture plants.

The weed risks of the perennial pasture programs include further plantings of existing weedy pasture species, release of new cultivars of existing weedy species and release of new, potentially weedy pasture species.

Inherent weed risks of exotic pasture plants

In a recent paper discussing the search for new perennial pasture species, agronomists Dear and Ewing comment that one of the desirable attributes of pasture species is that they are not invasive.[183] However, as the Future Farm Industries CRC has recognised, "persistent pastures have the same characteristics as weeds."[184] Desirable pasture attributes that contribute to the weed risk include:[185]

- wide geographic environmental adaptation
- persistence and productivity
- ready establishment from seed, and a high probability of successful germination and establishment
- high seed yield
- seed survives ingestion by stock
- extended growth phase
- tolerance of difficult climatic and soil conditions, such as drought, salinity, acidity, waterlogging
- insect tolerance
- grazing tolerance

The two most commonly targeted groups of plants for pastures are grasses and legumes, and partly because of that they are amongst the most invasive of all plant families.[186]

With about 10,000 species worldwide, and growing in most habitats on all continents, the grass family is very widespread, abundant and

175 Future Farm Industries CRC (2007).
176 Ridley and Pannell (2005).
177 As documented in the submissions and findings of the following parliamentary reports: House of Representatives Standing Committee on Science and Innovation (2004); Senate Environment Communication Information Technology and the Arts References Committee (2006).
178 Reed et al. (2008).
179 Future Farm Industries CRC (nd).
180 According to Dear and Ewing (2008), about 3 million hectares out of 100 million hectares of cleared land in Australia are planted to perennial pastures.
181 Stone et al. (2008b).
182 Threatened Species Scientific Committee (2008).
183 Dear and Ewing (2008).
184 Future Farm Industries CRC (2007).
185 Dear and Ewing (2008); Li et al. (2008); Loi et al. (2005).
186 Low (1997).

BOX 3.1 Relevant CRC programs

From the Future Farm Industries CRC website
http://www.futurefarmcrc.com.au/programs.html

Program 1 Future livestock production ($27.8 million)
Goals include "practice change on 2900 farms across 350,000ha within the life of FFI CRC with new perennials released for adoption on >3m ha." The Improved Perennial Grasses project will "breed new perennial grasses for areas with unproductive annual grasses and weeds on the inland slopes of the Great Dividing Range in Victoria and New South Wales," expanding on previous work on new cultivars of Cocksfoot, Tall Fescue and Phalaris.

Program 2 Future cropping systems ($17.1 million)
Goals include the "development of a new perennial pasture legume for the crop-dominated low rainfall zone" and "perennial pasture (non-crop) options fitted against soils and cropping constraints within regions." There are apparently several prospective native and exotic legume species (e.g. *Lotononis*, *Cullen*).

Program 4 Farming saline landscapes ($11.8 million)
Goals include "25% of salt affected producers managing newly re-vegetated saline land pastures to generate increased farm productivity" (150,000ha by 2020) and "three new salt and waterlogging tolerant pasture cultivars and an elite saltbush cultivar commercialised" (200,000ha by 2020). The development of four or more new herbaceous and woody forage species in the PastureSearch project include those suitable for:

- the warm season, summer dominant rainfall zone
- acid soils in high and medium rainfall zones
- the low/medium rainfall crop/livestock zone

Cocksfoot (*Dactylis glomerata*). Photo: Geoff Carr

Phalaris (*Phalaris aquatica*). Photo: Geoff Carr

Tall Fescue (*Festuca arundinacea*). Photo: Geoff Carr

Program 5 Biodiversity and water ($9.8 million)
Goals include protection of biodiversity "by minimising the risk of genetic pollution of native species, and introduction of weedy species."

successful.[187] Many grasses are productive (they have high photosynthetic efficiency), palatable (but able to withstand grazing) and competitive, and are thus desirable pasture species. Because of these qualities, they are one of the weediest of plant families in Australia and globally. With more than 22% of the world's grasses having been introduced to Australia by government agencies as pasture possibilities,[188] most of the 374 grass taxa[189] listed as weeds in Australia have been deliberate introductions. Many cause serious environmental harm. In recognition of this, invasion of native plant communities by exotic perennial grasses has been listed as a key threatening process in NSW under the *Threatened Species Conservation Act 1995*, with the Scientific Committee noting that:

> *The characteristics of vigorous growth, prolific seed production and effective seed dispersal enable many exotic perennial grasses to compete strongly with, or in some places displace, native vegetation. Exotic perennial grasses may also change the fuel load in plant communities. The changed structure and fire regimes of the habitat is likely to adversely impact on both native vertebrate and invertebrate fauna.* [190]

The seriousness of grasses as weeds is also reflected in the list of the 20 plant species/aggregates recognised as Weeds of National Significance of which three are grasses.[191]

Legumes are the other main focus of agronomists, because they fix nitrogen, a vital nutrient for livestock. Of the world's approximate 8000 species,[192] about 18% have been introduced into Australia by government agencies as pasture options.[193] Legumes also constitute some of the worst weeds in Australia, with their threats summarised in a review article by Paynter and others. [194] One quarter of Australia's 20 Weeds of National Significance are legumes.[195] They infest millions of hectares in Australia, invading pastures and eliminating native biodiversity. Some of the noxious legume weeds were benign or relatively beneficial for decades before going weedy after unpredicted events.[196]

The weed risk of pasture plants is due not only to their inherent weedy features, but also because they are widely planted – their 'propagule pressure' (or seed availability) is high – optimising their chances of spread. One of the clearest principles of invasion biology is that the more often a plant is introduced the more likely it is to become invasive.[197] Salinity scientists thus have a special responsibility to ensure that any plants they introduce do not pose a significant weed risk.

Promotion of existing invasive species for saltlands

The Future Farm Industries CRC has recently set up a website called *Saltland Genie* (see http://www.saltlandgenie.org.au) to synthesise

187 McCusker (2002).
188 Cook and Dias (2006). The number of grass species introduced is about double the number of indigenous grass species.
189 Lazarides (2002).
190 NSW Scientific Committee (2003).
191 See www.weeds.gov.au/weeds/lists/wons.html.
192 Mabberley (1997).
193 Cook and Dias (2006). The number of legume species introduced is about double the number of indigenous legume species.
194 Paynter et al. (2003).
195 See See www.weeds.gov.au/weeds/lists/wons.html.
196 Paynter et al. (2003). For example, *Mimosa pigra*, a weed of wetlands, only became seriously weedy after the seeds reached floodplains disturbed by buffalo, 100 years after its introduction.
197 Mulvaney (2001); Rejmanek (2001). A few studies have documented evidence for the stochastic effect of introduction pressure (or propagule pressure). Scott and Panetta (1993) found that the weed status of southern African plants in Australia was significantly correlated with both time from initial introduction and the number of times a species had been planted. Similarly, Rejmanek (2001) found that of 289 naturalised woody ornamental species identified in Adelaide, Canberra, Melbourne and Sydney, the vast majority had been amongst the most popular plantings.

BOX 3.2 Future Farm Industries Cooperative Research Centre's saltland 'solutions' involving perennial pastures

Solution 3: Saltbush (*Atriplex* species): Densely plant either native (River Saltbush, Old Man Saltbush) or exotic saltbushes (Wavy-leaf Saltbush).

Solution 4: Saltbushes with an understorey of 'improved species' involving annual legumes (such as Balansa Clover, Sub-clover, Burr Medic) and grasses (such as Annual Ryegrass).

Solution 5: Tall Wheat Grass.

STOP PRESS!

The Future Farm Industries CRC has just modified its recommendations regarding Tall Wheat Grass to say that it should not be grown in Victoria because of a 'very high' weed risk (December 2009).

Solution 6: Puccinellia.

Solution 7: Grasses that are established vegetatively (from surface or underground stems): *Sporobolus virginicus* (Marine Couch), *Paspalum vaginatum* (Saltwater Couch) and *Distichlis spicata* (Distichlis).

Solution 8: Temperate perennial grasses that have limited salt tolerance, such as Perennial Ryegrass (*Lolium perenne*), Phalaris (*Phalaris aquatica*) and Tall Fescue (*Festuca arundinacea*).

Tall Fescue (*Festuca arundinacea*) invasion in brackish creek at Mt Eliza, Victoria. Photo: Geoff Carr

Solution 9: Subtropical perennial grasses with limited salt tolerance, such as Kikuyu (*Pennisetum clandestinum*) and Rhodes Grass (*Chloris gayana*).

Solution 10: Legumes, the only available options having fairly low salinity tolerance: Burr Medic, Lucerne, Strawberry Clover and Balansa Clover.

information about productive use of saltlands. The site has 11 categories of 'saltland solutions', appropriate for different categories of salt-affected land, eight of which involve planting exotic pasture species. They are listed in Box 3.2.[198]

The 23 plant species nominated as solutions on the website are listed in Table 3.1, along with information about their weed status/ risk, focused in particular on Victoria. Three (possibly four) of the 23 are Australian natives, although not necessarily indigenous to where they will be planted, thus posing a weed risk in some circumstances. More than half (14 of 23, 70% of the exotic species) are existing environmental weeds in Australia. These are dominated by the grasses: of the 12 grasses promoted, one is native (and one other is contended by some to be native, but has nonetheless become invasive), 10 (more than 80%) are existing environmental weeds and the other one could become an environmental weed if it hybridises with a native species. As already noted, many exotic grasses have a high rate of invasiveness. This is recognised in the federal protocol for plant Weed Risk Assessment, with grasses (and woody legumes) automatically scoring more highly than species in other plant families. In contrast, fewer promoted legumes have become weedy. Of the eight listed, four are environmental weeds and one is a crop weed.

Just three of the 23 species in Table 3.1 have been subjected to published evaluations under the CRC weed risk assessment process (see Table 3.5). They were not required to go through a federal risk assessment (because they were already in the country when the Weed Risk Assessment system was instituted) and just one – Tall Wheat Grass – has been through a flawed Victorian Government assessment (as discussed in Chapter 2).

Comprehensive assessments are needed to understand the threat of these species if they were planted on a larger scale or in new or environmentally sensitive areas. Some either minor or serious weeds are already so widespread that further plantings will make little difference, while others constitute a serious threat that will be exacerbated by further plantings. We have particular concerns about further plantings, or plantings in new or sensitive areas, of Tall Wheat Grass, Phalaris, Puccinellia, Tall Fescue, Kikuyu and Saltwater Couch. We are also concerned about new cultivars of these species, selected or bred for increased drought tolerance or other attributes that will increase their ecological amplitude or invasiveness, as discussed below.

Development of new cultivars of existing invasive species

Some of the pasture species that are already weedy could become more invasive with the development of new cultivars to improve their tolerance to harsh conditions such

198 Land Water & Wool Program and Future Farm Industries CRC (2008).

199 These plants are promoted on the Salt Genie website at http://www.saltlandgenie.org.au/index.htm [accessed February 2009]. Information about weed risk comes from Lamp and Collett (1976) (LC76); Carr et al. 1992 (CYR92); Walsh and Entwisle (1994) (W94); Jeanes (1996) (J96); Muyt (2001) (M01); Briggs and Taws (2003) (BT03); Virtue and Melland (2003) (VM03); Keighery and Longman (2004) (KL04); Richardson et al. (2006) (RRS06); Randall (2007) (R07); Navie and Adkins (2008) (NA08); Victorian Saltmarsh Study Group (2009) (VSSG09); Carr et al. (in prep.) (CYSM in prep.); B. Semple (pers. comm.) (BS); G. Carr (pers. obs.) (GC).

TABLE 3.1 Weed status of plants promoted for planting on saltlands[199]

Species promoted		Environmental weed status or risk (references in footnote 199)
River Saltbush	*Atriplex amnicola*	Native to Gascoyne and Murchison area, WA. Could become a weed outside its native range, as have other native and exotic *Atriplex* (RRS06).
Old Man Saltbush	*Atriplex nummularia*	Native to southern & central Australia. Naturalised outsides its natural range in Victoria (GC). Could become a weed risk outside its native range, but the FFI CRC's assessment says the risk is low to negligible. Invasive overseas (R07).
Wavy Leaf Saltbush	*Atriplex undulata*	Native to Argentina. Naturalised in WA (KL04). Weedy overseas (R07). Has high weed risk (GC).
Rhodes Grass	*Chloris gayana*	Native to Southern Africa. An environmental weed in Qld, NSW, NT & Vic (R07, NA08). Has spread from roadsides & pastures to invade native bushland and rainforest margins in SEQ. Tolerates a wide range of conditions, can smother native ground cover species and form almost pure stands. Has a "developing reputation" as an invasive species. Regarded in NSW as contributing to the key threatening process of "invasion of native plant communities by exotic perennial grasses" (NA08). Regarded as a potentially serious invader in Victoria (CYR92, CYSM in prep.).
Distichlis	*Distichlis spicata*	Native to North and South America. A weed overseas (R07), but only available in Australia as NyPa ForageTM, which is sterile & reproduces vegetatively. There is concern that it could hybridise with an Australian Distichlis (*D. distichophylla*) to produce a weedy cross (BS).
Tall Fescue	*Festuca arundinacea*	Native to Europe, temperate Asia, and North Africa. Widely naturalised in temperate regions; environmental weed in NSW & Victoria. A high-threat invasive weed in Plains Swampy Woodland in the Glenelg Plain and Wimmera bioregions (NA08). A seriously invasive species in Victoria (CYR92, CYSM in prep.). One of the 20 worst weeds of Victorian saltmarsh (VSSG09).
Italian Ryegrass	*Lolium multiflorum*	Native to southern Europe, south west Asia and northern Africa. Widely naturalised; a crop weed & environmental weed (R07, NA08). In Vic a potential threat to plains riparian shrubby woodlands in the Wimmera bioregion and floodplain riparian wood-lands in Northern Inland Slopes bioregion. Invading conservation areas. Hybridises with other ryegrasses (NA08). Regarded as a potentially serious invader in Victoria (CYR92, CYSM in prep.).
Perennial Ryegrass	*Lolium perenne*	Native to Europe, temperate Asia and northern Africa. Widely naturalised; a crop weed; environmental weed in NSW, Vic, WA (R07, NA08). Regarded as a high-threat species in floodplain riparian woodlands in Highlands-Northern Fall bioregion; also a weed in natural alpine vegetation in north-eastern Victoria & native grassland communities in the south-west of the state. Has invaded saltmarsh communities at Lake Beeac (NA08). A very seriously invasive species in Victoria (CYR92, CYSM in prep.).
Annual Ryegrass	*Lolium rigidum*	Native to the Mediterranean region. Widely naturalised; a crop weed; environmental weed in Vic & WA (R07, NA08). A very serious invasive species in Victoria (CYR92, CYSM in prep.).
Burr Medic	*Medicago polymorpha*	Native to the Mediterranean region. Widely naturalised; environmental weed in Vic, NSW, WA (R07, NA08). A seriously invasive species in Victoria (CYR92, CYSM in prep.).

TABLE 3.1 Weed status of plants promoted for planting on saltlands[199]

Species promoted		Environmental weed status or risk (references in footnote 199)
Lucerne	*Medicago sativa*	Native to Europe and Asia. Escapes from cultivation (R07), widely naturalised. A troublesome weed in orchards in the Murray-Darling Basin (LC76).
Barrel Medic	*Medicago truncatula*	Native to the Mediterranean region. Widely naturalised (RRS06). Environmental weed (R07).
Saltwater Couch	*Paspalum vaginatum*	Native to tropical North and South America. Contention about whether it is native in some parts of Australia. Widely naturalised in Victoria (W94). Environmental weed (R07). One of the 20 worst weeds of Victorian saltmarsh (VSSG09, CYR92, CYSM in prep.).
Kikuyu	*Pennisetum clandestinum*	Native to tropical Eastern Africa. Widely naturalised; environmental weed in Vic, SA, WA, NSW, Qld (R07, NA08). The CRC risk assessment rated it a high risk for WA, SA, NSW & a medium risk for Vic. Invades coastal woodlands, dunes, grasslands, grassy woodlands, riparian areas, moist forests. Forms dense mats (M01). Listed as one of the grasses constituting a key threatening process in NSW. A very serious invasive species in Victoria (CYR92, CYSM in prep.).
Phalaris	*Phalaris aquatica*	Native to southern Europe. Widely naturalised; environmental weed in Vic, NSW, SA (R07, NA08). Invades pastures, grasslands, open woodlands, roadsides, waste areas, disturbed sites, creek banks, riparian vegetation, floodplains and wetlands. Forms dense stands, smothers ground plants, prevents regeneration of others. Increases fire risk. (CYR92, B01, M01, NA08, CYSM in prep.) Listed as one of the grasses that constitute a key threatening process in NSW. One of the 20 worst weeds of Victorian saltmarsh (VSSG09).
Puccinellia	*Puccinellia ciliata*	Native to Turkey. Naturalised in all southern states. Environmental weed (R07). Becoming an abundant weed in Vic and seriously invasive (CYSM in prep.).Found in salinised remnant woodlands, a threat to wetlands (BT03, VM03).
Marine Couch	*Sporobolus virginicus*	Native in all Australian state, and all warm-temperate and tropical countries.
Tall Wheat Grass	*Lophopyrun ponticum*	Native to southern and south-eastern Europe. Very serious environmental weed in Victoria & elsewhere, see previous chapter.
Strawberry Clover	*Trifolium fragiferum*	Native to Europe, the Middle East and western Asia. Widely naturalised (NA08). Environmental weed (R07). Seriously invasive in Victoria (CYR92, CYSM in prep.).
Gland Clover	*Trifolium glanduliferum*	Native to the Mediterranean region. Recently introduced to Australia.
Balansa Clover	*Trifolium michelianum*	Native to the Mediterranean region. Naturalised in Victoria (J96) and and a potentially serious invader (CYSM in prep.).
Persian Clover	*Trifolium resupinatum*	Native to Europe, the Middle East, western Asia and southern Africa. Widely naturalised. Environmental weed (R07). A weed in Victorian wetlands (GC) and potentially seriously invasive (CYSM in prep.).
Woolly Clover	*Trifolium tomentosum*	Native to Europe, the Middle East and northern Africa. Widely naturalised. Environmental weed in WA & Vic (R07, NA08). Potentially seriously invasive in Victoria (CYSM in prep.).

as salinity and drought.[200] McMahon and colleagues in their 1994 assessment of the risks of large-scale conversion to perennial pastures noted that Phalaris is "only limited in its invasive potential by drought stress..., and soil acidity and related elemental toxicities. The development of new cultivars to improve these tolerances would undoubtedly increase its invasive potential..."[201]

The attributes sought for new cultivars are typically those that increase a plant's competitiveness and range as a weed. For example, two recently developed cultivars of Tall Fescue – 'Fraydo' and 'ResoluteMaxP' – have been bred for "cool season vigour" and "persistence ... under stress" respectively.[202] Species likely to be targeted for 'improvement' include the environmental weeds Phalaris, Cocksfoot, Tall Fescue, Perennial Ryegrass, Tall Wheat Grass and Puccinellia.[203] New cultivars of Cocksfoot and Tall Fescue are being bred for lower rainfall areas (400-700mm), with tolerance to drought and persistence in acid and/or low fertility soils, and suitable for sowing across up to 20 million hectares.[204] This could greatly extend the area of weed spread and their competitiveness.

It has been suggested that breeding could also be used to reduce the weed potential in pasture grasses. Nichols and colleagues suggest that increasing the palatability of Tall Wheat Grass would "help allay weed risk concerns about the species."[205] Increasing palatability may reduce the risk to some degree because it will promote grazing and thereby reduce the potential for seed set, but it is far from being a 'solution', as it does not address many of the circumstances (eg. changes in farm management, creeping beyond a fence) under which spread occurs. Invasive pasture weeds include many palatable species.

The development of sterile cultivars of pasture plants could reduce weed risk.[206] The company NyPa has released a sterile cultivar of the pasture grass *Distichlis spicata* (a weed elsewhere),[207] which apparently has relatively low weed risk (although vegetatively spreading grasses can still be highly invasive, e.g. infertile infestations of *Pennisetum clandestinum*). However, there are concerns that it could hybridise with a native Distichlis (*D. distichophylla*) and thereby regain fertility and become invasive.[208] Infertile pasture plants require more labour-intensive sowing for establishment, which combined with their lack of reproductive potential limits their attractiveness for breeders and graziers. Breeding for low weed risk can be contrary to the goals of breeding for high pasture profitability and has yet to receive much research attention.

There are generally no impediments to the release of new cultivars of already permitted plant species. Weed risk assessments are mostly focused at the species level (although variants are sometimes assessed under the federal protocol). There is no intention by the Future Farm Industries CRC to assess different cultivars for weed risk. The assessment for Western Wreath Wattle (*Acacia saligna*) notes that its weed risk "may increase if traits such as increased pest and disease resistance, or tolerance to adverse environmental conditions, are selected for as part of the species domestication program."[209] But the issue was considered beyond the scope of the assessment and to be addressed as part of the domestication process (presumably with management guidelines).

Associated microorganisms: The productivity and invasiveness of pasture plants can be influenced by mutualistic microorganisms, such as mycorrhizae (soil fungi that form a symbiotic relationship with plant roots) and endophytes such as rhizobia (nitrogen-fixing bacteria). The latter are fungi or bacteria that occur inside plant tissues without causing disease symptoms.[210] Some increase the capacity of plants to withstand certain stresses or produce toxins that protect plants from herbivory. Part of plant breeding efforts has been to infect cultivated species with favourable endophytes. For example, the introduction of novel endophytes to two Tall Fescue cultivars has extended their cultivation range.[211] There are obvious invasive risks associated with mutualistic microorganisms, with the potential for plants to become more invasive or extend their invasive range if they acquire beneficial endophytes or for exotic endophytes to infect and change the fitness of native plants.[212] A leaf endophyte may have increased the invasive success of Tall Fescue in North America by "inducing higher vigour, toxicity to herbivores and drought resistance than in uninfected native grasses."[213] Research is currently underway to increase nitrogen-fixing capacity in Mediterranean Melilot (*Melilotus siculus*), a weedy annual legume being developed for saline pasture in Australia.[214] Enhanced nitrogen fixing may increase the invasiveness of a plant species or elevate soil nitrogen, thus indirectly promoting other weeds (e.g. annual grasses of upper saltmarsh).

There is very little information about these risks, and we do no more than flag them here as another potential problem that should be addressed by pasture agronomists working on annual or perennial pastures.

Development of new potentially invasive pasture species

Agronomists have been searching for new plants in Australia and overseas for both discharge and recharge sites, and reviewing samples held in Genetic Resource Centres (GRCs).[215] Since 2002 there have been at least 18 national and international seed-collecting missions undertaken by researchers coordinated through the Salinity CRC.[216] Hughes and colleagues reported in 2008 on the vast scale of experimentation:

> *In total, 671 species and 21 non-species-specific genera were identified as having potential to increase water use profitability of recharge lands and to improve the productivity of saline lands across a diverse range of agricultural environments in southern Australia. Through a series of activities, 201 of these species, representing legumes, herbs and grasses were identified as promising. These were then disseminated for evaluation in a range of environments across southern Australia. The progress of selected species was monitored and germplasm of the most promising 11 species and three leguminous genera was targeted for intensive acquisition and characterisation as the basis for selection and breeding. In addition to the identification and dissemination of promising species of immediate potential, a comprehensive collection of 544 native and exotic, wild and cultivated pasture species was conserved and is now available to service future plant improvement programs.* [217]

Recent reviews have nominated promising species for further investigation. From the 671 species and 21 genera collected, Hughes and colleagues' 2008 review nominated 120 "top 20 priority" legume, grass, non-leguminous herb and shrub species for recharge and discharge areas.[218] Rogers and colleagues' 2005 review identified 109 high priority grasses, legumes, herbs and shrubs with

200 Masters et al. (2007) note that forage plants used for biosaline agriculture have had very little selection for improved feeding value.
201 McMahon et al. (1994). The same is true of other pasture species. Cocksfoot was 'moderately to highly invasive' on lower slopes and drainable swales in areas in Victoria with an average rainfall above 500mm. Increasing its fitness for lower rainfall areas would considerably extend its potential invasive range.
202 Reed et al. (2008).
203 Reed et al. (2008) recommend a "nationally coordinated program of genetic improvement" of Phalaris, Cocksfoot, Tall Fescue and Perennial Ryegrass (the main perennial grasses sown in southern Australia) "co-ordinated with research on the management of perennial pasture species for long-term persistence under climatic stress". Bennett et al. (2002) suggest that Mediterranean varieties can be used to develop cultivars of Tall Fescue and Cocksfoot "able to combine summer survival under stress with some ability to respond to summer moisture", which will broaden their area of adaptation to medium to low rainfall areas. There are dozens of accessions from low rainfall parts of the Mediterranean basin in germplasm centres already in Australia. They also recommended breeding Tall Wheat Grass and Puccinellia for lower rainfall areas, either by selecting from within existing populations or by incorporating new germplasm from their centres of origin. In its Improved Perennial Grasses project the FFI CRC intends to "expand on the work done by CRC Salinity and CSIRO in creating new cultivars of Cocksfoot, Tall Fescue and Phalaris that are tolerant of high acidity and aluminium levels, and low rainfall."
204 Crosbie (2007).
205 Nichols et al. (2008).
206 Sterility has been proposed, for example, to reduce the weed risk of Leucaena (Leucaena leucocephala), a pasture legume promoted in Queensland for salinity and drought mitigation. It is best for non-rhizomatous, non-stoloniferous species.
207 Global Compendium of Weeds Distichlis spicata (Poaceae) at <http://www.hear.org/gcw/species/distichlis_spicata/>
208 B. Semple (pers. comm.).
209 See Environmental Weed Risk Assessment: Acacia saligna at www.futurefarmcrc.com.au/weed_risks.html. This assessment also notes the potential for genetic contamination: "Problems may also arise if genetically differentiated provenances are moved around the landscape in the south-west." As a reviewer of this present report noted, "'this could be a problem if at some stage it becomes a problem' statement is not good enough for science based decision making and precautionary approaches."
210 White and Backhouse (2007); Rodriguez et al. (2005).
211 Burnett (2008).
212 Desprez-Loustau et al. (2007); Richardson et al. (2006).
213 Desprez-Loustau et al. (2007), citing others.
214 Charman et al. (2006). Melilotus siculus has naturalised in Victoria, South Australia, Western Australia and New South Wales (Jeanes 1996). It is currently of limited distribution in Victoria, but a potentially serious invader of upper saltmarsh (G. Carr, pers. obs.).
215 Hughes et al. (2008); Rogers et al. (2005).
216 Hughes et al. (2008). The countries collected from included Kazakhstan, Macaronesian Islands, Turkmenistan, and Azerbaijan.
217 Hughes et al. (2008).
218 Hughes et al. (2008).

TABLE 3.5 Summary of information about priority pasture plants for recharge and discharge areas identified in three recent reviews

	Grasses # species (% total species)	Legumes # species (% total species)	Herbs & shrubs # species (% total species)	Total
Native	13 (20%)	9 (12%)	19 (37%)	41 (22%)
Prohibited weed[a]	5 (8%)	2 (3%)	1 (2%)	8 (4%, 5% of exotic species)
Permitted[b]	36 (55%)	48 (65%)	10 (19%)	94 (49%, 63% of exotic species)
Not listed[c]	11 (17%)	15 (20%)	21 (41%)	47 (25%, 32% of exotic species)
Weed in Australia	23 (35%)	25 (34%)	8 (16%)	56 (29%)
Weed elsewhere	43 (66%)	46 (62%)	19 (37%)	108 (57%)
Total	65 (34%)	74 (39%)	51 (27%)	190

[a]Prohibited = Not permitted entry into Australia, as described in the ICON database[222]
[b]Permitted = Permitted entry into Australia, as described in the ICON database
[c]Not listed = Not listed as either permitted or prohibited and therefore requiring further evaluation, as described in the ICON database

salt tolerance.[219] Masters and colleagues' 2007 review identified 50 "plant options for livestock in biosaline agriculture" of moderate or high salt tolerance.[220] The identified priority plants, totalling 190 species[221] (genera are disregarded), are listed in Tables 3.2-3.4 in Appendix 3 along with information about their known weed status in Australia or overseas. In Table 3.5 information about these nominated priority pasture species is summarised.

A substantial proportion of the plants identified as pasture priorities already exhibit weedy behaviour: almost one-third are weedy in Australia and more than one-half are weedy overseas. In particular, a high proportion of the grasses and legumes are known weeds: two-thirds of listed grasses and legumes are known weeds in Australia and/or overseas. (The lists include native species, so an even higher proportion of the exotic species are weeds, although three of the native species also behave as weeds in parts of Australia where they are not indigenous.) There are also likely to be potential weeds among these species as many have not been grown widely enough to demonstrate any weed tendencies. Some will be much more serious weeds than others; some are likely to be of only minor environmental consequence.

The weed risks receive only limited focus in the three reviews. Rogers and colleagues acknowledge there are potential weed issues and recommend Weed Risk Assessments. A very few species in their comprehensive list of plants with salt tolerance are identified as having low palatability and high weed potential. Masters and colleagues note there is weed potential with four of 50 listed species or genera, but fail to acknowledge the weediness of others such as Tall Wheat Grass, Puccinellia and Rhodes Grass. They include a general note that species should only be considered for use where they have passed a Weed Risk Assessment. Hughes and colleagues discuss the Weed Risk Assessment process but do not identify the weed risk of prioritised species. The attitude that emerges is that weed risk may be an impediment to the use of a few desirable pasture species but does not affect the overall program.

About one-fifth of the priority plants listed in

Appendix 3 are native, although the reviewers do not distinguish between native and exotic species in their priority lists. The exotic species are subject to federal quarantine regulations, but close to two-thirds can be freely imported because they have previously been allowed into the country, and more than two-thirds of these are known weeds in Australia or overseas. Only 5% of the exotic species listed are prohibited from import. The other one-third of exotic species would need to go through a Weed Risk Assessment or be subject to further evaluation.

Weed risks of abandoned trial sites

Even before plants are released and promoted to graziers, there are invasion risks associated with the perennials program. Agronomists have often neglected the weed risks associated with field trials of pasture plants, leaving plants to spread after experiments conclude.

In Queensland, for example, the Managing Old (discontinued) Plant Evaluation Sites project, a program to remove weeds from trial sites, assessed more than 100 former sites, and targeted four legumes for eradication over a large number of them (although eradication was not regarded as feasible at some sites), but left numerous other species uncontrolled.[223] In southern Australia, Emms and Virtue in 2003-04 found that 52 legume species had persisted in experimental sites planted in 1997 and 1998.[224] And in Western Australia, a CRC Salinity project involved visiting 270 former experimental sites planted with grasses, legumes and shrubs collected from Israel, Tunisia, Turkey and the USA in 1966-67.[225] That investigation seems to have been treated as an agronomic project rather than a weed project and there was no mention of cleaning up these old sites: "The visits to old sites have shown that stands of forage shrubs ... are still healthy after periods of up to 41 years." The Australian Weeds Committee recognised abandoned research sites as high-risk weed sources and recommended that states develop a monitoring and eradication program, although information about many sites has probably been lost.

We expect that there are now better experimental protocols in place, as the Future Farm Industries CRC has a policy that requires experimenters to eradicate plants from research sites after studies are completed.[226] But we cannot be certain unless monitoring programs are in place. Recent papers published by salinity agronomists do not mention in their methods that they have eradicated experimental plants. To do so often requires considerable effort over a number of years after a project has ended. One former researcher says he had returned annually for four years to an evaluation site to control a former planting, and his experience was that most researchers do not carry out this follow-up control work after project funding has ceased.[227] Semple and colleagues reported on

219 Rogers et al. (2005).
220 Masters et al. (2007).
221 Where entire genera were nominated they were disregarded, for the focus of weed risk assessment and quarantine is species.
222 ICON is AQIS's import conditions database. See <http://www.aqis.gov.au/icon32/asp/homecontent.asp>. "It can be used to determine if a commodity intended for import to Australia needs a quarantine permit and/or treatment or if there are any other quarantine prerequisites."
223 Bishop (2003).
224 Stone et al. (2008a), citing Emms & Virtue (2005).
225 Craig et al. (2003).
226 L. Stone (pers. comm.).
227 B. Semple (pers. comm..).

one project where regular control visits were required 13 years after the trial was sown.[228] Legume seeds in particular can remain viable for many years, or decades.

As Stone and colleagues note, ongoing monitoring to ensure eradication for some species "has significant time and financial implications", and the responsibility needs to be factored into research project costs.[229] There should also be national standards in place for research involving potentially invasive plants to require eradication and monitoring of research sites, and preventing spread of species from old research sites should be a high priority.[230]

When even professional researchers have not consistently taken responsiblity for weed spread, how can it realistically be expected of farmers?

3.3 Other environmental risks

There are strong grounds for concern about environmental impacts other than weed invasion. For example, in a Victorian Government-commissioned report in 1994, ecologists McMahon and colleagues warned that large-scale conversion to perennial pastures was likely to also degrade native grasslands and woodlands, cause wetland contraction, and contribute to rural tree decline. There was very little information available about these potential impacts, the authors recommending baseline surveys, research and monitoring programs to provide the basis for better decision-making about the salinity program. Because these recommendations were ignored, we remain in a state of similar ignorance 15 years later.

Loss/degradation of remnant vegetation

Natural saltlands are rare in the landscape and have extremely high conservation value. They support a range of rare and restricted plant and animal species but are botanically and zoologically very poorly documented. They are also likely to contain undescribed plant species, for example three grass species (narrow endemics of saline environments) have recently been described from primary brackish or saline sites on the Victorian Volcanic Plain and eastern Victoria – *Poa orba*, *P. sallacustris* and *P. physoclina*.[231] One of the major unacknowledged problems of the salinity program is the potential loss of biodiversity values of primary salinity sites due to pasture species being planted. Although the Victorian Government has developed plant-based criteria to distinguish between primary and secondary sites, it often requires expert botanical/geomorphological knowledge to do so. However, the distinction between primary and secondary salinity sites, as determined by any botanical criteria, is often far from clear. Many of the indigenous salt-tolerant plant species which are allegedly indicative of primary saline sites[232] have very effective dispersal mechanisms and do not necessarily indicate a salt-tolerant flora. Furthermore, many saline sites represent a combination of primary and secondary salinity (that is, they are secondarily expanded primary salinity sites). Primary and secondary sites may also be adjoining, so treatment of a secondary site can threaten a nearby primary saline site. Because these saltlands have not been comprehensively mapped across southern Australia, there is no way of monitoring how many have been lost or degraded by attempts to establish pasture through cultivation and sowing.

Many native grasslands have been lost when they have been sown to 'improved pasture' in southern Australia. It now requires a permit in Victoria to sow pasture within remnant vegetation. A guide to the use of native pastures (published by the Future Farm Industries CRC) notes that one-quarter of the landholders of 24 properties surveyed (in NSW and Victoria) indicated that they intended to replace native pastures with sown pastures over the next 10 years.[233]

Planting of perennial pastures often requires increased fertiliser, particularly during establishment.[234] Unless fertiliser use is judicious and pastures are well-managed, it can cause soil acidification.[235] Nutrient run-off compromises water quality and degrades native vegetation remnants. Elevated nitrogen levels increase the susceptibility of trees to insect damage, with insects responding to extra leaf nitrogen by increasing in fecundity, size and abundance.[236] This can contribute to eucalypt dieback. Fertiliser use substantially reduces the capacity for many native species, adapted to grow in low-nutrient soils, to persist in pastures.[237]

Introduced pasture plants can greatly increase fire hazard. Stoner and colleagues found that sites invaded by Phalaris had about three times the fine fuel loads of dense Kangaroo Grass (*Themeda triandra*) grasslands.[238] They concluded that the effect of Phalaris on fire behavior was "more likely to cause irreversible damage to some native plant communities", as well as to make prescription burning more hazardous and fire suppression more difficult.

Hydrological impacts

Perennial pastures reduce the salinity hazard by using more water than annual pastures, thereby lowering the water table.[239] But large-scale conversion of annual systems to perennial pastures could affect water security and environmental flows in some water-stressed catchments, and alter drainage to wetlands.[240] Acknowledging the lack of information, Walker and colleagues in a recent assessment of the hydrological risks of tree planting in the Murray-Darling Basin note a need to develop frameworks by which to understand the impacts of perennial pastures.[241] The hydrological effects of perennial pastures in high rainfall areas is much less than that for trees. A Victorian assessment found that the water yield loss for each additional 10% of a sub-catchment covered by woody vegetation is 20mm/year compared to 3mm/year for perennial pasture.[242] However, Walker and colleagues warn there may be hydrological risks in lower rainfall areas:

> *Non-tree land-uses such as pasture or cropping systems will use much less water than trees in higher rainfall zones, whereas for the lower rainfall zones, some perennial systems may use approximately the same amount of water as trees. There is some evidence that in these areas changing from annual pastures to perennial pastures can reduce catchment water yield and groundwater recharge. Compared to tree plantations, pastures occupy a large proportion of the catchment area and hence a small change in pasture water use could have significant impact on overall catchment water balance and recharge.*

Modelling studies of two NSW catchments, the Boorowa River and the Mandagery Creek catchments, found that large-scale plantings of perennial pastures would not substantially reduce salinity levels and improve water quality.[243] In the Mandagery Creek catchment, replacing annual pastures and 30% of cropping with perennial pastures would reduce the current mean annual stream salinity

228 Semple et al. (2004) note that "[s]pread of introduced material can be rapid on a saline site where few adapted competitors are present."
229 Stone et al. (2008a).
230 Also advocated by Cook and Dias (2006).
231 Walsh (2008); Weiller et al. (2005); Walsh (1991).
232 Allen (2007).
233 Dorrough et al. (2008).
234 Bennett and Price (2007); Liddicoat and McFarlane (2007); Wait (2007); McMahon et al. (1994).
235 Commissioner for Environmental Sustainability (2008). The cost of soil acidification to Victoria is an estimated $470 million per year (compared to $50 million for salinity). "Accelerated acidification is strongly associated with the addition of nitrogen (as fertiliser or symbiotically fixed nitrogen) to soil to support agricultural land uses."
236 Landsberg (1990); Landsberg et al. (1990).
237 Dorrough et al. (2008); Groves & Whalley (2002). According to Dorrough et al. orchids, lilies and shrubs "are quickly lost from grasslands when even low levels of fertiliser are applied.... Pastures with high levels of soil phosphorus support few, mostly exotic annual, species."
238 Simmons et al. (2006); Stoner et al. (2004).
239 Ridley and Pannell (2005).
240 McMahon et al. (1994) warned that large-scale conversion could alter drainage into wetlands, causing contraction and facilitating expansion of weeds (Phalaris in particular) into wetland areas no longer subject to prolonged flooding.
241 Walker et al. (2008).
242 WatLUC (2005).
243 Tuteja et al. (2003); Vaze et al. (2004).

TABLE 3.6 Weeds declared noxious in Victoria[249]

	State prohibited weeds	Regionally prohibited / controlled weeds[a]	Regionally restricted weeds[a]	Total declared noxious[b]
Declared noxious weeds	24	70	79	108
Pasture species from Appendix 3	0	1 *(Eragrostis curvula)*	1 *(Eragrostis curvula)*	1

a There is considerable overlap between these categories as plants prohibited or controlled in one or more regions are restricted in the other regions. The implications of each of these noxious weed categories is explained in Appendix 2.

b These species are mostly declared noxious under the *Catchment and Land Protection Act 1994*. Three are aquatic species declared under the Fisheries Act 1995.

assessed at the Eugowra gauging station by about 2%, whereas 30% tree cover would reduce it by 25%. Any benefits of perennial pastures may be restricted to certain areas, such as high salt-exporting sub-catchments. The potential to exacerbate water stress[244] will become a more serious issue where climate change reduces rainfall. In Victoria, predicted worst-case climate change impacts for 2030 are stream flow reductions for the east of the state of 20% and for the west of 40%.[245]

3.4 Weed risk assessment

Federal government

The federal government controls the importation of plants into Australia under quarantine regulations. Three categories of exotic plant species are recognised: those permitted for importation, those prohibited because they have been assessed as posing an unacceptable weed risk, and those requiring evaluation before being either permitted or prohibited. The evaluation initially consists of a weed risk assessment, which may result in the plant being permitted, prohibited or requiring further evaluation in the form of cost-benefit analysis.

The collection program of the Salinity CRC and Genetic Resource Centres referred to in Section 3.2 and described by Hughes and colleagues, resulted in the importation of a total of 4347 accessions (samples) of 515 exotic species over five years.[246] Those species not already on the permitted list were held in quarantine until assessments were conducted. Of 472 exotic species initially processed under quarantine regulations:

- 49% (231) were on the permitted list
- 12% (59) were prohibited species
- 18% (87) required further evaluation (after a prior weed risk assessment resulted in a score intermediate between 'permitted' and 'prohibited')
- 20% (95) required a weed risk assessment

Of those then subject to a risk assessment, 60% (72 species) were prohibited,[247] 7% were accepted and 33% required further evaluation. Most of the prohibited species were grasses.

In total, about three-quarters of the species collected (369, 72%) were permitted entry into Australia. However, this does not mean that three-quarters of the plants were assessed as low weed risk. The majority of those allowed in were already on the permitted list for historical reasons, because they had been imported into Australia prior to implementation of weed risk assessment in 1997. There are numerous plants on Australia's permitted list that are invasive and very serious weeds, for example Sow Thistles (*Sonchus* spp.) and Cobblers Pegs (*Bidens pilosa*).

Despite the large proportion of plant species permitted entry, the researchers were not entirely satisfied with the quarantine processes. Hughes and colleagues described the outcomes of weed risk assessments as "very conservative". While they expressed support for “the concept of minimising the risk of a new species becoming an environmental weed” they expressed concern “that the current WRA system is too risk-averse, discriminating against pasture species, especially those that possess good survival and persistence” and that it “does not consider the potential economic benefit in assessing the risk.”

Victorian Government

Although the Victorian Government has the capacity to ban or restrict the use of invasive pasture species, it tends not to regulate commercially valued plants no matter how invasive or harmful they are. Of the 13 known environmental weeds listed in Table 3.1 as pasture species for saltlands, none is declared a noxious weed in Victoria. Of the 190 plants listed in Appendix 3 as priority or potential species for salinity mitigation, of which 56 are already weedy in Australia and 108 are weedy overseas (Table 3.5), only one is declared noxious in Victoria (see Table 3.6). African Lovegrass (*Eragrostis curvula*) is listed as “prohibited” in some regions and “controlled” in others.

The Victorian Government has been reviewing and updating its declared weed list and implementing protocols for weed risk assessment. However, risk assessment was limited to species identified in Regional Weed Action Plans, the National Environmental Alert List and nominated by the Catchment

Phalaris (*Phalaris aquatica*) in coastal scrub near Mt Eliza, Victoria. Photo: Geoff Carr

Management Authorities.[248] The public could only nominate species for assessment through the Catchment Management Authorities, which were limited to nominating 10 weeds per region. Although plants such as Phalaris and Tall Wheat Grass are severe environmental threats they were not nominated. The government typically does not assess the

244 Crosbie et al. (2007).
245 Van Dijk et al. (2006).
246 Hughes et al. (2008).
247 Another 34 species were subsequently prohibited in 2007 as a result of AQIS amending the permitted list to close the loophole of entire genera being permitted entry.
248 See <http://www.dpi.vic.gov.au/DPI/Vro/vrosite.nsf/pages/weeds_vic_nox_review> for a description of the review process by the Victorian DPI.
249 See http://www.dpi.vic.gov.au/dpi/vro/vrosite.nsf/pages/weeds_listing_a (checked 20 November 2009).

weed risk of newly released pasture species/ cultivars.

The 1998 Victorian weed inquiry found there was an agricultural bias in weed declarations: that "the overwhelming majority of noxious weeds are of agricultural importance and that few are of primary or sole significance to natural ecosystems."[250] One of the reasons for this is that the department carrying out weed risk assessments – the Department of Primary Industries – is the same department releasing and promoting invasive pasture species for the benefit of graziers.

Catchment Management Authorities have similar conflicts of interest because of the major (legislated) involvement of primary producers, including graziers, in their management and activities.

Future Farm Industries CRC

In contrast to the Victorian Government's failure to assess the weed risk of pasture plants, the CRC researchers developing new cultivars and species for pasture in southern Australia have ostensibly taken some responsibility for weed risk. After being criticised for their neglect of weed issues, the Dryland Salinity CRC adopted a policy in 2006 that germplasm could not be promoted without prior weed risk assessment.[251] The Future Farm Industries CRC has adopted a similar policy and implemented an Environmental Weed Risk Assessment Protocol.[252]

TABLE 3.7 Weed risk scores, categories and management actions[254]

Frequency band of final score %	Designated weed risk	Proposed management action
80-100	Very high	Do not commercially release or promote species.
60-80	High	*Further analysis of risk, feasibility of control and potential benefits. Management plan required.*
40-60	Medium	*Management plan required.*
20-40	Low	*Identify vegetation at risk in agronomic information. No further assessment required.*
0-20	Negligible	*No further assessment required.*

The aim of the assessment is "to identify the level of weed risk that species under evaluation within the CRC pose to the natural environment." It consists of questions that are intended to assess potential weed risks in three categories – the likely invasiveness, impacts and distribution of a species. Species subject to assessment are those permitted entry to Australia but not assessed for weed risk by Biosecurity Australia.[253] The scores for each category of risk are multiplied to arrive at a final risk score. Table 3.7 shows the possible outcomes of this assessment.

An effective weed risk assessment protocol needs to be (a) precautionary – because information on which to base assessments is often limited and the costs of wrong decisions resulting in new weed problems can be very high, (b) undertaken by independent experts with the best available information, (c) applied comprehensively, and (d) linked with management responses appropriate to the level of weed risk. The CRC's protocol fails to meet some of these conditions. In particular, as Table 3.7 shows, the protocol specifies that only species returning a 'very high' risk score are required to be rejected.

Level of precaution: The CRC's weed risk assessment lacks some important elements of precaution. Prior history of weediness is one of the most reliable indicators of weed risk,[255] but in the CRC's assessment a species' history as a weed in Australia or overseas contributes less than 3% to the total weed risk score.[256] This dilutes the effect of that reliable predictor of weediness. Another non-precautionary element is that if the answer to a question is 'don't know', it receives a score of only 1 out of a possible 3, rating the unknown risk low.

Comprehensiveness: Although different cultivars of pasture species may have different propensities for invasion, the CRC's weed risk assessment is not used to "assess subtle differences between cultivars and species."[257] Rather, the CRC intends that "such differences are …dealt with in management plans where required."

Management responses to weed risk: The proposed responses to risk assessments are the major failing of the CRC's protocol. Only species assessed as 'very high' weed risk are rejected. Species designated 'high' risk are subject to further evaluation, and both 'high' and 'medium' risk species can be released and promoted with management guidelines.[258] The further evaluation, originally intended to be a formal cost-benefit analysis, will consist of an informal cost-benefit analysis conducted by the researcher. The CRC has confirmed that release/promotion of medium and high risk species with management guidelines is the most likely outcome.[259] The obvious conflict of interest the CRC has – funded to develop new pasture cultivars and species – means that it should not be relied upon to make responsible decisions about which plants to develop and promote.

Cost-benefit analysis: Problems with the proposed informal cost-benefit analysis conducted by the researcher include the following:

> *First, the benefits of new plants are often overstated by those who stand to profit from them, or by those who have invested a career in studying them. Second, weed costs are impossible to predict or calculate in advance. And when environmental harm is involved there is no acceptable way of measuring it. After a plant becomes a weed it is likely to remain in the landscape forever, and any cost-benefit analysis conducted today may lack meaning in a thousand years time. The economic approach can also lead to unfair outcomes because the benefits and costs of a plant usually flow to different sectors, and there is no accepted way to make those who benefit from a plant pay those who bear the costs.*[260]

Enthusiasm for a cost-benefit approach should be tempered by a broader and long-term evaluation of the costs of weeds (they are usually with us forevermore) and the *actual* benefits of already introduced plants.[261] A recent analysis of agricultural introductions to New Zealand found that most introductions contributed little to the economy and that 'important species' (those that covered more than 1% of cultivated area) had effective life spans of only about 10 years.[262] Relevant to Australia, as discussed, are the hundreds of grasses and legumes introduced to northern Australia, of which only 5% increased pasture productivity, while more than 60% of the

250 Environment and Natural Resources Committee (1998), citing McKenzie.
251 Stone et al. (2008a).
252 Stone (2008).
253 Stone (2008).
254 Stone et al. (2008a)
255 Hayes and Barry (2008) summarised the results of 49 studies testing the significance of 115 characteristics in seven biological groups in predicting invasion success. They found that "climate/habitat match, history of invasive success and number of arriving/released individuals are consistently associated with successful transition from introduction to establishment."
256 A species' history as a weed in Australia or overseas contributes 11% or 7% respectively to the total score for 'invasiveness'. The invasiveness score is multiplied by the scores for 'impacts' and 'distribution', so weed history contributes less than 3% to the overall score.
257 Stone et al. (2008a).
258 This contradicts the publicised intent of the weed risk assessment protocol (the earlier version developed by the Dryland Salinity CRC) to reject any species that showed "high" environmental weed risk, as stated by Stone (2006).The publicity about the weed risk assessment has been misleading by not making clear that only 'very high' risk species are rejected. The Farm Future Industries CRC's (2007) media release announcing the protocol said that "researchers when looking for new pasture plants can determine their weed potential fairly quickly and move on to other lower-risk species." The media release also says "Other species with significant weed potential will not be introduced to new areas." But the CRC has no way of preventing the introduction of weedy pasture species to new areas unless a government bans it. Griffiths (2007) says "if a plant has significant potential as a forage species but also some minor weed potential, then we can start looking at how it could be managed."
259 L. Stone (pers. comm.).
260 Low (2005).
261 Panetta et al. (2001).
262 Panetta et al. (2001), citing Halloy (1999).

TABLE 3.8 Outcome of CRC weed risk assessments[269]

Species	WA	SA	Vic	NSW	Weed status[270#]
Acacia saligna Western Wreath Wattle	**medium**	**high**	**high**	**high**	Native to southwest WA; **Environmental weed in Australia**.
Atriplex nummularia Old Man Saltbush	low	low	negligible	low	Native to arid & semi-arid parts of the mainland; environmental weed overseas; naturalised from ornamental plantings in Victoria.
Austrodanthonia caespitosa Common Wallaby-grass	low	low	negligible	low	Native to southern Australia.
Cichorium intybus Chicory	negligible	negligible	negligible	negligible	**Environmental weed in Australia**; invasive overseas.
Dactylis glomerata Cocksfoot	**high**	**medium**	**medium**	**medium**	**Environmental weed in Australia**; invasive overseas.
Ehrharta calycina Perennial Veldt Grass	**very high**	**very high**	**high**	**high**	**Environmental weed in Australia**; invasive overseas.
Eucalyptus occidentalis Flat-topped Yate	negligible	negligible	negligible	negligible	Native to southwest WA; naturalised in eastern Australia.
Eucalyptus rudis Flooded Gum	low	low	negligible	negligible	Native to WA; naturalised overseas.
Festuca arundinacea (syn. *Lolium arundinaceum* Tall Fescue	**medium**	**medium**	low	**medium**	**Environmental weed in Australia**; invasive overseas.
Lotus corniculatus Birdsfoot Trefoil	negligible	negligible	low	low	**Environmental weed in Australia**; invasive overseas.
Megathyrsus maximus Panic Grass	**medium**	low	low	**medium**	**Environmental weed in Australia**.
Melilotus siculus Mediterranean Melilot	negligible	negligible	negligible	negligible	**Environmental weed in Australia**.
Pennisetum clandestinum Kikuyu	**high**	**high**	**medium**	**high**	**Environmental weed in Australia**.
Phalaris aquatica Phalaris	**medium**	low	**medium**	**high**	**Environmental weed in Australia**.
Rhagodia preissii Mallee Saltbush	**medium**	low	low	low	Native to southwestern Australia. No history of introduction.
Secale strictum Mountain Rye	negligible	negligible	negligible	negligible	Invasive overseas.

remaining species became weeds.[263] Given the limited benefits of species promoted and planted thus far in response to salinity, there should be increasing doubt about the potential benefits of introductions[264] coupled with declining doubt about their potential harm.

Table 3.8 shows the outcomes of the 16 weed risk assessments published by the Future Farm Industries CRC as of November 2009. Just one of the 16 – *Ehrharta calycina* – returned scores of 'very high' risk for two states, which according to the CRC's protocol means it will not be released or promoted in Western Australia or South Australia. However, it could be released and promoted for Victoria and New South Wales, and farmers elsewhere could plant it unless it was banned. This invasive grass is a "major problem", replacing native plants and creating a fire hazard in its dry dormant state.[265] Another seven species returned scores of medium or high risk for at least one state, and six of these are already environmental weeds in Australia, some very serious. Kikuya (*Pennisetum clandestinum*), for example, is one of the top five weeds threatening biodiversity in New South Wales, impacting on 16 threatened species.[266] Tall Fescue (*Festuca arundinacea*) was assessed as 'low' risk for Victoria, despite being an environmental weed in Victoria, regarded as a high threat in plains swampy woodland in the Glenelg Plain and Wimmera bioregions[267] and one of the 20 worst weeds of Victorian saltmarsh.[268] Six of the species assessed were native to Australia, including one which is a serious environmental weed outside its native range.

The Future Farm Industries CRC intends to rely on voluntary management guidelines to mitigate the risk of species assessed as medium or high weed risk, although researchers involved with the development of the weed risk protocol have acknowledged there is no evidence that guidelines will be effective. They say the issue needs more research.[271] Chapter 4 provides evidence from other situations suggesting that management guidelines will be ineffective in addressing the weed risks.

3.5 Are there alternatives?

If weed risks were taken seriously, there would be a much stronger focus on defining the particular circumstances under which conversion to perennial pastures is desirable and safe, a focus on alternatives to weedy pasture species, different (and lower) expectations about what can be achieved and a stronger regulatory framework to prevent environmental harm.

Our goal is not to map out an alternative salinity program, but to indicate that there are alternative approaches, and to briefly discuss some of the options.

Prevention – maintain and rehabilitate native pastures: The Future Farm Industries CRC

263 Lonsdale (1994).
264 In response to criticisms of the federal weed risk assessment protocol that the 'base rate probability' of an introduced organism becoming a pest is low, Panetta et al. (2001) ask "Could it be that the probability that an introduced organism will be associated with a high benefit:cost ratio is similarly low?"
265 Navie and Adkins (2008).
266 Coutts-Smith and Downey (2006).
267 Navie and Adkins (2008); Carr et al. (1993); Carr et al. (in prep.).
268 Victorian Saltmarsh Study Group (2009).
269 See www.futurefarmcrc.com.au/weed_risks.html. This was the list of assessments available on 18 November 2009.
270 The weed status is mostly as specified in Randall (2007), with the exception of *Megathyrsus maximus*, which is based on Navie & Adkins (2008), and *Atriplex nummularia*, which is based on G. Carr (pers. obs.).
271 Stone et al. (2008a).

has recently published a guide to the use of remnant native pastures that highlights the benefits both for biodiversity and grazing of low-intensity grazing of native pastures.[272] Diverse native pastures may support from 20 to 60 native plant species and numerous wildlife species in decline elsewhere. They are low-risk and low cost pastures that efficiently capture and use water and nutrients and maintain a permanent biomass if grazed conservatively. Native pastures are highly resilient to drought, prevent erosion, resist weed invasion and reduce the risks of dryland salinity. During the 2006 drought native pastures on the slopes of southern NSW and northeastern Victoria were little affected by drying conditions, while "exotic dominated pastures quickly collapsed under the worsening conditions." Low-cost native pastures can be profitable, and in the long-term can be more profitable than sown pastures. There is also the prospect that native pastures "could provide alternative income sources through payments for biodiversity management, ecosystem services and carbon capture and storage."

Rehabilitating degraded and fragmented areas of native vegetation may also mitigate salinity. In a salinity guide for producers and agricultural advisers, Powell recommends reinvigorating or rehabilitating degraded native vegetation as a prevention strategy if there is a net increase in water use.[273]

Recovery / containment / adaptation – sow native perennials: After long neglect, there is increasing interest in developing native species options for perennial pastures. As indicated earlier, about 20% of the species nominated as priorities in three recent reviews of prospective pastures were native. In particular, some native legumes are considered promising. Rogers and colleagues reported that native legumes with "anecdotal or reported salt tolerance" include *Glycyrrhiza acanthocarpa*, *Lotus* spp., *Pultenaea* spp., *Swainsona* spp., *Trigonella* spp. and *Viminaria juncea*. One of the aims of the Future Farm Industries CRC's native perennial project is to "identify two to four native legumes which present low risk breeding opportunities and which will grow well in acid soils and a wider range of soil conditions."

Saltbushes (*Atriplex* spp.) are another group of native plants that have potential as forage plants for secondary salinity sites and are already in use. However, there are also exotic *Atriplex* species (*A. lentiformis* from the US and *A. undulata* from Argentina) which are weed risks, and there is a risk that saltbushes from Western Australia (eg. *A. amnicola*) will also be invasive outside their native range. Old Man Saltbush (*A. nummularia*) is naturalised in several southern Victorian locations, well outside its narrow natural range in north-western Victoria.[274]

The potential of indigenous species is regarded as limited by the low productivity of many species and 'shy' seeding.[275] However, this is partly a function of the limited research focus on native species.[276]

Adaptation – Facilitate volunteer revegetation of saline sites: One of the saltland solutions on the *Saltland Genie* website is to fence off salt areas and allow revegetation by volunteer species. According to the website, this option "has been underplayed when in fact it offers an exciting option in many situations because of its low cost, high marginal return, low risk and ease of implementation."

Information to support this option came from a Sustainable Grazing on Saline Land project assessing different salinity treatments on 120 farm sites and five core research sites across southern Australia. The control sites, necessary to test the effects of the treatment, were fenced off and grazed conservatively. The results surprised the researchers:

> *In most cases, 'pasture production' from the control plots was surprising – simply fencing-off the saline sites from the rest of the paddock, and grazing them conservatively, resulted in significant improvements in groundcover and productivity. Better still, the costs associated with the control plots were minimal (fencing only) and the risk of failure reduced to almost zero.*

Although total farm profits were found to be higher from sown pasture, the financial risk with the fence and volunteer pastures option was much lower and resulted in a higher marginal return on investment.[277] The productive options for saltlands other than sowing exotic perennial pasture plants reduce the rationale for exotic saline-tolerant pastures to one of increasing profits in some circumstances rather than that they are the 'only' realistic solution to salinity.

Prevention / containment – develop new land uses compatible with landscape goals: Where large-scale revegetation of catchments is needed to prevent salinity there may be alternative land uses, including non-production options, particularly for marginal areas. Farm forestry has received some attention, and is likely to be a more favourable option for biodiversity in some cases, as long as non-weedy species are planted, native vegetation is retained, plantings contain a diversity of species, and freshwater runoff in medium-high rainfall catchments is not compromised.[278] However, the potential for commercial timber harvesting is limited to higher rainfall areas. As Pannell points out, commercial options from woody perennials in drier agricultural areas will have to be based on "high value products, such as oils, or from local processing for products such as energy and panel board."[279]

Do nothing: Given the relatively small and declining size of the salinity problem in Victoria, the do nothing approach is better than planting with high risk weedy perennial pastures. Salinity programs encourage landholders to expect that saline areas can be made profitable when in reality many of them should be quarantined from use.

3.6 Conclusion

The Future Farm Industries CRC is promoting the use of serious weeds and is likely to release more weedy cultivars and species. This is being justified by a salinity problem that is far less serious in south-eastern Australia than the resulting weed problems will be. Their Weed Risk Assessment protocol sets a very low standard under which it is likely that almost no invasive plants will be rejected.

While the CRC should take a more responsible approach to weed risk, it is unlikely to do so as its priorities and commitments to funders are to produce more profitable and productive pasture options, and if weed risk is inimical to those goals it is likely to be downplayed or ignored. This is what the salinity program has demonstrated to date. The major responsibility for preventing the use of dangerous invasive pasture plants rests with federal and state governments.

272 Dorrough et al. (2008).
273 Powell (2004).
274 Carr (unpubl. data).
275 Nie et al. (2008); Reed et al. (2008); Rogers et al. (2005). Nie et al. comment that native grasses are adapted for spread by wind, water and animals, and long periods of flowering and seed ripening, which increase seedling survival under the extremely variable climate of Australia, but which limit seed harvest, seed germination and broad-acre establishment of pasture. They also require lighter grazing.
276 Firn (2007).
277 The definition of marginal return is "The increment in productivity or outputs that results from spending additional funds over the current base in a program." See <www.treasuryota.us/ust100/lessons/glossary.htm>
278 Powell (2004) notes that the dominant goal of the 1990s to minimise leakage as much as possible has been replaced by a view that for medium to high rainfall areas "minimising leakage should be balanced with the need to maintain run-off, especially in 'fresh' catchments."
279 Pannell (2001).

Discussion & Conclusion

It has been rare for agricultural research to consider the farming production system from the viewpoint of the ecosystem into which it has been cast. The emphasis and purpose of most agricultural research and development is improvement in short-term productivity.

– Weeds researcher Dick Williams, 1991

4.1 Business as usual

The introduction of weeds for the potential benefit of graziers has been standard practice in Australia. As Cook and Dias documented, more than 8000 exotic species were introduced under the Australian Commonwealth Plant Introduction Scheme, including about one-fifth each of the world's grass and legume species, in the hope they would be useful for fodder.[280]

The use of weeds to address perceived environmental problems has also been a regular practice. Erosion and slope instability were reasons for the now regretted introductions of Bitou Bush (*Chrysanthemoides monilifera* ssp. *rotundata*) and Marram Grass (*Ammophila arenaria*) on coasts in southern Australia, Brown-top Bent (*Agrostis capillaris*) and Red Fescue (*Festuca rubra*) in the Alps, and Spartina (*Spartina* spp.) along low-energy coasts in Tasmania.[281] Jatropha (*Jatropha curcas*) and Giant Reed (*Arundo donax*) have been proposed as biofuels.[282]

Despite much greater awareness of weed problems, and reformed laws and policies, the same mistakes are being repeated in salinity programs.

Exotic perennial pastures have contributed little to solving salinity problems, and are not likely to in the future. In most cases the agricultural gains with new exotic pasture species will be small and incremental, particularly those planted for salinity purposes. Although a serious problem in Western Australia, on a national scale salinity seriously affects only a small proportion of farmers and agricultural profits (with predicted profit declines of less than 1.5% over 20 years).[283] In south-eastern Australia most dryland salinity problems are either declining due to reduced rainfall or are not amenable to treatment in this way because it would require perennial pasture plantings on an unrealistically large scale. Despite hype and hope, there are no miracle plants that will transform marginal lands, including salt-affected lands, into highly productive grazing systems. Agronomists Masters and colleagues comment on the unrealistic expectations of halophytic shrubs in this regard, much of it "based on the performance of similar shrubs growing in non-saline environments."[284] For the sake of incremental improvements in productivity, Australia risks new weed problems without solving the old weed problems.

The reasons for this negligence include the following failures of governance, law and policy.

4.2 Abrogating responsibility

Governments are abrogating their responsibilities by allowing research institutes and companies to decide whether to release new weedy species, and individual landholders whether to plant them.

The federal government takes responsibility for weed risk primarily under quarantine laws that require risk assessment of imported species new to Australia. They are constrained by international trade laws that limit the banning of plant imports if a species is already naturalised and not being 'officially controlled'.[285] Because most weedy pasture species are not regulated by state governments, the federal government does not prohibit their import.

Most species of interest to agronomists are permitted entry without assessment because they were already in the country prior to the quarantine reforms of 1997. About three-quarters of the species collected recently for salinity research were permitted entry into Australia without assessment, because prior importations had been made (Chapter 3). Just 5% of 149 exotic species of interest listed in three recent reviews of pasture plants for salinity mitigation are prohibited from import, and 63% would be permitted entry without risk assessment.

While the government is constrained by trade laws, it can restrict the entry of genetically distinct cultivars of already permitted weedy species if they are likely to make the weed situation in Australia worse. New cultivars are likely to have attributes that increase the range, competitiveness or vigour of a weed.

However, because the majority of pasture species of interest to agronomists are already permitted into Australia, it is up to state governments to regulate their use. Under environment laws, the federal government could regulate the trade and use of some invasive species, but has not done so, despite their impacts on many recognised matters of national environmental significance.[286]

The Victorian Government and most other state and territory governments fail to exercise their regulatory capacity to prevent further plantings and release of serious weeds such as Tall Wheat Grass. The Victorian Government tends not to regulate commercially valued plants no matter how invasive or harmful they are. Of the 14 known environmental weeds recommended as pasture species for saltlands (listed in Table 3.1), not one is declared a noxious weed in Victoria. Of the 190 pasture plants identified as research priorities for salinity mitigation (Appendix 3), of which 56 are already weedy in Australia and 108 are weedy overseas, only one is declared in Victoria.

The Victorian system is reactive, ad hoc, and non-precautionary, based on the assumption that exotic plants are safe unless proven otherwise. Declaration processes are slow and typically instituted well after a plant has established itself as a weed (if at all), limiting possibilities for eradication. In contrast, the Western Australian and federal systems now require that new plant species are assessed for weed risk before being permitted entry.

Catchment Management Authorities have no regulatory capacity to ban weeds, but they influence land management by funding projects and providing advice to landholders and government. When they promote and fund the planting of weedy pasture species, and don't recommend invasive pasture species for weed risk assessment, they fail to meet their statutory obligations to coordinate management of catchments in a sustainable manner (including for biodiversity conservation) and to balance social, economic and environmental outcomes.

Some research institutions have ostensibly started to take responsibility for weed risk with the recent implementation of a weed risk assessment protocol by the Future Farm Industries CRC. But they have set the bar so low that only plants assessed as posing a 'very high' weed risk are rejected. The CRC intends to limit their responsibility for weed risk to providing information in the form of voluntary management guidelines.

Governments and research institutes expect or hope that individual land managers will take responsibility for weed risks. But there are no explicit legislative requirements for them to do so, and no penalties when plants escape. It is unrealistic to expect all landholders to understand or care about weed risk, to have the resources to undertake control, and to voluntarily refrain from planting pasture species promoted as profitable.

Voluntary management guidelines – the proposed method of mitigating weed risk – have not been successful in other domains

280 Cook and Dias (2006).
281 Navie and Adkins (2008); Carr (1993); Parsons and Cuthbertson (1992).
282 Low and Booth (2007).
283 Van Bueren and Price (2004).
284 Masters et al. (2007) noted that liveweight gain on these shrubs, even at low stocking rates, was unlikely.
285 According to the Secretariat of the International Plant Protection Convention (2007), "Contracting parties may apply phytosanitary measures only where such measures are necessary to prevent the introduction and/or spread of quarantine pests, or to limit the economic impact of regulated non-quarantine pests." A 'quarantine pest' is defined as "a pest of potential economic importance to the area endangered thereby and not yet present there, or present but not widely distributed and being officially controlled."
286 Their power to regulate the use of invasive species derives from their power to implement international agreements such as the Convention on Biological Diversity which require control of invasive species. Under section 301A of the *Environment Protection and Biodiversity Conservation Act 1999*, the government already has the basis for making regulations, but has declined to do so.

for comprehensively motivating responsible behaviour and are not likely to work to prevent weed escape from pastures (see below).

While research institutions, Catchment Management Authorities and graziers could and should take more responsibility for weed risks, it is state and federal governments who have both the regulatory capacity and primary responsibility to protect the environment from invasive species.

4.3 Ignoring conflicts of interest

While the Victorian Government could use existing laws (the *Catchment and Land Protection Act 1994*) to prevent the sale and planting of weedy species, the current arrangements make this unlikely. Weed assessments are conducted by the Department of Primary Industries, whose primary goal is to promote agriculture: to "sustainably maximise the wealth and wellbeing" generated by primary industries.[287] None of DPI's 2008-2011 strategies mention the environment. Rather, departmental priorities include a "strategic policy framework to help primary and energy industries meet the challenges of the future", the funding of research, development, demonstration, commercialisation and practice change in primary and energy industries, and the allocation of "Victoria's abundant natural resources" to "productive uses, where possible, through market means to maximise efficiency."

The DPI's conflict of interest is starkly exemplified by the fact that it was responsible for developing the most widely planted cultivar of Tall Wheat Grass (Chapter 2). The department has heavily promoted Tall Wheat Grass as a 'solution' for salinity, typically without any consideration of its weed threat to natural areas.[288]

The Catchment Management Authorities (the Boards of which by law must comprise at least 50% primary producers) that manage salinity programs and funding for projects may also have conflicts of interest, although their objectives and strategies are more inclusive of biodiversity. Focused as they are on involving graziers in projects and funding the 'win-win' approaches that have both agricultural and environmental benefits, they are understandably reluctant to recommend that invasive pasture species be banned when this would alienate their grazier stakeholders.

Agronomy research institutes and graziers have obvious conflicts of interest when making decisions about weedy pasture species that have career and commercial consequences. This is evident in the Future Farm Industries CRC decision to reject only 'very high' risk species under their weed risk assessment protocol, allowing the release of 'medium' and 'high' risk species.

4.4 Paying lip service to risk assessment

The federal weed risk assessment process is regarded as one of the best in the world.[289] However, as discussed, its application is limited to species new to Australia, and none of the pasture species currently promoted for salinity mitigation have been subject to federal assessment. Only a small proportion of weedy species of potential interest to salinity pasture researchers is prohibited from import.

The Victorian Government also has a weed risk assessment process but has limited the assessments to species identified in Regional Weed Action Plans and the National Environmental Alert List or nominated by the Catchment Management Authorities.[290] The species assessed did not include any of the weedy species promoted for salinity, and the government does not routinely assess the weed risk of newly released pasture species/ cultivars.

The one species promoted for salinity mitigation that has been assessed by the Victorian Government (prior to the current review process) was Tall Wheat Grass. As discussed in Chapter 2, despite recommending that Tall Wheat Grass invasion of saltmarshes be listed as a threatening process and finding that it had the potential to invade more than 10 million hectares of Victoria, the assessors recommended against declaring Tall Wheat Grass a noxious weed.

Unlike the Victorian Government, the Future Farm Industries CRC has adopted a policy requiring all species promoted or released to undergo weed risk assessment.[291] But to be rejected as unsuitable, a plant must pose a 'very high' risk. Half of 16 species assessed were rated as medium or high risk in at least one state, and could be released or promoted despite many being serious environmental weeds. This belies claims about the weed risk protocol that it would ensure that released plants would "have low weed risk to natural ecosystems"[292] and that "farming systems developed to solve one environmental problem [would] not cause another."[293]

4.5 Relying on voluntary restraint

The Future Farm Industries CRC intends to rely on voluntary management guidelines to address weed risks, although CRC-associated researchers acknowledge there is no evidence that guidelines will be effective.[294] Even agronomists have difficulties controlling the spread of some species grown experimentally. There is evidence to suggest that voluntary guidelines in comparable situations are mostly ineffective. In the USA, evaluations have found that the availability of weed species in Florida nurseries was not reduced by an industry agreement to voluntarily refrain from selling an agreed list of weeds;[295] that voluntary measures failed to protect endangered plant species on private property;[296] that ski resorts participating in a voluntary sustainability program had lower levels of environmental performance;[297] and that voluntary agreements for commercial whale watching were regularly breached.[298] The researchers in the latter case observed that the:

> *conclusion that the voluntary agreement did not work is troubling because the commercial whale-watching industry involved in the case study seemed an ideal candidate for the successful use of the voluntary approach to management.*

In an Australian example, the Queensland government has recently decided that regulations are necessary after five years of voluntary measures have failed to address water quality problems for the Great Barrier Reef caused by agriculture.[299] Few studies report success of voluntary measures,[300] and there is a lack of information about the conditions under which voluntary measures may be effective. Even if 95% of landholders did comply, weed spread from the remaining 5% of properties could be substantial.

4.6 Ignoring biodiversity

The problems discussed in this report are symptomatic of sectoral approaches to natural resource management, and the failure

287 See http://www.dpi.vic.gov.au/dpi/dpincor.nsf/childdocs/-D48B964653E8CE6DCA25744E000 94B08?open.
288 Nichols (2002).
289 Low (2005).
290 See <http://www.dpi.vic.gov.au/DPI/Vro/vrosite.nsf/pages/weeds_vic_nox_review> for a description of the review process by the Victorian DPI.
291 Stone (2008).
292 Stone (2006) said this about the protocol developed for the Dryland Salinity CRC, the forerunner to the protocol adopted by the Future Farm Industries CRC.
293 Stone et al. (2008b).
294 Stone et al. (2008a).
295 Caton (2005).
296 Rachlinski (1998).
297 Rivera and de Leon (2004).
298 Wiley (2008).
299 Brodie et al. (2008).
300 Kenow et al. (2003) reported the success of a voluntary program to reduce boat disturbance to waterbirds and Miranda et al. (2007) reported that voluntary agreements are helping to protect watersheds in Costa Rica. No other studies reporting success could be found.

to integrate conservation objectives. This perpetuates conflicts between resource use and conservation, and is highly wasteful as one government program is funded to repair what another program has funded. The weeds promoted using salinity funding will have to be managed under weed programs.

Salinity programs have failed to embrace the 'ecology' aspect of sustainability. Perennial pastures are claimed as a sustainable response to salinity and promoted regardless of the environmental consequences.

Agronomists have traditionally been blind to or dismissive of the environmental risks of pasture plants,[301] but have been forced to take some heed of wider community concerns. While the weed risk assessment protocol of the Future Farm Industries CRC is very unsatisfactory, it does at least represent some cultural progress, for it is an official acknowledgement that pasture introductions carry weed risks. There is official acknowledgement more generally of biodiversity within the CRC, with a specific biodiversity and water program, which aims for "improved conservation of biodiversity in agricultural ecosystems." However, it remains to be seen whether the biodiversity focus will have much influence. A 2007 report in the CRC's *Saltland Prospects*, claimed that "Biodiversity benefits do not require a production trade-off" and exemplified it with a "win-win situation" on a site in Western Australia planted with saltbushes and legumes, where the biodiversity 'win' was an increase in native plant species from one to three, in conjunction with an increase in exotic species from 10 to 15, constituting 91% of the biomass.[302] This is a very simplistic view of biodiversity.

The problems of weedy pasture species for biodiversity are poorly recognised in other forums as well. The Landmark assessment of sustainability on farms for the Murray Darling Basin Commission included a focus on biodiversity, but did not mention weedy pasture species as an issue for assessment and noted use of perennial pastures as a current recommended practice.[303]

There is virtually no management of invasive pasture species where they are invading natural ecosystems, even in recognised highly valuable environmental assets, such as Ramsar-listed wetlands.

Weeds receive far less attention than is warranted by the seriousness of their impacts. There is no equivalent of the $1.4 billion National Action Plan for Salinity for invasive species despite the greater harm they cause to biodiversity and agriculture. Land clearing is widely recognised as a threat to nature, for its destructiveness is immediate and obvious. In many places, weeds are just as effective at destruction – eliminating native vegetation and fauna and compromising ecological processes – but not recognised or regulated because the destruction is more insidious and the timescales much longer.

4.7 Recommendations

Investigate threats and protect ecosystems at risk: With high, but inadequately documented conservation values under threat, there should be surveys to assess values and threats, and eradication/control of infestations threatening conservation values.

- Place a moratorium on further plantings of Tall Wheat Grass until its environmental risks are assessed.
- Conduct a comprehensive survey of Tall Wheat Grass in Victoria, investigating its means of dispersal and impacts on the environment, concluding in a peer-reviewed report.
- Conduct an inventory of areas, species and values at risk from Tall Wheat Grass and other invasive pasture plants, including the poorly known flora and fauna of primary salinity areas.
- Conduct weed risk assessments of invasive pasture species, including Tall Wheat Grass and Puccinellia, and declare them in appropriate noxious weed categories to prevent further introductions and spread threatening biodiversity.
- Take immediate action to prevent Tall Wheat Grass and other invasive weeds

spreading into natural ecosystems from plantings or infestations in adjacent areas. Manage existing infestations on both public and private lands.

Prevent further harm: Further invasions of weedy pasture species into natural ecosystems should be prevented.

- Require that all species and cultivars proposed for introduction into new areas be assessed for their weed risk, and permit only low-risk taxa for release.
- Promote and develop low-risk pasture options, such as retention of native pastures, native species for sowing, and volunteer reclamation of saline areas.
- Assess invasive perennial pasture plants as a potential threatening process under both Victorian and federal legislation.
- Require landholders to prevent spread of sown pasture species that threaten biodiversity, by strengthening duty of care provisions and developing enforceable codes of conduct.

Address systemic problems: Reforms are needed to address conflicts of interest, ensure that there are clear responsibilities associated with the use of invasive species, and develop laws and policies to prevent the unsafe use of potential invasive species.

- Conduct an independent review of the institutional failings that have led to promotion of, and subsidies for, planting of Tall Wheat Grass and other harmful invasive species for salinity control.
- Address conflicts of interest in the Victorian regulation of weed listings by shifting responsibility for assessments and declarations to the environment department and allowing nominations from the public.
- Adopt a precautionary 'permitted list' approach to regulation of invasive species similar to that adopted by the federal government for import assessments and by Western Australia.
- Develop federal regulations to restrict the trade and use of invasive species that potentially harm matters of national environmental significance.
- As a condition of government funding for agronomy research require that research institutes such as those in the Future Farm Industries CRC only promote and release low-risk plant species as assessed by best practice weed risk assessment.

301 Cook and Dias (2006) comment on the agronomy culture represented by one prominent agronomist, L. Humphreys, who characterised those concerned about environmental weeds as "the adherents of the primitive" and praised the positive role of buffel grass around Uluru.
302 Bennett and Price (2007).
303 Clifton et al. (2007).

5

Chapter

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CHAPTER

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Appendices

Appendix 1: Institutions involved in planted-based responses to dryland salinity

Cooperative Research Centre for Plant-Based Management of Dryland Salinity

The Dryland Salinity CRC (2001-2007) consisted of 12 agricultural research organisations across southern Australia, including the Victorian Department of Primary Industries and the Victorian Department of Sustainability and Environment. The CRC included the leading proponents of the program to address Australia's dryland salinity problem by encouraging farmers to grow perennial pasture species. The CRC explained its role in the following way:

> *Through an improved understanding of the way natural and agricultural ecosystems work, the CRC will provide new plant-based land use systems that lessen the economic, environmental and social impacts of dryland salinity and thereby help to sustain rural communities.*

Through the 'New & Improved Legumes, Grasses & Crops' program, they conducted the collection, screening and testing of hundreds of new perennial species, including species tolerant of saline conditions.

Part of the CRC's program was Land Water & Wool's Sustainable Grazing on Saline Land (SSGL) program, that included 13 Victorian Producer Network sites, part of a national network of more than 120 group-based projects aiming to improve skills and knowledge of saltland management. The Victorian component of SGSL focused on developing "best practices for establishing and maintaining tall wheat grass-based pastures for saline land."

The SGSL sponsored the 2003 publication of *Saltland Pastures in Australia – a practical guide*. It overviewed pasture plants with nutritive value for grazing animals, their salinity and waterlogging tolerance, production performance, establishment and management (but lacked a focus on weed problems).

Future Farm Industries Cooperative Research Centre

The replacement for the Dryland Salinity CRC is the Future Farm Industries CRC, established in 2007. It consists of commercial agricultural companies, six state agricultural and environmental government agencies (from Vic, SA, WA, NSW), four universities and CSIRO. The CRC's goal is to develop "new and adaptable farming systems for Australia by creating new land-use systems which will make agriculture more productive, adaptable to climate variability, sustainable and diverse." Developing perennial plants for grazing is a key research focus.

The programs most relevant to this report (see Box 3.1) are the CRC's Future Livestock Producton, Future Cropping Systems and the Farming Saline Landscapes program, with goals including:

- Twenty-five per cent of salt affected producers managing newly re-vegetated saline land pastures to generate.
- Increased farm productivity – 150,000ha by 2020.
- Three new salt and waterlogging tolerant pasture cultivars and an elite saltbush cultivar.
- Commercialised (enhanced productivity and feed quality) – 200,000 ha by 2020.
- Practice change on 2900 farms across 350,000 ha within the life of FFI CRC with new perennials released for adoption on >3m ha.
- New perennial grasses for areas with unproductive annual grasses and weeds on the inland slopes of the Great Dividing Range in Victoria and New South Wales.
- The development of a new perennial pasture legume for the crop-dominated low rainfall zone.

- Perennial pasture (non-crop) options fitted against soils and cropping constraints within regions.

The CRC also has a Biodiversity and Water program, with goals that include minimising the risk of genetic pollution of native species, and introduction of weedy species.

> *The CRC's end-users are 72,000 broadacre primary producers who manage 60 million hectares of land. The CRC says it "will seek to increase the adoption of innovative perennial plant-based farming systems on 7.4 mha of agricultural land, establish new regional industries on 100,000 hectares and under conservative estimates delay or prevent salinity impacts on 1.6 mha in the crop-livestock and high rainfall zones."*

Victorian Department of Primary Industries

The Victorian DPI's stated purpose is:

> *To design and deliver government policies and programs that enable Victoria's primary and energy industries to sustainably maximise the wealth and wellbeing they generate.*

DPI staff, including some who are also Future Farm Industries CRC researchers, carry out research which includes development of new perennial species and cultivars. Current projects include 'Perennial Grass Improvement for Low-Medium Rainfall Recharge Environments' and 'New Forage Options to Stablise and Regenerate Saline Environments'. DPI researchers have led the EverGraze program for testing new farming approaches on properties, using perennial pastures. DPI staff were responsible for developing the 'Dundas' cultivar of Tall Wheat Grass, released in 1999.

The DPI is also responsible for weed issues, including the recommendation of species for declaration as noxious weeds. It recently implemented a Noxious Weeds Review, which:

> *... is a process being undertaken to assess all the Regionally Prohibited and Regionally Controlled species within Victoria as well as assessing potential weed species with the prospect of being declared under the Catchment and Land Protection Act (1994) and added to the noxious weed list.*

Genetic Resource Centres

GRCs collect, acquire, characterise, conserve and distribute 'germplasm' (genetic material) as part of a national and international network, primarily for agricultural purposes.

Victoria's Catchment Management Authority regions

GRCs with collections of temperate species potentially suitable as pasture plants are located in Adelaide and Perth. There is also a collection of perennial grass seeds held by the Victorian DPI. "Together, these GRCs established a rationale to acquire, identify, propagate, characterise and disseminate promising germplasm to the CRC Salinity Subprogram."[304]

Catchment Management Authorities

There are 10 catchment management authorities in Victoria (see map), established under the *Catchment and Land Protection Act 1994* and with responsibilities also under the *Water Act 1989*. They are community-based natural resource management organisations with obligations to, among other things:

- Facilitate and coordinate the management of catchments in an integrated and sustainable manner including as it relates to land, biodiversity and water resources.
- Take a sustainable approach by balancing social, economic and environmental outcomes.
- Plan and make decisions within an integrated catchment management context.
- Provide opportunities for community engagement in the integrated management of catchments and natural assets including land, biodiversity and water resources.

The CMAs delivered the National Action Plan for Salinity and Water Quality (NAP) and Natural Heritage Trust programs. The NAP program was jointly funded by the federal and state governments, and ran from 2000-2007/08. In Victoria, six of 10 CMAs (those with an identified salinity problem or risk) delivered the NAP program, with a total of about $300 million funding. Appendix 2 Relevant Victorian legislation and policy.[305]

304 Hughes et al 2008
305 Information mostly from Victorian Government websites.

Appendix 2: Relevant Victorian legislation and policy[306]

The principal legislation for regulation of weeds is the *Catchment and Land Protection Act 1994* (CaLP Act) (see www.dms.dpc.vic.gov.au).

Plants may be declared weeds on the recommendation of the environment minister (advised by the minister for primary industries, who is advised by the Department of Primary Industries) when s/he is satisfied that the plant is or has the potential to become a serious threat to primary production, Crown land, the environment or community health in Victoria or another Australian state or territory. The Victorian Catchment Management Council and the ten Catchment Management Authorities can nominate plant species for declaration. There is no avenue for nomination by members of the public.

There are 108 declared noxious weed species (checked 20 November 2009 through DPI weeds website at http://www.dpi.vic.gov.au/dpi/vro/vrosite.nsf/pages/weeds_listing_a), spread across four legislatively defined categories:

- State prohibited weeds: plants that either do not occur in Victoria or can be eradicated from Victoria.
- Regionally prohibited weeds: plants that do not occur or are not widely distributed in the region, and are capable of growing or spreading further, and can be eradicated.
- Regionally controlled weeds: plants that occur in the region and control measures are needed to prevent further spread.
- Restricted weeds: plants that are a serious threat and if sold or traded in Victoria there would be an unacceptable risk of them spreading.

The Victorian Government is responsible for the eradication of State Prohibited Weeds, but may direct land owners to prevent their growth and spread. Land owners must take all reasonable steps to eradicate Regionally Prohibited Weeds and prevent the growth and spread of Regionally Controlled Weeds on their land. Trade of Restricted Weeds is prohibited.

The Victorian Pest Management – A Framework for Action provides the "overarching policy framework to give strategic direction to current and future species strategies and Regional Action Plans." It enunciates a vision that "Pests no longer threaten the State's natural assets, its social values and productive capacity of its land and waters."

The framework specifies that there is a duty of care on all land and water managers to ensure they do not damage the land or water, and that they are responsible for meeting the costs of repairing any damage resulting from their actions. They are expected to pay for pest management to reach and maintain an "acceptable condition of their land and water, and ensuring pests do not impact on other lands or waters."

The Framework acknowledges that the declarations process has been ineffective in protecting the environment: "The impact of pests on environmental values has generally been neglected, as has the threat of new and emerging weeds."

The Framework identified an urgent need to revise the list of noxious weeds (and pest animals), according to clear and agreed criteria, with the intention that a "scientific, evidence based approach" be used to assess the "potential risk and impact of invasive plant species on Victoria's social, economic and environmental values".[307]

Appendix 3: Tables 3.2-3.4

Key to tables

Species: (D) = recommended for discharge sites (salt tolerant); (R) = recommended for re-charge sites. Note some names as listed in papers have been changed to accord with current taxonomic revisions.

Federal import status or native: NL = not listed; PRO = prohibited, PER = permitted.

Weed in Australia Source: A = Carr et al. (1992), Carr et al. (in prep); B = Hussey et al. (1997); C = Blood (2001); D = Muyt (2001); E = Groves (2003); F = Richardson et al. (2006); G = Randall (2007); H = Navie & Adkins (2008).

Recommended as priority for investigation /development for discharge or recharge sites (by authors of recent review papers): J = Rogers et al. 2005; K = Masters et al. 2007; L - Hughes et al. 2008.

306 Information mostly from Victorian Government websites.
307 Noxious Weeds Review (http://www.dpi.vic.gov.au/DPI/nrenfa.nsf/childdocs/-C288566198D-9F56E4A2567D80005ACFB-AD1311E486E564954A2567D80009DE05-DE2C9C09E4594F86CA2574030018F42A?open)

TABLE 3.2 Grasses of potential interest for discharge and/or recharge sites (from three recent review papers)

Species	Import status or native	Weed in Australia	Weed elsewhere	Recommended priority	Weed status in Australia
Achnatherum splendens (D)	NL			L	
Aeluropus lagopoides (D)	PRO			J, L	
Aeluropus littoralis (D)	PRO			J, L	
Agropyron cristatum (R)	NL			L	
Agropyron fragile (R)	NL			L	
Beckmannia eruciformis (D)	NL			L	
Bothriochloa macra (D)	Native			L	
Bromus auleticus (R)	PER			L	
Bromus biebersteinii (R)	PER			L	
Bromus carinatus (R)	PER			L	
Bromus catharticus (R)	PER	A, C, E, F, G, H		L	Environmental weed

TABLE 3.2 Grasses of potential interest for discharge and/or recharge sites (from three recent review papers)

Species	Import status or native	Weed in Australia	Weed elsewhere	Recommended priority	Weed status in Australia
Bromus coloratus (R)				L	
Bromus inermis (R)	PER	E		L	Minor weed
Bromus mango (R)	NL			L	
Bromus setifolius (R)	PER			L	
Bromus tomentellus (R)	PER			L	
Chloris gayana (D,R)	NL	A, E, F, G, H		J, K, L	Environmental weed
Cynodon dactylon (D)	PER	A, B, E, G, H		J, K, L	Sometimes regarded as native, sometimes as environmental weed
Dactylis glomerata (R)	PER	A, C, D, E, F, G, H		L	Environmental weed
Dactyloctenium aegyptium (D)	PER	E, F, H		J, L	Environmental weed
Distichlis distichophylla (D)	Native			J	
Distichlis palmeri (D)	PER			J, L	
Distichlis spicata (D)	PER			J, L	
Ehrharta calycina (R)	PER	A, C, D, E, F, G, H		L	Environmental weed
Elymus repens (D)	PER	E, H		L	Agricultural weed
Enteropogon acicularis (D)	Native			J, K	
Eragrostis curvula (D)	PER	A, C, D, E, F, G, H		J, K, L	Environmental weed
Eragrostis dielsii (D)	Native			J	
Eragrostis setifolia (D)	Native			J	
Festuca arundinacea (D,R)	PER	A, E, G, H		J, K, L	Environmental weed
Festuca beckeri (R)	NL			L	
Hordeum bogdanii (D)	PER			L	
Hordeum marinum (D)	PER	E, F, H		K	Environmental weed

TABLE 3.2 Grasses of potential interest for discharge and/or recharge sites (from three recent review papers)

Species	Import status or native	Weed in Australia	Weed elsewhere	Recommended priority	Weed status in Australia
Lachnagrostis adamsonii (D)	Native			J	
Lachnagrostis robusta (D)	Native			J	
Leptochloa fusca (D)	subsp *muerilli* PER	E, G		J, K, L	Environmental weed. *Leptochloa fusca* subsp. *fusca* is native
Leymus angustus (D)	PRO			K	
Leymus triticoides (D)	PRO			K	
Lolium multiflorum (D)	PER	A, E, G, H		K	Environmental weed
Lolium perenne (R)	PER	A, E, G, H		K, L	Environmental weed
Lophopyrum ponticum (D)	PER	A		J, L	Environmental weed
Pascopyrum smithii (D)	PER			K	
Paspalum distichum (D)	PER	A, E, F, G, H		J	Environmental weed
Paspalum vaginatum (D)	Native	G		J, K	Naturalised in WA. Environmental weed
Pennisetum ciliare (D)	PER	B, E, F, G, H		L	Environmental weed
Pennisetum clandestinum (D)	PER	A, C, D, E, F, G, H		J, K, L	Environmental weed
Phalaris aquatica (D)	PER	A, C, D, E, F, G, H		L	Environmental weed
Porteresia coarctata (D)	NL			J	
Psathyrostachys juncea (D)	PRO			L	
Puccinellia ciliata (D)	PER	A, E, F, G		J, K	Environmental weed
Puccinellia distans (D)	PER	E		J	Minor weed
Puccinellia festuciformis (D)	PER			J	
Puccinellia stricta (D)	Native			J	
Saccharum arundinaceum (D)	NL			J	

Appendices

TABLE 3.2 Grasses of potential interest for discharge and/or recharge sites (from three recent review papers)

Species	Import status or native	Weed in Australia	Weed elsewhere	Recommended priority	Weed status in Australia
Saccharum robustum (D)	NL			J	
Sporobolus airoides (D)	PER			K	
Sporobolus micranthus (D)	NL			J	
Sporobolus mitchellii (D)	Native			J	
Sporobolus virginicus (D)	Native			J, K	
Stenotaphrum secundatum (D)	PER	A, C, E, F, G, H		J	Environmental weed
Themeda triandra (R)	Native			L	
Thinopyrum intermedium (R)	PER			L	
Thinopyrum pycnantha (D)	PER			L	
Thinopyrum x littorea (D)	NL			L	
Zoysia macrantha (D)	Native			J	

TABLE 3.3 Legumes of potential interest for discharge and/or recharge sites (from three recent review papers)

Species	Import status or native	Weed in Australia	Weed elsewhere	Recommended priority	Weed status in Australia
Acacia ampliceps (D)	Native			K	
Acacia saligna (D)	Native WA	G, H		K	Environmental weed
Anthyllis vulneraria (R)	PER			L	
Astragalus adsurgens (D, R)	PER			J, L	
Astragalus ammodendron (R)	NL			L	
Astragalus brachypus (R)	NL			L	
Astragalus onobrychis (D)	NL			L	
Astragalus vulpinus (R)	NL			L	
Ceratoides latens (D)	NL			J	
Cullen spp. (R)	Native			L	
Dorycnium hirsutum (R)	PER			L	
Galega officinalis (R)	PER			L	
Glycyrrhiza acanthocarpa (D)	Native			J	
Glycyrrhiza glabra (D)	PER	E, F, G		J, L	Environmental weed
Hedysarum carnosum (D)	PRO			J, K	
Hedysarum coronarium (D, R)	PER	E		J, L	Minor weed.
Lathyrus pratensis (D)	PER			L	
Lotonis bainesii (R)	NL			L	
Lotus angustissimus (D)	PER	E, F, G		J	Environmental weed
Lotus corniculatus (D,R)	PER	A, E, G, H		J, K, L	Environmental weed
Lotus creticus (D)	PER	A, E, F, G		J	Environmental weed
Lotus cytisoides (R)	NL			L	
Lotus halophilus (D)	PRO			L	

TABLE 3.3 Legumes of potential interest for discharge and/or recharge sites (from three recent review papers)

Species	Import status or native	Weed in Australia	Weed elsewhere	Recommended priority	Weed status in Australia
Lotus maroccanus (D, R)	PER			J, L	
Lotus subbiflorus (D)	PER	A, E, G, H		J, L	Environmental weed
Lotus tenuis (D)	PER			J, K,L	
Medicago cancellata (D)	PER			J	
Medicago carstiensis (D)	PER			J	
Medicago ciliaris (D)	PER			J	
Medicago italica (D)	PER			J	
Medicago litoralis (D)	PER	G		J	Agricultural weed
Medicago polymorpha (D)	PER	A, E, G, H		J, K, L	Environmental weed
Medicago scutellata (D)	PER	G		J	Environmental weed
Medicago sativa (D,R)	PER, not WA	E, G		J, K, L	Escaped from cultivation
Melilotus albus (D)	PER	E, G		J, K, L	Environmental weed
Melilotus dentatus (D)	NL			L	
Melilotus elegans (D)	NL			L	
Melilotus indicus (D)	PER	A, E, G		J, K, L	Environmental weed
Melilotus infestus (D)	PER			L	
Melilotus italica (D)	PER			J, L	
Melilotus officinalis (D)	PER	A, E, G		J	Environmental weed
Melilotus segetalis (D)	NL			J, K, L	
Melilotus siculus (D)	PER	A, E, F, G		J, L	Environmental weed
Melilotus sulcatus (D)	NL			J, L	
Melilotus tauricus (D)	PER			L	
Onobrychis viciiifolia (R)	PER	E		L	Minor weed
Swainsona lessertifolia (D)	Native			J	

TABLE 3.3 Legumes of potential interest for discharge and/or recharge sites (from three recent review papers)					
Species	**Import status or native**	**Weed in Australia**	**Weed elsewhere**	**Recommended priority**	**Weed status in Australia**
Swainsona procumbens (D)	Native			J	
Swainsona purpurea (D)	Native			J	
Swainsona swainsonioides (D)	Native			J	
Trifolium alexandrinum (D)	PER	E		J, K	Minor weed
Trifolium ambiguum (D)	PER			K	
Trifolium angulatum (D)	NL			J	
Trifolium blancheanum (D)	NL			J	
Trifolium clusii (D)	PER			J, L	
Trifolium fragiferum (D)	PER	A, E, G, H		J, K, L	Environmental weed
Trifolium hybridum (R)	PER	E		L	Minor weed
Trifolium isthmocarpum (D)	PER			J	
Trifolium ligusticum (D)	PER	G		J	Environmental weed
Trifolium michelianum (D)	PER			J, K, L	
Trifolium ornithopoides (D)	PER	E, G		J	Environmental weed
Trifolium palaestinum (D)	PER			J	
Trifolium philistaeum (D)	PER			J	
Trifolium resupinatum (D)	PER	G		J, K	Environmental weed.
Trifolium squamosum (D)	PER	E, F, G		J, K	Environmental weed
Trifolium stipulaceum (D	NL			J	
Trifolium striatum (D)	PER	A, E, F, G		J	Environmental weed
Trifolium tomentosum (D)	PER	A, B, E, G, H		J, K, L	Environmental weed
Trifolium tumens (R)	PER			L	

TABLE 3.3 Legumes of potential interest for discharge and/or recharge sites (from three recent review papers)

Species	Import status or native	Weed in Australia	Weed elsewhere	Recommended priority	Weed status in Australia
Trifolium varietatum (D)	NL			J	
Trifolium wormskioldii (D)	PER			J	
Trigonella balansae (D)	PER			J	
Trigonella suavissima (D)	PER			J	
Viminaria juncea (D)	Native			J	

TABLE 3.4 Non-leguminous herbs and shrubs of potential interest for discharge and/or recharge sites (in three recent review papers)

Species	Import status or native	Weed in Australia	Weed elsewhere	Recommended priority	Weed status in Australia
Acanthus volubilis (D)	NL			J, L	
Allenrolfea accidentalis (D)	NL			K	
Anabasis aphylla (D)	NL			L	
Atriplex amnicola (D)	Native WA			J, K, L	
Atriplex cana (R)	NL			L	
Atriplex halimus (D)	PER			K, L	
Atriplex lentiformis (D)	PER			J, K, L	
Atriplex nummularia (D)	Native			J, K, L	
Atriplex portulacoides (D)	NL			J, L	
Atriplex rhagodioides (D)	Native			J	
Atriplex rosea (D)	NL			J, L	
Atriplex semibaccata (D)	Native	F		J, K, L	Sometimes weedy
Atriplex undulata (D)	PER			J, K, L	
Atriplex verrucifera (R)	NL			L	
Bassia scoparia (D)	PRO	B, E, F, G, H		K	Environmental weed
Calligonum aphyllum (R)	NL			L	
Calligonum caput-medusae (R)	NL			L	
Camphorosma monspeliaca (R)	NL			L	
Capparis herbacea (R)	NL			L	
Chenopodium album (D)	PER	E, F, G		K	Environmental weed
Chenopodium auricomum (D)	Native			J	
Cichorium intybus (D,R)	PER	E, G, H		J, L	Environmental weed
Elaegnus angustifolia (D)	NL			L	

TABLE 3.4 Non-leguminous herbs and shrubs of potential interest for discharge and/or recharge sites (in three recent review papers)

Species	Import status or native	Weed in Australia	Weed elsewhere	Recommended priority	Weed status in Australia
Ferula foetida (D)	NL			L	
Tecticornia doleformis (D)	Native			L	
Tecticornia indica (D)	Native			L	
Tecticornia lepidosperma (D)	Native			L	
Tecticornia pergranulata (D)	Native			L	
Haloxylon aphyllum (R)	NL			L	
Krascheninnikovia ceratoides (R)	NL			L	
Krascheninnikovia eversmanniana (R)	NL			L	
Maireana aphylla (D)	Native			J	
Maireana brevifolia (Small-leaf bluebush) (D)	Native			J, K, L	
Maireana oppositifolia (D)	Native			J, L	
Maireana platycarpa (D)	Native			J, L	
Maireana prosthecochaeta (D)	Native			J	
Maireana pyramiata (D)	Native			J	
Maireana sedifolia (D)	Native			J	
Medicago arborea (R)	PER	G		L	Environmental weed
Medicago citrina (R)	PER			L	
Medicago straseri (R)	PER			L	
Minuria cunninghammii (D)	Native			J	
Nitraria schoberi (D)	Native			L	
Plantago altissima (R)	NL			L	
Plantago coronopus (D, R))	PER	A, E, G		J, L	Environmental weed

TABLE 3.4 Non-leguminous herbs and shrubs of potential interest for discharge and/or recharge sites (in three recent review papers)					
Species	**Import status or native**	**Weed in Australia**	**Weed elsewhere**	**Recommended priority**	**Weed status in Australia**
Plantago lanceolata (D,R)	PER	A, C, E, G		J, L	Environmental weed
Plantago major (D,R)	PER	A, E, G		J, L	Environmental weed
Plantago media (R)	NL			L	
Plantago varia (D)	NL			J	
Rhagodia drummondii (D)	Native			J	
Salicornia bigelovii (D)	NL			K	
Ulmus pumila (D)	NL			L	

Appendices

Appendix 4: Acknowledgements

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Appendix 5: Glossary and abbreviations

Annual vegetation	Plants with a life cycle of only one year, in contrast to biennials (two years) and perennials (at least three years).
CMAs (Catchment Management Authorities)	Community-based natural resource management groups, of which there are 10 in Victoria, charged with delivering state-federal programs such as the National Action Plan on Salinity and Water Quality.
CRC (Cooperative Research Centre)	CRCs "bring together researchers from universities, CSIRO and other government organisations, and private industry or public sector agencies in long-term collaborative arrangements that support research and development and education activities to achieve real outcomes of national economic and social significance" (see < http://www.bushfirecrc.com/centre/whatisacrc2.html>)
Environmental weed	A weed that invades natural ecosystems. They can cause harm by competing with and eliminating native plants, destroying faunal habitat and altering ecological processes such as fire regimes and hydrology. Agricultural weeds threaten agricultural production. Weeds can be both environmental and agricultural weeds.
Exotic species	A species, sub-species or lower taxon that occurs outside its natural range (past or present) and dispersal potential (ie. beyond where it could spread without human intervention) (IUCN 2000).
Future Farm Industries CRC	A Cooperative Research Centre whose goal is to develop "new and adaptable farming systems for Australia by creating new land-use systems which will make agriculture more productive, adaptable to climate variability, sustainable and diverse." (See Appendix 1.)
Invasive species	An introduced species that becomes established in natural or semi-natural ecosystems or habitat, is an agent of change and threatens native biological diversity (IUCN 2000).
Naturalised species	An introduced species that has developed self-maintaining populations (not dependent on direct human intervention).
Perennial vegetation	Plants with a life cycle of at least three years, in contrast to annuals (one year life cycle) and biennials (two year life cycle). They are usually more deeply rooted than annuals and therefore use more of the soil's water.
Primary salinity	Salinity in areas that are naturally salty, such as saltmarshes and saline wetlands.
Secondary salinity	Salinisation due to human land use. Extensive land clearing across southern Australia, which has resulted in large-scale replacement of deep-rooted perennial native vegetation with shallow-rooted annual vegetation, has caused watertables to rise and mobilise salts in the soil, depositing them at the soil surface or in wetlands and streams.
Weed	An introduced plant (from overseas or other parts of Australia) which has, or potentially has, a detrimental impact on economic, social or conservation values (ARMCANZ & ANZECC 1997).

Weedy Pasture Plants for Salinity Control: Sowing the Seeds of Destruction

Authors: Carol Booth, Geoff Carr, Tim Low

Date: November 2009

invasive species council

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